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Effects of legume silages on the quantity and particle size distribution of rumen contents in Holstein-Friesian cows

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Introduction Poor animal performance associated with low digestibility silages results partly from the reduced nutrient yield per unit intake, but also from the associated lower intakes which were presumed to be a consequence of rumen fill effects. Legume silages have a lower average digestibility than grass silages, and yet often have higher intake characteristics. The objective of this work was to compare rumen fill and rumen particle size distribution for animals fed grass silage or legume silage-based diets.

Materials and methods Six Holstein-Friesian dairy cows (mean initial live-weight 577 kg), which were previously prepared with simple rumen and duodenal cannulae, were used in a 4-period incomplete changeover design experiment with 28-day periods. Cows were held in individual stalls, offered a flat-rate of 8 kg/day of a standard concentrate and had *ad libitum* access to one of 6 silages: grass silage (G), red clover silage (RC), white clover silage (WC), lucerne silage (L), and 50/50 (DM basis) mixtures of G and RC (GRC) and G and WC (GWC). The agronomy, ensiling procedures and concentrates were described by Dewhurst *et al.* (2000). Fresh forage was offered at 09:00 h each day and concentrates were given in equal portions at milking times (twice-daily). On the penultimate day of each period, rumen contents were emptied by baling, sub-sampled (every twentieth lot) and weighed before being returned to the animal just prior to the morning feed (09:00 h). Rumen contents were again weighed and sampled at 13:00 h on the final day of each period (4 hours after feeding). Duplicate 100 g samples of rumen digesta were used to assess particle size distribution by wet sieving (Waghorn *et al.*, 1989) using sieves with apertures of 4mm, 2mm, 1mm, 0.5mm, 0.25mm and 0.1mm. Intake and rumen contents information were analysed using REML (Genstat 5; Lawes Agricultural Trust, 1997) with a fixed model of 'diet x sampling time' and a random model of 'period + cow'.

Results There were highly significant effects of time (09:00 vs. 13:00 h) on the quantity of rumen digesta, both fresh weight (77.5 vs. 87.4 kg; s.e.d.=2.12; $P<0.001$) and dry weight (9.79 versus 10.64 kg; s.e.d.=0.335; $P<0.01$), but no significant interaction effects with diet. Diet effects on rumen digesta are shown in Table 1.

Table 1 Effects of legume silages of the amount, dry matter and particle size distributions of rumen contents.

	G	GRC	RC	GWC	WC	L	s.e.d.	Sig.
DM intake (kg/day)	18.2	18.1	19.4	21.3	20.7	19.0	1.90	NS
Rumen contents (kg)	90.9	88.0	85.9	87.4	69.1	73.5	4.19	***
DM of rumen contents (g/kg)	119	120	129	123	124	129	3.9	*
Rumen contents (kg DM)	11.0	10.6	11.2	10.8	8.5	9.3	0.68	***
Rumen contents (kg DM per kg DM intake)	0.55	0.58	0.57	0.49	0.45	0.43	0.040	***
Proportion of rumen DM >2mm (g/g)	0.430	0.374	0.399	0.415	0.440	0.331	0.0235	***
Proportion of rumen DM 0.1-2mm (g/g)	0.229	0.236	0.238	0.193	0.166	0.302	0.0149	***

Discussion Voluntary intakes were not significantly different, though they followed a similar pattern to the related, larger experiment (Dewhurst *et al.*, 2000). The volume of rumen contents, whether expressed on a fresh or DM basis, was significantly lower for WC and L, suggesting that these cows were not eating to maintain a constant rumen fill (intake was not constrained by availability of space in the rumen). Despite the similar high intakes and low rumen contents, WC and L had very different rumen degradation curves (assessed in a parallel study; WC: most degradable at all incubation times; L: largest undegradable fraction; M. Murphy, personal communication). The distribution of particle sizes in the rumens of cows fed ryegrass silage and lucerne silage were similar to those observed by Waghorn *et al.* (1989) for the fresh forages. It is suggested that high intakes of WC reflect its high degradability, whilst high intakes of L are made possible by a high rate of particle clearance from the rumen.

Acknowledgements
The financial support of MAFF, the European Union and MDC is gratefully acknowledged.

References
Dewhurst, R. J., Davies, D. W. R., Fisher, W. J., Bertilsson, J. and Wilkins, R. J. 2000. Intake and milk production responses to legume silages offered to Holstein-Friesian cows. This Meeting.
Waghorn, G. C., Shelton, I. D. and Thomas, V. J. 1989. Particle breakdown and rumen digestion of fresh ryegrass (*Lolium perenne* L.) and lucerne (*Medicago sativa* L.) fed to cows during a restricted feeding period. *British Journal of Nutrition* **61:** 409-423.

Prediction of intake potential of unwilted grass silage by dairy cows

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Introduction The intake potential of silage is determined by the intrinsic characteristics of parent herbage, e.g. plant species, cell wall content and digestibility. Measured intake may, however, be markedly reduced due to modifications of carbohydrate and N fractions during ensilage, and therefore the relationship between digestibility and intake has been weaker for ensiled than dried forages. Increased proteolysis and extent of fermentation have generally decreased silage DM intake (SDMI). However, correlations between fermentation characteristics and SDMI reported in literature are generally weak, particularly those based on individual cows data. In addition to D-value (g DOM/kg DM) and fermentation quality, SDMI is also influenced by DM content, amount and type of concentrates fed, production level and stage of lactation. Gordon *et al.* (1998) measured SDMI under standardized conditions in cattle and developed straight NIRS calibrations for the prediction of SDMI. The purpose of this study was to develop a SDMI index describing the relative intake potential using available data based on mean treatment digestibility, fermentation characteristics and SDMI values.

Material and methods The relationship between SDMI and D-value was estimated with regression analyses using treatment means data (n=24) from British and Scandinavian studies. Relationships between fermentation parameters and SDMI were estimated using the PROC MIXED procedure of SAS and data from 53 experiments (n = 260). Grass silages within each experiment were prepared from the same sward using different ensiling techniques. Wilted silages (DM content > 300 g/kg) were excluded from the data. The model included experiment as fixed factor and concentrate treatments within experiment as a random factor. SDMI index was calculated combining the effects of D-value and fermentation parameters to predict relative intake potential of silage assuming no interactions between these parameters.

Results SDMI increased 16 g per 1 g increase in silage D-value (R^2 = 0.939, residual mean square 0.441). There was considerable variation both in SDMI (mean 10.1, range 5.3-17.5 kg/day) and fermentation characteristics of silage: ammonia N (NH_3N; 73, 13-247 g/kg N), lactic acid (LA; 80, 5-176), VFA (25, 5-80), total acids (TA; 104, 10-225). Regression equations between some silage fermentation characteristics and SDMI are documented in Table 1. The best prediction of SDMI accounted for 0.95 of total variation.

Table 1 Relationship between silage fermentation characteristics (g/kg DM or N) and SDMI (kg/day)

Model[1]	N	Intercept (kg)	Slope1 (g)	P-value	Slope2 (g)	P-value	Residual (kg)
NH_3-N	254	11.22±0.244	-14.1±2.0	0.0001			0.505
LA	254	11.27±0.248	-13.0±1.6	0.0001			0.489
VFA	240	10.86±0.219	-25.9±4.0	0.0001			0.501
TA	234	11.70±0.253	-13.4±1.3	0.0001			0.429
LA, VFA	234	11.73±0.250	-11.9±1.5	0.0001	-21.4±3.5	0.0001	0.425
NH_3-N, LA	248	11.90±0.261	-17.1±1.6	0.0001	-11.4±2.0	0.0001	0.443
NH_3-N, TA	234	11.87±0.256	-7.1±2.2	0.002	-10.7±1.6	0.0001	0.417

[1] All models include experiment and concentrate(experiment)

SDMI decreased significantly with increasing concentrations of ammonia N and fermentation acids. LA and VFA explained more variation in SDMI than either LA or VFA alone, but secondary fermentation had a more detrimental effect on SDMI than lactic acid fermentation as indicated by a markedly higher slope for VFA than LA (-21.4 *v*. -11.9). Best prediction using two independent variables was obtained with a combination of NH_3-N and TA. Because of the positive correlation between NH_3-N and TA (r=0.51), both slopes in two factor model were smaller than when NH_3-N and TA were used as single independent variables. On the basis of the results the following SDMI index was calculated to indicate relative intake potential of unwilted silage: SDMI index = 100 + (D-value (g/kg) - 690) × 1.6 + [80 - TA (g/kg DM)] × 0.11 + [50 - NH_3-N (g/kg N)] × 0.07. SDMI index is 100 for a typical high quality restrictively fermented silage.

Conclusions The results of the present study demonstrate that D-value and fermentation quality have significant effects on SDMI. SDMI decreases with increasing proteolysis as indicated by the negative relationship between NH_3-N concentration and SDMI. SDMI also decreases when the extent of in-silo fermentation increases with secondary fermentation having a more detrimental effect than lactic acid fermentation. The derived equations can be used to predict a single SDMI index, which describes relative intake potential of silages differing in D-value and fermentation quality. In the future the model should be validated using independent data and improved by incorporating possible effects of silage DM content, plant species (grass *v.* legumes) and harvest (1st *v* . 2nd cut). Estimation of SDMI index is currently adopted in Finland.

References Gordon, F.J., Cooper, K.M., Park, R.S. & Steen, R.W.J. 1998. The prediction of intake and organic matter digestibility of grass silages by near infrared spectroscopy analysis of undried samples. *Animal Feed Science and Technology* **70**:339-351.

The biologically relevant unit for the analysis of short-term feeding behaviour of dairy cows

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Introduction Study of short-term feeding behaviour (STFB) could improve the understanding of variation in daily intake in dairy cows. STFB is generally measured in short bouts (e.g. visits to feeders) that are clustered in larger bouts (or meals). The value of bout analysis depends strongly on the choice of an appropriate bout. Before bouts can be grouped into meals, a meal criterion (MC, that is: the longest non-feeding interval accepted as part of a meal) must be estimated. Tolkamp and Kyriazakis (1999) criticised existing methods and recently developed a new technique to estimate meal criteria. These log-normal models were developed on basis of the idea that eating bouts end when animals are satiated (i.e., in a state of low feeding motivation) (Tolkamp and Kyriazakis, 1999). This implies that feed consumption during the relevant eating bout will result in a gradual increase in satiety. This will be associated with an increase in the probability of cows ending a bout. In this study we will analyse whether meals are a more biologically relevant unit of STFB than the short feeding bouts (i.e. visits) that are routinely recorded.

Materials and Methods Data were collected from a group of 16 group-housed lactating cows, in the first half of lactation (Tolkamp *et al.*, 1998). The cows had access to 12 computerised feeders which supplied a mixture of grass silage and concentrates (70:30, fresh basis; 464g DM/kg of feed). Time and weight of the feeder were recorded at start and end of each visit. These single visits were used for visit analyses. Subsequently, MC's of individual cows were estimated by fitting parameters of log-normal models to the observed data with maximum likelihood estimation, i.e. estimation of the most likely values of model parameters given the observed data (Genstat™, 1987; Tolkamp and Kyriazakis, 1999). The probability of cows ending a visit (or a meal) within 'x' sec in relation to time 't' since the start of the visit (or meal) was calculated as the number of visits (or meals) with a visit duration ♌t and ♋t+x, divided by the number of visits (or meals) with a duration ♌t.

Results Figure 1a shows that the frequency distribution of visit duration of the pooled data (N=86,166) approached a negative exponential. The double log-normal for estimating MC's converged for all individual cows but the addition of a third log-normal (see figure 1b, pooled data, MC = 7.99 log-unit = 49.1 min) improved the estimation for 11 cows only. Therefore, the MC's for 5 cows were estimated on the basis of the model of two log-normals and for 11 cows on basis of the model of three log-normals. Means of individual average characteristics were: daily intake (47.2 ± 0.9 kg fresh feed), meal size (8.3 ± 0.3 kg fresh feed), number of meals per day (5.8 ± 0.2), meal duration (37.3 ± 1.7 min) and feeding rate (323 ± 0.02 g/min). Figure 1c shows that the probability of ending a meal increases with increasing meal duration. In contrast there is very little change in the probability of cows ending a visit with increasing visit duration.

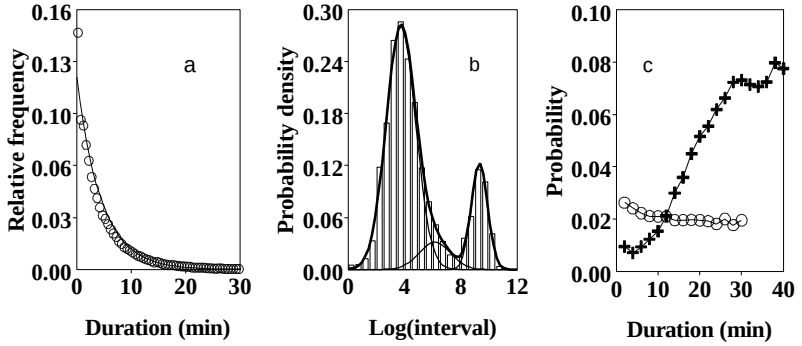

Figure 1 The fit of a negative exponential model to the pooled data of visit duration (a); the probability density function of the model of three log-normals fitted to the pooled frequency distribution of interval length between visits (b) and the probability of cows ending a visit within 6 sec in relation to visit duration (o) or a meal within 60 sec (Φ) in relation to the total visit time within a meal (c).

Conclusion The consistency in the probability of cows ending a visit shows that there is no increase in satiety during single visits. Therefore, visits will not be the biologically relevant unit of STFB for cows. The increase in probability of cows ending a meal with increasing meal duration strongly suggests that meals are the biologically relevant unit for the analysis of STFB. This study supports the view that the new method for estimating meal criteria is in agreement with the satiety concept. Without a proper method to group short bouts into meals the analysis of STFB will not have much biological relevance.

Acknowledgements This work was funded by BBSRC, BOCM, PAULS, SERAD and Socrates / Erasmus.

References Genstat™ 5. 1987. Lawes Agricultural Trust. Rothamstead Exp. Stn., Rothamstead, United Kingdom
Tolkamp, B.J., Dewhurst, R.J., Friggens, N.C., Kyriazakis, I., Veerkamp, R.F. and Oldham, J.D. 1998. Diet choice by dairy cows. 1. Selection of feed protein content during the first half of lactation. *Journal of Dairy Science*, **81**: 2657-2669.
Tolkamp, B.J. and Kyriazakis, I. 1999. To split behaviour into bouts, log transform the intervals. *Animal Behaviour*, **57**: 807-817.

Effect of ingestive mastication on the shear property of fresh grass fed to steers indoors at two stages of maturity and two chop lengths.

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Introduction While the shear property of grasses is considered to be an indicator of the resistance to physical breakdown of ingested particles, few effects on intake or retention time of digesta have been observed with ryegrasses differing in shear breaking load (Inoué et al. 1994). The aim of this study was to examine the effects of ingestive mastication on the differences of shear properties of ryegrass at two stages of maturity and two chop lengths.

Materials and methods Four steers fitted with rumen cannula were fed indoors with fresh ryegrass using a 4×4 latin square design. The 4 treatments were two stages of maturity, 15 vs 30 days of regrowth (15 vs 30) chopped to give two lengths of grass, long or short (L vs S). The grass was cut each morning. The long treatments were obtained by cutting at 4 cm above ground level, while the short treatments were obtained by two successive cuts, one at half the height of the grass above 4 cm and a second one at 4 cm above ground level; herbage from the two cuts were mixed before feeding. Each period lasted one week. Animals were fed at 0.65 of the *ad libitum* level and were fitted with bite meters. Dry matter intakes (DMI) and eating behaviour were recorded each day. Once in each period, for each steer before feeding, the rumen contents were removed and boli collected directly at the cardia for the first 10 minutes of the meal. The grass was sampled twice during each period. In each sample of herbage or boli, lamina, stem and pseudostem were manually separated. Particles of each category were randomly selected, soaked in water, measured for length and rolled in bundles of a fixed number of particles for each sample (herbage or boli) to ensure that each morphological unit was within the sensitivity limits of the measurement. Particles were aligned within the bundles so that they were sheared at their midpoint. The shear energy was the calculated energy expended at the cutting surface of the blades of scissors fitted to a texture analyser machine, divided by the number of particles in the bundle. After measurement (in triplicate for the herbage and duplicate for the boli), the fragments were oven-dried and weighted for the calculation of a linear weight (DM weight/length). Mean data of herbage (one mean per treatment in each period) and data of boli were analysed firstly in the same model to test the effect of the sample (herbage or boli). Then individual data of grass (two values in each period at two different days), data of boli and eating behaviour parameters were analysed separately in distinct models to test the effect of the treatments.

Results Neither the eating time per unit of DMI nor the number of jaw movements were affected by the treatments, averages being 39.3 min/kgDMI and 3.34 jaw movements/gDMI, respectively.
The shear energy (SE) was lowest for lamina, intermediate for pseudostem and highest for stem (Table1). In the boli compared to the herbage, the SEs of stem and pseudostem were reduced while the SE of lamina was not affected ($p>0.10$). The linear weights of lamina, stem and pseudostem were lower in the boli than in the herbage. However the ratio between SE and linear weight was not affected by the type of sample ($p>0.10$).
With increasing maturity, SE of stem in the herbage rose (Table 2, $p<0.05$) but the effect was not significant in the boli. The SE of pseudostem and lamina were not affected by the stage either in the herbage or boli. The initial chop length did not affect the SE in the herbage or boli.

Table 1 : Shear Energy (SE), linear weight (LinW) and ratio between both (SE/LinW) for herbage or boli.

	Herbage	Boli	Sample Effect	SD
Lamina				
SE (J)	1.68	1.54	NS	0.308
LinW (mg /cm)	0.75	0.63	***	0.071
SE/Lin W	2.23	2.47	NS	0.413
Stem				
SE	13.51	8.07	***	4.481
Lin W	3.00	2.05	***	0.698
SE/Lin W	4.49	3.76	NS	1.019
Pseudostem				
SE	6.46	3.18	***	1.182
Lin W	1.90	1.09	***	0.286
SE/Lin W	3.41	3.18	NS	1.298

Table 2 : Effect of the treatments on the shear energy per stem and pseudostem in herbage and boli.

	15L	15S	30L	30S	Treat. Effect	SD
	Shear Energy (J)					
Herbage						
Stem	12.79	10.51	15.93	14.84	*	3.902
Pseudo.	6.28	6.60	6.74	6.23	NS	1.367
Boli						
Stem	8.48	8.98	5.88	10.11	NS	5.089
Pseudo.	3.60	3.35	3.94	1.82	NS	0.909

Conclusion Ingestive mastication lowered the shear energy of the stem and the pseudostem particles of the boli by lowering the linear weight rather than by modifying cell wall architecture. Irrespective of the physical form, the animals may have chewed to achieve a certain threshold of shear energy of the boli particles. Because the treatment differences were not very extreme, the animals achieved this without changing their behaviour, perhaps by increasing the occlusion pressure of each jaw movement.

References Inoué T., Brookes I.M., John A., Kolver E.S., Barry T.N., 1994 Effect of leaf shear breaking load on the feeding value of perennial ryegrass *(Lolium perenne)* for sheep. II. Effects on feed intake, particle breakdown, rumen digesta outflow and animal performance. *J. Agric. Sci. (Camb.)* **123**, 137-147.

An assessment of the contribution of plant proteinases to proteolytic digestion in the rumen of sheep

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Introduction Protein breakdown in the rumen often leads to excessive ammonia production and inefficient use of dietary protein by ruminants (Wallace *et al.*, 1997). Attention has for many years focussed on the proteolytic activity of ruminal microorganisms (Wallace *et al.*, 1997). The wide variety of proteolytic species and proteolytic enzymes and their between-animal variability has made the task of decreasing microbial proteolytic activity difficult (Falconer & Wallace 1999). Much less attention has been paid to the contribution of proteinases originating from the feed. In particular, grass cells contain vacuoles harbouring broad spectrum proteinases which are known to be responsible for protein breakdown in the silo (Wetherall *et al.*, 1995). Theodorou *et al.* (1996) proposed that much of the rapid release of ammonia in grazing animals might be initiated by the action of plant, rather than microbial, proteinases. The present study was undertaken to compare the proteolytic activities of fresh grass and ruminal microorganisms and to evaluate their likely contributions to ammonia production in the rumen.

Material and Methods Fresh ryegrass was cut from swards in Aberdeen during August 1999. The grass was immediately packed in ice and chopped into 1-cm lengths. A 125-g sample was then added to 625 ml of ice-cold 0.1 M sodium phosphate buffer, pH 7.0, and homogenised in a Waring blendor for 5 min. Samples of the chopped grass and the blended grass were autoclaved at 121 °C. Ruminal fluid was removed from four sheep receiving a mixed diet comprising grass hay, barley, molasses, fish meal and minerals and vitamins, at 500, 299.5, 100, 91 and 9.5 g/kg dry matter respectively, 3 h after feeding. The ruminal fluid was strained through two layers of muslin, then 75 ml were added to flasks containing 25 ml of buffer + 5 g chopped grass (G), 25 ml of buffer + 5 g autoclaved chopped grass (GA), 25 ml of blended grass (B), or 25 ml of autoclaved blended grass (BA). Samples (5 ml) were removed at 0, 2, 4, 6, 8, 12 and 18 h into 5 ml of cold 10% trichloroacetic acid, centrifuged at 12,600 g for 15 min, and analysed for ammonia. The proteolytic activity of the blended grass preparation was determined using ^{14}C-labelled casein (Wallace 1983). Rates of ammonia production were fitted by linear regression of data and compared using a paired t-test (n=4).

Results Ammonia production from chopped grass decreased markedly as the result of autoclaving (Fig. 1). The rates were 0.38 and 0.13 mmol/l per h for G and GA respectively (P = 0.0002), indicating that inactivation of the grass proteinases had a major effect on the rate of protein breakdown. Ammonia was released from blended grass only slightly more rapidly than from chopped grass (P = 0.055), and autoclaving also decreased ammonia production (0.45 and 0.24 mmol/l per h for B and BA respectively; P = 0.0016). The proteolytic activity of blended grass with added ^{14}C-casein (0.2 mg casein hydrolysed/h per g of grass fresh weight), was small in comparison with the proteolytic activity of ruminal fluid, which is usually tenfold higher (Wallace 1983), indicating that the ammonia released during the incubation was derived mainly from endogenous grass protein.

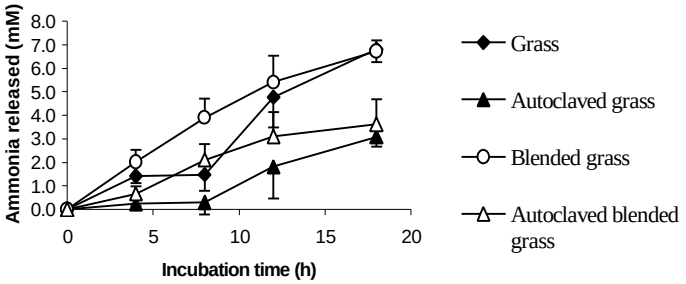

Fig. 1 Ammonia production from ruminal fluid in vitro

Conclusion Proteolysis within grass tissues following consumption by the ruminant contributes significantly to ammonia production. Measures which decrease grass proteinase activity are therefore likely to lead to improved N retention by ruminant animals.

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References

Falconer, M.L. and Wallace, R.J. 1998. Variation in proteinase activities in the rumen. *Journal of Applied Microbiology* **84:** 377-382.

Theodorou, M.K., Merry, R.J. and Thomas, H. 1996. Is proteolysis in the rumen of grazing animals mediated by plant enzymes? *British Journal of Nutrition* **75:** 507-510.

Wallace, R.J. 1983 Hydrolysis of ^{14}C-labelled proteins by rumen microorganisms and by proteolytic enzymes prepared from rumen bacteria *British Journal of Nutrition* **50:** 345-355.

Wallace, R.J., Onodera, R. and Cotta, M.A. 1997. Metabolism of nitrogen-containing compounds. In : The rumen microbial ecosystem (Hobson, P.N. and Stewart, C.S. Eds), Blackie Academic and Profesionnal, London. PP 283-328.

Wetherall, J.A., Armstrong, D.G., Finlayson, H.J. and Rooke, J.A. 1995. Reduction of proteolysis during ensilage of perennial ryegrass by protease inhibitors. *Journal of the Science of Food and Agriculture* **68:** 497-505.

The effects of increased dietary salt concentration on performance and behaviour of finishing pigs.

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Introduction Tail-biting is a behavioural vice with important welfare, economic and carcass quality implications observed in growing pigs. Fraser (1987) proposed that mineral deficiencies in the diet may be related to tail-biting while Beattie *et al* (1996) found that tail-biting did not occur in intensive housing when pigs had access to a rooting substrate. This study compared the effects on pig performance and behaviour of increased dietary salt concentration with a negative control (standard diet, no rooting substrate) and a positive control (standard diet, rooting substrate provided).

Materials and Methods This experiment involved 240 crossbred boars and gilts with undocked tails (¾Landrace x ¼Large White) in the finishing period (46 – 103 kg live weight). Pigs were housed in mixed sex groups of 8 in fully slatted concrete floor pens with a space allowance of 0.7 m^2 per pig. Feed was offered via one single space wet and dry feeder per pen and water was available from a nipple drinker in the feeder. There were three experimental treatments, each with 10 replicates. The three treatments were (1) control - cereal/soya finisher diet supplying 14.0 MJ DE, 11 g lysine and 180 g CP/kg (air dry), (2) salt – control diet with an additional 15 kg salt/tonne and (3) mushroom rack, control diet and a rack 1800 mm x 600 mm with 30 mm^2 grid size suspended horizontally at pig head height. Spent mushroom compost was placed on the rack and pigs could nose particles of compost through the grid. The rack was replenished with compost as required. All pigs were checked twice weekly for evidence of tail-biting in addition to normal husbandry checks and any tail-bitten pigs were taken off experiment and housed individually in straw bedded pens until slaughter. Pig behaviour was recorded daily until slaughter by group scanning the pens on each replicate consecutively 5 times at each observation. The number of animals performing the following behaviours at one instant was recorded; nose pig, nose ground, nose rack, nose below rack, fixtures explore, ingestion. Observers used an electronic data logger (Micro Scribe 600, Locomotive Software, 1986) to record data. Performance and behaviour data were blocked for replicate and treatment means compared by analysis of variance using Genstat 5.

Results Daily water consumption was higher ($P<0.001$) by 1.6 l for pigs offered the high sodium diet (Table 1). Pigs on the mushroom rack treatment had higher average daily feed intakes ($P<0.01$) and growth rates ($P<0.01$) than those of pigs on the other two treatments. FCR and KO% were similar for pigs on all treatments, the mean values being 2.40 and 74.9% respectively. Pigs on the mushroom rack treatment used 0.5 kg of spent mushroom compost per day. Less pigs ($P<0.001$) performed harmful social behaviours on the mushroom rack treatment so that there were no tail-bitten pigs. However 3% and 4% of control and salt treatment pigs respectively were tail-bitten and were removed from the experiment.

Table 1 *The effects of a high salt diet on finisher performance and behaviour*

	TREATMENT				
	Salt	**Mushroom rack (Positive control)**	**Negative control**	**SEM**	**Significance**
Feed intake (kg/d)	2.15	2.29	2.13	0.032	**
DLWG (g/day)	909[a]	955[b]	902[a]	10.8	**
P_2 (mm)	10.5	11.2	10.5	0.23	NS
Water intake (l/d)	6.2[b]	4.9[a]	4.4[a]	0.21	***
Nose Pig	0.84[b]	0.55[a]	0.87[b]	0.041	***
Nose Ground	0.62[b]	0.43[a]	0.59[b]	0.033	**
Fixtures Explore	0.56[b]	0.32[a]	0.52[b]	0.045	**
Ingestion	0.93[b]	0.83[a]	0.91[b]	0.016	**

Means with a common superscript are not significantly different ($P>0.05$)

Conclusions The results of the present study suggest that supranutritional salt supplementation of diets has no significant beneficial effects on pig performance or behaviour. However, providing a substrate for pigs to root reduces both the time spent by pigs nosing the fixtures of the pen and nosing other penmates suggesting that these behaviours observed in intensive housing are redirected rooting behaviour. Allowing the expression of rooting behaviour in intensive environments improved feed intake and growth rate and effectively reduced harmful social behaviour leading to tail-biting in the present study.

References

Beattie, V.E., Walker, N. and Sneddon, I.A. (1996). A method of enrichment for intensive housing of growing pigs. Proceedings British Society of Animal Science, (Winter meeting), Scarborough, pp 203.

Fraser, D. (1987). Mineral deficient diets and the pig's attraction to blood : implications for tail-biting. *Canadian Journal of Animal Science*, **67**, 909-918.

Feeder space requirement of growing pigs housed at different group sizes

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Introduction The resource requirements, such as feeding space, of pigs housed in large groups are poorly understood. The feed intake requirement may be unaffected by group size, but the ability to gain access to the feeders may be influenced by the changed social environment. The observation of pigs feeding may stimulate others to feed also. In large groups, the number of pigs attempting to feed simultaneously could lead to increased competition for access to the feeders (Spoolder et al., 1999). Consequently, the suitability of two feeder space requirements, derived from UK recommendations, for pigs housed at different groups sizes was investigated.

Materials and Methods A total of 800 Large White x Landrace growing pigs (start weight 29.3 s.e. 0.19 kg) were housed indoors on deep straw bedding. Animals were assigned, for 6 weeks, to 1 of 4 treatments in a 2 x 2 factorial design of 2 group sizes (20 *vs*. 80) and 2 feeder space allowances (42.5 *vs*. 32.5 mm feeding space/pig; H and L respectively). Treatments were replicated 4 times. Pelleted grower feed was weighed and offered *ad libitum*, all animals were weighed on the day of mixing and at the end of weeks 3 and 6. Feed was weighed back at the end of week 6. The number of skin lesions were counted on 15 randomly selected pigs per pen immediately before mixing, and again using the same pigs at 3, 21 and 42 days post-mixing. Treatment effects on average daily feed intake (ADFI), average daily gain (ADG), feed conversion ratio (FCR), coefficient of variation in ADG (CV ADG) and lesion score (LS) were investigated by two way analysis of variance using pen mean as the statistical unit.

Results ADFI was significantly lower in the low feeder space allowance treatments ($p<0.05$, Table 1). ADG was examined over the full 6 week period, and for the first 3 and last 3 weeks separately. Over the full 6 weeks, ADG was unaffected by treatment. There was a tendency for pigs in groups of 80 to have a reduced ADG during the first 3 weeks ($p<0.1$). During the last 3 weeks, pigs offered the low feeder allowance had a significantly lower ADG ($p<0.05$). Group size and feeder allowance did not interact to affect ADFI or ADG. FCR, CV ADG for the first or second 3 weeks, or for the full 6 weeks and mean LS over the 6 weeks were not significantly affected by treatment. Treatment did not influence the ADG of pigs beginning the experiment with an upper or lower inter-quartile start weight.

Table 1 Performance and lesion score of pigs at 2 group sizes and feeder space allowances

						Significance	
	20 pigs, H	20 pigs, L	80 pigs, H	80 pigs, L	s.e.	Group size	Feeder
ADFI (kg/pig/d)	1.60	1.40	1.52	1.47	0.049		*
ADG (kg/pig/d)							
weeks 1-3	0.61	0.56	0.52	0.56	0.025	p<0.1	
weeks 4-6	0.75	0.69	0.74	0.68	0.024		*
weeks 1-6	0.68	0.63	0.63	0.62	0.020		
lower inter-quartile start weight (1-6)	0.62	0.61	0.59	0.58	0.022		
upper inter-quartile start weight (1-6)	0.76	0.66	0.67	0.66	0.045		
FCR (feed:gain)	2.37	2.26	2.42	2.39	0.077		
LS (mean)	8.13	5.20	6.26	8.55	1.252		

Conclusions Restricting feeder space allowance from 42.5 to 32.5 mm/pig depressed feed intake. Growth rate was reduced by a low feeder allowance when pigs were between 41 and 56 kg liveweight, suggesting the restriction was experienced more severely as the pigs aged. The tendency for reduced ADG between weeks 1-3 in groups of 80 may result from the stress of mixing into a large group, but the similarity in lesion score would dispute this. The lack of significant interactions between group size and feeder space indicates that specific feeder space allowances are not required for different group sizes when fed a dry pelleted diet *ad libitum*.

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Reference Spoolder, H.A.M., Edwards, S.A. and Corning, S. 1999. Effects of group size and feeder space allowance on welfare in finishing pigs. *Animal Science*. In press.

Influence of feeder type on the performance and behaviour of weaned pigs

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Introduction Post-weaning 'growth check' due to low feed intakes continues to pose a problem for commercial producers. It may be possible to improve feed intake by weaned pigs through manipulating the way in which feed is presented to them. The objective of this study was to assess the influence of five different commercially-available feeders on the performance and behaviour of weaned pigs.

Materials and method In a randomised block design, one thousand, one hundred and twenty Large White x Landrace pigs were allocated to one of five feeders (Table 1) from weaning at 4 weeks of age until 11 weeks of age. Eight blocks were used, each containing seven groups of twenty pigs which were balanced for gender and weight. In each block, one group was assigned to each feeder except the Maximat and Lean Machine where two groups were assigned. This was because these feeders were fitted in the dividing wall between two groups and mean values from these two groups were used. In the Verba treatment, two feeders were placed side by side to allow enough feeding spaces for twenty pigs. The pigs were housed in combined Stage 1/Stage 2 accommodation with plastic slatted floors, thermostatically controlled ventilation and a space allowance of 0.38 m^2 per pig. All pigs were weighed individually at weaning and at 11 weeks of age. Feed intakes were recorded weekly and feed conversion ratios calculated. Each feeder was videotaped for a continuous 24 hour period each week and the number of pigs at the feeder at 20 minute intervals was recorded. Performance and behaviour data were blocked for replicate and treatment means were compared by analysis of variance using Genstat 5.

Table 1 Description of each of the feeders used

Feeder	Description
Dry multi-space	Traditional dry feeder with segregated feeding spaces in a rectangular trough
Wet and dry multi-space	Similar to above except with nipple drinker located in each feeding space
Maximat	Tube type wet and dry feeder with feed dispensed into a rectangular shared trough
Lean machine	Tube type wet and dry feeder with feed dispensed into a circular shared trough
Verba	Single-space wet and dry feeder with feed dispensed into a trough enclosed by side partitions

Results Results are given in Table 2. Apparent mean daily feed intakes were higher with wet and dry multi-space feeders than with all other feeders ($P<0.001$). Mean daily liveweight gain (DLWG) tended to be higher with wet and dry and dry multi-space feeders than with all other feeders, however this difference was not significant. Feed conversion ratios (FCR) were higher with wet and dry multi-space feeders than with all other feeders. The average number of pigs occupying the feeder was highest with Lean Machine, Maximat and Verba feeders and lowest with dry multi-space feeders ($P<0.001$).

Table 2 Average production performance and number of pigs at the feeder (expressed as a percentage of the group) between 4 and 11 weeks of age

Parameter	Feeder type					s.e.m.	Significance
	Dry multi-space	Wet and dry multi-space	Maximat	Lean machine	Verba		
Apparent food intake (g/d)	897[a]	951	863[ab]	839[b]	824[b]	17.6	***
DLWG (g/d)	598	605	577	572	575	13.4	
FCR	1.50[a]	1.58[b]	1.49[a]	1.47[ac]	1.42[c]	0.019	***
Mean no. of pigs at feeder (%)	1.2[a]	1.5[b]	1.8	1.9	1.9	0.06	***

[a,b,c] Means in the same row with a common superscript are not significantly different ($P>0.05$)

Patterns of feeder usage differed between feeders. Pigs with Maximat, dry, and wet and dry multi-space feeders showed characteristic feeding patterns whereby the average number of pigs at the feeder rose to a peak in the morning between 0900 to 10 00 h and then fell significantly between 1100 and 1200 h ($P<0.05$). However with Lean machine and Verba feeders, demand for the feeder did not drop significantly after the morning peak until after 1900 h.

Conclusions Both the wet and dry and dry multi-space feeders showed similar high levels of performance, and, as a consequence, showed lowest levels of post-weaning 'growth check'. However the poor feed conversion associated with the wet and dry multi-space feeder suggests greater amounts of feed wastage. The dry multi-space feeder appeared to facilitate feeding behaviour and reduce competition for feeding spaces. This was reflected in high feed intakes, low average numbers of pigs at the feeder and a reduction in demand for the feeder after the morning peak. The results suggest that the dry multi-space feeder is the optimum feeder type for weaned pigs.

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The effect of stage of lactation in dairy cattle on the partitioning of increments of metabolisable energy between milk and body tissue.

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Introduction The current energy rationing system in the U.K., the metabolisable energy (ME) system (AFRC, 1993) takes no account of the partitioning of increments of ME intake (MEI) between milk energy output (E_l) and body tissue (E_g). However, recent work at this Institute, Agnew *et al*., 1999, has shown that the response in E_l to increasing MEI complies to the law of diminishing returns, while the converse response is obtained for E_g. Rationing cows for economic milk production requires a full understanding of the dietary and animal factors which influence this partitioning. The objective of this study was to examine the effect of one animal factor, stage of lactation, on the partitioning of increments and decrements of MEI between E_l and E_g.

Materials and methods A total of twenty high genetic merit Holstein-Friesian dairy cows (PIN_{95} £81.8, sd 16.10) were used in a calorimetric study over two years. Cows were selected to represent three stages of lactation (days in milk; DIM) as follows: group E (4 cows, mean DIM 77; sd 12.6), group M (10 cows, mean DIM 225; sd 47.5) and group L (6 cows; mean DIM 423; sd 41.6). Total mixed rations, comprising concentrate and straw (0.82:0.18 DM basis) and concentrate and lucerne hay (0.70:0.30 DM basis) were offered in year 1 and year 2 respectively. Each cow was subjected to three periods of gaseous exchange measurement in indirect open circuit calorimeters. Each measurement period (P1, P2, and P3) lasted for 3 days, and was preceded by a two-week dietary adjustment period. In P1, cows were given an ME allowance calculated to meet requirements for maintenance and E_l (AFRC, 1993), plus an additional 10 MJ/d. In P2, each cows' ration was reduced by approximately 20 MJ/d, while in P3 cows were returned to the same ration as P1. The ME concentration of the diet was determined for each cow during either a six or nine day balance prior to, and including, the calorimetric period of P2. Partitioning of decrements of MEI was calculated from the changes in MEI, E_l and E_g between P1 and P2, and of increments of MEI between P2 and P3. Overall partitioning was determined as the difference between individual values in (P1 + P3)/2 minus the values obtained in P2. As level of E_g at a given time is known to influence partitioning, E_g at the start of each analytical period was used as a covariate in the analyses. One cow was ill prior to P1 and entered the experiment at P2 (results omitted from P1-P2 analysis), while 2 cows were removed at the end of P2 for health reasons (results omitted from P2/P3 analysis). The data for all three cows were excluded from the overall partition results. Data were analysed using the REML technique in Genstat 5 with year and lactation group as factors.

Results There were no significant year effects on any of the parameters measured and hence the results are presented as a mean across years. Overall partition and production data are presented in Table 1. All three lactation groups were significantly ($P<0.01$) different in E_l, while E_g was significantly lower in the E group of cows than in both the M and L groups ($P<0.05$). Overall, cows in the E group partitioned significantly more of a unit of MEI to milk than cows in the L group ($P<0.05$), while partitioning to E_g or heat was not influenced by lactation group. Partition data between P1/P2 and between P2/P3 are also presented in Table 1. Lactation stage did not significantly affect the partitioning of decrements of MEI to E_l or E_g between P1/P2. In contrast, adding additional increments of MEI (P2/P3) resulted in a significantly higher partitioning to E_l in the E group than the L group of cows ($P<0.01$), while partitioning to E_g or heat was not significantly influenced by lactation group. The proportion of additional MEI partitioned to milk (PM) (overall data) was regressed on initial E_l and a significant linear relationship developed as follows: $PM = 0.00439_{(0.00148)} E_l - 0.169_{(0.131)}$ ($P<0.01$) ($R^2 = 0.371$).

Table 1 The effect of stage of lactation on MEI and the partitioning of ME between milk (E_l) and body tissue (E_g)

	Overall input/output data (MJ/d)				**Overall partitioning**		**P1/P2 partitioning**		**P2/P3 partitioning**	
	MEI	E_l	E_g	HP	E_l	E_g	E_l	E_g	E_l	E_g
E	234.1[a]	110.3[a]	-7.1[a]	131.0	0.355[a]	0.418	0.369	0.406	0.372[a]	0.318
M	224.1[a]	87.3[b]	4.9[b]	131.9	0.224[ab]	0.367	0.248	0.381	0.180[ab]	0.381
L	177.5[b]	48.3[c]	12.1[b]	117.1	0.065[b]	0.396	0.176	0.384	-0.025[b]	0.508
sed	21.51	8.22	6.72	10.24	0.1237	0.1425	0.2039	0.2352	0.0988	0.1962
Sig	*	**	*	NS	*	NS	NS	NS	**	NS

Means in the same column with the same superscript are not significantly different

Conclusion The results of this study indicate that stage of lactation has a significant effect on the partitioning of increments of MEI given above requirements. This may reflect the higher milk production in early compared with late lactation.

References AFRC, 1993. *Energy and protein requirements of ruminants.* CAB Int., Wallingford, Oxon, England.
Agnew, R.E., Gordon, F.J., Kilpatrick, D.J., Yan, T. and Porter, M.G., 1999. The effect of incremental changes in metabolisable energy intake on the partitioning of metabolisable energy in dairy cows. *Proceedings of the British Society of Animal Science*, Annual meeting, p31.

Lactational performance and energy utilisation in high yielding cows

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Introduction Significant increases in genetic merit for milk production in the UK dairy herd have led to high and persistent milk yields becoming relatively common. Data relating this level of performance to the extent of the energy deficit in early lactation, possible impact on milk quality and the contribution of mobilised energy to milk production are relatively scarce. The aim of this study was to compare lactational performance in high- (HYC) and average- (AYC) yielding cows and to reconcile changes in body status (liveweight and condition score) of HYC with associated measurements of energy depletion and repletion.

Materials and methods Multiparous Holstein-Friesian cows of high and average yield potential (both n=20) were used in a continuous design. HYC (mean liveweight (LW) 623 kg, predicted 305 day milk yield (305dMY) >10000 kg) were fed, from calving, a total mixed ration comprising maize silage, grass silage, dried lucerne, grass hay, potato starch and concentrates (oven dry matter (DM) ratio; 31: 6: 14: 4: 5: 40; average 480g DM/kg). Average dietary composition (g/kg DM) was 217 starch, 67 sugars, 318 neutral detergent fibre and 178 crude protein. AYC (mean LW 639 kg, predicted 305dMY >7500 kg) were fed a similar ration containing reduced protein. All cows were cubicle-housed and individually fed; HYC and AYC were milked 3x/2x per day respectively. Milk yield and feed intake were recorded daily with body condition score (BCS) and LW weekly. A further 8 HY cows (mean LW 670 kg, predicted 305dMY >11000 kg) were housed separately in individual stalls and established on the same ration to provide data on energy utilisation (HYCC), using procedures described by Cammell *et al.* (1986). All treatment groups were fed *ad libitum* throughout the period of study.

Results The data were analysed using repeated measures by the mixed model procedure of SAS version 6.12. Mean DM intakes were significantly (P <0.05) higher for HYC compared with AYC, with significant differences in peak milk (P<0.01) and total solids (P < 0.01) yield (5.8, 4.9 kg/day respectively) and mean outputs of milk and milk solids (P < 0.01). LW and BCS at calving were similar for both treatment groups, but BCS (weeks 1-24) was significantly (P < 0.05) lower for HYC. Minimal LW occurred at lactation week 6 in both groups and then increased to week 24, whilst minimum BCS occurred at week 9 with little improvement thereafter. Data for treatment HYCC indicated that mean milk energy output decreased from 144 to 126 MJ/day during weeks 6-18, whilst milk fat and protein contents were largely unaffected by stage of lactation. GE intake (MJ/day) increased from 465 to 481MJ/day between weeks 6 and 12, whilst mean ratio of ME:GE was estimated at 0.615 MJ/MJ at production levels of feeding. Positive energy balance in HYCC was achieved between lactation weeks 12 and 18.

Table 1. Mean DM intake, milk yield (and peak), milk composition, body condition score(BCS) and live weight (LW) in High and Average yielding cows during lactation weeks 1-24

		HYC	*AYC*	*sed.*
DM intake (kg/day)		23.1	21.2	0.96
Milk yield (kg/day);				
	Mean	42.4	32.5	1.39
	Peak	49.1	37.8	1.66
Milk composition (g/kg)				
	Fat	38.8	43.0	0.92
	Protein	31.2	33.9	0.81
BCS	Week1	2.2	2.4	0.19
	Week 6	1.9	2.1	0.15
	Week 12	1.5	2.3	0.16
LW [kg]	Week 1	627	630	18.27
	Week5	615	632	16.65
	Week 12	625	647	16.93

Conclusions Despite similar initial LW and body condition scores for HYC and AYC, condition scores were lower for HYC after the early post partum period than AYC and remained lower up to week 24 suggesting greater tissue mobilisation by HYC. Measured ME intake did not exceed a mean value of 300 MJ/day for HYCC, similar to values previously reported by Beever *et al.* (1998). Body energy mobilisation, as defined by negative energy retention, occurred until at least lactation week 12, whilst minimum LW was achieved approximately 6 weeks. Whilst BCS may reflect in part changes in tissue energy depletion or repletion, it is concluded that LW change does not adequately reflect body energy status in early lactation.

References Beever, D.E., Cammell, S.B., Sutton, J.D., Rowe, N. and Perrott, G.E. (1998). Energy metabolism in high yielding cows. In: *Proceedings of the winter meeting of the British Society of Animal Science*, 1998.
Cammell, S.B., Thomson, D.J., Beever, D.E., Haines, M.J., Dhanoa, M.S., Spooner, M.C. (198)]. The efficiency of energy utilisation in growing cattle consuming fresh perennial ryegrass (Lolium perenne cv Melle) or white clover (Trifolium repens cv Blanca). *British Journal of Nutrition,* 55, 669-80

Intake and milk production responses to legume silages offered to Holstein-Friesian cows

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Introduction Earlier work showed that red clover silage has considerable potential for milk production (e.g. Thomas *et al*., 1985), though low digestibility and difficulties ensiling clovers were seen as problems that needed to be addressed. Advances in legume breeding and conservation technology as well as a renewed emphasis on extensive organic production systems within Agenda 2000 meant that it was timely to reconsider the potential of legume silages for milk production.

Materials and methods Pure stands of red clover (cv. Milvus), white clover (cv. Aran) and lucerne (cv. Vertus) as well as an area of ryegrass (mixture of cvs. AberElan, AberComo and Augusta) were established in late summer 1997. The legumes received their main application of P and K in mid-March (83 kg P and 216 (154 for white clover) kg/ha K). The grass received 160, 7 and 16 kg/ha N, P and K for the first cut and 84, 7 and 16 kg/ha N, P and K for subsequent cuts.
Each crop was harvested over 3 cuts during 1998, finishing on 23 September for the legumes and 11 August for the grass. Crops were mowed using a disc mower fitted with rubber rollers, left in the swath until shortly before baling and wilted aiming for a dry matter content of 30-35% (maximum 48 hours). Crops were baled using a round baler with a biological additive (Ecosyl; Ecosyl Products Ltd., Billingham, UK) applied at 1.5 litres per tonne of crop. Mixtures of the three cuts, in proportion to yields, were used in feeding experiments in order to make the results more representative of the season's production. Eighteen Holstein-Friesian dairy cows in early- to mid-lactation were used in a 3-period incomplete changeover design experiment involving 6 treatments: grass silage (G), red clover silage (RC), white clover silage (WC), lucerne silage (L), and 50/50 (DM basis) mixture of G and RC (GRC) and G and WC (GWC). Six of the cows had rumen and duodenal cannulae and were used for the 4-period experiment described by Dewhurst *et al*. (2000). Cows were given a flat-rate of 8 kg/day of a standard concentrate (starch: 229 g/kg DM; neutral detergent fibre (NDF): 247 g/kg DM; crude protein (CP): 220 g/kg DM) and had *ad libitum* access to the forages either through roughage intake control feeders (Insentec B.V., The Netherlands) or in individual stalls. Feed intake, milk yield and milk composition were recorded throughout and values from the final week of each 4-week period were used in the statistical analysis. DM digestibilities were measured using 6-day total collections of faeces from the fistulated cows in the third week of each period. Results were analysed using REML (Genstat 5; Lawes Agricultural Trust, 1997) with a fixed model of 'diet' and a random model of 'period + cow'.

Results All silages were well preserved, aerobically stable and acceptable to the animals, despite the wide range of DM contents achieved at baling. Chemical analysis of G, RC, WC and L silages gave the following values: for freeze-DM: 345, 376, 258 and 359 g/kg; for CP: 146, 205, 278 and 244 g/kg DM; for NDF: 548, 439, 287 and 458 g/kg DM; for lactic acid: 66, 74, 99 and 60 g/kg DM; and for pH: 4.45, 4.24, 3.85 and 4.68 respectively. Table 1 shows the effects of treatments on intake and production.

Table 1 Effects of legume silages on feed intake, diet digestibility and milk production

	G	GRC	RC	GWC	WC	L	s.e.d.	Sig.
DM intake (kg/day)[1]	17.9	18.4	19.0	19.9	20.4	19.4	1.15	NS
DM digestibility (g/g)	0.714	0.674	0.639	0.707	0.673	0.636	0.0096	***
Silage DM intake (kg/day)[2]	11.1	11.0	13.5	11.9	12.1	13.6	0.80	***
Milk yield (kg/day)	24.9	28.6	28.1	27.9	31.5	27.7	1.81	*
Milk fat (g/kg)	44.5	46.0	45.2	46.6	43.9	44.2	2.49	NS
Milk protein (g/kg)	32.6	32.1	31.4	32.2	32.0	32.6	0.54	NS
Milk lactose (g/kg)	47.1	47.2	46.8	47.4	47.1	46.6	0.41	NS

[1]digestibility experiment only; [2]milk production experiment

Discussion The results support earlier work, with higher intakes and higher milk production for the legumes and silage mixtures, despite lower digestibilities (Thomas *et al*., 1985). Breeding and additive advances mean that it is now possible to produce reliably well-fermented and stable legume silages and to use them to support high levels of milk production.

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References

Dewhurst, R. J., Merry, R. J., Davies, D. R., Moorby, J. M., Scollan, N. D., Neville, M. A. and Baker, D. H. 2000. Effects of legume silages on the quantity and particle size distribution of rumen contents in Holstein-Friesian cows. This Meeting
Thomas, C., Aston, K. and Daley, S. R. 1985. Milk production from silage. 3. A comparison of red clover with grass silage. *Animal Production* **41:** 23-31.

A comparison of four contrasting milk production systems for high genetic merit winter calving dairy cows in a grassland based production environment

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Introduction Meeting the greater nutrient requirements of high genetic merit dairy cows in grassland based systems provides a very real challenge. This study examines the performance of high genetic merit animals, managed on four contrasting grassland based systems of milk production, including both the winter and summer periods.

Material and methods Eighty winter calving Holstein/Friesian dairy cows (PTA_{95} fat + protein = 42.5 kg), comprising 50 multiparous animals and 30 primiparous animals, were used in this study. Animals had a mean calving date of 20 November 1997, and were allocated to one of four systems of milk production, F-F, F-C, C-F and C-C within 36 hours of calving. During the winter, animals on systems F-F and F-C were offered high feed value silages, supplemented with 6.0 kg/day of concentrate (crude protein concentration of 311 g/kg DM) through an out-of-parlour feeding system, while animals on systems C-F and C-C were offered medium feed value silages, supplemented with 12.5 kg concentrate per cow per day (crude protein concentration of 211 g/kg DM), in the form of a complete diet. The high and medium feed value silages were produced within a four and two harvest system respectively, cutting dates being 15 May, 16 June, 17 July and 18 August for the former, and 3 June and 6 August for the latter. From 25 February onwards, animals on each of systems F-F and C-F were given access to grazing for periods of increasing duration, achieving full turnout on 17 April. Thereafter, until 21 October, these animals were offered a large daily herbage allowance within a flexible grazing system (23.0 kg grass DM/cow, measured above a height of 4.0 cm), supplemented with 0.5 kg/day of a 'high magnesium'concentrate. Animals on systems F-C and C-C commenced grazing on 1 April, achieving full turnout on 17 April. Thereafter, until 21 October, these animals were managed on a rotational paddock grazing system (mean herbage allocation achieved, 17.6 kg DM/cow, measured above a height of 4.0 cm), and with concentrates (average allocation, 3.9 kg/day) being offered to yield. Herbage intakes were measured weekly using pre- and post-grazing herbage clips. The data were statistically analysed using ANOVA.

Results The high and medium feed value silages offered in this study had mean dry matter and ME concentrations (estimated using sheep) of 284 g/kg and 12.6 MJ/kg DM, and 202 g/kg and 10.8 MJ/kg DM respectively.

Table 1 System effects on animal performance †

	F-F	F-C	C-F	C-C	SEM	Significance
Number of days ‡	***314***	***306***	***303***	***306***		
Total input per animal (kg DM)						
Concentrates	857[a]	1279[b]	1627[c]	2050[d]	76.5	***
Silage	1448[b]	1592[b]	923[a]	958[a]	65.0	***
Grass	3270[b]	2440[a]	3061[b]	2489[a]	89.4	***
Total	5575	5311	5611	5498	164.5	NS
Total milk output/animal and milk composition						
Milk (kg)	7365	7490	7363	7640	339.3	NS
Milk fat (g/kg)	41.9	41.3	41.8	41.0	0.97	NS
Milk protein (g/kg)	32.7	32.8	33.1	33.3	0.43	NS

† All data adjusted to a common calving date (20 November)
‡ From calving until 20 October (or until drying off if sooner)

Total concentrate DM intake increased significantly from system F-F through to system C-C ($P<0.001$). Silage DM intake was significantly higher for systems F-F and F-C than for systems C-F and C-C ($P<0.001$), while grass DM intakes were significantly higher for systems F-F and C-F than for systems F-C and C-C ($P<0.001$). However, total DM intake was unaffected by system of milk production. Similarly, neither total milk output nor milk composition was significantly influenced by system of milk production.

Conclusions Four very different systems were established in this study, with concentrate, silage and grass proportions in the diet ranging from 0.15 to 0.37, 0.16 to 0.30 and 0.45 to 0.59 of total DM intake, respectively. However, despite the very different inputs of DM from individual ration components in each of the four systems, neither total milk output nor milk composition was affected by system of milk production.

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The effect of heifer rearing regime on body size and milk production during the first lactation

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Introduction The UK dairy industry has entered a period of rapid increase in cow genetic merit. Feeding and management during the rearing period will influence the extent to which the genetic merit of these animals is realised. Current systems for rearing dairy herd replacements are based on research undertaken in the 1960's and 1970's with animals of lower genetic merit. High genetic merit Holstein Friesian animals have an increased live weight and frame size at maturity compared with their medium merit contemporaries, which may have implications for the optimum weight at first calving. The aim of this study was to determine the effect of rearing regime, in terms of diet offered and target calving weight, on first lactation performance of high genetic merit heifers over a range of milk production systems.

Material and Methods One hundred and thirteen high genetic merit Holstein Friesian heifers (PIN (95) £88 s.d. 11.1) were used in the trial. Eighty of the heifers were supplied from 11 commercial farms, the remainder were supplied from the Institute herd. The heifers were collected from the farms at six weeks of age and were allocated on the basis of source, live weight and genetic merit to one of four rearing regimes. The target weights at calving were 540 kg (treatment 1) and 620 kg (treatments 2, 3 and 4). Treatments 1 heifers were offered grass silage-based diets during the winter and grass-based diets during the summer. Treatment 2 heifers were offered the same forage base along with concentrate supplementation. Treatment 3 heifers were offered a straw/concentrate diet during the winter and grass-based diets during the summer. Treatment 4 heifers received the same diets as treatment 3, apart from the first summer period when they were housed and offered a straw/concentrate diet. Live weights were recorded fortnightly and, if required, adjustments were made in concentrate supplementation to ensure target weights were met. The heifers were mated at 14 months of age and were returned to the 11 farms one month prior to calving. . Ease of calving was assessed on a five-point graded scale (1 represented a situation where the calf was born successfully with no assistance required, 5 represented a caesarean section). Milking characteristics of the udder were assessed on a scale of 1 to 4. A score of 1 characterised an udder that milked out well and a score of 4 indicated a fatty udder that milked out poorly. Post-calving, live weights, skeletal measurements, milk yield and composition were recorded monthly. The data was analysed by analysis of variance (Genstat, 1993). Covariate analysis was used to adjust the data for minor deviations from target weight pre-calving in each of the rearing treatments.

Results Heifers reared on treatment 1 weighed less and were of a lower condition score (CS) ($P<0.001$) before calving than heifers reared on the other treatments. The incidence of calving difficulties was not affected by rearing treatment. During early lactation (up to 3 months post-calving) heifers reared on treatment 1 lost less weight and CS ($P<0.001$) (42 kg, 0.59 CS) than heifers reared on treatments 2 (109 kg, 1.46 CS), 3 (122 kg, 1.50 CS) and 4 (94 kg, 1.30 CS). Mean winter milk and fat plus protein yields (kg/d) were lower for heifers reared on treatment 1 ($P<0.05$) than for heifers reared on the other treatments.

Table 1. The effect of rearing regime on pre- and post-calving liveweight and condition score and milk, fat and protein yield.

	Rearing Regime					
	1	2	3	4	s.e.m.	Sig.
Body size 1 month pre-calving						
Live weight (kg)	520	600	600	600	-	-
Condition score	2.74^{a}	3.52^{b}	3.33^{b}	3.30^{b}	0.081	***
Withers height (cm)	135^{a}	138^{b}	139^{b}	138^{b}	0.6	***
Calving period						
Calving difficulty (1-5)	1.81	1.79	1.47	1.59	0.217	
Udder characteristics (1-4)	1.63	1.35	1.45	1.67	0.257	
Body size 3 months post-calving						
Live weight (kg)	478^{a}	491^{ab}	478^{a}	506^{b}	6.6	*
Condition score	2.15^{b}	2.06^{b}	1.83^{a}	2.00^{ab}	0.062	**
Withers height (cm)	135^{a}	138^{b}	137^{ab}	137^{ab}	0.6	**
Winter milk production (mean 140 d)						
Milk yield (kg/d)	27.1^{a}	29.6^{b}	29.0^{ab}	29.6^{b}	0.76	*
Milk fat (g/kg)	37.7	38.1	38.8	37.8	1.08	NS
Milk protein (g/kg)	31.7^{b}	30.3^{a}	30.5^{a}	30.9^{ab}	0.37	*
Fat + protein yield (kg/d)	1.87^{a}	1.99^{b}	1.98^{ab}	2.02^{b}	0.048	*

Conclusions Milk yield during the first lactation was increased by rearing heifers to heavier weights at first calving. However, this increase in performance appeared to be achieved through mobilisation of body reserves as indicated by the reduction in live weight and body condition score post-calving. In line with this, milk protein concentration was lower in the heifers reared to heavier weights. Diet type offered during the rearing period had no effect on subsequent milk production.

References Genstat 1993. *Genstat 5 Release 3 Reference Manual.* Oxford Science Publications, Clarendon Press, Oxford.

An assessment of potential metabolic determinants of reproductive cycle problems identified through milk progesterone monitoring during the service period in lactating dairy cows

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Introduction Recent studies have reported a substantial increase in the incidence of reproductive cycle problems in modern dairy cows (Opsomer *et al.*, 1998; Royal *et al.*, 1999). This increase is often attributed to the ever-increasing metabolic demands placed upon these cows by continually increasing milk yields. In this study we have monitored a variety of metabolic parameters in lactating dairy cows and related these to reproductive function in an attempt to establish metabolic predictors of impending reproductive failure.

Materials and methods The study was carried out on cows within the University of Nottingham commercial holstein-friesian dairy herd calving during October - December 1997 (n = 41) and September - October 1998 (n = 33). Blood samples for metabolite analysis were collected and body weights recorded at 2-4 week intervals from day 40-50 post partum until day 90-120 post partum. Throughout the study period, milk yield was recorded weekly and an average yield determined for each cow. Plasma concentrations of urea (enzymatic glutamate dehydrogenase method; Randox Laboratories Ltd, Crumlin, Co. Antrim, UK), and β-hydroxybutyrate (β-hydroxybutyrate procedure 310-UV, Sigma Diagnostics, Fancy Road, Poole, Dorset, UK) were determined in each sample (3 per cow) and a mean value derived for each animal. A regression line was fitted through individual cow weights to estimate the rate of weight change for each animal. Reproductive function was monitored by measuring progesterone in milk samples collected at weekly intervals throughout the sampling period. In 1997 progesterone was measured by radioimmunoassay (Lamming and Bulman, 1976) and in 1998 by ELISA (Ridgeway Scientific). Progesterone profiles were used to define cycle problems (delayed onset of cyclicity - progesterone < 5ng/ml until > 65 days post partum; cessation of cyclicity - progesterone < 5ng/ml for > 2 weeks following period of > 5 ng/ml; luteal cysts - progesterone > 5ng/ml for >3 weeks. Cows were retrospectively allocated to either a normal cycle or a problem cycle group. Statistical comparisons were made using Student's t tests except for differences in conception rate which were compared using a Chi squared test.

Results Of 74 cows studied, 51 (0.69) had normal cycles (normal cycle group) while 23 (0.31) exhibited reproductive cycle problems (delayed onset, 0.08; cessation 0.14; luteal cysts, 0.09; problem cycle group). Milk yield, plasma metabolites and weight change of cows exhibiting normal and problem reproductive cycles during the study period are shown in Table 1. Cows exhibiting problem cycles had significantly higher milk yield and plasma β-hydroxybutyrate concentration than cows with normal cycles. Furthermore, problem cycle cows lost weight during the period of study

Table1. Comparison of parameters determined in cows exhibiting normal or problem reproductive cycles.

	Normal cycle group (n=51)	Problem cycle group (n=23)	Significance
Milk yield (l/d)	29.2 ± 0.6	34.6 ± 1.4	P < 0.001
Plasma Urea (mmol/l)	6.93 ± 0.19	7.27 ± 0.35	NS
Plasma β-hydroxybutyrate (mmol/l)	0.87 ± 0.04	1.04 ± 0.08	P < 0.05
Weight change (kg/day)	+ 0.182 ±0.050	- 0.028 ±0.093	P < 0.05
Conception to 1st AI	0.48 (n = 44)	0.33 (n=15)	NS

while cows with normal cycles actually gained weight In those cows in which an insemination was made during the study period conception rate was determine from milk progesterone profiles (progesterone >10ng/ml for >3 weeks). The conception rate in cows with normal reproductive cycles (0.48) was higher than in cows that exhibited problem cycles (0.33) though this difference was not significant in the relatively small groups of animals under investigation.

Conclusions The results suggest that reproductive cycle problems are more likely to occur in higher yielding cows loosing more body weight during the service period and exhibiting elevated plasma concentrations of β-hydroxybutyrate. These finding support the role of energy imbalance in the aetiology of reproductive cycle problems in lactating dairy cows while providing no support for a role of protein imbalance.

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References

Lamming, GE and Bulman, DC (1976). The use of milk progesterone radioimmunoassay in the diagnosis and treatment of subfertility in dairy cows. British Veterinary Journal 132, 507-517

Opsomer G, Coryn, M, Deluyker, H and de Kruif, A (1998). An analysis of ovarian dysfunction in high yielding dairy cows after calving based on progesterone profiles. Reproduction in Domestic Animals 33, 193 - 204.

Royal, MD, Darwash, AO & Lamming, GE (1999). Trends in the fertility of dairy cows in the United Kingdom. British Society for Animal Science Supplement, abstract 1.

Estimation of genetic variation in the LH response to a GnRH challenge in pre-pubertal Holstein-Friesian heifers

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Introduction Fertility of UK dairy cows is at an all time low (Royal *et al*., 2000). Genetic improvements through direct selection is minimal since parameters can only be measured in the mature female and generally have low heritability (h^2<0.1). It may be possible to overcome these genetic limitations with the use of an indirect selection criterion. Whilst commencement of luteal activity might prove a valuable genetic indicator of female fertility (Darwash *et al*., 1997), a major step forward would be the identification of a highly heritable trait in the male that is measurable in early life and genetically correlated to a measurement of female fertility. The physiological control of reproduction is by the same gonadotrophic hormones in both sexes (Land, 1973), and Haley *et al*. (1989) reported that the underlying variation in gonadotrophin response to GnRH is controlled by the same genes in both sexes. High heritabilities (0.4–0.55) for the response to GnRH have been reported in ram lambs (Haley *et al*., 1989) and beef bulls (Mackinnon *et al*., 1991). The objective of this study was to estimate the genetic variation in a number of parameters associated with the LH response to a GnRH challenge in pre-pubertal Holstein-Friesian (H/F) heifers.

Materials and Methods In accordance with optimal design theory (Robertson, 1959), the experiment intended to monitor a total population of 500 heifers with 8-10 offspring/sire. The results presented refer to the first 206 heifers monitored. These formed 58 paternal half-sib families varying between 1 and 23 daughters/sire. All animals were selected from four commercial farms using sire and age (120-140 days) as selection criteria. Heifers were challenged with 1ml Fertygyl (0.1mg.ml^{-1} of gonadorelin; Intervet) i.m. and seven heparinised blood samples were collected from the jugular vein at –30, 0, 30, 60, 90, 120 and 150 minutes. Concentrations of LH were measured using an established direct double antibody RIA. The mean sensitivity of the 7 assays performed was 0.18 Ê 0.06 ng.ml^{-1}. The intra- and inter-assay coefficients of variation were 6.6% and 8.5% respectively. The data were analysed using REML (Genstat). The magnitude of variance components, including the genetic variance, and mean values for the fixed effects were estimated for 10 parameters associated with the LH response. A likelihood ratio statistical test was used to determine the significance of random effects. Wald statistics were used to test the significance of the fixed effects.

Results Following analyses, only one parameter; $\log_{10}$ transformation of LH concentration (ng.ml^{-1}) recorded 30 minutes after the GnRH challenge, had a significant (P<0.01) estimate for h^2 (Table 1).

Table 1 Estimate of variance components and heritability estimate after fitting fixed effects into the model using REML

σ^2_S (s.e.)	σ^2_b	σ^2_e (s.e.)	σ^2_A	σ^2_P	h^2 (s.e.)
0.0035	----------	0.0239	0.0140	0.0274	0.51
(0.0022)		(0.0027)			(0.29)

σ^2_S, sire variance; σ^2_b, batch variance; σ^2_e, residual variance; σ^2_A, additive genetic variance, σ^2_P, phenotypic variance.

Conclusion This analysis has provided evidence to show that additive genetic variance is responsible for a substantial proportion of the phenotypic variation in the LH response to a GnRH challenge in pre-pubertal H/F heifers. Taking the optimal experimental design to be 100% efficient (i.e. producing the smallest standard error for heritability given the total population number), the present structure was 66% and 76% efficient for h^2 = 0.4 and 0.5 respectively. Further work is needed in order to increase the precision of the heritability estimates (i.e. reduce the large standard errors) of the parameters investigated. This can be achieved through the inclusion of more animals per sire family into the analysis and this is currently in progress. These results support the case that this trait may be of potential interest to dairy cattle selection programmes to improve fertility, not only as a measurement in heifers but also young bulls. This is of course provided that the high heritability estimates in the present study are confirmed, and the trait is shown to be correlated genetically to high reproductive efficiency in subsequent lactations.

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References

Darwash, A.O., Woolliams, J.A. and Lamming, G.E. 1997. The phenotypic association between the interval to post-partum ovulation and traditional measures of fertility in dairy cattle. *Animal Science* **65**: 9-16.

Haley, C. S., Lee, G.J., Fordyce, M., Baxter, G., Land, R.B. and Webb, R. 1989. Study of LH response to GnRH in the young male as a criterion of genetic merit for female reproduction in sheep. *Journal of Reproduction and Fertility* **86**: 119-133.

Land R.B. 1973. The expression of female sex-linked characteristics in the male. *Nature* **241**: 208-209.

Mackinnon, M.J., Corbet, N.J., Meyer, K., Burrow, H.M., Bryan, R.P. and Hetzel, D.J.S. 1991. Genetic parameters for testosterone response to GnRH stimulation and scrotal circumference in tropical beef bulls. *Livestock Production Science* **29**: 297-309.

Royal, M.D., Flint, A.P.F., Darwash, A.O., Webb, R., Woolliams, J.A. and Lamming, G.E. 2000. Declining fertility in UK dairy cattle. *Animal Science* (in press)

Genetic analysis of mastitis in dairy cattle with a Bayesian threshold model

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Introduction Genetic parameters of mastitis are required in genetic selection for mastitis resistance. Excluding cows that are culled at an early stage of lactation due to mastitis from genetic parameter estimation may introduce culling bias. The use of linear models, suitable for continuous traits, is inappropriate for analysis of mastitis records because it is recorded as an all or none (binary) trait. Here, a Bayesian-threshold model with Markov chain Monte Carlo (MCMC) techniques was used to analyze mastitis data. The objective was to estimate genetic parameters of mastitis in first and all-lactation cows using complete or incomplete records on disease.

Materials and Methods Mastitis records on Holstein cows were obtained from Livestock Services UK (LSUK) Ltd. Mastitis was expressed as a binary trait (0= absence, 1= presence). Four different data sets were created based on complete or incomplete lactations using number days in milk (DIM) and on first or all-lactations cows. The description of all data sets is given in Table 1. Pedigrees for each data set were created, suitable for a sire-maternal grand sire model. A mixed threshold model was adopted for underlying liability to mastitis. In threshold models, liability is assumed to be normally distributed. The threshold model for all data sets included herd, year of calving, age by season sub-classes, lactation number and covariate DIM as fixed effects and, sire and residual terms as random effects. Models for all-lactation data sets (3 and 4) included, in addition to the above effects, permanent environmental effects as random. Analyses were conducted using MCMC methods via Gibbs sampling, using our own software. Gibbs samples were obtained from marginal posterior distribution of each parameter. A long chain of 100000 samples was run for each model. Convergence of Gibbs chain for each model was assessed by CODA (Convergence Diagnostic Algorithms, MRC Biostatistics Unit, U.K). The first 20000 samples were discarded as burn-in period for all models. The remaining 80000 samples were used for computing the posterior mean and standard deviations of each parameter.

Table 1. Description and characteristics of four data sets for MCMC analysis of mastitis

Description of Data sets	*Records*	*Cows*	*Herds*	*Year*	*Sires*
1: First lactation (Complete; DIM > 285 days)	8671	8671	157	4	400
2: First lactation (Include partial lactations also; DIM > 0 days)	10967	10967	171	4	455
3: All lactations (Complete; DIM > 285 days)	32948	20092	241	4	949
4: All lactations (Include partial lactation also ; DIM > 0 days)	44268	24213	266	4	1084

Results Results are given in Table 2. All estimates were on the liability scale. The posterior mean of sire variance (σ_s^2) and heritability (h^2) was higher for first lactation data than for multiple lactations. This may be due to differences in mean incidences for first and multiple lactations data sets (as shown in Table 2). For multiple lactations, estimates of permanent environmental variance (σ_p^2) was higher for complete than incomplete lactations. Repeatability (r) was slightly higher than h^2, suggesting the existence of non-genetic effects for susceptibility to mastitis common to all lactations. Estimates of h^2 and r of mastitis agree well with literature values based on threshold animal models, reported by Pryce et al.(1999). In first or multiple-lactation data sets, point estimates of h^2 were lower (by about 1-2%) when DIM was included as a covariate in the model, to adjust for length of the opportunity period for infection. The regression of liability on DIM ($\beta_{\lambda,DIM}$) differed from zero, indicating that the probability of mastitis is higher for longer lactations.

Table 2. Posterior mean and standard deviations of estimates of σ_s^2, σ_p^2, h^2, r and $\beta_{\lambda,DIM}$ based on 80000 Gibbs samples.

Data sets	Mean	S.D	σ_s^2	σ_p^2	h^2	r	$\beta_{\lambda,DIM}$
1: First lactation	0.089	0.285	0.046 (0.017)	-	0.17 (0.06)	-	-
2: First lactation	0.087	0.282	0.042 (0.014)	-	0.16 (0.05)	-	0.001
3: All lactations	0.076	0.265	0.024 (0.008)	0.147 (0.028)	0.09 (0.03)	0.105	-
4: All lactations	0.072	0.258	0.020 (0.005)	0.107 (0.022)	0.07 (0.02)	0.088	0.001

Conclusions Threshold models based on MCMC method have been implemented to study inheritance of resistance to mastitis in dairy cows. This study supports earlier findings that heritability of mastitis is different for first and multiple lactation cows. It also indicates that regression on DIM should not be ignored in a model for evaluating sires from records in progress. Further research should investigate whether mastitis is a different trait across lactations, by fitting a multiple trait threshold model, and compare results with those found with repeatability models.

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References Pryce, J.E., Veerkamp, R.F., Thompson, R., Hill., W.G. and Simm, G. 1997. Genetic aspects of common health disorders and measures of fertility in Holstein Friesian dairy cattle. *Animal Science* 65: 353-360.

Genetic control of the periparturient rise in faecal egg counts in Scottish Blackface ewes facing mixed, natural nematode infections

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Introduction Infection by nematode parasites is an almost-inevitable consequence of sheep grazing improved pasture. Susceptible classes of sheep include growing lambs and ewes during the period of physiological stress caused by gestation and lactation. Nematode infections in lambs are well documented, less well documented is the decrease in resistance in ewes during the periparuturient period. The consequent elevation in faecal egg counts, the periparturient rise (PPR), leads to pasture infestation by worm eggs (Morris *et al*., 1998) - thus serving as a trigger for the subsequent epidemic in the lambs. Alternative control strategies to complement anthelmintics are continually being sought, with genetic selection of resistant animals a promising option (Woolaston, 1992). Unlike resistance in lambs, relatively little information exists on the genetic control of the PPR in ewes. The aim of this study is to quantify, and estimate the heritability of, the PPR in Blackface ewes grazing improved pasture and facing a natural mixed, nematode challenge.

Materials and Methods Measurements were recorded on a flock of 200 Blackface ewes at the Roslin Institute's Blythbank farm, over a period of three years from 1997 to 1999. Each year, faecal samples were taken on all ewes in the flock, including barren ewes, on two occasions at approximately 4 and 6 weeks post lambing. The number of Strongyle and Nematodirus eggs in each sample were counted were using the modified McMaster technique (Bairden, 1991). The data presented represents the mean from 4 replicate counts from each faecal sample. Nematodirus eggs were generally absent in this flock and results are reported only for Strongyle egg counts. The number of lambs born and subsequently reared for each ewe was recorded. Initial data analyses were performed using the GENSTAT statistical package. Egg counts were all strongly positively skewed and required log-transformation prior to statistical analyses. The effect of the ewes' lambing and rearing status on the PPR was quantified using Restricted Maximum Likelihood (REML) techniques within GENSTAT. The heritability and repeatability of the PPR, accounting for ewe reproductive status and excluding barren ewes, was estimated using the ASREML package (Gilmour, 1996), fitting an animal model including all known pedigree relationships between sheep.

Results A total of 1087 egg counts were performed, with counts ranging from zero (no evidence of a periparturient rise) to 3000 eggs/g. The majority of counts were less than 100 eggs/g. Shown in table 1 are geometric least squares mean values for faecal egg count, classified according to the reproductive status of the ewe in the peri- and post-parturient period, along with their 95% confidence intervals. Because of the skewness of the data these values are considerably lower than equivalent arithmetic least squares means, which are also shown for comparison. Increasing egg counts are associated with increasing reproductive burden ($p < 0.01$), but for all categories there were ewes with zero egg counts, i.e. no evidence of a PPR. The heritability of faecal egg count in non-barren ewes was 0.24 (s.e. 0.08) and the repeatability was 0.28 (s.e. 0.05).

Table 1. *Mean faecal egg counts (FEC) during the periparturient period for ewes with differing reproductive status*

No. lambs born:	0	1	2	1	2	2
No. lambs reared:	0	0	0	1	1	2
Geometric mean FEC (eggs/g) †	2.6	2.9	4.5	5.5	9.6	18.8
95% Confidence Interval†	1.2,4.8	0.5,9.1	0.7,16.4	3.9,7.6	5.1,17.4	14.3,24.7
Arithmetic mean FEC (eggs/g)	51.8	66.6	68.2	81.8	107.1	158.5

† Shown are backtransformed values, after analysis on the log-transformed scale

Conclusions It has been demonstrated that the PPR increases with increasing reproductive burden on the ewe and is heritable. This is in broad agreement with results presented by Morris *et al*. (1998) who reported a heritability of 0.37 in ewes facing a predominantly *Trichostrongylus colubriformis* challenge. Likewise, Woolaston (1992) found significant selection line differences in the PPR between ewes divergently selected, as lambs, for resistance to *Haemonchus contortus*. Thus, there are opportunities to decrease the PPR by selection. However, devising optimal selection strategies will depend on genetic relationships between the PPR and egg counts in lambs, and this is the focus of ongoing studies.

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References Bairden, K.1991.Ruminant parasitic gastritis:some observations on epidemiology and control. Ph.D. Univ. of Glasgow.
Gilmour, A.R., Thompson, R., Cullis, B.R. & Welham, S. 1996. ASREML. Biometrics Bulletin 3, NSW Agriculture.
Morris, C.A., Bisset, S.A., Vlassof, A., West, C.J. and Wheeler, M. 1998. Faecal nematode egg counts in lactating ewes from Romney flocks selectively bred for divergence in lamb faecal egg count. *Animal Science* **67:** 283-288.
Woolaston, R.R.1992. Selection of Merino sheep for increased and decreased resistance to *Haemonchus contortus*: peri-parturient effects on faecal egg counts. *International Journal for Parasitology* 22: 947-953.

Heritabilities of, and correlations between, faecal egg counts and cashmere traits in goats

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Introduction In animal production significant losses occur due to parasitism (Coop *et al.* 1985). The classic means of treating animals against parasites is with anthelminthic drugs. However, the recent years resistance to anthelminthic drugs has become a major problem in many countries. Novel ways of overcoming the problem of nematode parasites have been proposed. One of them is breeding for resistance to parasites (Bishop and Stear, 1999). The aim of this study was to estimate the genetic parameters needed to devise strategies to breed against nematode parasites. Faecal egg counts (FECs) are used as the indicator trait of resistance to parasites.

Materials and Methods The population under study was a crossbred population described by Bishop and Russel (1996). Within this population of goats, one line was selected for reduced faecal egg counts based on the mean of repeated FECs measurements (average n=5) from 12 to 17 months of age. Randomly selected animals from the rest of the population served as controls. The two sexes were grazed separately but the control and the selected animals of the same sex were grazed together. Live weight (LW) and cashmere measurements were taken when the animals were 5 months old. The dataset comprised FEC measurements taken on 830 goats over 5 years (1993-1997) and cashmere measurements taken on 3100 goats over 11 years (1987-1997). Cashmere traits included the cashmere weight in a 10 cm ^{2} patch (P_CASH), fibre length (LENGTH) and fibre diameter (DIAM). The FEC measurements were not normally distributed, and following Box-Cox analyses, they were transformed by taking the cubic root of each measurement (CFEC). The genetic analysis for estimating the heritabilities and correlations between traits was performed using ASREML (Gilmour *et al.* 1996). Maternal effects were important only for LW. The back-transformed means were calculated for FECs after a REML analysis using GENSTAT (Lawes Agricultural Trust, 1995).

Results Selection responses for reduced FEC are shown in Figure 1. In every year, except year 3, the selected animals had significantly lower FECs than the control animals. The heritability of a single CFEC was 0.17 (s.e. 0.02) and for the mean of repeated CFECs it was 0.31 (s.e.0.08). The heritabilities of cashmere production traits, and the genetic and phenotypic correlations with CFEC, are shown in Table 1. None of the correlations between CFEC and the production traits were significantly different from zero. This does not imply that nematode infections have no effect on these traits, it means that, when animals face the same parasitic challenge there is no relationship between animals' ranking on productivity and their ranking on FEC. Benefits from selection for reduced FEC will arise from reduce pasture nematode contamination, leading to reduced parasitic challenge and decreased anthelmintic requirements as shown by Bishop and Stear (1999).

Table 1. *Heritabilities (h^2) genetic (r_g) and phenotypic (r_p) correlations between CFEC and production traits*

Trait	h^2	r_g	r_p
LW	0.29	0.00	-0.01
P_CASH	0.44	0.10	-0.03
DIAM	0.53	0.19	-0.01
LENGTH	0.56	0.23	0.06

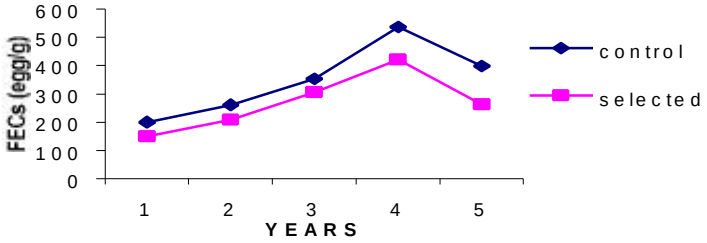

Figure 1. *Back-transformed means of FECs*

Conclusions FEC, a measure of resistance to gastrointestinal nematode infection, was found to be a heritable trait in goats and to respond to selection. Although the heritability of a single measurement was low, it was higher for the mean of repeated measurements, indicating the benefit of multiple measurements. For goats facing the same parasitic challenge, FEC was uncorrelated with cashmere production. This information can now be used in indices designed to improve both productivity and resistance to nematode parasites.

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References

Bishop, S.C. and A.J.F. Russel. 1994. Cashmere production from feral and imported cashmere goat kids. *Animal Production* **58:** 135-144

Bishop, S.C. and M.J. Stear. 1999. Genetic and epidemiological relationships between productivity and disease resistance: gastrointestinal infection in growing lambs. *Animal Science* **69:** 515-524.

Coop, R.L., Graham, R.B., Jackson, F., Wright, S.E. and K.W. Angus. 1985. Effect of experimental *Ostertagia circumcincta* infection on the performance of grazing lambs. *Research in Veterinary Science* **38:** 282-287

Gilmour, A.R., Thompson, R., Cullis, B.R. and S. Welham. 1996. ASREML. *Biometrics Bulletin*. NSW Agriculture.

Lawes Agricultural Trust. 1995. *Genstat 5. Release 3.2.* Rothamsted Experimental Station

The response of gilt body composition to low and high dietary protein during lactation

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Introduction Lactating sows will respond to increasing dietary lysine during lactation providing that energy does not become limiting. In a recent experiment Sauber et al. (1998) demonstrated that fat genotypes readily mobilised fat to make up for inadequate nutrient intake in lactation whereas lean genotypes mobilised protein. The aim of this experiment was to investigate whether fat versus lean animals of similar genetic merit were equally able to utilise diets varying in lysine content. The animals used in this experiment were of a high lean genotype and had been allowed to express their natural variation for fatness during rearing and gestation.

Materials and methods The experiment was a 2 x 2 factorial design involving 230 high lean potential gilts (JSR Healthbred). All gilts were weighed and P2 backfat thickness measured (6.5 mm from the midline over the last rib) at service. Gilts which had a P2 =15 mm were classed as lean (L) with those with a P2 >15 mm were classed as fat (F). At farrowing gilts which had a P2 =20 mm = L and those with P2 >20 mm = F. Only those gilts which remained in the same fatness classification between service and farrowing were used in the experiment, a total of 155 animals. Within body type gilts were randomly assigned to one of two isoenergetic (14.25 MJ DE/kg) lactation diets, Low protein (LP) 155g CP/kg, 7.7g lysine/kg or high protein (HP) 220g CP/kg, 13g lysine/kg. Sow live weight and P2 backfat thickness were measured at farrowing and at weaning. All litters were weighed and adjusted for litter size and live weight within 24 h of parturition. Litters were reweighed at weaning at a mean age of 24.2 (s.e. 0.2) days. Feed intake was recorded daily and all gilts were fed to appetite throughout the trial. No piglet creep feed was offered during lactation. Data was analysed by Minitab 10.1 using a GLM analysis of variance.

Results From the 230 gilts which started, 25 did not complete a successful lactation and 50 gilts changed body type from L to F, this therefore left 155 gilts. F gilts were significantly heavier and fatter at the start of lactation compared to L ($P<0.001$). No significant difference was seen between live weight loss during lactation. P2 backfat loss of L gilts was 2.2 mm lower than F gilts ($P<0.001$). There was also a significant interaction ($P<0.05$) with L-HP and F-LP having a lower P2 backfat loss. The HP diet produced a significantly higher litter weight gain compared to LP ($P<0.05$) and this resulted in a significantly heavier piglet at weaning ($P<0.05$). Total feed consumed during lactation was not significant between either body type or protein level. A summary of the results is given in Table 1.

Table1 *Performance response of body type (lean v fat) and dietary protein level (LP v HP) during the lactation period*

	Lean		**Fat**			*P*	*P*	*P*
	LP	HP	LP	HP	s.e.	Type	Diet	Inter
Number of animals	33	36	44	42				
Live weight at farrowing (kg)	206.3	213.2	226.5	225.6	1.75	***	NS	NS
P2 backfat farrowing (mm)	17.4	18.1	26.1	26.3	0.46	***	NS	NS
Live weight loss (kg)	16.8	14.7	19.5	19.2	1.22	NS	NS	NS
P2 backfat loss (mm)	4.2	3.6	5.4	6.9	0.23	***	NS	*
Litter start weight day 1 (kg)	12.7	12.9	13.1	13.0	0.19	NS	NS	NS
Litter weight gain (kg)	44.2	48.3	45.6	49.9	0.98	NS	*	NS
Piglet live weight weaning (kg)	7.0	7.5	7.3	7.7	0.11	NS	*	NS
Total feed consumed (kg)	131.3	129.2	127.9	134.9	2.23	NS	NS	NS

Conclusion Providing the opportunity for high lean potential gilts to achieve naturally diverse body compositions during gestation, does not produce a negative effect on lactation performance and is contrary to previous data which has shown lower feed intakes for fatter animals (Revell et al 1998). Modern high lean animals require controlled growth expression, not nutritional manipulation which can interfere with the animals metabolic status. This negative biological restraint is then released adversely during lactation when nutrient intake is elevated. The feeding of a high protein diet during lactation provides a beneficial response to piglet growth rate. Both lean and fat body types were able to utilise the high protein diet effectively and this dual response by animals with divergent body composition is an indication of optimal biological status pre farrowing.

Reference

T.E. Sauber, T.S. Stahly, N.H. Williams and R.C. Ewan 1998. Effect of lean growth genotype and dietary amino acid regimen on the lactational performance of sows. *Journal of Animal Science* **76:** 1098-1111.
D.K.Revell, I.H.Williams, B.P.Mullan, J.L.Ranford and R.J.Smits 1998. Body composition at farrowing and nutrition during lactation affect the performance of primiparous sows: I. Voluntary feed intake, weight loss, and plasma metabolites. *Journal of Animal Science* **76:** 1729-1737.

Genotype with nutrition interaction for protein and lipid deposition in pigs

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Introduction Testing different pig genotypes on a single diet may constrain protein and lipid deposition or reduce the efficiency of nutrient utilisation by under- or over-supply of nutrients. If the ranking of genotypes is dependent on the diet used when performance testing animals, then genotype-specific nutritional regimes may be required by breeding companies to identify animals of high genetic merit and by producers to realise the benefits obtained by genetic improvement programmes. In the Edinburgh lean growth project, divergently selected lines for efficiency of lean growth (LFC), for rate of lean growth with animals performance tested on *ad-libitum* (LGA) or restricted (LGS) feeding or for daily food intake (DFI) have been established with seven generations of selection in a Large White population (Cameron, 1994). The selection lines provide an experimental resource to estimate the genotype with nutrition interaction for protein and lipid deposition rates as differences between selection lines will relate to the selection strategy since the lines were derived from the one base population.

Materials and methods There were 320 Large White pigs in the study. In each of the eight selection lines, 30 pigs were *ad-libitum* fed one of three isoenergetic (14.0 MJ DE/kg) diets differing in lysine : energy (0.40, 0.76 and 1.12 g ileal lysine/MJ DE). The study also included 80 control line pigs, which were fed the 0.40 and 0.76 lysine diets. Two pigs from each selection or control line-diet subclass were slaughtered at either 30, 45, 60, 75 or 90 kg with subsequent chemical analysis of carcass and non-carcass components. Animals were performance tested in four batches, with a batch consisting of a pair of high and low selection lines and 20 animals from the control line. The control line was represented in each batch for estimation of non-genetic differences between the batches. Rates of tissue deposition were estimated in residual maximum likelihood analyses. The model for protein or lipid weight in the carcass included fixed effects of selection and control lines, diet, sex and the line-diet interaction and random effects of litter and batch, with litters nested in batches. Days on test was fitted as a covariate separately for each line-diet subclass, from which tissue deposition rates were determined.

Results In Figure 1 (or 2), estimated protein (or lipid) deposition rates from a model containing the selection line-diet interaction (X axis) are plotted against estimated protein (or lipid) deposition rates from the additive model, omitting the selection line with diet interaction, (Y axis). If estimates from the additive and interaction models were similar, such that there was no interaction, then points would lie on the line Y = X (as indicated).

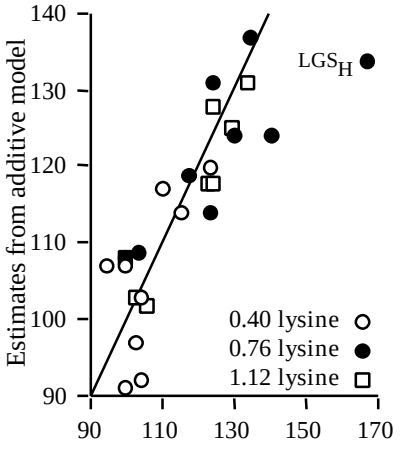

Figure 1. Protein deposition (g/day)

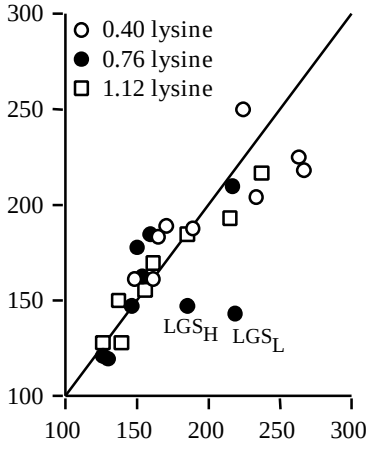

Figure 2. Lipid deposition (g/day)

The significant (P<0.05) selection line with diet interaction for protein deposition rate was primarily due to the high (H) LGS line, which had higher protein deposition on the 0.76 lysine diet than estimated from the additive model. The significant (P<0.05) selection line with diet interaction for lipid deposition rate resulted from high lipid deposition in the LGS lines on the 0.76 lysine diet, particularly the low (L) LGS line. When the high LGS line was excluded, the correlation between estimates for protein deposition rate from the interaction and additive models of 0.85 (s.e. 0.21) was not significantly different from unity. The correlation between estimates from the two models for lipid deposition rate was 0.89, when the high and low LGS lines were excluded; again not significantly different from one.

Conclusions There was no evidence of a genotype with nutrition interaction for protein or lipid deposition, excluding the LGS lines, such that ranking of the selection lines will be similar irrespective of the performance test diet. It may not be necessary to performance test pigs on diets substantially higher than 0.8 g ileal lysine/MJ DE, given the similar rates of protein and lipid deposition of pigs fed diets containing 0.76 and 1.12 g lysine/MJ DE. The selection strategy-diet combination of high LGS and 0.76 g ileal lysine/MJ DE provides an efficient and high protein deposition rate.

Acknowledgements
The research project was funded by the Ministry of Agriculture, Fisheries and Food. J. Fraser of SAC Edinburgh performed the carcass dissection and I. Barclay of SAC Auchincruive performed the chemical analyses.

References
Cameron, N.D. 1994. Selection for components of efficient lean growth rate in pigs. 1. Selection pressure applied and direct responses in a Large White herd. *Animal Production* **59**: 251-262.

Effect of xylanase addition in feed containing either pre-characterised wheat or wheat by-products on the performance of growing pigs

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Introduction Wheat and wheat by-products vary in their available energy and protein content (Batterham *et al*., 1980) leading to unpredictable growth rate and feed use efficiency. Carbohydrase enzymes, targeting the non-starch polysaccharides in these raw materials, may improve their nutrient availability. However, questions remain over the relationship between the quality of the dietary raw materials and the level of exogenous enzyme activity required in the feed to elicit a response from pigs. Hence, the response of pigs to the use of a fungal xylanase, produced by *Trichoderma longibrachiatum*, was studied in diets containing wheat and wheat by-products.

Materials and methods Two experiments were undertaken using individually housed entire male pigs of the Bunge synthetic genotype. In experiment 1, the positive control diet (14.0 MJ DE/kg and 0.7g available lysine/MJ DE) containing 'high' quality wheat was compared with four treatments where 'high' quality wheat was substituted with 'medium' or 'low' quality wheat (65%) and millrun (5%), with or without xylanase addition (minimum guaranteed 4000 U/g product). The quality of the wheat varieties was established in an earlier experiment based on the growth response of the pigs. Thirty-eight pigs were allocated randomly with 7-8 entire male pigs per dietary treatment. For experiment 2, 60 pigs were allocated randomly to 5 dietary treatments: positive control based on 63% wheat (14 MJ/kg DE, 0.98 av. lysine and 3.36% CF); negative control (NC) based on 43% wheat and 20% wheat millrun (13.3 MJ/kg DE, 1.01 av. lysine and 4.66% CF). Xylanase (minimum guaranteed 4000 U/g product) was added to NC at the following rates: NC+500g/t, NC+750g/t and NC+1000g/t. Feed was provided *ad libitum*. Pigs were allocated at 29 kg in both experiments and remained on treatment for 5 weeks over which time growth and feed conversion were measured. Data were analysed by one-way analysis of variance and treatment differences analysed by Duncans T-test.

Results Daily feed intake was reduced by the medium and low quality wheat diets in experiment 1 ($P<0.05$), whereas feed intake tended to increase with the addition of the wheat millrun in experiment 2 ($P<0.10$; Table 1). Xylanase addition improved growth performance of pigs fed the low and medium quality wheat diets to the same level as achieved by the high quality wheat diet (experiment 1). Enzyme supplementation improved feed conversion ratio of the negative control diets to the level observed in the positive control diet ($P<0.01$, experiment 2).

Table 1 Effect of xylanase on performance of pigs fed the experimental diets in both experiments

Treatment	Xylanase* (g/tonne)	Finish weight (kg)	Daily gain (g)	Daily feed intake (kg)	Feed Conversion Ratio
Experiment 1					
Wheat- high	0	61.9	960^{a}	1.77^{a}	1.84
Wheat- medium	0	60.2	918^{ab}	1.62^{ab}	1.80
Wheat- medium	1000	61.2	945^{a}	1.71^{ab}	1.81
Wheat- low	0	58.3	878^{b}	1.58^{b}	1.76
Wheat- low	1000	61.5	952^{a}	1.73^{a}	1.81
SED		0.65	12.4*	0.033*	0.021
Experiment 2					
Positive control	0	62.3	945	1.92	2.03^{b}
Negative control	0	61.5	926	2.15	2.33^{a}
Negative control	500	64.5	997	2.14	2.14^{b}
Negative control	750	63.4	986	2.01	2.04^{b}
Negative control	1000	62.0	937	2.04	2.18^{b}
SED		0.75	14.9	0.033	0.028**

* Xylanase at minimum guaranteed 4000 U/g product
^{a,b} Means within columns with different superscripts are significantly different * $P<0.05$, ** $P<0.01$

Conclusions The diets containing medium and low quality wheat sequentially reduced feed intake and daily gain. Substituting 20% wheat by millrun also reduced performance of growing pigs. Xylanase addition significantly improved performance in low quality wheat to a level equivalent to that of the high quality wheat diet and improved the performance of a diet containing wheat millrun to that having a high level of wheat. The differences between the levels of xylanase added were not significant although the inclusion rate of 750 g/kg xylanase (minimum guaranteed 4000 U/kg feed) was numerically the highest performing. The two experiments confirm that the performance of growing pigs will respond to the improved nutrient availability of wheat-based diets given xylanase supplementation.

References

Batterham E.S., Lewis C.E., Low R.F. and McMillan C.J. 1980. Digestible energy content of cereals and wheat by-products for growing pigs. *Animal Production.* **31:** 259-271

Serum leptin concentration in pigs selected for high or low daily food intake

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Introduction Leptin is synthesised and secreted from adipocytes into the blood stream and transported to the brain, where it acts to cause a release of factors which can reduce food intake (Houseknecht *et al*., 1998). There are two murine mutations of the recessive gene coding for leptin which are associated with obesity. The *Lep*^{ob} allele determines synthesis and secretion of leptin, while the *Lep*^{db} allele determines responsiveness to leptin. In the Edinburgh lean growth experiment in pigs, selection for high and low daily food intake (DFI) has been practiced for seven generations in a Large White herd, which provides the experimental resource to determine if the correlated response in fat deposition is consistent with insufficient leptin production or with insensitivity to leptin.

Material and methods In each of the high and low DFI selection lines, 20 Large White boars and gilts were penned individually and performance tested using the diet-choice procedure to reduce nutritional constraints on animals' genetic merit for growth. Animals were offered two isoenergetic (14.0 MJ DE/kg) diets differing in lysine (9.7 and 15.7 g/kg) throughout the test period of 30 ± 3 kg to 90 ± 5 kg. Blood samples were taken at the start and end of test and at 50 ± 4 kg and 75 ± 5 kg live weight. Serum leptin concentrations, expressed as ng/ml human equivalent (HE), were determined with a commercially available radio-immunoassay procedure using an antibody raised against human leptin which displayed 67% cross-reactivity to porcine leptin and had a detection limit of 1 ng/ml HE (Linco Research, Missouri). Differences between the high and low selection lines and the interaction with stage of performance test were estimated using residual maximum likelihood analysis. The model contained the two-way interaction of selection line and sampling stage, sex and laboratory assay as fixed effects, with litter and animal fitted as random effects.

Results Serum leptin concentrations in the high DFI line were significantly ($P<0.05$) higher than in the low DFI line and increased with live weight (Table 1). Backfat depth and DFI were significantly higher in the high DFI line, from 50 kg. Fat content was not measured in the current study, but in the previous generation (Cameron *et al*., 1999) fat contents of the high and low DFI lines were 249 and 190 g/kg (s.e.d. 7) at 85 kg. The positive correlation between serum leptin and backfat depth increased from 0.33 (s.e. 0.16) at 30 kg to 0.53 at 90 kg, but the change was not statistically significant. In contrast, correlations between serum leptin measured at each stage of test and performance test traits, such as growth rate (0.13) and total food intake (0.18), were not significantly different from zero.

Table 1 Serum leptin and performance of the high and low DFI lines

		Liveweight at measurement (kg)				
Trait	Line	30	50	75	90	s.e.d.
Serum leptin (ng/ml HE)	High DFI	2.48	2.55	2.93	3.38	
	Low DFI	2.21	2.23	2.30	2.34	0.20
Ultrasonic backfat depth (mm)	High DFI	7.8	11.5	14.9	17.3	
	Low DFI	6.6	8.8	10.6	12.0	0.74
		Between liveweights (kg)				
		30-50		50-75	75-90	
Daily food intake (g)	High DFI	1862		2362	2797	
	Low DFI	1611		1996	2394	182
Growth rate (g/day)	High DFI	867		933	902	
	Low DFI	766		840	845	49

Conclusions The positive response in serum leptin and a measure of fat deposition indicated that increased fat content was not due to insufficient leptin production, as in the *Lep*^{ob}/*Lep*^{ob} mouse. Serum leptin was more highly correlated with fat deposition than with food intake indicating that the response in serum leptin was primarily due to increased fat deposition rather than to higher energy intake *per se*. The consistent positive correlations between serum leptin and a measure of fat deposition indicate that serum leptin could usefully be incorporated in selection criteria for genetic improvement of carcass lean content in pigs. Further, the pair of high and low DFI selection lines could be considered as a porcine model for the human condition of obesity, given the association between leptin and fatness in humans (McGregor *et al*., 1996).

Acknowledgements The research project was funded by the Ministry of Agriculture, Fisheries and Food.

References Cameron, N.D., Nute, G.R., Brown, S.N., Enser, M. and Wood, J.D. 1999. Meat quality of Large White pig genotypes selected for components of efficient lean growth rate. *Animal Science* **68**: 115-127.
Houseknecht, K.L., Baile, C.A., Matteri, R.L. and Spurlock, M.E. 1998. The biology of leptin : a review. *Journal of Animal Science*. **76**: 1405-1420.
McGregor, G.P., Desaga, J.F., Ehlenz, K., Fischer, A., Heese, F., Hegele, A., Lammer, C., Peiser, C. and Lang, R.E. 1996. Radioimmunological measurement of leptin in plasma of obese and diabetic human subjects. *Endocrinology* **137**: 1501-1504.

Testing two theories of feed intake using the effect of temperature on the intake of bulky feeds in pigs

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Introduction Currently there are two theoretical frameworks for the prediction of feed intake of animals. The first considers feed intake to be a consequence of the animal eating to achieve its genetic potential (Kyriazakis and Emmans, 1999). When potential performance is not achieved it is because feed intake is being constrained, for example through the bulkiness of the feed or the hotness of the environment. The second framework considers feed intake to be an outcome of some process of optimisation so that intake is that which allows the maximisation of biological efficiency (Tolkamp and Ketelaars, 1992). The two frameworks differ in their predictions of the effect of temperature on the intake of bulky feeds. In the first, feed intake on bulky feeds is seen as a function of the type of feed; in the second, feed intake is a function of both the type of feed and the environment. The first framework predicts that in the cold the intake of low, but not high, bulk feeds will increase. The second framework predicts that in the cold intake will be increased regardless of the type of feed offered. This experiment was designed to provide a severe test of the two feed intake theories.

Materials and Methods Forty weaned pigs (twenty F1 hybrids and twenty Manor Meishans, PIC) at 4 weeks of age and weighing 8.5 (s.d. 1.3)kg were placed into individual pens and randomly allocated either to one of two high bulk feeds (14 pigs on each feed) or to a low bulk control feed (12 pigs). Each treatment was balanced for breed. The control feed (C, 13.1 MJ DE and 232g Crude Protein (CP) per kg fresh feed) was based on micronised wheat and the high bulk feeds were dilutions of the control feed with either 65% wheatbran (WB) or 65% unmolassed sugar beet pulp (SBP). The high bulk feeds were formulated to have similar ratios of amino acids and minerals to DE as that of C. Half of the pigs were maintained at a thermoneutral temperature (22^{o}C) for fourteen days followed by a low temperature (12^{o}C), which was assumed to be below the thermoneutral temperature of the pigs, for another fourteen days. The other half were maintained at 12^{o}C for fourteen days followed by 22^{o}C for a further fourteen days. Throughout the experiment feed intake was measured daily and liveweight was recorded twice a week. The data were analysed as a split plot design using REML to look for evidence of feed x temperature interactions.

Results There was a significant interaction between the type of feed offered and environmental temperature for feed intake ($P < 0.05$) and scaled feed intake (SFI, $P<0.001$). A reduction in temperature caused an increase in feed intake of the C feed but had no effect on the intake of the SBP feed. Pigs on the C feed increased consumption by 22% in the cold. LWG ($P<0.001$) was affected by the type of feed being fed, but not by temperature. Growth rate was severely restricted on the SBP feed; pigs on this feed had a feed intake that was significantly less than that of the C feed at both temperatures. The wheatbran feed did not restrict performance at 22^{o}C when compared with C. At 12^{o}C the wheatbran feed was restrictive, feed intake was increased compared to C, but growth rate was reduced.

Table 1: The daily rate of scaled feed intake (g kg liveweight^{-1} day^{-1}), absolute feed intake (g day^{-1}) and liveweight gain (g day^{-1}) of pigs fed three feeds at two different temperatures

	Scaled Feed Intake (g kg^{-1}d^{-1})		**Feed Intake (g d^{-1})**		**LWG (g d^{-1})**	
Food (F)	High (22ºC)	Low (12ºC)	High	Low	High	Low
C	38.42	43.68	978	1190	692	746
WB	50.90	58.44	1327	1459	765	604
SBP	40.48	40.80	1015	933	395	290
sed	2.3		82.9		95.4	
Effects						
Temperature (T)	***		***		ns	
Food (F)	***		***		***	
F*T	***		*		ns	

Conclusions The results of this study agree with the predictions made by the first framework. Intake was increased with a reduction in temperature on feeds that allowed greater growth rates, but not for the SBP feed. It was assumed that the low level of intake and performance on the SBP feed was due to the bulk content of the feed. Therefore, it was concluded that under the circumstances of this study the feed intake pattern of pigs is most appropriately described by the pig eating to achieve its genetic potential subject to constraints. A good theory of feed intake will allow the correct prediction of voluntary feed intake in pigs and will facilitate management and financial decisions.

References

Kyriazakis.I and Emmans G.C. 1999. Voluntary food intake and diet selection. *A Quantitative Biology of the Pig.* Edited by I.Kyriazakis. CABI Publishing.

Tolkamp B.J and Ketelaars J.J.M.H. 1992. Toward a new theory of feed intake regulation in ruminants2. Costs and benefits of feed consumption: an optimisation approach. *Livestock Production Science* **30**: 297-317.

Changes with time in the short chain fatty acid profile during *in vitro* incubations of feeds with rumen fluid and their effect on the prediction of ATP production

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Introduction The *in vitro* gas production technique is a means of measuring the dynamics of fermentation. It is related to short chain fatty acid (SCFA) production, and so could be used to estimate ATP supply for rumen micro-organisms. However, different fermentation patterns produce different amounts of gas. No fermentation gas is associated with the production of propionate, and so an increase in the proportion of propionic: (acetic+butyric) (P:AB) would be associated with a decrease in the volume of gas produced. If the molar proportions of SCFA changed during a fermentation, then this would complicate the interpretation of the gas production profile (GPP). If the GPP, combined with a measure of SCFA concentrations at the end of the incubation, was used to estimate ATP yield during the incubation, then changes in P:AB during the incubation may affect these estimates. The objectives of this experiment were therefore to determine whether P:AB did change during an *in vitro* incubation, and whether any such change affected the accuracy of the prediction of ATP yield with time.

Materials and methods Dried, ground (1 mm screen) samples (0.5 g) of high temperature dried grass (HTDG), straw (STR), wheat (WHT) and molassed sugarbeet feed (MSBF) were incubated twice (48 h, 39^0C) *in vitro* (Theodorou *et al.*, 1994) with 15 ml strained rumen fluid and 35 ml medium. At intervals, gas volume was recorded and three replicates of each substrate were analysed for SCFA. The amount of ATP produced (ATPP) was then estimated (mmol/g DM incubated) for each time interval (ATPPobs) by multiplying acetate, propionate and butyrate yield (mmol/g DM incubated) by 2, 3 and 3 respectively (Hespell, 1979). The effects of substrate and time on P:AB and ATPPobs were determined by analysis of variance. Stoichiometrically predicted gas volume at 48 h was divided by observed gas volume at 48 h to give a correction factor (CF) to allow for differences between predicted and observed gas volume. Total SCFA concentration at 48 h was divided by predicted gas volume to give SCFA yield (SCFAY, mmol/ml gas). The observed gas volume at each time interval was multiplied by CF and SCFAY to give a predicted concentration of total SCFA. This was then multiplied by the molar proportions of SCFA at 48 h to give a prediction of acetate, propionate and butyrate production. From these data, the predicted amount of ATPP at each time interval was calculated (ATPPpred) and the relationship between ATPPpred and ATPPobs determined by regression analysis.

Results Substrate (S) and time (t) affected both the P:AB ratio (Table 1) and ATPPobs. Mean ATPPobs was 7.05, 4.14, 9.56 and 9.87 for HTDG, STR, WHT and MSBF respectively (SEM 1.119). ATPPpred was well related to ATPPobs (Figure 1); adjusted R^2=0.858, SEC=1.43, P<0.001.

Table 1 Effect of substrate and time on the ratio of propionic:(acetic+butyric) acids

Incubation time (h)	Substrate			
	HTDG	STR	WHT	MSBF
2	0.193	0.193	0.100	0.231
4	0.174	0.147	0.235	0.302
6	0.292	0.220	0.364	0.335
8	0.297	0.251	0.227	0.287
10	0.362	0.284	0.240	0.298
12	0.288	0.287	0.219	0.299
18	0.313	0.295	0.211	0.291
24	0.291	0.352	0.221	0.318
48	0.275	0.268	0.197	0.246

SEM: 0.0243 Significance: S ***; t ***; S x t ***

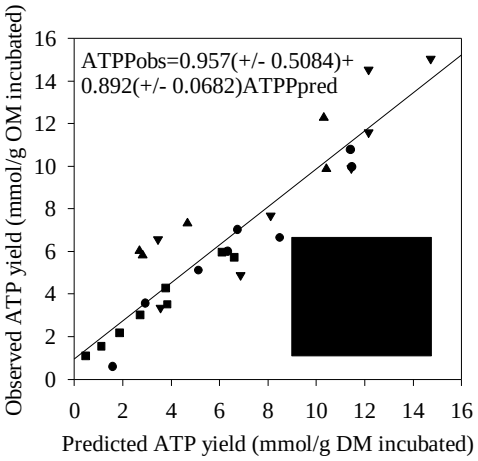

Figure 1 *Relationship between predicted and observed ATP yield*

Conclusions The SCFA profile does change during an *in vitro* incubation and this would have a small effect on the GPP. However, the changes are small and so the dynamics of ATPP can be predicted from the SCFA profile at 48 h in conjunction with the GPP.

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References Hespell, R.B. (1979) Efficiency of growth by ruminal bacteria. *Federation Proceedings* **38**: 2707-2712

Theodorou, M.K., Williams, B.A., Dhanoa, M.S., McAllan, A.B. and France, J. (1994) A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminant feeds *Animal Feed Science and Technology* **48:** 185-197.

The additivity of predicted ATP yields from feedstuffs incubated *in vitro* with rumen fluid

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Introduction Rumen micro-organisms ferment feeds to short chain fatty acids (SCFA) with the production of ATP. Measuring SCFA concentration *in vitro* could therefore be used to predict the yield of ATP *in vitro*. This estimate could then be used to predict the yield of synthesised microbial biomass. However, feeds may interact when they are incubated together, and so it is quite possible that ATP yield is not additive. The objectives of this experiment were therefore to determine whether the yield of total SCFA produced by feed mixtures was additive, and also whether the ATP yield of feed mixtures could be predicted from the calculated ATP yield of the individual feeds.

Materials and methods Six feeds: wheat grain (WH), soyabean meal (SBM), fishmeal (FM), rapeseed meal (RSM), molassed sugar beet feed (MSBF) and rice bran (RB) were milled through a 1mm screen and incubated *in vitro* alone and in combinations of 0.75:0.25, 0.50:0.50 and 0.25:0.75 (DM basis) for the following: WH with either SBM, FM or RSM; MSBF with FM or SBM; and RB with SBM. Two replicates (1.0 g) of each feedstuff and mixture were incubated three times at 39 ^{0}C for 8 h with 20 ml strained rumen fluid and 80 ml medium (Schofield and Pell, 1993). The incubation residues were analysed for SCFA and OMD. The effect of increasing the proportion of the protein concentrate in the mixture on total SCFA yield (mmol/g OM degraded) was determined using orthogonal contrasts to determine whether the effect was linear (L), quadratic (Q), or deviated from both L and Q (Dev). The ATP yields (mmol/g OM degraded) of the incubation residues were calculated by multiplying the yields of acetate, propionate and n-butyrate by 2, 3 and 3 respectively (Hespell, 1979) and then taking the sum of these products. The ATP yields from the feeds incubated alone were used to estimate the ATP yields of the mixtures. Observed and predicted ATP yields were then compared using regression analysis.

Results SCFA yield had a linear element for all feed mixtures except SBM and RB (Table 1), although many showed a quadratic element as well. Only SBM and WH showed a signifcant deviation from both L and Q.

Table 1 *The SCFA yields (mmol/g OM degraded) for a range of feedstuffs and simple mixtures*

	Proportions of Feed A:Feed B in mixture (DM basis)					SED	Significance of contrast		
Feed A:Feed B	1.00	0.75	0.50	0.25	0.00	df=3	L	Q	Dev
SBM : WH	6.2	6.7	8.2	9.4	9.0	0.21	**	**	**
FM : WH	2.6	4.3	6.8	8.8	9.5	0.85	**	NS	NS
RSM : WH	7.5	8.6	9.0	9.4	9.2	0.32	**	*	NS
FM : MSBF	3.1	5.8	8.3	9.8	10.3	0.36	**	**	NS
SBM : MSBF	6.0	7.0	8.0	8.9	9.1	0.13	**	**	NS
SBM : RB	5.6	6.2	7.2	7.7	5.8	0.81	NS	*	NS

The relationship between predicted and observed ATP yield was:
Observed ATP yield = 0.97+ (1.02 x Predicted ATP yield); adjusted R^2 =0.864; SEC=1.31; P<0.001.

Conclusions There is a complex relationship between feed mixtures and total SCFA yield, but for practical purposes it would appear that the yield is additive. Similarly, ATP yield may be predicted accurately for simple feed mixtures from the ATP yield of individual feeds. This potentially offers a reliable way of estimating the amount of energy available to rumen micro-organisms.

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References

Hespell, R.B. 1979. Efficiency of growth by ruminal bacteria. *Federal Proceedings* **38**: 2707-2712

Pell, A.N. and Schofield, P. 1993. Computerised monitoring of gas production to measure forage digestion *in vitro*. *Journal of Dairy Science* **76**: 1063 - 1073.

A comparison between *in situ* and *in vitro* measurement of rumen degradability of Brazilian feeds

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Introduction. The *in situ* measurement of rumen degradability explains properly the disappearance of rumen feeds by solubilization. However, this methodology does not assure wheather the material in the rumen indeed suffered microbial degradation, or if the loss of material occurred by other reasons. The *in vitro* gas production technique, on other hand, measures a product of the fermentation process. If the remains of the gas production is recovered at pre-determined intervals, we could also determine the rate and extent of the degradation occurred in the process. Thus, the aim of this work was to compare the rate and extent of the degradation obtained from these two methodologies.

Material and methods. Six adult whether with rumen cannulas were used as incubators for the *in situ* technique and as donors of rumen liquor to prepare the inoculum solution used in the *in vitro* technique. The animals were fed a forage/concentrate diet (80:20 ww). Eight substrates were tested in both techniques: Leucaena hay, Lucerne hay, corn grain, *Panicum* grass, soybean meal, sugarcane bagasse, Tifton (*Cynodon*X*Cynodon*) hay and corn silage. All these feeds were dried and grounded to 2mm for the *in situ* technique and to 1mm for the *in vitro* technique. The *in situ* experiment was conducted according to Ørskov & McDonald (1979) using dacron bags (n = 3 per substrate) drawn from the rumen at 3, 8, 16, 24, 48, 72 and 96 hs. The *in vitro* assay was conducted according to Theodorou *et al*. (1994), except that bottles (n = 3 per substrate) were drawn out at the same intervals as the bags mentioned above. Dry and organic matter degradability were determined from the differences between original and final weights of the samples after proper preparation (washing or filtering). The obtained results were adjusted by the model $p=a+b\ (1-e^{-ct})$ (Ørskov & McDonald, 1979), and the parameters were compared using regression and/or correlation.

Results. The *in vitro* degradability showed high relationship with those data obtained using the *in situ* technique. (Figures 1 e 2), for dry matter ($R^2 = 0.81$; $P < 0.01$) and for organic matter ($R^2 = 0.84$; $P < 0.01$). However, not all the parameters from the used model showed the same tendency. Only the rate of disappearance (*c*) showed significant correlation ($r = 0.71$; $P < 0.05$ for dry and organic matters). One of the most important problems with *in situ* assays is the material loss (washing loss) due to the porosity of the bags. This problem can be overcame using the *in vitro* technique because non-soluble particle loss is minimised by filtering the residues in crucibles, which have porosity much smaller. In addition to this, the lag phase is better noticed using *in vitro* technique. The lag time lasted about ten times more in gas production technique (8.0 and 7.3h for *in vitro* and 0.7 and 0.7h for *in situ* technique, respectively for dry and organic matter) and these results seemed to be more straight with real conditions.

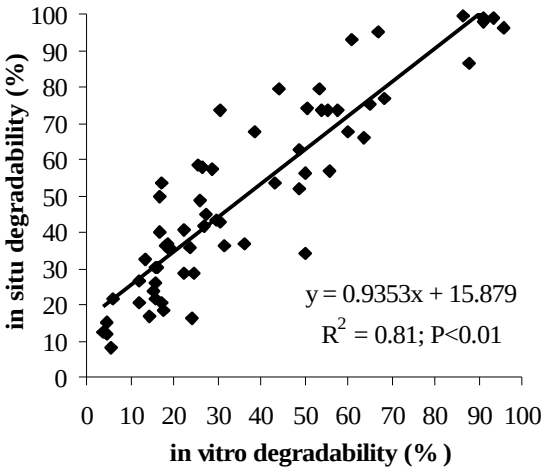

Figura 1. Regression between in vitro and in situ dry matter degradabilities

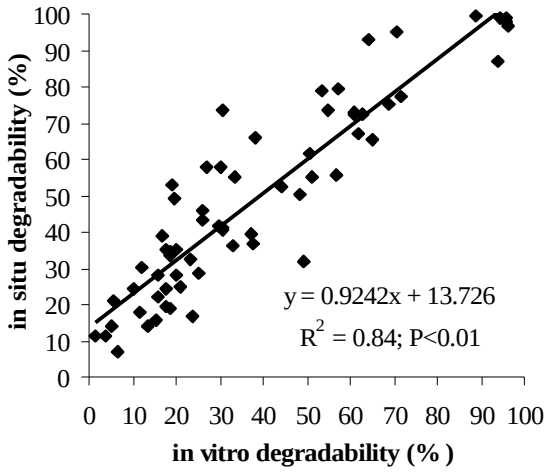

Figure 2. Regression between *in vitro* and *in situ* organic matter degradabilities

Conclusions. The *in vitro* technique allows a better control of every condition and its results are with straight relationship with those obtained from *in situ* experiments. Thus, from the gas production technique, it can be obtained the rate of degradation of the substrate, in addition to the information regarding the rate and extent of the product of the fermentation process.

References.

Ørskov, E.R. & McDonald, I., 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to the rate of passage. *Journal of American Science*. 92:449-53.

Theodorou, M.K.; Williams, B.A.; Dhanoa, M.S.; McAllan, A.B. and France, J., 1994. A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminant feeds. *Animal Feed Science and Technology* 48:185-97.

Fibrolytic enzyme mixtures as an alternative to rumen fluid for assessing feed degradation kinetics *in vitro*

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Introduction Several techniques involving enzymes as alternatives to rumen fluid in *in vitro* studies have been proposed. However, high cost, ill-defined characterisation and high variation among enzyme preparations and batches have discouraged their use. In addition, most studies have aimed at determining dry matter degradability (DMD) at a fixed time, commonly 48 h. Consequently little information has been published concerning the DM degradation dynamics of forages incubated with enzymes. Therefore the objective of the present study was to compare the ability of a commercial enzyme mixture to describe the fermentation dynamics of two contrasting forages, using the ANKOM *in vitro* fermentation system (Daisy II, ANKOM Co, USA).

Material and methods Protein content, cellulase and hemicellulase activities in the enzyme mixture (EM) were determined at 39°C and pH 5.5 (Colombatto *et al*., 1999). In the *in vitro* study, bags containing approximately 0.5 g DM of pre-dried (65°C) and milled (2 mm screen) maize silage (MS) or alfalfa hay (AH), were placed in vessels containing buffer plus either rumen fluid (2 vessels) or three levels of EM (2, 5 or 10 ml in 2.0 l medium) (2 vessels/level). Rumen fluid was taken from a hay-fed dry cow, 2 h before feeding and after straining 400 ml was added to each vessel, depending on treatments, together with 1.6 l of anaerobic buffer medium. In the case of enzyme treatments, 2.0 l/vessel of 0.05M sodium acetate buffer (pH 5.5) was applied. Triplicate bags were removed from each vessel after 3, 6, 12, 18, 24, 36, 48 and 96 h of incubation at 39°C, washed and then dried at 100°C for 24 h to determine dry matter degradation (DMD). The values were then fitted to the France *et al.* (1993) model.

Results The protein content of the EM was 76.03 mg/ml. Endoglucanase, exoglucanase, cellobiase, xylanase, β-D-glucopyranosidase, α-L-arabinofuranosidase and α-L-arabinopyranosidase activities were 647.1, 13.7, 8.9, 3820.1, 6.7, 4.7 and 0.8 µmol reducing sugars/ml.min, respectively. Filter paper cellulase activity was 7.5 filter paper units. Maize silage was degraded to a higher (780 vs. 529 g/Kg DM, $p<0.05$) extent than AH. In comparison to rumen fluid, the EM showed practically no lag phase with either of the forages used (Figure 1a and b). This was as expected with a free enzyme preparation, no bacterial attachment or growth being required before degradation occurring. The difference ($p<0.05$) in DMD values between rumen fluid and EM probably reflected a lower enzyme concentration or a lack of a specific enzyme activity in the enzyme mixture selected. In addition, increasing enzyme levels increased ($p<0.05$) DMD values, particularly for AH (419, 440 and 466 g/Kg for levels 1, 2 and 3, respectively).

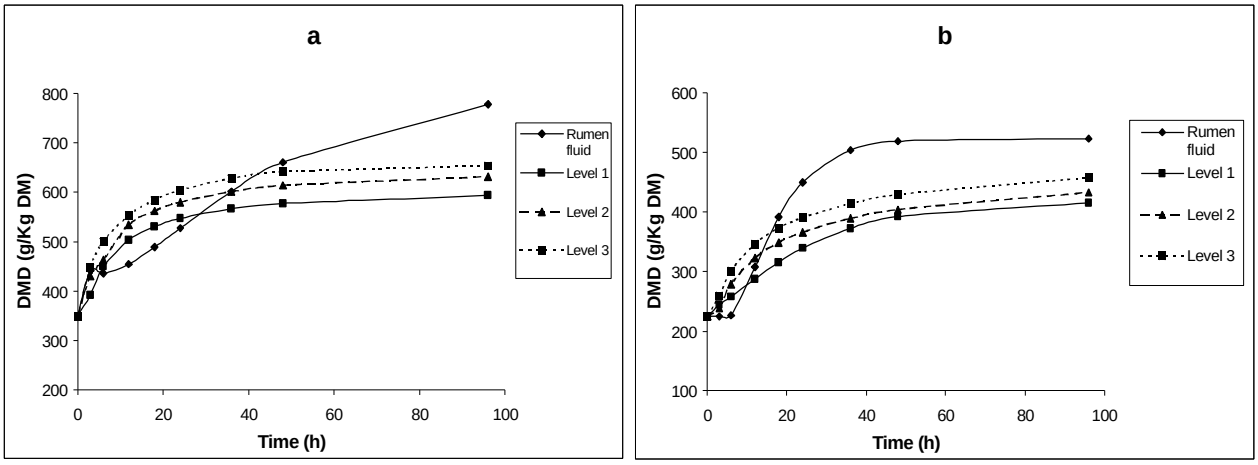

Figure 1 *In vitro* DMD of maize silage (a) and alfalfa hay (b) using rumen fluid or three levels of an enzyme mixture

Conclusions It is concluded that enzyme mixtures have the potential to describe the DMD profiles of maize silage and alfalfa hay, but further research is needed to determine the optimum enzyme array to be used for different feeds. In addition it appears that the ANKOM *in vitro* system can be adapted to utilise enzymes instead of rumen fluid inocula.

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References Colombatto, D., Bhat, M. K., Mould, F. L. and Owen, E. 1999. Characterisation and evaluation of a commercial enzyme for improving the nutritive value of ruminant feeds. *Proceedings of the British Society of Animal Science*, p 211.
France, J; Dhanoa, M. S.; Theodorou, M. K.; Lister, S. J.; Davies, D. R. and Isac, D. 1993. A model to interpret gas accumulation profiles associated with in vitro degradation of ruminant feeds. *Journal of Theoretical Biology*, **163**: 99-111.

The performance and behaviour of finishing beef cattle accommodated during the winter on different floor types

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Introduction The effect of rearing or finishing beef cattle on fully slatted floors on their welfare has recently been questioned. The objective of this experiment was to examine the effects of using different types of floors in accommodation for beef cattle on their performance and behaviour.

Material and methods In Year 1, sixty Continental-cross steers (mean initial live weight 450 (s.e. 2.5) kg) were blocked according to live weight and randomly assigned within blocks to one of three floor types, namely fully slatted floors, fully slatted floors covered with perforated rubber mats or solid floors bedded with straw. In Year 2 different animals and an additional treatment, which consisted of rubber strips secured directly onto slats, were used. Twenty steers were accommodated on each of the floor types in each year and thus in Year 2 a total of eighty steers were used (mean initial live weight 423 (s.e 2.8) kg. There were four pens of five animals in each treatment in each year. The diet consisted of grass silage offered *ad libitum* and supplemented with 4.0 kg per head per day of fresh cereal-based concentrates. Daily individual food intakes and live-weight and carcass weight gains were determined for a mean duration of 140 days in Year 1 and 142 days in Year 2. Each individual animal was observed directly, once per week in Year 1 and once per fortnight in Year 2. Individual observation periods lasted 10 minutes, during which all behaviours were recorded continuously. In addition, each pen of animals was recorded on video for a 72h period every fortnight in Year 1 and once every 4 weeks in Year 2. Overall carcass composition was estimated from the dissection of fore-rib joints. The mean of the individual behaviours of the five cattle in a pen was used as a replicate. Data were analysed using analysis of variance, with statistical differences between treatment means being tested using Student's *t* tests.

Results There was no significant effect of floor type on production parameters such as food intake, live-weight and carcass gains or carcass composition (Table 1).

Table 1 Food intake, animal performance and carcass data (kg/d, unless otherwise stated)

	Floor type								
	Year 1				Year 2				
	Slats	Mats	Straw	s.e.m.	Slats	Mats	Strips	Straw	s.e.m.
Dry matter intake	9.2	9.4	8.9	0.14	8.8	8.8	9.0	8.9	0.15
Live-weight gain	1.03	1.11	1.06	0.033	1.10	1.16	1.16	1.17	0.037
Est. carcass gain	0.67	0.68	0.66	0.019	0.67	0.70	0.71	0.72	0.020
Fat in carcass (g/kg)	215	207	209	6.7	213	209	205	208	6.0

Animals on straw spent significantly longer sniffing the ground than those on the other floor types in both Year 1 ($P<0.01$) and Year 2 ($P<0.001$) (Table 2). The proportion of time which cattle spent performing repetitive behaviours, which consisted of tongue rolling, repeated nose licking and lip curling, was not significantly affected by floor type. Cattle on slats and mats lay for longer than those on straw in Year 1 ($P<0.05$), but floor type had no significant effect on amount of time spent lying in Year 2. Cattle on slats got up and down significantly less often than cattle on the other floor types in both years ($P<0.001$). Cattle on mats (Years 1 and 2) and strips (Year 2) got up and down significantly less often those on straw ($P<0.001$).

Table 2 The effect of floor type on proportion of time spent performing behaviours

	Floor type								
	Year 1				Year 2				
	Slats	Mats	Straw	s.e.m.	Slats	Mats	Strips	Straw	s.e.m.
Direct observations:									
Sniffing ground	0.008	0.008	0.017	0.0018	0.003	0.004	0.000	0.014	0.0015
Repetitive behaviours	0.023	0.021	0.018	0.0021	0.014	0.017	0.017	0.025	0.0027
Video observations									
Lying	0.64	0.64	0.60	0.009	0.59	0.61	0.60	0.61	0.010
Number of position changes from standing to lying (per animal per day)	7.9	9.4	13.4	0.48	7.7	10.3	11.5	14.4	0.648

Conclusions Floor type did not significantly affect animal performance. The provision of bedding increased time spent sniffing the ground, which may be linked to the expression of foraging behaviour. However, floor type had no significant effect on the amount of time spent performing repetitive behaviours. There was a stepwise reduction in posture changes from bedding to mats/strips to slats.

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Subliminal perception of colour by cattle

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Introduction In humans **s**ubliminal perception is more evident in vision than other senses (Dixon, 1987) but it has not been reported in animals. The presence of subliminal visual perception might be suspected in cattle because of their low level of perceptual discrimination ability of visual cues relative to humans (e.g. Phillips and Weiguo, 1991), despite their sensory apparatus being similar in many respects. Experiments were therefore conducted to determine the extent of cattle colour perception and examine whether the effects of colour on cattle behaviour transcend that their perceptual abilities. We sought to a) confirm that cattle are dichromats, taking account of stimulus brightness, which has not always been the case in previous experiments investigating cattle colour vision, and b) investigate whether cattle exhibit differences in behaviour in isoluminant primary colours for trichromatic vision. Confirmation that cattle are dichromats, together with demonstrations of differences in behaviour in the three primary colours would suggest the existence of subliminal perception, and would question the validity of determining animal welfare requirements solely on psychophysical testing of supraliminal perception.

Materials and method *Trial 1 The ability of calves to discriminate between the three primary colours* Eight calves of 8 weeks of age were trained to select either the brighter of two white lights (4 calves) or the dimmer (4 calves), using a feed reward for the selection of the correct chamber in which the light was housed. The brightness of red, blue and green lights were then varied in pairs in two small chambers until the calves were unable to discriminate between them. A new group of eleven calves of the same age were then trained to discriminate between the three colours of light, made isoluminant according to results of the calf discrimination test. Lights were again compared in pairs. *Trial 2 The behaviour of calves in the three primary colours* Nine calves were selected at 8 weeks of age to be housed in either green, red and then blue light for 16 day periods (5 calves) or blue, green and then red light (4 calves). Light sources were isoluminant as determined in trial 1. At the end of each period the calves were subjected to tests that investigated their response to three different types of stimuli - novel, fearful and familiar. Novelty was provided by movement to a different pen, fear by dropping a board behind the calf at the entrance to a pen and finally responses to a familiar person were examined. In the fear test the time taken to negotiate a barrier and escape from the stimulus was recorded, and in the familiar test the time to reach the person was recorded. Movement of the calf in each 4 minute test was measured by an overhead camera linked to videodigitizing software. Values of most parameters had to be transformed to a square root function to achieve normal distribution before examining statistical significance with ANOVA.

Results *Trial 1* The red, blue and green lights were isoluminant to the calves at a ratio of 2.2, 1.4 and 0.7 x 10^{20} photons, respectively. After 24 training tests calves were able, in a further series of 32 tests, to discriminate red from green lights (mean correct choice [MCC] 87%), red from blue lights (MCC 83%) but not green from blue lights (MCC 50%), thus demonstrating dichromatic vision. *Trial 2* In the novel pen the calves were more active in the red light than the green (Table 1). In the fear test they were less active in the green light than the red or blue, and they took less time to negotiate the barrier and hide in the green light than the blue, perhaps due to greater stereoscopic acuity in the green light. In the test of a familiar stimulus, there was no difference in the total movement between colours but the calves performed stronger movements in the red colour and reached the person fastest in this colour.

Table 1: Calf responses to novel, fearful and familiar stimuli in the primary colours for trichromatic vision

	Blue	Green	Red	SED
Movement in novel pen (√pixel change/min)	3.0	2.3	3.5	0.38***
Movement in fear test (√pixel change/min)	2.8	2.3	2.8	0.27**
Time to hide in fear test (√% of 4 min.)	6.3	4.9	5.5	0.87***
Movement in familiar test (√pixel change/min)	2.8	2.5	2.7	0.39
Movement strength in familiar test (% pixel change)	19.4	19.3	21.3	1.02***
Time to person in familiar test (√ % of 4 min.)	6.4	5.3	3.7	1.13***

Conclusions Cattle demonstrated an ability to distinguish red from blue or green, but not green from blue, consistent with dichromatic vision. In response to a fearful stimulus, cattle were able to negotiate a barrier and hide faster in green than blue light, demonstrating that subliminal perception of differences in short to medium wavelength light affected their behaviour. On the assumption that such faculties exist in cattle, psychophysical tests of discrimination ability should be viewed with caution in prescribing environmental conditions for the welfare of farm animals.

References

Dixon, N.F. 1987. Subliminal perception. In (Gregory, R.L. ed) *The Oxford Companion to the Mind,pp 752-755*. Oxford University Press, Oxford.

Phillips, C.J.C. and Weiguo L. 1991. Brightness discrimination by cattle relative to that of humans. *Applied Animal Behaviour Science* **31**, 25-33.

Behavioural and heart rate responses of cows and calves to each other's vocalisations after early separation

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Introduction Current commercial dairy practice involves the removal of the calf from the dam within the first two days of life. This early separation may result in stress for both cow and calf. However, it may also be that separation occurs before the cow-calf bond is established. The aim of this study was to determine if cows and calves respond to each other's calls after separation and whether they could distinguish their own calf's or dam's calls from another calf's or cow's calls.

Materials and methods The study was carried out on 12, first to fourth parity, Holstein-Friesian cows and their 12 calves. The cows were separated from the herd 7 days prior to calving and were group-housed with 4-5 other pre-parturient cows. Immediately after calving, the cow and calf were moved to a single, straw-bedded pen. Each calf was separated from its dam at 24±12h after parturition, at 1200h and placed in a sawdust-bedded, individual calf pen in another building. The cow remained in the home pen. During the 24h period after separation, sample calls of the cow and the calf were recorded, using a hand-held microphone and a digital audio tape-recorder. These recordings were edited on computer using sound analysis software. Representative calls were selected from each cow and calf. Four or five calls were edited together to form separate playback sequences from each animal. For each call sequence, a paired white-noise sequence with an identical profile was generated. At 24h after separation, the cow and calf were fitted with heart rate (HR) monitors. Each cow was then subjected to four playback sequences in two pairs; own calf and white noise, other calf and white noise. Each calf was also subjected to four playback sequences in two pairs; own cow and white noise, other cow and white noise. The playback order was balanced and playbacks were carried out when all cows were standing and all calves were lying. HR and behaviour - ear movements, ear flicks, head movements and response score on a scale of 1 (no response) to 5 (approach and touch loudspeaker) - were recorded continuously during 3 periods: 1min immediately before playback; the 20s of playback; 2 min immediately after playback. The before playback measures were subtracted from the during and after playback measures and differences were statistically analysed using repeated measures ANOVA.

Results Cows responded more to calf vocalisations than to white noise during playback (see Table 1). During the 2min after playback, cows also had a greater maximal HR change (Call = 16.5±3.8%, Noise = 7.3±1.5%, $P<0.01$) carried out more head movements (Call = 1.1±0.5min^{-1}, Noise = -0.5±0.4 min^{-1}, $P<0.05$), had a greater increase in activity score (Call = 1.8±0.4, Noise = 0.4±0.1, $P<0.01$) and tended to vocalise more (Call = 0.2±0.2min^{-1}, Noise = -0.1±0.1min^{-1}, $P<0.1$) in response to calls. However, there were no significant differences in response between own calf calls and other calf calls. In response to calls, the calves showed greater number of head movements (Call = 4.2±0.9min^{-1}, Noise = 1.8±0.6min^{-1}, $P<0.01$) and ear movements (Call = 9.7±2.8min^{-1}, Noise = 2.1±0.8min^{-1}, $P<0.01$) during playback and tended to show a higher maximal HR response (Call = 20.8±3.1%, Noise = 16.3±2.3%, $P<0.1$). They also showed greater number of ear movements and tended to show greater peak HR change during playback of own mother calls compared with other cow calls (see Figure 1).

Table 1: Mean±s.e. behavioural and HR responses of cows during playback of calf vocalisations or white noise

	Call	Noise	Signif.
Change in mean HR (%)	3.7±2.0	-1.7±0.7	**
Change in peak HR (%)	11.7±3.5	2.5±0.9	**
Change in ear movements (number/min)	8.6±2.0	1.9±1.3	**
Change in head movements (number/min)	3.3±1.0	-0.1±0.6	***
Change in response (score)	1.7±0.4	0.5±0.1	**

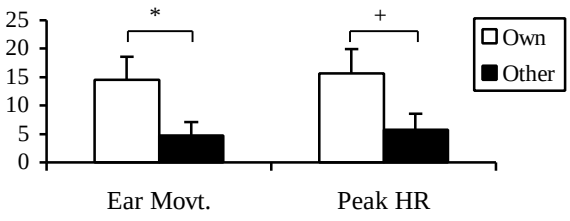

Figure 1: Mean+s.e. change in number of ear movements min^{-1} and peak HR change (beats per minute) of calves during playback of dam's or other cow's vocalisations

Conclusions Cows respond more strongly to calf calls than to white noise, but show little differential response to calls from their own calves. This may be because separation is carried out before calves are highly vocal. The calves showed subtle behavioural and HR responses to cow calls, but these responses were greater to their own dam's calls. During the pre-separation period, the cow is vocal towards the calf and under natural conditions, overt responses to cow calls could increase risk of predation.

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The effects of straw availability for nest-building on maternal reactivity of crated sows after farrowing

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Introduction Most indoor sows in Denmark and the UK continue to farrow in crates. Before farrowing, sows are highly motivated to nest-build and gilts farrowing in crates without straw have an especially large stress response over the nest-building period (Jarvis et al., 1997). In non-crated sows, the inability to nest-build affects the subsequent maternal behaviour of the sow after farrowing (Herskin et al., 1999). This study aimed to determine whether supplying straw before farrowing increased the anti-crushing and anti-predator behaviour of the crated sow after farrowing and improved piglet survival.

Materials and methods The study was carried out on six replicates of four Camborough-12 multiparous sows randomly allocated to one of two treatments; S - farrowing crates with straw (n=12); C - farrowing crates without straw (n=12). The sows were moved to the farrowing house five days before farrowing and fitted with heart-rate monitors. Both treatments were subjected to standard commercial husbandry procedures, being fed twice daily and having water available *ad libitum*. S treatment sows were given straw daily throughout the study period. C treatment sows received no straw until the first feeding post partum, but thereafter were also given straw daily. Reactivity of the sow to piglet distress calls was assessed at the 1st, 2nd and 3rd feeding after farrowing (Squeal 1,2 & 3). As the sow lay down from standing, piglet squeals were played from a loudspeaker behind the sow for 2 minutes or until the sow stood back up, whichever was sooner. Reactivity to the presence of a potential predator was assessed at 1st and 2nd feeding after farrowing (Fox 1 & 2). Whilst lying, the sow was subjected to simultaneous presentation of a stuffed fox and fox vocalisations played from a loudspeaker, placed at the front of the crate. Anal glands dissected out from a dead fox provided an olfactory stimulus. The test duration was always 3 min.

Behaviour and heart rate were recorded continuously during the tests. The sow's behavioural response was assigned a score, according to the magnitude of response, of between 1 (lying, no reaction) and 5 (changing posture from lying to standing) for the piglet distress tests or between 1 (lying, no reaction) and 7 (standing up and snapping) for the fox tests. Differences between treatments were investigated using either one-tailed or two-tailed Mann Whitney U-Tests, depending on whether or not the research hypothesis had direction. Differences between tests were investigated using Friedman two-way analysis of variance by ranks and relationships between variables were tested using Pearson correlation. Data from 5 sows were excluded from the analysis due to signs of post-farrowing illness or lameness.

Results Treatment did not affect the behavioural or heart rate parameters measured. Although total liveborn litter size did not differ between treatments, the presence of straw did reduce the number of liveborn piglets dying per litter (S=0.44±0.34, C=1.50±0.50, $P<0.05$). The number of piglets dying per litter was positively correlated to the behavioural response during Fox 1 ($R=0.47$, $P<0.05$). Whereas there was a degree of consistency within and between tests in behavioural and heart rate responses (see Tables 1 & 2), there was little relationship between behavioural responses to Fox 1 and other tests. Across both treatments combined, behavioural response scores to the piglet squeal test increased over time (squeal test 1= 2.21±0.40, squeal test 2 = 2.58±0.40, squeal test 3 = 3.11±0.41, $P<0.05$) but did not differ for the fox test.

Table 1 Pearson's correlation coefficients between behavioural response scores during reactivity tests

	Fox 1	Fox 2	Squeal 1	Squeal 2
Fox 2	0.37			
Squeal 1	0.49*	0.53*		
Squeal 2	0.40	0.55*	0.89***	
Squeal 3	0.23	0.07	0.60**	0.46*

Table 2 Pearson's correlation coefficients between maximum heart rate changes (%) during reactivity tests

	Fox 1	Fox 2	Squeal 1	Squeal 2
Fox 2	0.62**			
Squeal 1	0.37	0.57*		
Squeal 2	0.69**	0.58*	0.68**	
Squeal 3	0.52*	0.82***	0.47	0.38

Conclusions Sows' maternal reactivity appeared to be an individual trait. The provision of straw to sows in crates during the nest-building phase did not affect subsequent maternal reactivity. However, the presence of straw before and at farrowing did reduce liveborn piglet mortality perhaps in part due to its inherent thermal properties. Over time, behavioural responses to the squealing piglet test increased, indicating that crushing risk is high immediately after farrowing, when the sow may still be recovering from the exertion of farrowing.

Acknowledgement We thank Richard Hodgkinson and Beate Aldenhof of DMU Lincolnshire Farms Ltd.

References

Herskin M.S., Jensen K.H., Thodberg K. (1999). Influence of environmental stimuli on nursing and suckling behaviour in domestic sows and piglets. *Animal Science*, **68**: 27-34.

Jarvis, S., Lawrence, A.B., McLean, K.A., Deans, L.A., Chirnside, J. and Calvert, S.K. (1997) The effect of environment on behavioural activity, ACTH, β-endorphin and cortisol in pre-farrowing gilts. *Animal Science*, **65**: 465-472.

The effects of stocking density and pen shape on the behaviour, incidence of aggression and subsequent skin damage of sows mixed in a specialised mixing pen

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Introduction The mixing of unfamiliar sows at weaning forces the establishment of dominance hierarchies, which frequently involves aggression (Kay *et al*, 1999). The objective of this study was to determine whether different stocking densities and pen shapes would reduce the incidence of aggression and levels of skin damage. The ultimate aim was to design a mixing pen which could be used to enhance the welfare of groups of newly-weaned sows.

Materials and methods Forty groups of six sows were exposed to one of eight treatments (five groups/treatment) arranged in a 2x4 factorial design with two levels of stocking density (H: 4.1m^2 and L: 9.3m^2 per sow) and four types of pen shape (E: elongated rectangular, R: rectangular, S: square, and C: circular). The groups of unfamiliar sows were mixed at 10:00 on Day 1 (weaning), removed on Day 2 at 08:30 to individual feeding stalls and returned to the pen at 09:00. Sows were observed directly from 10:00–14:00 on Day 1 and video tape records were taken for 28 hours from 10:00 on Day 1. All aggressive interactions, and their durations, were recorded and categorised into three classes: brief (knock, snap or bite), one-sided fight (no retaliation by defender) or two-sided fights (defender retaliates). Skin damage scores were taken as the total number of lesions on the body. Scores were recorded pre-weaning, at 14:00 on Days 1 and 2 and were used to determine the increase in damage, due to aggression, over the mixing period. Resulting data were analysed using repeated measures ANOVA with group as the experimental unit.

Results The total number of aggressive interactions, per hour, decreased over the 28h period ($P<0.001$) with the majority of interactions occurring within the first four hours (Table 1). The mean number of aggressive interactions over the entire mixing period were; 89.6, 82.6, 90.4, 74.76 for pen shapes E, R, S and C respectively (s.e.d.=9.632, $P<0.01$). Overall, the lowest levels of aggressive interactions were observed in the E and C pen shapes at L stocking density ($P<0.001$, Figure 1). There were significant differences in the levels of aggression between the stocking densities in the E and C, but not the R and S, pen shapes. Interactions were shortest in the R pen shape treatment (Table 2). There were no significant differences in damage score on Day 1, however, over the whole of the mixing period, stocking density affected the increase in damage score; 54.3 vs. 64.7 lesions/sow for L and H respectively (s.e.d.=5.07; $P<0.05$).

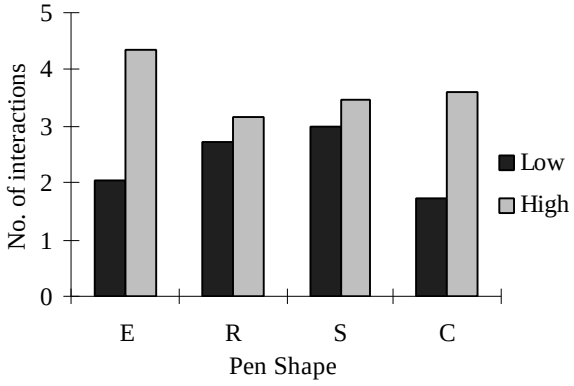

Figure 1 Mean number of aggressive interactions per hour, at different stocking densities, (s.e.d. 0.485).

Table 1 Effect of pen shape on mean number of interactions during the first four hours post-mixing.

	Pen shape				
Type	E	R	S	C	s.e.d.
Brief	37.5	36.9	32.0	29.5	5.600
One-sided	18.3	16.3	19.5	16.4	4.122
Two-sided	5.2	5.0	6.4	7.2	1.536
Total	53.2	58.2	57.8	53.0	8.220

Table 2 Mean duration of interactions (sec) over the total mixing period (s.e.d. 7.49).

	Pen shape			
Density	E	R	S	C
High	40.4	23.6	25.5	35.1
Low	30.6	15.6	35.7	44.6

Conclusions The absolute levels of aggression and increase in damage score were diminished at L stocking density. However, differences in the number of aggressive interactions between L and H stocking densities were only significant for the E and C pen shapes; suggesting that the choice of stocking density is less critical in an R or S shaped pen. When mixing sows in an E or C shaped pen, a low stocking density (9.3m^2 per sow) should be used. R and C pens produced the lowest mean number of aggressive interactions and it was found that duration of interactions were shortest within the R shaped pen. These data suggest that if a producer's objective is to reduce total aggression, the optimum choice would appear to be a C shaped pen with a very generous stocking density. However, if the objective is to reduce the level of aggression, the duration of interactions, and to provide a low cost pen which is robust to a range of stocking densities, R shaped pens could be viewed as a better choice.

Acknowledgements This work was funded by MAFF.

References R.M. Kay, A. Burfoot, H.A.M. Spoolder and C.M. Docking, 1999. Effect of flight distance on aggression and skin damage of newly weaned sows at mixing. *Proceedings of the British Society of Animal Science* (p.14).

Effects of protein and energy supply on the resistance to nematodes in pregnant ewes

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Introduction It has been proposed that the occurrence of the periparturient relaxation in immunity (PPRI) to gastrointestinal parasites is due to a lower partial priority of nutrient allocation to the immune functions, rather than to the reproductive functions, when parasitized hosts are offered scarce nutrient resources (Coop and Kyriazakis, 1999). This implies that immune functions directed towards gastrointestinal parasites will benefit from an increased supply from scarce resources, such as metabolizable protein (MP) and metabolizable energy (ME). In this experiment we studied whether the resistance in parasitized pregnant sheep is affected by an increased supply of MP, or ME, or both.

Materials and Methods Sixty twin-bearing, 3-4-year-old Greyface ewes were housed at d_{70} of pregnancy and trickle infected with *Teladorsagia (Ostertagia) circumcincta* at a rate of 10,000 L_3 per day for three days per week from d_{86} onwards; this was d_0 for the experiment. Their diets were calculated to supply a certain proportion of the requirements for MP (MPr) and ME (MEr); MPr and MEr were calculated for a litter birth weight of 10.3 kg. Three diets (LL, HL and HH) were fed for 42 days (n=20). The LL-diet was calculated to supply 0.7 and 0.7 times MPr and MEr, respectively. The levels were respectively 1.2 and 0.8 for the HL-diet, and 1.3 and 1.2 for the HH-diet. Body weight (BW) and body condition score (BC, by lumbar palpation and on a scale from 0-5) were measured weekly, and ultrasonic backfat depth and muscle depth fortnightly. Faecal egg counts (FEC, in eggs per gram faeces, epg) were assessed weekly from d_{14} onwards, and were transformed according to log(FEC+1) prior to statistical analysis. The analysis of variances followed a mono-factorial design with diet as main effect, and BW, BC, backfat depth and muscle depth at housing as covariates for these parameters.

Results The grand mean BW and BC at housing were 76.2±0.6 kg and 3.1±0.1, respectively. The LL-ewes did not gain BW and lost BC, while the HH ewes gained ~10 kg of BW but no BC (Table 1). The changes in BW and BC of the HL-ewes were intermediate.

Table 1. BW and BC at the end of the experiment (d_{42})

	Dietary treatments			SED	P-values
	LL	HL	HH		
BW	76.0	82.7	86.6	0.74	P<0.01
BC	2.4	2.8	3.1	0.09	P<0.01

Figure 1 shows the backfat depth, the muscle depth, and the FEC of the ewes. The FEC figures are back-transformed means and are therefore presented with 95% confidence intervals. The backfat depth decreased over time for the LL- and HL-ewes, and was lower compared to the HH-ewes at d_{42} (P<0.001). The muscle depth decreased rapidly over time for the LL-ewes, and was lower compared to the HH- and HL-ewes at d_{42} (P<0.001). The FEC of the LL-ewes increased rapidly over time to levels above 100 epg; the FEC of the HL- and HH-ewes increased slowly and stayed below 25 epg (P<0.01 at d_{42}).

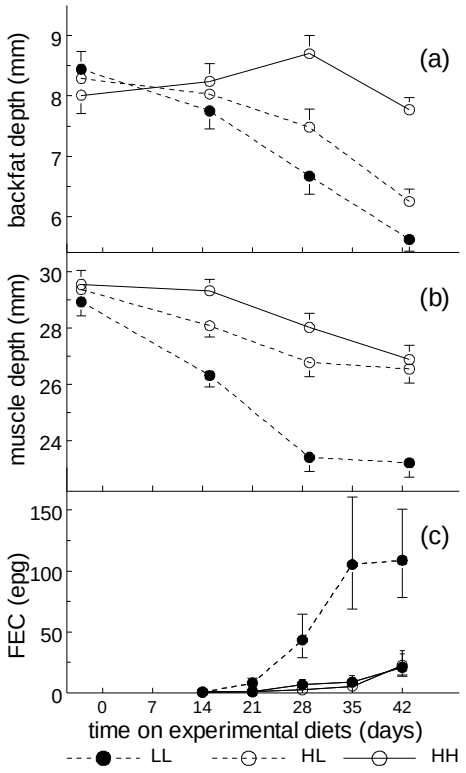

Figure 1: Backfat depth, muscle depth, and FEC of the ewes. See Materials and Methods section for the legend.

Conclusion The data strongly support the view that protein and not energy nutrition is involved in the occurrence of the PPRI to gastrointestinal nematodes in ewes. The changes in MP and ME intake were closely reflected in changes in backfat depth and muscle depth, respectively, but to a lesser extent in changes in body condition score. The latter suggests that strategic supplementation of the ewe to enhance resistance to gastrointestinal parasites might not always be effective when this is based on body condition score only. Nevertheless, the immune response to gastrointestinal parasites of pregnant ewes in poor condition (BC<2.5) may benefit from an improved protein nutrition.

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References Coop R.L. and Kyriazakis I., 1999. Parasite-nutrition interaction. *Veterinary Parasitology* **84**: 187-204.

Protein nutrition, reproductive effort and resistance to nematodes in lactating ewes

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Introduction A nutrient partitioning framework has been developed to account for host nutrition-parasite interactions in mammals (Coop and Kyriazakis, 1999). The framework puts forward a nutritional basis for the occurrence of the periparturient relaxation of immunity (PPRI) to gastrointestinal parasites in sheep. The PPRI would be expected to occur because it is proposed that the reproductive effort has a higher partial priority than the immune functions when hosts are given access to scarce nutrient resources, such as metabolizable protein (MP). This would imply that i) immune functions towards parasites will benefit from an increased MP supply, and that ii) the degree of the PPRI depends on the level of reproductive effort. We studied these predictions by comparing performance and resistance in parasitized twin- and single-rearing ewes, which were offered increasing amounts of MP.

Materials and Methods Twenty-one single- and twenty-one twin-bearing, 2-6-year-old Dorset-Finn ewes were housed individually from six weeks before the expected lambing date (d_{-42}) and then trickle infected with *Teladorsagia (Ostertagia) circumcincta* at a rate of 10,000 L_3 per day for three days per week throughout the experiment. The ewes were fed a low protein diet until d_{-21}; from d_{-21} to d_{35}, they were fed *ad libitum* one of three iso-energetic diets (12.0 MJ metabolizable energy/kg dry matter; n=7 for each litter size). These diets were calculated to supply 87, 105, or 130 g MP per kg dry matter, providing respectively 80% (L), 100% (M), or 120% (H) of the MP requirements for a maximum milk production of 2.5 kg per day (single-rearing ewes) and 3.5 kg per day (twin-rearing ewes). Dry matter intake (DMI, g/d) was measured twice weekly. The ewes and lambs were weighed weekly and within 12h of lambing; body condition score (BC) was assessed fortnightly by lumbar palpation on a scale from 0-5. Faecal egg counts (FEC, in eggs per gram faeces, epg) were assessed twice weekly, and were transformed according to log(FEC+1) prior to statistical analysis. ANOVA followed a 3×2 factorial design with diet and litter size as main effects. FEC and DMI were analyzed using repeated measurements. Here, we focus on the lactation part of the PPRI, and present main effects only since no diet × litter size interactions occured.

Results DMI averaged 3.0, 3.3 and 3.5 kg/d (SED 0.15) for the L-, M- and H-ewes, respectively ($P<0.05$) and was not affected by littersize. BW and BC at lambing averaged 84.2±1.63 kg and 3.5±0.06, respectively and were not affected by diet or litter size. Changes in BW and BC over time were not affected by diet but were higher for the single- than for the twin-rearing ewes (5.8 vs -0.1 kg, SED 1.47, $P<0.001$, and 0.0 vs -0.5, SED 0.14, $P<0.001$, respectively). Litter birth weight averaged 6.2, 7.2 and 7.2 kg for the L-, M- and H-ewes, respectively (SED 0.38, $P<0.05$). Litter gain averaged 17.4, 19.8, and 20.2 kg, respectively (SED 1.19, $P<0.10$). Figures 1 and 2 show the FEC of the ewes; these are backtransformed means and therefore presented with 95% confidence intervals. The L- and H-ewes had higher FEC than the M-ewes ($P<0.05$) during the temporary elevated FEC between lambing and d_{12}. There was a diet × time interaction from d_{12} onwards. The L-ewes tended to higher FEC than the M- and H-ewes at d_{23} and d_{33}. This effect was significant at d_{30} ($P<0.05$). Single-rearing ewes had lower FEC than twin-rearing ewes from d_{12} onwards ($P<0.001$).

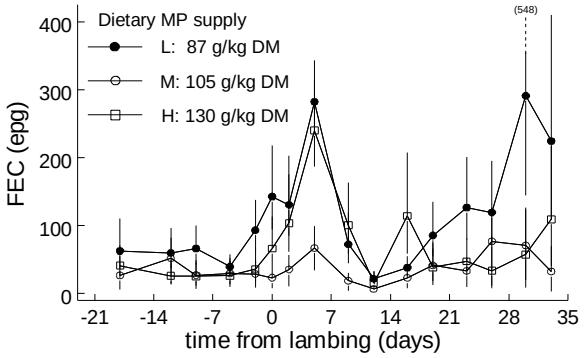

Figure 1. Effect of dietary MP supply on FEC of the ewe.

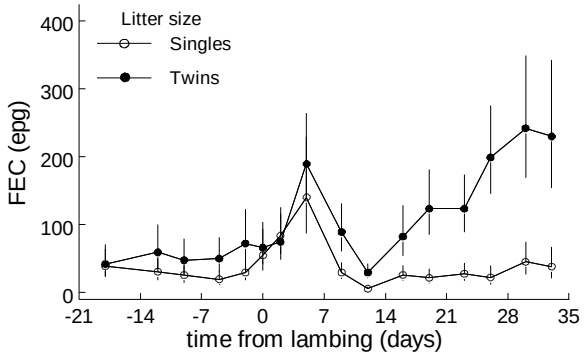

Figure 2. Effect of litter size on FEC of the ewe.

Conclusion The data support the view that the immune response towards gastrointestinal parasites benefits from an increased MP supply and that the extent of the PPRI depends on the level of reproductive effort. A transient breakdown in immunity, that started just before lambing, was observed for all treatments. Single-rearing ewes maintained their resistance from d_{12} onwards as did those offered an increased amount of MP. This shows that it is mainly the twin-rearing ewe that contributes to contamination of the pasture with parasite eggs; an improved protein nutrition targeting of these ewes could be an alternative management tool to control gastrointestinal parasite infections in their lambs.

Acknowledgements This work was supported by an EU-grant FAIR 3 CT96 1485 and SERAD.

References Coop, R.L. and Kyriazakis I., 1999. Parasite-nutrition interaction. *Veterinary Parasitology* **84**: 187-204.

Effects of continuous intake of condensed tannins on parasitised sheep.

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Introduction Parasitised sheep consuming forages high in condensed tannins (CT) show lower faecal egg counts (FEC) and total worm burden (TWB) compared to those consuming CT free forages (Niezen *et al.*, 1998). This may be due to an indirect effect of CT, through an increase in protein availability; extra protein could improve the host's ability to mount an effective response towards gastrointestinal parasites, during the expression of the immunity (Coop and Kyriazakis, 1999). However, CT have been also shown to have a direct anthelmintic effect on adult *Trichostrongylus colubriformis* (intestinal nematode), when they were administered for a short period (Athanasiadou *et al.*, 2000). The objectives of this experiment were i) to elucidate the effects of a continuous intake of CT during the development of a *T.colubriformis* infection and ii) to test whether these effects are dose dependent.

Materials and Methods Forty-two, three-month-old Texel × Scottish Greyface sheep were housed individually and dosed with 3,000 L_3 (third stage larvae) *T. colubriformis* / day. The animals were allocated to seven groups (n=6, mean liveweight 37.4 kg, SD 3.99). The experiment lasted 10 weeks and was divided into two periods: week 1-5, period of high establishment of the worms and acquisition of immunity (P_1); week 6-11, period of established infection and expression of immunity (P_2). Sheep were offered one of three foods: a CT free (0) food (150 g CP and 10 MJ ME /kg fresh matter) and the 0 food supplemented with either 30 (3) or 60 (6) g CT/ kg fresh matter. *Quebracho* extract was the source of CT used. The foods were offered at a 3.5% allowance of sheep liveweight in the two periods as follows (P_1 - P_2): 0-0, 3-3, 6-6, 0-3, 0-6, 3-0, 6-0 . Liveweight and FEC were monitored weekly. Animals were slaughtered at the end of week 10; TWB and eggs *in utero* (*in utero* fecundity) were counted and analysed by one-way analysis of variance. Liveweight at week 5 and 11, was analysed by one-way analysis of variance, using the starting weight as covariate. FEC were transformed (logx+1) and analysed using an ante-dependence model for repeated measurements.

Results Figure 1 shows that both 3 and 6 foods caused a significant reduction in the FEC in both periods in relation to CT free food ($P < 0.05$). Figure 2 shows that 0-6 sheep reduced their FEC in P_2 compared to 0-0 ($P < 0.05$) and 6-0 sheep increased their FEC in P_2 compared to 6-6 ($P < 0.05$). These effects were in the same direction but not statistically significant for the 3 series. TWB (12,531 SD 8267) and *in utero* fecundity of worms (7.5 eggs / female SD 4.73) were not different between the groups. The liveweight of sheep was affected by treatment up to week 5; the groups offered the 0 diet had higher liveweight compared to the groups offered the 3 and 6 diets (43.5 vs 42.3 kg, SED 0.38; $P < 0.05$). However, at the end of the experiment all animals had similar liveweight.

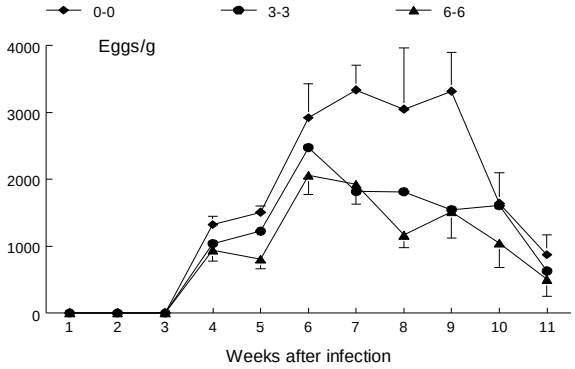

Figure 1. Effect of the 3 and 6 foods on the FEC of growing sheep.

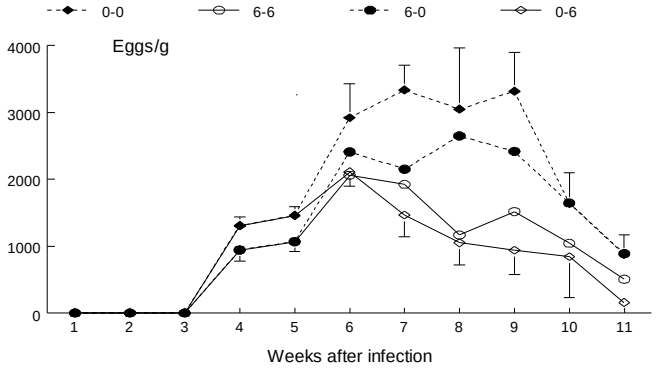

Figure 2. Effect of the change over of the 6 food, on the FEC of growing sheep. The FEC in P_1, are the means for the 0 (0-0 and 0-6) and the 6 (6-6 and 6-0) groups respectively.

Conclusion The results support the view that continuous CT intake reduces the FEC of parasitised sheep. The effect observed during P_1 was most likely a direct anthelmintic effect of CT towards *T.colubriformis*, since immune responses against worms would not be expressed at this time. The reduction in the FEC during P_2 could be due either to the direct or to an indirect effect of CT. However an indirect effect is rather unlikely, given that the amount of protein in the diet was adequate to cover the protein requirements of the sheep. The results in the 3 series, compared to the results in the 6 series, suggest that the anthelmintic properties of CT may be dose-dependent. CT are already being considered as one means of reducing the frequency of use of anthelmintic drugs in agriculture practices, due to their potential to reduce egg output and hence contribute to the control of parasitism.

References

Athanasiadou, S., Kyriazakis I., Jackson, F. and Coop, R.L. (2000) Effects of short term exposure to condensed tannins on adult *Trichostrongylus colubriformis. Veterinary Record* (In Press).
Coop, R.L. and Kyriazakis, I. (1999) Parasite-nutrition interaction. *Veterinary Parasitology* **84**: 187-204.
Niezen, J.H., Robertson, H.A., Waghorn, G.C. and Charleston, W.A.G. (1998) Production, faecal egg counts and worm burdens of ewe lambs which grazed six contrasting forages. *Veterinary Parasitology* **80**: 15-27.

An examination of the effects of level of energy intake and source of nutrients during late gestation on subsequent milk yield and composition of lactating dairy cattle

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Introduction The transition period of the dairy cow is physiologically and nutritionally stressful, particularly as feed intake is reduced and nutrient demands for foetal growth and initiation of milk synthesis are increased. It has been suggested that feeding concentrates in late gestation promotes the development of ruminal papillae, which takes 4 to 6 weeks to fully develop, consequently resulting in improved absorption of volatile fatty acids and increased food intake during early lactation. A recent study undertaken at this Institute (Keady *et al*. 1999) concluded that relative to silage offered *ad libitum* as the sole diet supplementation with 5 kg of concentrate during the last 28 days of gestation increased milk fat by 1.5 g/kg and improved milk yield by 0.6 kg/day during the first 12 weeks of the subsequent lactation. The response to dry cow supplementation reported by Keady *et al*. (1999) could have been mediated either by increased nutrient intake or by changes in the forage to concentrate ratio of the diet during the dry period. The present study was undertaken to evaluate the effect of level of energy intake and source of nutrients in late gestation on subsequent milk yield and composition.

Materials and Methods Two grass silages were ensiled. Silage A was ensiled from the primary regrowth of a perennial ryegrass sward, untreated, after a 48 hour wilt. Silage B was also ensiled from the primary growth of a perennial ryegrass sward, after a 36 hour wilt, treated with a bacterial inoculant. Two concentrates were formulated using barley, wheat, maize gluten, sugar beet pulp and soyabean and offered either pre-calving (PC) or post calving (LC). Twenty-eight days prior to expected calving date 64 Holstein/Friesian dairy cows were offered either silage A restricted (SL) or *ad libitum* (SH), or a total mixed ration comprising of silage A and concentrate PC in a 40:60 forage:concentrate ratio to supply the same predicted metabolisable energy intake as diets SL (TMRL) and SH (TMRH) respectively in a 2 x 2 factorial design experiment. Post calving, for the first 16 weeks of lactation, all cows received silage B *ad libitum* supplemented with 7 kg/day of concentrate LC which was offered in three equal feeds per day through out-of-parlour feeders.

Results For silages A and B pH and concentrations of dry matter, crude protein and ammonia nitrogen were 4.65 and 4.00, 319 and 301 g/kg, 200 and 160 g/kg DM and 154 and 89 g/kg N respectively. For concentrates PC and LC dry matter and crude protein concentrations were 865 and 868 g/kg and 196 and 227 g/kg DM respectively. There were no level of energy intake by source of nutrient interactions on food intake or animal performance during weeks 1-4, 5-8, 9-12, 13-16 or 1-16 of lactation. The effects of level of energy intake and source of nutrients on food intake and animal performance during the first 16 weeks of lactation are presented in Table 1. Increasing the level of energy intake tended to increase milk fat content ($0.05<P<0.1$) during weeks 1-16. The response in milk fat content to level of energy intake declined as lactation progressed being 2.16, 1.10 and 0.7 g/kg for weeks 1-4, 5-8 and 9-12 of lactation respectively. Level of energy intake and source of nutrients did not significantly alter silage intake post calving, the yields of milk and milk fat plus protein, or the concentrations of protein and lactose.

Table 1 Main effects of level of energy intake and source of nutrients during late gestation on animal performance during weeks 1-16 of lactation

	Level of energy intake(L)		Source of nutrients (S)			Sig†	
	Low	High	Silage	Silage + concentrate	Sem	L	S
Silage intake (kg DM/day)	10.5	10.3	10.2	10.6	0.35	NS	NS
Milk yield (kg/day)	26.6	27.3	27.1	26.8	0.77	NS	NS
Milk composition (g/kg)							
Fat	43.3	44.7	43.7	44.4	0.87	NS	NS
Protein	33.0	33.0	33.0	33.1	0.43	NS	NS
Lactose	49.6	50.0	49.7	49.7	0.30	NS	NS
Fat + protein yield (kg/d)	2.04	2.13	2.08	2.09	0.059	NS	NS

† There were no level of energy intake by source of nutrient interactions

Conclusion Increasing the level of energy intake in late gestation improved milk fat content during the first 4 weeks of lactation. Otherwise level of energy intake or source of nutrients in late gestation did not alter food intake, milk yield or composition. The results of the present study support those of Keady *et al*. (1999) confirming that any potential benefits in terms of adapting the rumen environment to the lactation diet in late gestation have not been translated into increased animal performance in the subsequent lactation.

References

Keady, T.W.J., Mayne, C.S. and Fitzpatrick, D.A. 1999. An examination of the effect of level of concentrate supplementation during late gestation on subsequent milk yield and composition of lactating dairy cattle. *Proceedings of the British Society of Animal Science*, p. 21.

Returns from genetic improvement in dairy cattle over a twenty year horizon

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Introduction Genetic improvement is permanent and cumulative. Improvements made in one generation are passed onto the next. In the UK two selection indexes are currently available to the dairy industry, they are PIN (Profit Index; production only) and £PLI (Profitable Lifetime Index; production plus lifespan). Much of the current and anticipated index research and development will be on broader breeding goals that include health and fertility traits. Economic responses expected for PIN and £PLI over a 20 year period were calculated in addition to a hypothetical index where it was assumed that PTAs (predicted transmitting abilities) for mastitis (M) and calving interval (CI) were available (£PLI+M+CI).

Materials and methods Selection responses for a single round of selection were calculated using selection index methodology. Genetic and phenotypic variance-covariance matrices for goal and index traits were constructed using UK parameter estimates (Brotherstone et al., 1997; Pryce et al., 1998). It was assumed that sire PTAs were based on progeny groups of 75 daughters per sire. The economic values used were –0.02, 0.30, 2.62, 27.5, 4 and 100 for milk, fat, protein, lifespan, calving interval and mastitis. The economic values for production and lifespan were updated from those in the version of £PLI available to UK dairy farmers to account for the current and future milk price and are under consideration by the dairy industry at present. Annual returns were calculated as 0.22 standard deviations of the aggregate genotype, this is the value approximating the selection response in a 'typical' four-pathway dairy cattle breeding scheme (Robertson and Rendel, 1950). The cumulative economic response to selection in three indexes were calculated using the formula suggested by Smith (1978) and adapted to include the effect of several years of selection (Equation 1). It was assumed that returns would be recouped starting at year 8 (y) which is the age of proven bulls when their daughters start milking. The final year after selection was assumed to have started was 20 (n). An inflation free discount rate of 5% was also assumed (d). Annual returns (G) were calculated for each of the indexes assuming a population of 2 million dairy cows.

$$\text{Returns}(n,t) = \sum_{m=1}^{n-y+1} \sum_{t=y+m-1}^{n} \left(\frac{1}{1+d}\right)^{t} \cdot G \qquad \textit{Equation 1}$$

Results Annual responses per cow are presented in Table 1. Selecting for a breeding goal that included production, lifespan, mastitis and calving interval was most profitable. The economic response of £PLI+M+CI was sensitive to the heritability assumed for CI and were £9.31 and £11.90 when the heritability was 0.02 and 0.05 respectively. The discounted returns for the UK dairy industry that accrue after twenty years time from selection alone were estimated to total £457m, £647m and £813m when selection is on PIN, £PLI and £PLI+M+CI respectively. These responses include the benefit from previous years of selection. Comparisons between the results of selection on differing indexes are complicated by the fact that there have been several generations of selection on PIN, or criteria close to it, whereas £PLI has only become available recently and PTAs for CI and M are not yet available. Also, in practice, selection in different pathways may not give equal emphasis to these indexes, especially as the UK relies on about 80% of imported semen.

Table 1 Expected annual responses to selection per cow

Index	PIN	£PLI	£PLI+M+CI
Total response (£)	5.41	7.66	9.63
Milk (kg)	103.0	93.5	53.2
Fat (kg)	4.56	4.12	1.88
Protein (kg)	3.36	3.05	1.94
Mastitis (/lactation)	0.003	0.002	-0.0004
Calving interval (d)	0.60	0.28	-0.57
Lifespan (lactations)	0.0	0.059	0.099

Conclusions Selection on criteria available in the last decade (PIN) has led to major economic benefits for the UK dairy industry. There will be substantial economic cost to continuing selection on production criteria alone in terms of a decline in mastitis resistance and fertility. These negative consequences of selection can be very effectively mitigated by broadening of breeding goals with substantial economic benefits.

Acknowledgements We acknowledge financial support from SERAD, HUKI, MAFF and MDC.

References

Brotherstone, S, Veerkamp, R. F., Hill, W.G. 1997. Genetic parameters for a simple predictor of the lifespan of Holstein-Friesian dairy cattle and its relationship to production. *Animal Science* **65**: 31-37.

Pryce, J.E., Veerkamp, R.F., Simm, G. 1998. Expected correlated responses to selection on production in dairy cattle. *Proceedings of the 6th World Congress on Genetics Applied to Livestock Production* **23**: 383-386.

Robertson, A. and Rendel, J.M. 1950. The use of progeny testing with artificial insemination in dairy cattle. *Journal of Genetics* **50**: 21-31.

Smith, C. 1978. The effect of inflation and form of investment on the estimated value of genetic improvement in farm livestock. *Animal Production* **26**: 101-110.

Relative weights on pedigree information and performance in evaluations based on a test day model

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Introduction Genetic evaluations for milk production traits in dairy cattle based on test day yields (TD) have generated much interest recently due to a number of advantages, including improved accuracy of predicting breeding values and estimation of persistency evaluations. One of the methods proposed for a test day evaluation system is the random regression model (RRM) approach fitting covariance functions such as the Legendre Polynomials. Preliminary genetic evaluations using this approach have been produced by the Animal Data Centre in the United Kingdom based on the research of Brotherstone *et al* (1999). The objective of this paper is to estimate relative weights on pedigree and TD in evaluations of cows using RRM fitting Legendre Polynomials and compare with 305-day yield evaluations. Secondly to examine the efficiency of using part lactation TD information to predict breeding values for cows.

Material and methods The equations for the random regressions ($\hat{b}$) of the first three Legendre Polynomials coefficients for a cow evaluated for one trait (eg fat) with both parents known is

$$[\emptyset' \emptyset + a^{ii} M] [\hat{b}] = M(PA) + \emptyset' (y_c);$$

where $\emptyset$ = vector of the first three coefficients of Legendre Polynomials, a^{ii} = elements of the inverse of the relationship matrix, $M = s^2_e G^{-1}$, with G being the covariance matrix for the random regressions, PA = vector of average random regressions for parents and y_c is the vector of TD for the cow corrected for fixed lactation curves and other effects and permanent environment. From the above equations relative weights on pedigree and TD were derived for cows with varying number of test days. Similar weights were calculated for evaluations based on projected 305-day yield again based on several test days.

Using RRM described by Mrode and Swanson (1999), breeding values (BV) were calculated for Jersey cows. The data consisted of TD records of first lactation milk, fat and protein yields of 24,871 Jersey cows calving since 1991. The efficiency of limited TD information in a lactation to predict BVs for completed lactation was examined by comparing BVs based on 8, 5 and 2 TD with those based on 10 TD for the same group of 300 cows.

Results The relative weights on pedigree and TD information when using the RRM to calculate BVs based on 3, 6 and 10 tests are shown in Table 1.

Table 1 Relative weights on Pedigree and Test Day Information

	Test Day		Projected 305-day yield	
Tests	Pedigree	Test Day	Pedigree	Test Day
3	0.70	0.30	0.86	0.14
6	0.58	0.42	0.81	0.19
10	0.43	0.57	0.72	0.28

Genetic Evaluations based on RRM places more emphasis on actual cow yield compared with BV based on 305-day yields. The correlations between BVs based on 8, 5 and 2 TD from the RRM with those on 10 TD on the same cows were 0.99, 0.97 and 0.93 respectively for fat yield. Corresponding estimates of regressions of BV from 10 TD on BV from part TD were 1.0, 0.98 and 0.95. The standard deviation (SD) of BVs from part TD were slightly lower than those from 10 TD.

Conclusion Genetic Evaluations based on TD using a test day model places more emphasis on yields compared with evaluations based on 305-day yields. This is useful in identifying cows with good Mendelian sampling effects but there could be greater problems if there is substantial preferential treatment. The results indicate that evaluations based on 2 TD or more using a test day model were efficient in predicting BV for 10 TD.

References

Brotherstone, S., White, I.M.S. and Mayer, K 1999. Genetic modelling of daily milk yield using orthogonal polynomials and parametric curves. *Submitted to Animal Science*

Mrode, R. A. and Swanson, G. J. T. 1999. Preliminary test day genetic evaluations on the United Kingdom involving the use of Legendre polynomials and Wilmink functions. *Proceedings of the 1999 Interbull meeting, Zurich, Switzerland*

A bio-economic approach to estimating economic values for UK hill sheep

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Introduction Profitability of sheep production systems depends on several different animal characteristics rather than a single trait. Economic selection indexes combine information from more than one trait into an overall score, to maximise genetic gain. Economic values (EVs) are required for each trait in the breeding goal so that selection emphasis is proportional to the economic importance of each trait. Defining clear breeding goals is more complex for hill breeds than for other sectors of the sheep industry because they provide breeding females in addition to lambs for slaughter. The aims of this paper are to i) describe how EVs for breeding goal traits suitable for UK hill sheep were derived for a combination of carcass, maternal and 'sustainability' traits using a bio-economic model, and ii) show how these EVs vary between different production systems as a result of the differences in the physical constraints of farm size, pasture availability and the biological limits of sheep in extensive rearing environments.

Materials and method Three 100-ewe Scottish Blackface hill farms were modelled to reflect the diverse farm systems in the hill sector. The *extensive* farm characterises store lamb producing farms located in cold and wet hill areas, the *intensive* hill farm is at the other extreme occupying drier, hill areas with higher levels of production. The *semi-intensive* farm type lies between the former two farm types. Monthly estimates of hill pasture availability, digestibility and offtake of hill and reseeded pastures by all classes of sheep (Armstrong *et al*.,1997) were included together with equations from 'Feedbyte' (SAC) to provide predictions of animal energy requirements to meet changing physiological needs. Markov chain methodology was used to determine flock age structure and replacement requirements. The number of single, twin and triplet births was determined by equating the mean and variance of litter size to their expectations i.e. singles = $3 - 2.5\mu + 0.5\mu^2 + 0.5\sigma^2$, twins = $4\mu - 3 - \mu^2 - \sigma^2$ and triplets = 1 - proportion single - proportion twin, where μ = mean number of lambs born per ewe lambing and $\sigma^2 = (0.36\ \mu)^2$. Lamb weights were derived using a form of the Gompertz growth equation with an additional multiplier to allow for limiting growth conditions (Amer *et al*., 1997). Ten goal traits were considered for inclusion into the breeding objective for hill sheep. They are i) mature live weight, ii) longevity, iii) number of lambs reared, iv) lamb loss, v) maternal component of weaning weight, vi) fleece weight vii) direct weaning weight, viii) carcass weight, ix) carcass conformation score and x) carcass fat class. The first derivative of the gross margin per flock was used to determine the EVs after a marginal change in each goal trait whilst holding all other goal traits constant. Non-linearity in the gross margins with changing goal trait values was investigated. The sensitivities of the EVs to price changes of major costs and returns of each farm system were explored by changing them by proportionally 0.5 above and below those originally used in the models.

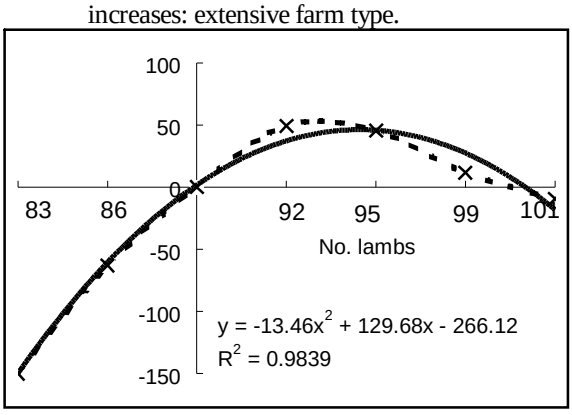
Results EVs per 100 ewe flock are shown in Table 1. In general, the EVs are higher for the intensive farm type than those for the less intensive farm types although the comparison is different for different traits. Mature size has a negative EV for all three farm types. Reducing lamb losses has a higher EV than increasing number of lambs reared. The change in farm gross margin for the extensive farm system as the number of lambs reared increases is shown in Figure 1. Increasing the number of lambs born beyond the capacity of the farm to accommodate genetic change results in zero or negative EVs for the extensive farm system. Sensitivity analyses show that, in general, the economic values are robust.

Table 1 Economic values for the three farm types (£ per 100 ewe flock)

	Exten-sive	Semi-intensive	Inten-sive
Mature weight (/ kg)	-10.4	-13.6	-11.8
Longevity (/ day)	5.4	6.2	6.8
No. lambs reared (/ %)	16.9	17.5	27.1
No. lambs lost (/ %)	-22.0	-27.0	-31.9
Maternal weaning weight (/kg)	50.3	52.7	54.1
Fleece weight (/ g)	1.2	1.2	1.2
Weaning weight (/ kg)	43.9	50.2	55.0
Carcass weight (/ kg)	-	20.0	76.3
Conformation (/ unit)	-	31.3	78.9
Fat class (/ ESF%)†	-	-7.9	-19.9

†ESF% = estimated subcutaneous fat %

Figure 1 Change in gross margin as number of lambs reared increases: extensive farm type.



--x-- Actual, derived from model ___ Fitted relationship

Conclusions Modelling the extremes of hill farm systems provides a base to define the economic limitations to genetic improvement in harsh environments. EVs differ according to the level of production and capacity of hill farms to accommodate genetic improvement. In particular, too great an increase in the number of lambs reared, for extensive farms, results in economic loss. The performance of breeding flocks should be evaluated regularly and where necessary, EVs re-calculated to more accurately reflect the economic impact of continuing to select for traits when farm resources are limited.

Acknowledgements The authors are grateful to SERAD, MLC and BWMB for funding this work.

References Amer, P.R., Emmans, G.C. and Simm, G. 1997. Economic values for carcass traits in UK commercial beef cattle. *Livestock Production Science* **51**: 267-281.
Armstrong, H.M.,Gordon, I.J, Grant, S.A. Hutchings, N.J., Milne, J.A. and Sibbald, A.R. 1997. A model of the grazing of hill vegetation by sheep in the UK. *J.Appl. Ecology* **34**:166-185.

The effect of stage of growth on the genetic and phenotypic parameter estimates of food intake in pigs using a covariance function model.

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Introduction Many traits that are of interest to breeders, such as food intake, are expressed continuously during the life of an animal and the individual's phenotype will change with age. Traditional genetic analysis of these traits has treated as them as discrete traits, ignoring the correlations among records at different ages. Recently methods have been developed to overcome this deficiency and allow an infinite dimensional approach, which can provide more accurate estimates of genetic and phenotypic parameters (Kirkpatrick *et al.* 1994, Meyer and Hill 1997). The aim of this study was to investigate the effect of stage of growth on the genetic and phenotypic parameter estimates of daily food intake.

Materials and Methods The data used in these analyses were compiled from individual feeding records of 1588 boars from 70 sire families. They were fed *ad libitum* using FIRE (feed intake recording equipment, Hunday Electronics Ltd.) feeders at the Cotswold Pig Development Company. The pigs were on test between 45 kg (s.d. 2.8) and 95 kg (s.d. 6.8). Weekly measurements of daily food intake (DFI g/day) were taken with performance test traits of food conversion ratio (FCR g/g), average daily gain (ADG g/day) and backfat depth at 95 kg (BF mm). Heritabilities, genetic and phenotypic correlations between ages for food intake were estimated using an AI REML algorithm for predicting covariance functions in longitudinal data (Meyer and Hill 1997) in the DFREML suite of programs fitting an individual animal model. The model for each trait included fixed effects of pen and date off test, a covariate of weight at the start of test and a random effect of the permanent environment due to the animal. Genetic and phenotypic correlations were also estimated for food intake at each stage of growth with performance test traits using an AI REML algorithm (Meyer 1997) in the DFREML suite of programs. The model for each trait included fixed effects of pen and date off test, a covariate of weight at the start of test and a random litter effect.

Results The estimates of heritability for food intake in different stages of growth were slightly lower than usually found over the whole test period for group-housed pigs using electronic feeders (Hall *et al.* 1999), but increased with age. This increase in genetic variation over time was greater than would be expected due to the scale effect of the increasing mean. The genetic and phenotypic relationships of food intake between different stages of growth were always high and positive and are presented in Table 1. Correlations were generally highest between adjacent weeks. The genetic correlations of food intake at different stages of growth with performance test traits changed over time. The genetic correlation between food intake and daily gain was positive (0.40 to 0.54) and increased during the test period to peak in week 4 then slowly declined to week 7. There was little change over time in the genetic correlation of food intake with food conversion ratio. The genetic correlation of food intake with backfat at the end of test was also positive (0.64 to 0.86) and increased by 0.22 between week 2 and week 7. The increase in the genetic correlation between fat depth and food intake as the animals aged indicates that selection for higher early food intake with no change in appetite at later stages of growth would result in more efficient lean growth. The correlation between early and late food intake was 0.6-0.7, which may allow some selection based on the shape of an individual's food intake curve.

Table 1: Heritabilities (diagonal) genetic (below) and phenotypic (above) correlations of food intake and growth traits

	DFI 2	DFI 3	DFI 4	DFI 5	DFI 6	DFI 7	FCR	ADG	BF
DFI 2†	**0.15**	0.51	0.49	0.49	0.48	0.48	0.14	0.37	0.26
DFI 3	0.96	**0.14**	0.50	0.52	0.52	0.52	0.16	0.42	0.31
DFI 4	0.88	0.94	**0.16**	0.52	0.53	0.53	0.15	0.39	0.33
DFI 5	0.78	0.92	0.98	**0.18**	0.56	0.57	0.17	0.44	0.35
DFI 6	0.69	0.86	0.95	0.99	**0.20**	0.59	0.22	0.42	0.37
DFI 7	0.61	0.80	0.92	0.97	0.99	**0.23**	0.19	0.40	0.36
FCR	0.61	0.63	0.65	0.66	0.61	0.62	**0.12**	-0.24	0.03
ADG	0.40	0.42	0.54	0.50	0.48	0.49	-0.15	**0.25**	0.39
BF	0.64	0.61	0.69	0.75	0.80	0.86	0.29	0.42	**0.38**

† number refers to week of test Standard errors of genetic parameter estimates were between 0.07 and 0.14

Conclusions It was concluded that there are changes in the genetic variation of food intake during the life of a pig and it may be possible to select pigs based on the shape of their food intake curve especially if data were collected for a longer time period during the growth of the animal.

References Hall A.D., Hill W.G., Bampton P.R. and Webb A.J. 1999 Genetic and phenotypic parameter estimates for feeding pattern and performance test traits in pigs. *Animal Science*. **68:1:** 43-48

Kirkpatrick, M., Hill, W.G. and Thompson, R. 1994 Estimating the covariance structure of traits during growth and ageing, illustrated with lactation in dairy cattle. *Genetical Research.* **64:** 57-69

Meyer, K. 1997 An average information Restricted Maximum Likelihood algorithm for estimating reduced rank genetic covariance matrices or covariance functions for animal models with equal design matrices. *Genetics, Selection, Evolution*. **29:** 97-116

Meyer, K. and Hill, W.G. 1997 Estimation of genetic and phenotypic covariance functions for longitudinal or repeated records by restricted maximum likelihood. *Livestock Production Science.* **47:** 185-200

Characterisation and mapping of the Booroola (*FecB)* gene using regression analysis in sheep

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Introduction The Booroola Merino strain of sheep carries a major autosomal mutation (*FecB*) which increases ovulation rate (Davis *et al.*, 1982). To map the gene, heterozygous sires (B+) were mated to non-carrier ewes (++). The female progeny were then examined by laproscopy to determine ovulation rates and these phenotypes used to assign progeny genotypes (B+, ++ or undetermined). Linkage analysis between the assigned Booroola genotype and a set of marker genotypes was used to assign the Booroola gene to a region of sheep chromosome 6 (OOV6) (Montgomery *et al.*, 1994). These studies relied on accurate genotype assignment and a constant gene effect across animals and breeding seasons. This study aims to use regression analysis to verify the validity of these assumptions.

Materials and Methods Data were available from 728 animals in backcross and halfsib flocks segregating for the Booroola gene. The ovaries of all female progeny were examined twice a year, over two years, by laproscopy following sedation and local anaesthesia (Montgomery & Hawker, 1987) to determine ovulation rates. Measurements were taken at early breeding season (typically early April) on 1½ (OR1) and 2½ (OR3) year old ewes and later season (ca. 20 days later, OR2 and OR4 respectively). If a measurement could not be taken or no *corpora lutea* were observed the ovulation rate was recorded as missing. Animals were genotyped for up to 21 DNA markers on OOV6. The data were analysed using a least squares interval mapping method developed for data from outbred line crosses with multiple generations (Dodds, 1999). The analyses investigated a single quantitative trait locus (QTL) model assuming an equal effect of all Booroola alleles (Model 1), a single QTL model with different effects from alleles originating in different rams (Model 2) and a two QTL model (Model 3). The null hypothesis (Model 0) was the basic least squares model with no QTL fitted.

Results The comparisons of alternative models are given in Table 1. There was highly significant evidence for a QTL affecting all four measurements (P<0.001). The data for OR1 suggest a second QTL affecting ovulation rate on OOV6, however this is not supported by results for other measurements. The data for OR4 suggest that Booroola alleles of different origins have differing effects, but this too is not supported by results for other measurements. Positions, confidence intervals and effects are given in Table 2 for Model 1. Locations for all measurements are between 76.3cM and 79.1cM and 99% confidence intervals overlap between 74.9-79.8cM. The effects are constant between years but with some suggestion that the Booroola effect is larger in later season (OR2 and OR4). The mean allele substitution effect across all measurements was 1.3 *corpora lutea*, close to the value of 1.24 reported by Davis *et al.* (1982).

Table 1: Comparison of the alternative underlying genetic models of the Booroola gene

	Model 1 vs. 0		Model 2 vs. 1		Model 3 vs. 1	
	F	P	F	P	F	P
OR1	267	<0.001	0.66	NS	6.52	<0.05
OR2	483	<0.001	1.39	NS	2.46	NS
OR3	223	<0.001	1.05	NS	0.51	NS
OR4	302	<0.001	2.09	<0.01	0.98	NS

Table 2: Comparison of position, 99% confidence interval (CI) and allele substitution effects

	Position (cM)	99% CI (cM)	Effect (se) (*Corpora Lutea*)
OR1	76.3	72.7-79.8	1.2 (0.09)
OR2	77.5	74.9-80.2	1.4 (0.08)
OR3	79.1	74.9-83.4	1.2 (0.09)
OR4	76.3	72.7-79.9	1.4 (0.10)

Conclusions This study suggests that the Booroola gene is a single gene located on OOV6 with only small evidence to suggest differing effects from different allelic sources. There was evidence (<0.05) for a second QTL affecting OR1, but this test did not adjust for the multiple testing undertaken by searching along the chromosome. The effect of the Booroola allele appears to be larger at later stages of the season. This should be investigated further and could assist in the understanding of the mode of action of the Booroola gene.

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References

Davis, G.H., Montgomery, G.W., Allison, J.A., Kelly, R.W. and Bray, A.R. 1982. Segregation of a major gene influencing fecundity in progeny of Booroola sheep. *New Zealand Journal of Agricultural Research* **25:** 525-529

Dodds, K.G. 1999. Haley-Knott regression mapping of quantitative trait loci in extended pedigrees. *Proceedings of the Association for the Advancement of Animal Breeding and Genetics* **13:** 313-316.

Montgomery, G.W. and Hawker, H. 1987. Seasonal reproduction in ewes selected on seasonal changes in wool production. *Journal of Reproductive Fertility* **79:** 207-213.

Montgomery, G.W., Lord, E.A., Penty, J.M., Dodd, K.G., Broad, T.E., Cambridge, L., Sunden, S.L.F., Stone, R.T. and Crawford, A.M. 1994. The Booroola fecundity (*FecB*) gene maps to sheep chromosome 6. *Genomics* **22:** 148-153.

Genomic contributions in a cattle introgression program

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Introduction Not all commercial lines and breeds contain the best alleles for genes of economic importance. Introgression strategies transfer a gene from a non-commercial source to a commercial line by incorporating the favourable allele of a gene from the donor animals whilst retaining beneficial alleles affecting commercial traits in the recipient animals. This is achieved through generations of backcrossing and the resulting heterozygotes are selected and intercrossed to produce animals homozygous for the gene of interest. Animals produced from an introgression program can be inferior to commercial animals because of the contribution from the donor genome at loci not under selection. This genetic lag experienced in an introgression program can be partly attributed to the intercross as a higher number of animals are selected primarily upon genotype thereby reducing the selection intensity for other traits (Visscher and Haley, 1999). The chromosome segment containing the desired introgressed gene (linkage drag) can be quite large, e.g., 32 cM for a 100 cM chromosome in backcross 6 (Stam and Zeven, 1981). The aim of this study is to examine the genomic contribution of each generation to animals produced after the intercross and the level of homozygosity.

Materials and Methods Computer simulation was used to model an introgression scheme of six generations of backcrossing followed by an intercross between animals heterozygous for the marker under selection. Individuals in each generation were selected for the presence of a centrally placed marker assumed to be the desired allele of the gene to be introgressed. Mating was at random after the selection. Population sizes (N) were 20, 50 or 100, number of offspring per mating (n) were 1, 3 or 5 for a chromosome length of 100cM. A chromosome of a 100cM undergoing random mating and no selection for a marker was used to denote another chromosome in the genome. Each parameter set was run for 500 replicates. Contributions from the donor genome (DG) and each generation of backcrossing (R1-R7: R1=recipient contribution from F1 cross, R7=recipient contribution from backcross 6), were recorded. The length of linkage drag segment and the length of the homozygous segment within it (due to overlapping) in homozygous animals were recorded. Also recorded were the mean number and range of homozygous animals after introgression.

Results Genomic contributions from each generation of selection for the allele of interest and no selection are presented in Table 1. There was no significant difference between other population parameters and those presented (N=100 and n=3). The no selection scenario follows expectations with contributions doubling with each additional generation of backcrossing. However, when selecting for the presence of a favourable allele, the genomic contributions change. It can be seen that DG has the highest contribution with the recipient genomic contributions increasing towards the more recent generations of backcrossing but not in the two fold pattern seen with no selection. The increase in the proportion of DG and earlier generations can be attributed to the donor genome "dragged" around the selected marker (linkage drag) which has a length of 27.7 cM for a 100 cM chromosome after the intercross. The linkage drag length was not affected by the population structure applied.

Table 1: Proportion genomic contributions from each generation (DG, R1-R7) after an introgression scheme. Figures shown are for animals homozygous for the gene of interest after the intercross generation (selection) and contributions to all animals assuming no selection, using population parameters of N=100 and n=3.

	DG	R1	R2	R3	R4	R5	R6	R7
Selection*	0.312	0.043	0.055	0.068	0.085	0.111	0.142	0.184
No selection*	0.008	0.008	0.015	0.032	0.063	0.127	0.251	0.497

*All standard errors of figures presented were = 0.002.

The proportion homozygosity across the chromosome pair of animals selected as homozygous for the gene of interest (N=100 and n=3) is 0.317 (±0.002). Half of the total homozygosity can be attributed to the 16 cM (±0.11) of homozygosity due to the overlapping of linkage drag segments. The remaining homozygosity is outside the linkage drag area and is due to homozygosity of both donor and recipient genome. Contribution to homozygosity ranges from 0.5% for DG (outside linkage drag) increasing to 13.6% for R7 genome. Homozygosity is affected by population size, decreasing with an increasing population size (not presented), as does homozygosity within the linkage drag. The mean number of homozygous animals after the intercross generation was 38 with a range of 21-59 across replicates.

Conclusions Genomic contributions in an introgression scheme are heavily influenced by donor genome on the chromosome containing the gene of interest, thereby minimising the contribution of recipient genome. However, on other chromosomes this is much less evident and the last generation of recipient genome has the highest contribution. Therefore donor contributions across the entire genome will be low with the highest contribution of donor genome from the chromosome containing the allele for the gene of interest. In cattle (29 chromosome pairs and XY), the proportion of donor genome will approximately be 1.8%. Homozygosity is important as it can be related to alleles that are identical by descent (IBD). The homozygosity decreases with increasing population size and therefore suggests that more animals are needed in an introgression program to minimise homozygosity.

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References Stam, P. & Zeven, A.C. (1981). The theoretical proportion of the donor genome in near isogenic lines of self-fertilizers bred by backcrossing. *Euphtica*, 30: 227-238.
Visscher, P.M. & Haley, C.S. (1999). On the efficiency of marker-assisted introgression. *Animal Science*, **68:** 59-68.

The consequences of carrying the Booroola fecundity (*FecB)* gene on sheep liveweight

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Introduction The increase in ovulation rate caused by the Booroola gene was first observed in the Booroola Merino strain of sheep (Davis *et al.*, 1982) and the gene was subsequently mapped to sheep chromosome 6 (OOV6) (Montgomery *et al.* 1994). The low heritability of fertility traits and the desire to produce more lambs per ewe from meat breeds has lead to many crossbreeding programs seeking to obtain the benefits of the Booroola gene. However, many producers report animals carrying a Booroola allele to be lighter than non-carriers (G. Davis, personal communication). The Booroola Merino strain of sheep is typically lighter than recipient breeds used in the introgression programmes e.g. Romney. This study aims to determine whether the Booroola gene has a pleiotropic effect on liveweight or whether there is any evidence to suggest a closely linked quantitative trait locus (QTL) affecting liveweight that may 'hitchhike' with the Booroola gene.

Materials and Methods 401 measurements of weaning weight (WWT) and 581 measurements of 1½ year old mating weight (MWT) were collected on ewes in flocks where the Booroola gene was segregating. The liveweight data were analysed using an interval mapping method (Scan) developed for data from outbred line crosses with multiple generations (Dodds 1999) and accounted for the effect of sex, contemporary group and birth rank. The position of the highest test statistic (F-ratio) across the chromosome was found and a 95% confidence interval was calculated to investigate whether this contained the region of chromosome known to contain the Booroola gene. In addition, a 'Booroola' analysis tested and estimated the effect of the Booroola gene on liveweight by observing the results at the location of the Booroola gene (77.1cM) estimated in previous studies.

Results The results are presented in Table 1. There was some evidence that the Booroola gene affects MWT. However, the chromosome scan also indicated a QTL affecting WWT approximately 20cM distal to the Booroola gene. An effect on MWT was also observed within this region, so the effect observed on this trait in the 'Booroola' analysis may be due to linkage with the putative QTL affecting WWT. The effect on MWT is not present when the model is adjusted for the effect on WWT for either the 'Booroola' or 'Scan' analyses (results not shown). The 95% confidence interval for the QTL affecting WWT does not include the position of the Booroola gene. The subsitution effect of a single allele of the QTL reduces WWT by 1.37kg. There was no evidence for the effect differing between founder Booroola alleles.

Table 1: Results from the 'Booroola' and 'Scan' analyses with the effect at the best estimated position and the 95% confidence interval (CI) for the 'Scan' analyses

Trait	Analysis	Position (cM)	95% CI (cM)	Effect (se) (kg)	F-Ratio	P
WWT	Booroola	77.1	-	-0.55 (0.40)	1.85	NS
MWT	Booroola	77.1	-	-1.13 (0.48)	5.52	<0.05
WWT	Scan	98.0	86.0-127.0	-1.37 (0.43)	10.18	<0.01
MWT	Scan	65.0	3.0-182.0	-1.23 (0.48)	6.50	<0.05

Conclusions These data show that the Booroola gene does not have pleiotropic effects on liveweight, but may be closely linked to a QTL affecting growth from birth to weaning. The QTL can 'hitchhike' with the Booroola allele in introgression programs. Sheep inheriting the QTL allele on the same haplotype as the Booroola allele in the founding sires are, on average, 1.4kg lighter at weaning. These lighter weaning weights have a subsequent effect on 1½ year old mating weight, although the data suggest growth is not affected by the QTL after weaning. Further work should investigate whether the effects at weaning influence mature size or slaughter weight. Booroola introgression programmes may need to implement measures to break the association between the Booroola allele and the low WWT QTL allele.

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References

Davis, G.H., Montgomery, G.W., Allison, J.A., Kelly, R.W. and Bray, A.R. 1982. Segregation of a major gene influencing fecundity in progeny of Booroola sheep. *New Zealand Journal of Agricultural Research* **25:** 525-529

Dodds, K.G. 1999. Haley-Knott regression mapping of quantitative trait loci in extended pedigrees. *Proceedings of the Association for the Advancement of Animal Breeding and Genetics* **13:** 313-316.

Montgomery, G.W., Lord, E.A., Penty, J.M., Dodd, K.G., Broad, T.E., Cambridge, L., Sunden, S.L.F., Stone, R.T. and Crawford, A.M. 1994. The Booroola fecundity (*FecB*) gene maps to sheep chromosome 6. *Genomics* **22:** 148-153.

Reproductive performance of the Thoka Cheviot sheep

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Introduction The Thoka gene for fecundity, a gene which originally occurred in Icelandic sheep, was introduced to the UK in 1985 and through a programme of crossbreeding was established in Cheviot sheep (Russel et al, 1997). Ewes are now retained as "Thoka carriers" only if they have lambed in each of the first three years and had at least two sets of twins. The gene has been introduced into separate North and South Country Cheviot (NCC and SCC) lines which are now phenotypically indistinguishable from purebred animals and contain proportionately less that 0.2 of the Icelandic genotype. The purpose of this analysis was to determine the increase in fecundity in the two breeds and whether or not the reproductive response to the incorporation of the Thoka gene differs between NCC and SCC breed types.

Material and methods The performances of Thoka-Cheviot ewes were assessed on the basis of the litter sizes of ewes (lambing over two to five years) of groups of 36 NCC-type and 25 SCC-type ewes which, on the basis of their parentage, were possible carriers of a single copy of the gene. The performances of these animals were compared with similarly managed non-carrier groups of 118 NCC and 183 SCC ewes which were not subject to a breeding programme. Logistic regression was used to model the proportion of ewes that met the criteria of Thoka carriers after two lambings. Terms were fitted for the year in which the the ewe first lambed, whether it was NCC or SCC (breed), whether it was a Thoka or pure-bred animal (group) and the interaction between group and breed.

Results Seventy five per cent of Thoka NCC, 25% of purebred NCC, 72% of Thoka SCC and 20% of purebred SCC ewes lambed in each of the first two years and produced at least two lambs in one of those years. The effect of group (Thoka gene carrier or pure-bred) was highly significant ($P<0.001$). The difference between the two breeds was significant ($P<0.05$) but there was no significant interaction between breed and group. Table 1 shows the litter size of each lambing classified by genotype and parity. In the case of the Thoka ewes, only the 27 NCC and 18 SCC ewes that met the selection criteria were included at any age. While it remains to be determined whether or not the observed levels of performance will be maintained in the progeny of the selected animals, litter sizes (per ewe lambing) of animals retained (Table 1) were higher in carrier than pure-bred NCC and SCC ewes. This was primarily attributable to the higher incidence of twin births. The mean litter size also increased with parity but the effect was much smaller in carrier than pure-bred ewes.

Table 1. Numbers of ewes in each litter size class and mean litter sizes (lambs born per ewe lambing) of ewes of each genotype and of each parity. Thoka groups include only data from animals that met the selection criteria.

Parity	Thoka NCC					Purebred NCC				Thoka SCC				Purebred SCC			
	Litter size				Mean	Litter size			Mean	Litter size			Mean	Litter size			Mean
	1	2	3	4		1	2	3		1	2	3		1	2	3	
1	4	18	5	0	2.04	93	10	0	1.10	6	11	1	1.72	154	25	0	1.14
2	7	16	4	0	1.89	77	30	1	1.30	2	16	0	1.89	144	23	0	1.14
3	1	13	4	1	2.26	36	38	2	1.55	1	11	2	2.07	84	31	0	1.27
4	1	12	4	0	2.18	17	27	3	1.70	3	10	0	1.77	38	32	0	1.46
5	3	2	0	0	1.40	7	11	1	1.68	1	5	2	2.13	19	9	0	1.32
Overall mean					**2.03**				**1.37**				**1.89**				**1.21**

Conclusions . The proportion of ewes with multiple births in at least one of the first two years was significantly greater for Thoka than purebred ewes. Amongst ewes selected as being “probable carriers” of a single copy of the Thoka gene, there were approximately 0.6 more lambs per ewe in both NCC and SCC lines than amongst purebred ewes. The Thoka Cheviot may have a role where reduced stocking rates are encouraged to reduce grazing pressure on vegetation; use of this genotype would allow a reduction in stocking rate while maintaining total lamb output and profitability.

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References

Russel, A.J.F., Alexieva, S.A. and Elston, D.A. 1997. The effect of the introduction of the Thoka gene for fecundity on lamb production from Cheviot ewes. *Animal Science* **64** 503-508.

The effect of laboratory on the rate and extent of gas production *in vitro*

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Introduction *In vitro* cumulative gas production is a means to determine the rate and extent of feed fermentation. However, different apparatus and methods used at different laboratories cause variations in the gas production profiles (GPP) obtained. The objective of this experiment was to determine whether any significant difference between laboratories was observed when the same apparatus and method was used.

Materials and methods The oven-dried (60^0C), ground (1 mm screen) substrates used were: molassed sugarbeet feed (MSBF), maize gluten feed (MGF), soyabean hulls (SBH), wheat (WHT), whole crop cereal silage (WCC), grass silage (GS), maize silage (MS) and glucose. These substrates were distributed to three laboratories: ADAS, IGER and WAU. At each laboratory, all donor sheep were fed twice daily a maintenance diet of hay and proprietary concentrate (70:30 DM basis). Rumen fluid was collected from two mature wethers before the morning feed. On two occasions at each laboratory, the GPP of each substrate was estimated (Theodorou *et al*., 1994) using a manual pressure transducer with four replicates (1 g) of each substrate incubated at 39^0C with 15 ml strained rumen fluid and 85 ml medium. The GPP obtained were fitted to the monophasic model of Groot *et al*. (1996). GPP were described in terms of the total volume of gas produced (a) and the maximum rate of gas production (R_{Mgas}). The effects of laboratory (L), substrate (S) and laboratory x substrate (LxS) on a and R_{Mgas} were estimated by analysis of variance.

Results WAU generally produced more total gas than IGER and ADAS, and the rate of gas production was generally slower at WAU compared with ADAS and IGER (Figure 1). Although this was not the case for all substrates, the interaction between laboratory and substrate was not significant for either total gas volume or the maximum rate of gas production (Table 1).

Figure 1 *Effect of laboratory on the GPP (mean of all substrates)*

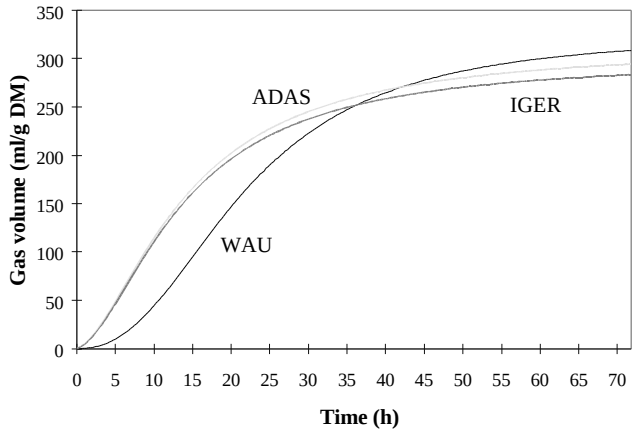

Table 1 *Effect of substrate and laboratory on the GPP parameters*

	Lab.	Substrate								SEM	Significance		
		MSBF	MGF	SBH	WHT	WCC	GS	MS	GLU		L	S	LxS
a	ADAS	338	273	358	366	276	230	315	350	14.2	***	***	ns
ml/g	IGER	315	302	350	340	257	215	295	331				
DM													
	WAU	352	294	389	365	267	243	331	367				
R_{Mgas}	ADAS	18.0	13.1	12.1	19.9	9.7	10.8	12.7	18.2	1.20	***	***	ns
ml/h	IGER	16.6	15.2	11.3	19.5	8.8	9.9	12.2	22.4				
	WAU	11.1	8.9	10.6	18.8	7.2	8.7	9.9	14.9				

Conclusions When used to rank feeds (for both rate and extent of fermentation), results obtained from one laboratory may be extrapolated (with caution) to another. However, different laboratories produce different GPP. This is probably because of differences in the inoculum, which would arise partly from differences in the host animals' diet. This illustrates the need to develop an inoculum which is not prone to the variation observed in rumen fluid.

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References Groot, J.C.J., Cone, J.W., Williams, B.A., Debersaques, F.M.A., and Latinga, E.A. (1996). Multiphasic analysis of gas production kinetics for *in vitro* fermentation of ruminant feeds *Animal Feed Science and Technology* **64:** 77-89.

Theodorou, M.K., Williams, B.A., Dhanoa, M.S., McAllan, A.B. and France, J. (1994) A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminant feeds *Animal Feed Science and Technology* **48:** 185-197.

Development of a radio-immunoassay (RIA) for bovine and ovine leptin.

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Introduction Leptin is the 16 kDa product of the *obese* gene secreted by white adipose tissue in proportion to energy intake. In several species, plasma leptin levels correlate with, and may be and endogenous signal of, the extent of body fat reserves. Leptin acts via the hypothalamus to regulate feed intake in rodents and may control gonadal activity through this same axis. Significantly, the mutant *ob/ob* mouse lacks functional leptin and is both hyperobese and infertile. Leptin may be a useful diagnostic and/or therapeutic aid in high-yielding dairy cows in which infertility is rising inexorably and is anecdotally linked to the scale of the early post-partum negative energy balance. Our objectives were to recombinantly synthesise, and raise antibody to, a leptin-protein conjugate and to develop a useful and specific RIA for ruminant leptin.

Materials and methods Total RNA was extracted from flash-frozen renal fat biopsied from a 24-month Holstein steer. Reverse transcription-polymerase chain reaction (RT-PCR; Superscript II and Taq polymerase) was used to synthesise cDNA encoding bovine leptin using primers deduced from an ovine leptin cDNA sequence (GenBank acc^{n} U84247). Amplified DNA was purified and verified by electrophoresis. The target gene was ligation independently cloned into a pET-35B (+) vector (Novagen) with T4 DNA polymerase. Ligated expression plasmid was transfected into *E.col*i (Novablue) and transformants screened by colony PCR prior to automated construct DNA sequence confirmation. After transformation into *E.coli* competent cells (BL21, DE3), a leptin fusion protein housing a cellulose binding domain (CBD) and an S.Tag sequence, was expressed by growing cells at 37^{o} overnight in LB broth containing kanamycin following induction with isopropyl-β-D-thiogalactoside. Target protein was cytoplasmically expressed in insoluble inclusion bodies. Cells were harvested centrifugally, sonically lysed and washed. Inclusion bodies were solubilised in 6M guanidine-HCl and refolded by dilution and removal of denaturant by stepwise dialysis in the presence of mercapto-ethanol and dithiothreitol. Final dialysis was in the presence of 5mM ox./0.5mM red. glutathione. Refolded product was adsorbed on CBIND resin (Novagen), eluted by ethylene glycol and desalted into phosphate buffer. Fusion protein size (39kDa) was verified by SDS-PAGE. Antiserum was raised in guinea pigs by primary immunisation with refolded CBD-bovine leptin in complete Freund's adjuvant and re-immunisation in incomplete Freund's after 8 weeks, prior to a terminal bleed 12 days later. Recombinant bovine and ovine leptins (re-BL; re-OL) were used as RIA standards and ^{125}I-iodinated labels (purified on Sephadex G-50). RIA buffer was 0.03M PBS, pH 7.4 with 0.025M EDTA, 0.1% NaN_3, 0.05% Triton X-100 and 0.5% BSA. Antibody-antigen precipitation was by SacCel. The assay was used to measure leptin and leptin recovery in serum and heparinised plasma from growing heifers, dairy cows and fed and starved sheep.

Results Antiserum was used at 1:16000 (final dilution) in a 3-day RIA with an optimum ED_{50} of 21ng leptin/ml sample. Leptin concentration means and ranges in serum and heparinised plasma from cattle and sheep were as shown in Table 1.

Table 1 Serum and plasma leptin concentrations (means and ranges) in cattle and sheep in different physiological states

Animal	Physiological state	No.	Sample matrix	Mean leptin (ng/ml)	Leptin conc^{n} range (ng/ml)
10-month dairy heifers	growing, non-pregnant	18	hep-plasma	16.6	13.6 - 21.3
24-month dairy heifers	recently-calved	20	hep-plasma	17.4	11.4 - 24.5
> 36-month dairy cows	late lactation, pregnant	25	serum	19.5	15.5 - 24.4
30kg wether sheep	maintenance fed	5	hep-plasma	21.8	16.2 - 26.6
30kg wether sheep	5-days starved	5	hep-plasma	22.9	19.0 - 27.3
Lambs	growing males/females	11	hep-plasma	14.8	10.7 - 18.4

Mean recoveries of re-BL, added at 7.5 and 15.0 ng/ml to hep-plasma from recently-calved 24-month heifers, were 100.2 and 85.6% respectively but only 34.8 and 42.8% respectively when added to serum from multiparous, pregnant cows in late lactation. By contrast, mean recoveries of re-OL (at 18.5 ng/ml) were 88.7 and 85.6% in sheep sera and hep-plasma, respectively. Leptin was unchanged in plasma from wethers fed for 14 days at maintenance and then starved for 5 days.

Conclusions An RIA for ruminant leptin has been developed which successfully measures leptin in heparinised plasma and serum from non-pregnant, non-lactating ruminants without need for sample dilution. Leptin concentrations were higher than currently published values obtained using a commercial multi-species kit. The recovery of leptin from cattle serum and hep-plasma suggested the presence of a leptin binding protein in pregnant and/or late-lactation ruminants. Physiologically, a pregnancy-related leptin binding protein could modulate leptin signalling to the hypothalamus, allowing the desirable accumulation of fat to proceed unhindered in the late pregnant dairy cow. The absence of a change in plasma leptin between fed and starved sheep (despite a NEFA rise of 208%, an IGF-1 fall of 44 % and an RQ change from 1.019 to 0.782; Wylie, 1995) suggests a complex relationship between leptin and adipose tissue metabolism.

Acknowledgement Re-BL and re-OL (assay standards) were gifts from Prof A Gertler (Hebrew University of Jerusalem)

References Wylie, A.R.G. 1995. Metabolic and hormonal responses to starvation and re-feeding in sheep. *Proceedings of the Nutrition Society* **54:** 77A.

Value of ADIN as a measure of unavailable nitrogen in treated rapeseed meal

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Introduction Acid detergent insoluble nitrogen (ADIN) is used in the UK Metabolisable Protein system (AFRC, 1992) to estimate the amount of indigestible nitrogen (N) in a feedstuff. A novel process has been developed which is intended to increase the proportion of undegradable protein in rapeseed meal. *In situ* work on this treated rapeseed product (TRSM) has shown a reduced rate of rumen degradation compared with the untreated product (UTRSM). However when these data were used in combination with ADIN content to calculate digestible undegraded protein (DUP), there was a minimal increase in DUP due to the high content of ADIN in the TRSM. There have been other cases where products have high ADIN content (e.g. distillery by-products; Webster, 1992) but when whole tract determinations of indigestible N were made, this was considerably lower than estimated from ADIN content. This raises some concerns about the use of ADIN to estimate indigestible protein for by- and treated- products. The objective of this study was to investigate whether the ADIN content of the untreated and treated rapeseed products was representative of the indigestible N.

Materials and methods One sample each of UTRSM and TRSM product were used. The samples were analysed for oven dry matter (DM), N and ADIN. The untreated sample required no further sample preparation and the treated sample was broken down to provide a similar particle size to the UTRSM sample with a pestle and mortar. Each feed was incubated for 10h in duplicate polyester fibre bags (PSF, 43 μm pore size) in the rumen of three non-lactating cows maintained on a grass silage/rolled barley based diet (80:20 on a DM basis), all bags (six replicates per sample) were encased in a larger bag (195 μm pore size). Upon removal from the rumen the bags received a cold water machine wash, each were placed inside a 10 μm pore size bag and then recieved a pepsin-HCl digest for 3h. The resulting residue was placed in the duodenum and collected from the faeces of each cow 4 to 36 h later and immediately machine washed in cold water. The residue was analysed for N. Separately, ADIN water solubility and disappearance after 10h rumen incubation plus pepsin/pancreatin digestion were determined in triplicate for each sample. The results were statistically analysed for treatment effect by t-test.

Results The chemical composition, indigestible N and sites of digestion of ADIN for the UTRSM and TRSM are shown in Table 1. ADIN content was higher in the TRSM while indigestible N determined in mobile nylon bags (MNB) was similar. Indigestible N calculated from ADIN was similar to the MNB value for the UTRSM but was nearly three times as high for the TRSM. It was seen that the ADIN was apparently water soluble in both feeds, but as the solubility reduced with decreasing filter pore size, then it is likely that the ADIN was not water soluble but was lost with the fine particle loss. ADIN disappearance after rumen and enzyme digestion was significantly lower for the TRSM but the resulting indigestible N was 7.6 and 66.5 g kg^{-1} N for untreated and treated respectively.

Table 1. *Chemical analysis, indigestible nitrogen and ADIN disappearance of the untreated and treated rapeseed.*

	UTRSM	TRSM	t	P
Chemical analysis				
Oven dry matter (g kg^{-1})	906	883		
Nitrogen (g kg^{-1} DM)	60.0	57.7		
ADIN (g kg^{-1} DM)	5	14		
Indigestible nitrogen MNB (g kg^{-1} N)	108	122	-3.0	0.009
Indigestible nitrogen calculated from ADIN (g kg^{-1} N)	83	243		
ADIN disappearance				
Water solubility (PSF bags, 43 μm, %)	4.3	13.1	-42.5	0.0006
Water solubility (glass sintered crucibles, 100-160 μm, %)	14.0	36.1	-16.3	0.0005
Rumen 10h/pepsin-pancreatin digestion residue (%)	90.9	72.6	32.9	0.0009

Conclusion The results clearly prove the hypothesis that ADIN content of the TRSM product is not a good estimator of indigestible N. The use of ADIN to estimate indigestible N for heat treated products is therefore not advisable and would significantly reduce the apparent benefit of heat treatment on increasing the digestible undegradable fraction of the product.

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References AFRC, 1992. AFRC TCORN Report No. 9. Nutritive Requirements of Ruminant Animals: Protein. *Nutrition Abstracts and Reviews* (Series B) **62**: (No. 12).

Webster, A. J. F., 1992. The metabolizable protein system for ruminants. In: P. C. Garnsworthy, W. Haresign and D. J. A. Cole (eds) *Recent Advances in Animal Nutrition*, pp 93-140 London: Butterworths.

Predicting the *in vitro* gas production profile of dried grass with strained rumen fluid from the *in vitro* gas production profile of dried grass with faeces

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Introduction The *in vitro* gas production (GP) technique was developed using strained rumen fluid (SRF) as an inoculum. This requires the use of surgically modified animals and it is questionable whether maintaining cannulated animals for this purpose can be justified. Faeces (FAE) have been used as an alternative inoculum, but while total gas volume tends to be the same, the rate of gas production is usually slower. This is probably because of a lower microbial activity in FAE. If the initial activities of the two inoculum sources were controlled, the differences between them may be reduced. The objective of this experiment, therefore, was to compare the GP profiles obtained when different concentrations of SRF and FAE were used, and the initial activity of the inocula equalised.

Materials and methods The SRF and FAE were taken from the same three ewes. FAE (50 g) was collected the day before inoculation, ground in a pestle and mortar, washed into a flask with 800 ml medium and 6 g high temperature dried grass (HTDG), incubated overnight (39^0C), and then strained through four layers of cheesecloth. SRF was collected before feeding on the morning of inoculation and strained as for FAE. The activity of the SRF and FAE were estimated from their absorbance at 600 nm (A_{600nm}, Nagadi *et al*., 1999). The GP profiles of three replicates of milled (1 mm screen) HTDG were then recorded on three occasions over 48 h with 10, 20, 30 and 40 ml SRF and the necessary volume of FAE to give the same A_{600nm}. Buffered medium was added so that the total volume of incubation medium was 100 ml. The GP profiles were fitted to the model of Groot *et al*. (1996). The effects of inoculum source (S) and concentration (C) were determined by analysis of variance. The FAE GP profile parameters were then compared with the SRF GP parameters by regression analysis.

Results The GP profiles produced by SRF and FAE were significantly different. SRF profiles were best described by a single phase while FAE profiles were best described by two phases. Total gas volume (*a*) was not affected by inoculum source but increased with inoculum concentration. Time to half *a* (*k*) was longer and the maximum rate of gas production (R_{MGas}) slower for FAE compared with SRF. R_{MGas} tended to increase with inoculum concentration.

Table 1 *Effect of inoculum source and concentration on the GP profile*

	Inoculum concentration (ml/1 incubation medium)*									Significance		
	100	159	200	318	300	477	400	637	SEM	Source	Conc.	SxC
	SRF	FAE	SRF	FAE	SRF	FAE	SRF	FAE		(S)	(C)	
a (ml/g DM)	225	273	263	245	265	292	276	283	16.4	ns	*	ns
k (h)	11.5	40.0	11.5	31.1	11.3	40.0	10.1	347	3.34	***	ns	ns
R_{MGas} (ml/h)	12.2	4.4	14.2	7.3	15.1	6.2	18.0	5.6	1.23	***	ns	ns

*FAE inoculum concentrations were altered so that FAE and SRF had the same A_{600nm}. The FAE inocula of 159, 318, 477 and 637 ml/l had the same A_{600nm} as the SRF inocula of 100, 200, 300 and 400 ml/l respectively.

The FAE GP profile parameters (*a*, *k* and the shaping characteristic, *n*) for the two phases were regressed with the SRF GP profile parameters. The best predictions were:

SRFa = 348 - 25.5 FAE n_1 + 0.741 FAE a_2 + 1.49 FAE k_2 - 47.1 FAE n_2 (Adjusted R^2=0.691; SE=13.6; P<0.05)

SRFk=28.5-0.03FAEa_1-1.14FAEk_1+1.21FAE n_1-0.12FAEa_2-0.75FAEn_2 (Adjusted R^2=0.976; SE=0.19; P<0.001)

SRFn=- 0.02-0.18FAE k_1+0.54FAEn_1-0.01FAE a_2+0.01FAE k_2+ 0.50 FAEn_2 (Adjusted R^2=0.971; SE=0.037; P<0.01)

where the subscripts refer to the phase of GP.

Conclusions Ensuring that inocula had the same initial microbial activity (assessed by the absorbance at 600 nm) did not remove the difference between FAE and SRF. For comparing SRF and FAE inocula, therefore, measuring absorbance may not be an appropriate means of assessing microbial activity. However, the dynamic GP profile parameters (*k* and *n*) produced by SRF can be accurately predicted from the GP profile parameters produced by FAE, and so results obtained using one of these inoculum sources could be extrapolated (with caution) to the other.

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References

Groot, J.C.J., Cone, J.W., Williams, B.A., Debersaques, F.M.A. and Lantinga, E.A. (1996) Multiphasic analysis of gas production kinetics for *in vitro* fermentation of ruminant feeds. *Animal Feed Science and Technology*. **64**:77-89.

Nagadi, S., Herrero, M. and Jessop, N.S. (1999) Effect of frequency of ovine ruminal sampling on microbial activity and substrate fermentation. *Proceedings of the British Society of Animal Science 1999.* p. 154.

The use of extracted lignin from steam-treated wheat straw to protect protein from rumen microbial degradation

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Introduction During steam treatment of lignocellulosic materials lignin is depolymerised (Zahedifar, 1996) to lower molecular weight phenolic compounds. Those phenolics may have protein precipitating capacity (PPC) due to bearing some hydroxyl groups on their molecule (Kawamoto *et al*, 1992) as do some other phenolics like tannins. Protein precipitating capacity of tannins may have a positive effect in ruminants by protecting proteins from microbial degradation in the rumen. The aim of this study was to assess the PPC of the phenolic compounds extracted from steam-treated wheat straw (STWS) and possible use of them to protect protein from rumen microbial degradation.

Material and methods Wheat straw was steam-treated at 19 bar pressure and 5 min reaction time. The treated material was soaked in 1M NaOH solution and then filtered to get the solution. The pH of the solution was gradually reduced to 2.5 by 2M H_2SO_4 to precipitate lignin. The obtained lignin was neutralised then dried. Lignin (100 mg) and tannin (5 mg tannic acid) were added to 5 ml Bovine Serum Albumin (BSA) solution (10 mg/ml). Concentration of protein in the solution was measured after addition of the phenolics. The PPC of lignin and tannin was expressed as the units of protein eliminated from the solution (adsorbed to phenolics) per units of used phenolics. Analysis of protein was carried out by the method described by Makkar, 1987. The ability of lignin to protect protein was assessed *in vitro* by the following method: mixtures of casein solution (3.5 ml-16 mg/ml) and 4 levels of lignin (0, 100, 200 and 400 mg) were prepared then 30 ml of rumen liquor and artificial saliva mixture was added to the lignin-casein mixtures. Concentration of ammonia and iso-acids at different hours after incubation were used as indices of protein degradation by rumen microbes. Effect of lignin on food digestion was assessed using *in vitro* gas production technique. Four levels of lignin (0, 100, 200 and 400 mg) mixed with 200 mg rye grass and put in glass syringes then rumen liquor was injected and gas production was measured at different hours of incubation. Effect of pH on lignin-protein complex was studied using the following method. Forty mg of lignin was added into a test tube containing 2 ml BSA solution (10 mg/ml). The mixture was centrifuged and the solid fraction was obtained. The precipitate was mixed with 12 ml acetate buffer (0.2 M, pH 4.0) and the pH was reduced slowly by adding 1 M HCl. Samples taken at different pH values and analysed for protein content. Effect of levels of lignin on NH_3 and iso-acid concentration at each incubation time was analysed by ANOVA, completely randomised design.

Results It was shown in this study that the lignin extracted from STWS, like tannin, can bind to protein and precipitate it. The PPC of tannin was 2.5 mg protein per gram tannin and 0.5 g for lignin. Levels of lignin significantly ($p<0.01$) reduced production of NH_3 *in vitro*. A significant ($p<0.01$) reduction was also observed in production of iso-acids which mainly produced from degradation of proteins. Different levels of lignin did not affect digestion of rye grass which mean that lignin had no detrimental effect on rumen microbial activity. Therefore, the reduction in protein degradation can be attributed to protection of protein from microbial degradation by lignin. Reducing the pH of a solution containing lignin-protein complex showed that adsorption of lignin to protein is a pH dependent reaction as is for tannins. By reducing the pH, protein was appeared in the solution and at pH 2.2, 93% of the adsorbed protein to lignin was released.

Effect of lignin extracted from steam-treated wheat straw on the concentration of NH_3 (mg/l) and iso-acid (Mm)

levels of lignin	NH_3 (mg/l) incubation time(h)				Iso-acid (Mm) incubation time (h)			
	6	12	24	48	6	12	24	48
0 (control)	76.0^a	171.9^a	226.0^a	365.0^a	1.65^a	2.55a	3.55^a	3.75^a
100 mg	47.8^b	107.9^b	142.7^b	216.9^b	0.60^b	1.10^b	1.40^b	2.25^b
200 mg	40.3^b	63.8^c	114.4^c	179.3^c	0.45^c	0.95^b	1.10^c	1.70^c
400 mg	27.0^c	55.1^d	92.9^d	131.0^d	0.25^d	0.50^c	1.10^c	1.50^d
SEM[1](n=2)	4.19	7.68	4.72	8.67	0.050	0.152	0.035	0.152

[1] standard error of mean
Values with different superscript in the same column are significantly different ($p<0.01$)

Conclusion The extracted lignin from STWS can react with protein and precipitate it. The adsorbed protein to lignin is protected from rumen microbial degradation. The lignin-protein complex is broken down at low abomasal pH. The lignin extracted from steam-treated wheat straw can be used as a protein protective material in ruminant nutrition.

References Kawamoto, H.; Nakatsubo, F. and Murakami, K. (1992) Protein adsorbing capacities of lignin samples. Mukuzai Gakkaishi. 38, 81-84.
Makkar, H.P.S.; Dawra, R.K. and Singh, B. (1987) Protein precipitation assay for quantitation of tannins: determination of protein in tannin-protein complex. Analytical Biochemistry. 166, 435-439.
Zahedifar, M. (1996) Novel uses of lignin and hemicellulosic sugars from acid-hydrolysed lignocellulosic materials, PhD thesis, University of Aberdeen, UK.

Mixture design to study *in vitro* associative effects of feed mixtures

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Introduction. Associative effects of feed mixtures have been studied looking at the differences (*i.e.* gas production) between single and mixed substrates, and significant differences have been found when fodder trees were mixed (Rosales *et al.*, 1998). This may not be the more appropriate form to analyze mixtures, because small departures from simple additivity may result in significant differences as the sum of all its components equals one. Taking this fact into account mixture designs have been suggested as an adequate tool when dealing with mixtures (Mead, 1988). Mixtures design are a special class of response surface designs in which the sample under study is made up of several components or ingredients, thus the response depends on the relative proportion of the components. The objective of the present study was to asses the power of mixture designs to identify associative effects in feed mixtures.

Materials and methods. The *in vitro* gas production technique (Theodorou *et al*., 1994) was employed. Rumen liquor from two cannulated cattle was used as source of inoculum. Leaves from *L. leucocephala* and *Piscidia piscipula* were incubated as single substrate (1.0) or mixed with grass hay (*Pennisetum purpureum*) and concentrated (180 gCP/kgDM) (soybean / sorghum) in all possible combination resulting from the 0.0, 0.25, 0.50 and 0.75 proportions. Pressure and gas volume were measured at regular intervals up to168 h. When incubation finished the residuals were filtered and *in vitro* DM digestibility (IVDMD) assessed by difference between initial and final amounts of sample (after correcting for blanks). All samples were run with 4 replicates. A mixture design was used in multiple regression analyses. The model included the principal effects (single components), double and multiple interactions. The simplified model can be written as: $y= x_1C + x_2G + x_3T + x_{12}CG + x_{13}CT + x_{23}GT + x_{123}CGT$, where: y= the response variable (ml gas, IVDMD), x_{1-n} =coefficients for single components and interactions and C, G and T = relative proportions of components (Concentrate, Grass and Fodder Tree respectively).

Table 1 Chemical composition (g/kgDM) of ingredients in the mixtures

	DM	EE	Ash	NDF	ADF	L	CP
L. leucocephala	967	39	76	374	247	116	268
P. piscipula	956	34	133	409	251	119	140
Taiwan grass	885	22	14	841	521	147	75
Sorghum	899	32	67	255	52	-	98
Soybean meal	946	12	47	75	48	-	481

DM =Dry matter, EE =ether extract, NDF =Neutral Detergent fiber, ADF= Acid detergent fibre. L =lignin, CP =Crude protein

Results. The ingredients employed in the mixtures had standard chemical composition (Table 1). The mixtures presented departures from additivity, but not all of them were significant (Table 2 and 3). Observed and expected cumulative gas productions are presented in table 3.

Table 2 Partial regression coefficients for *in vitro* dry matter digestibility (IVDMD) (g/kgDM) and cumulative gas production (ml gas/g sample)

	C	G	T	C*G	C*T	G*T	C*G*T	R^2
IVDMD								
L leucocephala	912**	604**	532**	- 89	-443**	142	53	72.7**
P. piscipula	907**	620**	374**	-107	189**	-276**	86	95.6**
Total gas production								
L leucocephala	285.5**	187.2**	114.9**	57.0	72.5*	47.6	11.5	89.5**
P. piscipula	290.1**	181.6**	150.8**	58.6	-40.2	178.4**	-142.9	59.6**

C = concentrate (sorghum-soybean), G = *Pennisetum purpureum* hay,
T = Fodder tree, * P<0.05, ** P<0.01.

Conclusions. The inclusion of fodder trees and/or grass depressed IVDMD and gas production proportionally to its inclusion level, although the depression caused by fodder trees was significant and different for each tree. Mixture designs are a powerful tool to identify associative effect in feed mixtures.

References Mead, R. 1988. The design of experiment. Cambridge Univ. Press, UK.
Rosales, M., Gill, M., Wood, C.D.. & Speedy, W. 1998. Associative effects *in vitro* of mixtures of tropical fodder trees. In: Occasional publication No. 22 BSAS. Pp 175-177.
Theodorou, MK, Williams, BA, Dhanoa, MS, McAllan AB &France J. 1994. A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminants feeds. Anim. Feed Sci. Technol. 48:185-197.

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Table 3. Observed (o) and expected (e) cumulative gas production (ml gas/g sample) from individual feeds and its mixtures

M	PPo	Ppe	LLo	LLe
1	150	150	114	114
2	192**	158	141	133
3	178	185	171*	157
4	210**	166	163	151
5	210	220	218*	200
6	188	193	176	175
7	223	228	218	218
8	196	201	194	193
9	207**	173	178	169
10	247	255	256*	242
11	274	263	271	260
12	250	235	250	236
13	219	208	222	211
14	290	290	285	285
15	181	181	187	187

*p<0.05, **p<0.01, PP=*P piscipula*, LL=*L leucocephala*, M=Tree–grass-concentrate mixture: 1=1-0-0, 2=0.75-0.25-0, 3=0.75-0-0.25, 4=0.5-0.5-0, 5=0.5-0-0.5, 6= 0.5-0.25-0.25, 7=0.25-0.25-0.5, 8= 0.25-0.5-0.25, 9=0.25-0.75-0, 10= 0.25-00.75, 11=0-0.25-0.75, 12=0-0.5 0.5, 13=0-0.75-0.25, 14=0-0-1, 15=0-1-0

Application of the *in vitro* Reading Pressure Technique to demonstrate the patented Regulated Release™ technology incorporated in a number of molasses-based liquid feeds

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Introduction Regulated Release™ (RR) is a patented liquid feed technology designed to reduce costs associated with protein supplementation. By causing the rate of ammonia release to mimic that of feed protein, through complexing urea and sugars, RR allows urea to act as a cost-effective ammonia source. However as molasses is used as the carrier it is difficult to demonstrate the efficacy of this technology using standard feed evaluation methodologies such as the artificial fibre bag technique of Ørskov *et al.* (1980). However the Reading Pressure Technique (RPT, Mauricio *et al.*, 1999) can evaluate such feeds *in vitro* and the opportunity was therefore taken to examine the ability of RR to alter the rate and extent of fermentation by comparing a blended molasses with three RR molasses-based liquid feeds. As the majority of the CP in these feeds originates from urea rather than true protein, little if any gas will be produced from CP degradation. It was therefore hypothesised that an alteration in measured gas production, relative to that of *Stockmol 20*, would be due to the influence of RR technology limiting carbohydrate fermentation.

Materials and methods The fermentation profiles of three RR products - *Regumix*, *Regumaize 44* and *Regumaize 65* were compared with *Stockmol 20*, a blended product based on standard sugar cane molasses and fermented molasses co-products. While the crude protein content of these supplements varied considerably (270, 440, 657 and 85 g/kg dry matter (DM) for *Regumix*, *Regumaize 44*, *Regumaize 65* and *Stockmol 20*, respectively total sugars were broadly similar at 530, 550, 490 and 560 g/kg DM, respectively. The *in vitro* procedure utilised was that detailed by Mauricio *et al* (1999). Four replicates were used with approximately 1.0g molasses added to each fermentation flask. The rumen fluid inoculum was obtained pre-feeding from a dry cow offered first-cut grass hay *ad libitum*. Head-space gas pressure readings were taken at 2, 4, 6, 8, 10, 12, 15, 19, 24, 30, 36, 48, 72 and 96 hours post-inoculation and accumulated gas released following each reading. Gas volume (ml) estimates were generated using the quadratic function specific to this site, corrected for the quantity of DM incubated and direct gas production from the inoculum. The model of France *et al.* (1993) was applied to describe the cumulative gas profiles, in terms of potential gas production (*A*), lag phase (*L*), time to attain the half-asymptote value (*T/2*) and the fractional rate of gas production (*m*) at T/2.

Results Significant differences in cumulative gas production were identified within two hours of inoculation (Table 1). Subsequently at all measurement intervals all three RR substrates, ranked *Regumix* > *Regumaize* 65 > *Regumaize 44* in terms of gas release, produced significantly less gas (P>0.05) than *Stockmol 20*. Rate of gas production profiles (Figure 1) clearly differed between the RR substrates but all were lower relative to *Stockmol 20*. Fermentation parameters obtained using the France model confirmed these findings. Estimated potential gas production (*A*) values for the RR substrates of 108 to 118 ml, compared to 164 ml / g DM for *Stockmol 20*, suggested that RR technology reduced the extent of fermentation by about one-third at 96h. As release rates were similar >24h post-inoculation (Figure 1) and these (liquid) materials are likely to have a short rumen retention time, fermentation data to 18h post-inoculation will provide a more appropriate indication of *in vivo* degradation.

Table 1 *Cumulative gas production (ml / g DM)*

Molasses	Incubation (hours)								
	2	4	6	8	10	12	24	48	96
Stockmol 20	5.2^{a}	26.9^{a}	55.0^{a}	70.8^{a}	83.9^{a}	94.4^{a}	139.4^{a}	159.8^{a}	163.3^{a}
Regumix	4.4^{ab}	23.6^{ab}	42.4^{b}	53.4^{b}	60.8^{b}	66.3^{b}	96.1^{b}	110.7^{b}	117.7^{b}
Regumaize 44	3.9^{ab}	21.6^{b}	40.7^{b}	49.3^{b}	52.8^{c}	52.6^{c}	68.7^{d}	85.6^{c}	95.5^{c}
Regumaize 65	2.7^{b}	22.9^{ab}	42.1^{b}	51.4^{b}	55.5^{bc}	57.3^{c}	80.2^{c}	95.8^{c}	103.2^{c}
s.e.	0.45	1.54	1.69	1.98	2.28	2.27	3.07	3.49	3.78

[1] Means within columns without common superscripts are significantly different (P>0.05)

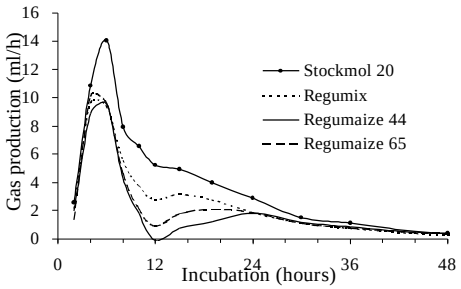

Figure 1 *Rate of gas production (ml/h)*

Conclusion These data confirm that the incorporation of Regulated Release™ technology into a molasses-based liquid feed provides an efficacious method with which to modify rate of fermentation, as identified by the variation in both rate and extent of gas release. From this it is inferred that supplemental ammonia release from urea *in vivo* will be similarly influenced, although a number of factors such as the rate of passage need to be incorporated before an accurate estimate of the rate of ammonia release as influenced by RR technology can be estimated.

References

France, J., Dhanoa, M.S., Theodorou, M.K., Lister, S.J., Davies, S.J. & Isac, D., 1993. A model to interpret gas accumulation profiles with *in vitro* degradation of ruminant feeds. *Journal of Theoretical Biology*, 163:99-111.

Mauricio, R.M., Mould, F.L., Dhanoa, M.S., Owen, E., Channa, K. S. and Theodorou, M.K. 1999. A semi-automated *in vitro* gas production technique for ruminant feedstuff evaluation. *Animal Feed Science and Technology*, **79**:321-330.

Ørskov, E.R., Hovell, F.D.DeB. and Mould, F. L. 1980. The use of the nylon bag technique for the evaluation of feedstuffs. *Tropical Animal Production*, **5**: 195-213.

In vitro fermentation profiles of a number of commercially available sugar cane molasses-based liquid feeds described using the Reading Pressure Technique.

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Introduction The differential rate and extent with which molasses-based feed supplements are fermented in the rumen, relative for example to starch-based concentrates, could be used to position these products in the market. There are, however, currently no data available to support such an assertion, in part due to the problem of how to assess degradation, as clearly standard feed evaluation methodologies such as the nylon bag technique (Ørskov *et al.*, 1980) are inappropriate for liquid feedstuffs. The ability of the recently developed Reading Pressure Technique (RPT) (Mauricio *et al.*, 1999) to examine such feeds was therefore utilised to describe or "fingerprint" the fermentation profiles of a range of commercially available molasses-based feeds.

Materials and methods The fermentation profiles of five sugar cane molasses blends were compared to that of *Standard* cane molasses (ST). *Economol* (EM) is cane molasses blended with water to produce a less viscous product. While all based upon standard cane molasses, *Stockmol 20* (SM) and *Molmax* (MX) also contain fermented molasses co-products, *Molale* (MA) an equal proportion of pot-ale syrup and *Proplus* (PP) other liquid co-products. These blends (ST, EM, SM, MX, MA and PP) had stated crude protein and total sugar contents of 50, 50, 85, 160, 160, 180 and 640, 640, 560, 450, 420, 300 g/kg DM, respectively. The *in vitro* procedure followed was that of Mauricio *et al.* (1999). Four replicates were used with approximately 1.0g of each molasses added per fermentation flask. The rumen fluid inoculum was obtained pre-feeding from a dry cow offered first-cut grass hay *ad libitum*. Head-space gas pressure readings were taken at 2, 4, 6, 8, 10, 12, 15, 19, 24, 30, 36, 48, 72 and 96 hours post-inoculation and the accumulated gas released following each reading. Gas production (ml) estimates, corrected for the quantity of DM incubated and direct gas production from the inoculum, were generated from pressure measurements using the quadratic function specific to this site and the values used to prepare cumulative and rate of gas production profiles. LS means and s.e. values were generated using SAS GLM procedures.

Results A marked variation between the cumulative gas production profiles of the molasses blends was readily identified using the RPT system (Table 1). Although little difference was observed up to 4h post-inoculation, thereafter the gas release curves differentiated into three groups, reflecting their stated compositions. ST, EM and SM showed broadly similar curves in terms of rate of gas release over time (Figure 1) resulting in equivalent levels of gas production at 96 hours. While MX and MA produced equivalent amounts of gas at 96 h, their rate of release profiles ("fingerprints") were dissimilar, with that of MA peaking earlier and higher than MX. PP exhibited a similar release profile to that of MA although cumulative gas production was significantly lower ($P<0.001$) from 6h post-inoculation. Earlier work suggests that peak release rates occurring at the same time post-inoculation indicate components which degrade at the same rate while the height of the curves provides an indication of the relative proportions of these components. It is interesting to note that the release profiles of ST and EM are essentially identical on a DM basis, confirming that these products only differ in the quantity of water incorporated into the EM. The SM release curve follows these two, with the slightly lower maximum value a direct result of the lower total sugar and higher CP content of this blend. Although MA and PP exhibit similar gas release profiles, the magnitude of the PP curve is about 0.75 that of MA corresponding almost directly to the lower stated total sugar content. In addition as the CP content of these two substrates differs markedly it is concluded that degradation of CP produces little direct fermentation gases.

Table 1 *Cumulative gas production (ml / g DM)*

Molasses	Incubation (hours)								
	2	4	6	8	10	12	24	48	96
ST	4.0	23.9	55.8	75.5	90.2	100.5	140.9	158.8	162.4
EM	4.2	22.4	55.0	73.9	87.8	98.7	143.1	162.3	166.5
SM	5.2	26.9	55.0	70.8	83.9	94.4	139.4	159.8	163.3
MX	4.0	26.2	49.3	64.3	76.5	86.7	128.2	149.7	154.8
MA	4.8	35.3	57.9	73.8	87.3	98.4	138.3	156.7	158.8
PP	5.0	26.9	43.1	54.6	64.9	72.7	104.6	122.3	128.4
s.e.	0.42	1.76	1.79	2.03	2.35	2.54	3.82	4.61	4.78

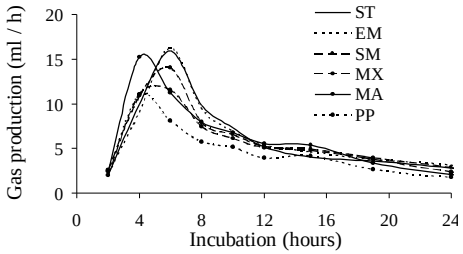

Figure 1 *Rate of gas production (ml/h)*

Conclusion The RPT system was readily able to differentiate these substrates. Total and rate of gas production were both found to vary in accordance with their stated composition, with the majority of these effects occurring within eight hours of inoculation. The successful application of this technique suggests a methodology with which to examine similar products with regards quality control or to screen novel liquid feed supplements.

References

Mauricio, R.M., Mould, F.L., Dhanoa, M.S., Owen, E., Channa, K. S. and Theodorou, M.K. 1999. A semi-automated *in vitro* gas production technique for ruminant feedstuff evaluation. *Animal Feed Science and Technology*, **79**:321-330.

Ørskov, E.R., Hovell, F.D.DeB. and Mould, F. L. 1980. The use of the nylon bag technique for the evaluation of feedstuffs. *Tropical Animal Production*, **5**: 195-213.

The influence of rumen fluid pH on the rate and extent of maize silage and wheat straw degradation estimated *in vitro* using the Reading Pressure Technique

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Introduction Fermentation of the increasingly energy-dense rations offered to meet the nutrient demands of today's high yielding dairy cows ought to adversely rumen fibre degradation. Not only could rumen fluid pH be depressed below that assumed critical to cellulolysis for extended periods of time but the quantity of readily fermentable carbohydrate available will further exacerbate this effect. These, together with the reduced rumen retention time of feed particles associated with high feeding levels could significantly limit fibre degradation. This *in vitro* study was designed to identify the pH at which degradation becomes impaired, the extent of this depression and whether the effect varies according to the feedstuffs offered.

Method The Reading Pressure Technique (Mauricio *et al.,* 1999) was used to examine the fermentation characteristics of two substrates incubated *in vitro* at a range of pH values. Gas production profiles and both rate and extent of degradation of wheat straw (WS) and maize silage (MS) were examined. Citric acid (0, 12.5, 25 and 37.5 ml / l) was used to alter the initial pH of the incubation medium to 6.4, 6.2, 5.9 and 5.4, respectively prior to inoculation with rumen fluid. Although citrate can be fermented by rumen bacteria, Grant and Mertens (1990) found no confounding effect on NDF degradation *in vitro*. A 2x4 factorial design with three replicates per treatment, together with controls (no substrate, with and without citric acid) were included for each treatment combination was used.Gas production profiles, corrected for the quantity of OM incubated and gas released from the controls, were used to prepare cumulative and rate of gas production profiles. Flasks withdrawn on eight occasions to estimate degradation, expressed as OMD. Incubation medium pH was also measured. DM loss was assessed by drying at 100°C for 24 hours and OM losses by difference following ashing at 500°C overnight.

Results The addition of increasing quantities of citric acid resulted in mean incubation fluid pH values of 6.47, 6.34, 6.17 and 5.91 (WS) and 6.27, 5.97, 5.75 and 5.62 (MS), respectively. In all cases pH declined during incubation to 48 hours then increased slightly. Citric acid was fermented, with gas production increasing with the level of acid added (27, 43, 68 and 109 ml, respectively at 96 h). Cumulative gas production (ml, 96h) varied directly with pH level (200, 207, 185 and 115; 301, 279, 217 and 141, for WS and MS, respectively). Degradation of wheat straw became impaired, relative to that without citric acid inclusion, when the incubation medium pH was reduced to 6.2, thereafter it declined rapidly (Table 1). Although degradation at 96h (pH 6.2) was only slightly lower than that obtained at the highest pH, the initial period of microbial growth and attachment prior to substantial degradation (lag phase) was prolonged. This effect found was to a greater extent as pH declined with 96h degradation at pH 5.9 reduced to 374 mg/g compared with 530 mg/g (pH 6.5). In contrast 96h degradation values for maize silage remained essentially unaltered at pH 6.0, although the fermentation during the lag phase was slightly depressed. However at lower pH values (below 5.8) highly significant effects on both the lag phase and the extent of degradation occurred.

Table 1 *Influence of incubation medium pH on organic matter degradation (mg OMD/g DM)*[1]

Wheat straw							Maize silage						
Mean	Incubation (hours)						Mean	Incubation (hours)					
pH	6	12	19	24	48	96	pH	6	12	19	24	48	96
6.47	32a	122a	228a	280a	459b	530a	6.27	140a	528a	629a	660a	797a	799a
6.34	19a	79b	205a	269a	480a	525a	5.97	146a	379b	557b	604b	728b	775a
6.17	26a	38c	111b	180b	408c	506b	5.75	173a	247c	446c	459c	595c	681b
5.91	19a	39c	45c	66c	282d	374c	5.62	122a	143c	143c	236d	236d	517c
s.e.	6	5	7	13	2	4	s.e.	31	36	8	5	6	5

[1] Means within substrates in columns with common letters are not significantly different (P>0.05)

Conclusion The difference observed in the incubation fluid pH below which degradation became severely depressed appeared to vary according to the substrate examined. The extent to which this occurs is probably due to the nature of the substrates used (especially the fibre content and composition) and this aspect needs to be examined further, as does the direct effect of citric acid on degradation. However it may offer an indication as to why intakes of high-producing dairy cows offered maize-based TMRs are maintained, despite these animals exhibiting rumen fluid pH levels that are considered to be deleterious to cellulolylsis.

References

Grant R.J. and Mertens, D.R. 1990. A buffer system for pH control and evaluation of pH effects upon fiber digestion in vitro. *US Dairy Forage Research Centre 1989 Research Summaries. ARS-USDA, Madison, WI.*

Mauricio, R.M., Mould, F.L., Dhanoa, M.S., Owen, E., Channa, K. S. and Theodorou, M.K. 1999. A semi-automated *in vitro* gas production technique for ruminant feedstuff evaluation. *Animal Feed Science and Technology*, 79:321-330.

Biochemical and *in vitro* assessment of six enzyme preparations as potential feed additives

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Introduction Considerable research efforts have been directed towards the use of cell wall degrading enzymes as feed additives. However, the factors affecting the response to a certain enzyme preparation are not well understood. A better knowledge of the enzymatic activities present in the preparations and their interaction with a substrate in presence of rumen fluid is needed. The objectives of this study were to characterise the main enzymatic activities of six enzyme preparations and to evaluate them in the presence of rumen fluid, using the *in vitro* Reading Pressure Technique (RPT).

Material and methods The enzyme preparations used in this study were *Depol 40* (D, Biocatalyst), *Liquicell 2500* (L, Specialty Enzymes), *Enzyme B* (B, Monsanto Co), *Enzyme C* (C, Finnfeeds International), a crude extract from *Aspergillus niger* (Aa, Prof. Atev, University of Sofia, Bulgaria), and a crude extract from *Thermoascus aurantiacus* (Ta, prepared by the authors). Cellulase and hemicellulase activities were determined in desalted and freeze-dried preparations at 39°C and pH 5.5 as described in a previous study (Colombatto *et al.*, 1999). Two forages, maize silage and alfalfa hay, were used for the *in vitro* assay. Both forages were pre-dried at 65°C and milled to pass a 2mm screen. The enzymes, normalised according to their xylanase activity, were applied to the forages 20 h prior to incubation at a rate of 15.25 µmol reducing sugar/g DM**.** The RPT system (Mauricio *et al*., 1999) was used to describe both the gas production (GP) and the organic matter degradation (OMD) profiles. Approximately 1 g of organic matter (OM) was added to each bottle for fermentation. Rumen fluid was taken from a hay-fed dry cow, 2 h prior to the morning feeding. Gas readings were taken at 2, 4, 6, 8, 10, 12, 15, 19, 24, 30, 36, 48, 72 and 96 h, and complete sets of treatments, with three replicates per treatment, were removed after 6, 12, 24, 48 and 96h of incubation. Positive and negative controls containing untreated substrates or rumen fluid only, respectively, were also included at each removal time. GP and OM degradation values were fitted to the France *et al.* (1993) model. A (2X6) factorial arrangement was used, with substrate (2) and enzymes (6) as main variables, and the OMD data were subjected to an ANOVA analysis using GENSTAT.

Results The enzyme preparations tested showed a wide range of variation in their activities, as shown in Table 1. The gas profiles were similar between treatments, suggesting no fermentation differences due to enzyme addition. No significant differences ($P<0.05$) were observed in the OMD values within substrates, in agreement with the gas data. The Table 2 shows the final GP and OMD obtained.

Table 1 Enzyme activities (µmol sugar/ml.min)

	Enzyme preparations					
	D	L	B	C	Ta	Aa
Xylanase	1358	14864	3820	3924	7653	1505
Endoglucanase	963.1	1699	647.7	765.8	344	9.2
Exoglucanase	3.6	6.8	13.7	7.8	0.1	0.02
Cellobiase	8.2	8.0	9.0	4.9	11.2	0.4
True cellulase	30.9	30.4	7.5	10	5.2	nil
beta-D-glucopyranosidase	12.3	35.1	6.7	5.6	13.7	0.4
alfa-L-arabinofuranosidase	3.9	1.1	4.7	0.8	0.8	0.5
alfa-L-arabinopyranosidase	0.8	2.8	0.8	1.3	1.4	0.1
beta-D-xylopyranosidase	nil	nil	nil	1.8	2	0.7

Table 2 GP and OMD values

Treatment	GP (ml)	OMD (g/kg DM)
Control MS	239	746
D MS	241	739
L MS	248	740
B MS	245	753
C MS	256	743
Ta MS	249	731
Aa MS	260	746
Control AH	158	496
D AH	163	491
L AH	164	476
B AH	164	489
C AH	164	483
Ta AH	164	486
Aa AH	172	481
s.e.		8.92

Conclusions The enzyme preparations examined differed in their cellulase and hemicellulase activity values. However, *in vitro* evaluation showed no evident effects on the OMD, which may have been related to insufficient enzyme level or to a loss of some side activities due to the freeze drying process.

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References Colombatto, D.; Bhat, M. K.; Mould, F. L. and Owen, E. 1999. Evaluation of the ability of a commercial enzyme to improve the nutritive value of ruminant feeds. *Proceedings of the 3rd Carbohydrate Bioengineering Meeting*, Section 6.8. Newcastle, UK.

France, J; Dhanoa, M. S.; Theodorou, M. K.; Lister, S. J.; Davies, D. R. and Isac, D. 1993. A model to interpret gas accumulation profiles associated with in vitro degradation of ruminant feeds. *Journal of Theoretical Biology*, **163**: 99-111.

Mauricio, R.M.; Mould, F. L.; Owen, E.; Channa, K. S. and Theodorou, M. K. 1999. A semi-automated in vitro gas production technique for ruminant feedstuff evaluation. *Animal Feed Science and Technology*, **79**: 321-330.

Cloning and properties of a lysozyme from the rumen ciliate protozoan, *Entodinium caudatum*

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Introduction The breakdown of bacterial protein in the rumen leads to a nutritionally wasteful cycle of protein breakdown and re-synthesis, decreasing the flow of microbial protein from the rumen to the small intestine (Williams and Coleman, 1992). Engulfment and subsequent digestion by ciliate protozoa was demonstrated to be the most important cause of bacterial lysis in mixed ruminal micro-organisms incubated *in vitro* (Wallace and McPherson, 1987). Despite their importance, little is known about the enzymes responsible for the digestion of bacteria in rumen ciliates. The objective of this study was to clone and characterise a lysozyme from *Entodinium caudatum*, a common rumen protozoan important in the ingestion and breakdown of rumen bacteria (Williams and Coleman, 1992).

Materials and methods *E. caudatum* cells were recovered from the rumen fluid of a monofaunated sheep by filtration and sedimentation. A cDNA library was produced and screened using an antibody raised in rabbits against partially purified lysozyme from *E. caudatum* as described previously (Eschenlauer *et al*., 1998). Phagemids were excised and the activity expressed in *E. coli* in the presence of isopropyl-β-D thiogalactopyranoside (Eschenlauer *et al*., 1999). Lysozyme activity was visualised by the lyso-plate lysozyme assay of Osserman and Lawlor (1966) and quantified by following the decline in the optical density at 650 nm of a suspension of *Micrococcus lysodeikticus*. To determine enzyme specificity, the products of hydrolysis from incubations with *M. lysodeikticus* were determined on a Waters Pico-tag amino acid analyser. The pI of the enzyme was determined from the relative binding of activity to carboxymethyl cellulose at different pH values. Optimum pH was determined by measuring activity in McIlvaine's buffer at between pH 3 and 7.5.

Results Among the clones isolated, one 884 nucleotides long and encoding a 240-residue protein (estimated MW 24.5 kDa) showed close homology to lysozyme sequences isolated from a number of bacteriophages. When expressed in *E. coli* there was clear lysis of *M. lysodeikticus*. No lysis was noted when a clone encoding glutamate dehydrogenase (Eschenlauer *et al*., 1999) was tested in the same assay. The cloned activity cleaved the N-acetylmuramyl → 1,4-beta-N-acetylglucosamine bond in the *M. lysodeikticus* peptidoglycan with subsequent release and destruction of muramic acid residues (0.041 v 0.088 mmole muramic acid/ mmole glutamic acid for incubations with or without the cloned enzyme) but not glucosamine (0.110 v 0.115 mmole glucosamine/ mmole glutamic acid, respectively) suggesting it was an N-acetylmuramidase (lysozyme). The enzyme had a pI of 5.5 and an optimal pH 4.8 (figure 1).

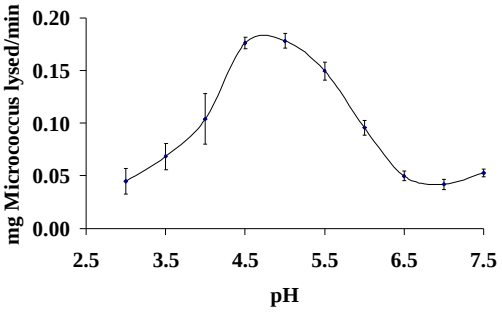

Figure 1. The pH optimium of cloned enzyme

Conclusion A lysozyme has been cloned from *E. caudatum*, it differs from the previously described lysozyme from this ciliate which had an estimate Mr of 14 kDa, a pI of 9 and a optimum pH of 6.5 (Martin *et al*., 1997). Indeed the cloned activity has more in common with the previously un-isolated activity described by Newbold *et al*. (1999) which appeared to be the major lytic activity in this ciliate.

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References

Eschenlauer, S.C.P., McEwan, N.R., Calza, R.E., Wallace, R.J., Onodera, R. and Newbold, C.J. 1998 Phylogenetic position and codon usage of two centrin genes from the rumen ciliate protozoan, *Entodinium caudatum. FEMS Microbiology Letters* **166**:147-154.

Eschenlauer, S.C.P., McEwan, N.R., Nelson, N., Calza, R.E., Wallace, R.J.. and Newbold, C.J. 1999 An NAD-dependent glutamate dehydrogenase cloned from the rumen ciliate protozoan, *Entodinium caudatum. South African Journal of Animal Science* **29:** 58-59.

Martin, H.C., M^{C}Intosh, F.M., Wallace, R.J. and Newbold, C.J. 1997 Purification and characterisation of a lysozyme-like enzyme from the rumen ciliate *Entodinium caudatum* Reproduction Nutrition Development **88** (Suppl 1) 47.

Newbold, C.J., Martin, H.C., McIntosh, F.M., Onodera, R., Wallace, R.J. and Calza, R.E. (1999) Breakdown of bacterial cell walls by the rumen ciliate protozoan, *Entodinium caudatum. South African Journal of Animal Science* **29:** 114-115.

Osserman, E. F. and Lawlor, D.P. 1966. Serum and urinary lysozyme (muramidase) in monocytic and monomyelocytic leukemia. *Journal of Experimental Medicine* **124**: 921-951.

Wallace, R. J., and C. A. McPherson. 1987. Factors affecting the rate of breakdown of bacterial protein in rumen fluid. *British Journal of Nutrition* **58:**313-323.

Williams, A. G., and G. S. Coleman. 1992. The rumen protozoa. Springer-Verlag, New York.

Influence of growing conditions on rumen escape protein and chemical composition in grass

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Introduction The amount of rumen escape protein is commonly determined with the nylon bag technique. However, there is also an *in vitro* technique described using a protease of *Streptomyces griseus* (Aufrère et al., 1991; Cone et al., 1996), allowing systematical analysis of protein quality in a large number of samples. The aim of this study was to identify the influences of growing conditions on content of rumen escape protein in grass and grass silage and to investigate the relationships between rumen escape protein determined *in vitro* and *in situ* and chemical composition.

Materials and methods Grass was grown in 1996 and 1997 on clay soil (Lelystad) and sandy soil (Maarheeze), annually fertilized with 150 or 300 kg N ha^{-1}. Grass was mown with a drum mower every month from May till September during 3 subsequent weeks after a growing period of 3 weeks. Duplicate samples were stored fresh at –20 °C and as a silage after wilting to 25 or 45 % dry matter. All samples were chemically analysed and the *in vitro* undegraded protein fraction (%U24) was determined in duplicate after 24-h incubation with a protease from *Streptomyces griseus* (Cone *et al*., 1996) in a randomised block design. Rumen escape protein was determined with the nylon bag technique for 27 samples in triplicate in 3 dairy cows. Differences between samples were calculated using ANOVA.

Results and discussion Table 1 shows the % undegradable protein after 24-h incubation (%U24) *in vitro* with a protease of *Streptomyces griseus* for the different grass and silage samples. There was a significant ($p<0.001$) influence of harvest year and ensiling on %U24 and chemical composition. Location and N-fertilization also showed a significant ($p<0.01$) influence on chemical composition, but not on %U24. The influence of harvest year on %U24 may be attributable to weather conditions in 1996 and 1997. Ensiling results in fermentation, converting grass protein into microbial protein. Moreover, during the ensiling process cell wall structures break down and cell proteins become accessible to micro-organisms. There was only a small variation in %U24 during the growing season of 1996 and 1997. In 1997 %U24 increased slightly during the growing season, possibly due to two dry periods in 1997. The obtained nylon bag data (not shown) on percentage rumen escape protein (%REP) correlated with the *in vitro* data (% U24). For the silage samples the relationship was slightly higher (R^2 = 0.64, RSD = 3.8) than for the grass samples (R^2 = 0.59, RSD = 2.7). The *in vitro* determined amount of undegradable protein (U24, g kg^{-1} DM) showed a good relationship with chemical composition and harvest date (days after 1 April) (R^2 = 0.76, RSD = 5.3). Also %U24 showed a fairly close relationship with chemical composition and harvest date (R^2 = 0.73, RSD = 4.4).

Table 1 Mean percentage undegradable protein (%U24) determined *in vitro* after 24-h incubation with a protease of Streptomyces griseus

Kg N ha^{-1}	year	%U24 (% of CP)		
		grass	**silage (25 % DM)**	**Silage (45 % DM)**
Clay				
150 N	1996	21.6 (± 2.6)	18.9 (± 2.4)	19.4 (± 2.9)
	1997	25.9 (± 2.9)	21.0 (± 2.3)	24.4 (± 2.1)
300 N	1996	23.8 (± 1.8)	18.0 (± 1.9)	20.5 (± 3.4)
	1997	25.9 (± 5.1)	19.8 (± 3.1)	24.3 (± 3.9)
Sand				
150 N	1996	22.7 (± 1.6)	19.7 (± 4.9)	22.0 (± 3.5)
	1997	26.0 (± 3.1)	17.5 (± 4.0)	23.8 (± 4.7)
300 N	1996	23.0 (± 1.2)	18.4 (± 2.0)	22.5 (± 2.5)
	1997	26.7 (± 4.0)	17.5 (± 3.3)	23.7 (± 3.7)

Conclusions Location, year and N-fertilization significantly ($p<0.01$) influenced different chemical characteristics of the grass and silage. The *in vitro* percentage undegradable protein was significantly influenced by harvest year and ensiling, but not by location and N-fertilization. Rumen escape protein could be estimated with both the *in vitro* method and chemical characteristics.

References

Aufrère, J., Graviou, D., Demarquilly, C., Vérité, R., Michalet-Doreau, B. and Chapoutot, P. 1991. Predicting *in situ* degradability of feeds proteins in the rumen by two laboratory methods (solubility and enzymatic degradation). *Animal Feed Science and Technology* **33**: 97-116.

Cone, J.W., Van Gelder, A.H., Steg, A. and Van Vuuren, A.M. 1996. Prediction of *in situ* rumen escape protein from *in vitro* incubation with protease from Streptomyces griseus. *Journal of the Science of Food and Agriculture* **72**: 120-126.

Comparison of digestibility coefficients in different farm animal species

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Introduction Because feed evaluation of new feeds for animal nutrition requires *in vivo* trials, which can be expensive, harmful to the animals and time consuming, alternatives have been developed. *In vitro* techniques are used commonly for many farm animal species. However, *in vitro* data do not always predict *in vivo* data satisfactorily. As many processes in the gastro intestinal tract of different animal species are comparable also the digestibility of feeds may be comparable. The aim of this research was to identify similarities in digestibility coefficients between different farm animal species. If it is possible to use *in vivo* data of one animal species for the evaluation of alternative techniques for another species, this would enlarge existing data sets, accelerate the validation of new techniques and reduce the number of harmful animal trials.

Materials and methods The Dutch feed evaluation table gives a broad overview of feed composition and digestibility coefficients (DC) of all feed ingredients used in the Netherlands for pigs, poultry, broilers and ruminants (Anon., 1998). The DC values listed are generally adjusted values. For this research, data on the digestibility coefficients of crude protein (CP), nitrogen free extract (NFE) and crude fat in pigs, poultry and broilers were compared. NFE (g/kg) is calculated by subtracting moisture, crude ash, crude protein, ether extract and crude fibre from 1000. The digestibility coefficients given by the feed evaluation table are total tract digestibilities. Regression analyses was conducted to look for similarities in digestibility coefficients (%) between the different animal species.

Results Data on pigs, poultry and broilers were used, because the digestive processes in these animals are comparable. No relationship was found between animal groups for digestibility of crude fat (R^2_{adj}<0.4). Figure 1 shows the relationship of digestibility coefficients of CP between pigs and broilers. The lower cluster of points contained tapioca and molasses cane with low protein contents. Without these points a poor relationship was obtained (R^2_{adj}=0.40, p<0.001, n=44). As expected, data in broilers and poultry for the digestibility coefficients of CP related well (R^2_{adj} =0.94, p<0.001, n=49). However poultry data were a less pronounced predictor of the values in pigs (R^2_{adj} =0.70, p<0.001, n=105). Figure 2 shows the relationship of digestibility coefficients of NFE between pigs and broilers. No relationship could be found between the two animal species, which was also the case for the comparison of pigs and poultry (R^2_{adj} =0.42, p<0.001, n=105). Again a good relationship was found between the DC in broilers and poultry (R^2_{adj} =0. 96, p<0.001, n=47).

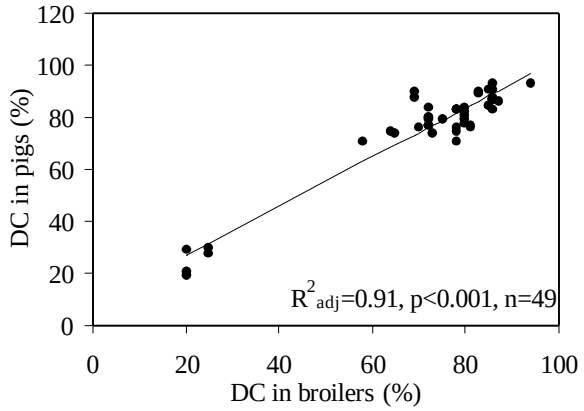

Figure 1 Relationship between digestibility coefficients (DC, %) of CP in pigs and broilers.

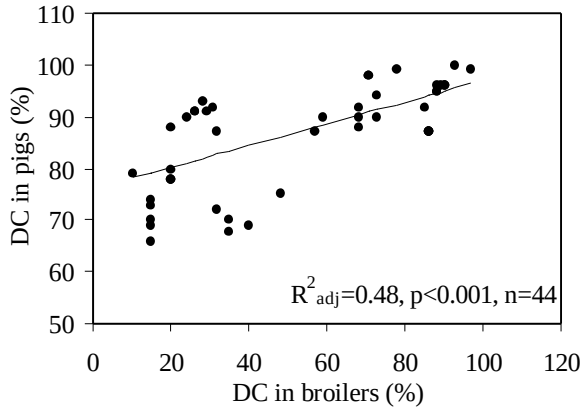

Figure 2 Relationship between digestibility coefficients (DC, %) of NFE in pigs and broilers.

Conclusions For practical application DC in one species should accurately predict the DC in another species. The results indicate that for NFE and crude fat total tract digestibilities were not directly comparable between animal species. The data set was not sufficient to support broilers as a model for pigs. The underlying digestive processes in the different animal species should be investigated more closely. Possibly, relationships in ileal digestibility between the different animal species can be found.

References

Anonymous, 1998. The Dutch Feeding Table (In Dutch). Centraal Veevoederbureau, Produktschap voor Veevoeder, The Hague.

Effect of a dried live yeast culture on *in vivo* apparent digestibility and on *in vitro* fibrolytic activity of large intestine fluid contents, in horses fed high fibre or high starch pelleted feeds

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Introduction Performance horses are often fed very energetic diets including large amount of grains. Thus, a important quantity of soluble carbohydrate is bound to reach the hindgut, altering biochemical and microbial composition of the intestinal contents (Julliand *et al*., 1999) and leading to a wide variety of diseases like colic, laminitis and diarrhoea (Clarke *et al*., 1990). In high concentrate rations, live yeast cultures have been reported to stimulate specific groups of bacteria, and moderate large ruminal pH decreases (Williams *et al*., 1991). Therefore, this trial was designed to evaluate the effect of a live yeast culture preparation (Yea Sacc^{1026} ™) on the activity of the intestinal ecosystem (caecum and colon) of horses fed high fibre (HF) or high starch (HS) pelleted feeds. This current summary reports only the results of the nutrient digestibility *in vivo* and the ability *in vitro* of large intestine fluid contents to degrade straw.

Materials and methods Eight fistulated mature male horses (mean live-weight of 305 (s.e. 83,5) kg) were allotted into pairs consisting of one caecum and colon fistulated horse and one caecum fistulated horse. Pairs were assigned to a balanced 4x4 Latin square (4 pairs x 4 treatments). Treatments were: HF, HF supplemented with 10 g/h/d of yeast culture (YS), HS, HS supplemented with 10 g/hd/d of YS. Horses were housed individually in flax bedding (ECOlit™) with a free access to water and trace mineralised salt block. They were fed two equal meals per day, consisting of 900 g of pelleted feed and 175 g dry matter (DM) of straw per 100 kg of live weight. The HF diet, based on a 548 g/kg alfalfa pelleted feed (889 g DM/kg; 341 g NDF; 219 g ADF; 139 g starch), was designed to meet 120% of the energy requirement of horses, whereas the HS one, based on a 535 g/kg barley pelleted feed (881 g DM/kg; 218 g NDF; 103 g ADF; 359g starch), ensured a significant amount of starch reaching the hindgut. Both the HF and HS diets provided similar amounts of protein. Each experimental period began with a 3 week diet adaptation period. Then, caecal and colonic fluid samples (7 ml) were collected and inoculated into 39°C pre-heated flasks (100 ml), containing 63 ml of Lowe medium and 350 mg of straw. DM disappearance of straw (DMdS) was calculated after 21, 72 and 100 h incubation. The last 6 days of the period involved total faecal collection for digestibility measurements. The apparent total tract digestibility of (DM), organic matter (OM), mineral matter (MM), NDF, ADF, ADL were calculated.

Results The HS diet increased the digestibility of DM, OM ($P<0.01$) and digestibility of MM, NDF ($P<0.05$). The addition of yeast culture (YS) to the HF diet increased (non-significantly) the coefficients of apparent digestibility. No yeast culture effects were found with the HS diet (Table 1). However, *in vitro* straw degradability was enhanced ($P<0.05$) by the addition of yeast cultures in both the HF and HS diets, after 21 hours of incubation (Figure 1). This stimulation was quit similar in both the colon and caecal (data not shown) contents.

Table 1 Coefficients of apparent digestibility (g/kg)

	Treatment				Statistical analysis			
	HF	HF,YS	HS	HS,YS	s.e.m	diet	YS	d*YS
DM	591	611	706	694	3.88	**	ns	ns
OM	473	512	445	434	3.65	**	ns	ns
MM	607	624	736	724	10.23	*	ns	ns
NDF	332	376	383	362	6.95	*	ns	*
ADF	333	377	354	341	7.00	ns	ns	ns
ADL	5	71	36	55	9.15	ns	ns	ns

(* P<0.05, ** P<0.01, *** P<0.001)

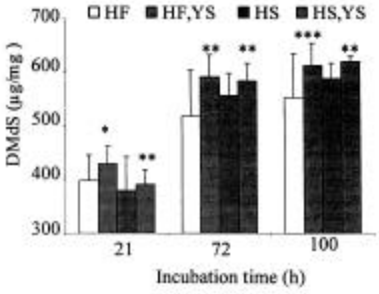

Figure 1 Fibrolytic activity of colonic contents

Conclusions. The significant increase of *in vitro* straw degradability, suggests that fibrolytic activity of the large intestine fluid contents was stimulated by the yeast culture preparation. I*n vitro* straw disappearance was improved in both the HF an HS diets supplemented with yeast, whereas apparent digestibilities of fibre contents (NDF, ADF, ADL) only increased numerically with the yeast supplemented HF diet. Further measurements of digesta flow rate in the large intestine are needed to better understand last results.

References

Clarke, L.L., Roberts, M.C., Argenzio, R.A., 1990. Feeding and digestive problems in horses : physiologic responses to a concentrated meal. *Vet. Clinics of North America: Equine practice*, 6 (2) : 433-450.

Julliand, V. , De Fombelle, A., Drogoul, C., and Jacotot, E., 1999. Effect of the hay:grain ratio on microbial and physico-chemical characteristics of cecal and colonic contents in ponies. *Proc. Sixteenth Equine Nutr. and Physio. Symp.* Raleigh, North Carolina. 153-155.

Williams, P.E., Tait, C.A., Innes, G.M., Newbold, C.J., 1991. Effect of the inclusion of yeast culture in the diet of dairy cows on milk yield and forage degradation and fermentation patterns in the rumen steers. *J. Anim. Sci*.. 69: 3016-3026.

The influence of urea and white rot fungi on the nutritional value of wheat straw

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Introduction In Iran, wheat straw which is produced in huge amounts has been used in animal feed. However, the use of straw as animal feed is limited by its low nutritional value and its low nitrogen content. Various chemical delignification methods to improve the digestibility of straw have extensively investigated (Sundstol and Owen, 1984). Biological methods of treating straw using fungi such as white-rot-fungi have also been reported (Zadrazil, 1984). The solid state fermentation (SSF) of wheat straw with white-rot fungi is a complex process which is influenced by factors such as the species of fungus, substrate, temperature and moisture (Zadrazil, 1984). The objective of this study was to investigate the effect of pre-treating the straw with urea and incubation with two species of *Pleurotus* fungi on the chemical composition and digestibility of wheat straw.

Materials and methods Wheat straw was cut into 3-5 cm lengths and treated with 2% of urea solution (2 kg of dried urea mixed with 100 litres of water). Fifty litres of this solution was added to 100 kg of the straw and kept for three weeks. The treated straw (TS) was then steamed and inoculated with, spawn of either *Pleurotus ostreatus* (TS1) or *Pleurotus* persian wild (TS2) at a rate of 3 percent (w/w). Five plastic bags, 2 kg each, of TS1 or TS2 were incubated at 25-30o C for four weeks period. All fermented samples were chemically analysed (AOAC, 1984), and the digestibility of DM and OM were measured using *in vitro* technique (Tilley and Terry, 1963). A completely randomised design was used to find out the effect of the tested species on the nutritive value of straw.

Results Table below shows the results. On average, treating wheat straw with urea and either spices of *Pleurotus* significantly ($P<0.05$) decreased the concentration of OM, NDF, hemicellulose, cellulose and lignin, whereas the CP content, and the digestibilies of OM and DM have increased significantly ($P<0.05$). The increased CP in the treated straw was likely due to the pre-treatment with urea.

Table 1 : Chemical composition and digestibility of wheat straw treated with 2% urea after 4 weeks of solid state fermentation with two spieces of fungi *(Pleurotus ostratus* (TS1) and *Pleurotus* persian (TS2)).

Treatment	OM	CP	Cellulose	HC	ADF	NDF	lignin	IVDMD	IVOMD
WS	94.4^{c}	1.6^{a}	43.5^{b}	19.3^{c}	56.5^{a}	75.8^{b}	13.0^{c}	25.2^{a}	26.0^{a}
UWS	91.9^{c}	2.7^{b}	45.4^{b}	18.7^{c}	56.9^{a}	75.6^{b}	11.5^{b}	24.2^{a}	27.1^{a}
TS1	80.8^{b}	3.79^{c}	40.0^{a}	11.8^{b}	50.9^{a}	62.8^{a}	10.9^{b}	37.4^{b}	42.2^{c}
TS2	86.9^{a}	4.44^{c}	45.7^{c}	9.1^{a}	55.8^{a}	64.9^{a}	9.9^{a}	34.3^{b}	35.8^{b}
P- value	**	**	***	***	ns	***	***	***	***

WS = untreated wheat straw. UWS=(wheat straw + urea). HC = Hemicellulose. IVDMD= *in vitro* dry matter digestibility. IVOMD=*in vitro* organic matter digestibility.
($P<0.01$) *($p<0.001$) a, b, c different letters in column indicate significant differences ($p<0.05$).

Conclusion Pre-treating of wheat straw with 2% urea and incubating with pleurotus ostreatus fungi has improved the IVDMD and increased significantly ($p<0.05$) the IVOMD when compared to *pleurotus* Persian fungi.

References

AOAC, 1984. Official methods of analyses of Association of Official Analytical chemists. In:William, S. (Ed.), 14th edn. Arlington, VA, U.S.A.

Ssundstol, F. and Owen, E. 1984. Straw and other fibrous by-product as feed. Elsevier, Amsterdam.

Tilley, J.M.A. and Terry, R.A. 1963. A two stage technique for *in vitro* digestion of forage crops. British Grassland Soc., 18:104-111.

Zadrazil, F., 1984. Microbial conversion of lignocellulose into feed. Chap. 9. In: F. Sundstol and E. Owen (Editors), Straw and Other fibrous By-products as feed. Elsevier, Amsterdam. pp. 276-292.

Effect of the anti bloat agent poloxalene on n-alkane concentration in cattle faeces.

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Introduction Current pressures to extensify agricultural systems are leading to more emphasis on incorporating legumes, such as white clover, into swards thus reducing the amount of fertiliser nitrogen used. Cattle fed clover rich diets often receive poloxalene (Bloat guard ®, Agrimin Limited) as a feed additive to prevent bloat. Poloxalene is a surfactant, reducing surface tension of bubbles caught in froth, and thus reducing foam formation in the reticulo-rumen. The n-alkane technique (Dove and Mayes 1991) to measure intake is widely used in grazing experiments. Alkanes are saturated hydrocarbons found in the waxy cuticle of plants, which are used as internal markers to estimate herbage intake and to determine dietary composition in grazing ruminants. Animals are typically dosed with a controlled release bolus (Captec^{TM} FERNZ, New Zealand) containing an even-chained synthetic alkane (C_{32}). Mean daily dry matter intake is calculated using the assayed release rate of C_{32} and the concentrations of C_{32} and C_{33} in herbage and faeces (Dove and Mayes, 1991). Given that poloxalene is a surfactant, it could potentially interact with the n-alkanes and therefore invalidate the technique. The aim of this experiment was to investigate the effect of including poloxalene in the diet on the n-alkane concentration in faeces from dairy cattle.

Materials and methods A two period cross over design used two groups of seven lactating Holstein-Friesian cows (mean calving date 11 January 1999) which grazed predominantly ryegrass swards and were milked twice daily. Group 1 was fed poloxalene in the parlour for 7 consecutive milkings. Group 2 received 3 kg standard concentrate (180g/kg CP), while group 1 received the same rate but with poloxalene included (8.3g/kg) at each milking. On day 4, faecal samples were taken after observing individual cows defecating at dawn prior to milking. Treatments crossed over on day 8, with group 2 receiving poloxalene for 7 consecutive milkings and next sampling was on day 11. Samples were freeze dried, ground and n-alkanes extracted using the method described in Mayes and Lamb (1984). The data were analysed by analysis of variance with cow and period used as block effects. Individual animals were used as replicates which was considered justified as the effect of poloxalene was mediated internally.

Results There was no significant treatment effect of poloxalene on the concentration of C_{29}, C_{31} and C_{33} n-alkanes, which occur naturally in grass and clover (Table 1).

Table 1. Mean alkane (C_{29}, C_{31} and $C_{33)}$ concentrations (mg kg^{-1}) in the faecal samples from the poloxalene fed and control groups.

	Poloxalene	Control	s.e.d	F.pr
C_{29}	202.0	211.3	18.37	0.621
C_{31}	295.0	317.0	25.80	0.415
C_{33}	216.7	221.5	15.00	0.758

Conclusions There was no effect of poloxalene administration on n-alkane concentration in faeces. It is therefore valid to use the anti bloat agent poloxalene when carrying out dietary composition and intake trials using n-alkanes with dairy cattle on clover-rich pastures.

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References

Dove, H. and Mayes, R.W. 1991. The use of plant wax alkanes as marker substances in studies of the nutrition of herbivores: a review. *Australian Journal of Agricultural Research*, **41**: 913-952.

Mayes, R. W. and Lamb, C.S. 1984. The possible use of n-alkanes in herbage as indigestible faecal markers. *Proceedings of the Nutrition Society*, **43**:39A

The impact of particle size on the rate and extent of *in vitro* fermentation investigated using the Reading Pressure Technique

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Introduction The extent of rumen degradability of a feedstuff depends on the interaction between rate of degradation and residence time. *In situ* techniques require that substrates are ground to obtain a homogenous sample and to reduce result variability. However undegraded feed particle losses increase with bag pore size and fineness of grinding. If these particles are degraded at a similar or lower rate than the retained material, degradability, especially for short-term incubations, will be overestimated. In contrast if the feed particles lost are more readily degraded the degradability measurements obtained will be unaffected. Where improvements due to grinding have been recorded *in situ* these are assumed to result from variations in the proportion of fine particles that are immediately soluble or rapidly degradable. Gas-based *in vitro* feed evaluation systems offer the possibility of quantifying this effect directly and a study was therefore conducted to investigate the impact of particle size on the rate and extent of fermentation using the Reading Pressure Technique (Mauricio *et al*., 1999).

Method Three forage feedstuffs - wheat straw (WS), maize silage (MS) and grass hay (H) - were examined. These were pre-dried (65°C for 4 h) then sequentially milled through three screens sizes (5, 4 and 1) with apertures of 16.0, 12.6 and 3.1mm^2, respectively. A 3x3 factorial design was used with approximately 1.0g substrate x screen size combination added to each fermentation flask. Three replicates were used for each of the six withdrawal periods (6, 12, 19, 24, 48 and 96h post-inoculation) to determine the rate and extent of organic matter degradation (OMD). DM loss was estimated by drying the fermentation residues at 100°C for 24h and OM losses by difference following ashing at 500°C overnight. Head-space gas pressure readings were taken at 2, 4, 6, 8, 10, 12, 15, 19, 24, 30, 36, 48, 72 and 96h post-inoculation with the accumulated gas released following each reading. The inoculum was prepared from rumen fluid obtained pre-feeding from a dry cow offered first-cut grass hay *ad libitum*. Gas volume estimates, corrected for the quantity of OM incubated and gas released from the negative controls (inoculum alone), were used to prepare cumulative and rate of gas production profiles. SAS GLM ANOVA procedures were used to identify significant differences between treatments.

Results Particle size reduction produced a variable response in terms OMD (Table 1). Little effect was observed with WS although MS degradation, and to a lesser extent that of H, significantly increased with grinding fineness up to 48 and 24hours post-inoculation, respectively. In contrast cumulative gas production profiles of all three substrates showed a significant response. Not only did gas production increase inversely with screen size, but the greatest response occurred with the most fermentable substrate (MS, screen size 1 at 19h). In addition rate of gas production profiles readily identified that particle size reduction did not alter the time (hours post-inoculation) at which a given substrate component was fermented but merely increased the quantity degraded at that time. These results suggest that processing will have no apparent effect unless it exposes otherwise undegradable material.

Table 1 *Influence of particle size on OMD and cumulative gas production*[1]

Substrate	Screen	Organic matter degradation (g/kg)						Cumulative gas (ml / g OM)					
		Incubation (hours)						Incubation (hours)					
		6	12	19	24	48	96	6	12	19	24	48	96
WS	5	77a	109a	262b	329a	478a	555a	5b	21ab	66a	90ab	152a	189b
	4	71a	111a	233a	272b	446b	561a	5b	19b	60b	85b	148a	186b
	1	60a	104a	230b	287b	467ab	583a	7a	23a	66a	93a	158a	206a
MS	5	319a	410b	518b	573b	705c	785a	20c	97c	147c	178b	240b	270a
	4	328a	443ab	574a	602b	749b	807a	23b	117b	166b	193b	245ab	266a
	1	199b	454a	582a	667a	786a	795a	25a	131a	185a	212a	261a	280a
H	5	272a	348c	568b	636b	763a	787a	37ab	89b	145a	170ab	225a	238a
	4	272a	379b	585a	602c	756a	793a	36b	89b	144a	168b	223a	245a
	1	271a	408a	572b	657a	760a	768b	39a	97a	151a	179a	232a	254a
s.e.		10	6	16	10	10	5	0.7	2.6	3.3	3.9	4.5	6.0

[1]Substrate means within columns without common scripts are significantly different (P>0.05)

Conclusion These observations suggest that rate of fermentation is directly related to the surface area available for colonisation by the rumen microorganisms. In addition as increasing the surface area of poorly degradable material had little effect, apparent improvements in degradation attributed to grinding, obtained with similar substrates using the nylon bag technique, probably results directly from increased particle losses.

References

Mauricio, R.M., Mould, F.L., Dhanoa, M.S., Owen, E., Channa, K. S. and Theodorou, M.K. 1999. A semi-automated *in vitro* gas production technique for ruminant feedstuff evaluation. *Animal Feed Science and Technology*, 79:321-330.

Additive direct and maternal breeding values of imported sires in the nucleus flock of a cooperative sheep breeding group.

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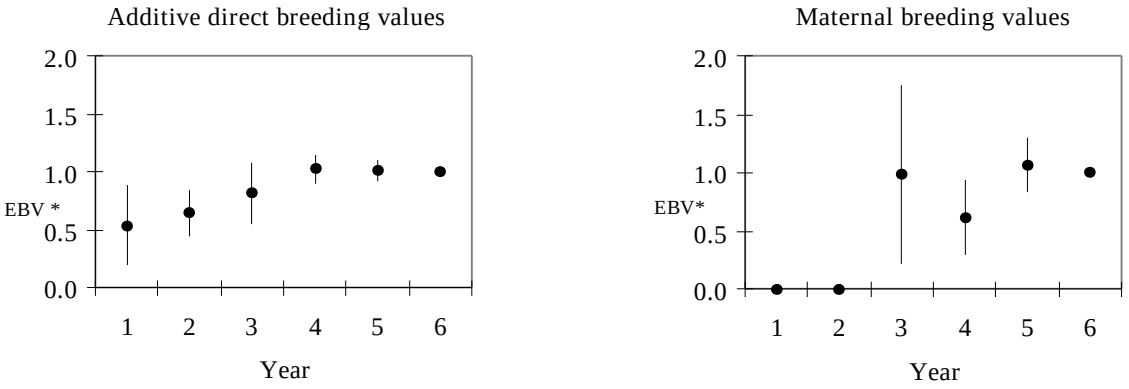
Introduction Members of the CAMDA cooperative group breeding scheme have expressed concern about the breeding values of imported sires, with a suggestion that their breeding value was underestimated. Analyses were conducted to examine changes in estimated breeding values for sires imported into the CAMDA nucleus flock.

Material and Methods The data file consisted of 11,201 12-week weight (12WW) records recorded annually from 1977 to 1998 in the nucleus flock of the CAMDA cooperative breeding group (Saatci *et al.*, 1999). Mean weight was 20.6kg (±0.04). Fifteen imported sires were identified from lambing years 1984-93. These sires were selected on the basis of 4 criteria: (a) there were sufficient 12WW records for the flock in the first year the sire was used (n>3,000), (b) their ancestors were unknown i.e they had been imported, (c) their breeding values could be estimated from the first year in which they had progeny and for a further five years, (d) the sires had over 20 progeny 12WW records. The majority of the sires were used for only one mating season. Additive direct and maternal breeding values were estimated using an animal model that included the fixed effects of year, sex, birth-rearing type, and age of dam; lamb age at weighing as a covariate; and animal (lamb), maternal direct and maternal permanent environment as random effects. The model was used for 15 datasets having 12WW records from 1977-1984 through to 1977-1998. Breeding values were obtained, by BLUP, for the selected sires from the first year in which they had progeny and for a further 5 years. Breeding values for each sire were expressed relative to the breeding value of the sire in Year 6. Means of the relative direct and maternal breeding values were calculated for years 1 to 6.

Results Trends in the mean additive direct and maternal breeding values are shown in Figure 1. Additive direct breeding value was underestimated in the first and second year after a sire had been used compared with year 6. Results in years 4 and 5 were comparable to those obtained in Year 6. There was greater variation in breeding values relative to Year 6 in the first and second years. Maternal breeding values were consistently close to zero in years 1 and 2. Whilst there was no consistent evidence of underestimation of the maternal breeding values compared to year 6, there was a large variation in values, particularly in year 3.

Figure 1. Mean breeding values for 15 sires from the first year in which they were used (year 1) and for five years thereafter (years 2-6). Breeding values are relative to year 6*.



Conclusion The results suggest that the additive direct breeding values of imported sires may be underestimated in the first and second lambing year after they are introduced into the flock. Thereafter the breeding values are comparable to those estimated after six years. Underestimation in years 1 and 2 reflect the fact that in a hill flock an imported sire's progeny will produce offspring 2 years after the ram first produced offspring. Maternal breeding values were close to zero in years 1 and 2, reflecting the fact that a sire's daughters will not contribute progeny until year 3. The underestimation of additive direct breeding values and lack of information on maternal breeding values for imported sires in years 1 and 2 is of concern since selection decisions about sires' progeny have to be made based on breeding value estimates obtained in these years. Given the desire of many flock owners and cooperative groups to import sires some attention should be directed to addressing the problems caused by inaccurate estimates of breeding value in the first two years after a sire has been imported. Allocating sires to genetic groups is a possibility but in the CAMDA data the imported sires were not obviously from similar origins that could be used as a basis for grouping.

Acknowledgements CAMDA Cooperative Group Breeding Scheme and Signet

References

Gilmour, A.R. and Thompson, R. 1997. ASREML. NSW Agriculture, Orange, Australia.
Saatci, M., Ap Dewi, I. and Ulutas, Z. 1999. Variance components due to direct and maternal effects and estimation of breeding values for 12-week weight of Welsh Mountain lambs. Animal Science 69, 345-352.

Effect of sire and dam origins on the weaning weight of Welsh Mountain lambs produced by embryo transfer.

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Introduction The project, conducted at ADAS Pwllpeiran, was based on mating individuals from several sources in Wales, using multiple ovulation and embryo transfer (MOET) to generate substantial numbers of progeny per sire and dam combination. The project represents the first attempt to create co-operative links between Welsh Mountain sheep breeding groups in Wales. The current analysis was conducted to determine whether sire and dam origins affected weaning weight.

Material and Methods The project ran over two years and used 9 sires and 36 embryo donors per year. Sires and donors came from co-operative groups in North, South and mid-Wales. The sources are listed in Table 1. The pedigree file created for the analyses contained the sire and genetic dam of each lamb and information about the ancestors of these animals obtained from the source groups. The CAMDA records generally included ancestors up to great grand-parent whilst CAMP and Llysfasi were to grand-parents. Some ancestors of Llysfasi animals had been imported from identifiable flocks and 9 "dummy" parents were included to reflect the sources of imported animals. Ancestor information was not available for sires from Bangor, Ceredigion and Rhayader which were ram performance tests. The data file contained lamb number, sire number, genetic dam number, sire origin, genetic dam origin, year, rearing dam number, age of rearing dam (years), sex of lamb and lamb weaning weight. Lamb weaning weight was analysed using the program ASREML (Gilmour and Thompson, 1997). The initial model included the fixed effects of year, rearing dam age, sex, sire origin, dam origin, the interaction between sire and dam origin and the interaction between year and sex. The model also included the random effects of animal (lamb direct genetic effect) and rearing dam. Rearing dam was included as a random effect, not correlated with the direct genetic effect of animal. In this context the effect of rearing dam represents an environmental effect on the lamb, being a combination of genetic and permanent environmental effects associated with the rearing dam. Lamb age at weighing was not included since the age range in each year was small due to the controlled breeding programme. The interaction between sire and dam origin was not significant and it was excluded from the final model.

Results The datafile contained 401 weaning weight records with a mean of 33.2kg (±0.22). There were lambs from each combination of sire and dam origin but with only one lamb from Ceredigion x Llysfasi (Table 1). Numbers of lambs in the other combinations ranged from 13 to 34. Numbers of lambs per sire origin group ranged from 54 to 94 and for dam origin group from 129 to 141. No significant effects of sire origin, dam origin or their interaction were found.

Table 1. Distribution of observations by sire and dam origin and mean weaning weights (kg) by origins

Sire Origin	Dam Origin					
	CAMDA	CAMP	Llysfasi	Total obs.	Arithmetic mean (s.e.)	LSM[*]
CAMDA	32	18	34	84	33.9 (0.50)	34.3
CAMP	21	49	24	94	32.5 (0.43)	32.7
Llysfasi	18	16	22	56	33.7 (0.45)	33.8
Bangor	12	15	27	54	33.9 (0.60)	32.8
Ceredigion	28	20	1	49	32.9 (0.61)	32.9
Rhayader	30	13	21	64	32.9 (0.60)	33.6
Total obs.	141	131	129	401		
Arithmetic mean (s.e.)	33.4 (0.35)	32.8 (0.38)	33.4 (0.39)			
LSM[*]	33.4	33.3	33.3			

[*] LSM - Least squares mean based on an animal model as described in the text.

Conclusion There was no evidence that weaning weight was affected by sire origin, dam origin or the interaction between these factors. It might have been expected that lambs would differ by origin, given the phenotypic differences between animals from the sources used, which included North, South and mid-Wales. The absence of an interaction between sire and dam origin suggests that there was no effect of heterosis on weaning weight. The conclusions about origin should be treated cautiously since single rams were used from some origins and only 2 from others. The comparatively low number of progeny per sire origin and dam origin combination could also have affected the significance of differences between origins.

Acknowledgements Technical and farm staff at ADAS Pwllpeiran, members of the cooperative groups - CAMDA, CAMP, Llysfasi, Bangor, Ceredigion and Rhayader.

References

Gilmour, A.R. and Thompson, R. 1997. ASREML. NSW Agriculture, Orange, Australia.

Genetic resistance to internal parasites in lambs

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Introduction Progressive inefficacy of chemoprophylactic therapy to control gastro-intestinal (GI) nematode infection in sheep has been a major contributory factor in stimulating research into the development of alternative means of internal parasite control. This research aims to investigate the possibilities for selecting UK sheep for increased genetic resistance to naturally acquired GI nematode parasite infections.

Materials and methods Over two years, thirty Bluefaced Leicester rams were mated to mixed groups of Hardy Speckled Face and Scottish Blackface ewes on three farms. Faecal samples were collected from 800 of the resultant mule lamb progeny at fourteen and eighteen weeks of age in year one and two, with an additional sample in year two collected from 650 lambs at twenty-two weeks of age. Lambs were exposed to natural infection and all faecal samples were collected four weeks after drenching with a benzimidazole based anthelmintic. Faecal egg counts (FEC) were established using the improved modified McMaster method. Due to the skewed distribution of the FEC data a logarithmic transformation was used [$\log_{10}$ (FEC + 100)] in all statistical analyses. The FEC data were analysed using the REML alogarithm of Genstat, fitting the fixed effects of breed of dam, sex, rearing type, year and farm. All two-way interactions were tested and sire, dam and lamb were fitted as random effects.

Results Mule lambs from Hardy Speckled Face ewes had significantly ($P<0.05$) lower FEC at eighteen weeks of age than the Scottish Blackface progeny (Table 1). This breed difference was also significant ($P<0.05$) at the other ages. Male lambs had significantly ($P<0.05$) higher FEC than female lambs [males 384 eggs per gram of faeces (EPG) and females 323 EPG]. The sex by year interaction approached significance. Rearing type did not affect FEC. There was an interaction between farm and year for FEC at eighteen weeks of age ($P<0.01$; Table 2). Heritability estimates for fourteen, eighteen and twenty-two week old lambs were not significantly different from zero however there was a trend towards a higher heritabilty with increasing age of lamb (Table 3).

Table 1 Mean $\log_{10}$ (FEC + 100) in Mule lambs at eighteen weeks of age for breed of dam.
Back transformed mean (EPG) in parentheses.

	Age (weeks)
Breed of Dam†	18
Scottish Blackface	2.60 (395)
Hardy Speckled Face	2.50 (314)

†Mean FEC differed between breeds of dam ($P<0.05$). Average s.e.± 0.027 for $\log_{10}$(FEC+100)

Table 2 Mean $\log_{10}$ (FEC + 100) in Mule lambs at eighteen weeks of age for farm unit and year.
Back transformed mean EPG in parentheses †.

	Farm unit		
Year	Tan y graig	Morfa Mawr	Pwllpeiran
1998	2.82 (658)[a]	2.35 (224)[b]	2.37 (233)[b]
1999	2.34 (217)[c]	2.73 (535)[d]	2.68 (479)[d]

†An interaction between farm unit and year was found ($P<0.01$). [a, b, c, d] Means within a row lacking a common superscript differ ($P<0.05$). Average s.e.±0.033 for $\log_{10}$(FEC+100)

Table 3 Heritability (h^2) estimates for FEC in Mule lambs at fourteen, eighteen and twenty-two weeks of age.

	Age (weeks)		
	14	18	22
Heritabilty (h^2) for FEC	0±0	0.08±0.07	0.14±.0.08

Conclusions The low heritability estimates for FEC and the trend towards increasing values at older ages is consistent with the results of Bishop et al., (1996). This suggests that selection for genetic resistance to internal parasites is limited in the young lamb and is likely to be more successful at later ages.

Acknowledgement This work is carried out in collaboration with the Scottish Agricultural College and ADAS and is funded by the Welsh Sheep Strategy, MAFF and the MLC.

References Bishop, S.C., Bairden, K., McKellar, Q.A., Park, M. and Stear, M. 1996. The inheritance of faecal egg count following natural predominantly Ostertagia circumcincta infection in Scottish Blackface lambs. *Animal Science* **63**: 423-428.

Genetics of maternal behaviour in Scottish Blackface sheep under field conditions: factors affecting maternal behaviour scores and their influence on lamb live weights and survival

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Introduction Behavioural studies of sheep have shown that poor maternal behaviour by the ewe immediately post-parturition can lead to reduced lamb survival and ewe production (O'Connor *et al.*, 1985). Under field conditions, behaviour may be quantified by the maternal behaviour score (MBS) - a six-point scale assessing ewe flight distance when lambs(s) are handled for the first time, within 24 hours of birth (adapted from O'Connor *et al.*, 1985). Greater scores are awarded to ewes remaining closer to their lamb(s). The objectives of this study were (1) to investigate the factors affecting MBS in Scottish Blackface ewes; (2) to determine if MBS affects the average weight of lambs reared or the number of lambs dying before weaning; (3) to estimate genetic and phenotypic parameters for MBS and correlations between MBS and lamb performance.

Materials and Methods MBS was measured on approximately 850 Scottish Blackface ewes on two experimental hill farms, over a maximum of four parities. Weights of lambs born to these ewes were measured at approximately 42 days of age (marking), when male lambs were castrated and females ear-notched, and at approximately 120 days of age (weaning). Regression techniques were used to identify significant fixed effects and covariates affecting MBS, and least square means were estimated using the restricted maximum likelihood procedure in Genstat v.4.1 (Lane and Payne, 1996). The VCE package (Groeneveld, 1997) was used to estimate the genetic parameters for MBS, average weight of lambs at marking and at weaning and the number of lambs which died from birth to weaning. MBS was analysed as the same trait across parities and also as a different trait in each parity.

Results MBS was significantly higher ($p<0.05$) for ewes with more lambing experience; for older ewes and for twin-bearing ewes compared to ewes with single lambs. MBS was also affected by farm (though farm and scorer were unavoidably confounded), ewe pre-lambing weight and condition score and lambing date. MBS was under genetic control ($h^2= 0.131$, $pe^2=0.19$ when analysed as the same trait across parities) and genetic correlations between MBS in different parities were high (Table 1), giving a repeatability of 0.35. In parity 4 the heritability estimate may be unreliable due to the small data set and the loss of ewes which may have led to selection bias. Ewes with a MBS of 1 (ewe flees and does not return to her lambs) reared significantly lighter lambs to marking and lost significantly more lambs to weaning than ewes receiving a higher MBS. However, MBS had no significant effects on lamb weaning weight. Low genetic correlations were estimated between MBS and the average marking and weaning weights, and between MBS and the number of lambs which died before weaning (Table 2).

Table1. *Heritabilities†, genetic and phenotypic correlations for MBS within and between different parities*

	MBS parity 1	MBS parity 2	MBS parity 3	MBS parity 4
MBS parity 1	**0.16** (0.08)	0.91 (0.26)	0.73 (0.42)	0.75 (0.38)
MBS parity 2	0.29	**0.20** (0.09)	0.99 (0.41)	0.65 (0.20)
MBS parity 3	0.21	0.33	**0.14** (0.09)	0.74 (0.22)
MBS parity 4	0.32	0.31	0.29	**0.47** (0.18)

Table 2. *Heritabilities†, genetic and phenotypic correlations for MBS and lamb traits*

	MBS	Average lamb marking weight	Average lamb weaning weight	Number of lamb deaths
MBS	**0.13** (0.03)	0.27 (0.19)	-0.06 (0.18)	0.04 (0.38)
Average lamb marking wt	-0.07	**0.04** (0.01)	0.95 (0.04)	0.64 (0.27)
Average lamb weaning wt	-0.04	0.65	**0.09** (0.03)	0.58 (0.36)
Number of lamb deaths	0.07	0.01	-0.04	**0.05** (0.05)

†In both tables: heritabilities on the diagonal, genetic correlations (with s.e.s) above and phenotypic below.

Conclusions These findings suggest that maternal behaviour score is a heritable trait of the Scottish Blackface breed. Least square means suggest that ewes with the poorest assessed behaviour (MBS = 1) produce lambs with poorer growth to marking and increased lamb loss to weaning. Selection or husbandry strategies which reduce the proportion of ewes in this category would be beneficial. Repeatability of scoring within and between observers should be examined and further work, using larger data sets, undertaken to assess whether it would be beneficial to include MBS in selection criteria used in breeding programmes for Blackface sheep.

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References Groeneveld, E. 1997. VCE4. User's guide and reference manual.
O'Connor, C.E., Jay, N.P., Nicol, A.M. and Beatson, P.R. 1985. Ewe maternal behaviour score and lamb survival. *Proceedings of the New Zealand Society of Animal Production* **45:** 159-162.
Lane, P.W. and Payne, R.W. 1996. Genstat for windows:an Introductory couse (2nd Edn). Lawes Agricultural Trust.

A comparison of Scottish Blackface and Wicklow Cheviot ewes and five sire breeds in terms of lamb output in hill sheep systems

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Introduction Improvements in the level and quality of lamb output are required to help sustain the financial viability of hill sheep farming. In the lowland sector breed substitution has been shown to be an effective means of increasing ewe productivity and lamb carcass lean content. However, there is a lack of adequate contemporary breed comparisons for the hill sector to base breeding decisions on. Consequently, the objectives of this study were to investigate the effects of ewe and ram breed on lamb output under a range of hill environments.

Material and Methods This experiment was carried out over two years on six hill farms located in the main hill regions in Northern Ireland. On each farm groups of 40 Scottish Blackface ewes were allocated according to the randomised block design of the experiment for mating to Scottish Blackface, Blue-Faced (BF) Leicester and Texel rams on the basis of ewe condition score. Minor adjustments were made to balance the mating groups for age and live weight. Likewise, groups of 40 Wicklow Cheviot ewes were allocated to Cheviot, Suffolk and Texel rams. Thus a total of 1440 ewes were put to the ram in each year of the experiment. A total of 10 Scottish Blackface, 10 BF Leicester, 10 Cheviot, 7 Suffolk and 14 Texel rams were used, each from unrelated bloodlines. At weaning, 16 representative wether lambs of each breed type from each farm were selected and finished off indoors on silage-based diets on a low or high plane of nutrition. Representative samples of lambs were slaughtered at weaning and at 38 and 46 kg live weight. All analyses were carried out using the REML procedure in the Genstat statistical package for the analysis of variance of unbalanced data (NAG, 1994). This fitted fixed effects for farm and the various ram breed X ewe breed combinations. Individual sires were fitted as random effects to provide a comparison of the three ram breeds within each ewe breed. A comparison was also made between the Blackface and Cheviot ewe breeds when crossed with a common ram breed i.e. Texel.

Results Prolificacy was similar in Blackface and Cheviot ewes (Table 1). Mortality levels in lambs produced from Blackface and Cheviot ewes did not differ significantly. Overall, the weight of lambs weaned per ewe was higher in Cheviot compared with Blackface ewes ($P<0.05$). However, on a weight of lamb weaned per kg of ewe metabolic weight basis the difference was reversed ($P=0.09$). At a constant fat class endpoint, lambs produced from Cheviot ewes were of superior conformation classification.

With Blackface ewes the weight of lambs weaned was higher with BF Leicester and Texel compared with Blackface-sired lambs ($P<0.001$). At a constant fat classification endpoint the number of days to slaughter was greater with Blackface-sired lambs ($P<0.001$). Furthermore, carcass weight was significantly lower ($P<0.001$) in Blackface compared with BF Leicester and Texel-sired lambs. Carcass conformation classification was significantly higher in Texel-sired lambs ($P<0.001$). With Cheviot ewes, Suffolk ($P=0.06$) and Texel ($P<0.001$) sires produced a greater weight of lambs at weaning compared with Cheviot sires. The number of days to slaughter was lower in Suffolk and Texel-sired lambs compared with Cheviot-sired lambs ($P<0.05$). Carcass conformation classification was higher in Texel compared with Suffolk and Cheviot-sired lambs ($P<0.001$)

Table 1 *The effects of ewe and ram breed on lamb output and carcass quality*

	Ram breeds crossed with Blackface ewes			Ram breeds crossed with Cheviot ewes				Sig.	
	B'face	BF L'cester	Texel	Cheviot	Suffolk	Texel	Av s.e.m.	Over-all	Ewe breed
Lamb output									
Proportion of productive ewes	0.79	0.85	0.85	0.83	0.84	0.85	0.021	NS	NS
No. lambs born/ewe lambed	1.54	1.55	1.52	1.49	1.57	1.55	0.024	NS	NS
No. lambs weaned/ewe lambed	1.32	1.30	1.28	1.24	1.24	1.36	0.081	NS	NS
Wt. lamb weaned/ewe mated (kg/kg $M^{0.75}$)	1.46^{a}	1.79^{b}	1.77^{b}	1.49^{A}	1.60^{A}	1.67^{B}	0.052	***	NS
Lamb carcass parameters (adjusted to fat class 3 endpoint)									
Days to slaughter	297^{b}	259^{a}	250^{a}	258^{B}	242^{A}	244^{A}	4.8	***	NS
Carcass weight	17.8^{a}	19.1^{b}	19.1^{b}	19.2	19.1	19.4	0.19	***	NS
Conformation classification	2.39^{a}	2.43^{a}	2.82^{b}	2.68^{A}	2.74^{A}	3.13^{B}	0.074	***	**
Lipid content (g/kg)	179	193	183	196	201	182	7.15	NS	NS

[a, b, A, B] Means with a common superscript within each ewe breed are not significantly different ($P>0.05$)

Conclusions

Lamb output and carcass quality was higher from Cheviot compared with Blackface ewes. Moving to crossbreeding programmes in hill flocks leads to major improvements in lamb output. Using Texel sires increased lamb carcass quality.

References

NAG. 1994. *Genstat 5 Reference Manual*. Clarendon Press, Oxford

The effects of genotype of crossbred ewes, evaluated under lowland conditions, on lamb output

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Introduction Lowland sheep farmers in Northern Ireland depend heavily on the hill sector for replacement breeding ewes. Thus changes in the genetics of the ewes and rams used in the hills are likely to have major implications on the performance of lowland breeding ewes. Crossbred females were produced in the study by Carson *et al.* (2000) as a result of crossing Scottish Blackface and Wicklow Cheviot ewes with a range of sire breeds. The objective of this study was to provide information on the productivity of these crossbred females for lowland producers.

Materials and methods The experiment was carried out over a period of two years (1997-98 and 1998-99) on four (year 1) and five (year 2) lowland farms located throughout Northern Ireland. Four breeds of ewe, obtained from the study by Carson *et al* (2000) were used. These were Blue Leicester X Scottish Blackface (Mule) (BLXB), Texel X Scottish Blackface (TXB), Suffolk X Wicklow Cheviot (SXCH) and Texel X Wicklow Cheviot (TXCH). The ewes as ewe lambs (year 1, farms 1 to 4; year 2, farm 5) and hoggets (year 2, farms 1 to 4) were mated with either Suffolk or Texel rams. Ewe liveweights and condition scores were measured pre mating, pre and post lambing and at weaning. At lambing, mothering ability, incidence of dystocia and colostrum supply of the ewes was assessed. Mothering ability was assessed on a three point scale where a score of 1 was given when the ewe accepted the lamb readily and 3 when the ewe rejected the lamb totally. Dystocia was assessed on a five point scale where a score of 1 was given when no assistance was required and 5 was given when a caesarian was necessary. Colostrum supply was assessed on a three point scale where a score of 1 represented a situation of no milk supply and three a situation of abundant colostrum supply. The lambs were weighed at lambing, approximately 6 weeks of age and at fortnightly intervals until weaning. All data were analysed using the REML procedure for the analysis of variance of unequally replicated data.

Results On average 0.72 of the ewe lambs and 0.91 of the hoggets lambed. Mules were the most prolific as ewe lambs ($P<0.001$) and hoggets ($P<0.01$) compared with the other three breeds. Texel X Blackface and Texel X Cheviot ewe lambs and hoggets produced similar number of lambs. However, Suffolk X Cheviot ewe lambs produced lower numbers of lambs per ewe mated than the Texel X Blackface ($P<0.05$). This effect had disappeared in the Suffolk X Cheviots hoggets. There were no major lambing problems with any of the ewe breeds as ewe lambs or hoggets. All breeds were good mothers (mean score 1.09 for ewe lambs, 1.04 for hoggets) and produced ample colostrum (mean score 2.84 for ewe lambs, 2.93 for hoggets). As ewe lambs, the Suffolk X Cheviot produced lighter lambs than the Mule and Texel X Cheviot ($P<0.05$). Lamb birth weight was similar with the four ewe breeds as hoggets. Mules produced the greatest number of lambs weaned per ewe lambed ($P<0.001$) as both ewe lambs and hoggets, while the other three breeds had similar numbers of lambs weaned per ewe lambed.

Table 1 Effect of ewe breed (as ewe lambs and hoggets) on lamb output

	Ewe breed					
	BLXB	TXB	SXCH	TXCH	sem	Sig
Ewe lambs						
No lambs born per ewe mated	1.18^{a}	0.95^{b}	0.79^{c}	0.93^{bc}	0.056	***
Dystocia index (1-5)†	1.67	1.70	1.53	1.78	0.105	NS
Birth weight (kg)	3.85^{a}	3.46^{ab}	3.14^{b}	3.92^{a}	0.196	*
No lambs born dead/ewe lambed	0.20	0.27	0.20	0.16	0.051	NS
No lambs weaned per ewe lambed	1.10^{a}	0.80^{b}	0.81^{b}	0.82^{b}	0.060	***
Hoggets						
No lambs born per ewe mated	1.77^{a}	1.38^{b}	1.40^{ab}	1.25^{b}	0.083	***
Dystocia index (1-5) †	1.69	1.88	1.63	1.73	0.112	NS
Birth weight (kg)	4.73	4.67	4.39	4.47	0.213	NS
No lambs born dead/ewe lambed	0.07	0.06	0.12	0.10	0.070	NS
No lambs weaned per ewe lambed	1.71^{a}	1.33^{b}	1.35^{b}	1.27^{b}	0.078	***

† 1= no assistance required; 5 = caesarian; means within rows with same superscripts are not significantly different ($P>0.05$).

Conclusions The results of the present study indicate that Mules as ewe lambs and hoggets were the most prolific of the four breeds examined. Suffolk X Cheviot ewe lambs had a poorer level of performance than the other breeds. However, this effect disappeared in the hoggets. As hoggets, Texel X Blackface and Texel X Cheviot ewes had similar levels of performance, in terms of lamb output, to the traditional Suffolk X Cheviot breed.

References

Carson, A.F., Irwin, D. And D.J. Kilpatrick (2000). A comparison of Scottish Blackface and Wicklow Cheviot ewes and five sire breeds in terms of lamb output in hill sheep systems. *Animal Science* (submitted)

The effect of a formulation of natural essential oils used as an additive with a milk replacer and a compound feed on the feed efficiency of calves

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Introduction Some in-feed antibiotic growth promoters have been suspended from use within the EU. Alternatives to these antibiotics are actively being sought, especially 'natural' alternatives, such as essential oils, to try and maintain the performance advantage attributed to the use of these antibiotics. Some essential oils, e.g. thyme and origanum, have been shown to have anti-microbial activities (Hammer *et al*., 1999). The active compounds responsible for this property have been identified, and include cinnamaldehyde, cineol and eugenol. A specific formulation of essential oils reinforced with their active compounds has been combined into a form suitable for use as a feed additive (Multi-Functional Feed Additive, MFA). An experiment was conducted to determine the effect of this MFA on the food conversion ratio (FCR) of calves.

Materials and Methods Twenty-four calves, in two batches of 12, were used for the experiment. At the start of the experiment the calves were *ca*. 2 weeks old. The calves remained on trial for 8 weeks. They were individually penned on straw and had free access to water and barley straw throughout the experiment. The calves in each batch were paired according to live-weight (LW) age, breed and sex. The animals in each pair were then randomly assigned to either a control diet (milk replacer and compound feed containing no MFA), or treatment diet (milk replacer and compound feed with MFA included in both at 200 g MFA/t). The compound feed was provided *ad libitum* (10% excess of the previous day's intake). Two litres of milk replacer (250 g milk replacer powder/l of water) was fed twice daily until both members of the pair were consuming 1 or more kg of compound feed per day, whereupon they were weaned (*ca*. week 5 of experiment). Food refusals were collected each morning and weighed so that daily compound food intake could be determined. Calves were subjectively scored for diarrhoea on a daily basis, using a scale of 0 (no diarrhoea) to 5 (extreme diarrhoea). Daily LW gains (DLWG) were determined by linear regression using the weekly LW measurements. Data was analysed by paired t-test.

Results Table 1 shows the overall experimental means (Week 2-8) for compound feed DMI, DLWG, FCR and diarrhoea scores of calves fed either the control or treatment diet. Although there was a trend for animals fed the treatment compound feed to have a greater DMI than those fed the control compound feed, this was not significant. However, animals fed the treatment diet did have a significantly ($P<0.05$) greater DLWG than animals fed the control diet. This resulted in a significantly ($P<0.05$) lower FCR in animals fed the treatment diet compared with the control diet. There was no difference between the control and treatment diets with respect to diarrhoea scores.

Table 1 Experimental means (Week 2-8) for concentrate dry matter intakes (DMI), daily live-weight gains (DLWG), food conversion ratios (FCR) and diarrhoea scores of calves fed either the control or treatment diet.

Parameter	Control	SE	Treatment	SE	P value (n=11)
DMI (g/kg LW/d)	17.9	1.6	21.0	1.5	0.059
DLWG (kg/d)	0.61	0.04	0.75	0.05	0.039
FCR	2.22	0.17	1.94	0.14	0.042
Diarrhoea score	0.48	0.04	0.42	0.07	0.360

Conclusions The results clearly demonstrate that the MFA had a positive effect on calf performance. Calves receiving the MFA had significantly greater DLWG and there was a trend for these calves to have a greater DMI. Most notably, calves fed the MFA had a significantly lower FCR. These results possibly indicate that the MFA was not just acting as a palatant, but was also having a significant effect in the digestive tract. Further work is required to identify the mode of action at the level of the digestive tract.

References

Hammer, K.A., Carson, C.F. & Riley, T.V. 1999. Antimicrobial activity of essential oils and other plant extracts. *Journal of Applied Microbiology* **86**: 985-990.

A comparison of milled and rolled lupin seeds and soya bean meal as protein sources for young beef cattle

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Introduction The degree of processing of protein-rich feeds affects their physical properties. Seeds which are less comminuted, whether cracked or rolled, may have properties which make their behaviour, in the rumen and post-ruminally, distinct from fine ground material and which may therefore alter their performance as feed proteins. The use of lupin seeds as a replacement for soya in ruminant diets has been demonstrated (Moss *et al*, 1997). This project aimed to assess whether the processing of lupin seeds, either hammer milling or rolling, affected the performance of young cattle fed the seed as their principal source of protein.

Materials and methods Three cereal beef diets were offered *ad libitum* using soya bean meal (SBM), hammer milled (3 mm screen) lupin seed (HML) or rolled lupin seed (RLS) as the principal source of protein. Details of the diets are given in Tables 1 and 2. Sixty Belgian Blue X Friesian bull calves, aged five months at the start of the experiment, were used. Each treatment was replicated in four pens, each of five animals, in a randomised block design. Cattle were weighed on two consecutive days prior to the start of the experiment and animals were blocked on the mean of these liveweights. Prior to the experiment all cattle were fed a cereal beef diet based on soya bean meal. At blocking the treatment diets were introduced at 30% of the cereal beef ration, increasing to 60% after three days and 100% on the seventh day. Rations were fed *ad libitum* twice daily with refusals weighed back once each week. Animals were weighed again at 7, 8, 35, 63 and 64 days after blocking. Start weight was taken as the mean of liveweights at 7 and 8 days after blocking. Final weight was taken as the mean of liveweights at 63 and 64 days after blocking. Results were analysed by ANOVA.

Table 1 Composition of treatment diets (kg/tonne)

Diet	Hi-pro soya	Lupins	Barley	Sugar beet pulp	Molasses	Minerals
SBM	150	-	700	100	25	25
HML	-	260	590	100	25	25
RLS	-	260	590	100	25	25

Table 2 Nutritive values of treatment diets, g/kg DM unless stated otherwise

Diet	DM g/kg	CP	Fibre	NCGD	Oil	Ash	ME MJ/kg DM
SBM	857	201	74	852	30	66	12.65
HML	855	177	104	850	43	68	12.95
RLS	853	187	96	862	50	62	13.35

Results Details of the performance of cattle on the three diets are given in Table 3. There were no significant differences in DM intake or in DLWG across the three treatment groups. However, the FCE of cattle on the HML ration was significantly better than that of cattle on the RLS ration, perhaps because of the release of oil in the rolled lupins reducing the efficiency of the rumen.

Table 3 Performance of cattle on different treatment rations

Ration	Initial liveweight (kg)	Start weight (kg)	Final weight (kg)	Days on trial	DLWG (kg/head)	DM intake (kg/head/day)	FCE
SBM	192	214	306	57	1.61	6.1	3.8
HML	193	216	308	57	1.62	6.0	3.7
RLS	192	216	301	57	1.49	6.0	4.0
s.e.d.	0.7	1.8	4.9	na	0.09	0.2	0.1

Conclusions The results of this study indicate that the processing of lupin seeds does not affect the growth performance of cattle fed lupin seed as the principal protein source within cereal beef rations. Furthermore, the results support those of Moss *et al* (1977) in that cattle fed lupins as the principal source of protein did not perform significantly differently to those fed soya bean meal.

Acknowledgements The support of the EAGGF, MAFF and Countrywide Farmers is gratefully acknowledged.

References Moss, A. R., Givens, D. I., Grundy, H. F. & Wheeler, K. P. A. 1997. The nutritive value for ruminants of lupin seeds from determinant plants and their replacement of soya bean meal in diets for young growing cattle. *Animal Feed Science and Technology*, **66**: 247 - 256.

The effect of abrupt and frequent changes in forage quality on nitrogen balance in crossbred steers fed napier grass (*Pennisetum purpureum*) and barley straw.

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Introduction Sanda et al. (1999) studied the effects on crossbred steer liveweight gain of alternating the same quantities of napier grass and barley straw at five day intervals over a 40 day period. These animals lost significantly more weight ($p<0.05$) than animals on one and ten day frequencies of alternation and those receiving the same quantities of the two feeds mixed together at each meal. These responses could not be explained by differences in *in vivo* digestibility or intake. The present study was designed to test the hypothesis that there are gradual changes in the rumen environment as animals adapt to the intake of a given forage and that, during this adaptive phase nitrogen is not used efficiently, which could explain the poor performance.

Materials and Methods Six Friesian steers with permanent rubber rumen cannulae and mean initial live weight of 308 (s.d. 31) kg were blocked according to live weight (M) and two treatment groups balanced for M. Animals received either Napier grass or barley straw at a rate of 2.4 and 1.4% M. Forage type offered was altered every ten days, one group starting with barley straw and one group with napier grass over a period of 30 days. Mean DM of 206 and 844 g/kg and CP and NDF contents of 82 and 22; 682 and 766 g/kg DM were found for napier grass and barley straw, respectively. Total N intake, plus excretion in faeces and urine were determined daily over the second and third 10-day periods. Daily microbial protein supply to the small intestine was estimated from excretion of purine derivatives. The data were analysed as a normal split plot design by analysis of variance, with animal, period and feed as main plot terms and day and day by feed interaction as sub-plot terms. The sum of squares for day and day by feed interaction effects were further separated using orthogonal polynomial comparisons into linear, quadratic and cubic relationships.

Results DM and N intakes were relatively stable for straw, but for Napier decreased sharply on day 2 then gradually increased. For animals consuming napier grass, urine and faecal nitrogen production gradually increased to a maximum on day 6, then decreased reflecting a gradual improvement in efficiency of nitrogen utilisation, retention/ intake (NR/NI) and digestibility from day 6. For microbial N supply, there was a sharp increase from day 1 to 2, followed by a more gradual increase to a maximum at day 7. Significant ($p<0.001$) interactions between day and feed and significant linear and quadratic components for all parameters ($p<0.05$) reflect reverse trends for straw (Table 1). In contrast to curves observed for Napier, the straw parameters either declined (faecal, urinary and microbial N) or increased (N digestibility and NR/NI) during the first 5-6 days to a minimum or maximum.

Table 1 Main effect means (across 10-day period) for nitrogen intake, faecal and urine production, retention and apparent digestibility for animals adapting to Napier grass or barley straw (n = 6).

	Main effect Mean		Sed		Significance Polynomials			
					Day		Day x Feed	
Parameters	Napier	Straw	Day	Day x Feed	L	Q	L	Q
N Intake, g day $^{-1}$	62.3	11.7	1.37	2.96	ns	ns	***	***
Faecal N g day $^{-1}$	28.9	18.1	1.15	1.75	ns	ns	***	***
Urinary N	13.8	8.1	1.49	2.07	***	ns	***	***
N Digestibility, %	53.9	-59.2	7.62	11.04	***	***	***	***
N retained/N intake %	32.1	-131.2	15.1	21.7	***	***	***	***
Microbial N supply (g N day^{-1})	22.6	13.9	2.93	3.96	**	ns	***	*

Conclusion For straw, the gradual increase in N utilisation to a plateau at 6 days may reflect time taken for previous residues from Napier grass to be voided from the rumen. High urinary N production immediately after a change to barley straw may have been from nitrogen recycled from napier fed previously. However, the improvement in N utilisation from day 6-10 for Napier grass cannot be explained in a similar way and may indicate improvements in efficiency reflecting gradual adaptation of rumen micro-organisms. The relatively poor efficiency of N utilisation in the first 5 days may explain the poor growth rates for animals changing feed type every 5 days in steers (Sanda *et al.* 1999).

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Reference Sanda, I., Romney, D., Tanner, J., Thorne, P. and Leaver, J.D. 1999. Effect of abrupt and frequent changes in forage quality on digestibility and performance of crossbred cattle offered Napier grass (*Pennisetum purpureum*) and barley straw. *Proceedings of the British Society of Animal Science 1999*, p88

The effect of composition of gain during a winter store period on carcass characteristics in beef steers

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Introduction In the UK, 18-month beef finishing systems are common. Previous work has focused on the effects of the rate of gain during a winter store period on performance (Lowman *et al*., 1994) and carcass composition (Wright and Russel, 1991). However, few data are available relating the composition of gain during the winter store period to subsequent carcass characteristics. This study was designed to determine the effect of high and low body fat levels at the end of the store period on carcass characteristics, both in Spring, and after finishing on grass in Autumn.

Methods Twenty eight Limousin cross steers were allocated to four diet*slaughter-date treatments according to liveweight, in a randomised block design. Steers were individually fed through Calan-Broadbent gates for a six month winter store period. Fourteen steers were fed a diet low in metabolisable protein (LMP) to achieve a high fat body composition (silage-based diet, supplemented with barley and a rumen by-pass fat (Magnapac)), while the remaining fourteen steers were fed a high metabolisable protein (HMP) barley-beef ration, supplemented with digestible undegradable protein (DUP; Sopralin) to achieve a low fat body composition. Both diets contained a vitamin and mineral supplement. All steers were fed to achieve target growth rates of 0.6 kg/day. At the end of the store period (Spring), seven steers from each treatment were slaughtered. Carcasses were classified according to MLC specifications for fat class and conformation and one half of each carcass was dissected. The fourteen remaining steers were zero-grazed, before being slaughtered and having similar carcass measurements made (Autumn). Steers were fed grass silage for the last two months of the study, due to a shortage of grass. Data are expressed as a mean ± standard error of the mean, and were analysed by ANOVA, unless stated otherwise.

Results At the end of the winter store period, carcass weight, killing out percentage and fat class were significantly greater in LMP compared with HMP steers. Commercial joint weights were consistently higher in LMP than HMP animals, but that this only reached statistical significance for topside, fillet and brisket. However, after a four month finishing period, there were no significant differences between treatment groups with respect to any carcass measurements, although there was a tendency for LMP steers to have better conformation than HMP steers.

Table 1 *Carcass characteristics and specific joint weights for animals at turn-out and when finished*

	Spring			Autumn		
	LMP	**HMP**	***P***	**LMP**	**HMP**	***P***
Carcass characteristics						
Live weight (kg)	291 ± 7	288 ± 6	NS	386 ± 5	377 ± 7	NS
Carcass weight (kg)	162 ± 4	146 ± 4	*	212 ± 5	202 ± 5	NS
Killing out %	55.63 ± 0.44	50.71 ± 0.66	***	54.66 ± 0.96	53.54 ± 0.97	NS
Fat class†	2 (2,3)	1 (1,2)	**	3 (2,3)	3 (2,3)	NS
Conformation†	O+ (O-,R)	O- (O-,O+)	NS	O+ (O+,R)	O+ (O+)	0.051
Specific joint weights (kg)						
Topside	6.04 ± 0.22	5.48 ± 0.10	*	7.73 ± 0.51	7.21 ± 0.24	NS
Fillet	1.57 ± 0.07	1.40 ± 0.04	*	1.90 ± 0.07	1.85 ± 0.09	NS
Brisket	6.81 ± 0.44	5.3 ± 0.37	*	9.58 ± 0.37	9.09 ± 0.30	NS
Rump	3.74 ± 0.22	3.20 ± 0.22	NS	5.14 ± 0.34	5.02 ± 0.24	NS
Sirloin	3.81 ± 0.16	3.42 ± 0.18	NS	4.51 ± 0.40	4.18 ± 0.23	NS

* P <0.05, ** P <0.01, *** P <0.001. † Data presented as Median (Range), and analysed by Chi-squared.

Conclusions Feeding diets of HMP and LMP to steers had the desired effects on body composition, as measured by MLC fat classification. The composition of gain during a winter store period had significant effects on carcass characteristics at Spring, but these were not evident at the end of the finishing period. The mechanisms by which the manipulation of body composition alters carcass growth clearly warrant further study, and the role of the GH-IGF axis is currently being investigated.

Acknowledgements The funding of this work by MAFF is gratefully acknowledged.

References

Lowman, B.G., Hunter, E.A., Hinks, C.E. and Lewis, M. (1994) Effect of breed type, sex and method of rearing on lifetime performance and carcass composition in a 20-month beef system: effects of winter feeding treatments. *Animal Production* **58;** 347-355.

Wright, I.A. and Russel, A.J.F. (1991) Changes in body composition of beef cattle during compensatory growth. *Animal Production* **52;** 105-113.

Intake, growth rate and carcass quality of beef cattle fed forage mixtures of grass silage and maize silage

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Introduction Replacing grass silage with maize silage in the diets of finishing beef cattle can improve DM intake and performance even when starch content of the maize silage is low (McCabe, O'Mara and Caffery, 1995). The objective of this experiment was to investigate the response of beef cattle fed diets containing different proportions of maize silage and grass silage with the same level of concentrate supplementation.

Materials and Methods 48 Simmental cross steers were used in a randomised block design experiment. These animals were initially 13 months old and 424 (s.d. 11.5) kg LW, and were housed in six pens, each containing eight animals. The four dietary treatments were based on forage mixtures of grass and maize silage with maize silage comprising 0, 33, 67 or 100% of the forage DM (diets G, GGM, MMG and M, respectively). Diets were isonitrogenous but not isoenergetic. Composition of the maize silage was 332 g DM/kg, 11.3 MJ ME/kg DM, 301 g starch/kg DM, 84 g CP/kg DM, pH 3.8 and the grass silage 265 g DM/kg, 10.4 MJ ME/kg DM,120 g CP/kg DM, pH 3.8. The two silages were thoroughly mixed in a small feeder wagon before feeding diets GGM and MMG. 2 kg DM of a concentrate supplement containing varying amounts of cracked wheat, soyabean meal and rapeseed meal was also fed in two daily meals on top of the silage. Crude protein concentrations of the supplements for diets G, GGM, MMG and M were 225, 269, 313 and 362 g/kg DM, respectively. Individual feed intake was recorded using electronic feed gates. Live weight was recorded fortnightly with start and final weight calculated as the mean of two consecutive days. Animals were slaughtered having reached a minimum live weight of 560kg. Carcasses were dressed by removal of the skin, head, tail, feet and abdominal and thoracic viscera. Kidney knob and channel fat was not removed nor were any other fat deposits trimmed before carcasses were weighed and classified for fatness and conformation.

Results The results are presented in Table 1.

Table 1 *DM intake and performance of beef cattle fed forage mixtures containing grass silage and maize silage*

	Diet					
	G	GGM	MMG	M	s.e.d.	Sig
DM intake (kg/d)						
Silage	6.33	6.82	7.39	7.76	0.195	0.001
Concentrate	1.99	2.00	2.01	2.01		
Total	8.32	8.82	9.40	9.77	0.195	0.001
Total DMI (g/kgLW)	16.9	17.8	18.7	19.7	0.40	0.001
Physical performance						
Final LW (kg)	566	569	571	574	2.7	0.030
Days on treatment	160	138	119	122	8.3	0.001
DLWG (g/d)	920	1070	1186	1262	48.5	0.001
FCR (kgDMI/kgLWG)	9.12	8.31	8.03	7.78	0.317	0.001
Carcass weight (kg)	311	318	321	325	2.8	0.001
Killing out (g/kgLW)	551	559	561	567	3.3	0.001
Carcass gain[1] (g/d)	579	708	808	868	31.7	0.001
Fat score[2]	3.2	3.4	3.3	3.5	0.32	0.875
Conformation score[3]	3.9	3.9	4.0	3.8	0.15	0.719

[1] initial killing out % of 52.3 [2] Based on fat score 1 (leanest - 1) to 7 (fattest - 5H) [3]Based on -U =5, R=4, O+=3

Forage and total DM intake of all diets containing maize silage was significantly higher than diet G and DM intake relative to live weight increased significantly at each increment of maize silage inclusion in the diet. Daily live weight gain increased significantly between diets G, GGM and MMG, and this was reflected in increased carcass gains. Cattle fed diet G converted feed to gain less efficiently than cattle fed diets containing maize silage. Dressing proportion was greater for cattle fed all diets containing maize silage compared to diet G with no significant differences in carcass fatness and conformation evident between any of the diets.

Conclusion Replacing grass silage either wholly or partly with maize silage in the diet of finishing beef cattle can increase forage DM intake and rate of live weight gain. This offers the potential to increase carcass weights as well as reduce days to slaughter. Feed conversion efficiency was also improved and there were no effects on carcass quality.

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References McCabe, N.H., O'Mara, F.P. and Caffery, P.J. (1995). Evaluation of Maize Silage in the Diet of Finishing Steers. *British Society of Animal Science Winter Meeting, Paper 162.*

The effect of fodder beet inclusion on nitrogen and energy utilisation of grass silage based diets by beef steers

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Introduction In a previous experiment with dairy cows at this Institute, in which fodder beet was included as a third component of the diet along with grass silage and concentrate, fodder beet considerably increased metabolisable energy intake (MEI), but there was little effect on milk yield *(unpublished data)*. The main objectives of the present study were to examine the effects of including fodder beet versus concentrate in a grass silage diet, on the digestibility of nutrients and the utilization of nitrogen (N) and energy at equal MEI in beef cattle.

Materials and Methods Twelve continental cross beef steers, 502 kg (s.d. 48.3) average initial live weight, were offered three treatment diets in a partially balanced changeover design with two periods (23 days/period), which provided 8 replications of each of the 3 treatments. Treatments A and B consisted of fodder beet and grass silage at a 50:50 (DM basis) beet plus soya mix: silage ratio, and treatment C comprised concentrate plus grass silage at a 50:50 forage:concentrate ratio (DM basis). The concentrations of N were similar in all diets (DM basis). The diets were offered at; treatment A 71.0 g DM/kg $W^{0.75}$ (nominal *ad libitum*), treatment B 49.4 g DM/kg $W^{0.75}$ (0.70 of A) and treatment C 60.4 g DM/kg $W^{0.75}$ (0.85 of A). Ration digestibilities and energy exchange data using indirect open-circuit respiration calorimetry, were determined during the last 9 and 3 days of each period respectively. The MEI for treatment C was projected to lie within the range of MEI for treatments A and B, and in order to predict values for a beet treatment at a similar MEI to that recorded with the control concentrate C (predicted treatment D) for each response variate, the mean for treatment C was compared to the means of A and B interpolated on the basis of MEI. The data were subjected to analysis of variance to compare the three diet means and to investigate differences between C and the predicted values, D.

Results The dietary treatments had no significant effects on the digestibility of dry matter (DM), organic matter (OM), ash and gross energy (GE) (Table 1). Significant differences were observed in digestibility of nitrogen (N), ADF and NDF, and also in heat production. The predicted digestibilities of ADF and NDF for the beet diet were significantly higher ($P<0.001$ and $P<0.01$ respectively) at similar MEI to that recorded with the concentrate control diet, which reflects the highly digestible nature of the fibre in fodder beet. Both predicted N digestibility and N retained/N intake for the beet diet were significantly lower ($P<0.05$) than for treatment C. The lower N retention with the beet diet was associated with higher ($P<0.05$) urine N/digested N than with the concentrate diet. While no other significant effects were observed between the predicted beet D and treatment C fed at similar MEI, the concentration of ME tended to be lower for the beet diet ($P=0.07$). The close similarity in heat production between treatments C and D indicates that the utilization of MEI, by the steers was unaffected by the source of ME.

Table 1 The effects of fodder beet inclusion on digestibility and energy utilization

	Fodder beet		Control	Predicted	A vs B vs C		D vs control C	
	A	B	C	D	s.e.d.	Sig	s.e.d.	Sig
Digestibility								
Dry matter	0.771	0.782	0.771	0.775	0.0089	NS	0.0078	NS
Organic matter	0.788	0.802	0.785	0.793	0.0084	NS	0.0073	NS
Nitrogen	0.653	0.680	0.701	0.663	0.0160	*	0.0139	*
ADF	0.670	0.696	0.624	0.679	0.0144	***	0.0127	***
NDF	0.646	0.675	0.612	0.657	0.0152	***	0.0133	**
ASH	0.531	0.539	0.526	0.534	0.0155	NS	0.0137	NS
Energy	0.746	0.763	0.749	0.752	0.0106	NS	0.0092	NS
Urine N/digested N	0.709	0.770	0.648	0.732	0.0380	**	0.0339	*
N retained/ N intake	0.18	0.15	0.24	0.17	0.035	*	0.031	*
Urine energy/GE	0.029	0.039	0.038	0.032	0.0040	*	0.0356	NS
Methane energy/GE	0.083	0.087	0.078	0.084	0.0060	NS	0.0053	NS
ME (MJ/kg DM)	11.03	11.11	11.47	11.06	0.238	NS	0.208	NS
MEI (MJ/day)	83.2	60.3	74.5	74.5	2.99	***	-	-
Heat production (MJ/day)	78.0	67.5	73.7	74.0	1.57	***	1.26	NS

Conclusions The results of the present study show a higher digestibility of fibre in the total diet with the inclusion of beet versus the inclusion of concentrate in a silage based diet with beef steers at similar MEI. Nitrogen utilisation was lower with the beet diet, however source of ME had no effect on the utilization of ME.

Performance responses and partitioning of nutrients in steers fed on either grass silage or grass silage and concentrate at similar levels of metabolisable energy intake

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Introduction It is generally accepted that diets for beef cattle containing a high proportion of grass silage compared to concentrates may result in poorer performance responses (intake, liveweight gain). Scollan *et al.* (1999) reported that in comparison to feeding grass silage alone, supplementing with additional concentrates increased growth rates, but the animals achieved the same amounts of carcass protein whilst depositing more fat. This study examined the effect of feeding a grass silage alone compared to silage and concentrate at the same level of metabolisable energy (ME) intake on animal performance and body composition.

Material and methods Eighteen Hereford x Friesian steers were randomly assigned to two dietary treatments; grass silage alone or a mixture of grass silage and a barley/soya concentrate (80:20) in the ratio of 60:40 (on a ME basis), and one of 3 slaughter liveweights, 250, 350 or 500 kg. Animals were weighed weekly and ration quantities adjusted for the following week period such that each animal received 800 kJ ME per kg $M^{0.75}$ per day. Animals were individually fed and all received 100 g/d of a commercial premix. At slaughter, individual fat depots were dissected (omental, mesenteric, perirenal) and half carcasses were minced for the determination of carcass fat and protein. The regression equations, established by Scollan *et al.* (1999) for the body composition of animals of the same breed and liveweight, were used to estimate initial composition and to calculate daily gains of carcass protein and fat. Intake and liveweight gains were analysed for the diet effect and two-way analysis of variance was used to test the effects of diet and stage of development and interactions on all other measured parameters. Since diet x slaughter weight interaction effects were not significant, only the main dietary effects are reported in this paper.

Results The composition of silage was 226.4 g freeze dry matter/kg, 23.5 g total-N/kg DM, 106 g ammonia-N/kg total-N, 13.8 g water soluble carbohydrates/kg DM, 10.9 MJ ME/kg DM and a pH of 3.8. The total-N and ME values of the concentrate were 31.7 g/kg DM and 13.5 MJ/kg DM. Actual ME intakes were 791 and 822 (s.e.d 15.6, $P > 0.05$) kJ/kg $M^{0.75}$ per day on silage alone and silage-concentrate, respectively. Feeding silage-concentrate mixture resulted in higher gains of liveweight ($P < 0.01$), carcass ($P < 0.01$), carcass fat ($P < 0.05$) and protein ($P < 0.01$). The amounts of protein and fat in the carcass and total body fat were not different between treatments (Table 1).

Table 1 Effect of diet on animal performance and carcass composition (residual d.f. = 11)

	Diet			P-value
	Silage	Silage-Concentrate	s.e.d.	Diet
DM intake (g/kg liveweight)	18.3	17.4	0.64	NS
Liveweight gain (kg/d)	0.74	0.91	0.056	0.01
Killing-out rate (%)	0.55	0.55	0.009	NS
Days to reach target slaughter weight	293	248	21.1	0.05
Feed conversion efficiency (kg gain/kg intake*100)	16.3	20.5	1.06	0.01
Carcass weight (kg)	198.4	202.7	8.73	NS
Carcass protein (kg)	36.1	37.0	1.33	NS
Carcass fat (kg)	34.1	36.5	4.46	NS
Non-carcass fat (kg)	22.6	24.8	2.73	NS
Fat:protein ratio	0.87	0.91	0.078	NS
Carcass gain (g/d)	416	528	31.1	0.01
Carcass protein gain (g/d)	73.9	96.1	7.11	0.01
Carcass fat gain (g/d)	81.0	103.0	7.54	0.05
Fat:protein gain ratio	1.07	1.11	0.115	NS

Conclusions When fed at similar levels of ME intake, then the additional dietary protein supplied in the silage-concentrate compared to grass silage alone, was used to increase the rate of tissue accretion, but the nutrient partitioning between fat and protein deposition was similar.

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References

Scollan, N.D., Cooper, A., Dhanoa, M.S., Wright, M., Dawson, J.M. and Buttery, P.J. 1999. Performance responses and partitioning of nutrients by Hereford x Friesian steers fed on grass silage based diets. *Proceedings of the 12th International Silage Conference*, pp. 218-219.

Effect of inclusion of varying levels of green gram(*Vigna radiata*) Chuni in concentrate mixtures on nutrient utilization in native male buffaloes

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Introduction Pulse chunies are byproducts obtained from processing of pulses while preparing dals and are available to an extent of 3 million tonnes annually in India. They contain broken seed coat, germ and small pieces of broken cotyledons constituting around 15-20% of total weight of pulses. Very little information is available in the literature on effective levels of inclusion of chunies in complete rations for ruminants. The objective of this experiment was to study the effect of inclusion of varying levels of green gram (*Vigna radiata*) Chuni in the concentrate mixtures for native buffaloes on the nutrient utilization.

Materials and methods Four isonitrogenous concentrate mixtures with 20% CP were prepared by incorporating green gram chuni at 0 (CM-1), 20 (CM-2), 35 (CM-3) and 50% (CM-4) levels. The control concentrate mixture(CM-1) consisted of maize, 300; deoiled groundnut cake, 270; deoiled ricebran, 400; mineral mixture, 20 and salt, 10g per kg. The complete rations 1 to 4 comprised of 1.5 kg of respective concentrate mixture plus 4 kg of rice straw and are isoenergetic to meet the nutrient requirements for maintenance as per Kearl (1982). These rations were evaluated in a 4x4 latin square design experiment (14 d preliminary +7d collection period) using four fistulated native male buffaloes (279 ± 2.5kg) to study the nutrient utilization.

Results The feed offered was totally consumed without any refusal and the DM intake ranged between 5.06 to 5.11kg for the four dietary treatments. Inclusion of green gram chuni at 20,35 and 50% levels in the concentrate mixtures has no significant effect on DM, CP and NFE digestibilities of the total ration in buffaloes. However, the digestibilities of NDF and cellulose ($P<0.01$) and ADF and hemicellulose ($P<0.05$) linearly increased with increase of green gram chuni in the concentrate mixtures indicating that fibre fraction of green gram chuni was fairly digestible. All the animals were in positive balance for N, Ca and P. N retention (g/d) increased linearly ($P<0.05$) with increase in green gram chuni inclusion in concentrate mixture of the rations owing to the effective utilization of absorbed nitrogen. Ca retention increased ($P<0.01$) and P retention decreased ($P<0.01$) linearly as the level of inclusion of green gram chuni increased in the concentrate mixtures of complete rations.The calculated DE intake increased linearly with increase of green gram chuni inclusion in concentrate mixtures indicating higher digestibility of green gram chuni. The pH and NH_3-N concentration decreased ($P<0.01$) and TVFA concentration increased ($P<0.01$) in the strained rumen liquor of the buffaloes as the inclusion level of green gram chuni increased. Perusal of the data indicate that the pH and TVFA concentrations were optimal for cellulolytic activity and the rate of absorption at 50% level inclusion of green gram chuni. The DCP (g/d) and DE (Mcal/d) intake of buffaloes fed concentrate mixtures were adequate to meet the suggested nutrient requirements for maintenance of buffaloes (Kearl, 1982).

Table 1 ***DM intake, nutrient utilization and plane of nutrition in buffaloes fed concentrate mixtures containing green gram chuni.***

	CR-1	CR-2	CR-3	CR-4	SEM	STAT.SIGN
Dry matter intake (kg/d)	5.06	5.11	5.08	5.07	0.002	NS
Dry matter digestibility (%)	54.1	54.3	54.9	55.0	2.37	NS
CP digestibility (%)	52.6	51.3	50.0	49.5	5.18	NS
NDF digestibility (%)	49.5^a	49.8^a	52.6^b	52.7^b	1.07	**
ADF digestibility (%)	45.9^a	46.2^a	49.3^b	49.9^b	2.84	*
Hemicellulose (%)	55.9^a	57.1^a	59.7^b	60.0^b	2.18	*
Cellulose (%)	64.5^a	64.9^a	67.4^b	67.5^b	0.11	**
NFE digestibility (%)	62.0	62.5	62.0	61.9	8.22	NS
Nitrogen retention (g/d)	8.7	9.4	9.4	9.7	0.23	NS
Calcium retention (g/d)	9.5^a	9.7^a	10.9^b	14.1^a	0.22	**
Phosphorus retention (g/d)	12.3^a	11.0^b	10.5^b	10.1^b	0.40	**
DCP intake (g/d)	226	221	213	210	9.3	NS
DE intake (Mcal/d)	11.56	11.78	11.89	11.91	0.120	NS

* $P<0.05$ ** $P<0.01$

Conclusion It is concluded that green gram chuni can be included at 50% level in concentrate mixtures of native male buffaloes fed on rice straw based rations for maintenance without any adverse effect on nutrient utilization.

Rferences

Kearl, L.C. 1982. *Nutrient requirements of ruminats in developing countries*. International Feedstuffs Institute. Utah State University, Logan, Utah, 84324, USA.

Combining grazing with different periods of access to an indoor diet to alleviate high rates of decline in milk yield of dairy cows

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Introduction High rates of decline in milk yield of >3.0% /week are common when dairy cows are grazing due to low herbage intakes. Under indoor feeding conditions rates of decline are often <2.0% /week. Behavioural factors control intake at grass, in particular the time spent grazing and the rate of intake. Low intakes produce high rates of decline in milk yield and potentially could lead to problems of poor fertility and welfare in high merit cows. The objective of this research is to examine the replacement of time available for grazing with time made available for eating forage-based diets indoors. This experiment was carried out in the spring.

Material and Methods Forty eight Holstein Friesian cows were allocated to 16 treatments in a factorial design. There were four durations of grazing (G)/ access to indoor diets (I); 5h G + 15h I, 10h G + 10h I, 19hG + 1h I, 20h G + 0h I. When indoors, cows were offered maize silage + soyabean meal (M+S) *ad libitum* in the ratio 0.82:0.18 (160gCP/kgDM). Two sward heights of 4-6 and 8-10cm, and two concentrate (160gCP/kgDM) levels of 0 and 6kg/day were also compared. The experiment lasted for 6 weeks in spring 1999. Milk yield and silage intake were recorded daily, milk composition and liveweight weekly and two 48h studies of grazing and indoor feeding behaviour were carried out. The results were analysed as a 4x2x2 factorial using the GENSTAT package (version 5, release 4.1) with covariance on initial values for production data.

Results The main effects of treatments are shown in Table 1. There were no significant differences between the four G/I treatments in milk yield (MY), milk yield decline (MYD), milk constituent yield or milk protein content. Milk fat was significantly depressed on the 5h+15h treatment. The mean rate of milk yield decline was equivalent to 3.3% /week. Maize silage + soyabean meal intake increased with increased access to the indoor diet, and this was associated with increased liveweight gain (although the latter may have been influenced by gut-fill differences between groups). Increasing sward height and concentrate level significantly increased milk yield. Grazing time, maize silage plus soyabean meal feeding time and intake were significantly influenced by system, sward height and concentrate level.

Table 1 Main effects of grazing/indoor system, sward height and concentrate level on the performance of dairy cattle.

	MY (kg/d)	MYD (kg/d)	Fat (g/kg)	Protein (g/kg)	LWG (kg/d)	Grazing time(min/d)	M+S eating time(min/d)	M+S intake (kgDM/d)
Grazing/Indoor(h)								
5 + 15	27.1	0.14	35.8	32.3	1.34	182	163	11.2
10+ 10	27.4	0.12	37.6	33.1	0.89	356	59	3.9
19 + 1	27.5	0.14	39.2	32.7	0.68	490	32	3.2
20 + 0	27.6	0.15	37.1	32.3	0.40	506	0	0
sed	1.06NS	0.020NS	1.15*	0.43NS	0.157***	11.9***	3.2***	0.32***
Sward height(cm)								
4 – 6	26.5	0.15	37.6	32.3	0.75	394	76	5.2
8 – 10	28.3	0.12	37.4	32.9	0.91	372	51	3.9
sed	0.69*	0.014NS	0.80NS	0.32NS	0.111NS	8.4*	2.3***	0.23***
Concentrates (kg/d)								
0	25.8	0.17	37.7	32.1	0.73	396	70	5.0
6	29.0	0.11	37.1	33.1	0.92	370	57	4.2
sed	0.76***	0.014***	0.80NS	0.30**	0.111NS	8.4**	2.3***	0.23**

Conclusions There was no clear advantage in milk yield or milk yield decline of replacing grazing with indoor access to maize silage plus soyabean meal. Concentrate level had the most significant effect on milk yield and milk yield decline. Nevertheless all of the treatments had rates of milk yield decline over 2.5% /week.

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The effects of composition of gain during a winter store period on carcass composition determined by Velocity of Sound Scanning (VOS) at spring and autumn in beef steers

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Introduction Restriction of feed during the winter store period is an important part of current beef systems to exploit compensatory growth from cheap grazed grass. Previous studies have demonstrated that the composition of finished carcasses can be altered by the type of diet fed during the winter feed restriction period (Baker *et al*; 1985). The aim of this study is to examine the effects of body composition at the end of the winter store period on the composition of gain during the subsequent grass feeding period.

Method Twenty eight spring born, autumn weaned Limousin cross steers were randomly allocated to one of two dietary treatments. Fourteen steers were fed a diet low in metabolisable protein (LMP) to achieve a high fat composition (silage based diet supplemented with barley and rumen bypass fat (Magnapac)). The remaining 14 steers were fed a diet high in metabolisable protein (HMP) to achieve a lean composition (straw based diet supplemented with barley and a source of digestible undegradable protein (Sopralin)). Throughout the winter store period steers were individually fed through Calan-Broadbent gates to grow at 0.6 kg per day. In spring all 28 animals (mean weight 289.5 kg) were scanned using VOS across the 10th rib, 13th rib and 3rd lumbar vertebrae to determine the proportion of fat/lean in the carcass (Fisher; 1997). Seven animals from each treatment were slaughtered after scanning and fat class was graded according to MLC specifications. The remaining seven steers from each group were weighed weekly and zero grazed on *ad libitum* grass through Calan-Broadbent gates to determine liveweight gain and dry matter intakes. Steers were fed silage in the final two months of the experiment due to poor grass growth in order for them to achieve a heavier slaughter weight. By the end of the *ad libitum* period steers had reached a mean weight of 382 kg and were scanned using VOS prior to slaughter. All statistical analysis was carried out using ANOVA apart from fat class where Chi-squared analysis was used. Data is expressed as a mean ± standard error of the mean.

Results Daily liveweight gains and dry matter intakes of grass were not significantly different between treatment groups. Following the period of winter feed restriction, the VOS measurements at the 13th rib was significantly ($P<0.05$) higher in LMP compared with HMP steers, indicating a higher content of fat. In accordance with these results, HMP steers that were slaughtered at Spring were leaner, as measured by MLC fat class than LMP steers ($P<0.01$). After the period on *ad libitum* grass, cattle that had been fed the LMP diet during the winter had a higher fat content at the 3rd lumbar region, as determined by VOS. This effect was not observed at the 10th or 13th ribs and there was no difference in fat class between LMP and HMP groups.

Table 1 *Daily liveweight gains (DLWG,) dry matter intakes (DMI) and VOS results for cattle slaughtered in spring and autumn*

	Winter Dietary Restriction			Ad Lib Grass		
	LMP	HMP	*P*	LMP	HMP	*P*
DLWG (kg)	0.635 ± 0.35	0.629 ± 0.290	NS	0.858 ± 0.225	0.798 ± 0.227	NS
DMI (kg)	-	-	-	6.35 ± 0.352	6.29 ± 0.290	NS
10th Rib	6.278 ± 0.009	6.276 ± 0.007	NS	6.383 ± 0.024	6.349 ± 0.012	NS
13th Rib	6.312 ± 0.013	6.272 ± 0.006	*	6.310 ± 0.015	6.280 ± 0.008	NS
3rd Lumbar	6.369 ± 0.017	6.340 ± 0.015	NS	6.328 ± 0.013	6.281 ± 0.007	**

* *P*. <0.05, ** *P* <0.01, NS not significant

Conclusion VOS measurements suggested that an increase in the proportion of lean tissue occurs as a result of supplying MP levels above requirement during the winter store period, an effect that persists after the grass feeding period. The treatment effect on VOS measurements was not consistent across the different sites and there was no relationship to fat class according to the MLC specifications.

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References

Baker, R.D., Young N.E. and Jaws L.A. (1985). Changes in body composition of cattle exhibiting compensatory growth and the modifying effects of grazing management. A*nimal Production*, **41:**309-321

Fisher, A.V. (1997) A review of the technique of estimating the composition of livestock using the velocity of ultrasound. *Computers and Electronics in Agriculture* **17:** 217-231

Simple mixes of molassed sugar beet feed and distillers grains for lactating ewes

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Introduction Feeding of lowland sheep on straw-based systems during pregnancy and in early lactation has shown that ewe and lamb performance can be satisfactory, providing adequate compound supplementation is fed (Davies and Chapple, 1995). Whole barley and soya bean meal has been the standard ration. However, soya bean meal is imported and not fully traceable. Experiments with January- and March-lambing ewes have shown that traceable, home-produced feeds based on equal quantities of molassed sugar beet feed and either maize or barley distillers grains can replace a barley/soya supplement when fed with straw or silage-based diets in late pregnancy (Chapple *et al*., 1998 and 1999). The objective of this work was to evaluate the effects on ewe and lamb performance of feeding sugar beet feeds with distillers grains to March-lambing ewes rearing twin lambs at pasture.

Materials and Methods 120 March-lambing North Country Mule ewes, weighing 66 kg at lambing and suckling twin Suffolk cross lambs, were divided into three treatment groups with two replicates of 20 ewes and lambs per treatment. They were turned out to pasture within 48 hours of lambing. Ewes were fed a supplement of 80:20 rolled barley/soya-bean meal (BS), 50:50 maize distillers/molassed sugar beet feed (MDB) or 50:50 barley distillers/molassed sugar beet feed (BDB). The energy (MJ/kg DM) and protein content (g/kg DM) of the supplementary rations were: BS 13.2 and 212, MDB 13.3 and 194, BDB 12.1 and 198 respectively. Feed supplementation continued for six weeks after turnout, starting at 0.75 kg reducing to 0.25 kg/head/day by the end of the period (5 May 1999). Lambs did not receive any creep feed and the experiment finished when they were approximately 10 weeks old. The experiment was a randomised block design and animal performance data were analysed using analysis of variance. Ewe condition scores were analysed using the Chi-square test.

Results Ewes fed the MDB diet had a significantly lower liveweight ($P < 0.05$) than the BDB ewes at 6 weeks post-lambing, but by the end of the experiment (4 June) all ewe liveweights were similar. Ewes on all treatments lost some condition during the feeding period but then maintained or slightly increased condition to the end of the experiment. MDB ewes were significantly leaner ($P < 0.05$) on 4 June, than those on the other treatments (Table 1).

Table 1 *Ewe Performance*

	BS	MDB	BDB	s.e.d.
Liveweight (kg) :				
Post-lambing	66.2	66.5	66.6	0.41
End of feeding (5 May)	65.3	64.5	67.2	0.99
Final (4 June)	58.9	57.2	59.1	0.96
Condition score:				Probability of χ^2
Post-lambing	2.7	2.7	2.7	0.59
End of feeding (5 May)	2.5	2.3	2.5	0.14
Final (4 June)	2.6	2.3	2.6	0.01

The performance of all lambs was similar throughout the whole of the trial period and growth rates averaged 257 g/day from birth to 10 weeks of age (Table 2).

Table 2 *Lamb Performance*

	BS	MDB	BDB	s.e.d.
Birth weight (kg)	5.05	5.06	4.98	0.129
10-week weight (kg)	24.4	24.0	23.3	0.55
Daily gain: Birth-10 weeks (g)	264	257	251	6.0

Conclusion Feeding a 50:50 maize distillers and sugar beet mix or a 50:50 barley distillers and sugar beet mix can replace a rolled barley/soya-bean ration when fed to lactating ewes suckling twin lambs without affecting ewe or lamb performance.

Acknowledgements Financial support from Trident Feeds is gratefully acknowledged.

References Davies, M.H. and Chapple, D.G. (1995). Development of a high output lowland sheep system. *World Sheep and Wool Congress, Malvern (Abstract)*

Chapple, D.G., Wheeler, K.P.A. and Perrott, G. (1998). Evaluation of sugar beet feeds and maize distillers dark grain as supplements for pregnant ewes fed straw-based diets. *Proceedings of the British Society of Animal Science, March* 1998 p.102

Chapple, D.G., Wheeler, K.P.A., Perrott, G. and Witt, M. (1999). Comparison of sugar beet feeds and distillers grains as supplements for early lambing ewes fed straw-based and big-bale silage diets. *Proceedings of the British Society of Animal Science, March* 1999 p.126

Effects of protein source and formaldehyde treatment on the metabolism and performance of pregnant and lactating ewes fed straw

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Introduction Fishmeal is a suitable protein source for pregnant and lactating ewes, providing higher levels of undegradable protein (UDP) than vegetable protein sources, with an improved biological value (Robinson, 1987). The lower amounts of UDP supplied by vegetable protein sources may however be improved by formaldehyde treatment. The objective of the current experiment was to compare the effects of feeding concentrates containing fishmeal with concentrates containing vegetable protein sources with or without formaldehyde treatment.

Materials and methods At 103 days of gestation, 60 Charollais x Lleyn, Charollais x Cambridge and Friesland x Lleyn twin-bearing ewes were allocated to treatment by breed, weight and condition score. There were five dietary treatments which differed in main protein source contained in the concentrate; rapeseed meal (RSM; 119g/kgDM), field beans (FB; 164g/kgDM), formaldehyde treated rapeseed meal (fRSM; 119g/kgDM), formaldehyde treated field beans (fFB; 164g/kgDM) or fishmeal (F; 71g/kgDM). fRSM and fFB were treated with 2.38g/kg formaldehyde per kg of test protein. All concentrates were designed to be isonitrogenous (206gCP/kgDM) and isoenergetic (13MJ/kgDM) and to produce an ERDP:FME ratio of greater than 11.5g/MJ in the concentrate during pregnancy. The ewes were housed and fed the diets from six weeks pre-partum to four weeks post-partum. Eight ewes per treatment were individually housed, with the remainder allocated to one of five group pens. Straw was offered at proportionally 1.25 of the previous day's intake and refusals were recorded. Daily concentrate fed per ewe was increased from 0.9kg at - 6 weeks to 1.3kg at lambing and 1.8kg from lambing to + 4 weeks. Weekly blood samples were analysed for non esterified fatty acids (NEFA). Lamb birth and weekly live weights were recorded, along with initial colostrum and 21-day milk yields. Nitrogen degradability coefficients for the concentrates were determined by the method of Ørskov and McDonald (1979) using 4 rumen cannulated wether sheep. The production experiment was analysed as a 2 (protein source) by 2 (with or without formaldehyde) factorial with an additional control treatment (F) using ANOVA.

Results Fish had a high rate of nitrogen (N) degradation (c), with a high (a) fraction. Formaldehyde treatment of rapeseed meal and field beans reduced the soluble N fraction (a) and the rate of degradation (c) of the potentially degradable N fraction (b), with the decrease in 'c' being greater in FB than RSM (Table 1). This lead to greater improvements in calculated metabolisable protein (MP) supply in fFB vs FB, than in fRSM vs RSM. Ewes fed diet F had lower pre-partum plasma NEFA concentration ($p<0.01$). Initial colostrum yield was lower in ewes fed FB than RSM ($p<0.05$). No effect of treatment on litter birth weight was observed. However, ewes fed diet F had lambs with lower growth rates ($p<0.05$). Formaldehyde treatment reduced 21 day milk yield, ($p<0.05$), but increased post-partum straw intake ($p<0.05$).

Table 1 *N degradability coefficients and calculated MP supply (g/day) for the concentrates fed*

	a	b	c	MP (g/day) (Pre-partum)	MP (g/day) (Post-partum)
Fish	0.50	0.39	0.183	120	199
RSM	0.43	0.51	0.136	117	201
fRSM	0.35	0.56	0.107	131	203
FB	0.32	0.62	0.310	109	184
fFB	0.28	0.63	0.103	124	199
s.e.d	0.008	0.002	0.0130	3.9	4.7

Table 2 *Ewe performance and metabolism*

	F	RSM	fRSM	FB	fFB	s.e.d	control	form	type
Mean pre-partum straw intake *(g fresh weight/day)*	631	541	689	586	541	80.5	NS	NS	NS
Litter birth weight *(kg)*	8.20	8.64	8.05	8.57	8.75	0.48	NS	NS	NS
Initial colostrum yield *(ml)*	854	820	765	547	437	185.0	NS	NS	*
Mean pre-partum plasma NEFA conc. *(mmol/l)*	0.43	0.61	0.53	0.50	0.57	0.051	*	NS	NS
Mean post-partum straw intake *(g fresh weight/day)*	667	454	592	507	667	80.7	NS	NS	*
Lamb growth rate (0-28d) *(g/d)*	244	264	289	266	261	13.3	*	NS	NS
21 day milk secretion rate *(ml/h)*	105	117	103	131	103	13.4	NS	*	NS
Mean post-partum plasma NEFA conc. *(mmol/l)*	0.58	0.53	0.53	0.46	0.45	0.082	NS	NS	NS

Conclusions Ewes fed fishmeal produced lambs with lower growth rates. Increases in calculated MP supply were achieved by addition of formaldehyde. Formaldehyde treatment increased post-partum straw intake, but reduced 21-day milk yield, which may be a result of sub-optimal degradable protein supply at a time when outflow rates are high. Inclusion of field beans reduced initial colostrum yield. Fishmeal can be successfully replaced by alternative protein sources in concentrates fed to pregnant and lactating ewes with acceptable performance.

References

Ørskov, E.R. and McDonald, I. (1979). The estimation of protein degradation in the rumen from incubation measurements weighted according to rate of passage. *Journal of Agricultural Science, Cambridge* **92**:499-503.
Robinson, J.J. (1987). Energy and protein requirements of the ewe. In *Recent Advances in Ruminant Nutrition.* pp187-204. (Eds) Haresign, W. and Cole D.J.A. Butterworths; London.

The effect of nutritionally-mediated placental growth restriction in adolescent sheep on the yield, nutrient composition and immunoglobulin content of colostrum

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Introduction In adolescent sheep, high nutrient intakes to promote rapid maternal growth during pregnancy results in a major restriction in placental growth which leads to a significant reduction in lamb birthweight relative to moderate intake adolescents of equivalent gynaecological age (Wallace *et al* 1996). Placental hormones play a crucial role in the development, differentiation and function of the mammary gland and we have previously reported that maternal concentrations of progesterone, growth hormone and pregnancy-specific protein B are significantly reduced in high intake dams with growth restricted placentae (Wallace *et al* 1997 a,b). For newborn lambs, the ingestion of adequate quantities of nutrient dense colostrum is essential to provide fuel for heat production and to ensure absorption of maternal antibodies to give immunological protection against infection. The objective of the present study was to examine the effect of nutritionally-mediated placental growth restriction on colostrum yield, nutrient composition and immunoglobulin content.

Material and methods Embryos recovered from superovulated ewes were transferred in singleton to the uterus of peripubertal adolescent recipients (mean ± sem, 43.8 ± 0.44 kg LW). Post-transfer, adolescent dams were offered a high or moderate level of a complete diet calculated to achieve rapid or normal maternal growth rates during the first 100 days of gestation. After Day 100 of gestation the feed intake of the moderate dams (n=25) was adjusted weekly to maintain body condition score while the high dams (n=27) continued to be offered the diet *ad libitum*. Gestation length, lamb birthweight and fetal placental weight were recorded after spontaneous vaginal delivery of a live lamb. Colostrum yield was measured before lamb suckling and within 30 minutes of parturition. Oxytocin was administered i.v. to induce milk let-down and the ewe milked by hand until all the available colostrum was stripped from the udder. Colostrum samples were stored at -20^{o}C until analysed for protein, butterfat and lactose content. IgG concentration was determined by a specific ovine ELISA.

Results Daily liveweight gain during the first 100 days of gestation was 278 ± 8.3 and 71 ± 3.3 g/day for the high and moderate intake dams respectively (P<0.001) while body condition immediately prior to parturition was 3.0 ± 0.07 and 2.1 ± 0.06 score units (P<0.001). Gestation length was shorter in the high compared with moderate intake dams (142.6 ± 0.61 vs. 145.3 ± 0.69 days, P<0.01). Similarly, high maternal intakes were associated with a marked reduction in total placental mass (280 ±17.7 vs. 449 ± 24.9 g, P<0.001) and a resultant decrease in lamb birthweight (3039 ± 167 vs. 4701 ± 172 g, P<0.001) relative to moderately-fed dams. The yield of colostrum immediately after parturition was significantly decreased in high versus moderate groups (Table 1) and irrespective of dietary intake, colostrum yield was positively correlated with placental weight (r=0.523, P<0.001).

Table 1. Colostrum yield, nutrient composition and IgG content

	Maternal Intake		Significance
	High (n=27)	Moderate (n=25)	Of differences
Colostrum yield (g)	115±21.4	301±44.2	0.001
Colostrum composition			
Butterfat (g/100g)	7.6±0.64	9.7±0.61	0.05
Lactose (g/100g)	2.2±0.21	2.9±0.24	0.05
Crude protein (g/100g)	18.4±0.86	16.6±0.45	NS
IgG (mg/ml)	163±17.4	116±11.9	0.05
Total butterfat (g)	9.8±2.41	31.7±3.46	0.001
Total lactose (g)	2.3±0.39	9.3±1.44	0.001
Total crude protein (g)	21.6±5.13	53.9±5.41	0.001
Total IgG (g)	16.3±3.93	33.6±3.88	0.002

On a concentration basis, colostrum samples from high intake dams contained more IgG, less butterfat and lactose, and similar amounts of crude protein relative to the moderate group. However, when expressed relative to individual colostrum yield, the total IgG, butterfat, lactose and crude protein available to the neonate was significantly reduced in the high compared with the moderate maternal intake group

Irrespective of dietary treatment, placental weight was positively correlated with colostrum butterfat concentration (r= 0.469, P<0.002) and negatively correlated with colostrum IgG concentration (r=-0.401, P<0.01)

Conclusion Inappropriate nutrient partitioning during pregnancy in overnourished adolescent sheep results in impaired placental growth which in turn impacts on the yield and composition of the colostrum accumulated prenatally. In the absence of human intervention these effects on both the quality and quantity of colostrum available to the newborn could further jeopardise the survival of these low birthweight animals.

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References Wallace JM, Aitken RP & Cheyne MA (1996) J.Reprod. Fert. 107, 17-22
Wallace JM, Aitken RP, Cheyne MA & Humblot P (1997a) J.Reprod. Fert. 109, 53-58
Wallace JM, Da Silva P, Aitken RP & Cruickshank MA (1997b) J.Endo. 155, 359-368

The effect of the pea to wheat ratio and harvest date on the voluntary feed intake, *in vivo* digestibility and nitrogen retention of pea-wheat bi-crop silages by sheep

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Introduction Pea-wheat bi-crop silages were reported to have moderate nutritive value when the proportion of peas in the sward was less than 200 g/kg (Adesogan *et al*., 1999). These authors also suggested that improvements in the digestibility, intake and nitrogen (N) balance of the forages may result from increasing the proportion of peas in the sward. This experiment was designed to examine this theory by determining the *in vivo* apparent digestibility, N retention and voluntary feed intake (VFI) in sheep of pea-wheat bi-crop silages containing different ratios of peas to wheat and harvested at two stages of growth.

Materials and methods Spring varieties of peas (cv. Magnus) and wheat (cv. Axona) sown with either a high (HP) or low (LP) pea inclusion rate were harvested after 13 (CUT 1) or 15 (CUT 2) weeks and conserved in clamp silos. The ratios (total plant dry matter [DM]) of peas to wheat in the mixtures were 2:1 (HP) and 2:3 (LP) for CUT 1 and 3:1 (HP) and 2:3 (LP) for CUT 2. Twenty mature Lleyns wethers, each weighing approximately 74 kg were used to evaluate the bi-crops and a control grass silage (GS) treatment. All the forages were fed as the sole diet to each of four replicate sheep in a completely randomized design. The forages were offered twice daily at 150% of the previous day's intake in order to achieve *ad libitum* intake. A mineral vitamin supplement (7g animal^{-1} day^{-1}) and *ad libitum* fresh drinking water were also provided. The diets were fed for an acclimatization period of 14 days followed by a balance period of 10 days, during which forage DM intake and total faecal and urine output were measured. The apparent digestibility of DM, organic matter (OM), crude protein (CP) and neutral detergent fibre (NDF) were also measured. Data collected were subjected to analysis of variance using the one way design model and the means were separated using the Fisher's LSD procedure and 5% error rate.

Results The DM (g kg^{-1}), CP and NDF (g kg^{-1} DM) content of the GS and bi-crop silages were respectively 222, 111 and 605 for GS; 284, 170 and 494 for HP CUT1; 299, 197 and 529 for HP CUT2; 308, 159, and 520 for LP CUT1; and 336, 152 and 569 for LP CUT2. The DM intake, apparent digestibility coefficients and N balance of the GS and bi-crop silages are presented in Table 1. Except for the bi-crop HP cut 1, intake of other bi-crops was higher ($P<0.05$) than that of GS. The DM and OM digestibility coefficients were significantly lower ($P<0.05$) in the bi-crop LP cut1 than in the other bi-crops or GS. NDF digestibility was significantly higher in the GS than in all the bi-crop silages. In contrast, CP digestibility was generally higher ($P<0.05$) in the bi-crop silages than in the GS. N-intake and N-balance were also significantly higher for the bi-crop silages than for the GS. N-intake and N-balance were also significantly higher in the bi-crop silages. Between the bi-crops, DM intake, N-balance and proportion of N-retained were highest for LP CUT2.

Table 1. Intake, apparent digestibility and nitrogen balance of grass silage and whole-crop pea-wheat bi-crop silages

	DMI	Digestibility coefficient				N-intake	N-balance	Proportion
Silage	(g d^{-1})	DM	OM	CP	NDF	(g d^{-1})	(g d^{-1})	of N-retained
GS	792^{a}	0.607^{a}	0.623^{a}	0.560^{a}	0.625^{a}	14.7^{a}	1.85^{a}	0.1^{a}
HP CUT1	983^{ab}	0.602^{a}	0.623^{a}	0.660^{b}	0.552^{b}	30.5^{b}	6.96^{bc}	0.23^{b}
HP CUT2	1113^{b}	0.589^{a}	0.606^{a}	0.583^{a}	0.541^{b}	27.6^{b}	5.08^{b}	0.1^{ab}
LP CUT1	1141^{b}	0.535^{b}	0.555^{b}	0.631^{b}	0.495^{c}	32.1^{b}	6.06^{b}	0.19^{ab}
LP CUT2	1280^{b}	0.577^{a}	0.596^{a}	0.635^{b}	0.571^{b}	31.9^{b}	10.1^{c}	0.31^{c}
SED	151	0.015	0.014	0.019	0.021	3.74	1.51	0.04
F-Prob.	<0.054	<0.002	<0.001	<0.001	<0.001	<0.002	<0.001	<0.002

^{a,b}: means with common superscripts in columns are not significantly different ($P>0.05$); HP: high pea; LP: low pea; GS: grass silage; DM: Dry matter; OM: Organic matter; CP: Crude protein; NDF: Neutral detergent fibre; N: Nitrogen

Conclusions Sheep fed bi-crop silages have higher voluntary feed intakes and retain more N than those fed GS. Despite the moderate digestibilities of the bi-crops, their higher intakes in sheep relative to grass silage intakes could translate into better performance as a result of higher digestible nutrient intake. There were no notable effects of increasing the proportion of peas in the sward on nutritive value except for an increased CP content. Last sentence removed

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References Adesogan, T.A., Salawu, M.B., Fraser, M.D., Evans, S.T., Fychan, R. and Jones, R. **1999**. Intake, digestibility *in vivo* and nitrogen balance in sheep of pea-wheat bi-crop silages harvested at three stages of maturity. *Proceedings of the British Society of Animal Science.*

Conditioned feeding responses of sheep towards food flavours associated with administration of ruminally degradable and/or undegradable protein sources

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Introduction The basis of diet selection for protein by ruminants has been questioned by Tolkamp *et al.* (1998). They suggested that diet selection by ruminants is based on the ruminally degradable protein (RDP) of foods whereas the metabolizable protein (MP) yield has no effect when the foods offered as a choice contain adequate RDP. However, it is necessary for an animal to have some knowledge of the nutritional properties of the available foods in order to select appropriately between them, as the prevailing view is that its feeding behaviour depends largely on learning (Arsenos and Kyriazakis, 1999). The objective of this study was threefold: (i) to test whether sheep are able to form specific associations between food flavours and post-ingestive consequences (PIC) induced by the administration of a ruminally undegradable, but readily digestible protein source (DUP); (ii) to investigate the relative importance of RDP and DUP sources and their consequent PIC in the development of such associations; and (iii) to test whether such associations can be formed when DUP is administered concurrently with a RDP source. Following Tolkamp *et al.*'s (1998) suggestion we have hypothesised that learned associations would be dictated by the PIC attributed to RDP rather than DUP administration.

Materials and Methods The experiment consisted of three consecutive conditioning periods (each lasted 8 days). Two foods (basal and test) with different CP (92 and 64 g/kg DM respectively) and the same ME (9.1 MJ/kg DM respectively) supply were used on a total of 48 Texel x Greyface female lambs (49.5 ±4.93 kg). The test food was used in combination with two flavours, orange and aniseed, (7.5 g flavour/kg). Two nutritive stimuli (casein, C and formaldehyde treated casein, FC) were chosen such as to provide major contrasts in their RDP and DUP contents, on isonitrogenous basis. Sheep were randomly assigned to one of four treatments (n=12 per treatment) and were conditioned to associate one flavour added to the test food with a nutritive stimulus or water (W) as follows: C *v.* W, FC *v.* W, FC *v.* C, and FC+C *v.* C. Flavour order and flavour association with a particular nutritive stimulus or W were completely randomised within a conditioning period. For the first two days (days 1 & 2) half of the sheep were offered one flavoured food paired with the administration of a particular nutritive stimulus and the other half were offered the opposite flavoured food paired with the administration of W or another nutritive stimulus. The following two days (days 3 & 4) sheep were offered the basal food. During days 5 & 6 the order of association between flavours and nutritive stimuli was reversed. In the morning (9:00 h) of day 7, sheep were offered a choice between the two flavoured foods for 20 min. Preference Ratios (PRs) were calculated as the intake (g) of a flavoured food associated with C (C *v.* W), FC (FC *v.* W and FC *v.* C) or FC+C (FC+C *v.* C) as a proportion of total flavoured food intake (g). For the rest of day 7 and during day 8 the basal food was offered. Data were arcsine transformed and analysed as a split-plot design.

Results PRs were increased as a result of repeated conditioning on the three out of four treatments ($P<0.05$, Table 1). Sheep preferred the flavoured food associated with C or FC over the opposite flavoured food associated with W ($P<0.05$ in C *v.* W and $P<0.01$ in FC *v.* W treatment respectively). In the FC *v.* C treatment sheep preferred the flavoured food previously associated with the administration of FC to that associated with isonitrogenous administration of C ($P<0.05$). In the FC+C *v.* C treatment sheep showed an equal response towards the food flavours associated with either nutritive stimuli. The total mean intakes of the flavoured foods for the three preference tests were: 413, 392, 377 and 418 g (s.e.d. 33.06) for treatments C *v.* W, FC *v.* W, FC *v.* C and FC+C *v.* C respectively.

Table 1. Backtransformed mean Preference Ratios (PRs, g of flavoured food associated with a nutritive stimulus indicated in bold / g of total intake of flavoured foods) calculated from the choices made during 20-min preference tests performed at the end of each conditioning period.

	Treatment			
Conditioning	**C** *v.* W	**FC** *v.*	**FC** *v.* C	**FC+C** *v.* C
1st	0.587	0.567	0.541	0.468
2nd	0.609	0.653	0.680	0.470
3rd	0.714	0.720	0.726	0.447
mean	**0.638**	**0.647**	**0.651**	**0.462**

Conclusion The results (i) indicate that sheep are able to form learned preferences for food flavours associated with the administration of RDP or DUP, and (ii) suggest that sheep are able to distinguish between food flavours associated with the administration of RDP and DUP sources. They prefer flavours associated with DUP over flavours associated with RDP, however, such preferences do not develop when DUP is administered concurrently with RDP. These results extend the concept of the development of learned preferences for protein by sheep (Arsenos and Kyriazakis, 1999). Given these learned responses of sheep towards flavours associated with RDP and DUP the expectation is that they should be able to select their diets on the basis of these qualities when they are offered a choice.

References Arsenos, G. and Kyriazakis, I. 1999. The continuum between preferences and aversions for flavoured foods in sheep conditioned with administration of casein doses. *Animal Science* **68:** 605-616.
Tolkamp, B.J., Kyriazakis, I., Oldham, J.D., Lewis, M., Dewhurst, R.D. and Newbold, J.R. 1998. Diet choice in dairy cows. II. Selection for metabolizable protein or for rumen degradable protein? *Journal of Dairy Science* **81:** 2670-2680.

Growth and carcass characteristics of three lamb genotypes finished on the same level of feeding

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Introduction Improving the efficiency of lean meat production is of major importance to the UK sheep industry. Compared to a range of other breeds, Texel-sired lambs have been found to contain a higher proportion of carcass lean content. Carson *et al*. (1999) found that Texel X Greyface (Border Leicester X Scottish Blackface) lambs contained 38 g/kg more lean than Rouge de l'Ouest (Rouge) X Greyface lambs. The aims of the present experiment were (a) to investigate the efficiency of liveweight and carcass gains in Greyface, Rouge and Texel lambs at equal dry matter intakes of a standard diet (b) to test the hypothesis that carcass chemical composition would be similar in Greyface, Texel and Rouge lambs when finished on the same level of feeding.

Materials and methods Lambs used in this study had an initial weight of 31.9 (s.d. 1.36) kg. Greyface (n=24) represented the Border Leicester X Scottish Blackface crossbred lamb. The Texel (Dutch strain) was represented by 12 pure-bred lambs and 12 Texel X Texel-Greyface (75% Texel genes) lambs. The Rouge genotype was represented by 12 pure-bred and 12 Rouge X Rouge-Greyface (75% Rouge genes) lambs. Equal number of male and female lambs were present in each genotype group. At the beginning of the experiment six males and six females of each genotype were selected to form a pre-experimental slaughter group to establish initial body composition. The remaining 12 animals from each genotype were individually housed and offered dried grass nuts for the 14 week duration of the experiment. Texel lambs, which had the lowest food intake in the pre-experimental period, were fed to appetite. This level of feeding was then offered to the other two groups. Feeding levels were adjusted weekly and aimed at ensuring that there were no food refusals. All lambs were slaughtered at the end of the 14 week duration of the study and body composition determined. The results were analysed by analysis of variance (Genstat, 1993) corresponding to the 3 genotypes (Greyface, Texel and Rouge) X 2 gender (male, female), factorial design of the experiment. Initial weight of the lambs was used as a co-variate for the growth data. As there were no significant genotype X gender interactions only main effect means are presented in the table

Results Live weight gains were significantly lower (P<0.01) in Texel compared to Greyface lambs, with Rouge lambs intermediate between the other two genotypes (Table 1). Carcass and non-carcass component weight gains followed the same pattern. Lamb genotype had no significant effect on the proportion of chemical constituents in carcass gains. At the end of the study water content was lower in Greyface compared with Texel lambs (P<0.05). Carcass protein, lipid and energy content did not vary significantly between the genotypes. Carcass ash content was lower in Texel compared with Greyface (P<0.01) and Rouge (P<0.05) lambs. When the data was adjusted to a constant carcass weight the lipid content of the carcass was significantly lower (P<0.05) in Texel compared with Greyface lambs (218 and 270 (s.e.m. 13.1) g/kg respectively).

Table 1 *Effects of lamb genotype and gender on lamb gains (kg/d) and carcass chemical composition*

	Lamb genotype				Lamb gender			Significance	
	Greyface	Rouge	Texel	s.e.m.	Male	Female	s.e.m.	Genotype	Gender
Gains (kg/d)									
Live weight	0.169^{b}	0.156^{ab}	0.146^{a}	0.005	0.161	0.153	0.004	*	
Carcass weight	0.098^{b}	0.094^{ab}	0.086^{a}	0.003	0.098^{B}	0.088^{A}	0.003	*	*
Non-carcass weight	0.061^{b}	0.053^{ab}	0.050^{a}	0.003	0.061^{B}	0.049^{A}	0.002	*	***
Chemical composition of carcass gains (g/kg)									
Water	403	414	432	28.2	455^{B}	378^{A}	22.9		*
Protein	132	135	142	8.2	145	128	6.6		P=0.09
Lipid	427	416	388	34.2	362^{A}	458^{B}	27.8		*
Ash	39	35	38	3.3	38	37	2.7		
Energy (MJ/kg)	19	20	18	1.2	17	21	1.0		**
Carcass chemical composition - end of experiment									
Water	530^{a}	556^{ab}	565^{b}	11.04	565^{B}	536^{A}	8.98	*	*
Protein	160	166	167	2.75	170^{B}	159^{A}	2.24		**
Lipid	264	233	228	13.35	221	263	10.85		*
Ash	46^{b}	44^{b}	40^{a}	1.24	45	42	1.01	**	P=0.07
Energy	13.8	13.2	12.6	0.42	12.1^{A}	14.2^{B}	0.35		***

$^{a, b, A, B}$ Within rows lamb genotype or lamb gender not sharing the same differ significantly (P<0.05)

Conclusions The reduction in efficiency of converting feed into live weight gain puts Texel lambs at a financial disadvantage in production systems in which feed resources are limited and lambs are marketed live on a weight basis.

References

Carson, A.F., Moss, B.W., Steen, R.W.J. and Carson, A.F. 1999. Effects of the percentage of Texel or Rouge genes in lambs on carcass characteristics and meat quality. *Animal Science 69: 81-92*

Genstat. 1993. Genstat 5 Release 3 Reference Manual, Oxford Science Publications, Clarendon Press, Oxford.

Bioavailability of dietary copper and zinc proteinates and sulphates in adult Texel sheep

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Introduction Mineral deficiencies for livestock are reported from almost all world regions. Deficiency can be caused by inadequate intake or by the presence of antagonists in the diet. Traditionally, inorganic salts, such as oxides and sulphates have been added to the diet to meet the requirements of the animal. More recently, there has been increasing interest in mineral chelates. Studies by Rojas *et al*. (1995) and Ward *et al*. (1996) have reported that the copper and zinc availability in copper and zinc chelates is greater than in the traditional inorganic salts. Other studies by Kegley *et al*. (1994) and Schell *et al*. (1996) reported contradictory results. In this study, two separate trials were carried out to compare the effects of Bioplex copper and Bioplex zinc with the effects of copper and zinc sulphate on plasma copper and zinc levels in adult Texel sheep.

Materials and methods Forty adult Texel sheep were housed in individual pens and fed 500 g concentrates plus 750 g grass nuts per day which constitutes a maintenance diet. After becoming accustomed to this diet the sheep were randomly divided into groups of 10, except where indicated in Table 1, and supplemented daily with additional copper (for 80 days, October to December 1998) or zinc (for 100 days, February to May 1999) as follows. Treatment groups: 1, 15 mg Bioplex copper, 2, 25 mg Bioplex copper, 3, 15 mg copper sulphate and 4, 25 mg copper sulphate; and 5, 75 mg Bioplex zinc, 6, 150 mg Bioplex zinc, 7, 75 mg zinc sulphate and 8, 150 mg zinc sulphate, respectively. Bioplexes are mineral chelates supplied by the Alltech Biotechnology Centre, Co. Meath, Ireland. The copper supplements were mixed and fed with the concentrates, whereas the zinc supplements were administered as a drench once per day. Samples of blood plasma were taken from each sheep at the start and at the end of each trial and analysed for total copper or zinc using a Varian SpectrAA-220 atomic absorption spectrophotometer. The significance of plasma increases in each group was determined using the paired 2-tail t-test (Table 1). Comparisons between groups were determined using the ANOVA F-test followed by the Fisher PLSD-test (Table 2), using a StatView 5.0 programme for PowerMac.

Results Mineral supplementation resulted in significantly higher plasma levels for all treatments except for the groups supplemented with zinc sulphate (Table 1). Treatments with the lower levels of Bioplex copper and zinc resulted in significantly greater increases in plasma levels than the corresponding inorganic treatments. Table 2 summarises the relative increases in plasma copper and zinc and the significance of the differences between groups.

Table 1 Effect of supplementation with Bioplex and sulphate forms of copper and zinc on plasma levels

Plasma Samples	Copper Treatments				Zinc Treatments			
	1	2 [a]	3	4 [b]	5	6	7	8
Pre-treatment	1.96 ± 0.05	2.10 ± 0.10	2.30 ± 0.06	2.17 ± 0.07	0.73 ± 0.03	0.72 ± 0.04	1.04 ± 0.12	0.91 ± 0.13
Post-treatment	2.69 ± 0.04	2.74 ± 0.11	2.61 ± 0.04	2.61 ± 0.06	1.23 ± 0.08	1.24 ± 0.08	1.15 ± 0.09	1.14± 0.03
Significance	p<0.0001	p<0.0001	p<0.005	p<0.005	p<0.001	p<0.0001	N.S.	N.S.

Plasma levels (mg/l) are expressed as the mean ± s.e.m. For all groups N = 10; except for a, N = 9 and for b, N = 11.

Table 2 Comparison of effects of various treatments on overall copper and zinc plasma increases

Plasma Samples	Copper Treatments (F: p<0.005)				Zinc Treatments (F: p<0.05)			
	1	2	3	4	5	6	7	8
Increase (mg/l)	0.73 ± 0.05	0.64 ± 0.10	0.31 ± 0.10	0.44 ± 0.13	0.50 ± 0.10	0.52 ± 0.08	0.12 ± 0.12	0.23 ± 0.13
Significance	a, e	c	d, f	b	g	i	h	

Increases (mg/l) are expressed as the mean ± s.e.m. For numbers of sheep in each group see legend to Table 1.
Significant differences, for copper: groups ab, p<0.05; cd, p<0.005; ef, p<0.0005; and for zinc: gh, p<0.05; hi, p<0.01.

Conclusions We conclude that Bioplex copper and zinc are more bioavailable to sheep that the sulphate forms of these minerals particularly at moderate supplementation levels.

References Kegley, E.B. and Spears, J.W. 1994. Bioavailability of feed-grade copper sources (oxide, sulphate or lysine) in growing cattle. *Journal of Animal Science* **77:**2728–2734.
Rojas, L.X., McDowell, L.R., Cousins, R.J., Martin, F.G., Wilkinson, N.S., Johnson, A.B. and Velasquez, J.B. 1995. Relative bioavailability of organic and inorganic zinc sources fed to sheep. *Journal of Animal Science* **73:**1202–1207.
Schell, T.C. and Kornegay E.T. 1996. Zinc concentration in tissues and performance of weanling pigs fed pharmacological levels of ZnO, Zn-methionine, Zn-lysine, or ZnSO4. *Journal of Animal Science* **74:**1584–1593.
Ward, J.D., Spears, J.W. and Kegley, E.B. 1996. Bioavailability of copper proteinate and copper carbonate relative to copper sulphate in cattle. *Journal of Dairy Science* **79** (Suppl. 1)**:**127–132.

Effect of legume silages fed to Holstein dairy cows on plasma alpha-tocopherol concentration, milk alpha-tocopherol and malonic dialdehyde in milk samples stored at 4°C and 20°C

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Introduction Alpha-tocopherol is the natural antioxidant in milk preventing the oxidation of milk fat and development of off-flavour and off-odour. The feeding of dairy cows can significantly affect plasma and milk concentrations of α-tocopherol. There is growing interest in the use of legumes in milk production and so it is important to investigate their effects on milk a-tocopherol as well as the oxidation of milk fat during storage and, hence, shelf-life of milk.

Materials and methods Six multiparous Holstein-Friesian dairy cows in late lactation were offered six legume silages in 4-period cyclical changeover design experiment, with periods of 4 weeks (Dewhurst *et al*., 2000). The legume silages were grass silage (G), red clover silage (RC), white clover silage (WC), lucerne silage (L), grass and red clover silages (GRC) mixed (50:50 DM basis) and grass and white clover silages (GWC) mixed (50:50 DM basis). Animals were offered *ad libitum* one of 6 silage treatments during each period. Silages were sampled three times a week for dry matter (DM) and once for α-tocopherol. Blood and milk samples were collected in week 4 of each period. Alpha-tocopherol was extracted from plasma and milk on the same day. Sixty ml of milk from each cow from each milking were mixed and split into two Sterilin tubes, 6 tubes (one tube for each animal) were stored at 20 °C in the dark and 6 tubes at 4 °C in a refrigerator for periods of 48 and 96 hours. A high performance liquid chromatograph-fluorescence detector (HPLC-FL) with a column LC 18 (25 cm x 4.6 mm, 5 μm) was used to determine the concentration of α-tocopherol in plasma, milk and silages. Milk fat oxidation was determined from malonic dialdehyde (MDA) concentration (Vyncke, 1975). Data were analysed using REML (Genstat 5; Lawes Agricultural Trust, 1997) with a fixed model of 'diet' and a random model of 'period + cow'.

Results Table 1 shows the concentrations of a-tocopherol in forages, the effects of forages on concentrations of a-tocopherol in plasma and fresh milk, as well as effects on oxidative deterioration of milk (accumulation of MDA). There were no significant differences in the concentrations of a-tocopherol (mean=0.35 μg/ml) and MDA (mean=0.42 μg/ml) in fresh milk. However, concentrations of α-tocopherol decreased and MDA increased with storage time and these changes were greater at 20 °C that at 4 °C. The oxidative stability of milk from animals fed lucerne or red clover was lower compared with other silages.

Table 1 Effects of forage treatments on a-tocopherol and oxidative stability of milk.

	G	GRC	RC	GWC	WC	L	s.e.d.	Sig.
Silage a-tocopherol (μg/g DM)	10.7	18.7	16.5	15.2	18.6	11.3	1.59	**
Plasma a-tocopherol (μg/ml)	2.05	1.51	2.24	2.58	3	0.98	0.412	***
Milk a-tocopherol (μg/ml):	0.37	0.38	0.27	0.38	0.41	0.30	0.079	NS
48h/4°C	0.29	0.3	0.22	0.3	0.37	0.12	0.071	*
96h/4°C	0.21	0.18	0.13	0.13	0.23	0.11	0.049	NS
48h/20°C	0.18	0.20	0.09	0.14	0.17	0.13	0.031	**
96h/20°C	0.14	0.11	0.04	0.09	0.12	0.07	0.031	**
Malonic dialdehyde (μg/ml)	0.30	0.00	0.79	0.76	0.48	0.26	0.380	NS
48h/4°C	4.5	4.8	4.5	3.8	3.0	4.8	1.16	NS
96h/4°C	7.6	7.6	8.4	6.2	7.7	7.5	1.17	NS
48h/20°C	7.8	7.6	10.3	5.7	6.4	9.0	1.19	**
96h/20°C	13.0	13.3	15.0	11.8	14.5	13.0	1.76	NS

Conclusions
Silage type, storage conditions and plasma α-tocopherol concentration can affect the α-tocopherol content and oxidative stability of milk. Effects on oxidative stability of milk were not directly related to α-tocopherol in silage.

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References
Dewhurst, R. J., Merry, R. J., Davies, D. R., Moorby, J. M., Scollan, N. D., Neville, M. A and, Baker, D. H. 2000. Effects of legume silages on the quantity and particle size distribution of rumen contents in Holstein-Friesian cows. This Meeting
Vyncke, W. 1975. Evaluation of the direct thiobarbituric acid extraction method for determining oxidative rancidity in Mackerel *(Scomber scombrus* L.*) Fette, Selfen, Anstrichniltted*, 77: 239-240

A comparison of the responses of dairy cows with high and low milk yield potential to the application of sodium fertilizer

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Introduction Tabulated sodium requirements of dairy cows, such as those of the Agricultural Research Council (ARC, 1980), are all based on milk yield. The principle for this is the apparent homeostatic control of sodium concentration in the milk of cattle, with sodium loss in milk being approximately proportional to milk yield. However, there is evidence that low yielding cows respond more than high-yielding cows to a sodium supplement when grazing lucerne with a low sodium content (Joyce and Brunswick, 1975), and the present study therefore investigated the effect of dairy cow milk yield potential on the response to the application of a fertilizer containing sodium.

Materials and methods A 6.7 ha area of predominantly perennial rye-grass pasture was divided into 8 equal-sized paddocks, which were allocated at random to one of two sodium treatments: receiving nitrogen only (444 kg N/ha/year) (treatment N) or receiving the same level of nitrogen with the addition of 32 kg Na/ha/year (Treatment Na). For the Na treatment nitrogen was applied as a compound fertilizer of NH_4NO_3 and $NaNO_3$, which replaced an isonitrogenous quantity of the NH_4NO_3 applied to treatment N. In late April, thirty-two spring-calving Friesian dairy cows were arranged in similar pairs and one cow from each pair was allocated at random to graze each of the two fertilizer treatments from late April until the end of September. Milk yield, fat, protein and lactose contents were measured weekly, together with the live weight of the cows, and the Somatic Cell Count (SCC) was measured monthly, with treatment differences examined by analysis of variance. Milk yield persistency was calculated for each cow by linear regression of milk yield with time.

Results and discussion The application of sodium fertilizer increased the herbage concentrations of sodium from 3.3 to 5.1 g/kg DM, of magnesium from 1.8 to 2.0 g/kg DM and of calcium from 6.3 to 7.3 g/kg DM. Applying sodium fertilizer increased the milk yield and milk fat concentration and decreased somatic cell count in the low production potential cows only, whereas it increased the weight gain and milk yield persistency of the high production potential cows (Table 1). Milk lactose concentration was increased by applying sodium fertilizer equally in both groups. This suggests that increased nutrient supply from sodium-treated pasture was used primarily for milk production in the low potential cows, whereas in the high potential cows it was used to restore live weight.

Table 1. Milk yield and composition, and weight gain, of Low- and High-yielding cows on treatments Control (N) and Sodium (N + Na).

	Low yielders		High yielders		SED and significance		
	N	N+Na	N	N+Na	Sodium	Yield class	Na x Y. class
Mean yield (l/d)	20.7	24.8	24.3	25.1	0.68***	0.68***	0.96*
Yield persistence (l/d/d)	-0.05	-0.13	-0.11	+0.03	0.044	0.044	0.063*
Milk fat (g/kg)	36.4	42.6	37.4	38.2	0.73**	0.73*	1.03***
Milk protein (g/kg)	34.8	34.7	32.5	32.7	0.42	0.42***	0.59
Milk lactose (g/kg)	45.1	46.9	45.6	46.7	0.34**	0.34	0.49
Somatic cell count (log_{10})	1.63	0.67	0.92	0.99	0.224*	0.224	0.317*
Live weight change (kg d^{-1})	0.42	0.42	0.15	0.28	0.91	0.91*	1.29***

Conclusions The most immediate advantage to the application of sodium fertilizer will be gained from increasing the herbage sodium concentration for low yielding cows.

References

Agricultural Research Council (ARC) (1980*). Nutrient Requirements of Ruminant Livestock*. Farnham Royal, Bucks: Commonwealth Agricultural Bureaux.

Joyce J.P. and Brunswick L.C.F. (1975). Sodium supplementation of sheep and cattle fed lucerne. *New Zealand Journal of Experimental Agriculture* **3:** 299-304.

Somatic cell count and reduction in antibiotic use in dairy cows by dietary supplementation with trace elements and vitamins given as a ruminal bolus system

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Introduction Many references (review, Hemingway, 2000) indicate that giving supplementary dietary selenium (Se) and vitamin E during the dry period in amounts greater than accepted nutritional requirements can decrease the incidence, duration and severity of high somatic cell counts (SCC) and mastitis in dairy cows. Low dietary Se intakes and plasma Se concentrations are more frequent than those for vitamin E. As one example, Erskine *et al.* (1987) investigated two groups each of 16 herds each having either > 700 x 10^3 SCC /ml (High) or < 150 x 10^3 SCC /ml (Low). Mean contrasting plasma concentrations (µg /ml) were respectively 0.074 and 0.138 ($P < 0.01$) for Se with 4.2 and 4.8 (NS, adequate) for vitamin E. Supplementary dietary Se and vitamin E were given more frequently to the Low SCC herds. The present experiment investigated the effect of two multi-trace element/vitamin boluses ('All-Trace', Agrimin Ltd. DN20 0SP) which, *inter alia*, release 2 mg Se and 9 i.u. vitamin E /day giving a significant increase in glutathione peroxidase activity over an 8-month period (Allan *et al.*, 1993)

Material and methods As individual cows in a Holstein/Friesian herd were dried off in turn over a 2-year period, each alternate cow (selected at random and without regard to previous history) was given *either* two boluses *or* was untreated. There were 52 cows /group. All the cows in both groups were additionally given long-acting intra-mammary antibiotic at the same time. The cows were winter-housed in cubicles and were given grass silage, brewers grains, sugar beet pulp and compound feed; at grass in summer they received only limited concentrate. Milking was in a modern parlour with full daily individual cow hygiene. SCC for each cow was determined monthly by the routine procedure of Livestock Services (UK) Ltd. Individual cows were given intra-mammary antibiotic during lactation as indicated by the appearance of fore milk or the skin temperature and appearance of the udder. Statistical evaluation of SCCs was by paired t-tests and by chi-squared analysis for cows requiring antibiotic.

Results The mean dry period was 57 (s.d. 14.3) days. Giving boluses significantly reduced mean SCC over the whole lactation and particularly during the first month. In Scotland, only bulk milk with < 150 x 10^3 SCC /ml receives the highest price premium. Significantly fewer of the cows given the boluses required antibiotic therapy during lactation. Identified bacteria in individual abnormal milk samples were *Staphylococcus aureus, S. chromogenes, S. epidermis, S. xylosus, Streptococcus uberis, Escherichia coli,* and *Actinomyces pyogenes.* No bacteria were isolated from 0.31 proportion of milk samples submitted for examination. Similar findings (range 0.27 to 0.38 proportion) have been reported by other investigators.

Table 1 *Mean group SCC (x 10^3 /ml) and the number of individual cows given intramammary antibiotic in lactation*

	Two Boluses 51 cows /group	Untreated 52 cows /group	s.e.d.	Sig. *P*
First month of lactation	97	220	56.3	< 0.05
Whole lactation	102	158	23.7	< 0.05
Lactating cows given antibiotic	7	17	5.69$^+$	< 0.02

$^+$ chi-squared

Conclusions The bolus treatment supplied (mg /day) Se 2.0, Cu 138, Co 2.0, I 2.1, Mn 71 and Zn 113 with (i. u. /day) vitamin E 9, vitamin A 4644 and vitamin D 929. Administration to cows at the start of the dry period resulted in a significant reduction in somatic cell counts and the need for antibiotic therapy during the following lactation. Giving boluses at a defined time is a more certain means of uniform supplementation than reliance on free-access mineral/vitamin provision particularly when dry cows are at grass. Following appropriate advice, the boluses may be used in 'organic' milk production systems.

References

Allan, C.L., Hemingway, R.G. and Parkins, J.J. 1993. Improved reproductive performance in cattle dosed with trace element/vitamin boluses. *The Veterinary Record* **132:** 463-464.

Erskine, R.J., Eberhart, R.J., Hutchinson, L.J. and Scholz, R.W. 1987. Blood selenium concentrations and glutathione peroxidase activities in dairy herds with high and low cell counts. *Journal of the American Veterinary Medical Association* **190:** 1417-1421.

Hemingway, R.G. 2000. The influences of dietary selenium and vitamin E intakes on milk somatic cell counts and mastitis in cows; a review. *Veterinary Research Communications* (in the press).

The effect of molybdenum, sulphur and iron on the copper status of store lambs.

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Introduction Clinical copper deficiency is the second most common mineral deficiency in the world, the main cause being high dietary levels of molybdenum, sulphur and iron. Phillippo *et al*, (1987) reported that clinical signs of deficiency resulted from high dietary Mo and S. However, Fe and S resulted in hypocupraemia but did not induce clinical signs of deficiency. Therefore is was concluded that clinical copper deficiency was due to a direct effect of dietary Mo and S on copper metabolism in ruminants. Mackenzie *et al.* (1997) reported that plasma copper levels were not an accurate indicator of copper status and unlikely to predict animals requiring copper supplementation. Caeruloplasmin is large copper enzyme and accounts for 88% of plasma copper and Mackenzie *et al.* (1997) proposed that a caeruloplasmin to plasma copper ratio may provide a more accurate biochemical indicator of copper status. This trial was designed to investigate the effect of dietary Mo, S and Fe on the copper status of the lambs.

Materials and Methods Sixty Texel cross store lambs with an initial weight of 33.3 kg (s.e. 1.03) were group housed and randomly allocated to three treatment groups with 20 lambs per group. The lambs were fed a basal complete diet (1.4 kg/day) based on hay (350 g/kg), barley (440 g/kg), soyabean meal (110 g/kg), molasses (60 g/kg) and mineral premix (40 g/kg) (ME 9.6 MJ/kg DM; CP 155 g/kg DM) for seven days before the start of the trial. One group of lambs received 10 mg/kg DM molybdenum and 2g/kg Sulphur (Mo) in their diet and the second group received 500 mg/kg DM iron and 2 g/kg DM sulphur (Fe). The third group continued to receive the basal diet for the duration of the trial. Lambs were selected for slaughter when they reached 42 kg liveweight. Blood samples were collected by jugular venepuncture on day 0, 21 and 35 of the trial. Plasma copper (Pl-Cu) concentration were determined by atomic absorption and serum caeruloplasmin (CP) activities were measured on a Cobas-Mira (Roche). Copper status was determined by the ratio of caeruloplasmin activity to plasma copper concentration (CP/Pl-Cu) (Mackenzie *et al.*, 1997). Statistical analysis of the results was by Analysis of Variance (GLM) for a completely randomised design with the variables on day 0 being used as a covariate.

Results There were no significant effects on lamb growth rates, carcass weight, carcass grade or killing out percent. Similarly, there was no significant effect of treatments on plasma copper concentration (Table 1). Caeruloplasmin activity was significantly reduced in the Mo and Fe groups on days 21 and 35 compared with the controls ($p<0.001$). Also on day 21 the Mo lambs had significantly lower CP activities compared with the Fe lambs ($p<0.001$). The Mo lambs had significantly lower CP/Pl-Cu ratios compared with the controls and Fe lambs on days 21 and 35 ($p<0.001$) (Table 1).

Table 1. *Effect of treatment on copper status of Texel cross store lambs.*

	Day	Control	Mo	Fe	s.e.d.	P
Pl-Cu	0	19.8	19.4	17.4	1.89	NS
(μmol/l)	21	19.4	19.6	17.6	1.65	NS
	35	18.0	17.5	14.9	1.65	NS
CP	0	17.9	14.2	17.3	2.54	NS
(mg/dl)	21	35.9	23.6	29.6	2.78	p<0.001
	35	29.6[a]	18.1[b]	19.2[b]	2.43	p<0.001
CP/Pl-Cu	0	1.40	1.48	1.60	0.080	NS
	21	1.84[a]	1.22[b]	1.73[a]	0.078	p<0.001
	35	1.62[a]	1.02[b]	1.36[a]	0.125	p<0.001

Means with the different letter ([a,b]) within a row were significantly different ($p<0.05$)

Conclusion Treatment had no effect on lamb performance as growth rate is relatively insensitive to copper deficiency. The results confirm previous observation that plasma copper does not provide an accurate method of assessing status. Although CP activity was significantly reduced in both the Mo and Fe groups, most activities were in the normal range for sheep(>15 mg/dl). The use of the CP/Pl-Cu may be beneficial for detecting ruminants that are likely to suffer from clinical copper deficiency due to high dietary molybdenum and sulphur.

References

Mackenzie, A.M., Illingworth, D.V., Jackson, D.W. and Telfer, S.B. 1997. The use of caeruloplasmin activities and plasma copper concentrations as indicators of copper status in ruminants. In: *Trace Elements in Man and Animal -9: Proceedings of the Ninth International Symposium on Trace Elements in Man and Animals.* (Edited by P.W.F. Fischer, M.R. L'Abbé, K.A. Cockell and R.S. Gibson). NRC Research Press, Ottawa, Canada. pp. 137-138.

Phillippo, M., Humphries, W.R., Atkinson, T., Henderson, G.D. and Garthwaite, P.H. 1987. The effect of dietary molybdenum and iron on copper status, puberty, fertility and oestrus cycle in cattle. *Journal of Agricultural Scence* **109**: 321-336.

An evaluation of the effects of rate of nitrogen fertilisation and stage of maturity on degradability of grass in the rumen

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Introduction Grass forms the basal forage for the majority of ruminant livestock in Ireland and the UK. Level of nitrogen (N) and harvest date are the two major factors affecting the yield of herbage. In a concurrent study, Keady *et al*. (1999) concluded that herbage dry matter (DM) yield of the primary growth of a perennial ryegrass sward is increased by 7.9 kg DM/ha/kg N and by 152 kg DM/ha/day delay in harvest respectively. However as herbage yield increases, particularly as a result of delayed harvest, digestibility declines. The present study was undertaken to evaluate the effects of rate of N fertilisation application and harvest date on the degradation characteristics of grass.

Materials and Methods Seventy-five plots, each 10 x 1.5 m, were laid out in three replicated randomised blocks on a predominantly perennial ryegrass sward comprised of intermediate varieties. Nitrogen (N) was applied on 24 March in the form of calcium ammonium nitrate (275 g N/kg) with 72, 96, 120, 144 or 168 kg N/ha applied to 5 plots at random within each block. Each plot also received 20 and 100 kg/ha of P_2O_5 and K_2O respectively on 31 March. Herbage from one plot for each rate of N application per block was harvested on either 10, 17, 24 or 31 May or 7 June. The herbage was mown to a stubble height of 4.5 cm using a reciprocating mower and weighed for the determination of yield. Subsequently the herbage was passed through a precision chop forage harvester, and subsamples were frozen prior to rumen incubation. Samples of chopped herbage were incubated in dacron bags, which were suspended in the rumen of three steers fitted with rumen fistulae, in a partially balanced changeover design experiment. The steers received silage as the sole diet. Four bags containing the herbage were withdrawn after 0, 3, 6, 12, 24, 48 and 72 hours. The parameters a, b and c were calculated from the disappearance measurements and the degradabilities of DM, N, acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined.

Results Increasing the rate of N fertiliser application increased herbage crude protein (CP) concentration (P<0.001) and decreased DM content (P<0.001). The concentrations of NDF and ADF increased (P<0.05 or greater) as the rate of N fertiliser increased from 72 to 144 kg N/ha. Delaying harvest date decreased (P<0.001) herbage CP concentration. Delaying harvest date from 17 May to 6 June increased (P<0.001) NDF. The concentration of ADF declined as harvest date was delayed from 10 May to 24 May but increased thereafter. The effects of rate of N fertiliser and harvest date on the degradability of DM, N, ADF and NDF are presented in Table 1. Increasing the rate of fertiliser N application increased (P<0.001) the degradability of N, NDF and ADF. Rate of fertiliser N did not alter (P>0.05) DM degradability. Delaying harvest date decreased (P<0.001) the degradability of DM, CP, ADF and NDF. There were significant harvest date by rate of N fertiliser application interactions (P<0.05 or greater) for the degradability of DM, CP, NDF and ADF.

Table 1 The effect of rate of nitrogen fertiliser application on herbage degradability (%) (assuming an outflow rate of 0.05)

	Nitrogen (kg/ha)						
	79	96	120	144	166	Sem	Sig†
Dry matter	60.2	59.5	60.2	60.0	60.2	0.24	NS
Nitrogen	69.5^{ab}	68.1^{a}	71.5^{c}	70.9^{bc}	72.2^{c}	0.64	***
NDF	40.0^{a}	40.5^{ab}	41.9^{cd}	41.4^{bc}	42.5^{d}	0.35	***
ADF	36.5^{a}	36.2^{a}	38.5^{b}	37.8^{b}	39.7^{c}	0.35	***
	Harvest date						
	10/5	17/5	24/5	31/5	7/6	Sem	Sig†
Dry matter	65.9^{e}	65.2^{d}	61.0^{c}	55.7^{b}	52.3^{a}	0.24	***
Nitrogen	74.1^{d}	70.7^{c}	72.3^{cd}	66.5^{a}	68.6^{b}	0.64	***
NDF	49.3^{c}	46.6^{d}	41.2^{c}	35.2^{b}	34.1^{a}	0.35	***
ADF	44.4^{d}	41.3^{c}	37.8^{b}	32.9^{a}	32.3^{a}	0.35	***

^{a,b,c,d,e} Mean values in a line carrying the same superscript are not significantly different (P<0.05)
† There were significant NxHD (P<0.05 or greater) interactions for the degradability of DM, N, NDF and ADF

Conclusions Although rate of N fertiliser did not alter DM degradability it significantly increased the degradability of N, NDF and ADF. Delaying harvest date decreased the degradability of DM, N, NDF and ADF, consequently having the greatest effect on feeding value.

References

Keady, T.W.J., Mayne, C.S. and Fitzpatrick, D.A. 2000. The prediction of silage feeding value from the analysis of the herbage at ensiling and the effects of level of nitrogen fertilizer, date of harvest and additive treatment on grass silage composition. *Journal of Agricultural Science, Cambridge* (In press).

An examination of rate of nitrogen fertiliser, date of harvest and additive treatment on degradability of grass silage in the rumen

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Introduction Grass silage forms the basal forage for the majority of beef and dairy cattle during the winter indoor feeding period. Previous studies undertaken at this Institute have clearly indicated that the major factors affecting the feed value of grass silage are the date of harvest, rate of fertiliser nitrogen (N) application and additive treatment. The present study was undertaken to evaluate the effects of rate of N fertiliser application, harvest date and additive treatment on in-sacco degradation characteristics of grass silage.

Materials and Methods Seventy-five plots, each 10 x 1.5 m were laid out in three replicate randomised blocks on a predominantly perennial ryegrass sward. Nitrogen was applied on 24 March at the rate of 72, 96, 120, 144 or 168 kg N/ha to 5 plots at random within each block. Herbage from one plot for each rate of N application per block was harvested on either 10, 17, 24 or 31 May or 7 June, and precision chopped. The herbage from each plot was subdivided into three quantities of 6 kg and either untreated or treated with either formic acid applied at 3 ml/kg herbage or an inoculant applied at the rate of 3 ml/kg herbage, resulting in a total of 75 treatments. The herbage was ensiled, unwilted in 150 (2 per treatment) plastic pipe silos for a 176 day fermentation period. Silage from the two replicates per treatment were mixed and fresh silage subsamples (approximately 5 g DM) were placed into dacron bags. The dacron bags were suspended in the rumen of three steers fitted with rumen fistulae in a partially balanced changeover design experiment. The steers received grass silage as the sole diet. The silages were withdrawn after 0, 3, 6, 12, 24, 48 and 72 hours. The parameters a, b and c were calculated from the disappearance measurements and the degradabilities of dry matter (DM), N, acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined.

Results The silages offered in the present study differed dramatically. For example silage ammonia N, DM, crude protein (CP), NDF and ADF varied from 34 to 125 g/kg total N, 162 to 223 g/kg, 79 to 171 g/kg DM, 450 to 621 g/kg DM and 285 to 365 g/kg DM respectively. The effects of additive treatment, rate of N application and harvest date on rumen degradability of the silages are presented in Table 1. Additive treatment significantly (P<0.001) decreased the degradability of DM, N, NDF and ADF. Increasing the rate of N fertiliser application increased N degradability (P<0.001), The degradability of NDF and ADF decreased as the rate of N fertiliser was increased from 144 to 168 kg/ha. Delaying harvest date decreased the degradability of DM and N. Also when harvest date 31 May was omitted, delaying harvest date decreased the degradability of NDF and ADF. There were significant AxN, AxHD, NxHD and AxNxHD interactions for the degradability of DM, N and NDF, and significant AxHD, NxHD and AxNxHD interactions for ADF degradability.

Table 1 The effects of rate of nitrogen fertiliser, harvest date and additive treatment on rumen degradability of silage (%) (assuming an outflow rate of 0.05)

	Additive (A)				Nitrogen (kg/ha) (N)					
	Control	Formic	Inoculant	Sem	72	96	120	144	168	Sem
DM	64.4^{c}	61.7^{b}	55.0^{a}	0.13	60.0^{a}	60.3^{a}	60.4^{ab}	60.8^{b}	60.2^{a}	0.16
N	84.2^{c}	82.5^{b}	80.6^{a}	0.12	82.0^{a}	81.9^{a}	82.4^{b}	83.0^{c}	82.9^{c}	0.16
NDF	38.9^{c}	37.5^{b}	32.0^{a}	0.22	36.1^{b}	36.1^{b}	36.7^{b}	36.6^{b}	35.2^{a}	0.28
ADF	39.3^{c}	37.5^{b}	32.2^{a}	0.23	36.6^{b}	36.3^{ab}	36.5^{b}	36.9^{b}	35.6^{a}	0.29

	Harvest date					
	10/5	17/5	24/5	31/5	7/6	Sem
DM	62.3^{d}	59.9^{b}	60.4^{c}	60.6^{c}	58.7^{c}	0.16
N	83.3^{c}	82.5^{b}	82.3^{b}	82.6^{b}	81.6^{a}	0.16
NDF	37.3^{c}	35.3^{b}	34.8^{ab}	38.9^{d}	34.3^{a}	0.28
ADF	36.9^{c}	35.3^{b}	35.9^{b}	39.3^{d}	34.4^{a}	0.29

^{a,b,c,d} Mean values in a line carrying the same superscript are not significantly different (P>0.05)
Additive treatment and harvest date significantly altered (P<0.001) the degradability of DM, N, NDF and ADF.
Rate of N significantly altered the degradability of DM (P<0.01), N (P<0.001), NDF (P<0.01) and ADF (P<0.05)

Conclusions Additive treatment had the greatest effect while rate of nitrogen fertiliser application had the least effect on silage degradability. Increasing N fertiliser application and delaying harvest date had a greater effect on rumen degradability of the parent herbage in a concurrent study (Keady *et al*., 2000) than on the resultant silages.

Reference

Keady, T.W.J., Mayne, C.S. and Fitzpatrick, D.A. 2000. An evaluation of the effects of rate of nitrogen fertilisation and stage of maturity on rumen degradability of grass. *Proceedings of the British Society of Animal Science* (This meeting).

Rumen and post-rumen digestion in lactating dairy cows fed fat from three sources

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Introduction Whole oil seeds represent an alternative to many commercial rumen-protected fat sources as energy supplements in rations for lactating dairy cows. Rumen protection reduces the potential for negative effects of unsaturated fatty acids on fibre digestion, but the structure of many whole oil seeds are thought to reduce the reactivity of their fat in the rumen. Cotton seed is often imported for inclusion in UK dairy rations, but rape seed represents a home grown oil seed which has potential as an economical fat and protein source in UK dairy rations. However, the seed must be crushed or chemically treated to be digested effectively and crushing may liberate oil to the extent that rumen digestion is altered. In a 20 week lactation study, supplemental fat from rumen-protected fat, cotton seed and rape seed fed at 25 g/kg dry matter (DM) in a grass-silage based total mixed ration (TMR) increased milk yield to a similar extent. However, DM intake was reduced by cotton seed and milk protein was reduced by rumen-protected fat (Reynolds et al., 1998). These responses may reflect alterations in digestive function, thus the objective of the present study, conducted simultaneously to the lactation study, was to evaluate the effects of the same diets on rumen, post-rumen and total digestion in lactating dairy cows.

Materials and Methods Four multiparous Holstein-Friesian cows (630 kg body weight, s.e.m. 3.2) with cannulas in the rumen and duodenum were used in a balanced 4 X 4 Latin Square design study with 5 week periods. Cows were fed for *ad libitum* intake a control diet which was a TMR containing on a dry matter (DM) basis 400 g grass silage, 600 g concentrate and 180 g crude protein (CP) per kg until the start of the experiment. Treatments were the control diet or diets formulated to contain 25 g supplemental fat/kg DM from Megalac® (Volac Ltd., Royston, Herts), whole cotton seed or crushed rape seed at the expense of wheat and using soya bean meal to equalize total nitrogen content. Digestion trials during the last week of each period included measurements of N balance using total faecal and urine collection for 5 to 6 days and sampling of duodenal contents at intervals over 3 days. Duodenal flow was measured by dilution of continuously infused Cr EDTA and Yb acetate. Cows were fed for *ad libitum* intake until the week of sample collection when DM offered was equal to the intake for the previous week to minimize refusals. Cows were fed three times daily and milked twice daily. Data were statistically analyzed by analysis of variance and means were separated by orthogonal contrasts comparing control and fat supplemented diets (A), rumen-protected fat and oil seeds (B) and the cotton and rape seed diets (C).

Results Milk yield (36.1 kg/d, s.e. 1.3) and composition (data not shown) and DM intake (Table 1) were not affected by diet. Ruminal and postruminal digestion of DM were not affected by diet (Table 1). Similarly, ruminal and postruminal digestion of NDF (3.76 [s.e. 0.23] and 0.38 [s.e. 0.20] kg/d, respectively) and ADF (2.34 [s.e. 0.13] and 0.23 [s.e. 0.09] kg/d, respectively) were not affected. Although N intake was not affected by diet (561 g/d, s.e. 10), duodenal flow of non-ammonia N (NAN) was decreased by all 3 fat supplements (Table 1). However, diet had no effect on milk (166 g/d, s.e. 6) or retained (4 g/d, s.e. 6) N.

Table 1. *Intake, rumen and post-rumen digestion of dry matter (DM, kg/d) and duodenal non-ammonia N flow (NAN, g/d) in lactating dairy cows fed 3 sources of dietary fat.*

	Diet						Contrast *P*-values		
	Control	Megalac	Cotton	Rape	s.e.	*P*-value[1]	A	B	C
DM intake	20.22	19.81	19.82	20.27	0.37	*0.72*	*0.58*	*0.63*	*0.42*
Rumen DM digestion	6.63	5.52	6.52	6.94	0.42	*0.20*	*0.57*	*0.06*	*0.51*
Post-rumen DM digestion	7.82	8.55	7.77	7.59	0.20	*0.06*	*0.53*	*0.02*	*0.54*
Duodenal NAN flow	673	645	623	632	12	*0.09*	*0.03*	*0.26*	*0.61*

[1]Probability corresponding to the hypothesis of no effect of diet.

Conclusions Feeding cotton seed and crushed rape seed had no effect on NDF or ADF digestion. All 3 fat supplements decreased the flow of NAN to the duodenum, which likely reflects a decrease in rumen fermentable energy, but only Megalac lowered milk protein concentration in the companion lactation study. The present results suggest that the reduction in milk protein observed was not solely due to a decrease in duodenal NAN flow. Results from the present study do not support the concern that feeding crushed rape seed might impair rumen digestion.

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References

Reynolds, C.K., Phipps, R.H., Jones, A.K. and Beever, D.E. 1998. Milk production response of lactating dairy cows to dietary fat from three sources. *Proceedings of the British Society of Animal Science*, 223

Replacement of soyabean meal by maize distillers grains for lactating dairy cows

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Introduction Maize distillers grains (MDG) are a traceable and valuable energy and protein feed for dairy cows (Owen and Larson, 1991) but little is known about the ability of UK MDG to replace more conventional protein sources, particularly their effects on the supply of protein to the cow. The purpose of the present experiment was to examine the effects of replacing soyabean meal with MDG on digestion in the rumen and flow of protein to the duodenum of lactating dairy cows.

Materials and methods Four multiparous Holstein-Friesian cows with permanent rumen and duodenal cannulas were offered 4 diets in a 4x4 Latin square experiment with 4-week periods in mid-lactation. For 3 days in week 4 rumen samples were taken for pH, ammonia and VFA simultaneously with duodenal samples to give 2-h intervals from 6.30 to 22.30 h overall. Measurements of duodenal flow were based on Yb acetate and CrEDTA as markers.

The cows were offered *ad libitum* a total mixed ration based on 175 g grass silage, 350 g maize silage and 475 g concentrates/kg (DM basis). The treatments consisted of 4 formulations of concentrates in which MDG replaced soyabean meal stepwise on a N equivalent basis to give treatments MDG 0, 0.33, 0.67 and 1.0 (Table 1). Urea and Megalac were included to help balance energy and ERDP.

Table 1. *Principal ingredients (kg/t fresh weight) and composition (g/kg DM) of concentrate mixes*

	MDG 0	MDG 0.33	MDG 0.67	MDG 1.0
Ground wheat	393	384	364	326
Hipro soya	216	145	71	0
Molassed sugar beet feed	195	190	181	159
Rapeseed meal	147	115	103	122
Maize distillers grains	0	121	243	364
Megalac	29	19	9	0
Urea	1	7	10	9
NDF (g/kg DM)	179	199	233	234
Crude protein (g/kg DM)	251	254	249	248
Oil B (g/kg DM)	57	52	53	45

Results There were no significant effects of the treatments on DM intake or digestion in the rumen of DM, organic matter (OM), neutral detergent fibre (NDF) or starch (Table 2). However there was a trend for digestibility of DM, OM and NDF to decline with increasing MDG inclusion. There were no significant effects on intake or digestion in the rumen of total N or the flow of non-ammonia N (NAN) to the duodenum.

Rumen VFA concentration and the molar proportion of acetic acid were lower on MDG 1.0 than the other treatments ($P<0.05$) but mean rumen pH and ammonia concentration were unaffected by treatments.

Table 2. *Dry matter intake, digestion in the rumen and N intake and digestion (one missing value for MDG 0.33)*

	MDG 0	MDG 0.33	MDG 0.67	MDG 1.0	s.e.d.
DM intake (kg/day)	17.29	16.73	17.38	17.63	0.845
Rumen digestion (g/g)					
DM	0.341	0.356	0.308	0.283	0.0373
Organic matter	0.433	0.443	0.404	0.377	0.0353
NDF	0.520	0.532	0.479	0.426	0.0475
Starch	0.820	0.790	0.787	0.822	0.0176
Total N intake (kg/day)	0.500	0.473	0.499	0.504	0.0247
Rumen N digestion (g/g)	-0.104	-0.075	-0.157	-0.184	0.0661
NAN flow at duodenum (kg/day)	0.503	0.465	0.527	0.548	0.0461

Milk yield (20.0, 21.9, 18.6 and 18.7 (s.e.d. 2.43) kg/day) and composition were unaffected by the treatments.

Conclusions It is concluded that when soyabean meal is completely replaced by MDG for lactating cows, the supply of non-ammonia N to the duodenum is unaffected. No significant effects on feed intake, digestion in the rumen or milk production were detected. However further work is needed to examine the tendency for NDF digestion in the rumen to decline and to measure the effects on milk production of cows in early lactation.

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Reference

Owen, F.G. and Larson, L.L. 1991. Corn distillers dried grains versus soyabean meal in lactation diets. *Journal of Dairy Science* **74:** 972-979.

The nutritive value of wheat for ruminants: Factors affecting starch content and availability to the rumen

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Introduction The current UK Recommended Lists For Cereals (Anon., 1997), include grain quality information on each variety outlining its potential value to the miller, baker or maltster. These grain quality measures are used as a basis for premiums paid to producers. However, no such standards exist for feed grains with the exception that contracts often indicate a minimum specific weight. This is in spite of the fact that feed grains account for 41% of wheat and 50% of barley sales from UK produced cereals. Usage may be increased if its nutritive value was better defined to include information such as the proportion of the starch that is rumen degradable and the rate of degradation of this starch in the rumen. It is vital to know the quantity of starch available to the rumen since it is a major source of energy for microbial protein synthesis (see Reynolds *et al*., 1997). This study aimed to use the *in vitro* automated gas production (GP) technique to estimate rate and extent of starch degradation from a large population of wheat grains obtained from wide ranging agronomic conditions and relate this to chemical and quality parameters.

Materials and methods Sixty-one samples of wheat grain were obtained from the 1996 harvest from a wide range of sites and grown under contrasting environmental and management conditions (yield and quality parameters were reported with these samples). The population comprised 13 varieties (11 'Hard' and two 'Soft'), grown at eight different sites. Samples were ground through a 3mm screen using a hammer mill (Christy Norris). Dry matter (DM), nirogen (N), starch and neutral detergent fibre were determined. The 61 samples of wheat were randomised across 7 runs, providing two replicates/sample, this was then repeated a further two times. Approximately 1.0g sample were incubated in buffered rumen fluid (0.2 rumen fluid) at 39^{O}C with agitation for 48h with GP logged every 15 min. 48h terminal pH and organic matter digestibility (OMD) were determined. After correction for the controls and sample DM content, gas volumes were fitted to the model of France *et al*. (1993) and effective OMD (EOMD) at 0.06 rumen outflow estimated. Cluster analysis was performed on EOMD and combined rate of GP and as a result a sub-population of 15 samples were identified for further analysis. The sub-population had 8 h GP, pH, SCFA and starch disappearance determined *in vitro*, and physical parameters including grain hardness (near infra-red reflectance spectroscopy (NIRS) at 1680 and 2230nm) and endosperm texture (light transflectance, steely or mealy). All samples were scanned by NIRS.

Results Grain N and starch content ranged from 10.3 to 25.8 and 641 to 814 g kg^{-1} DM respectively and were negatively correlated (Starch=906.5-8.89N, r^2=0.541) and EOMD ranged from 50.6 to 55.6%. Starch disappearance (mg at 8h, Y) was positively related to total GP at 8h (ml g^{-1} DM, X) Y=2.85X, r^2=0.649. This relationship was improved when endosperm texture was included (Y=84+0.265 mealy(%)+1.71 total gas at 8h (ml), r^2=0.765, SEP=0.0096). There was a poor relationship between starch disappearance (%) and total GP at 8h (r^2=0.208), which implies that the starch content of the grains has a strong influence on the amount of starch fermented *in vitro*. Endosperm texture (mealiness) was negatively correlated with grain hardness (r= -0.890) and both were negatively and positively correlated (respectively) with grain N content. Specific weight and N content could be predicted in the whole grain by NIRS (SEC=0.426, 0.044 r^2=0.976, 0.980, SECV=0.821, 0.054 r^2=0.910, 0.971 respectively).

Conclusion It can be concluded that the grain N content (which is influenced by N fertiliser application) will have a substantial influence on the amount of starch available for degradation in the rumen due to its negative affect on starch content. This implies that bread making (hard) wheats grown with high rates of fertiliser N will lead to a lower starch supply to the rumen. In addition, the characteristics of the starch in terms of mealiness and steeliness and any variety effect on hardness or softness will further influence the amount of starch available to rumen microbes. This work confirms that it is the texture of the starch within the endosperm along with starch content that are the main factors which determine the amount of starch disappearing *in vitro* and hence available from a particular sample of wheat. These findings provide the possibility that starch content and quality in wheat may be manipulated by crop management although further work is required on the factors which control protein deposition in the endosperm and hence the mealy/steely characteristic.

Acknowledgements Funding by HGCA is gratefully acknowledged.

References Anon., 1997. UK Recommended List For Cereals 1997. NIAB, Cambridge.

France, J., Dhanoa, M. S., Theodorou, M. K., Lister, S. J., Davies, D. R., and Isaac, D., 1993. A model to interpret gas accumulation profiles associated with *in vitro* degradation of ruminant feeds. *Journal of Theoretical Biology* 163: 99-111.

Reynolds, C. K., Sutton, J. D. and Beever, D. E., 1997. Effects of feeding starch to dairy cattle on nutrient availability and production. In: P. C. Garnsworthy (Ed) Recent Advances in Animal Nutrition 1997, Nottingham University Press, pp. 105-133.

Prediction of methane emissions from dairy cows using multiple regression analysis

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Introduction The UK is bound by the UN Framework Convention on climate change to reduce methane emissions to below 1990 levels by the year 2000. The Kyoto protocol requires a further cut of 12.5% by 2010. Ruminants are estimated to produce 74 Tg of methane per year (Benchar *et al*. 1998) which represents about 15% of total emissions (Crutzen *et al*., 1986). Therefore any reduction in the release of methane gas by enteric fermentation from the dairy herd is environmentally important. The objective of this study was to use data obtained from calorimetry trials to generate multiple regression equations predicting the levels and variability of methane emissions from dairy cows.

Materials and methods Data consisting of 840 daily values from a series of 6-day energy balance studies were taken and combined to provide 140 mean values for each individual balance period. The data were compiled from 10 feeding experiments covering lactation weeks 5 to 30 for cows with an average liveweight of 628 kg, and included daily measurements of methane over four 24-hour periods using open-circuit indirect respiration calorimetry similar to that described by Cammell *et al.* (1986). All diets were fed at or near *ad-libitum* and varied in type from maize silage with concentrates, whole wheat crop, fresh forage (zero grazed) and total mixed rations. Daily dietary intakes ranged from 13.8-28.4 kg of volatile corrected dry matter (VCDMI),12.7-26.3 kg organic matter, 276-524 MJ gross energy, 356- 848 g nitrogen, 1.90-6.65 kg starch, 4.81-10.28 kg NDF and 2.41-6.19 kg ADF. Hourly methane production ranged from 16.18-30.15 l/h with a mean and standard deviation of 23.83 l/h and 2.8 l/h respectively. The data were examined for relationships between diet, nutritional intakes and methane production using analysis of variance, analysis of covariance and stepwise multiple regression.

Results Analysis of variance showed that the individual feeding experiments had a significant effect on methane production ($P < 0.001$). When analysis of covariance was used to analyse the data it was shown that dietary intakes were significant covariates in predicting methane and that the actual feeding experiments were not significant factors. The analysis showed that if the diets were divided into silage based diets (n=125) and fresh forage based diets (n=15) that a more accurate equation could be obtained for silage based diets than if the all the data were combined. In the case of fresh forage based diets there were too few data to estimate a satisfactory equation, however, some positive correlations were observed between methane production and VCDMI ($P < 0.05$), organic matter intake ($P < 0.05$) and NDF intake ($P < 0.05$). Two regression equations have therefore been developed. The first to predict methane production from all diets, and the second to predict methane from silage based diets.

The best equation for all diets was (figures in parentheses are S.E. of coefficients);

CH_4 (MJ/d) = 1.36 + 1.21(0.120) VCDMI (kg) - 0.825 (0.263) DM from concentrates (kg) + 12.8 (6.62) ratio of NDF (kg) to VCDMI (kg) adj $R^2 = 0.54$, r.s.e = 1.97

The best equation for silage based diets was (figures in parentheses are S.E. of coefficients);

CH_4 (MJ/d) = -35.5 + 0.0216 (0.00331) N intake (g) + 27.6 (11.22) ratio of DM from silage (kg) to VCDMI (kg) + 1.63 (0.575) ratio of gross energy intake (MJ) to VCDMI (kg) adj $R^2 = 0.72$, r.s.e = 1.68

Conclusions The results showed that there are differences in the prediction equations between the chemical components of diets with methane production depending upon whether the forage component comprises either silage or fresh grass. The best equation for all diets showed a contrast between total dry matter intake and the proportion of dry matter arising from concentrates which suggests that methane production can be reduced by increasing the amount of concentrate dry matter in the total dietary dry matter. In this trial the ratio of concentrate dry matter to forage dry matter ranged between 0.37 and 1.09. For silage based diets the results showed that methane production is increased for diets containing high amounts of N, high gross energy intake and a high ratio of dry matter from ensiled forage to total dry matter. Although no satisfactory equation could be developed for fresh forage based diets several positive correlations between dietary components and methane production were observed. No correlation was observed between dry matter from fresh forage and methane, which is in contrast to the case of dry matter from ensiled forage and methane. This may, in part, be due to relatively few observations for fresh forage diets.

References

Benchar, C., Rivest, J., Pomar, C. and Chiquette, J. 1998. Prediction of methane production from dairy cows using existing mechanistic models and regression equations. *Journal of Animal Science* **76**:617-627.

Cammell, S. B., Thomson, D. J., Beever, D. E., Haines, M. J., Dhanoa, M. S. and Spooner, M. C. 1986. The efficiency of energy utilisation in growing cattle consuming fresh perennial ryegrass (*Lolium perenne* cv Melle) or white clover (*Trifolium repens* cv Blanca). *British Journal of Nutrition* **55**:669-680.

Crutzen, P. J., Aselmann, I. and Seiler, W. 1986. Methane production by domestic animals, wild ruminants, other herbivorous fauna and humans. *Tellus* **38B**:271-284.

Validation of the UK metabolisable energy system and other energy systems

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Introduction The UK metabolisable energy (ME) system for dairy cattle and net energy (NE) systems presently used in Europe and America were developed over 30 years ago. Recent studies have however indicated that these systems could under-predict the ME (ME_m) or NE (NE_m) requirement for maintenance for current dairy cows (e.g., Yan *et al.*, 1997). The objective of the present study was to validate these systems using calorimetric data produced with lactating dairy cows and published around the world since 1976.

Materials and methods Forty two published studies (more than 1500 individual animal data) were selected, in which dietary, animal and energy metabolism data are available. Experimental mean data were used to validate UK (AFRC 1990 and 1993) and Australian (SCA, 1990) ME systems and USA (NRC, 1988) and Dutch (Van Es, 1978) NE systems. AFRC (1993) is a working version of AFRC (1990) which adds proportionately 0.05 to total ME requirement predicted from AFRC (1990). Mean-square prediction error (MSPE) was used to compare the prediction accuracy of those systems between actual energy (ME or NE) intake (A_i) and predicted energy requirement (P_i) (equation 1),

$$MSPE = 1/n \sum(A_i - P_i)^2 = (A_m - P_m)^2 + S_P^2(1 - b)^2 + S_A^2 (1 - R^2) \quad (1)$$

where n is the number of pairs (n = 42); A_m or P_m is the mean of A_i or P_i, S_P^2 or S_A^2 is the variances of A_i or P_i; b or R is the slope or correlation coefficient of the linear regression of A_i on P_i. The three components are thus due to mean bias ($A_m - P_m$), line bias (the deviation of the slope) and random variation of the slope. In order to compare the accuracy of prediction between ME and NE systems, the MSPE is expressed as the mean prediction error ($MPE = (MSPE)^{1/2}/A_m$).

Results The results of the present validation are presented in Table 1. AFRC (1990) had the highest MPE, indicating that this prediction is the least accurate. The predicted error was largely derived from an under-prediction of total energy requirement, which resulted in a large ratio of mean bias/MSPE. The prediction of AFRC (1993), by adding proportionately 0.05 to the prediction of AFRC (1990), had however a similar accuracy to NRC (1988) and SCA (1990). Van Es (1978) had a marginally higher MPE than NRC (1988), SCA (1990) and AFRC (1993), because the former prediction had a higher mean bias and consequently a higher ratio of mean bias/MSPE. However, the approach of AFRC (1993) is highly questionable. The mean efficiency of ME use for lactation (k_l) predicted from AFRC (1990) was 0.63 and is similar to those reported elsewhere. The ME requirements for lactation and liveweight change predicted from AFRC (1990) are thus unlikely to be underestimated. The underestimated part is likely to be the ME_m. This would be supported in the validation of SCA (1990) which uses the same k_l as AFRC (1990) but a higher ME_m by adjusting it with total ME intake. In the 2 NE systems the efficiency of ME use for maintenance (k_m) is assumed to be same as k_l. This assumption however is biologically not correct, because research evidence indicates that k_m is higher than k_l (Van Es, 1978; AFRC, 1990), and could thus cover the under-prediction of NE_m with Van Es (1978) and NRC (1988). The metabolic rates are similar between Van Es (1978), NRC (1988) and AFRC (1990). These 42 experimental mean data were also used to estimate ME_m and k_l. The linear regression of $E_{l(0)}$ (milk energy output (E_l), corrected for energy balance (E_g)) against ME intake (MEI) ($E_{l(0)} = 0.637_{(0.036)}$ MEI $- 0.371_{(0.056)}$, R^2=0.89), and the multiple regression of MEI against metabolic liveweight (MW), E_l and E_g (MEI = $0.664_{(0.047)}$ MW + $1.452_{(0.076)}$ E_l + $1.079_{(0.120)}$ E_g, R^2=0.92), indicate a mean ME_m of 0.62 MJ/$kg^{0.75}$ and k_l of 0.66. The latter is similar to but the former is 0.27 higher than those predicted from AFRC (1990).

Table 1 Prediction precision of different energy systems in calorimetric data of dairy cows published since 1976 (n=42)

	Systems	Energy intake (MJ/d) Actual	Predicted	Bias	MSPE	MPE	Proportion of MSPE Bias	Line	Random
ME	AFRC (1990)	181	171	9.9	219	0.082	0.45	0.01	0.54
	AFRC (1993)	181	179	1.4	129	0.062	0.01	0.07	0.92
	SCA (1990)	181	182	-1.6	116	0.060	0.02	0.13	0.85
NE	Van Es (1978)	110	106	3.6	56	0.068	0.23	0.03	0.74
	NRC (1988)	112	111	0.5	43	0.059	0.01	0.07	0.92

Conclusions Maintenance energy requirements predicted from AFRC (1990), Van Es (1978) and NRC (1988) are likely to be lower than for present dairy cows. The assumption that k_m is equal to k_l in Van Es (1978) and NRC (1988) can cover the under-prediction of NE_m.

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References AFRC. 1993. Energy and protein requirements of ruminants. CAB International, Wallingford, Oxon, UK.
AFRC. 1990. Technical Committee on Responses to Nutrients, Report No 5. *Nutrition Abstracts & Reviews-B* **60**: 729.
NRC. 1988. Nutrient requirements of dairy cattle. Sixth revised edition, National Academy Press, Washington, D. C.
SCA. 1990. Feeding standards for Australian livestock - Ruminants. CSIRO, Australia.
Van Es, A. J. H. 1978. Feed evaluation for ruminants. *Livestock Production Science* **5**:331-345.
Yan, T., Gordon, F.J., Agnew, R.E., Porter, M.G. and Patterson, D.C. 1997. *Livestock Production Science* **51:**141-150.

The effects of sequence of feed allocation within the day on microbial protein production and diet digestibility in lambs fed barley or sugar beet based diets

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Introduction Feeding lambs diets formulated to be synchronous in terms of hourly energy and protein supply to the rumen has been reported to improve the efficiency of energy utilisation (Richardson *et al.* 1999). In a previous study Sinclair *et al*. (1995) reported that the efficiency of microbial protein production was improved when animals were fed a synchronous diet. The objectives of the present study were to investigate whether the changes in metabolism reported by Richardson *et al*. (1999) may be related to rumen microbial protein production and diet digestibility.

Materials and Methods Twenty four entire male lambs with an initial live weight of *c.* 25kg were randomly allocated to one of 6 diets in a 2 x 3 factorial design, the factors being energy source (barley (B) or unmolassed sugar beet pulp (P)) and synchrony (synchronous (S), intermediate (I) or asynchronous (A)). Diets B and P were formulated based on the *in situ* degradability of nitrogen (N) and organic matter (OM) of 5 feed ingredients (Table 1) and had predicted ME contents of 10.4 and 10.3MJ/kgDM and CP contents of 154 and 157g/kgDM respectively. Lambs were fed 1kg fresh weight per day in two equal meals at 09.00 and 16.00h. Within each energy source, differences in synchrony were achieved by feeding equal quantities of energy in each meal, and altering the pattern of supply of the protein components of the diets such that animals received either: equal quantities of protein in each meal (S), slowly degradable protein in the morning and rapidly degradable protein in the evening (I), or the majority of the protein in the morning (A). The trial consisted of two periods of 21 days, each one having a 9 day period of adaptation to the experimental diet during which lambs were housed in individual pens, a 5 day period for adaptation to the metabolism crates, and a 7 day collection period, during which total urine and faecal collection was carried out. Urine was analysed for N and purine derivatives (PD), and feed and faeces for N, OM and neutral detergent fibre (NDF). Results were analysed using analysis of variance.

Table 1. *Diet formulation (g/kgDM).*

	B	P
Sugar beet pulp	0	412
Barley	420	0
Wheat straw	320	300
Distillers grains	164	60
Rapeseed meal	60	199
Urea	12	5
Vits & Mins	24	24

Results Lambs on the barley diets had a significantly higher level of PD excretion and microbial N production than lambs on the P diets ($p<0.05$). Within energy source however, there were no significant differences (Table 2). OM and NDF digestibility were significantly higher in lambs on the P diets ($p<0.001$). Lambs on diet P retained significantly more N (g/d) than lambs on diet B ($p<0.001$) and the proportion of N intake retained was also significantly greater in the lambs on diet P ($p<0.005$).

Table 2. *Microbial N production, diet digestibility and N balance of lambs fed diets based on different energy sources (E) at different levels of synchrony (Syn).*

								Significance	
	BS	BI	BA	PS	PI	PA	s.e.d.	E	Syn	Interaction
Purine excretion (mM/d)	16.4	13.1	13.7	10.79	11.49	9.61	1.57	***	NS	NS
Microbial N (g/d)	14.2	11.3	11.8	9.2	9.8	8.2	1.39	***	NS	NS
N digestibility	0.67	0.71	0.69	0.69	0.70	0.68	0.016	NS	NS	NS
OM digestibility	0.62	0.63	0.64	0.67	0.67	0.66	0.012	***	NS	NS
NDF digestibility	0.41	0.44	0.44	0.63	0.63	0.60	0.026	***	NS	NS
N intake (g/d)	21.5	22.5	21.3	22.5	22.5	22.3	0.32	***	***	***
Faecal N output (g/d)	7.10	6.43	6.56	7.03	6.68	7.07	0.369	NS	NS	NS
Urinary N output (g/d)	8.65	8.75	10.56	8.76	9.17	6.88	1.072	NS	NS	*
N retained (g/d)	5.73	7.28	4.18	6.66	6.61	8.35	0.946	*	NS	*
N retained (g/g intake)	0.27	0.33	0.20	0.30	0.29	0.37	0.044	*	NS	*

Conclusions Dietary synchrony had no significant effect on microbial N production or N balance. Although microbial N production was higher on the rapidly degradable energy source (B), N retention was greater on the slowly degradable energy source (P). Within diet B the similarity in OM and NDF digestibility indicates that the improvement in energy metabolism in lambs fed the synchronous diet as reported by Richardson *et al.* (1999) was not due to an improvement in energy digestibility.

References

Richardson, J. M., Sinclair, L. A. and Wilkinson, R. G. 1999. The effects of sequence of feed allocation within the day on the growth and carcass characteristics of lambs fed barley based diets. *Proc. British Society of Animal Science.*

Sinclair, L. A., Garnsworthy, P. C., Newbold, J. R. and Buttery, P. J. 1995. Effects of synchronising the rate of dietary energy and nitrogen release in diets with a similar carbohydrate composition on rumen fermentation and microbial protein synthesis in sheep. *Journal of Agricultural Science, Cambridge* **124:** 463-472.

Effect of diets formulated to contain similar amounts of ERDP with different protein sources on blood free and peptide-bound amino acid-N concentrations in Iranian Baloochi lambs

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Introduction Recent data indicate that rumen fluid contains a relatively high concentration of peptide nitrogen and that it is influenced by the source of protein in the diet (Mesgaran & Parker, 1995). In addition, it has been demonstrated that ruminant gastrointestinal tract may have the potential for absorbing intact peptides, and that the hydrolysis rate of the peptides is influenced by peptide structure in the blood (Mesgaran, 1996; Mesgaran & Parker, 1996). The objective of the present experiment was to investigate the effect of altering the sources of protein in diets with similar effective rumen degradable protein (ERDP), on blood free and peptide-bound amino acid-N (FAA-N and PBAA-N) concentrations in Iranian Baloochi lambs.

Materials and Methods Four Iranian Baloochi lambs weighing 33±1.3 Kg, each with a permanent rumen fistula, were fed twice daily with diets differing in protein sources in a 4^2 latin square design. The diets consisted of a basal diet of chopped lucerne, barley and sugar beet pulp (190, 230 and 170 g DM d^{-1}, respectively) which was supplemented with lucerne (L), cottonseed meal (C), soybean meal (S) or molasses+urea (M+U) (210, 118, 84 and 80+9 g DM d^{-1}, respectively). The diets provided similar ERDP (87 g Kg^{-1} DM). Blood samples were taken by jugular venipuncture into heparinized evacuated tubes at 0.0, 1, 2, 3, 4 and 6 hours after the morning feed. Plasma samples were prepared for FAA-N and PBAA-N analysis using sulphate-tungstate method described by Chen et al. (1987). Tungstate acid-precipitate nitrogen was assayed by a standard macro-Kjeldahl procedure. Data were analyzed as a change-over design using the general linear model procedure of SAS (1989).

Results The FAA-N and PBAA-N concentrations at each sampling time are shown in the Table. The protein sources did not significantly influence the quantity of blood FAA-N and PBAA-N. However the average blood PBAA-N concentrations was notably higher compared to FAA-N during the sampling times.

Table Jugular blood FAA-N and PBAA-N concentrations (mg $litre^{-1}$) in Iranian Baloochi lambs fed diets differing in protein sources but similar in effective rumen degradable protein

Time (h)	Treatments								SEM		Statistical significant	
	L		C		S		M+U					
	FAA	PBAA	FAA	PBAA	FAA	PBAA	FAA	PBAA	FAA	PBAA	FAA	PBAA
0	79	162	93	150	112	162	116	160	16	30	NS	NS
1	86	275	83	178	80	213	134	232	10	56	NS	NS
2	68	144	75	195	72	98	94	136	20	44	NS	NS
3	71	145	82	151	98	105	99	80	9	19	NS	NS
4	115	104	90	202	66	113	129	274	20	131	NS	NS
6	80	120	75	120	69	88	117	243	23	52	NS	NS

Conclusions Under the conditions of this experiment, it is concluded that the pattern of blood FAA-N differed markedly from the PBAA-N concentrations. In addition, the nature of the protein sources did not significantly influence the blood FAA-N and PBAA-N concentrations when diets provided similar amounts of ERDP. In the present study, the highest peptide-N concentrations were generally observed during 1 hour after feeding. Therefore, it may be important to consider the physiological aspects of these variations in the metabolism of peptides in the blood.

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References

Chen, G., Russell, J. B. and Sniffen, C. J. 1987. A procedure for measuring peptides in rumen fluid and evidence that peptide uptake can be a rate-limiting step in ruminal protein degradation. *Journal of Dairy Science.* **70:**1211-1219.

Mesgaran, M. D. and Parker, D. S. 1995. The effect of dietary protein and energy sources on ruminal accumulation of low molecular weight peptides in sheep. *Animal Science.* **60:** 535.

Mesgaran, M. D. 1996. Ruminal accumulation and fate of low molecular weight peptides in sheep. PhD Thesis, University of Newcastle upon Tyne.

Mesgaran, M. D. and Parker, D. S. 1996. Influence of dipeptide structure on hydrolysis by rumen fluid and blood of sheep. *Animal Science.* **62:** 669-670.

The maize crop as a source of food and feed for livestock on smallholder dairy farms in the Kenyan highlands

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Introduction A major constraint on smallholder dairy farms in Kenya is inadequate feed supply resulting in low productivity. In Kiambu district of the Central Highlands, principal feed resources are cultivated Napier grass, roadside grass and fodder from maize, including stover and higher quality thinnings cut during the growing period. An average farmer in Kiambu owns 0.8 ha of which 0.19 and 0.17 ha are dedicated to Napier and maize cultivation, respectively, and 2.2 cows producing 5.8 kg milk/day (Staal *et al.* 1998). Meeting the feed requirements of the dairy animals, while maintaining food production is already a challenge. There are indications that the maize crop will become increasingly important as a source of fodder (Staal *et al*. 1998). Methu (1998) showed that by planting 4 rather 2 maize seeds per hole, 1.9 t DM/ha of thinnings, with high energy and N content could be harvested without affecting significantly the yields of stover or grain. The present study explored further the potential of increasing production of good quality thinnings without jeopardising grain yield in a series of on-farm trials.

Materials and Methods Individual experiments were carried out on three farms. Each had the same basic design, a 2 X 2 factorial with seed density (high and low) and manure/fertiliser rate (high and low) as the two factors, each treatment being replicated four times. The sixteen plots of 6x4 m were laid out in a randomised block design. Farmers defined actual rates (low levels reflecting current farmer practice) and made all decisions concerning subsequent maize management. The role of researchers was to take quantitative measurements of DM offtake as thinnings, stover and grain. Data from each farm were analysed separately using analysis of variance.

Results On farms F1-3, plant density increased by 50, 71 and 17% respectively at the higher seed rate. All farmers applied similar rates of manure (5.4-6.9 t DM/ha) and fertiliser (69-105 kg N/ha) to the control plots. However, increases varied, F1-3 increasing manure 100, 100 and 200% and fertiliser rates by 18, 20 and 0%, respectively. Increasing seed rate increased thinning production ($p<0.05$) by up to 2.4 t DM/ha, representing increases of 48, 166 and 59% for F1-3 respectively (Table1). F2 and F3 both stated that the thinning regime employed was driven largely by animal needs at a time when fodder supply was not plentiful. In contrast, F1 sold most of the thinnings, suggesting that the thinning was driven by crop needs. While the quantity of thinnings increased, total amounts of dry stover did not change significantly. Grain yields were only changed for F2, while increasing seed rate ($p<0.001$) and manure/fertiliser rate ($p<0.01$) both resulted in an increase in yield.

Table 1 Means of dry matter production for fodder and grain (t/ha) showing main effect means for each farm

		Total thinnings			Total stover			Grain yield		
		F1	F2	F3	F1	F2	F3	F1	F2	F3
Seed	Low	3.59	1.45	3.49	5.42	6.80	4.71	8.54	5.41	6.16
rate	High	5.31	3.85	5.54	6.78	8.31	3.77	10.64	9.46	5.10
Manure	Low	4.88	2.71	4.23	5.29	7.03	4.32	8.31	6.11	5.88
Rate	High	4.02	2.59	4.79	6.91	8.18	4.16	10.88	8.76	5.29
Sed	Main	0.679	0.296	0.394	0.975	1.171	0.618	1.516	0.944	0.934
	Interaction	0.960	0.418	0.557	1.379	1.656	0.874	2.144	1.335	1.321
	Seed	*	***	*	ns	ns	ns	ns	***	ns
Sig.	Manure	ns	ns	ns	ns	ns	ns	ns	**	ns
	Interaction	*	ns	ns	ns	ns	ns	ns	**	ns

Conclusion Methu (1998) reported CP contents of 170 and 105 g/kg DM for early and late thinnings compared to 56 g/kg for stover. Results from the present trial indicate that increasing plant density might increase quantity of good quality fodder by 48-166% depending on the plant density. Even at the lowest thinning yield of 1.45 t DM/ha, a farmer with 0.17 ha maize could produce an additional 118-409 kg DM which, using an ME value of 8.3 MJ/kg DM, could provide maintenance requirements for 19-66 days for a typical dairy cow in Kiambu which weighs 350 kg.

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References Methu J.N (1998) Strategies for utilisation of maize stover and thinnings as dry season feed for dairy cows**.** *PhD thesis, Reading University.*
Staal S.J., Chege L., Kenyanjui M., Kimari A., Lukuyu B., Njubi D., Owango M., Tanner J., Thorpe W. and Wambugu M. (1998). Characterisation of dairy systems supplying the Nairobi milk market : A pilot survey in Kiambu district for the identification of target producers. *KARI/MoA/ILRI Collaborative Research Project Report*

Effects of the addition of polyunsaturated fatty acids on rumen degradation of dry matter and neutral detergent fibre of Guinea grass (*Panicum maximum*) in Pelibuey sheep.

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Introduction. Fat is often fed to sheep and cattle as a means to increase dietary energy concentration. There is increasing interest in the supplementation of ruminant diets with fats and oils. However feeding fat may reduce dry matter digestibility, and feeding ruminant animals large quantities of fat (>5% of total dry matter intake) can result in a marked negative effect on fibre and dry mater intake. The aim of the present study was to investigate the effect of fat supplementation on ruminal degradation of dry matter (DM) and neutral detergent fiber (NDF) of sheep fed a tropical hay.

Materials and Methods. Eight rumen cannulated Pelibuey rams (36.5 ± 5.6 kg) housed in metabolic crates were used in a 4x8 latin rectangle design (Mead *et al.*, 1993). The rams were fed *ad libitum* with guinea grass (*Panicum maximum*) hay, and 300 g of a protein supplement containing 0, 4, 8 or 12% maize oil which gave 0, 1.2, 2.1 or 3.0 % corn oil in total dry matter of the whole diet. The diet was offered daily (1 kg of hay at 0800h) for fourteen days, nine days adaptation and five days for incubation of nylon bags. To evaluate the effect of addition of long chain fatty acids on degradation of DM and NDF, samples of 6 g of guinea grass were incubated for 6, 12, 24, 48, 72 and 96 h in the rumens of the rams given these four diets (giving eight replicates per dietary treatment). Analysis of variance was carried out with the General Lineal Models procedure of the Statistical Analysis System (SAS; Inc, 1987). Differences between means were assayed with the Tukey test and statistical significance was declared at $P<0.05$.

Results. No overall significant differences (F test, Table 1) were observed in rumen degradation of DM and NDF of guinea grass when corn oil was incorporated in the supplement. However when paired 't' tests were applied, the fractional rate constant 'c' was lower ($P<0.05$) with 3% oil addition than with the 0, 1.2 and 2.1% oil treatments. The potential degradability (a + b) of the grass was not changed. This would conform with the concept that the high level of oil affected the rumen environment (slowing down degradation), but did not affect potential degradability which is predominately a characteristic of the material being incubated. This was reflected in the 'a' values (zero time intercept of the curve) which were higher ($P<0.05$) when the 'c' values were lower (a flatter degradation curve), (Table 1). Rumen degradation of NDF ranged from 30.47 to 36.51% when corn oil was incorporated in the supplement regardless of the level of oil in the supplement.

Table 1. Effect of incorporation of corn oil in the diet on rumen degradation of DM of guinea grass in Pelibuey sheep (n = 8)

Rumen degradation constants†	Level of incorporation of corn oil in the diet (%)					
	0	**1.2**	**2.1**	**3 0**	**SEM**	**P (F test)**
a (%)	8.8	12.0	8.2	15.4	1.72	NS
b (%)	41.4	39.4	39.1	35.0	1.71	NS
a + b (%)	50.3	51.5	47.3	50.4	1.84	NS
c (/h)	0.063	0.045	0.055	0.038	0.005	NS

† When degradation 'P' after 't'hours is given by $P = a + b (1-\exp^{-ct})$

Conclusion. From the results described above, it can be concluded that when low levels of corn oil were incorporated in the supplement there was no effect on rumen DM or NDF degradation of guinea grass fed to Pelibuey sheep. However at an inclusion rate of 3.0% there were indications that the rumen environment was adversely affected..

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References

Mead R, Curnow RN, Hasted AM (1993). Statistical Methods in Agriculture and Experimental Biology. Second Edition. Texts in Statistical Science. Chapman & Hall. pp 78-87.
Sas Users Guide: Statistics (1987). Cary, North Caroline. SAS Institute Inc. USA.

Intake and apparent digestibility of hay, haylage, big bale and clamp silage by ponies

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Introduction

Grass hay is the traditional conserved fodder fed to horses in the UK, yet good quality hay is often scarce and expensive. Working or breeding equines often require a higher plane of nutrition than that provided by hay, yet feeding high levels of concentrates can lead to a number of metabolic disorders such as colic and laminitis. Furthermore, the high dust content of hay can elicit the onset of the debilitating disorder, chronic obstructive pulmonary disease. Thus, there is increasing interest in feeding horses forage-based diets which are both low in dust and have enhanced nutritive values. The aim of this experiment was to determine the intakes and digestibility of four types of conserved forage by ponies.

Materials and Methods Four mature Welsh pony geldings (*c*. 320-370 kg LW) were used in a 4 x4 Latin square experiment consisting of four, 28 day periods, a 23 day adaptation phase followed by a 5 day collection phase. One of four ryegrass-based forages, hay (H), haylage (HY), big bale silage (BB) or clamp silage (CS) were offered to ponies in two equal meals at 0800 and 2000 hours at 1.65kg DM/100kg LW/d. Water was available *ad libitum.* Ponies were weighed weekly. Lyophilised feed and faecal samples were analysed for DM, ADF, NDF, and CP. Sample total non-starch polysaccharides (TNSP) were measured by the method of Englyst and Cummings (1984) and apparent digestibilities of nutrients were calculated.

Results. The chemical composition of the four feeds in the following order, H, HY, BB, CS were (g/kg DM) CP, 44, 70, 11,154; ADF, 410, 359, 389, 357; NDF, 529, 602, 654, 557; Total NSP, 408, 293, 405, and 353 . The corresponding DM were 922, 676, 500, 337. Pony liveweight, diet component digestibilities and daily intakes of nutrients are shown in Table 1. Digestibilities of all nutrients were significantly higher from HY, BB and CS compared with hay, and those of CP, ADF, NDF and TNSP were significantly greater from CS than either H or HY. Intakes of CP and GE were greatest from HY and BB and elicited the highest liveweights. Although DM intakes of CS were significantly lower than from the other feeds, in terms of digestible nutrients, intakes of DCP from CS were similar to and greater than those from HY and H respectively whereas intakes of digestible GE from CS was similar to that from H.

Table 1. Pony liveweight, nutrient apparent digestibilities and daily intakes of energy and protein

	H	**HY**	**BB**	**CS**	**Sed**	**Significance**
Liveweight (kg)	333^{a}	340^{b}	341^{b}	317^{a}	8.99	*
Digestibility (g/kg DM)						
DM	389^{a}	570^{b}	610^{b}	667^{b}	46.0	*
CP	198^{a}	484^{b}	664^{c}	676^{c}	41.3	*
ADF	311^{a}	451^{ab}	574^{bc}	668^{c}	61.8	*
NDF	333^{a}	470^{ab}	582^{bc}	661^{c}	58.3	*
TNSP	412^{a}	448^{a}	668^{b}	757^{b}	64.8	*
GE	331^{a}	519^{b}	553^{bc}	646^{c}	48.5	*
Intakes (per kgW $^{0.75}$ per d)						
Dry matter (g)	62.9^{a}	79.2^{b}	74.6^{ab}	38.8^{c}	6.06	*
Digestible energy (MJ)	0.388^{a}	0.715^{b}	0.734^{b}	0.460^{a}	0.0787	*
Crude protein (g)	34^{a}	212^{b}	447^{c}	306^{b}	51.5	*

^{abc}, values in the same row not sharing common superscripts are significantly different, $p<0.05$

Conclusions The high nutritive value and intakes of BB and HY would reduce the requirement for feeding concentrates for working or breeding equines, and together with their relatively low DM and therefore dust contents, these feeds would be suitable for all classes of equine.

Reference Englyst,H.N. and Cummings J.H.(1984). Simplified method for the measurement of total non-starch polysaccharides by GLC of constituent sugars as alditol acetates. *Analyst* **9:**937-942

The effect of feeding dairy cattle during the transition phase on dry matter intake, blood metabolites, milk yield and milk composition

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Introduction Feeding the dairy cow during the transition phase (dry to lactating) has been found to effect subsequent feed intake and milk yield (Moorby *et al*., 1996; Olsson *et al*., 1998). The aim of this study was to compare the effect of feeding a liquid feed during the prepartum period on; feed intake, milk yield, milk composition, live weight loss and blood metabolite levels.

Materials and methods 36 Holstein Friesian cows were selected from the Seale-Hayne dairy herd at random and allocated at 25 days prepartum, in pairs according to calving date, to one of two dietary treatments. 18 cows were given a liquid form 'transition' feed (2.0 litres /head/day) (Trans) and 18 cows were given a dry cow mineral supplement at 100g /head/day (MinS). These feeds were added to a total mixed ration (TMR) basal diet, which consisted of grass silage, maize silage (80:20 ratio) and either 2 kg of barley straw (MinS) or 3 kg of barley straw (Trans) /head/day. The two diets were isoenergetic. At parturition, cows all received a TMR *adlibitum* consisting of grass and maize silage (50:50 ratio) 2.5 kg of a 38 % crude protein (CP) supplement, 2 kg of wheat and 2 kg of 'stockmol 20'. In addition, cows received a maximum of 8 kg of concentrated feed (22 % CP) in the parlour. The two treatment groups were balanced for previous milk yield, milk composition, lactation number, condition score and live weight. Individual daily feed intake and feeding pattern was recorded electronically for 21 days prepartum and 56 days postpartum. Live weight and milk yield were recorded daily, milk composition was recorded twice weekly using composite samples from two consecutive days. Condition score was recorded weekly (1 - 5 scale). Blood BHB, NEFFA, urea, Ca, insulin and glucose levels were measured weekly for two weeks prepartum and 3 weeks postpartum. Data were found to be normally distributed and treatment means were compared, using animals as individual observations, by ANOVA, General Linear Modelling.

Results

Table 1. *Mean feed intake, milk yield, milk composition and metabolite levels*

	Trans	MinS	SEM	Significance
Daily intake (FM)	55.4	51.1	0.72	*
Peak milk yield (kg)	42.1	39.7	0.31	*
Daily mean yield (kg)	30.1	28.2	0.18	*
Milk fat (g/kg)	40.1	41.0	1.03	NS
Milk protein (g/kg)	32.5	32.8	0.52	NS
Lactose (g/kg)	49.1	47.0	0.41	NS
Liveweight loss (kg)	45.1	50.5	0.23	*
Condition loss (1-5)	1.13	1.50	0.12	NS
NEFA (µmol/l)	180	320	20.1	*
BHB (mmol/l)	0.32	0.41	0.06	NS
Urea (mmol/l)	3.1	3.2	030	NS
Glucose (mmol/l)	3.1	2.9	0.02	*
Insulin (µIU/ml)	9.7	11.6	0.91	NS
Calcium (mmol/l)	2.27	2.31	0.03	NS

Cows fed transition feed had significantly greater fed intake, milk yield and blood glucose levels compared with cows fed mineral supplements. Feeding transition feed resulted in cows having significantly lower blood NEFA levels and mobilising lower levels of liveweight. Insulin and calcium levels were not significantly affected by dietary treatment.

Conclusion The feeding transition liquid feed increased levels of feed intake and milk yield compared with feeding minerals. This increase milk yield was probably due to increased energy and protein intake and a reduced negative energy balance during the postpartum period.

References

Moorby, J. M, R. J. Dewhurst and S. Marsden. 1996. Effect of increasing digestible undegraded protein supply to dairy cows in late gestation on the yield and composition of milk during the subsequent lactation. *Animal Science.* **63**:201-213.

Olsson, G. Emanuelson, M., Wiktorsson, H. 1998. Effects of differing nutritional levels prepartum on the subsequent performance of dairy cows. *Livestock Production Science.* **53**:279-290.

The effect of choice feeding during the rearing period on reproductive function in the gilt

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Introduction Previous studies (e.g. Cia et al. 1998) have shown that modification of body composition of the pre-pubertal gilt has effects on responsiveness of gilts to exogenous gonadotrophin. Growing pigs are able to select a diet from different foods differing in protein:energy ratio (Dalby 1998); however there is little evidence of what effect the conflicting nutritional demands of growth and reproduction have on diet selection. The objectives of the experiment were to quantify the effects of choice feeding on responsiveness of gilts to exogenous gonadotrophin (Cia et al. 1998) and to investigate the effect of protein source on diet selection as Jones et al.(2000) have observed selection by breeding gilts against a high protein diet containing fishmeal.

Materials and Methods A total of 36 gilts (Large White x Landrace) were selected from the breeding herd in three blocks of 12 at approximately 114 days of age. Gilts were blocked by weight and assigned to pens each containing 3 animals. After a training period of 6 days with alternating diet, each pen was assigned to one of two choice-feeding treatments. The treatments were a choice between a Low protein diet (140g CP, 13.1 MJ DE and 4.8g lysine / kg) and one of two High protein diets (247g CP, 13.1 MJ DE and 10.5 g lysine / kg); the High protein diets contained different protein sources, fishmeal (Fish) or potato protein (Potato). Individual live-weights and back-fat thickness (P2) and pen intakes of Low and High feeds were recorded weekly. Puberty (first oestrus) was induced by injection of gonadotrophin (PG600) on day 160. Heat detection was carried out twice daily with a mature boar. Gilts were slaughtered at 193 days of age, after recording signs of a second spontaneous oestrus, reproductive tracts recovered and ovaries sectioned and corpora lutea (CL) and albicantia (CA) counted. Data were analysed using a randomized block design. Relationships between numbers of CA and CL and body composition were analysed using multiple stepwise regression.

Results Gilts offered a high protein diet containing fishmeal consumed more high protein diet overall ($P<0.05$). As a result, gilts fed the fishmeal containing diet tended to grow faster particularly prior to puberty induction (weeks 0-6, $P=0.07$). Regardless of type of protein supplement, gilts selected a diet containing a lower proportion of the high protein diet ($P<0.001$); the proportion of high protein diet selected increased from 0.18 (week 1) to 0.38 (week 6) prior to puberty induction but then declined to 0.24 (week 10; quadratic effect, $P<0.001$). The proportion of gilts responding to puberty induction (30/35) was greater ($P<0.05$) than those displaying a natural second oestrus (14/34) but these were unaffected by the nature of high protein supplement offered. Numbers of CA (13 sd 5.7) were less ($P<0.05$) than CL (16 sd 3.9) but were unaffected by the protein source fed. Overall, ovulation rate at first oestrus (CA) was not influenced by gilt body composition but at second oestrus (CL) was significantly ($P<0.01$) correlated with live-weight (kg) at puberty induction and predicted empty body fat gain (kg) during weeks 0 to 6:

$$CL = 2.41 + 0.37 \text{ Weight} - 1.92 \text{ fat gain } (r^2\ 0.55,\ P<0.05,\ n=14)$$

Week	0-6			7-10			Overall		
	Fish	Potato	sed	Fish	Potato	sed	Fish	Potato	Sed
Gain (kg/day)	0.92	0.81	0.051	1.10	0.99	0.090	0.99	0.89	0.064
Intake (kg/day)									
Total	2.72	2.49	0.176	3.08	2.82	0.213	2.87	2.66	0.183
High protein	0.94	0.64	0.136	0.87	0.77	0.128	0.91	0.69	0.091
High/Total	0.35	0.26	0.062	0.29	0.27	0.050	0.32	0.26	0.043
FCR	2.97	3.09	0.127	3.09	2.97	0.315	3.13	2.98	0.279

Conclusions Breeding gilts selected a diet which changed as weight increased and in response to puberty induction and was dependant on the type of protein source offered. Type of protein did not influence reproductive performance but body composition at puberty induction did influence ovulation rate at the second (natural) oestrus.

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References

Cia, M. C., Edwards, S. A., Glasgow, V. L., Shanks, M. and Fraser, H. 1998. Modification of body composition by altering the dietary lysine to energy ratio during rearing and the effect on reproductive performance of gilts. *Animal Science* **66**:457-463.

Dalby, J. A. 1998. Behaviour and choice feeding. In *Progress in Pig Science (*ed. J. Wiseman, M. A. Varley and J. P. Chadwick) pp.183-208.Nottingham University Press, Nottingham.

Jones, G. M., Edwards, S. A., Sinclair, A. G., Gebbie, F. E., Rooke. J. A., Jagger, S. and Hoste, S. 2000. Litter performance and glucose tolerance in lactating gilts of two different genotypes in response to choice-feeding in the pre-pubertal stage and pregnancy. *Proceedings of the British Society of Animal Science 2000.*

Litter performance and glucose tolerance in lactating gilts of two different genotypes in response to choice-feeding in the pre-pubertal stage and pregnancy

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Introduction The extent to which young sows, which still have a strong drive to continue maternal growth, partition nutrients from body reserves towards milk production, may be influenced by their genetic growth target. Modern genotype sows, with a high mature body protein mass, are thus particularly challenged. It has been suggested that to optimise their metabolic state for expressing lactational potential they will have to achieve a satisfactory proportion of their mature body protein mass before farrowing. This could be constrained by current feeding and breeding regimes. To test this hypothesis, gilts of genotypes differing in their body protein:lipid content were given the choice between a low and a high protein diet during rearing and pregnancy, and their intake, subsequent performance and metabolic state in lactation were measured.

Materials and Methods 48 gilts, of which 24 were of lean (L) genotype (NPD 402, high protein:lipid ratio) and 24 of a more obese (F) genotype (Camborough 23, lower body protein:lipid ratio) were allocated to one of two dietary treatments at a mean weight of 74.5kg (s.e.m.1.51). 12 gilts of each genotype were either fed a control (R) regime (conventional diets fed ad libitum during rearing and restricted in pregnancy to 2 kg/d) or fed ad libitum and given the choice (C) between a low (120g/kg CP) and a high protein diet (218g/kg CP), which were isoenergetic, until puberty and throughout pregnancy. During lactation sows were fed either a diet supplying adequate amounts of nutrients to yield 8kg milk /d (HE) or a diet deficient in energy (0.67 of HE). Sows and piglets were weighed individually on a weekly basis from farrowing to weaning at 28 days. Sows were also ultrasonically measured for backfat thickness and eye-muscle depth at the P_2 site. On day 13 post partum, glucose infusions (0.5g/kg body weight) were carried out via ear vein catheters in a subsample of sows (25) for a glucose tolerance test. Milk composition produced by sows was determined from samples manually extracted after the administration of oxytocin on 5 days across lactation. Data were analysed by analysis of variance using genotype and feeding regimes as factors.

Results During rearing, feed intakes were similar for all treatments. However, C gilts chose predominantly the low protein diet (92%), and thus had a lower protein intake than R gilts relative to energy, irrespective of genotype (Table 1). This choice continued throughout the whole of pregnancy but, because of the higher feed intakes compared to R gilts, overall energy and protein intakes were higher in C gilts. This resulted in heavier and fatter animals with greater eye-muscle depth at farrowing. Dietary treatments pre-lactation and during lactation had no effects on piglet performance, despite increased milk energy content ($P<0.05$) in C gilts. L gilts had a lower ($P<0.05$) P/E ratio in milk than F gilts and weaned lighter piglets irrespective of dietary treatments. Glucose tolerance in lactation was not affected by genotype. C gilts had higher ($P<0.01$) peak glucose levels than R gilts (18.3v15.6, s.e.d. 0.61). Insulin response to glucose challenge showed large variation between individuals and was not significantly affected by sow treatments.

Table 1 Gilt and piglet measurements in response to main treatments

	L	F	sed	R	C	sed
Feed intake (kg/d)[1]	3.06	3.08	0.13	3.16	2.99	0.13
P/E (g/MJ)[1]	11.6	11.7	0.20	14.0	9.3	0.20***
Feed intake (kg/d)[2]	3.47	3.69	0.33	2.10	3.58	-
P/E (g/MJ)[2]	8.9	9.0	0.13	10.6	9.0	-
Sow weight (kg)[3]	206	215	6.26	193	228	6.14***
Sow backfat (mm)[3]	22.3	22.9	1.52	19.1	26.1	1.49***
Eye-muscle (mm)[3]	94.9	86.7	2.35**	84.4	97.2	1.67***
Milk energy (MJ/kg)	6.3	6.1	0.14	6.4	6.1	0.14*
Milk P/E (g/MJ)	7.5	8.1	0.23*	7.9	7.8	0.22
Litter growth (kg/d)[4]	1.61	1.84	0.10*	1.69	1.76	0.09
Litter weaning wt (kg) [4]	58.3	65.4	2.83*	59.8	64.0	2.74

[1]pre-puberty, [2]pregnancy, [3]at farrowing, [4]litter size co-variate

Conclusion Gilts of both genotypes appeared to be energy rather than protein limited in the pre-lactational stages as indicated by the choice of diet. However, the selected dietary nutrient intakes gave no advantage in terms of partitioning of nutrients towards milk production, as indicated by litter performance, despite large differences in body composition of gilts at farrowing. This was further supported by relatively little difference in metabolic state between treatments. Lactation performance showed no genotype by dietary treatment interactions.

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The effect of feeding sows an increased feed level from day 28-56 of gestation on progeny performance

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Introduction The consumption and utilisation of feed during the growth period from 40-100 kg live weight, is a major determinant of efficient pig meat production. It has been previously observed that feed inputs to the sow at different phases of gestation, can profoundly influence the efficiency of lean tissue deposition in progeny through changes to foetal development (Dwyer et al 1994). The aim of the present study was to examine the effect of increased energy intake during a specific period of gestation (days 28-56), on progeny growth from weaning to slaughter.

Materials and Methods Twenty four multiparous sows (JSR Genepacker 90) were randomly divided between two treatments from day 28-56 of gestation. These were: Standard level (**ST**), 2.5 kg/d or Elevated (**EL**) 5.0 kg/d. All sows were offered a conventional dry sow diet during gestation, providing 130g CP/kg, 5.5g lysine/kg and 12.9 MJ DE / kg. At weaning three boars and three gilts were taken from each of the 24 litters to give a total of 144 pigs (72 per treatment), with a mean weight of 8.3 (s.e. 0.1) kg. From weaning at 25 days, pigs were housed together in groups of 72 until day 58, after which time they were split in to six pens of 12 pigs per treatment. All pigs remained in these pens until slaughter at 97.6 (s.e 0.7) kg and were weighed on day 93, 128 and 159.

Results The **t**otal quantity of feed (kg) consumed from service to farrowing for ST and EL sows was significantly different. ST sows consumed 322 kg and EL sows consumed. 383 kg, ($P<0.01$). There were no significant differences between ST and EL sows for number born alive, litter weight (kg) at birth and weaning or feed intake (kg/d) during lactation. Live weight gain (kg/d) from weaning to day 58 and day 58-93 showed no significant differences. From day 93-128 progeny from EL sows produced a significantly higher live weight gain (kg/d) compared to progeny from ST sows ($P<0.05$), FCR during this period also showed a significant response for EL progeny ($P<0.05$) see Table 1. Live weight gain (kg/d) and FCR from day 128 to slaughter at day 159 was not significant. P2 backfat (mm) at day 128 and slaughter was not significant, where as rib lean (mm) showed a positive response (52.3 vs. 54.4, s.e.d 1.1, $P<0.08$) towards progeny from EL fed sows. The amount of feed (kg) consumed per pig from day 93-159 was similar for both ST and EL pigs, although progeny from EL sows gained more live weight (kg) compared to ST pigs 53.6 vs. 52.1 kg.

Table 1 *Performance results of progeny born to sows provided with either ST or EL nutrient levels during gestation*

	ST-Progeny	EL-Progeny	s.e.d.	Significance
Day 58-93				
Live weight day 58 (kg)	20.1	19.6	0.52	NS
Live weight gain (kg/d)	0.706	0.709	0.018	NS
Feed intake (kg/d)	1.281	1.271	0.028	NS
FCR	1.824	1.803	0.021	NS
Day 93-128				
Live weight day 93 (kg)	44.8	44.4	1.02	NS
Live weight gain (kg/d)	0.697	0.743	0.018	*
Feed intake (kg/d)	1.822	1.830	0.024	NS
FCR	2.631	2.472	0.058	*

Conclusion There were beneficial effects of the EL treatment on the live weight gain (kg/d) and FCR between 93-128 days for progeny from EL sows. This corresponded with the accelerated development phase of pig growth and could be associated with modifications to muscle fibre number during foetal development.

Reference Dwyer,C.M.,Stickland,N.C.and Fletcher,J.M 1994. The influence of maternal nutrition on muscle fibre number development in the porcine foetus and on subsequent postnatal growth. *Journal of Animal Science* **72:** 911-917.

The effect of feeding salmon oil during pregnancy on causes of piglet deaths prior to weaning

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Introduction Pre-weaning mortality is a major source of economic loss to the pig industry which despite improvements in husbandry and farrowing crate design remains about 10% of piglets borne alive. The causes of death are multi-factorial (Varley, 1995) but a large proportion may be due to low neonatal vigor. Commercial pig diets do not normally contain long chain *n-3* fatty acids, a deficiency of which has been implicated in reduced visual and neural development in premature human babies and in experimental animals. The objectives of the present experiment were to quantify the causes of piglet mortality in sows of modern genotype and to determine the effects of salmon oil supplementation of the diet of the sow, providing long-chain *n-3* fatty acids, on this mortality.

Materials and Methods A total of 216 Large White sows (parity 2-5) were housed in groups of approximately 20 at three days post-service and assigned to one of two diets which differed in that salmon oil (35 g/kg diet of a meal containing 500 g/kg salmon oil, UFAC UK Ltd, Newmarket) replaced vegetable oil (17.5 g/kg) in the control diet. Different diets were formulated for pregnancy and lactation. Sows were moved to farrowing crates 7 days before parturition and allowed to farrow naturally. On a subset of 134 litters, individual piglet weights and numbers of piglets born mummified or dead (lungs not inflated) were recorded at birth. Deaths prior to weaning were classified into three groups: deaths due to crushing bruising, trauna damage to internal organs, suffocation), starvation (no colostrum or milk in stomach) or to other causes (abnormalities, infection etc). Data for the fate of a total of 1776 piglets were analysed by cross-tabulation and Chi-squared tests. Treatment effects on litter data were analysed by one-way ANOVA

Results Adding salmon oil to the diets reduced the ratio of *n-6*:*n-3* fatty acids from 8.7 to 4.3 in the pregnancy and 6.9 to 3.7 in the lactation diets; the salmon oil diet supplied 40 g 20:5 *n-3* and 22:6 *n-3* / kg total fatty acids whereas the control diet did not contain long chain *n-3* fatty acids. Sows fed salmon oil had longer gestations (115.7 v 115.2 days, se 0.18, P=0.08; 134 litters; 115.8 v 115.4 days, se 0.14, P=0.04) than control sows. There were no significant differences between diets in litter size (12.2 v 12.3, salmon v control, se 0.41) but piglets born to sows fed salmon oil were lighter (1.45 v 1.52 kg, se 0.024, P=0.04) than control piglets The percentage of piglets born alive to control sows was higher (97.0%) than for salmon oil-fed sows (96.2%); this difference was non-significant and probably due to the higher mean parity (4.1 v 3.5, se 0.09, P<0.001) of salmon oil-fed sows as numbers borne dead were significantly (Chi-square 18.2, df 8) greater in fifth parity (6.2%) than other sows (3.0%). As expected, pre-weaning mortality was higher for piglets of lower birth–weight with mortality in the lightest quartile (birth-weight <1.25 kg, 22.7%) being significantly (Chi-square 46.8, df 6, P<0.001) higher than for all piglets (10.9%)..

Table Effect of diet and gestation length on causes of pre-weaning mortality (%)

	Diet		Gestation length (days)				
	Salmon oil	Control	<114	114	115	116	>116
Crushed	3.7	6.6	8.3	10.1	3.6	4.6	2.9
Starved	2.6	1.4	4.4	1.0	2.5	1.3	1.8
Other	3.0	3.9	3.3	3.8	3.4	3.1	3.6
Total	9.3	11.9	16.0	14.9	9.5	9.0	8.3

Overall mortality tended to be lower (Chi-square 3.29, df 1, P<0.1) for piglets born to salmon oil-fed sows. The causes of mortality differed between sow diets (Chi-square 11.1, df 3, P<0.025) with fewer piglets being crushed by salmon oil-fed sows. These differences were associated with increased gestation length of salmon oil-fed sows as pre-weaning mortality decreased as gestation length increased (Chi-square 22.4 df 7, P<0.005, see Table), regardless of sow diet, largely due to a reduction in deaths caused by crushing.

Conclusions The major causes of pre-weaning mortality in sows of modern genotype were crushing and starvation. Despite a reduction in mean birth-weight, feeding salmon oil reduced deaths caused by crushing probably by increasing gestation length. It is possible that the reduction in deaths caused by crushing reflected improved neonatal vigor of salmon-oil fed piglets.

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References

Varley, M. A. 1995. *The Neonatal Piglet Development and Survival*. CAB International, Wallingford, Oxfordshire.

Supplement containing immunoglobulins fed post weaning promotes nursery pig performance

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Introduction Post weaning performance is determined by weaning weight and week one growth rate (Miller, et al., 1999). Strategies which increase feed intake in the immediate post-weaning period would be expected to increase overall post-weaning performance through better week one growth rate. Top dressing normal pelleted feed following weaning with a palatable nutrient dense supplement should increase nutrient intake and hence week 1 growth rate. This strategy might be particularly beneficial for low weaning weight pigs. Inclusion of ingredients containing immunoglobulins (Ig) in immediate post-weaning diets have been shown to increase post weaning performance (Coffey and Cromwell, 1995). We hypothesise that the use of a palatable nutrient dense supplement containing bovine Igs will improve feed intake and growth rate post weaning. The aim of this experiment was to investigate this hypothesis using low weaning weight piglets.

Materials and methods A total of 64 crossbred piglets (62.5% Large White, 25% Landrace, 12.5% Duroc) were weaned into fully slatted flat deck pens. The piglets were weaned at 23 ± 0.4 days of age (mean ± SEM) and 5.3 ± 0.18 kg liveweight (LW). Piglets had been born and reared outside and had not received creep feed prior to weaning. Eight piglets were allocated to each pen (1.99 m^2) on the basis of litter, liveweight and sex. Four pens were randomly allocated to each of two treatments; with (S) or without (O) supplementation with a whey globulin concentrate based diet containing 4 % Igs (18.4 MJ DE/kg, 17.5 g total lysine/kg) at 60 g/d for 4 days post weaning. All piglets were individually weighed at weaning, 7, 14 and 20 days after weaning. Food and water were provided *ad libitum* throughout the 20 day trial period. All piglets received a starter diet (17.5 MJ DE/kg, 17.5 g total lysine /kg) for week 1, followed by a second stage starter diet (16.5 MJ DE/kg, 16.5 g total lysine/kg) for week 2 and a third stage diet (15.0 MJ DE/kg, 15.0 g total lysine/kg) for week 3. Data were analysed using the GLM procedure of Minitab 12, start weight and age were used as covariates.

Results Piglet performance during the experiment is given in Table 1. Piglets which had received supplementation during the first four days after weaning were heavier than those which did not at the end of the trial, 12.7 versus 12.2 kg respectively, ($P< 0.05$). There was no difference in growth rate between the two groups during the first week of the trial but during the second week S pigs grew an average of 34 g/day faster ($P= 0.05$) and their overall gain was improved by 24 g/day ($P< 0.05$). Feed intakes were significantly better for S pigs in week 2 and overall but were numerically higher in all weeks of the trial. Feed conversion ratio (FCR) was not different between the treatments during any period of the trial.

Table 1 Piglet weaning weights, average daily gains for week 1 (ADGwk1) and week 2 (ADGwk2), average daily feed intakes for week 1(ADFIwk1), week 2 (ADFIwk2) and overall (ADFI) and weights at the end of the trial for piglets receiving no supplement or a nutrient dense supplement during the first four days after weaning

Treatment	Start weight (kg)	ADGwk1 (g/d)	ADFIwk1 (g/d)	ADGwk2 (g/d)	ADFIwk2 (g/d)	d20 weight (kg)	ADFI (g/d)
Supplemented	5.3	244	197	396	375	12.7	364
Not supplemented	5.3	231	181	361	343	12.2	343
SEM	0.18	12.6	1.1	9.0	6.1	0.11	3.7
P value*	N.S.	N.S.	N.S.	0.05	0.02	< 0.05	< 0.02

*N.S. No significant difference between treatments

Conclusions The use of a whey globulin based supplement for 4 days immediately post-weaning did improve overall feed intake and growth rate. Surprisingly this improvement in performance took place mainly in the second week of the trial. Nutrient intake in the first few days after weaning does not explain the improved performance. This suggests that bovine Igs or some other component of the supplement had enduring effects on piglet performance. Further work is required to investigate this observation.

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References Coffey, R.D. and Cromwell, G.L. 1995. The impact of environment and antimicrobial agents on the growth response of early-weaned pigs to spray-dried porcine plasma. *Journal of Animal Science* **73**: 2532-2539.
Miller, H.M., Toplis, P. and Slade, R.D. 1999. Weaning weight and daily live weight gain in the week after weaning predict piglet performance. *Manipulating Pig Production VII* ed. Cranwell, P.D., APSA, Atwood, Victoria, Australia, in press.

Effect of dietary energy intake during pregnancy on liveweight gain and backfat gain of primiparous sows kept in an outdoor system under tropical conditions

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Introduction Energy requirements for maintenance in pregnant sows increase when they are kept outdoors under temperate climates in comparison to indoors. However, there is little information on the energy requirements of breeding sows kept outdoors in tropical environments. Knowledge about the correct feeding management for pregnant sows kept outdoors will optimise the utilisation of feeding resources available in the tropics. The aim of this study was to evaluate the effect of energy level supply during pregnancy on backfat change and liveweight change of primiparous sows kept outdoors under tropical conditions.

Material and methods The experiment was carried out in Merida, Yucatan, Mexico. Twenty-four primiparous pregnant sows weighing 114.8 ± 11.1 kg at mating were allocated randomly in four blocks and three treatments. The treatments were three diets designed to supply 19 (L), 26 (M) and 33 (H) MJ of DE/day. Additionally, the sows had opportunity to graze freely on a paddock of star grass (*Cynodon nlemfuensis*). During lactation the sows were fed *ad libitum* with a commercial lactation diet (150 g CP/kg and 13 MJ DE/kg). The sows liveweight was recorded and backfat thickness was monitored ultrasonically by a Renco lean meter, at 65 mm on each side of the midline at the level of the last rib (P2). These measurements were made at mating, at farrowing and at weaning. Data from weight and backfat thickness were analysed as a randomised block experiment. Energy level supply during gestation was taken as the independent variable. Initial weight and initial backfat thickness of each sow was used as covariables to analyse statistically weight changes and backfat changes respectively. The treatment effects were partitioned into linear trend and any deviation from this.

Results The adjusted means by least square means for weight changes and backfat changes are given in Table 1. The weight at farrowing and weight gain from mating to farrowing showed a deviation of linear trend ($P<0.01$) as a response to energy supply during gestation. The weight at weaning and weight gain from mating to weaning increased linearly ($P<0.01$) from treatment L to treatment H. The backfat depth at farrowing and backfat gain from mating to farrowing increased linearly ($P<0.001$) as energy supply during gestation increased. Similarly, the backfat at weaning increased linearly ($P<0.001$) with energy intake during pregnancy from treatment L to treatment H. However, sows in treatment L had a negative balance in backfat gain from mating to farrowing and from mating to weaning.

Table 1 *Weight changes and backfat changes of sows fed three levels of energy during pregnancy in an outdoor system.*

	Treatment			s.e.	Significance †
	L	M	H		
Weight changes (Kg)					
No of sows	8	8	8		
At mating	113.9	116.6	114.0	1.1	
At farrowing	148.7	150.1	166.8	1.0	T**
At weaning	144.4	152.9	162.7	2.2	T**
From mating to farrowing	33.9	36.1	52.0	1.0	T**
From mating to weaning	30.5	36.3	48.7	2.2	T**
Backfat changes (mm)					
At mating	12.8	12.4	12.1	0.4	
At farrowing	12.4	14.2	17.0	0.1	T***
At weaning	11.5	12.9	15.7	0.4	T***
From mating to farrowing	-0.1	1.8	4.5	0.1	T***
From mating to weaning	-1.3	0.5	3.6	0.4	T***

† From a variance analysis (randomised block design) where weight at mating was used as covariable, including level of energy (T), block (B) and interactions as main effects.

Conclusions Increases in energy intake during pregnancy were associated with increases in backfat and liveweight. Feeding sows close to 19 MJ DE/day during pregnancy resulted in mobilisation of fat reserves to maintain the pregnancy and increased the backfat lost during lactation. Utilisation of a level of energy between 26 and 33 MJ DE/day will ensure the adequate storage of backfat reserves in primiparous pregnant sows kept in an outdoor system under tropical conditions.

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Finishing performance of progeny of Continental cross suckler cows by two sire breeds

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Introduction Previous ADAS trials have shown the potential of Continental cross suckler dams to increase calf growth rates in a hill environment (Keatinge *et al.,* 1994), and to improve carcass quality when the progeny are finished intensively (Chapple *et al.,* 1995). The aim of this experiment was to compare the progeny of two Continental dam genotypes, using either Charolais or Aberdeen-Angus sires, when finished at 18 months of age.

Materials and Methods An autumn-calving herd of Simmental x Holstein/Friesian (SM) and Belgian Blue x Holstein/Friesian (BB) suckler cows was artificially inseminated using semen from five Charolais (CH) or five Aberdeen-Angus (AA) bulls at ADAS Redesdale. The calves were born during September/October 1997 and transferred to ADAS Rosemaund, at weaning at 8 months of age, for subsequent finishing. After a summer at grass the yearling cattle were housed in October and finished on *ad libitum* good quality grass silage (DM 296 g/kg, ME 10.9 MJ/kg, CP 166 g/kg DM). The cattle (38 steers and 40 heifers) were penned according to breed-type and sex, with two pen-replicates of 4 or 5 animals. The silage was fed daily and refusals were weighed weekly. For steers, the silage was supplemented throughout with 1.0 kg mineralised rolled barley/head/day whereas the heifers initially received silage only, an additional 1.0 kg of mineralised rolled barley being fed for 5 weeks prior to slaughter. At slaughter, all animals were dissected and proportions of saleable meat, bone and fat-trim were calculated. The data were analysed using a 2 x 2 factorial analysis of variance.

Results Steers from BB dams had higher dressing proportions , higher yields of saleable meat and lower percentages of bone than SM steers. Heifers out of BB dams had higher dressing proportions and higher yields of saleable meat than heifers out of SM dams. Growth rates of steers were not affected by dam breed (Table 1).

Table 1 *Performance and carcass data analysed by dam breed*

	Steers			Heifers		
Dam breed	SM	BB	s.e.d. (25 d.f.)	SM	BB	s.e.d. (27 d.f.)
Daily liveweight gain (kg):						
At grass	0.79	0.81	0.030	0.43	0.38	0.026
Housing to sale	0.90	0.95	0.043	0.84	0.80	0.033
Carcass weight (kg)	283	296	8.1	245	247	4.5
Dressing proportion (g/kg)	496	508	5.2	480	499	6.1
Saleable meat (%)	70.5	72.8	0.46	71.8	73.4	0.66
Bone (%)	23.3	21.3	0.50	21.2	20.4	0.43
Fat-trim (%)	6.2	5.9	0.39	7.0	6.2	0.45

Steers by CH sires had significantly heavier carcasses, higher dressing proportions, higher percentages of bone and less fat-trim than steers by AA sires. Heifers by CH sires had heavier carcasses, higher dressing proportions, higher yields of saleable meat and less fat-trim than heifers from AA sires (Table 2).

Table 2 *Performance and carcass data analysed by sire breed*

	Steers			Heifers		
Dam breed	AA	CH	s.e.d. (25 d.f.)	AA	CH	s.e.d. (27 d.f.)
Daily liveweight gain (kg):						
At grass	0.79	0.81	0.030	0.38	0.43	0.026
Housing to sale	0.91	0.95	0.043	0.83	0.81	0.033
Carcass weight (kg)	279	300	8.1	236	255	4.5
Dressing proportion (g/kg)	496	508	5.2	482	497	6.1
Saleable meat (%)	71.2	72.1	0.46	71.9	73.4	0.66
Bone (%)	21.8	22.8	0.50	20.5	21.0	0.43
Fat-trim (%)	7.0	5.1	0.39	7.6	5.6	0.45

Conclusions Progeny from BB dams had higher dressing proportions and higher saleable meat yields. Although steers and heifers by CH sires produced heavier carcasses and had higher dressing proportions, this did not compensate for the premium (20p/kg carcass) paid for AA sired cattle.

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References Keatinge, R., Christensen, K.A. and Rowlinson, P. (1994). Comparative performance of two primiparous continental genotypes in a hill suckler herd: Reproductive performance. *Animal Production*, **58**, p.432.
Chapple, D.G., Davies, M.H., Grundy, H.F. and Keatinge, R. (1995). Comparative performance of two continental genotypes in a hill suckler herd: Calf performance. *Animal Science*, **60**, p525.

Estimation of lactation curve parameters for Iranian Holstein dairy cows using non-linear models

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Introduction In dairy cattle breeding programmes the knowledge of cow's lactation curve could be an effective tool to make selection decisions. In order to obtain an accurate shape of lactation curve a variety of mathematical models have been used in which parameters of production peak, inclining and declining phases of milk production over the course of lactation have been estimated by linear or non-linear techniques. The main purpose of this research was to compare four non-linear functions for the estimation of first lactation curve of Iranian Holstein dairy cows.

Material and Methods A total of 36820 monthly test-day milk records from 3682 Iranian Holstein dairy cows with first lactation and calving between September 1983 and June 1995 distributed in 171 herds from different climatic regions of Iran was used in this study. Four non-linear models Incomplete Gamma Function (IGF), Inverse Quadratic Polynomial Function (IQPF), Exponential Function (EF) and Polynomial Regression Function (PRF) were applied to estimate lactation curve parameters. For each function the amount of monthly milk yield and day of recording was fitted to estimate of relevant parameters using Marquardt algorithm described by Draper and Smith (1998).

Results The estimated parameters for individual functions are given in table 1. As it can be seen, among applied functions the correlation coefficients between actual and predicted daily milk yield, and mean absolute of prediction error (MAPE) were the highest and lowest respectively for both IGF and PRF. These results show that the IGF and PRG functions can fit the shape of lactation curve more precisely that is in good agreement with results obtained by Olori et al. (1999). This could be due, at least in part, to greater number of polynomials terms particularly in PRF. The graph 1 also shows comparison of actual and predicted milk yields in different lactation months.

Table 1 Estimated parameters of milk lactation curve

Function	a	b_1	b_2	b_3	b_4	*MAPE*[5]	r
IGF[1]	20.564	0.204	0.074			3.627	0.997
IQPF[2]	0.034	0.019	0.003			3.636	0.986
EF[3]	119.403	-100.240	-4.334			3.634	0.978
PRF[4]	21.330	-2.271	0.034	4.623	0.534	3.621	0.997

1. $y_t = a\ \ t^{b_1} e^{-b_2 t}$, 2. $y_t^{-1} = a + b_1 t^{-1} + b_2 t$, 3. $y_t = a + b_1 e^{-0.05t} + b_2 t$,

4. $y_t = a + b_1 t + b_2 t^2 + b_3 \log t + b_4 (\log t)^2$, 5. Mean Absolute of Prediction Error

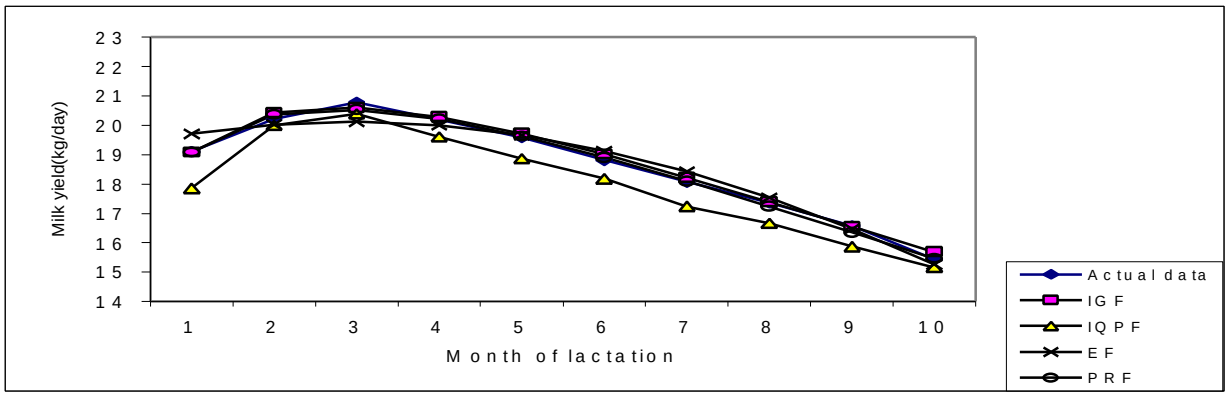

Figure 1 Actual and predicted daily milk yields using different non-linear models for first lactation cows

Conclusion The results obtained in this study indicate that the variations of monthly milk yield during first lactation of Iranian Holstein dairy cows would be more accurately explained by non-linear functions of Incomplete Gamma and Polynomial Regression. This is of great importance in particular for genetic evaluation of dairy cows and sires when prediction of their breeding values is based on test day records rather than 305-day yield. Hence, in a test day model such these functions could be used to take account of shape of lactation curve.

References

Olori, V.E., Brotherstone, S., Hill, W.G. and McGuirk, B. 1999. Fit of Standard models of the lactation curve to weekly records of milk production of cows in a single herd. *Livestock Production Science* **58**:55-63.
Draper, N.R. and Smith, H. 1998. *Applied regression analysis*, 3rd Ed., John Wiley and Sons, New York.

The economic value of somatic cell counts

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Introduction Veerkamp *et al.* (1998) make the case for including somatic cell count (SCC) in the index of total economic merit (ITEM, Veerkamp *et al.*, 1995) used to rank dairy bulls and cows in the UK for breeding purposes. They go on to describe an empirical method to obtain a suitable economic value for SCC, reflecting the milk quality payment scheme. Since this work was carried out, the milk price has fallen while price penalties against SCC have risen. Bulk-tank SCC (BTSCC) has fallen in response. Some of this improvement may be due to culling cows with high cell counts. The objective of this work was therefore to establish an economic value for somatic cell counts which reflected the milk quality payment scheme and took into account culling strategy.

Materials and methods A dynamic programming (DP) model was used to establish the economic value of individual cow somatic cell count (ICSCC). The method employed here was as used for other goal traits in the ITEM index (Veerkamp *et al.* 1995). It was necessary to extend the original DP model to include 11 states representing a range of possible ICSCC values at each of 12 lactations. The assumptions in the model were also updated to represent current milk prices and input costs. Each ICSCC state in the model was assigned an SCC penalty or premium depending on the relative contribution to BTSCC and hence to herd average milk price. This depended on the relative contribution of the state to BTSCC (i.e. on yield and on ICSCC in the state relative to BTSCC) and on the marginal cost of BTSCC. The standard error of BTSCC (assumed to be 13.9 kcounts) was used to estimate the reliability of successive bulk tank SCC readings and hence establish the expected marginal cost of BTSCC per kcount SCC per litre for a 100 cow herd of given BTSCC (Figure 1). Milk price adjustments were +0.2, 0, -0.5, -10 and -10 ppl for SCC price bands 1 to 5 respectively, a compromise regime based on the data from a number of milk buyers. Mean ICSCC was set to 80, 101, 121, 139 and 135 kcounts/ml for lactations 1 to 5 respectively. For lactations 5 to 12 it was assumed to be 159 kcounts/ml. This scenario gave a baseline (before culling for ICSCC) BTSCC of 151 kcounts/ml, reflecting a herd with a low rate of mastitis infection. The economic value of ICSCC was obtained by comparing the annualised net present value of milk production given by the DP model before and after a 0.01 reduction in ICSCC. The process was repeated for a baseline BTSCC of 228 kcounts/ml and 308 kcounts/ml.

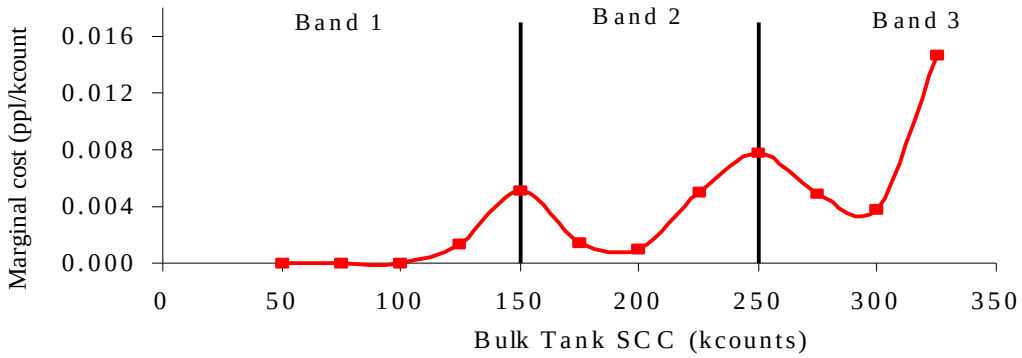

Figure 1 Expected marginal cost of bulk-tank SCC for a 100 cow herd

Results Economic values of ICSCC were 0.52, 0.74 and 0.78 £/cow/year for BTSCC of 151, 228 and 308 kcounts/ml respectively. Optimal culling strategies were affected by BTSCC.

Conclusion Results indicate that it is important to consider the optimal culling strategy when estimating ICSCC economic values. Higher economic values close to the price band threshold reflect the increased risk of moving between bands. This approach measures the immediate risk, and its attendant economic pressures, not the annual average position calculated by Veerkamp *et al.* 1998. It may therefore be particularly suitable for use when preparing a customised index for herds based on their BTSCC pattern. For example, seasonal breeding herds have a greater BTSCC variablity than those calving all year round.

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References

Veerkamp, R.F., Hill, W.G., Brotherstone, S., Stott, A.W. and Simm, G. 1995. Selection for longevity and yield in dairy cattle using transmitting abilities for yield and type. *Animal Science* **61**: 189-197.
Veerkamp, R.F., Stott, A.W., Hill, W.G. and Brotherstone, S. 1998. The economic value of somatic cell count payment schemes for UK dairy cattle breeding programmes. *Animal Science* **66**: 293-298.

Relationships between bull proofs for lifespan (LS) in the United Kingdom (UK) and various countries.

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Introduction Longevity or lifespan has proved to be an important trait when it comes to profitability for the dairy farmer. Selecting for longer herdlife not only reduces the replacement rate and thereby the replacement cost, but also gives the opportunity to cull for low production (as opposed to health problems) and increases the milk yield through a higher proportion of mature cows in the herd. Predicted Transmitting Abilities (PTA's) for LS are calculated from a bivariate analysis including indirect information in the form of a phenotypic index of four linear type traits (fore udder attachment, foot angle, udder depth and teat length) closely related to longevity, and from direct lactation information, i.e. survival measured in number of lactations corrected for milk yield (Brotherstone *et al.*, 1998). Genetic evaluations for LS were introduced in the United Kingdom (UK) in August 1998 (Mrode *et al*., 1999).

LS proofs for foreign bulls are calculated indirectly from converted foreign type information. It would be desirable to convert a LS value or equivalent from foreign countries as is the case for production, conformation and somatic cell counts (Animal Data Centre, 1999). The aim of this study was to investigate the relationships between LS proofs in the UK and other countries, and produce conversion formulae for LS.

Material and Methods LS PTAs were obtained from the UK November 1999 genetic evaluation update. The latest evaluation results for LS equivalents were obtained from the USA, Canada, Netherlands, New Zealand (August 1999) and France (October 1999). Regression analyses were carried out using SAS to estimate correlations and conversion factors between the UK and the five countries. Only bulls born from 1980 and onwards were included in the analyses to make sure that they were based on a young set of bulls. At least 85 % reliability in both countries was required for inclusion in the analyses (INTERBULL, 1990). Additional analyses were performed on sets of bulls with at least 90 and 95 % reliability. The US and Canadian data sets contained bulls from those countries only.

Results For France and New Zealand, the number of bulls available for analysis after the restrictions were applied, was too small to continue.

Table 1. Relationships between different measures of Lifespan between the UK and other countries.

Country / Proof	No of bulls	Reliability % (UK & Other country)	Correlation	a-value	b-value
Canada / Herd Life	67	85	0.75	-3.15	1.10
	56	90	0.76	-3.20	1.12
	39	95	0.83	-3.42	1.19
USA / Productive Life	57	85	0.52	0.05	0.07
	42	90	0.59	0.04	0.08
	20	95	0.59	0.06	0.08
Netherlands / Durability	92	85	0.58	-2.55	0.03
	66	90	0.66	-3.05	0.03
	42	95	0.71	-3.10	0.03

The correlation between Canadian Herd Life evaluations and UK LS PTAs was 0.75 for bulls with 85 % reliability and 0.83 for bulls with 95 % reliability. Lower correlations were found between US Productive Life and UK LS of 0.52 to 0.59. This was due to the fact that the US proofs are not corrected for milk yield, as are the UK PTAs. Dutch Durability showed moderately high correlations with LS of 0.58 for bulls with 85 % reliability and 0.71 for bulls with 95 % reliability.

Conclusions At this point only the conversion formula between Canadian Herd Life and UK LS meets the minimum INTERBULL recommendations for publication.

References

Animal Data Centre Ltd. August 1999. UK Statistics for Genetic Evaluations (Dairy).
Brotherstone, S., Veerkamp, R. F. and Hill, W. G. 1998. Predicting breeding values for herd life of Holstein Friesian dairy cattle from Lifespan and type. *Animal Science 67, 405-411*.
INTERBULL, 1990. Recommended procedures for international use of sire proofs. Bulletin No 4., INTERBULL Centre, Uppsala, Sweden
Mrode, R. A., Swanson, G. J. T. and Lindberg, C. M. Genetic correlations of somatic cell count and conformation traits with herd life in dairy breeds, with an application to national genetic evaluations for herd life in the United Kingdom. *Livestock Production Science*, submitted.

Sensitivity of genotypes to feeding systems for production, weight and feed intake in dairy cattle

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Introduction Getting reliable genetic parameter estimates for dry matter intake is difficult because recording it is expensive, hence it is tempting to combine data from research herds. However, there are large differences in feeding and management systems, which causes differences in means across herds. Furthermore, variances or heritabilities may differ and genetic correlations may be less than one between herds. This is one of the reasons why it is important to investigate effects of genotype by environment interaction (GxE). Another reason is that it is important to understand how high genetic merit cows perform in different feeding systems. The objective of this study was to estimate the effect of GxE for three feeding systems at two research herds belonging to ID-Lelystad (ID) and to SAC/University of Edinburgh (Langhill).

Materials and methods ID cows were fed a complete ration *ad libitum* of artificially dried grass, corn silage and concentrates of 29:24:48 (dry matter). Langhill data were from two *ad libitum* feeding systems, both were grass silage based, but varied in the relative proportions of concentrate to brewer's grains and silage: 20:5:75 for the Low Concentrate (LC) diet and 45:5:50 for the High Concentrate (HC) diet. Data were on daily dry matter intake (DMI) and daily milk, fat and protein yields (MY, FY and PY) and weekly live weights (LW). All traits were averaged over the first 15 weeks of lactation. Firstly, variance components where estimated within each of the feeding systems. Secondly, six models of different complexity for the variance components across herds were compared using a likelihood test (ASREML, Gilmour *et al*., 1999). One extreme was where the three systems were ignored in estimating variance components (only a mean adjustment fitted), i.e. variances were the same for each system, and genetic correlations were unity. The other extreme was a model where variances were different for each system, and the three genetic correlations were estimated.

Results ID cows produced the most milk, had the greatest DMI but were also lightest over the first 15 weeks of lactation (Table 1). Results from the univariate model indicate that there was more genetic variation for production traits for HC than either ID or LC. The genetic variance and heritability of DMI was smallest for LC.

Table 1 Means, genetic (A) and residual (E) variances, genetic CVs (CVa) and heritabilities (h^2) in the feeding systems

	ID-Lelystad (N = 631)					Langhill HC (N = 357)					Langhill LC (N = 217)				
	Mean	A	E	CVa	h^2	Mean	A	E	CVa	h^2	Mean	A	E	CVa	h^2
MY (kg/d)	29.9	5.9	11.5	0.08	0.34	25.6	8.4	10.6	0.11	0.44	22.5	3.8	8.1	0.09	0.32
FY (g/d)	1202	14180	14647	0.10	0.49	1011	19134	12604	0.14	0.60	944	16288	20947	0.07	0.22
PY (g/d)	1014	4054	9443	0.06	0.30	820	7201	7394	0.10	0.49	687	4270	7941	0.03	0.35
DMI (kg/d)	18.5	1.82	1.06	0.07	0.63	15.9	1.45	0.74	0.08	0.66	13.3	0.38	1.40	0.05	0.22
LW (kg)	527	956	900	0.06	0.41	541	1261	814	0.07	0.61	534	1135	825	0.06	0.58

Table 2 Model description, number of parameters (n) in models and the log likelihood for models describing the residual (E) and genetic (A) variances, and the genetic correlations (rg) for ID, HC and LC

	Model [#]				Log likelihood									
	E	A	rg	n	MY		FY		PY		DMI		LW	
1	a a a	b b b	1 1 1	2	0		0		0		0		0	
2	a b c	d d d	1 1 1	4	10.5	**	5.1	**	12.4	**	5.8	**	1.8	
3	a a a	b c d	1 1 1	4	8.6	**	6.4	**	10.6	**	9.1	**	2.7	
4	a a a	b b b	c d e	5	0.8		0.3		2.8		13.5	**	3.6	
5	a b c	d e f	1 1 1	6	11.5	**	6.6	*	14.1	**	10.3	**	2.8	
6	a b c	d e f	g h i	9	12.1	**	7.0		16.0	**	13.5	**	6.5	

[#]Letters indicate if parameters were the same or different across feeding systems (ID, HC, LC) and 1 indicates genetic correlations of unity.

Including separate genetic or environmental variances for each of the systems improved the likelihood significantly for all traits except live weight (Table 2; model 2 and 3 v. 1 respectively). However allowing the genetic correlations to differ (whilst maintaining similar variances) gave improvement for DMI only (4 v. 1). Model 6 contains most parameters (n=9) and is significantly better than model 1 for all traits (except LW). However, when comparing models 5 and 6 there is no significant reduction in the likelihood, when the three correlations are fixed to unity. Power to estimate correlations between herds was low as genetic ties were weak (nine sires appeared in all data sets).

Conclusions These results suggest that GxE affects genetic and residual variances, but unity genetic correlations might be assumed for the same trait in the three systems used here.

Acknowledgements We acknowledge funding from the EU (GIFT). SAC receives financial support from SERAD.

Reference Gilmour, A.R., Cullis, B.R., Welham, S.J. and Thompson, R. 1999. *ASREML user manual. New South Wales Agriculture, Orange Agricultural Institute, Forest Road, Orange, NSW, 2800, Australia.*

Effect of relationship between mastitis and somatic cell count on genetic selection for mastitis resistance in dairy cattle

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Introduction Differences in banding scales for milk quality penalties, as determined by bulk tank somatic cell count (SCC), prevent the use of a single economic value for SCC in an overall economic-genetic selection index (Veerkamp et al., 1998) such as, Profitable Lifetime Index or £PLI. But SCC could be used as a predictor of mastitis as genetic correlation estimates between mastitis and SCC are medium to high (review of Mrode and Swanson, 1996). This suggests that, although deriving a direct single economic value (EV) for SCC based on bulk tank SCC is difficult, a single financial value could still be assigned to SCC based on its relationship with mastitis. Here we use a genetic regression method to calculate the EV of SCC (EV_{SCC}) as a predictor of mastitis. However, the dependency of regression coefficients on mastitis incidence (p) could make such EV_{SCC} variable. The main objective of this study was to evaluate the impact of such relationship on EV_{SCC} and genetic selection in dairy cattle using predicted transmitting abilities of SCC (PTA_{SCC}).

Materials and Methods Data on lactational occurrence of mastitis (0/1 in a lactation) and test-day somatic cell counts (SCC) were extracted from Livestock Services UK (LSUK) database. After editing, there were 45449 records in 300 herds. Three groups of herds were first identified as low, medium and high incidence herds (Table 1). Number of records for genetic regressions (of mastitis on PTA_{SCC}) were fewer than those available for phenotypic regressions (of mastitis on $\log_e$ of lactation mean SCC or LSCC) because of editing on availability and reliability (>65%) of PTA_{SCC}. Analyses were based on linear and threshold models using the ASREML software package (Gilmour et al., 1998). EV_{SCC} was based on EV for mastitis (EV_{MAST} was £100/cow/lactation; A.Stott, personal communication) as $EV_{SCC} = \beta_{MAST,\ SCC}.EV_{MAST}$ where $\beta_{MAST,\ SCC}$ was a genetic regression coefficient. Genetic responses to selection were computed using £PLI that included mastitis and SCC as goal and index traits, respectively. Approximate genetic correlations obtained from linear genetic regressions and standard deviations of SCC and of mastitis were used in the computation of genetic responses.

Results Both phenotypic and genetic regressions showed that for the same unit change in LSCC or PTA_{SCC}, predicted means for mastitis incidences differ across herd groups with different incidences of mastitis. The increase in incidence was lower in low incidence groups than high incidence groups for a unit increase in LSCC or PTA_{SCC}. This applied to both the linear and threshold models. When regression coefficients from all groups were averaged, the mean was very close to the regression coefficient from the pooled data set, indicating that these differences tend to cancel out in population-based mastitis analyses. Because of dependency of the genetic coefficients on incidence, economic values were also different for different herd groups, suggesting that a single economic value for SCC based solely on its relationship with mastitis is also difficult. Genetic responses to selection, as given in Table 1, shows that greater reduction in number of mastitis cases is achieved in high incidence herds than low incidence herds because of high genetic correlations in high incidence herds. These results, therefore, suggest that using SCC as an indicator trait for mastitis resistance would be specific to herd incidences**.**

Table 1: Range and mean incidences of mastitis, genetic regression coefficients, correlations and corresponding responses (in %) for 4 herd groups.

Herd groups	Range of mastitis incidences (p)	Mean incidence	$\beta_{MAST,\ SCC}$ (s.e) (linear model)	Genetic correlations	Genetic response (cases of mastitis per 100 cows)
Low	$0 < p \leq 0.025$	0.012	0.0002 (0.0001)	0.25	1.9
Medium	$0.025 < p \leq 0.110$	0.062	0.0006 (0.0003)	0.34	1.8
High	$0.110 < p \leq 0.571$	0.204	0.0027 (0.0004)	0.86	0.9
Pooled	$0 < p \leq 0.571$	0.093	0.0012 (0.0002)	0.57	1.5

Conclusions SCC could be used in a selection index as a criterion for mastitis resistance. The response in mastitis is dependant on the genetic correlations between mastitis and SCC which were greater in high incidence herds. The financial value of SCC directly attributable to cost of mastitis and, genetic response to selection using future versions of £PLI that include mastitis would be different on a herd-basis, but these differences are unlikely to affect population-wise genetic response to mastitis. This study also has demonstrated how correlated genetic responses with any binary disease or disorder traits are variable in an overall national selection index framework, but may be appropriate for customised selection indexes.

Acknowledgment The authors thank ADC, HUKI and LSUK, for providing data and PTAs. The Milk Development Council (MDC) is thanked for funding this research. SAC receives financial support from SERAD.

References

Gilmour, A.R., Cullis, B.R., Welham, S.J. and Thompson, R. 1998. ASREML User's Manual, October, 1998. New South Wales Agriculture, Orange Agricultural Institute., Orange, NSW, Australia.

Mrode, R.A. and Swanson G.J.T. 1996. Genetic and statistical properties of somatic cell count and its suitability as an indirect means of reducing the incidence of mastitis in dairy cattle. *Animal Breeding Abstracts* 64: 847-857.

Veerkamp, R.F., Stott, A.W., Hill, W.G. and Brotherstone, S. 1998. The economic value of somatic cell count payment schemes for UK dairy cattle breeding programmes. *Animal Science* 66: 293-298.

An examination of the effects of level of concentrate supplementation of dairy cattle in late gestation on subsequent reproductive performance

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Introduction The transition period of the dairy cow is physiologically and nutritionally stressful as feed intake is reduced whilst nutrient demand for the support of foetal growth and initiation of milk synthesis are increased. Also during this period the diet of dairy cows changes from being predominantly forage, often of mediocre quality, to a diet often containing high levels of concentrate and high quality forage or mixture of forages. In the recent past nutritional management of the dairy cows during the transition period has centred on protein nutrition. While some studies have shown responses to milk yield or composition from protein nutrition in late gestation, many have shown no response. The objective of the present study was to examine the effects of level of concentrate in late gestation on subsequent reproductive performance. The effects of treatment on animal performance have been presented by Keady *et al*. (1999).

Materials and Methods Three grass silages were produced from predominantly perennial ryegrass swards. Silage A was ensiled on 12 June untreated after a 6-hour wilting period, silage B was ensiled on 15 May after a 24-hour wilting period and treated with a bacterial inoculant while silage C was ensiled on 8 July after a 24-hour wilting period and treated with an inoculant. Twenty-eight days prior to predicted parturition, 60 cows were offered silage A *ad libitum* as the sole diet (0C) or silage A *ad libitum* supplemented with 5 kg concentrate (5C) formulated using barley, wheat, maize gluten, sugar beet pulp, soya, SoyPass, molasses and minerals, in a randomised block design experiment. The concentrate was offered in two equal feeds per day through out-of-parlour feeders. For the first 28 days post calving the cows were offered silage B supplemented with 7 kg concentrates/cow/day. From days 28 to 84 the animals received 7 kg concentrates/cow/day and silage C *ad libitum*. Post calving the concentrates were offered in three equal feeds through out-of-parlour feeders. Samples of milk were retained twice weekly for the determination of progesterone analysis. First progesterone rise was taken to be the day when the first of two successive milk progesterone concentrations rose above 1 ng/ml. Detailed measurements of herd reproductive performance were recorded, as outlined in Table 1. Data were analysed as a randomised block design experiment using Genstat.

Results For silages A, B and C dry matter and ammonia nitrogen concentrations, and D-values were 210, 202 and 211 g/kg, 181, 121 and 176 g/kg N, and 668, 687 and not determined g/kg DM respectively. For the concentrate offered pre- and post-calving, crude protein and starch concentrations were 174 and 218 g/kg DM, and 415 and 322 g/kg DM respectively. For treatments 0C and 5C during the last 4 weeks of gestation silage intakes were 9.28 and 6.93 kg DM/day and total DM intakes were 9.28 and 11.03 kg/day respectively. Treatment did not affect milk yield during the first 12 weeks of lactation. Although the cows had similar condition scores at the initiation of the trial, condition score for treatments 0C and 5C at weeks 2 and 10 post calving were 2.88 and 2.96 (sem = 0.050) and 2.75 and 2.60 (sem 0.055) respectively. The effects of pre-partum treatment on reproductive performance are presented in Table 1. Increasing concentrate feeding pre-calving increased days to first progesterone rise ($P<0.01$), the onset of cyclicity ($P<0.01$) and the number of services/conception ($P<0.05$). Days to first observed heat and predicted calving interval were not significantly altered due to pre-partum feeding. Conception to first, and first and second service were lower when concentrate was fed pre-partum.

Table 1 The effect of pre-partum treatment on reproductive performance

	Treatment			
	0C	5C	Sem	Sig
Days to first progesterone rise	21.6	29.0	1.72	**
Onset of cyclicity (days post calving)	15.3	22.8	1.72	**
Days to first observed heat	40.6	42.4	3.08	NS
Conception to first service (%)	53	40		
Conception to first and second service (%)	70	60		
Number of services/conception†	1.52	2.10	0.165	*
Predicted calving interval (days)†	382	381	5.6	NS

† 4 and 2 animals removed from treatments 0C and 5C as not in calf

Conclusions Overall, feeding concentrates in late gestation increased the interval to onset of cyclicity and increased the number of services per conception.

References

Keady, T.W.J., Mayne, C.S. and Fitzpatrick, D.A. 1999. An examination of the effect of level of concentrate supplementation during late gestation on subsequent milk yield and composition of lactating dairy cattle. *Proceedings of the British Society of Animal* Science, p. 21.

Effects of feeding space on growing pigs housed with a reduced level of floor space

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Introduction The live weight range 20-40 kg is a critical phase for lean growth optimisation. One of the constraints on efficient pig growth is floor space allocation which is often seen as a compromise between maximum performance and economic return / unit of floor space. It is documented that a reduction of floor space, usually by removing or increasing the number of pigs in the pen, decreases both pig growth and feed intake (Kornegay et al 1984). Interpretation of these experiments is difficult, as the modification of other pen resources such as feeding space are not adjusted for. It is therefore hypothesised that by reducing floor space provision whilst at the same time increasing feeding opportunity will optimise pig performance. The objective of this experiment was to test this hypothesis.

Materials and Methods A total of 396 growing pigs, mean weight 21.3 (s.e. 0.1) kg were used in a randomised block design incorporating three treatments. The three pen designs were: Standard (**ST**) 0.4 m^2 / pig +50 mm feeding space / pig, minimum (**M**) 0.3 m^2 / pig +50 mm feeding space / pig and minimum + (**M+**) 0.3 m^2 / pig + 100 mm feeding space / pig (EU requirement for a 40kg pig = 0.4m^2). All pen designs which conformed to and followed welfare procedural guidelines, had a standardised layout which took into account pen dimensions and extra feeding space. The experimental period was 28 days and pigs were weighed individually at the start of the experiment, day 14 and day 28. Individual live weight gain (kg/d), pen feed intake (kg/d) and FCR were calculated for each two week block and all pigs were fed the same grower diet which provided 210g CP / kg, 12.5g lysine / kg and 14 MJ DE during the 28 day growing period. Data was analysed by Minitab 10.1 using a GLM analysis of variance and differences between treatment groups was done by calculating (s.e.d.) and (L.s.d).

Results A total of eleven pigs were removed during the experiment for poor growth, this resulted in four, five and two pigs for ST, M and M+ pen design respectively. There were no significant differences between start weight or live weight day 14. Feed intake during the first two weeks was significantly higher for ST than M ($P<0.05$). Between day 15-28 ST and M + had a significantly higher live weight gain compared to M ($P<0.05$). Feed intake was also significantly higher for ST and M + during day 15-28 compared to M ($P<0.05$; $P<0.001$ respectively) see Table1. No significant differences were seen between live weight at day 28. Live weight gain over the 28 day experimental period was significantly different between ST and M (0.605 v 0.567, s.e.d 0.013, $P<0.01$), but not between ST and M +. Feed intake from day 0-28 was significantly different between ST and M (1.149 v 1.075, s.e.d 0.010, $P<0.001$) and M + v M (1.110 v 1.075 s.e.d 0.010, $P<0.05$). The coefficient of variation for live weight gain from day 15-28 for ST, M and M + was 0.23, 0.24 and 0.19 respectively and from day 0-28 0.17, 0.22 and 0.17. Total live weight gain kg / m^2 of floor space from day 15-28 was significantly lower for ST compared to M and M+ (1.79 v 2.25 and 2.37, s.e.d 0.053, $P<0.001$) and M v M+ (2.25 v 2.37, s.e.d 0.053, $P<0.05$).

Table 1 *Performance of pigs housed with different combinations of floor and feeding space allocation.*

	ST	**M**	**M+**	
Floor space m^2 / pig	0.40	0.30	0.30	
Feeding space mm / pig	50	50	100	s.e.d
Live weight start (kg)	21.1	21.4	21.4	0.25
Live weight day 28 (kg)	38.1	37.4	37.8	0.47
Day 0-14				
Live weight gain (kg/d)	0.486	0.461	0.465	0.014
Feed intake (kg/d)	0.911^{a}	0.871^{b}	0.883	0.017
FCR	1.917	1.965	2.013	0.047
Day 15-28				
Live weight gain (kg/d)	0.719^{a}	0.676^{b}	0.713^{a}	0.018
Feed intake (kg/d)	1.395^{c}	1.287^{ad}	1.360^{b}	0.018
FCR	1.954	1.928	1.892	0.057

Values in the same row with different superscripts are significantly different ^{ab} ($P<0.05$), ^{cd} ($P<0.001$).

Conclusion A decrease of floor space *per se*, results in a depressed live weight gain and feed intake. Supplementing a reduced floor space allocation with increased feeding opportunity provides a beneficial performance response and increased growth uniformity. This alteration to pen design environment provides a resource substitution, especially when other important pen facilities become limiting. Understanding the complex interactions between floor and feeding allocation per pig can elicit substantial improvements to efficient pig meat production, both in terms of pig performance and output kg / m^2.

Reference E.T.Kornegay, D.R.Notter 1984. Effects of floor space and number of pigs per pen on performance. *Pig News and Information* **5**: 23-33.

Component digestibility in cannulated and intact pigs fed diets containing different raw materials.

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Introduction. The effects of cannulation have not been widely studied in pigs. It is possible that digestive processes may be affected due to alterations in the gut micro-ecosystem and anaerobic conditions at the cannulation site. In studies where cannulated animals are used for digestibility measurements over the total tract as well as at the terminal ileum, it is important to determine if the process of cannulation can affect the results. The objective of this study was to evaluate the effect of cannulation on digestion in the pig by determining total tract digestibility of components from diets containing different raw materials (A-E) using both intact pigs and pigs fitted with simple T-pieces at the terminal ileum.

Material and methods A metabolism trial was conducted using twelve female pigs, (modern commercial white hybrid), six intact and six fitted with T-piece cannulas at the terminal ileum. Animals were housed in individual pens for the duration of the trial. A basal diet was formulated, (744g/kg wheatfeed, 51g/kg oil, 51g/kg fish meal and 154g/kg hipro soya) and six experimental meal diets subsequently prepared using 5 different conventional raw materials (Table 1). An inert marker, titanium dioxide, was incorporated into each experimental diet at a rate of 1g/kg together with appropriate levels of vitamin and mineral premix, salt and limestone flour.

Table 1 *Composition of experimental diets (g/kg)*

DIET	1	2	3	4	5	6
Basal	1000	300	300	300	300	650
A	-	700	-	-	-	-
B	-	-	700	-	-	-
C	-	-	-	700	-	-
D	-	-	-	-	700	-
E	-	-	-	-	-	350

In two 5x5 Latin Squares, each diet was fed to one cannulated and one intact pig in each of five collection periods. Pigs were fed on a twice daily restricted regime of 0.90 estimate for DE requirement (ARC, 1981) with amounts offered being based on initial live weight of 25kg and subsequently on live weight at the end of each collection period. Water was offered to appetite after each meal. Each collection period consisted of five days acclimatisation followed by five days of faecal collection.

Analysis for titanium dioxide and components, (listed Table 2) allowed the calculation of coefficients of component digestibility over the total tract in both intact, (CD_{TT}) and cannulated pigs, (CD_{CTT}).

Results Digestibility coefficients did not differ significantly between intact and cannulated pigs (*NS)* for DM, CP, CF or EE (Table 2). Mean coefficient of starch digestibility was 0.974 and 0.966 for intact and cannulated pigs respectively, (s.e.d. 0.0017, $P<0.001$). Data for CD_{TT} and CD_{CTT} were not influenced by collection period for any of the components or diets (*NS*).

Table 2 *Coefficients of component digestibility in intact (CD_{TT}) and cannulated (CD_{CTT}) pigs*

		DM	CP	OIL EE	CF	STARCH
DIET 1	CD_{TT}	0.698	0.816	0.886	0.223	0.933
	CD_{CTT}	0.699	0.818	0.863	0.225	0.914
DIET 2	CD_{TT}	0.828	0.851	0.898	0.218	0.985
	CD_{CTT}	0.823	0.847	0.896	0.189	0.980
DIET 3	CD_{TT}	0.825	0.839	0.883	0.247	0.983
	CD_{CTT}	0.793	0.797	0.860	0.172	0.977
DIET 4	CD_{TT}	0.827	0.810	0.909	0.289	0.989
	CD_{CTT}	0.818	0.790	0.897	0.248	0.987
DIET 5	CD_{TT}	0.777	0.786	0.885	0.193	0.985
	CD_{CTT}	0.783	0.805	0.857	0.233	0.982
DIET 6	CD_{TT}	0.747	0.809	0.863	0.327	0.967
	CD_{CTT}	0.756	0.822	0.876	0.375	0.957
	CD_{TT}	*0.784*	*0.819*	*0.888*	*0.250*	*0.974*
Means for	*CD_{CTT}*	*0.779*	*0.813*	*0.875*	*0.227*	*0.966*
diets 1-6	*s.e.d*	*0.0051*	*0.0083*	*0.0066*	*0.0160*	*0.0017*
	(P)	*NS*	*NS*	*NS*	*NS*	*<0.001*

Conclusions Determination of total tract digestibility of components is largely unaffected by the process of ileal cannulation, although further investigation of starch digestibility is required. Coefficients of digestibility for intact and cannulated pigs are not affected by time. These results suggest that the cannulation process utilised in this study allows accurate total tract digestibility measurements to be made using pigs that have been modified for ileal digestibility determinations.

Acknowledgments The support of ABN Ltd (J. Bibby Agriculture and Trident Feeds) is gratefully acknowledged.

References Agricultural Research Council. 1981. The Nutrient Requirements Of Pigs: technical report by ARC working party. Farnham Royal: Commonwealth Agricultural Bureaux.

The use of an *in vitro* nitrogen digestibility screening method to assess the effect of protease pre-treatment of soyabean meals.

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Introduction. The assessment of the potential usefulness of enzymes as animal feed additives or treatments requires an understanding not only of the effect an enzyme has on its target substrate but also on the digestibility of that substrate. *In vivo* digestibility studies are expensive, time consuming and often involve invasive procedures that necessitate premature slaughtering of experimental animals. Preliminary laboratory screening methods can be used to indicate potential beneficial treatments prior to undertaking animal trials. The objective of this study was to assess the effect of protease pre-treatment of four differently processed soyabean meals on the digestibility of protein using an *in vitro* digestibility of nitrogen (Boisen and Fernandez 1997) technique as a screening method. The assumption implicit in this objective was that, if protease pre-treatment did not improve *in vitro* digestibility, it was unlikely to improve *in vivo* digestibility.

Materials and methods. The study was conducted according to a two factor factorial design. The first factor was the type of soyabean meal, steam pressure cooked at 110 - 120^{o} C for 15 - 20 min (SPC), micronized (MIC), toasted (TSD) or autoclaved at 109^{o} C for 5 min (AUT). The second factor was the presence or absence of 20 000 units g^{-1} N of microbial proteases P2, P3 or P4 (Finnfeeds International Ltd). Each soyabean meal was sieved through a 0.5mm sieve and slurries (3 water:1meal) prepared from the sieved fractions. Three replicate samples of each slurry were treated with 0 or 20 000 units g^{-1} N of P2, P3 or P4. The pH of the slurries was 6.5 which was within the optimum pH range for proteases P3 and P4. Slurries treated with P2 were adjusted to pH 4 (pH optimum for P2) with 4 M HCl. All slurries were incubated for 24 h at 20^{o} C. After incubation 1 - 2g of each slurry was accurately weighed (± 0.001 g) into conical flasks and was subjected to digestion with porcine pepsin and then pancreatin according to the method of Boisen and Fernandez (1997) with the following modification. After digestion with pancreatin, soluble protein was precipitated with 20% sulphosalicylic acid, the digests were filtered and the residue washed with ethanol and acetone prior to drying to constant weight in a forced air oven at 50^{o} C. The dried residues and samples of each slurry prior to digestion were analysed for total N using a CNS2000 analyser (LECO UK Ltd). *In vitro* N digestibility was calculated using the equation $(N_o - N_d)/N_o$, where N_o = nitrogen content of the original sample and N_d = nitrogen content remaining after digestion. The results were subjected to analysis of variance.

Results. The results of *in vitro* nitrogen digestibility of different soyabean meals in response to treatment with P2, P3 and P4 are presented in Table 1. Factorial analysis of the effect of protease treatments showed that there were no overall significant differences between P2, P3 or P4 but they significantly increased (P <0.001) *in vitro* nitrogen digestibility by 6.5%, 7.4% and 7.2% respectively compared to the controls.

Table 1 *In vitro* nitrogen digestibility of steam pressure cooked (SPC), micronized (MIC), toasted (TSD) and autoclaved (AUT) soyabean meals steeped for 24 h at 20^{o} C with 0 or 20 000 units g^{-1} N of proteases P2, P3 or P4.

	Protease				
	0	P2	P3	P4	s.e.d.
SPC	0.80^{1b}	0.84^{a2}	0.85^{a1}	0.88^{1c}	0.014
MIC	0.75^{2b}	0.80^{a1}	0.83^{1c}	0.78^{a2}	0.014
TSD	0.68^{3b}	0.74^{a3}	0.74^{a2}	0.75^{a3}	0.014
AUT	0.70^{4b}	0.81^{a1}	0.78^{3c}	0.82^{a4}	0.014

^{1,2,3,4} means in the same column with different superscripts differ significantly P <0.05
$^{a, b, c}$ means in the same row with different superscripts differ significantly P <0.05

Although there was a significant interaction (P < 0.001) between protease treatment and soyabean meal no single protease gave consistently better results with all soyabean meals. No antagonistic interactions were observed between protease treatments and *in vitro* N digestibility.

Conclusions This study showed that *in vitro* nitrogen digestibility of soyabean meals was increased in response to pre-treatment with proteases. The differences in N digestibility observed between different soyabean meals, in untreated and protease treated samples, was probably due to differences in protein conformation caused by heat induced interactions during processing. This may affect the availability of binding sites for both digestive and exogenous proteases and hence the degree of protein degradation. These results cannot be extrapolated to an *in vivo* situation as the method cannot account for endogenous nitrogen losses. However, they give an indication of possible protease / soyabean meal combinations which may have beneficial effects on protein digestibility in the pig.

References Boisen, S. and Fernandez, J. 1997. Prediction of the total tract digestibility of energy in feedstuffs and pig diets by *in vitro* analyses. *Animal Feed Science and Technology*, **68,** 277-286.

Cassava leaves as protein supplement to basal diet for weaner pigs in a sustainable swine production system in the tropics

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Introduction Swine production is gradually being practised in Nigeria in an integrated manner where farmers apart from keeping pigs also grow root and legume crops on the farms. One of such major crops often grown is cassava. The roots have been shown to be of tremendous value as an energy source in swine feeding (Iyayi and Tewe, 1994). The leaves which are often discarded on the farm after harvest can be processed and used as protein supplement for rearing pigs because of its high protein content (19.67-39.90%, Allen, 1984). The objective of this study was to use wilted cassava leaves as supplement to basal diets for weaner pigs and estimate the overall performance, serum metabolites and nutrient digestibility of animals on such diets.

Materials and method Twelve weaner pigs (6males and 6 females) were used in this study. They were randomly allocated on bases of body weight and sex to 3 treatment diets each with 2 males and 2 females serving as replicates. Diet 1 was a weaner concentrate diet used on our Teaching and research farm with 21% protein and 2860kcal kg^{-1} energy. Animals on diets 2 and 3 had the same concentrate diet but the quantity of the ration was reduced by fixed amounts and the short falls were then replaced with equivalent quantities of cassava leaves which were harvested the previous day, chopped and air dried. The animals' daily supply of the respective rations according to their feed requirement was 4000g basal concentrate for animals in group 1, 3200g basal concentrate + 800g cassava leaves for animals in group 2 and 2400g + 1600g cassava leaves for animals in group 3. The rations were supplied in a free choice manner 3 days of the week. All other standard management practices were adhered to. For 10 weeks, 5 ml of blood samples were collected in heparinized bottles and serum harvested from them by centrifugation at 1784 G for 10minutes. Records of feed consumption and body weight of the animals were taken weekly after which they were. transferred to metabolic cages for digestibility studies. All data were statistically analysed by ANOVA technique and means separated by the multiple range test.

Results The mean performance data and changes in serum total protein are presented in Table 1. Changes in digestibility of dry matter (DM), crude protein (CP) and crude fibre (CF) are presented in Figure 1.Using cassava leaves as supplement to feed weaners resulted in significant ($P<0.05$) improvement in their feed consumption and daily weight gain apparently due to better feed conversion and efficiency of feed utilization. The serum total protein was also significantly ($P<0.05$) in creased; an indication of a better quality of such diets. Digestibility of DM, CP and CF were significantly ($P<0.05$) improved with supplementation of cassava leaves. Perhaps cassava leaves alters the retention time of the feed through the GIT making for a possible higher digestibility of the feed. Similar findings have been reported by Smith (1988)

Table 1. Performance and serum total protein data

	Cassava leaves (g)/animal		
Parameters	0	200	400
Daily feed intake (g)	540[a]	667[b]	672[b]
Daily weight gain (g)	137[a]	265[b]	267[b]
Feed conversion	0.25[a]	0.40[b]	0.40[b]
Efficiency of feed Utilization	3.93[a]	2.52[b]	2.52[b]
Serum total protein (mg/100ml)	5.08[a]	6.00[b]	5.78[b]

Means with different superscript on same row are significantly ($P<0.05$) different.

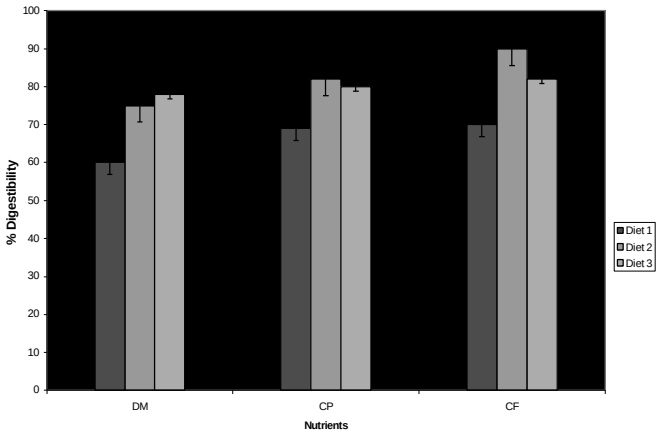

Figure 1. % Digestibility of nutrients in pigs

Conclusion Results of the present study show that cassava leaves, a waste on the farm, can serve as a good supplement to concentrate feed for weaner pigs. Feeding cassava leaves leads to improved digestibility of nutrients by the animals and hence their overall performance in a cassava-swine production system

References

Allen, R.D. (1984). Feedstuff ingredient analysis table. *Feedstuffs* (USA) A56 (30): 25-30.
Iyayi, E.A. and O.O. Tewe (1994). Cassava feeding in small holder livestock units. *Acta Horticulturae* 375: 261-269.
Smith, O.B. (1988). A review of ruminant responses to cassva-based diets. In: Hahn, S.K., L.Reynolds and G.N. Egbunike (eds). *Cassava as livestcok feed in Africa. Proceedings of IITA/ILCA/University of Ibadan workshop*,14-18 November, 1988, pp 39-53.

Liquid diets fed prior to weaning enhance performance of weaned piglets

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Introduction Creep feeding enhances weaning weight (King *et al*., 1998) and may also enhance early post-weaning growth rate, both of which are positively correlated to subsequent performance (Miller *et al*., 1999). When pre-weaning feeds are offered, current practice in the UK is to feed either dry feed from day 14 to weaning or acidified milk replacer from days 3 to 18. Intakes of dry feed pre-weaning are generally low whereas liquid feeds are consumed more readily. Our objectives were 1) to offer creep feed as a gruel to test whether this would enhance intake of creep and provide an alternative to milk replacer, and 2) to provide all three forms of supplementary feeding together to determine whether this further increased performance. Piglets receiving no supplementary pre-weaning feed were the negative control.

Materials and methods Twenty five crossbred litters were randomly allocated to one of five treatments; A) no supplementary feed; B) acidified milk replacer to appetite from days 3 to 18; C) dry creep pellets fed from days 14 to 24; D) diet C as a gruel (1:2 meal to water) from days 14 to 24; E) combination of B, C and D. All feeds were fed to appetite. Daily intakes were recorded. Intact litters were weaned at 24 days of age into individual flatdeck pens and offered the same weaner feed. Stocking density was standardised by adjusting pen size. Individual pig weights were recorded at weaning and on days 7 and 35 after weaning. Data were analysed by litter using the GLM procedure of Minitab 12.2 using start weight as a covariate.

Results Piglet performance during the experiment is given in Table 1. Providing creep feed from day 14 as a gruel enhanced intake above that of dry creep and gave equivalent performance to milk replacer. Greater pre-weaning feed intake was achieved by combining all forms of supplementary feeding, however, this failed to improve weaning weight or post weaning performance above that of gruel alone. Litters which received dry creep had the lowest growth rate in the week after weaning. Piglets which received milk replacer from day 3 had significantly lower weaning weights than piglets which did not.

Table 1 *Piglet weaning weights and weights 35 days post-weaning, average daily gain for week 1 (ADGwk1) and for the first 35 days (ADG35d) after weaning and feed intake (FI) the first 35 days after weaning for piglets receiving different pre-weaning supplementary feeds*

Supplement	A	B	C	D	E	SEM
Number of litters	5	5	5	5	5	
Litter size	10.2	10.6	11.0	10.0	11.6	
Prewean FI (g/pig)	0	158	90	441	792	
Wean weight (kg)	6.68 ^{bc}	6.30 ^{a}	6.69 ^{bc}	6.95 ^{b}	6.38 ^{ac}	0.159*
ADGwk1 (g)	75.1 ^{c}	97.9 ^{ac}	40.9 ^{b}	114.6 ^{a}	94.2 ^{ac}	13.9**
FI 35d (g/pig/day)	551.6	600.5	546.5	636.9	590.0	36.0
ADG35d (g)	355.6 ^{bc}	387.4 ^{a}	339.9 ^{b}	401.1 ^{a}	376.5 ^{ac}	13.1**

* significant difference among groups $P < 0.05$, ** significant difference among groups $P < 0.01$, ^{abc} numbers in the same row with the same superscript are not significantly different from each other.

Conclusions These results suggest that offering creep feed as a gruel enhances creep feed intake. Similar increases in post weaning feed intake and growth rate were achieved by both milk replacer and gruel, although surprisingly in this experiment, there was no direct relationship between preweaning feed intake and post weaning performance. It is interesting to note the low weaning weights of piglets which received milk replacer from day 3 (B and E). Further work is required to determine whether early provision of milk replacer affects piglet demand for sow's milk in early lactation thereby compromising her overall milk output.

References

King, R.H., Boyce, J.M. and Dunshea, F.R. 1998. Effect of supplemental nutrients on the growth performance of sucking pigs. *Australian Journal of Agricultural Research* **49**: 883-887.

Miller, H.M., Toplis, P. and Slade, R.D. 1999. Weaning weight and daily live weight gain in the week after weaning predict piglet performance. *Manipulating Pig Production VII* ed. Cranwell, P.D., APSA, Atwood, Victoria, Australia, in press.

Early post-weaning benefits of porcine plasma re-emerge in later growth performance

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Introduction Porcine plasma is known to improve immediate post-weaning performance but this is often only evident in the first week to ten days after weaning (Toplis and Miller, 1999). Few if any studies have investigated whether there are any long term effects over the entire growth period. It has previously been shown that piglets in poor health situations (Coffey and Cromwell, 1995) demonstrate markedly greater responses to porcine plasma. The objective of this study was to determine whether porcine plasma produced long-term benefits and whether this was modulated by health challenge during the weaning period.

Materials and methods One hundred and twelve piglets (JSR Healthbred) with no previous access to creep feed were weaned at 23.0 ± 0.3 days of age (mean ± SEM) and 7.12 ± 0.12 kg liveweight into conventional, fully-slatted, flat-deck pens (1.99m^2) each fitted with a feed hopper (1.45m length) across the front and two nipple drinkers mounted on the rear wall. Two of the four pens used for each replicate were of new construction and had not previously housed pigs. Flat-deck temperature was reduced on a pre-set scale from 28^{o}C to 22^{o}C over the 20 days following weaning. Piglets were allocated to 4 treatments in a 2 x 2 factorial design ensuring each group was balanced for litter origin, weaning weight and gender profiles. Treatments were new (N) or old (O) flat-decks and 0 g (C) or 75 g (P) plasma/kg diet. Diets were formulated to be isonutritious (16 MJ DE/kg, 16 g lysine/kg) and to provide the ideal profile of the major amino acids. Trial diets were fed to 20 days post-weaning. Feed disappearance was recorded daily. Piglets were weighed at weaning and on days 7, 14 and 20 thereafter. From day 20 pigs were grown according to usual commercial practice to a slaughter weight of 87.8 ± 0.7 kg. Liveweight and age were recorded prior to slaughter (n = 76). Food and water were available *ad libitum* throughout. Treatment effects were analysed using the GLM procedure of Minitab 12.2 with litter origin and gender included in the model.

Results No significant treatment interactions were observed. There were no significant differences in feed intake, feed conversion ratio and overall average daily gain (ADG) among treatment groups during the 20 days post-weaning (P>0.05). ADG days 1 to 7 following weaning was significantly higher in P pigs (Table 1). In contrast, ADG days 8 to 14 and days 15 to 20 was significantly greater for C piglets (P<0.01 and P<0.05 respectively). Mean slaughter weights were similar for all treatment groups (P<0.05). ADG from day 20 to slaughter was significantly greater in P pigs and resulted in a significant reduction in number of days from weaning to slaughter (DWS). DWS was significantly greater in N-C pigs than for other treatment groups (P<0.01).

Table 1 Effect of treatment during the weaner period on growth performance of pigs from weaning to slaughter.

Treatment	Average daily gain (g/pig/day)					Weaning to slaughter (days)
Days	1-7	8-14	15-20	1-20	20-slaughter	
Control	120^a	407^c	417^a	315	621^c	130.1^c
Plasma	154^b	317^d	379^b	300	648^d	124.9^d
New	147	386	397	310	627	129.2^a
Old	127	388	399	304	642	125.8^b
New-Control (N-C)	128	402	411	314	607	133.3
Old-Control (O-C)	113	413	423	316	635	127.0
New-Plasma (N-P)	167	370	383	307	647	125.2
Old-Plasma (O-P)	140	363	375	293	650	124.6

Means in the same column with different superscripts differ significantly; ^{ab} P<0.05, ^{cd} P<0.01

Conclusion Inclusion of porcine plasma in weaner diets improved pig growth rates from transfer to slaughter despite having produced only transient improvements in piglet growth in the immediate post-weaning period. This suggests that porcine plasma in the nursery diet conditions the piglet via some as yet unidentified mechanism. Surprisingly, N piglets performed less well than the O piglets although this effect was mitigated to some extent by inclusion of plasma in the nursery diet. This indicates that in this experiment the effects of porcine plasma and environment were not additive and therefore may share common mechanisms of influence. The results of this study suggest that weaner environment and nutrition impact on subsequent growth performance.

References

Coffey, R.D. and Cromwell, G.L. 1995. The impact of environment and antimicrobial agents on growth response of early-weaned pigs to spray-dried porcine plasma. *Journal of Animal Science* **73**: 2532-2539.
Toplis, P. and Miller, H.M. 1999. Postweaning benefits of porcine plasma. *Proceedings of the British Society of Animal Science. 1999*, p.173.

Kola-pod husk as a partial substitute for maize in layer diets

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Introduction The continued search for alternative feed resources for poultry in Africa is necessitated by the competition between people and poultry for cereal grains. Several farm and agro-industrial by-products have been evaluated for this purpose in West-Africa. One of such by-products, cocoa-pod husk (CPH) has shown promise in laying hen diets in Ghana and Nigeria (Osei et al., 1991; Sobamiwa, 1998). Another farm by-product sharing several similarities with CPH but of higher crude protein and lower crude fibre contents is Kola-pod husk (KPH). Nigeria produces 70% of world kola (Cola *nitida* Vent) and consequently the bulk of KPH which is estimated at 210,000 tones annually (Ogutuga, 1975). The present study investigates the partial replacement of maize with KPH in laying hen diets in South Western Nigeria. This is the region of kola production and it is characterized by small holder rural poultry farms which could easily adopt the findings of this study.

Materials and Method Freshly broken KPH were collected from the Kola Unit of CRIN. They were dried under direct sunlight of 4-6 days. Forty Nera Black chickens in their 12^{th} month of lay were used in the 10-week experiment. The birds were housed two per pen, five of which represented a treatment. The rations included the control diet (CD; 50% maize) and three diets in which the maize in CD was substituted with KPH at 200,400 and 600gkg^{-1} levels. Feed intake per replicate group was measured weekly. Eggs were collected daily per replicate and pooled weekly to calculate percentage egg production and average egg weight. Feed efficiency was calculated from the egg mass and feed intake data. During the 5^{th}, 7^{th} and 10th week, 10 eggs were randomly selected per dietary treatment to determine shell percentage. Feed cost/kg egg was calculated using prevailing market prices of feed ingredients. The cost of KPH was fixed similar to that already in use for CPH. Data from the trial were analysed by the ANOVA technique and means were separated by the Multiple Range Test.

Results Data on the biological and economical efficiencies of the control and test diets are presented in Table 1. Feed intake was higher ($P<0.05$) at the 400gkg^{-1} maize replacement level (400MRL) The test diets did not differ from the control in percentage egg production, egg weight and mass, feed efficiency and egg shell percentage. Feed cost/kg egg declined with increasing MRL.

Table 1 Bird performance and economic returns

	Maize Replacement Level (gkg^{-1})					
Parameters	0	200	400	600	P value	s.e.m.
Feed intake (g bird^{-1}d^{-1})	110.40^{b}	106.82^{b}	119.64^{a}	110.38^{b}	0.01	7.61
Percent egg production	67.49	64.53	71.30	68.28	0.07	5.42
Egg weight (g)	57.62	60.30	58.94	58.32	0.27	3.10
Egg mass (g bird^{-1}d^{-1})	38.41	38.33	41.87	40.01	0.11	3.53
Feed efficiency	0.35	0.36	0.35	0.36	0.82	0.03
Egg shell percentage	9.07	9.41	8.74	8.93	0.23	0.50
Feed cost/kg egg (N)	57.40	51.00	47.10	40.90	-	-

^{ab} Means in the same row with different superscripts differ significantly ($P< 0.05$).

Conclusion The results of this premier study on kola-pod husk as a feedstuff in layer diets show that this farm waste product could suitably replace up to 600gkg^{-1} maize in the feed with increased profit margin.

Acknowledgment The permission of the Director, CRIN, Ibadan, Nigeria to publish the paper is acknowledged.

References

Ogutuga, D.B.A. 1975. Chemical composition and potential commercial uses of kolanut, *Cola nitida* Vent. (Scholt and Endlicher). Ghana Journal of Agric. Science, 8: 121-125.

Osei, S.A. Atuahene, C.C. Heathooke, D., Frimpong, E.B. and Adomako, D. 1991. Cocoa pod husk meal as a feed ingredient in layer diets. Animal Feed Science and Technology, 40: 267-272.

Sobamiwa, O. 1998. Performance and egg quality of hens fed cocoa husk-based diets. Nigerian Journal of Animal Production, 25(1): 22-24.

Factors affecting the eating quality of pork

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Introduction A Belgian study shows that the five most important meat attributes for the consumers are as follows: quality, taste, freshness, absence of hormones and healthiness (Verbeke and Viaene, 1999). This corroborates with the results of a French survey by Touraille (1992), who found that sensory properties and security aspects (hormones) of meat are of paramount importance for the consumer. It is important to direct pork production towards an acceptable product adapted to the consumer's demand. The objective of this study is to evaluate in which way and how strong the sensory quality parameters are influenced by different factors.

Materials and methods Meat samples from 120 animals, half castrates, half gilts and belonging to Piétrain x Belgian Landrace, Piétrain x Seghers hybrid and Piétrain x Large White cross, were analysed. For each animal daily feed intake, daily gain, feed conversion, carcass weight, loin fat thickness, backfat thickness (3/4th last rib), lean meat content and conformation (S.K.G.-II) were registered. At 24 hrs p.m., the *longissimus thoracis et lumborum* (LTL) of the left carcass side was sampled and divided into pieces (2.5 cm). One piece of the LT and the LL were minced together in a cutter, followed by intramuscular fat (IMF) extraction (chloroform/methanol/water) and fatty acid determination (gas chromatography). The mid-loin was vacuum packed and stored at -18°C for several months for the determination of eating quality. At each panel session, three pieces of grilled meat (internal temp. 74°C) from animals of the same sex and originating from the three genotypes, were offered to six out of eight selected and trained panel members. They judged the meat on a scale from 1 to 8, from extremely bad to extremely good for tenderness, tastiness and juiciness. General linear models with the sensory parameters as dependent variables and respectively breed and sex as factors were applied. Pearson correlation coefficients were calculated between the sensory properties and the other parameters.

Results Respectively, 22, 23 and 2% of the variation in tenderness, taste intensity and juiciness can be explained by genotype, while only 2, 4 and 3% can be explained by sex (results not shown). Daily feed intake and daily gain are not significantly related to the eating quality parameters (Table 1). An increased feed conversion ratio improves slightly the tastiness of pork, without affecting tenderness or juiciness. The IMF content increases linearly with daily feed intake and daily gain of the animals. The carcass parameters are of minor influence for juiciness of the pork. Thicker loin fat and backfat layers are positively associated with tenderness of the meat. Concomitantly, higher lean meat contents and, even to larger extent, better conformations (lower type indexes), are strongly associated with tougher and less tasty meat, and lower IMF levels. The IMF content is better correlated with tenderness and taste intensity than with juiciness. For the fatty acid pattern of the IMF it is clear that the saturated (SFA) and monounsaturated (MUFA) fatty acids correlate positively with the sensory parameters, while the polyunsaturated fatty acids (PUFA) correlate negatively.

Table 1 Pearson correlations between sensory parameters and animals performance, carcass and IMF characteristics

	Tenderness	Taste intensity	Juiciness	IMF content
Daily feed intake (kg/dag)	0.13	0.15	0.09	0.42 (P=0.000)
Daily gain (kg/dag)	0.07	0.01	0.07	0.32 (P=0.000)
Feed conversion ratio (kg/kg)	0.06	0.20 (P=0.033)	-0.00	0.03
Carcass weight (kg)	-0.06	-0.19 (P=0.036)	0.04	0.26 (P=0.004)
Loin fat thickness (mm)	0.23 (P=0.013)	0.18	0.08	0.52 (P=0.000)
Backfat thickness (mm)	0.19 (P=0.037)	0.13	0.20 (P=0.031)	0.37 (P=0.000)
Lean meat content (%)	-0.37 (P=0.000)	-0.37 (P=0.000)	-0.14	-0.53 (P=0.000)
Conformation (Type index)	0.50 (P=0.000)	0.50 (P=0.000)	0.11	0.43 (P=0.000)
IMF content (g/100g meat)	0.31 (P=0.001)	0.31 (P=0.001)	0.15	-
SFA (g SFA/100g fatty acids)	0.32 (P=0.000)	0.24 (P=0.009)	0.24 (P=0.01)	0.60 (P=0.000)
MUFA (g MUFA/100g fatty acids	0.21 (P=0.023)	0.13	0.02	0.69 (P=0.000)
PUFA (g PUFA/100g fatty acids)	-0.32 (P=0.000)	-0.22 (P=0.017)	-0.14	-0.80 (P=0.000)

Conclusions Animal performance characteristics only slightly influence the sensory characteristics of pork. Genotype, carcass quality and to a lower extent IMF level significantly affect the eating quality of pork.

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References

Touraille, C. 1992. Consumer evaluation of meat quality criteria. *Proceedings of the 38th International Congress of Meat Science and Technology*, 23-28 August, Clermont-Ferrand, France, 301-304.
Verbeke, W., Viaene, J., 1999. Beliefs, attitude and behaviour towards fresh meat consumption in Belgium: empirical evidence from a consumer survey. *Food Quality and Preference* **10**: 437-445.

Changes in the relationship between porcine fetal size and organ development during pregnancy

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Introduction Individual piglet birthweight is a major determinant of subsequent survival and weaning weight of the litter. Low birthweight piglets are more likely to die from starvation and thermoregulatory stress than their heavier littermates, while those that do survive grow more slowly and reach a lower mature body weight with a higher body fat to muscle ratio. Inadequately grown porcine fetuses are often characterised by assymetrical organ development although it is not clear when this difference in relative organ size arises and whether this is a consequence of changes in cell size or cell number. The objectives of this study were to assess a range of determinants of fetal growth at stages of gestation and to determine when changes in the relationship between fetal size and organ development occur.

Materials and Methods Twenty-one Large White x Landrace litters were examined. Pigs were slaughtered on Day 30 (n=3), Day 45 (n=5), Day 65 (n=3) or Day 100 (n=5) of pregnancy, all live fetuses were weighed and the lightest fetus (S) and a normal sized fetus (N) identified. All live-born piglets obtained from 5 litters on the day of birth (Day 0 *pp*) were also weighed and the lightest (S) and a normal sized (N) neonate identified. The liver, brain, lungs, heart, kidney, gut, spleen and gonads were dissected from S and N fetuses/neonates, weighed and stored in liquid nitrogen. However, day 30 fetal lungs were insufficiently developed and gonadal and gut tissues unavailable on days 100 and 0 pp. Fetal liver and kidneys from Days 30, 45 and 65 and lungs from day 45 and 65 were homogenised and levels of DNA, RNA and protein measured to determine if changes in relative organ size reflected cell hyperplasia or hypertrophy. The effect of day of pregnancy and fetal/neonatal size on individual organ weights, relative organ weight and the relationship between brain weight:individual organ weight were analysed using residual maximum likelihood algorithm (REML). The effects of day of pregnancy and fetal size on total DNA and both the DNA:protein and RNA:protein ratios were analysed using ANOVA. Relationships between fetal weight and both litter size and uterine position were examined. Uterine position was expressed on a uniform scale from 0 to 1 (Ashworth, 1991). Allometric curves were drawn for the organs most affected by size differences.

Results REML analysis indicated that the liver, lungs and kidneys were most affected by day of gestation and fetal size ($p<0.05$) for Days 30, 45 and 65 of gestation (table 1). On Day 100 and 0 *pp*, there was no significant effect of fetal/neonate size on the ratios between fetal weight and organ weight. DNA, RNA and protein content of all tissues examined increased as gestation progressed ($p<0.05$) but were not affected by fetal size. However, the kidney RNA:protein ratio was higher ($p<0.05$) in small fetuses. Fetal weight was weakly correlated with uterine position throughout gestation with a greater incidence of lighter fetuses at the cervical end of each uterine horn. Apart from Day 45, fetal weight was negatively correlated with litter size. Allometric curves showed two distinct clusters throughout pregnancy, except on Day 65 of gestation where the cluster from S fetuses approached the cluster of N fetuses, suggesting compensatory growth.

Table 1 Mean ± s.e. fetal weight (Fwt) and brain weight (Bwt) to organ weight ratios for normal-sized (N) and lightest (S) fetuses on days 30, 45 and 65 of pregnancy

Day	30		45		65		Significance	
	N	S	N	S	N	S	Day	Size
Fwt:Liver	10.17 ± 0.61	9.68 ± 0.87	9.95 ± 0.398	10.55 ± 0.74	24.07 ± 1.44	22.71 ± 2.04	*	ns
Fwt:Lungs			37.57 ± 1.50	33.03 ± 2.31	26.11 ± 1.31	24.55 ± 2.21	*	*
Fwt:Kidney	21.57 ± 1.73	23.95 ± 3.11	66.27 ± 3.98	81.93 ± 8.19	76.86 ± 6.15	75.92 ± 9.87	*	*
Bwt:Liver	1.97 ± 0.02	2.07 ± 0.37	0.35 ± 0.03	0.43 ± 0.06	0.72 ± 0.08	0.87 ± 0.16	*	*
Bwt:Lungs			1.322 ± 0.08	1.33 ± 0.13	0.77± 0.06	0.91± 0.12	*	ns
Bwt:Kidney	4.47± 0.67	5.51 ± 1.32	2.32 ± 0.28	3.32 ± 0.63	2.30 ± 0.34	2.93 ± 0.70	*	*

ns = not significant ($P>0.05$)

Conclusions In inadequately grown fetuses brain growth was spared at the expense of liver, lungs and kidney. Surprisingly the cell number and cell size of these organs were proportional to total body weight at all stages of gestation studied. The growth of inadequately fetuses appears to deviate from their normally grown littermates between days 45 and 65. Inadequate fetal growth prior to day 65 appears to depend on factors other than uterine position and litter size.

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Reference

Ashworth, C.J. 1991. Effect of premating nutritional-status and postmating progesterone supplementation on embryo survival and conceptus growth in gilts. *Animal Reproduction Science*, **26**: 311-321.

Preferences of housed finishing beef cattle for different floor types

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Introduction There is increasing public concern about the welfare of farm animals and one of the issues recently raised has been the use of totally slatted floors for rearing and finishing beef cattle. However, human perception of the needs of animals may not necessarily reflect that of the animals' needs. The objective of this experiment was to examine beef cattle preferences for different floor types, in order to provide scientific information that will be valuable in formulating a policy on the housing requirements of beef cattle.

Material and methods Six pairs of steers were allowed to choose between two types of floors in a paired choice test. The four floors tested in the first experimental period were a fully slatted floor, a fully slatted floor covered with rubber mats, a solid floor with sawdust bedding and a solid floor with straw bedding. All combinations of floor types were tested to give a total of six comparisons. The choices were repeated, using naïve animals, to give eight replicates per treatment and treatments were arranged as 6 x 6 Latin square plus two extra replicates (replicates one and four repeated). A further treatment, slats versus slats, was used as a control and was examined at the end of the first experimental test period. A total of 112 crossbred Continental steers with a mean initial live weight of 536 (s.e. 5.1) kg were used. In the second test period, pairs of steers were given a choice of rubber strips placed directly over slats or rubber mats. Similarly, the choice was repeated using naïve animals to give eight replicates. The 16 crossbred Continental steers used had a mean initial live weight of 537 (s.e. 7.8) kg. The animals were allowed 17 days to habituate and their behaviour was recorded by video for 72 hours on days 18 to 21. The animal's choice of floor, and their behaviour when in the chosen pen, was recorded. The time spent in each choice pen was calculated for time spent lying and standing over the 72 hours. Then *t* tests were carried out to determine if the proportion of time spent performing these behaviours in the each of two choice tests pens was significantly different from 0.5.

Results In the comparison of slats and slats covered with rubber mats animals preferred to lie and stand ($P<0.001$) on the slats covered with the rubber mats rather than on the concrete slats. When animals were given the choice of slats or sawdust, they preferred to lie on sawdust ($P<0.001$), but had no significant preference as to where they stood. Animals showed a preference for lying ($P<0.001$) and standing ($P<0.01$) on straw rather than on slats. Animals preferred to lie on sawdust rather than mats ($P<0.001$), but showed no significant preference as to where they stood. Animals preferred to both lie and stand ($P<0.001$) on straw rather than on mats. In the comparison of sawdust and straw, animals preferred to lie in the straw-bedded pen ($P<0.05$). However, there was no significant difference in the proportion of time spent standing in the two pens. No significant preferences were noted in the control (slats versus slats). There was no significant preference for either lying or standing on rubber mats or rubber strips.

Table 1 Mean proportion of time spent performing behaviours in each substrate area, over a 72h period for each paired substrate comparison

Behaviour	Substrates compared		s.e.m.	Substrate compared		s.e.m.
	Slats	**Mats**		**Slats**	**Sawdust**	
Lying	0.0	1.0	0.00	0.02	0.98	0.019
Standing	0.16	0.84	0.026	0.42	0.58	0.045
	Slats	**Straw**		**Mats**	**Sawdust**	
Lying	0.0	1.0	0.00	0.03	0.97	0.024
Standing	0.32	0.68	0.038	0.41	0.59	0.046
	Mats	**Straw**		**Sawdust**	**Straw**	
Lying	0.06	0.94	0.040	0.19	0.81	0.108
Standing	0.29	0.71	0.028	0.44	0.56	0.063
	Slats	**Slats**		**Mats**	**Strips**	
Lying	0.45	0.55	0.126	0.58	0.42	0.122
Standing	0.45	0.55	0.094	0.53	0.47	0.094

Conclusions Straw was the most preferred floor type in finishing beef cattle, followed by sawdust, then mats and then slats. In particular these preferences were prevalent in lying choices, suggesting that cattle prefer bedding when resting.

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An examination of factors affecting the dirtiness of housed finishing beef cattle

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Introduction Cattle presented for slaughter must now attain a very high level of cleanliness. The objective of this on farm study was to investigate the factors that affect the cleanliness of housed beef cattle in order to provide sound scientific information on the relative importance of these factors and to provide a basis for advice to the industry on producing cleaner cattle.

Materials and methods During an on farm study carried out over two years, from early December to mid February, one hundred and thirty three farms were visited, and one hundred and sixty four units of cattle were monitored. Information with regard to the housing, feeding and management of the cattle was collected. The quality of the ventilation in the cattle accommodation was assessed using a scale of 1 to 4, with 1 representing the worst ventilated sheds and 4 the best. In each case the size of the pen, the proportion of the floor area as void (in slatted pens) and as solid, the number of cattle in the pen, the mean liveweight of the animals and the length of time housed were recorded. The amount of concentrates fed was recorded, and representative chemical analyses were performed on the grass silages and the concentrates which were fed. The cattle were dirt scored using the scale developed by Scott and Kelly (1989). Comparisons were made between slatted and non-slatted accommodation and between wet and dry concentrates and silages by analysis of variance, without blocking, using Genstat 5, third edition for windows. Correlation coefficients between individual parameters and dirt score were obtained using Microsoft excel.

Results Cattle in slatted accommodation were dirtier than cattle in non slatted accommodation ($P<0.01$) and those that were housed for a longer time period ($P<0.001$) and in more poorly ventilated sheds ($P<0.01$) were dirtier. In slatted accommodation increasing the proportion of the pen floor as solid concrete (PFSC) increased the dirtiness of the animals ($P<0.05$). The overall correlation between concentrate oven dry matter content (CODM) and dirtiness was not significant. However, cattle given wet concentrates (mean DM 473.8g/kg s.e.m.18.2) were significantly dirtier ($P<0.01$) than those given dry concentrates (mean DM 846.9g/kg, s.e.m. 3.0). Increasing the amount of concentrates fed on both a fresh weight (TCFR) and on a dry matter (TCDM) basis resulted in dirtier cattle ($P<0.001$). Silage toluene corrected dry matter content (SDM) was negatively, but non-significantly correlated to dirt score for all housing types. However, cattle given silage with a DM content of over 300g/kg were significantly cleaner ($P<0.01$) than those given wetter silages.

Table 1 *Correlation coefficients between cattle dirt score and housing, management and feed factors*

	All housing types		Slatted accommodation only	
	Correlation coefficient (r)	Significance	Correlation coefficient (r)	Significance
Pen size	-0.260	**	-0.150	NS
Number of cattle in pen	-0.212	*	-0.117	NS
Stocking density	0.236	**	0.089	NS
PFSC	-0.086	NS	0.184	*
Length of time housed	0.342	***	0.432	***
Ventilation	-0.246	**	-0.204	*
TCFR	0.328	***	0.303	**
TCDM	0.325	***	0.319	**
CODM	-0.071	NS	-0.029	NS
Concentrate ash (DM)	0.202	*	0.185	*
Concentrate A.D.F.(DM)	0.184	*	0.121	NS
SDM	-0.152	NS	-0.055	NS

Conclusions Increasing both the proportion of the pen floor as solid area and the length of time the cattle were housed, and decreasing the pen size and the number of cattle in the pen increased the dirtiness of the animals. Cattle on non-slatted accommodation were cleaner than those on slats. Improving ventilation quality in cattle accommodation resulted in cleaner cattle. Low stocking densities on slatted floors did not result in dirtier cattle, indeed there was a slight trend toward dirtier cattle at very high stocking densities. Dirt score increased significantly with increasing level of concentrate feeding. Cattle fed silage with a DM content above 300g/kg were significantly cleaner than those receiving wetter silage.

Acknowledgements This project has received financial assistance from the Northern Ireland Agricultural Research and Development Council and the Department of Agriculture for Northern Ireland.

Reference Scott, G.B. and Kelly, M. 1989. *Farm Building Progress* **95:** 21-24.

Biochemical, biomechanical and histological analyses of failure of supportive structures in cattle hooves

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Introduction The most common and intractable condition which leads to lameness in cattle is claw horn disruption (CHD). Although many risk factors have been associated with CHD, such as calving and housing, the mechanisms of tissue damage are unknown. It is proposed here that this chronic condition results from failure of the suspensory apparatus of the hoof, leading to solear ulcers and white line disease. The aim of this study is to develop methodologies which permit quantitative evaluations of the relationships between connective tissue biochemistry and the biomechanical properties of supportive structures of the hoof.

Materials and methods Hooves were taken from 2 yr maiden Friesian heifers, the claws separated and stored at -20°C. Using a bandsaw, segments of hoof were cut perpendicular to the anterior wall, measuring 0.8 x 0.8cm, and included horn of the anterior wall, pedal bone, and interposed corium. Four sequential segments were taken down the hoof, 1cm in from the axial wall, the first cut being 1cm dorsal to the laminae. Each segment was accurately measured for cross sectional area, thawed (where necessary), and mounted on an Instron mechanical testing frame, fixed top and bottom at the horn and pedal bone respectively. The segments were loaded to failure at a constant strain rate, and the maximum load recorded in each case. Studies were also undertaken to compare the biomechanical properties of hooves analysed fresh and after frozen storage. Segments were then either fixed, for histological examination, or processed for analysis of markers of connective tissue remodelling. Pro- and activated matrix metalloproteinase (MMP) -2 and MMP-9, being markers of homeostatic and inflammatory remodelling respectively, were measured by gelatin substrate gel electrophoresis (zymography). Tissue inhibitors of MMPs (TIMPs) -1 and -2 were measured by reverse zymography. Analyses were normalised to tissue dry mass. Unpaired student t-tests were performed using Statworks statistical software package, with $p<0.05$ regarded as significant.

Results The strength of the hoof segments was found to increase progressively down the hoof (dorsal:ventral $p<0.005$; Fig. 1). Histological examination of the stretched segments demonstrated that the point of failure was in the corium near to the peri-osteum, and not within the laminae. Frozen storage was found to have no influence on the biomechanical strength of the hoof segments, nor on the point of failure. Levels of proMMP-2 in the corium were found to increase down the hoof (dorsal:ventral $p=0.012$; Fig. 2), and to correlate with biomechanical strength. No MMP-9 was detected in the corium of any of the maiden heifers examined. TIMP-1 also increased in expression down the hoof (dorsal:ventral $p<0.005$), whereas TIMP-2 remained unchanged.

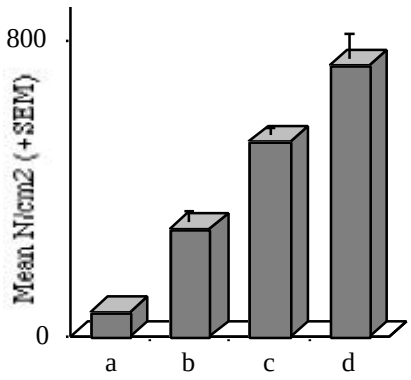

Figure 1 Maximum resistance to load of sequential hoof segments

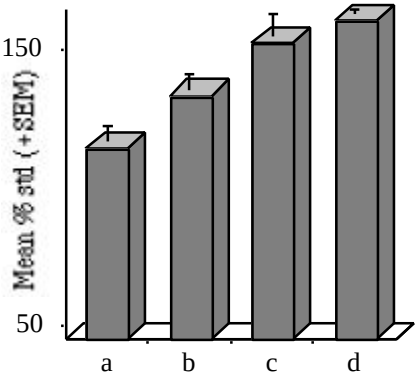

Figure 2 Levels of pro-MMP-2 in sequential hoof segments

Conclusions The biomechanical characteristics of sections of hoof may be accurately and consistently evaluated *ex vivo*, and correlated with biochemical markers in the same tissue samples. Results demonstrated that lower regions of the hoof provide the greatest mechanical support, and markers of co-ordinated remodelling of the collagenous matrix (MMP-2 and TIMPs) show these regions to be subject to the greatest levels of homeostatic maintenance. Histological examination of failed hoof segments indicate that the laminae are not the weakest component of the suspensory apparatus of the normal hoof, and may therefore be resistant to failure in CHD. Frozen storage and transportation does not effect the biomechanical properties of the hooves, facilitating collection of specimens from remote sites.

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Diet and hoof health: a comparison between high starch and high fibre diets.

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Introduction Lameness in the dairy cow not only causes major financial loss but also has serious welfare implications. Both environmental and nutritional factors have been implicated in its occurrence, which is commonly observed as laminitis, white line disease and sole ulcers, which are disorders of the corium. The aim of the current study was to examine the effect of diet composition in the form of non-structural carbohydrates on hoof health.

Materials and methods Six weeks prior to calving 48 multi-parous Holstein cows were randomly allocated to four treatments and housed in a cubicle yard with individual feeding. Prior to calving all cows received a total mixed ration (TMR) containing on a DM basis 0.45, 0.15, 0.25, 0.06, 0.04, 0.04 and 0.01 g/kg grass silage (GS), maize silage (MS), barley straw, soybean meal (SB), molassed sugar beet feed (MSBF), cracked barley (CB) and minerals, respectively and a supplement/day of either MSBF (1.08 kg DM) or CB (1.0 kg DM) to produce the fibre (Ft) and starch (St) based transition diets. At calving all cows received a TMR containing GS and MS 0.40, 0.15 g/kg, and for the high starch (Sl) and high fibre (Fl) rations, 0.20, 0.05, 0.09, 0.085, and 0.025 g/kg cracked wheat, maize meal, SB, rapeseed meal and minerals and 0.09, 0.085, 0.085, 0.170 and 0.02 g/kg wheatfeed, SB, rapeseed meal, MSBF and minerals, respectively. The four treatments described on the basis of their transition and lactation ration are FtSl, StSl, FtFl and StFl. The crude protein (CP), neutral detergent fibre (NDF), starch and sugar content for the transition Ft and Sl rations, were 115, 470, 61 and 68 g/kg DM and 116, 460, 108 and 45 g/kg DM, respectively, while the corresponding values for the Fl and Sl rations were 185, 376, 77 and 89 g/kg DM and 191, 341, 192 and 49 g/kg DM. Prior to calving and on five further occasions between weeks 4-8, 9-14, 14-18 and 19-22 of lactation laminitis on the medial and lateral claws of both back feet was assessed (Greenough *et al.*, 1997. See Figure 1). Zones 1 to 5 were used in the current study and each scored on a scale from 0 to 4. The higher the value the poorer the foot health. In addition a visual health assessment of the whole hoof was recorded with the left and right scores added together to give each cow a maximum possible score of 8 per assessment. The left and right hoof scores were combined to produce one score, for each zone, for the lateral and medial claws and a total score. These values were compared using the Kruskal-Wallis non-parametric test.

Results The results presented in Table 1 are for the lateral claw only as the values recorded indicated that its health was markedly worse than the medial claw where only very limited treatment effects were noted. Treatment effects were mainly noted in zones 3 and 4, which are associated with sole ulcers and hemorrhages. Data are also only presented for the pre-calving and the last assessment at weeks 18-22 of lactation, as few differences were apparent prior to this point. For the data shown in Table 1 there were no significant differences for pre-calving assessments. The median scores for zones 3 and 4, the total score and the visual assessment were all higher for treatments StSl compared with FtFl with significant differences ($P < 0.05$) noted for zone 4, total and visual scores. Intermediate values were noted for the two remaining treatments.

Table 1 Median lateral claw scores.

Lateral claw score	FtFl	FtSl,	StFl	StSl
Zone 3. Pre-calving	1.0	2.0	2.0	2.0
Weeks 18-22	2.0	3.0	2.0	3.5
Zone 4. Pre-calving	1.0	2.0	1.5	2.0
Weeks 18-22	3.0	3.0	3.5	4.5*
Total. Pre-calving	4.0	6.0	4.5	6.5
Weeks 18-22	9.0	11.0	8.0	14.5*
Visual assessment				
Pre-calving	1.0	1.5	1.5	2.0
Weeks 18-22	2.0	2.5	3.0	3.5*

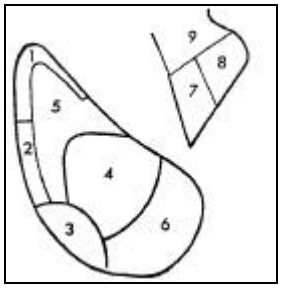

Figure 1. Zone placement on the hoof.

Conclusions In the current study the total non-structural carbohydrate content of the low and high starch lactation diets were 166 and 251 g /kg DM, respectively. While the difference between treatments is marked the value recorded for the high starch TMR could not be considered as excessive. However, even under these conditions diet composition was shown to have a marked effect on hoof health, which may influence the subsequent lactation. With the declining price of wheat and the increasing genetic potential of dairy cows attention to diet composition is important in trying to maintain hoof health.

Reference Greenough, P.R., Weaver, A.D., Broom, D.M., Esslemont, R.J., and Galindo, F.A. 1997. Basic concepts of Bovine Lameness. In *Lameness in Cattle,* (eds. Greenough, P.R. and Weaver, A.D.). WB Saunders.

Effect of stage of development and pre-natal nutrition on hoof characteristics of fetal sheep.

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Introduction Lameness is a major welfare problem in farm animals and poor hoof (claw) health frequently causes painful lesions. Such lesions frequently arise from damage to the underlying dermal and epidermal soft tissues causing impaired production of the horn on the external surface of the claw (Budras *et al*., 1998) Precisely timed interactions between embryonic dermis and epidermis, are essential for normal development and function in other integumental tissues such as the hair follicle (Galbraith, 1998), but have not been confirmed for claw tissue. The time course of development of cellular and extra-cellular structures has not been described, nor has the question of whether fetal pre-natal claw development may be affected by undernutrition of the ewe such as frequently occurs in extensive production systems. The aims of the study were to investigate external physical dimensions and internal cellular development of fetal claws and how these may be influenced by stage of gestation and maternal nutrition.

Materials and methods Fetal claws (hind right lateral) were obtained at slaughter at 50 or 65 days gestation and stored at -70^{o}C. The foetuses (n =5 per group) were collected from ewes fed as follows: Group: 1.1 x Maintenance (M); Group 2: 0.5M from day 0-30, then 1.1M; Group 3: 1.1M day 0-30, then 0.5 M; Group 4, 0.5 M.
Physical measurements of claws were taken using electronic callipers and histological examination was performed on 5µm sections, prepared by wax embedding technique and conventionally stained using the van Gieson method. Statistical comparisons between means were made by Student`s t-test.

Results and discussion Physical dimensions (pooled means) for length, height, and diagonal (toe to upper extremity of heel) for fetal claws at 50 day gestation, were significantly smaller than claws at 65 days (Table 1). Expressed as a proportion of the 50d foetus values, the magnitude of differences ranged from 0.46 to 0.56 and indicated the presence of rapid tissue accretion during this stage of gestation. Effects of maternal nutrition were tested by comparing claws from groups 1 to 4. Mean values (mm, ± s.e.) for claw dimensions at the extremes of treatments (group 1 vs group 4) and after 65 days gestation, are as follows: length, 4.53 vs 4.64 ± 0.27, NS; height, 3.62 vs 3.74 ± 0.116, NS; diagonal, 5.64 vs 5.17 ± 0.146 ($P<0.05$). Differences in means for length and height were not significant, but claw diagonal was greater on average in claws from group 1 which received the higher level of maternal nutrition.
Histological sections of the wall and sole showed the appearance of interdigitating laminae of the wall region between 50 and 65 days in all groups with concentrations of cells only apparent at the dermal-epidermal border of the laminar region at 50 days. Dermal tissue was more densely stained in sections from 65 day than 50 day claws suggesting a greater production of extra-cellular connective tissue. Comparisons of sections of claws at 65 days at the toe-sole region also indicated a greater inter-penetration of epidermis and dermis and initial formation of dermal papillae (not shown) in group 1 compared with group 4 which received the lower level of nutrient input.

Table 1 Effect of gestation length (GL: 50 or 65 days) on physical dimensions (mm) of fetal claws

GL	Length	Height	Diagonal
50 days	2.25	1.62	3.06
65 days	4.50	3.56	5.42
s.e.d	0.080***	0.069***	0.104***

*** Statistically significant $p<0.001$

Conclusions These results indicate (a) the importance of the time period between day 50 and 65 in the growing claw and suggest that some anatomical measurements and development of cellular and extra-cellular structures may be sensitive to alteration in maternal nutrition at this time. The consequences of this for the post-natal performance and health of the claw will require future study.

Acknowledgements
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References
Galbraith, H. (1998). Nutritional and hormonal regulation of hair follicle growth and development. *Proceedings of the Nutrition Society* **57**: 195-205.
Budras, K-D., Gayer, H., Maier, J. and Mulling, C.K.W. 1998. Anatomy and structure of hoof horn (Workshop Report). In *10th international symposium on lameness in ruminants* (ed. Ch. J. Lischer and P. Ossent), pp. 176-188. University of Zurich, Zurich.

Individual differences in sociability and their consequences for foraging behaviour in sheep.

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Introduction The spatial distribution of grazing sheep is influenced by the distribution of vegetation and by social behaviour. Where there are conflicts between grazing preferred vegetation and maintaining normal inter-individual distances, animals may have to make trade-offs based on the relative strengths of their motivation to feed or to be social. Social motivation, or sociability, has been assessed in chickens by measuring the rate at which isolated individuals move towards their companions (Suarez and Gallup, 1983) and in sheep by studying nearest neighbours (Sibbald *et al*, 1998). The aim of this experiment was to test whether individual differences in sociability affect the foraging behaviour of sheep, when animals have to choose between grazing or remaining close to their companions.

Materials and Methods
Fifty-six one-year-old, female, Scottish Blackface sheep were used in an experiment to compare the behaviour of individuals in a standardised test, with an independent estimate of their sociability. The test provided a potential conflict between grazing and remaining close to companions. The sheep were divided into 8 groups of 7 animals to provide replication, since sociability is a function of both the individual and the group. Sociability was measured within each group, over a period of 4 weeks, by observing the 7 animals grazing in a 30 x 33 m grass plot for a period of one hour on 10 independent occasions. Sociability indices (Sibbald *et al*., 1998) were calculated from the frequencies with which focal sheep were nearest neighbours to other sheep in their group. Each individual in a group will have a sociability index of 1.0 if they are all observed to be another sheep's nearest neighbour the same number of times. Higher and lower values indicate sheep that are more or less sociable than each other. Statistical analyses test for differences between individuals, within a group, which are consistent across observation periods. Behavioural tests were carried out after a rest period of 2 weeks. Each group was tested on a different day within a 10-day period, starting at the same time of day on each occasion. Within each group, sheep were tested successively and in random order. For the test, each sheep was isolated from its group for approximately 2 min and then released into a 66 x 33 m grass area for 15 min, where it was separated from its companions by a simple wire fence. Mean sward height in the test area was kept below 2.5 cm within 7.5 m of the fence, around 4 cm between 7.5 and 15 m from the fence and increased from around 6 to around 9 cm over the next 20 m. This created a gradient in intake rate away from the group of sheep. Each sheep was released into the test area at a point 66 m from the dividing fence. The rate at which each sheep initially moved towards the fence and the rest of the group was measured between two points, 15 m apart and in the middle of the field, using video recording. Behaviour and position were monitored throughout the 15 min test by time sampling, using a 30-sec sample interval (Martin and Bateson, 1986). The delay before grazing started and total grazing time for each sheep are thus expressed as number of sample points (Martin and Bateson, 1986). Results were analysed using linear regression and analysis of variance, with group effects taken into account.

Results There were significant differences between the sociability indices of individuals within 6 of the 8 groups ($P<0.05$), where values typically ranged between 0.7 and 1.3. When data for these animals were analysed and group/day effects included in the model, both the delay before sheep started grazing and the total time spent grazing were linearly related to the sociability index, with respective slopes of 14.6 and -19.9 sample points per unit of sociability ($P<0.05$). When data for all 8 groups were analysed, the delay before sheep started to graze was linearly related to the rate at which the sheep initially moved towards their companions (slope = 1.72 sample points per m/sec; $P<0.01$), as was the total time spent grazing (slope = -3.01 sample points per m/sec; $P<0.001$) and the mean distance of the sheep from the fence while grazing (slope = -2.46 m per m/sec; $P<0.05$). The mean distance from the fence while grazing, for the sheep that initially moved all the way to the fence without stopping, was shorter than that of sheep who stopped to begin grazing before they reached the fence (mean distances = 23.8 v 31.4 m (SED 3.71); $P<0.05$).

Conclusions The results support the hypothesis that individual differences in social motivation affect the trade-offs that sheep make when foraging. When faced with a choice between remaining close to other sheep or moving away to graze, more sociable individuals grazed less.

Acknowledgements This study was funded by SOAEFD.

References Martin, P. and Bateson, P. 1986. *Measuring Behaviour*. Cambridge University Press, New York.
Suarez, S.D. and Gallup, G.G. 1983. Social re-instatement and open-field testing in chickens. *Animal Learning and Behavior*, **11:** 119-126.
Sibbald, A.M., Smart, T.S. and Shellard, L.J.F. 1998. A method for measuring the social behaviour of individuals in a group: an example with sheep. *Measuring Behavior '98. Proceedings of the 2nd International Conference on Methods and Techniques in Behavioral Research* (ed. L.P.J.J.Noldus), pp 260-261, Groningen, The Netherlands. (http://www.noldus.com/events/index.html)

Relationship between tail-biting and aggression in pigs reared in two different environments

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Introduction A recent survey showed that 4.3% of pigs slaughtered in Great Britain were tail-bitten (Guise and Penny, 1998). This figure could be reduced through a better understanding of the individual traits associated with tail-biting. The objective of this study was to investigate the relationship between tail-biting and aggression in pigs reared in barren and enriched environments.

Material and methods Forty-eight Large White x Landrace pigs were allocated in four replicates to one of two environmental treatments from 4 to 15 weeks of age. The pigs were housed in groups of six and four groups were reared in barren environments which had expanded metal floors and recommended space allowances. The remaining four groups were reared in enriched environments which had three times the recommended space allowance, solid floors partially bedded with compost and pigs had access to straw from a rack. Each animal was observed directly in the resident pen for 5 minutes each week between 8 and 15 weeks of age. During these observations the time spent tail-biting and being tail-bitten was recorded. Each pig was subjected to a social confrontation test at 8, 10 and 12 weeks of age. This involved placing a pig from one group into a wooden test box (1.6 x 1.6 x 0.78 m) together with a pig from another group for 10 minutes. In each test both pigs were unfamiliar but were from the same environmental treatment. Behaviour was recorded in real time via a camera placed overhead and the frequency of fights was recorded. Treatment differences were assessed by Analysis of Variance for repeated measures. Pearson's product-moment correlations were calculated between tail-biting, being tail-bitten and the mean frequency of fighting in the three social confrontation tests.

Results Treatment means are given in Table 1. Pigs in barren environments spent more time tail-biting than those in enriched environments ($P<0.001$). Consequently, the time spent being tail-bitten was also higher in barren environments, although this effect was not significant. Pigs from barren environments fought more frequently in the social confrontation test than their counterparts from enriched environments ($P<0.001$). Correlations coefficients are given in Table 2. In enriched environments fighting was negatively correlated with tail-biting and positively correlated with being tail-bitten ($P<0.05$). In barren environments there were no significant correlations between fighting and tail-biting or being tail-bitten.

Table 1 Time spent tail-biting and being tail-bitten in barren and enriched environment (expressed as a percentage of the observation time) and mean frequency of fighting during social confrontation tests at 8, 10 and 12 weeks of age

	Barren	Enriched	s.e.m.	Significance
Resident pen behaviour				
Tail-biting (%)	0.5	0.1	0.05	**
Being tail-bitten (%)	0.7	0.2	0.2	
Social confrontation test				
Frequency of fights	4.5	1.9	0.21	***

Table 2 Correlation coefficients between percentage of time spent tail-biting and being tail-bitten in barren or enriched environments and mean frequency of fighting during social confrontation tests at 8, 10 and 12 weeks of age

Parameter	Barren			Enriched		
	Tail-biting (%)	Being tail-bitten (%)	Frequency of fights	Tail-biting (%)	Being tail-bitten (%)	Frequency of fights
Tail-biting (%)	-			-		
Being tail-bitten (%)	0.088	-		-0.150	-	
Frequency of fights	0.262	0.114	-	-0.413*	0.421*	-

* denotes significance at $P<0.05$ level

Conclusions Environmental enrichment improved the welfare of pigs by reducing tail-biting and aggressiveness, which agrees with previous research (Beattie et al., 1995). The individual traits associated with tail-biting appeared to differ depending on rearing environment, with the least aggressive animals performing tail-biting in enriched but not barren environments. The relationship between aggressiveness and being tail-bitten in enriched environments may be due to the fact that aggressive pigs tend to have low social status in enriched environments (O'Connell and Beattie, 1999).

References

Beattie, V.E., Walker, N. and Sneddon, I.A. 1995. Effects of environmental enrichment on behaviour and productivity of growing pigs. *Animal Welfare* **4:** 207-220.

Guise, H.J. and Penny, R.H.C. 1998. Tail-biting and tail-docking in pigs. *Veterinary Record* **142:** 46.

O'Connell, N.E. and Beattie, V.E. 1999. Influence of environmental enrichment on aggressive behaviour and dominance relationships in growing pigs. *Animal Welfare* **8:** 269-279.

The effects of handling and environmental enrichment on the welfare of finishing pigs

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Introduction The general well-being of growing pigs is known to be affected by both the quantity/quality of stockperson input invested and the complexity of their housing environment (Pearce *et. al*., 1989). However, the nature of the interactions which exist between these two factors is still largely unknown. The aim of this experiment was to investigate the separate and interactive effects of handling and environmental enrichment on the welfare and performance of growing pigs.

Materials and Methods Thirty-two groups of 10 growing pigs (5 male and 5 female) were selected with an initial mean live weight of 29.1 kg (sd=3.11) and exposed to one of 8 treatments arranged in a 2x4 factorial randomised block design, for a period of 10 weeks. This design comprised two levels of handling (M: minimal and P: pleasant), and four levels of environmental enrichment (B: barren, C: chain, S: chopped straw, or T: destructible toy). Groups exposed to treatment M received minimal stockperson:animal contact, and groups exposed to treatment P received five minutes of positive interaction with the same stockperson each day (Monday - Friday). Pen enrichment consisted of either a 30cm loop of chain, half a bucket of straw per day, or a destructible, nutritious toy. At selection and weeks six and 10 of the experiment pigs were weighed. Feed intake was recorded throughout the test period. In addition, an approach test was conducted in the home pens to measure fear levels of four focal animals in each group, and the ease with which the groups could be handled was determined by timing the weighing procedure. The behaviour of four focal pigs in each group was video taped for 24h during weeks two, six and 10 and time budgets were recorded using time sampling with a 10 minute interval. The ethogram used detailed the animal's posture, behaviour, and the substrate the behaviour was directed towards. Post-slaughter measurements of muscle pH changes and stomach lesions were also taken. The resulting data were analysed using repeated measures analysis of variance with pen mean as the experimental unit.

Results Daily feed intake was significantly affected by handling during the 0-6 week period with the P groups eating more feed than the M groups (1.88 vs. 1.75 kg/day; sed=0.077; $P<0.05$), however, this increased intake was not reflected in daily live-weight gain or feed conversion ratio during the same period. There was a significant interaction between experimental period and handling on the latency to touch the handler (80.4 vs. 66.3 sec at week 6 and 27.6 vs. 44.4 sec at week 10 for P and M respectively; sed=8.48; $P<0.05$). The latency to approach within 0.5m of the handler tended to be affected by environment (see Table 1; $P=0.097$) where the three forms of environmental enrichment appeared to make pigs less fearful than the barren treatment. The time taken for a group of pigs to exit their pen during the ease of handling test was significantly affected by the handling treatments (46.2 vs. 37.8 sec for P and M groups to exit their pen respectively; sed=3.38; $P<0.05$). The behaviour of the groups, the change in post-mortem muscle pH and the number of stomach lesions were all unaffected by the treatments.

Table 1: ***Separate (and interactive) effects of handling and environmental enrichment on indices concerning fear of humans.***

	M				P				SED	HAN	ENR	HAN x Enr
	B	C	S	T	B	C	S	T				
Latency to approach within 0.5m /sec	66	35	52	43	51	43	38	44	11.6		+	
Latency to first touch /sec	72	48	62	40	59	56	51	51	11.9			
Duration within 0.5m /sec	134	165	140	154	126	137	147	148	15.1			
Number of touches	3.0	4.2	3.7	3.2	3.4	2.1	3.6	3.3	0.42	*		***

Conclusions Pleasantly handled pigs are more difficult to move during routine husbandry tasks such as weighing which may be mediated through their reduced fear of humans. Although no significant differences were detectable in the levels of pen-mate manipulation at weeks six and 10, environmental enrichment may benefit animal welfare because the groups exposed to the barren environment treatment were found to be more fearful of humans than their counterparts housed in enriched environments.

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References

Pearce, G. P., Paterson, A. M. and Pearce, A. N. 1989. The influence of pleasant and unpleasant handling and the provision of toys on the growth and behaviour of male pigs. *Applied Animal Behaviour Science* ***23:*** *27-37***.**

The effect of an environmental enrichment device - the PECKABLOCK $^{\hat{0}}$ - on the behaviour and growth performance of broiler chicks

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Introduction Rearing houses for broiler poultry breeders are relatively barren buildings which provide for the basic environmental comfort and nutritional needs of the birds, but offer little in the way of additional novel stimuli (FAWC, 1998). The Farm Animal Welfare Council (FAWC) recommends that environmental enrichment should be available in rearing houses. The Peckablock is a cereal-based enrichment device which is suspended in front of broiler breeders and provides birds with a novel material at which to peck, mimicking their natural behaviour. The manufacturers claim that this stimulus, plus the reward of cereal grains that are loosened and have fallen into the undertray, can help to ameliorate the potential problem of cannibalism. The aim of this study was to investigate the effect of providing Peckablocks on the behaviour and performance of commercial broiler chicks at two different levels of light intensity.

Materials and methods A total of 200 mixed sex, day-old chicks of a commercial meat-type genotype (Cobb 500) were used in the study, housed in eight pens of 25 in a controlled environment building which was partitioned to create two rooms of differing light intensity. There were 2 replicates per treatment. The circular pens were 0.75 m high and were and bedded with woodshavings to a depth of approximately 7 cm. The diameter of each pen was gradually increased to reach a maximum area of 2.84m^2 by Day 42 (equivalent to 25kg liveweight per m^2). Both rooms were heated by radiators, with heat lamps suspended above each pen. Temperature within the building was 29^{o}C on Day 0, gradually reduced to 21^{o}C (falling 1^{o}C every 3 days). Birds had continual access to water and commercial specification starter, grower and finisher rations (Metabolizable Energy 12.8, 13.2 and 13.5 MJ/kg and Crude Protein 230, 215 and 190 g/kg respectively). From Day 0 to Day 7, both rooms had continuous light at an intensity of 20 lux. From Day 7 onwards, the light intensity was gradually increased or decreased so that by Day 21, it was 100 lux in the bright treatment, and 10 lux in the dim treatment, maintained for 23 hours every day with one hour of permanent darkness. The Peckablocks, measuring approximately 18 x 7 cm and weighing on average 714 g were suspended at bird height in four pens (two per lighting treatment), the height being adjusted as the chicks grew. The behaviour of birds in each pen was observed for 15 minute-periods over seven separate observation days, spread over the seven weeks of the trial. Scan samples of behaviour were taken at 5 minute intervals, recording the number of birds engaged in each of 7 behaviour categories, combined with focal observations in the intervening period of the number of times individual birds performed each of 18 categories. The extent of feather pecking was assessed at the end of the trial using a scoring system designed by Hughes and Duncan (1972), ranging from 0 (No sign of pecking) to 4 (Haemorrhage produced by broken skin). The results were analysed by analysis of variance using Minitab (Version 9.2; Minitab Inc., USA).

Results There was no significant effect of either light intensity or the availability of Peckablocks on daily gain, feed intake or food conversion ratio. Scan samples showed that birds in the bright light spent significantly more time feeding and pecking at substrates (feeder, drinker, pen sides or litter) ($P<0.05$), and less time inactive ($P<0.05$) compared to those in dim light (Table 1). In pens with Peckablocks, birds spent on average 0.02 of observation time pecking at these devices, and performed significantly less pecking of other birds ($P<0.001$). Birds with access to Peckablocks also spent more time moving around the pen ($P<0.05$). Feather pecking damage was not recorded in any bird.

Table 1 Proportion of overall time engaged in different behaviours obtained from scan samples

Category	100 lux	10 lux	s.e.d.	P value	Category	Block	No block	s.e.d.	P value
Feeding	0.11	0.08	0.005	*	Feeding	0.10	0.09	0.005	ns
Drinking	0.08	0.07	0.006	Ns	Drinking	0.08	0.07	0.006	ns
Movement	0.10	0.10	0.005	Ns	Movement	0.11	0.09	0.005	*
Inactivity $^{\phi}$	0.59	0.66	0.010	*	Inactivity $^{\phi}$	0.61	0.64	0.013	ns
Peck-bird	0.03	0.02	0.003	Ns	Peck-bird	0.01	0.04	0.003	***
Peck-substrate	0.08	0.06	0.004	*	Peck-substrate	0.07	0.08	0.004	ns
Peck-block	0.01	0.01	0.001	Ns	Peck-block	0.02	0.00	-	

$^{\phi}$A significant light intensity by enrichment interaction occurred for the category inactivity ($P<0.05$), where the reduction in the number of birds being inactive in bright light was only significant for groups with Peckablocks.

Conclusions Although there was no physical damage due to feather pecking, the provision of Peckablocks significantly reduced the proportion of aggressive behaviour directed at other birds. In housing conditions which are less than ideal, this form of environmental enrichment may help to prevent outbreaks of cannibalism from occurring, by providing a focus for pecking behaviour and directing the birds' attention away from bird to bird interactions.

References

FAWC, 1998. *Report on the Welfare of Broiler Breeders*. Farm Animal Welfare Council. Booklet No.: PB 3907, Ministry of Agriculture, Fisheries and Food, London.

Hughes, B.O. and Duncan, I.J.H. 1972. The influence of strain and environmental factors upon feather pecking and cannibalism in the fowl. *British Poultry Science* **13**:525-547.

The effects of offering different degrees of social contact in indoor farrowing systems on the welfare of piglets post-weaning.

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Introduction Previous research into free-farrowing systems for pigs has found that although sow welfare is better than in crated systems, piglet mortality levels are often unacceptably high. Whilst on-going research programmes are investigating methods to address this problem, the effect of alternative farrowing systems on piglet behaviour and welfare post-weaning is largely unknown. A recent study found that the increased social contact between piglets reared outdoors prior to weaning resulted in welfare benefits post-weaning (Cox and Cooper, 1999). The aim of this experiment was to investigate whether offering different degrees of social contact in an indoor community-lactation system would confer similar enhancements to piglet welfare post-weaning.

Materials and methods The experimental subjects were 32 groups of five litters. Each group had been born concurrently within one room of the ADAS Pig Research Unit experimental farrowing facility. The experimental design was a randomised block with four treatments. These treatments were imposed by managing the pre-weaning environment under one of four regimes; CRATE: sows and litters kept individually throughout lactation in standard farrowing crate, PEN: sows and litters kept individually throughout lactation in an open farrowing pen but piglets released into sow get-away area at day 10 post-farrowing, PEN(10): sows and piglets kept individually in an open farrowing pen during early lactation but mixed at day 10 post-farrowing, PEN(1): sows allowed to mix pre- and post-farrowing but piglets not allowed to mix before day 10 post-farrowing. At day 24 (±3 days) post-farrowing, the piglets from each room were weaned as a group into a strawed flatdeck pen and their body weight, food intake and level of skin damage recorded for 8 days. Piglets were identified and weighed individually at birth, on day 10 post-partum, at weaning, and on days four and 8 post-weaning. Two piglets, one male and one female, were identified as 'focal' animals in each litter and damage scored on days 10, 14, and 18 post-partum, at weaning, and on days 4 and 8 post-weaning. Piglets were given access to a commercial creep diet only after weaning. The resulting data were analysed using repeated measured analysis of variance.

Results At weaning there were no significant differences between treatments in terms of either live weight (7.16, 7.29, 7.07 and 6.61 kg for CRATE, PEN, PEN(10) and PEN(1) respectively; sed=0.337), or levels of skin damage (8.6, 7.0, 6.5 and 10.2 lesions per pig for CRATE, PEN, PEN(10) and PEN(1) respectively; sed=3.94). Over the first four days post weaning, the treatments were found to have a significant effect on both liveweight gain (see Figure 1; $P<0.05$), and the increase in skin damage due to aggression (see Figure 2; $P<0.05$). The mean total food intake over the eight day post-weaning period was unaffected by treatment (0.958, 1.008, 1.246, 1.065 kg/pig for CRATE, PEN, PEN(10) and PEN(1) respectively; sed=0.1760).

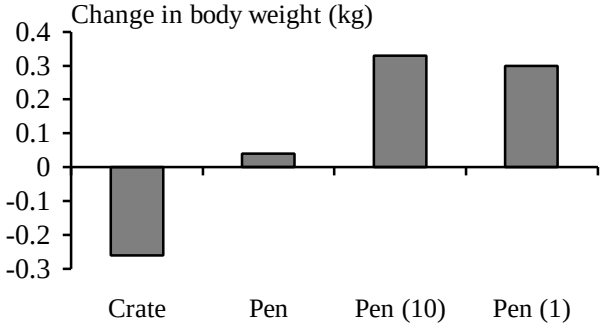

Figure 1 The change in live weight between weaning and four days post-weaning (sed=0.207).

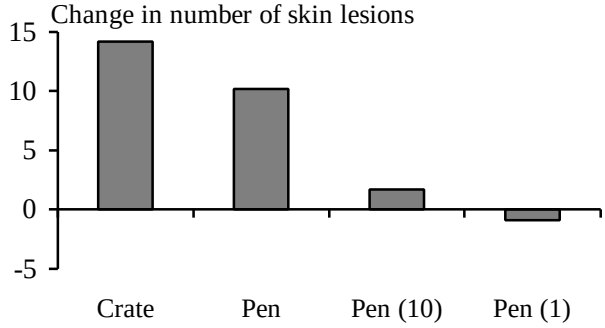

Figure 2 The change in level of skin damage between weaning and four days post weaning (sed=6.75).

Conclusions These results suggest that offering an increased degree of social contact in an indoor farrowing system does effect the welfare of piglets post-weaning. Piglets which have been able to mix and socialise with other litters prior to weaning are less likely to perform aggressive behaviours post-weaning to establish dominance hierarchies. The sow which is able to distance herself from her litter in the latter stages of lactation may better equip her offspring to cope with the challenges of weaning because litters which have been allowed greater freedom to mix and socialise prior to weaning have a higher liveweight gain compared to litters reared in more restrictive environments.

Acknowledgements This work was funded by MAFF.

Reference

Cox, L. & Cooper, J. J. 1999. The effect of pre-weaning environment on piglets' post weaning behaviour. Proceedings of BSAS, p13.

Variation in behavioural style during an attack latency test: a potential source of additional information about aggressiveness in young pigs.

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Introduction Aggression seen on mixing of young pigs is a major welfare concern in modern farming. One solution may be to reduce the likelihood of aggression within a group by using combinations of individuals that facilitate rapid integration. This idea has been investigated by Mendl and Erhard (1997) using pigs with various levels of aggressiveness. An attack latency test was used to measure individual aggressiveness. Experimental pigs were placed in a familiar pen with an unfamiliar pig and the time taken to attack (i.e. attempt to fight) the intruder measured. In a substantial number of tests (e.g. 61% in the present study) no attack occurs in the time allowed (5 minutes) These pigs vary in their interactions with the intruder, ranging from no interest at all to persistent interest with isolated aggressive acts but no escalation to fighting (personal observation). The aim of this study was to investigate social behaviour throughout the test, thereby allowing a more detailed analysis of aggressiveness to be made.

Materials and methods Sixteen resident litters of eight weaned crossbred pigs (total=128) were used in this study. Unfamiliar pigs (intruders) were younger to give a weight difference of 20%. Pigs were weaned at approximately 28 days and tested for aggressiveness on days 18 and 19 post-weaning. Testing took place in small pens constructed in a corner of the resident litter's home pen. Testing procedure was as follows: the resident pig was placed in the testing pen, followed by the intruder pig. The pigs were separated using pig boards upon first escalated aggressive interaction, or after 5 minutes if no such aggression occurred. This procedure was repeated with a different intruder the following day. An ethogram was devised to cover all aspects of the pig interactions, focusing on the body and head positions of the pigs relative to each other (after Rushen & Pajor 1987) and aggressive acts (head knocks, shoves and bites). Relative head position gave an indication of physical contact between the pigs during interactions (high involved the tip of the resident's snout only, low the whole of the head and shoulders). Persistence of interest measured the proportion of test time spent in social interaction (SI) with the intruder. Time spent in body and head positions and the frequencies of aggressive acts were calculated as proportions of SI time. To avoid distortion of proportions highly non-social pigs were excluded from analysis. The range of SI values for attacking pigs was used as a baseline and any non-attacking pigs outside this excluded. Data for each day were analysed separately to maintain independence. Attacking pigs were analysed using Spearman's ranked correlations to identify any relationships between various behaviours and attack latency. Mann Whitney tests were used to compare the behaviour of attacking and non-attacking pigs.

Results Due to space limitations only the results that were significant on both days are presented. Attacking pigs with a short attack latency also showed a short interval between first contact and first aggressive act (day 1 r_s=0.733, 41 df***, day 2 r_s=0.464, 51 df***), a high persistence of interest (day 1 r_s=-0.379, 41 df*, day 2 r_s=-0.382, 51 df**) and a high frequency of bites (day 1 r_s=-0.607, 41 df***, day 2 r_s=-0.752, 51 df***). Comparison of the two groups showed that attacking pigs (day 1 N=43, day 2 N=53) displayed a higher persistence of interest, a higher frequency of all aggressive acts and spent a larger proportion of time in low and intermediate head positions. Non-attacking pigs (day 1 N=52, day 2 N=37) spent longer in the high head and rear contact positions (Table 1).

Table 1 Comparisons between attacking and non-attacking pigs

	Day one medians (Q1, Q3)			Day two medians (Q1, Q3)		
Behaviour	Attacking	Non-attacking	Comparison	Attacking	Non-attacking	Comparison
Persistence of interest	82.0 (50.4, 97.1)	39.4 (29.7, 59.2)	U=2690.0***	92.9 (63.5, 98.1)	48.2 (36.2, 61.7)	U=3081.0***
Low head	1.4 (0.0, 9.1)	0.0 (0.0, 0.0)	U=2637.5***	2.8 (0.0, 6.8)	0.0 (0.0, 0.0)	U=3045.5***
Inter. head	66.5 (54.7, 84.6)	23.0 (11.7, 54.8)	U=2861.0***	75.4 (66.0, 84.9)	26.9 (12.6, 44.3)	U=3274.0***
High head	14.3 (4.9, 30.1)	63.1 (29.6, 85.5)	U=1203.0***	5.7 (0.9, 15.1)	57.5 (43.5, 69.1)	U=1541.0***
Rear contact	9.2 (3.1, 12.7)	13.4 (7.8, 18.3)	U=1692.5**	5.1 (1.8, 11.4)	10.2 (6.7, 17.5)	U=2020.0**
Agg acts/min	14.2 (9.3, 22.6)	0.4 (0.0, 2.0)	U=3102.0***	15.0 (9.1, 26.7)	0.7 (0.0, 3.9)	U=3302.0***

Medians reported with interquartile range (Q1, Q3), 'U' denotes the Mann-Whitney test statistic for comparisons.

Conclusions Attacking and non-attacking pigs show definite behavioural differences during the test, allowing the identification of behaviours predictive of aggression. This information can be used to develop a more comprehensive scale of aggressiveness and therefore a more accurate prediction when using the attack latency test. Greater accuracy should aid future research aimed at reducing the aggression seen on mixing unfamiliar pigs.

References

Erhard, H.W. and Mendl, M. 1997. Measuring aggressiveness in growing pigs in a resident-intruder situation. *Applied Animal Behaviour Science* **54:** 123-136.

Rushen, J. and Pajor, E. 1987. Offence and defence in fights between young pigs (sus scrofa). *Aggressive Behavior* **13:** 329-346.

The effect of mixing litters pre weaning on the performance of piglets pre and post weaning

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Introduction Major psychological stress occurs when piglets are weaned and in particular the stress of mixing piglets into new social groups may be one of the most significant of all (Musgrave *et al*, 1991). The objective of the experiment was to determine whether the practice of mixing litters prior to weaning and at weaning had any effect on performance both before and after weaning.

Materials and methods A total of 24 Large White x Landrace sows and their litters were selected according to farrowing date and parity. They were arranged in two blocks of 12 and analysed as an unbalanced randomised block design. Pre weaning, 6 litters stayed in their individual litter groups until weaning (C) and 6 litters were mixed in two groups of three litters by removing the dividing partitions between pens when the piglets reached 14 days of age (M). Weaning took place at 24 days and whole litters were allocated to pens containing two litters. Post-weaning treatments were: (C1) 2(C) litters were mixed for the first time at weaning; (M1) 2 (M) litters previously mixed were weaned and housed together and (M2) 2(M) litters previously mixed were mixed again at weaning with piglets from a different 'mixed in lactation' group. All sows farrowed in pens with crates on partly slatted floors. Where fostering was required it was carried out within 48 hours of birth and normal husbandry practices carried out. Piglets were tagged at birth and weights recorded on days 4, 14, 17 and weaning, and again 5, 21 and 42 days post-weaning. Lesions on the piglets were assessed 5 days post-weaning on a scale (0-5). Food intakes were recorded from 14 days to weaning, weaning to day 5 and, day 5 to day 22 post-weaning.

Results Mean piglet birth weights were not significantly different between treatments (1.7 kg and 1.8 kg, sed. 0.09) for (C) and (M) respectively. Growth, lesion and intake results are given in Tables 1 and 2. By weaning there was a significant difference (C) 8.5 kg and (M) 9.4 kg (sed. 0.381, $p<0.05$). At 42 days post weaning within treatment variation in weight had increased and there was no significant difference between treatments 34.3 kg, 35.3 kg and 37.8 kg (sed. 2.12) for (C1), (M1) and (M2) respectively. All treatments suffered a post-weaning check in growth rates but this was significantly worse in the (C) piglets. The average creep intake from day 14 to weaning was 32.8 and 41.0 g/piglet/d for (C) and (M) respectively, however these figures could not be analysed for statistical significance. During the 5 days following weaning, mean feed intakes were low in (C) compared to (M1) and (M2), however this was not a statistically significant result. At 5 days post weaning the level of skin damage on (C) piglets was significantly higher indicating a higher incidence of fighting.

Table 1. A comparison of pre-weaning growth rates, post-weaning growth rates, lesion scores and feed intakes of piglets mixed or unmixed during lactation and at weaning.

Pre-weaning:	C	M		s.e.d	P
Growth rate					
Day 14-17	321	403		24.9	0.003
Day 17-24 (weaning)	368	425		31.5	NS

Post-weaning:	C1	M1	M2	s.e.d	P
Growth rate					
Weaning + 5 days	25.7	77.3[a]	130.5[a]	37.33	0.018
Day 5 to Day 22	580	602	615	52	NS
Day 22 to Day 42	775	758	845	60	NS
Lesion Score (Scale 0-5)					
5 days after weaning	2.39	0.58[a]	1.05[a]	0.31	<0.001
Feed intake					
Weaning + 5 days	0.09	0.11	0.15	0.05	NS

[a,] means with the same superscript within the row are not significantly different

Conclusion Mixing piglets in lactation improves weaning weight and post weaning performance. By prior mixing piglets suffer less from the post-weaning check and fighting is reduced. There is an indication that where pigs have had previous experience of social mixing then further mixing may act as a stimulus for food intake. Mixing piglets in lactation is an inexpensive method of assisting the piglet's adaptation to weaning.

Acknowledgement This experiment was carried out by kind permission of Mr J.A. Glover.

References Musgrave, K., Varley, M.A., Hughes. P.E., Ferlazzo, J. and Pearce, G.P. 1991. The effect of weaning, moving and mixing on the growth and behaviour of piglets after weaning. *Animal Production*. **52:** 575-576 (Abstr.).

Effects of re-grouping on behaviour, immune function and production in sows

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Introduction The re-grouping of sows is a common procedure in pig production systems and is one which can have adverse consequences for both welfare and production (Arey and Edwards, 1998). Sows in an indoor dynamic group system, in which group structure was changed repeatedly, had a high rate of returns to service which may have been due to them receiving greater levels of aggression (Rigat et al., 1998). The aim of this experiment was to determine the effects of re-grouping on sow aggression and how this affected behaviour, immune function and productivity.

Material and methods 60 mixed parity sows in groups of 6 were assigned to either a stable treatment in which sows remained in their original group from weaning to farrowing (n=30) or to a disrupted treatment in which each group of 6 was re-grouped at day 28, 56 and 84 (n=30). Sows were weaned (day 1) from farrowing crates and mixed into straw-bedded pens with individual feeding stalls. At re-grouping, sows ranked 1,3,5 (1=dominant) were combined with sows ranked 2,4,6 from another pen and vice versa. Each triad remained together at subsequent re-groupings. Lesion scores (total number of fresh lesions) were measured before and after re-grouping. Social rank was determined from paired feed displacement tests. At day 56, each sow was blood sampled and then injected with 2ml inactivated Newcastle disease virus (Intervet, UK). Blood samples were collected at day 84 and 112. All samples were analysed for total IgG and Newcastle virus specific IgG concentrations using ELISA assays. For 24 h prior to farrowing in crates, behaviour was recorded for 12 sows from each treatment using video recording equipment. Production data were recorded for each sow. Differences between stable and disrupted groups were compared using ANOVA and Kruskal-Wallis tests.

Results Lesion scores for the two treatments are given in Table 1. Scores increased each time the disrupted groups were re-grouped ($p<0.001$). Social rank correlated negatively with lesion scores in stable groups on day 112 ($r_s=0.46$; $p<0.05$) and in disrupted groups on days 28 and 56 ($r_s=0.41$; $p<0.05$). Total IgG concentrations did not differ between stable and disrupted groups and remained unchanged over time. Anti-Newcastle virus IgG concentrations were similarly unaffected by treatment but increased in both groups from inoculation at d56 to d84 (Table 2). Immune response was not correlated with social rank except in stable groups at day 112 for IgG concentrations ($r_s = 0.42$; $p < 0.05$). Prior to farrowing, there were no difference in the amount of time spent lying, sitting, standing or in the number of posture changes between treatments. Pre-partal behaviour did not correlate with social rank. The numbers of piglets born alive/dead and weaned, and piglet growth rates were unaffected by treatment. Productivity did not correlate with social rank with the exception of born dead piglets for stable groups ($r_s = 0.43$; $p < 0.05$).

Table 1 Mean lesion scores over time

Day	Stable	Disrupted	s.e.	Difference
1	0	0	0	
28	3.5	6.0	0.89	p = 0.03
29	-	25.8	3.48	
56	5.5	12.8	1.60	p = 0.01
57	-	19.5	2.97	
84	6.9	8.0	1.11	N.S.
85	-	21.6	3.02	
112	8.7	8.7	1.70	N.S.

Table 2 Mean concentrations of anti-Newcastle virus IgG over time.

Day	Stable	Disrupted	s.e.	Difference
56	0.36	0.43	0.03	N.S.
84	0.79	0.89	0.04	N.S.
112	0.84	0.80	0.04	N.S.

Conclusion The results show that immune response to challenge, pre-partal behaviour and mass of piglets reared were largely unaffected by repeatedly disrupting the social environment for pregnant sows. The measures used also gave little evidence that low ranking individuals were more affected than those of a high rank. The increase in lesions 24 h after re-grouping indicated that aggression remained a welfare concern, though levels at the end of pregnancy were the same as those observed in the stable groups. Re-grouping sows in small groups with individual feeders therefore had limited affect on sow productivity.

Acknowledgement SAC receives financial support from SERAD.

References

Arey, D. S. and Edwards, S. A. (1998). Factors influencing aggression between sows after mixing and the consequences for welfare and production. *Livestock Production Science*, **56**:61-70.

Rigat, J., Jamieson, W. G., Edwards, S. A. and English, P. R. (1998). Evaluation of a dynamic serving system for indoor herds. Proc. 15th IPVS Congress, Birmingham, vol. 3 p84.

Reproductive behaviour and performance of gilts bred at the same age but at different post pubertal heat in a dynamic service system

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Introduction The heat period at which gilts are bred affects first reproductive performance and overall sow productivity. However, most studies which have examined this subject have confounded chronological age (i.e. days) with physiological age (i.e. number of heat periods experienced) and the importance of each factor remains unclear. The Dynamic Service System (DSS) is a recently developed variant of group mating and the optimum heat period at which gilts should be bred has never been established. This study tested the hypothesis that the physiological age at which gilts are first mated in a DSS will affect their first reproductive behaviour (i.e. mating frequency and quality) and performance.

Materials and Methods Puberty was induced in replicated batches of gilts at either 200 (2H) or 180 (3H) days of age using exogenous gonadotrophin (PG600, Intervet UK Ltd.). Following induction, gilts were group-housed with ad libitum feeding until 215 (sem=1.5) days of age, when they were introduced into service pens to be mated at second (2H) or third (3H) post pubertal heat. 96 2H and 94 3H gilts were allocated to treatments and the reproductive behaviour of half of them was continuously (24 hour/day) recorded whilst in the service pens. The mating management of the present DSS has been described elsewhere (Grigoriadis et al., 2000). Four service pens were used and each one consisted of a team of boars (5 males) and 20 gilts. Four females were introduced into each service pen every week and a record of their weight and backfat thickness (P2) was taken three days post entry. Gilts remained in the service pens for 5 weeks, giving the possibility of two oestrus periods. The observed boar mating attempts (MAs) were evaluated using quantitative behavioural criteria (Grigoriadis et al., 2000). Treatments were compared using Student's T test for ordinal data or χ^2 test for nominal data.

Results 2H gilts were on average 4 kg heavier than their 3H counterparts (T=2.41, $p<0.05$) at three days post entry, but there was no significant difference in their backfat thickness. Altogether 1093 MAs were recorded. No significant difference was identified in the quality of MAs received by gilts of different treatment (Fig.1), or the reason for MA termination. There was no significant difference between 2H and 3H gilts in the total number (10.3 vs 9.9, sed=0.9) or number of 'Very good'+'Exceptionally good' (3.2 vs 3.7, sed=0.5) MAs received at first heat period. There was no significant treatment effect on the frequency and quality of MAs that gilts received per hour of oestrus ($F_{1,56}=0.67$, $p>0.05$; Fig. 2 and $F_{1,56}=2.05$, $p>0.05$ respectively). Moreover, 2H and 3H gilts did not differ significantly in oestrus duration (31.0 vs 27.1 hrs, sed=6.1). Finally, conception rate (84.7 vs 80.8, ns) and subsequent litter size (12.0 vs 11.5, sed=0.5, n=52 vs 42) did not differ significantly between 3H and 2H gilts respectively.

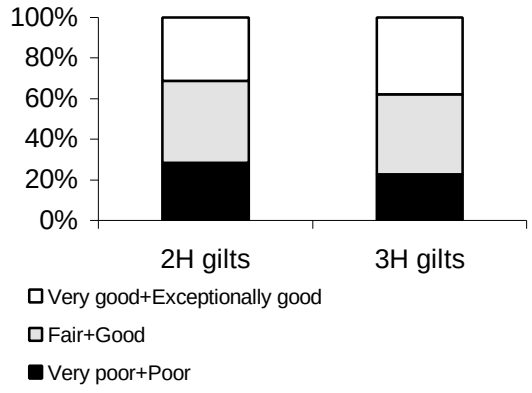

Fig. 1: Mating quality per treatment (n=1093)

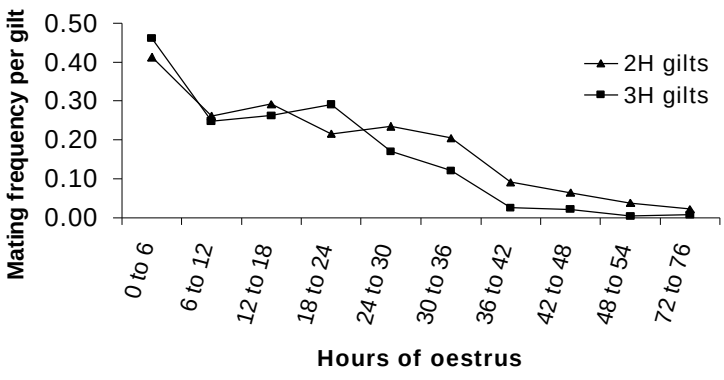

Fig. 2: Mating frequency per hour of oestrus

Conclusion The results of the present study indicate that, when controlled for age, the number of heats that a gilt experiences prior to her entry into a dynamic service pen does not have any significant effect on her first reproductive behaviour and performance. The repeated and frequent services, which are common in a DSS may have a compensatory influence on the reproduction of gilts mated at an early oestrus rather than a later one.

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References

Grigoriadis, D.F., Edwards, S. A., English, P. R. and Davidson, F. 2000.The reproductive behaviour of pigs in a dynamic service system for gilts. *Applied Animal Behaviour Science* **66**:203-216.

Effect of dietary energy intake during pregnancy on grazing behaviour of primiparous sows kept in an outdoor system under tropical conditions

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Introduction Grazing activity observed in sows kept outdoors is influenced by different factors such as their nutritional status and reproductive stage. Reduction in concentrate feed intake and pregnancy development in sows kept outdoors resulted in an increase in time spent by them in grazing under temperate conditions (Robert *et al*., 1997). Little information is available about behaviour of sows kept outdoors under tropical conditions. The aim of the present study was to investigate the effect of three planes of energy at three points in pregnancy on grazing behaviour of sows kept outdoors under tropical conditions.

Material and methods The experiment was carried out in Merida, Yucatan, Mexico. Twenty-four primiparous pregnant sows weighing 114.8 ± 11.1 kg at service were allocated randomly in four blocks (I, II, III and IV) distributed through a year and three treatments. The treatments were three diets designed to supply 19 (L), 26 (M) and 33 (H) MJ of DE/day. Diets L, M and H were equivalents to once, 1.3 times and 1.7 times energy requirement for maintenance respectively. The diets supplied the same daily amount of protein, vitamins, minerals, amino acids and fibre. Additionally, the sows had opportunity to graze freely on a field of star grass (*Cynodon nlemfuensis*). The star grass field was divided into four paddocks by electric fences. Each paddock was grazed for seven days followed by 21 days rest. Distance walked throughout the day was recorded by measuring distances walked between marked points in the paddock. Grazing time were measured by direct observation. Activities that related to grazing behaviour were recorded every 10 minutes using sample point methodology. These measurements were made at 35, 70 and 105 days of gestation from 7:00 to 19:00 hours. Rectal temperature was measured at 35, 70 and 105 days of gestation from 10:00 to 16:00 hours every two hours. Ambient temperature was measured with a thermograph during those days. Data were analysed as a randomised block design with a 3X3 factorial arrangement. Factors take into account were energy level (L, M, and H) and day of gestation (35, 70 and 105). The treatment effects were partitioned into a linear trend and any deviation from this.

Results Average results for grazing behaviour and rectal temperatures are showed in table 1. Time spent grazing ($P<0.001$) and grazing activity ($P<0.001$) reduced significantly as energy supply increased. Distances walked were significantly more ($P<0.01$) in treatment L in comparison to treatment M and H. Rectal temperature increased significantly ($P<0.01$) as energy intake increased. There was no significant effect of day of gestation ($P<0.05$) on grazing behaviour. The average ambient temperature recorded in block IV (34 °C) was higher than average ambient temperature recorded in block I (29.6 °C), block II (29.5 °C) and block III (28.8 °C). The significant interactions observed in this experiment indicate that the extremely high environmental temperatures recorded in block IV affected the grazing behaviour and rectal temperature of the sows. The grazing behaviour and rectal temperature were more affected by ambient temperature than by the plane of energy intake and stage of gestation when the ambient temperatures were very high.

Table 1 *Effect of energy level supply during pregnancy and days of gestation on grazing time, grazing activity, distance walked and rectal temperature.*

	Treatment			Day of gestation				
	L	M	H	35	70	105	s.e.	Significance †
Grazing time (min/day)	130·4	96·1	67·8	98·9	97·1	98·4	3.1	T***, B***, BxD*
Grazing activity (%)	17·4	13·2	9·2	13·2	12·6	13·9	0.5	T***, B***
Distance walked (m)	305·8	185·8	169·8	234·7	202·8	224·0	5.8	T**, B***, TxB*, BxD*
Rectal temperature (°C)	38·9	39·1	39·1	39·0	38·9	39·1	0.04	T**, B***, BxD*

† Including level of energy (T), day of gestation (D), block (B) and interactions as main effects.

Conclusions Sows fed the low energy level during pregnancy had the lowest rectal temperature and increased grazing behaviour. An increase in energy intake during pregnancy on the other hand, reduced the grazing behaviour and increased the rectal temperature. Keeping sows on a low energy intake during pregnancy could increase the amount of energy spent in grazing activities. Also, feeding pregnant sows above their energy requirements increased their heat stress under tropical conditions.

Acknowledgements To the staff at Nutrition Department, FMVZ-UADY. Sponsored by CONACYT, Mexico.

References

Robert, S., Rushen, J. and Farmer, C. 1997. Both energy content and bulk of food affect stereotypic behaviour, heart rate and feeding motivation of female pigs. *Applied Animal Behaviour Science*. **54**:161-171.

Assessment of hypothermia in outdoor newborn piglets and comparison with an indoor system

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Introduction In the last few years, there has been an increase in outdoor pig production in many countries. Outdoor herds, on average, are still less productive than indoor herds, often due to higher pre-weaning piglet mortality. Hypothermia is one of the most important underlying causes of piglet mortality in early post-natal life (English and Morrison, 1984). Although the extent of hypothermia suffered by the new-born piglet in an indoor system has been demonstrated (Pattison *et al*, 1990), no data of this kind are available regarding the outdoor situation. The objectives of this study were to evaluate the extent of hypothermia suffered by outdoor piglets at 30 and 60 minutes after birth, and to compare this with piglets born indoors.

Materials and Methods The study was carried out in Summer (May and June 1998) on an outdoor farm (O) and an indoor farm (I), located in North East Scotland. In O, 93 sows farrowed in straw-bedded, ark type insulated huts with plastic curtains in the doorway. In I, 121 sows farrowed in conventional farrowing pens with crates. The pens had slatted plastic floors and no bedding was used. One 250 Watt heat lamp at the rear of the sow was switched on during farrowing. Environmental temperatures during farrowing were recorded with digital thermometers, outside the hut (TO), at 0.20 m below the hut's roof (TR) and at the rear of the sow (TB) in O. In I, temperatures were recorded under the heat lamp, away from the heat lamp and at the rear of the sow and their average calculated (TA). In a sample of the piglets, rectal temperatures were recorded 30 (RT30) and 60 (RT60) minutes after birth, by introducing a digital thermometer 3-4 cm into the rectum. The time taken to reach the udder (U) and to suckle (S) were also recorded. Student's *t* test was used for comparison of farm effects, and χ^2 test was used for comparison of proportions. Linear Regression was used to investigate relationships between variables.

Results TA was significantly higher than TB (22.5 *v*. 14.7, s.e.d. 1.0 °C, $p<0.001$). There was a strong positive relationship between TB and RT30 ($R^2=0.60$, $p<0.01$) and between TB and RT60 ($R^2=0.65$, $p<0.01$). Piglets born in O were heavier than those born in I (1.53 *v*. 1.41, s.e.d. 0.018 kg, $p<0.001$). There was a positive relationship between BW and RT30 ($R^2=0.29$, $p<0.001$ in I; $R^2=0.15$, $p<0.001$ in O) and also between BW and RT60 ($R^2=0.22$, $p<0.001$ in I; $R^2=0.07$, $p<0.05$, in O). RT30 (adjusted for BW) did not differ significantly (36.3 *v*. 36.5, s.e.d. 0.15 °C, $p>0.05$, $n_i=251$ and $n_o=86$, respectively), but adjusted RT60 was significantly higher in I than O (37.1 *v*. 36.6, s.e.d. 0.19, $p<0.05$, $n_i=223$ and $n_o=81$). This trend was maintained when different categories of BW were considered, although the difference was only significant in the piglets that weighed >1.5 kg at birth (Fig 1). The proportion of piglets that increased their RT60 with respect to RT30 was significantly higher in I than O ($p<0.001$). This trend was also maintained when different categories of birthweight were considered (Fig 1). Long term identification of piglets in O was not possible, so the relationship between RT30, RT60 and mortality was only made in I. Adjusted RT30 and RT60 of the piglets which died in the first 2 days of life in I were lower than of those which survived (RT30= 35.64 *v*. 36.24, s.e.d. 0.319 °C, $p=0.07$; RT60= 35.51 *v*. 36.84, s.e.d. 0.526 °C, $p<0.05$). There were no differences between farms in U and S. There was a negative relationship between RT30 and S and RT60 and S, the strength of which varied between farms. Thus, whereas it was weak in I ($r=0.14$, $p=0.06$; $r=0.24$, $p=0.001$ for RT30 and RT60 respectively), it was strong for O ($r=0.62$, $p<0.001$ and $r=0.73$, $p<0.001$, respectively).

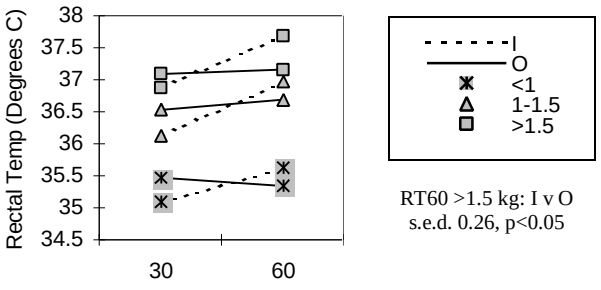

Fig 1. RT30 and RT60 in different categories of BW (kg) in I and O

Conclusions The extent of reduction of rectal temperatures was similar in I and O, even with lower environmental temperatures in O, indicative of a microenvironment around the udder and effective huddling behaviour. However, O piglets were less able to increase their temperatures to homeothermic levels than I piglets. Since hypothermia was associated with mortality in I, where each piglet could be traced, it is also expected to be related with mortality in O. O piglets appear to be more dependent on a successful suckle very soon after birth than I piglets to maintain their body temperatures.

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References English, PR and Morrison, V, 1984. Causes and prevention of piglet mortality. *Pig News Inf*. **5**, 369-376.
Pattison, R, English, PR, MacPherson, O, Roden, JA and Birnie, M, 1990. Hypothermia and attempted control in newborn piglets. *Anim. Prod*. **50**, 568.

Seasonal and interbreed variation in the thermoregulatory capacity of equine pelage

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Introduction The adaptation of horses (*Equus caballus*) to diverse environments throughout their range (e.g. Iceland and Arabia) has given rise to numerous phenotypically distinct breeds, many of which are currently maintained within the UK for sporting or leisure purposes. The welfare (energy balance) of outwintered horses has been associated with the ability to minimise heat loss by the growth of deep insulative pelage (Cymbaluk, 1994). Identification of breeds acclimated to UK conditions but retaining pelage adaptations appropriate to their environment of origin may facilitate management.

Materials and methods Seven, diverse breeds of domestic horse were used to assess the insulative properties of equine pelage (Shetland [S], Welsh Mountain [WM], Welsh [W], Icelandic [I], Arabian [A], thoroughbred [T], Shire [SH; n=5]) in summer and winter. Unless otherwise stated each group comprised six animals. All animals were maintained in a near natural state at pasture and were adapted to similar environmental conditions (53°N; within a ten-mile radius). Skin (T_{sk}) and coat surface (T_c) temperatures (at an anatomically consistent point on the mid-shoulder region) were automatically recorded (Squirrel data logger, Grant Instruments Ltd., Cambridge) using thermistors (0.6 mm tip diameter). Coat depth (x; mm) was recorded with an engineering ruler. Thermal conductance (C; $W.m^{-2}.^oC^{-1}$) through the pelage layer of each animal was calculated using equation 1 (Bruce, 1993):

$$\mathbf{C = q / (t_{sk} - t_c)} \qquad (1)$$

Where: $q\ (W.m^{-2}) = T_{sk} - T_c / (k/x)$
k = thermal conductivity of animal fur (0.0380744 $W.m^{-1}.K^{-1}$; Schmidt-Nielson, 1997)

Insulative capacity (I; $W^{-1}.m^2.^oC$), the inverse of thermal conductance, was subsequently calculated. Seasonal and interbreed differences in insulation and conductance were analysed using Student's t-tests.

Results Thermal conductance was exponentially related to coat depth ($R^2 = 0.88$; Figure 1) and was greater ($p < 0.01$) in all breeds during summer, when coat depths were minimal (< 5 mm). Conversely, thermal insulation increased in a linear manner ($R^2 = 0.97$) as pelage deepened. Insulation provided by the summer pelage did not differ significantly between breeds. Pelage insulation was significantly increased ($p < 0.05$) in winter for each breed studied. During winter the greatest insulative capacity was demonstrated in the native S group (1.029 ± 0.03 $W^{-1}.m^2.^oC$; $p < 0.01$; Figure 1) and the least insulative pelage belonged to the desert-adapted A (0.28 ± 0.06 $W^{-1}.m^2.^oC$; Figure 1).

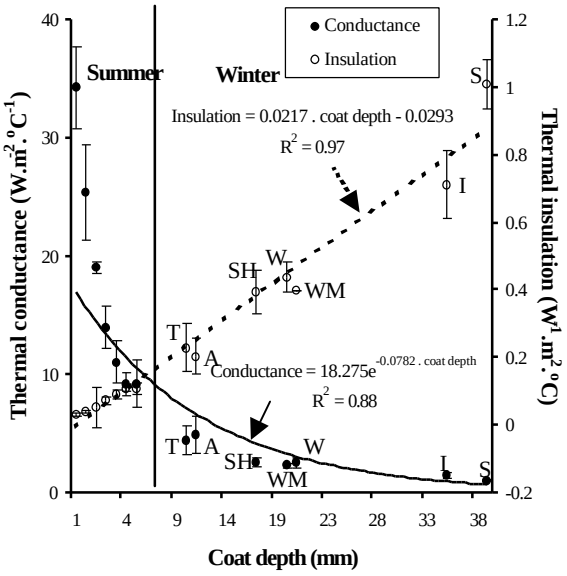

Figure 1 Relationship between coat depth, thermal conductance and thermal insulation in seven horse breeds.

Conclusions Irrespective of ecological background, the insulation conferred by the pelage of each breed was significantly greater during the winter months. However, the extent of thermal insulation conferred by the winter pelage of the different breeds varied radically e.g. the insulation offered by the pelage of Shetland ponies was 4-fold greater than that of thoroughbred horses (of Arabian decent). The cold-adapted pony breeds (S, I) evolved at the extreme Northern limits of the equine range and correspondingly demonstrated the greatest seasonal change in insulation. However, horse breeds (A, T) displayed greater thermal conductance than pony breeds irrespective of season. Changes in pelage insulation recorded in the cold-adapted pony are directed towards minimising winter heat loss, by increasing insulation, and thus reducing winter energy demands when food availability is scarce.

References

Bruce, J. M. 1993. Interactions between the animal and its environment. In *Quantitative aspects of ruminant digestion and metabolism* (eds. J. M. Forbes, & J. France), pp. 495-508 CAB International, Oxon.

Cymbaluk, N. F. 1994. Thermoregulation of horses in cold winter weather. *Livestock Production Science* **40**. 65-71

Schmidt-Nielsen, K. 1997 Temperature. In *Animal physiology - adaptation and environment.* 5th edition. pp. 217-297 Cambridge University Press, Cambridge.

Development of a model to predict dry matter intake of individual dairy cattle on commercial farms

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Introduction Nutritional research on commercial farms is difficult to carry out due to the problems associated with measuring individual animal dry matter intake (DMI). This research was aimed at developing a satisfactory method of estimating DMI from routine farm records, supplemented by cow body condition score and height at withers of the cow.

Material and Methods Metabolisable Energy Requirements (MER) for individual cows were calculated using the equation described by AFRC (1995) where total MER is equal to the sum of the ME for, Maintenance, Lactation, Live Weight Change (ΔLW) and Gestation. The MER is divided by the ME density of the diet to calculate DMI. To overcome the problem of weighing cows on farms, an equation was constructed to describe LW, using observations from 114 cows on the Wye College, University of London Dairy Unit. The equation described LW in terms of body condition score (BCS), height at withers (Ht), parity (P) and stage of gestation (SG) (Equation 1).

Equation 1 LW (kg) = -736 + (58.7 x BCS) + (7.92 x Ht) + (18.3 x SG) + (42.7 x P)

$r^2 = 0.78$ (RMS = 1720, 109 d.f.)

Two sets of data were used to validate the DMI model, both of which involved Holstein Freisian cows. The first data set (A) came from a total of 40 cows split into 2 equal groups. Group 1 was fed a simple ration containing a 2:1 ratio of grass to maize silage and group 2 was fed a total mixed ration with 3:1 maize to grass silage. Intakes were calculated as the average for each group at 10 fortnightly intervals through out the trial period. The second data set (B) involved 28 individually fed cows, offered four different concentrate types and grass silage *ad libitum*. Measured and predicted DM intakes were compared.

Results The two data sets (A & B) illustrate that the mean predicted DMI (pDMI) and measured DMI (mDMI) is similar (table 1). Where group mDMI and pDMI (A1 & A2) were analysed the difference was less than 0.8kg, and where individual cow results were used the difference reduced to 0.4kg (B). The results of paired t-tests (table 1) found that the differences between predicted and measured DMI were not significant (A1, A2 and B). The pDMI and mDMI, for data set B, were found to be correlated (0.6) highly significantly (p=0.001). The predicted values were compared to mDMI that may also contain errors, such as weighing out feeds, measuring refusals and the calculation of the DM for silages.

Table 1 Results of the validation of the estimation of DMI model (Paired t-test)

group		N	mean	s.e.m	s.e.d	t	p
A1	pDMI	10*	18.81	0.24	0.46	1.69	0.125
	mDMI	10*	18.04	0.37			
A2	pDMI	10*	20.91	0.48	0.63	-1.05	0.323
	mDMI	10*	21.56	0.23			
B	pDMI	28	22.20	0.49	0.44	0.92	0.365
	mDMI	28	21.79	0.32			

N is the number of observations
*group measurements

Conclusions The results indicate that it is possible to predict DMI of animals based on energy requirements, with requirements being calculated from easily obtainable values such as parity, stage of gestation, height and milk production. It is concluded that the method can be used to obtain values of DMI in on-farm situations with relatively high degree of accuracy using routine farm records supplemented by body condition score and height measurements.

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References AFRC 1995. Energy and protein requirements of ruminants, An advisory manual prepared by the technical committee on responses to nutrients, CAB International, Wallingford, Oxon, UK

Effects of varying silage quality for dry cows on feed intake, weight change and performance in the subsequent lactation

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Introduction Earlier studies (e.g. Dewhurst *et al.*, 1996, 1999) have shown marked declines in forage voluntary intake as calving approaches. The resultant reduction in nutrient supply may compromise performance in the next lactation, because it coincides with a period of intense metabolic activity in preparation for the next lactation. Feeding concentrates to dry cows did not overcome this problem (Dewhurst *et al.*, 1999). The objective of the current experiment was to investigate alternative dry cow strategies, using only high-quality grass silage, to minimise the severity and consequences for subsequent milk production of the reduction in nutrient supply in this period.

Materials and methods First-cut grass silages were prepared on 9 May 1998 (High D (H)) and 15 June 1998 (Low D (L)). Both silages were well preserved and results from an internal marker study (faecal grab samples analysed for acid insoluble ash) indicated DM digestibilities (g/g) of 0.72 and 0.58. Crude protein (CP) and neutral detergent fibre (NDF) contents were (201 and 144) and (452 and 592) g/kg DM for H and L respectively. Forty-eight cows in their second and subsequent lactations, calving from September to November 1998, were used. They had a mean weight of 618 kg and body condition score of 2.2 at the start of the experiment. They were dried off 60 days prior to the anticipated calving date and grazed on bare pasture for 4 days before being introduced to grass silage through roughage intake control feeders (Insentec B.V., The Netherlands). Six weeks before anticipated calving, the cows were balanced for parity and calving date and allocated to 3 treatment groups, denoted HH, LH or LL according to the sequence of silages that they were offered for weeks −6 to −4 and −3 to −1 respectively. After calving cows went onto a single lactation diet based on 8 kg/day of standard concentrate (starch, NDF and CP were 229, 247 and 220 g/kg DM respectively) and *ad libitum* first-cut grass silage until the end of lactation week 8. Results were analysed using REML (fixed model = 'diet') for the dry period measurements and repeated measures analysis of variance (treatment = 'diet') for lactation measurements (Genstat 5; Lawes Agricultural Trust, 1997).

Results Mean DM intakes of H and L (kg/day) were 14.1 and 10.4 (s.e.d.= 0.38; $P<0.001$) for week −5 and 12.6 and 9.5 (s.e.d.=0.34; $P<0.001$) for week −1. Dry period live-weight gains for treatments HH, LH and LL (calculated by difference between weeks -5 and −1) were 1.69, 1.19 and 0.24 kg/day (s.e.d.=0.143; $P<0.001$), whilst there was little difference in live-weight change from lactation weeks 2 to 8 (-0.10, 0.11 and 0.07 kg/day; s.e.d.=0.189; NS). Mean silage DM intakes, milk yield and milk composition for the first 8 weeks of lactation are shown in Table 1.

Table 1 Effects of dry period treatments on intake and milk production in the first 8 weeks of lactation

Dry period treatment:	HH	LH	LL	s.e.d.	Sig.
Silage DM intake (kg/day)	9.79	9.76	9.71	0.376	NS
Milk yield (kg/day)	28.4	27.9	26.7	1.29	NS
Milk fat (g/kg)	48.4	47.1	42.8	1.81	*
Milk protein (g/kg)	33.3	32.6	31.7	0.77	NS
Milk lactose (g/kg)	47.6	48.3	47.9	0.50	NS
Milk fat (g/day)	1371	1308	1147	66.9	**
Milk protein (g/day)	938	909	850	35.1	*
Milk lactose (g/day)	1348	1347	1286	57.7	NS

Discussion These relatively thin dry cows consumed large quantities of the high quality grass silage and gained a lot of weight (1.7 kg/day), confirming the high drive of dry cows to eat and gain weight. Silage quality in the late dry period had a substantial effect on milk fat content after calving. Giving high quality forage for just the final 3 weeks of gestation avoided the tendency for lower yields of milk solids and poorer milk composition that resulted from feeding the low D silage right up to calving. The reduction in milk protein yield with LL occurred without a concomitant decline in silage intakes or energy balance; indeed energy balance was highest for these cows.

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References

Dewhurst, R. J., Davies, D. W. R., Fisher, W. J. and Aston, K. 1996. Effects of dry period diet on food intake, body composition and subsequent lactational performance of dairy cows. *Animal Science* **62:** 621(abstract).

Dewhurst, R. J., Davies, D. W. R. and Fisher, W. J. 1999. Effects of varying forage type and offering additional concentrates to dry cows. *Journal of Dairy Science* **82 (Suppl.1):** 120(abstract).

The effect of slurry application timing on grass silage fermentation and intake by dairy cattle

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Introduction Many farmers apply slurry to grassland as a fertiliser or a means of waste disposal. There is evidence that winter slurry application leads to higher losses of nitrogen due to leaching subsequently reducing the efficiency of slurry N utilisation when compared with spring applications (Smith et al 1995). This suggests that slurry applications should be undertaken in spring, but the effect of timing on the extent of grass contamination is unknown. When grassland is used for silage production, contamination of the sward can lead to reduced silage fermentation and acceptability (Boxem and Remmelink 1987). A study was conducted to investigate the effect of timing of slurry application on fermentation and dry matter intake of first and second cut grass silage.

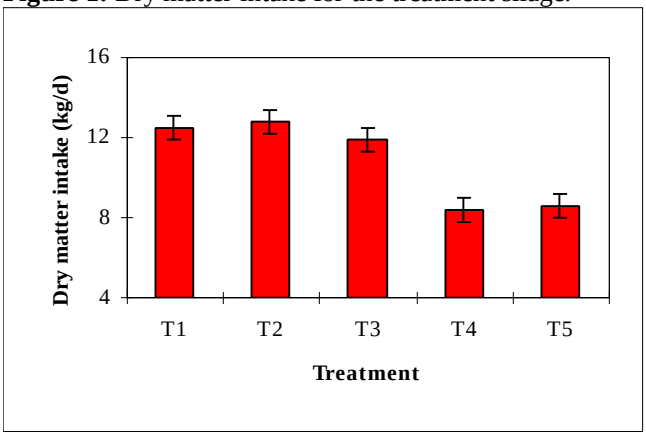
Material and Methods A total of fifteen Italian ryegrass plots were used in this study. Treatments consisted of plots receiving slurry (mean DM content = 30 g/kg) at one of five different timings; 10, 6, or 2 weeks prior to first cut (T1, T2 & T3) or 6 or 2 weeks prior to second cut (T4 & T5) at a rate of 30 tonnes/hectare (fresh basis). This resulted in 3 randomly allocated replicate plots per treatment. Grass was ensiled as big bale silage without any additives or inoculants. Silage samples were taken from each bale after a minimum of 100 days of fermentation, bulked to form 3 bulk samples per treatment. They were analysed by NIR for dry matter (DM), crude protein (CP), neutral detergent fibre (NDF), ash, pH, volatile fatty acid (VFA), ammonia-N and estimated metabolisable energy (ME) content. Ten individually fed non-lactating Holstein dairy cows were used to measure the intake potential of the silage fed alone and to appetite on one occasion daily. Cows were allocated according to live weight measured before the study to a replicated 5 x 5 Latin square (5 treatments x 5 treatment periods). Each period was 12 days in duration, the first 7 days for acclimatisation and the remaining 5 days for daily intake measurement. Intake and silage quality data was analysed using analysis of variance with non-orthogonal contrasts to compare T1 versus T2, T1 versus T3, T2 versus T4 and T4 versus T5.

Results There was no significant difference in dry matter intake when the interval between slurry application to first cut was reduced from 10 weeks (T1) to either 6 or 2 weeks (T2 & T3 respectively)(Figure 1). Reducing the interval between slurry application and second cut from 6 to 2 weeks (T4 & T5 respectively) also had no significant ($P > 0.05$) effect on dry matter intake. Dry matter intake was 4.4 kg/day lower ($P < 0.01$) for second cut (T4) silage when compared with first cut silage (T2), when slurry was applied 6 weeks prior to ensiling. Second cut silage (T4) had a significantly lower dry matter content ($P < 0.01$, s.e.d = 55.2) but higher ammonia-N ($P < 0.05$, s.e.d = 5.54) and total VFA ($P < 0.01$, s.e.d = 27.6) content than first cut silage (T2) when slurry was applied 6 weeks before ensiling (Table 1).

Table 1: Composition of the treatment silage (g/kg DM unless otherwise stated).

Parameter	T1	T2	T3	T4	T5	se
DM (g/kg)	499	465	458	325	288	30.4
CP	127	128	122	133	151	4.7
Ash	76	78	79	85	93	1.4
NDF	566	572	583	578	577	7.9
ME (MJ/kg DM)	10.5	10.2	9.9	9.8	9.5	0.17
pH	5.0	4.9	4.9	4.6	4.8	0.12
NH_3-N (% TN)	4.3	2.7	1.4	13.5	25.4	3.05
Total VFA	12	14	13	68	104	15.1

Figure 1: Dry matter intake for the treatment silage.



Conclusions Decreasing the time between slurry application and ensilage from 10 weeks to 2 weeks for first cut and from 6 weeks to 2 weeks for second cut had no effect on the intake of big bale Italian rye grass silage when applying slurry with a low DM content. The significantly lower intake with second cut silage compared with first cut maybe due to an increase in the ammonia-N and total VFA content of silage.

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References Smith, K.A., Jackson, D.R., Unwin, R.J., Bailey, G. and Hodgson, I. 1995. Effect of winter and spring applied slurry on yield of herbage. *Grass and Forage Science* **50**:124-131.

Boxem, T.J. and Remmelink, E.J. 1987. The effect of regular application of cattle slurry on grassland during the growing season on grass yield and daily milk production. In *Animal Manure on Grassland and Fodder Crops* [Eds Van der Meer, H.G., Unwin, R.J., Van Dijk, T.A. and Ennik, G.E.] Martinus Nijoff, Dordrecht. pp 313-315.

Effect of maturity of Napier grass (*Pennisetum purpureum*) hay on intake, digestibility, and rumen dynamics when given to zebu bulls

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Introduction Cattle in the tropics mostly depend on pastures. During dry periods the forage available is usually mature, constraining both intake and digestion. These constraints need to be understood, for intake and digestibility define productivity. Intake depends on the rumen space made available by fermentation and outflow. Markers such as PEG (liquid phase), and chromium mordanted fibre (solid phase) can be used to measure rumen volume and outflow, but have limitations. The objective of this experiment was to measure intake, digestibility, and rumen kinetics of cattle fed *ad libitum* forages with very different degradation characteristics, and also to compare rumen volumes measured with markers with those obtained by manual emptying.

Materials and methods Six zebu bulls (317±14kg) fitted with permanent rumen canulae of 10 cm diameter and housed in individual pens were used. Hays were cut at 6 (young) or 28 weeks (mature). chopped, sun dried, and then coarsely ground (25mm screen) to minimise selection. They were supplemented with minerals and urea (30gN per kg potentially degradable OM measured *in sacco*) and mixed with molasses (50g DM/kgDM) to reduce dustiness. The experiment was a cross-over design with two periods of five weeks as- Weeks 1 & 2 adaptation, and measurements as:- Week-3; hay intake; (offered to 20% in excess of DMI). Week-4; digestibility (total collection) and degradability (hays incubated *in sacco* in all bulls when eating the hay being incubated. Incubation times (2 bags) were:- Young hay 6, 12, 24, 48, 72, & 96 h. Mature hay 12, 24, 48, 72, 96 & 120 h. Degradation values were fitted as $P = a+b(1-e^{-ct})$ where: 'P' is degradation after 't' hours and 'a', 'b' and 'c' are constants. 'B', the insoluble degradable fraction was defined as: B = (a+b) – Wo (zero time washing loss). Week-5; digesta kinetics and pool sizes by Cr-mordanted fibre, PEG and manual emptying. ANOVA was for variation due to diet, animal and period.

Results Intake of young hay DM was double that of mature hay (P<0.001), and due to its greater digestibility (P<0.01), ME intake (ccalculated as 0.82 of DE when DE = 18.8MJ/kgDOM), was 2.6 times greater. There were clear differences between hays. The potential degradability (a+b) of the DM of the young hay was 33% greater than that of the mature hay. The NDF of the young hay had a potential degradability 40% greater than that of the mature hay. The rumen DM pool size was greater (P<0.05) with the mature than with the young hay with both methods of measurement which did not differ significantly. The liquid pools with the two hays were not significantly different, however liquid volumes by emptying the rumen were more than 30% greater than by PEG (P<0.01). The fractional rate of rumen liquid outflow, was almost two times greater (P<0.01) with young than with mature hay. The fractional rate of rumen solid outflow was also higher (P<0.05) with young hay. Faecal production was 1.6 times greater (P<0.01), indicating greater outflow of undegraded material. Mean rumen retention times derived from DM pool (manual emptying) (Minson, 1966) gave 64h with mature and 22h with young hay. Retention time calculated as time 't' needed to achieve apparent digestibility (D) by substituting 'D' for 'P' in the degradation equation gave 21 and 64 hours for the young and mature hays respectively, good agreement between independent estimations.

Table 1 Intake, digestibility, rumen and degradation characteristics when hays of two qualities were fed to zebu bulls

	Hay quality				Degradation characteristics of hays				
	Young	Mature	SED	P		Young	Mature	SED.	P
DMI (g/kgW $^{0.75}$/d)	91.4	44.3	1.8	***	**DM** a	15.3	11.3	5.93	ns
ME (kJ/kgW $^{0.75}$/d) #	759	297	-	-	b	60.4	45.5	5.10	**
Digestibility DM	0.59	0.45	0.029	**	c	0.0665	0.0279	0.0083	***
NDF	0.67	0.48	0.025	**	a+b	75.6	56.8	2.19	***
Rumen DM pool (kg) (Man)	6.3	9.0	0.58	*	B	47.6	37.8	2.02	***
Rumen DM pool (kg) (Cr)	7.4	9.9	0.61	*					
Solid outflow (%/h)	3.8	1.5	0.58	*	**NDF** a	-13.7	2.3	-	
Faeces (kgDM/d)	2.9	1.8	0.17	**	b	84.4	39.2	-	
Rumen liquid pool (kg) (Man)	41	48	3.0	ns	c	0.050	0.029	-	
Rumen liquid pool (kg) (PEG)	27	32	2.5	ns	a+b	70.7	41.5	-	
Liquid outflow (%/h)	9.0	4.8	0.65	*	B	61.6	37.2	-	

Conclusions Greater intake of the young hay was due to a combination of greater degradability and a higher outflow rate of undegraded material from the rumen. It was not due to differences in rumen volume. Rumen pool DM size determined by Cr-fibre agreed reasonably well with that measured by manual emptying, whereas agreement with liquid volumes determined by PEG was poor. However treatment trends were the same.

Reference Minson, D.J. (1966) The apparent retention time of food in the reticulo-rumen at two levels of feeding by means of an hourly feeding technique. *British Journal of Nutrition.* **20**, 765-773.

Influence of milk production level of cow and protein content of supplement on the selection of maize and grass silages by dairy cattle given a choice of forages

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Introduction A previous study (Syed and Leaver, 1999) showed that offering maize and grass silages alternately either within days or between days resulted in higher intakes of maize than grass silage, and lower total intakes than when fed mixed together. The factors influencing the choice of forages are not well researched. The hypothesis tested was that as maize and grass silages are similar in ME value but very different in crude protein, nutrient demand for protein, and protein level in the supplement would influence forage selection. This experiment examined the influence of the milk yield level of the cow and the protein level of a supplement.

Material and Methods Sixteen Holstein Friesian cows including 8 with low (15kg/day) and 8 with high (30kg/day) yields were used in a changeover design comparing a low protein (6kg rolled barley + 1kg soyabean meal/day) and a high protein (3.5kg rolled barley + 3.5kg soyabean meal/day) supplement. Difference between yield groups was mainly associated with stage of lactation. There were two periods each of 3 weeks with the final week used for measurement. The cows were each offered two forages *ad libitum* through two Calan gates, one with grass and one with maize silage. The positions of the two silages were alternated daily. The grass and maize silages contained respectively 297 and 280gDM/kg, 749 and 688gDOM/kgDM (estimated ME 11.8 and 10.8MJ/kgDM), and 188 and 77gCP/kg DM respectively. A 48h continuous observation of feeding behaviour was carried out in each period. The results were analysed as a series of Latin Squares using the GENSTAT (version 5, release 4.1) package.

Results The main results are presented in Table 1.The cows showed a strong preference for the grass silage with a mean ratio of 0.87:0.13 grass silage : maize silage DM intake (sed 0.025***). The intakes of the two silages were not significantly affected by milk yield level of cow or by protein level of supplement. The CP contents of the total diet intake averaged 169 and 208gCP/kg DM for the low and high protein supplement diets respectively. The high protein supplement significantly increased total forage DM intake. The rate of intake of DM (R of I kg/min) was higher for grass than maize silage. There were no significant interactions between milk yield level and protein level in the supplement for any of the measurements.

Table 1 Main effects of milk yield level of cows and of protein level of supplement on choice of grass and maize silages by dairy cows.

	Milk Yield		Protein Suppl.		Yield		Protein	
	Low	High	Low	High	sed	sig	sed	sig
Grass silage DMI (kg/day)	11.5	12.0	11.5	12.0	0.62	NS	0.31	NS
Maize silage DMI (kg/day)	1.6	1.8	1.5	1.9	0.38	NS	0.17	*
Forage DMI (kg/day)	13.1	13.8	13.0	13.9	0.56	NS	0.28	**
Total DMI (kg/day)	19.2	19.9	19.1	20.0	0.56	NS	0.28	**
Feeding time grass silage (min)	150	182	161	171	19.9	NS	5.3	NS
Feeding time maize silage (min)	35	46	38	43	4.5	*	3.9	NS
R of I grass silage (kgDM/min)	80	70	76	75	9.4	NS	4.0	NS
R of I maize silage (kgDM/min)	53	39	46	46	8.7	NS	7.6	NS

Conclusions The cows selected a high proportion of grass relative to maize silage (0.87:0.13). Milk yield level of cow and protein level in supplement had no significant effect on choice of silage, indicating that neither nutrient demand for protein nor protein supply in the supplement were influential on forage selected. The high ME value of the grass silage is one possible explanation for its preference. However research is required to understand what characteristics of silages influence preference and whether preference is related to DM intake when the same forages are offered separately.

Acknowledgements J.S S. acknowledges the financial support of the Pakistan Government.

Reference Syed, J.S. and Leaver, J.D. (1999) Effect on milk production in dairy cows of feeding grass silage and maize silage as a mixture, or separately within days or on alternate days, with low or high protein supplements. *Proceedings of the British Society of Animal Science* 1999, p202. BSAS.

Relationship between plasma ammonia and the urea concentration of milk and plasma in the lactating dairy cow

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Introduction The objective of this study, which formed part of a larger project, was to investigate the effect of feeding high levels of urea on the reproductive function of the lactating dairy cow. Increasing dietary protein intake can increase milk production, but may reduce reproductive performance (Laven and Drew 1999). McEvoy et al (1997), based on work which fed urea to sheep, suggested that this effect on fertility may be caused by ammonia. However, there is little information on the effect of feeding quickly degradable nitrogen (QDN) on the concentration of plasma ammonia in the dairy cow and the accurate measurement of plasma ammonia is difficult. The measurement of a more stable metabolite, such as urea, may be more useful, if it can be shown to be correlated with plasma ammonia.

Materials and methods Forty-two, mature Holstein cows were group fed one of two diets. The Control diet was formulated to meet the metabolisable energy and metabolisable protein requirements for early lactation cows according to the UK systems (AFRC, 1993). All cows were fed the Control diet for 3 weeks after which half of the cows were allocated, using a randomised block design, to a diet supplemented with urea (High QDN). This comprised the Control diet plus 250 g urea per cow per day (equivalent, on a metabolic bodyweight basis, to that fed by McEvoy et al. (1997)). The two diets were isoenergetic but the High QDN diet supplied 50% more QDN than the Control (95g/kg DM against 61 g/kg DM). At study start, all cows were non-pregnant and less than 112 days post partum, their mean daily milk yield was 37 litres. Milk samples were collected three times weekly for determination of urea concentration. Blood was collected within three hours of feeding, three times during the first week after urea introduction, and then weekly until seven weeks post conception. Samples were chilled immediately and plasma stored at -18^0C until analysis for urea and ammonia concentration. The results were statistically analysed using repeated measures ANOVA and correlation between milk urea, plasma urea and plasma ammonia.

Results The results showing treatment mean milk and plasma urea and ammonia concentrations and the correlations between these parameters are summarised below in Tables 1 and 2. Cows fed the High QDN diet had significantly higher levels of milk urea, plasma urea and plasma ammonia. Milk and plasma urea levels were significantly correlated in both treatment groups but plasma urea and plasma ammonia only showed a significant correlation in the High QDN group. None of the correlations were strong as illustrated by the small r values.

Table 1 : Milk and plasma concentrations of urea and ammonia

	Control	High QDN	P
Mean milk urea (mmol/l)	5.6	7.2	<0.001
Mean plasma urea (mmol/l)	6.5	8.2	<0.001
Mean plasma ammonia (umol/l)	85.2	100.4	0.018

Table 2 : Correlation coefficients for milk urea, plasma urea and plasma ammonia concentrations

Correlation	Control correlation coefficient (r)	P	High QDN correlation coefficient (r)	P
Milk urea and plasma urea	0.249	<0.001	0.371	<0.001
Plasma urea and plasma ammonia	-0.017	NS	0.218	<0.001
Milk urea and plasma ammonia	0.046	NS	0.001	NS

Conclusion. In this study, urea supplementation significantly increased the concentration of plasma ammonia, though not as high as the 150 μmol/l seen in the study of McEvoy et al. (1997). This may be associated with the increased dietary intake of a lactating dairy cow reducing the rate of absorption of ammonia from the rumen. This study confirms the correlation between plasma and milk urea. This relationship was not as strong as that seen previously (Laven and Drew 1999), probably because the plasma samples collected in this study were timed to capture peak urea concentration, unlike the milk which represents a 12 hour 'mean'. This averaging effect also explains the lack of correlation between milk urea and plasma ammonia. The relationship between plasma urea and plasma ammonia is more complex illustrated by the fact that plasma ammonia was correlated with plasma urea only in High QDN cows.

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References

Laven R.A. and Drew S.B. (1999) Dietary Protein and Reproductive Performance of the Cow: A Review of the Effects and mechanisms. Veterinary Record (in press)

McEvoy T.G., Robinson J.J., Aitken R.P., Findlay P.A., and Robertson I.S. (1997) Dietary excesses of urea influence the viability of preimplantation embryos and may affect fetal growth among survivors. Anim. Rep. Sci. 47: 71-90

The effect of a period of early season part-grazing on the performance of animals managed on two contrasting systems of milk production during the winter

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Introduction In a previous study, spring calving dairy cows exhibited considerable milk yield responses when given access to spring grass for short periods (Sayers and Mayne, 1998). The current study seeks to examine the performance of autumn calving (later lactation) dairy cows when given access to spring grass. In addition, this study seeks to identify if winter management system (forage or concentrate based systems) influences the response achieved.

Material and methods Sixty autumn calving Holstein/Friesian dairy cows (PTA_{95} fat + protein = 43.5 kg) comprising 33 multiparous animals and 27 primiparous animals, were used in this study. Animals had a mean calving date of 4 November 1997, and were allocated to one of two systems of milk production, HF or HC, within 36 hours of calving. During the winter, animals on system HF ('high forage') were offered high feed value silages, supplemented with 6.0 kg/day of concentrate (crude protein concentration of 311 g/kg DM) through an out-of-parlour feeding system. Animals on system HC ('high concentrate') were offered medium feed value silages, supplemented with 12.5 kg concentrate per cow per day (crude protein concentration of 211 g/kg DM), in the form of a complete diet. The high and medium feed value silages were produced within a four and two harvest system respectively, cutting dates being 15 May, 16 June, 17 July and 18 August for the former, and 3 June and 6 August for the latter. On 25 February animals on each of systems HF and HC were divided into two sub-groups, with one sub-group from each of systems HF and HC commencing a period of early season grazing (ESG), while the two remaining sub-groups continued to be housed (H). This period of grazing continued until 24 March, with the grazing time increasing from an initial time of 2 – 3 hours per day post turnout to a maximum of 8 hours per day at the end of the period. During this four-week period all animals continued to be offered their full winter concentrate allocation and silage *ad libitum*. Herbage intakes were estimated daily from pre and post-grazing sward heights, as measured using a rising plate meter.

Results Energy balance values for systems HF and HC during the week prior to the start of early season part grazing, calculated using the estimated ME concentrations of the diets as described by Ferris *et al*. (2000), were 6.7 and –2.6 MJ per day respectively. Concentrate intakes for animals on treatments ESG and H, within each of the two winter systems, were virtually identical, while herbage intakes for treatment ESG were 3.4 and 3.6 kg DM with systems HF and HC respectively. Giving animals access to a period of early season grazing resulted in a significant reduction in silage DM intake ($P<0.001$), but increased total DM intake ($P<0.001$), while the interaction between system and treatment was significant for each of these two parameters. However milk yield, while being higher with animals on system HF compared to HC, was not influenced by grazing treatment. Similarly, grazing treatment had no effect on either milk fat or protein concentration, or on milk fat or protein yield.

Table 1 Effect of winter production system on performance during a period of early season part-grazing

	HF System		HC System			Significance		
	ESG	H	ESG	H		System	Treat	Interaction
Concentrate DMI (kg/day)	5.2	5.2	10.6	10.7	0.25	***	NS	NS
Silage DMI (kg/day)	10.4	12.7	6.1	7.1	0.27	***	***	*
Grass DMI (kg/day)	3.4 sd 1.93	0	3.6 sd 2.15	0				
Total DMI (kg/day)	18.9	17.9	20.3	17.8	0.22	**	***	***
Milk yield (kg/day)	29.2	29.2	28.5	28.3	0.32	*	NS	NS
Milk Fat (g/kg)	41.2	42.4	41.8	41.6	0.84	NS	NS	NS
Milk protein (g/kg)	32.8	32.3	33.4	33.3	0.22	***	NS	NS
Fat + protein yield (kg/day)	2.15	2.15	2.14	2.12	0.031	NS	NS	NS

Conclusions In the current study, autumn calving dairy cows exhibited no milk yield or milk constituent yield response when given access to a period of early season grazing, irrespective of whether they were managed on a high concentrate (HC) or high forage (HF) system over the winter period. This lack of responses, which occurred despite considerable increases in total DM intake, may reflect the fact that animals were estimated to be either in positive energy balance (HF) or only in mild energy deficit (HC) at the time when the ESG treatment animals were given access to grass.

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References

Sayers, H.J. and Mayne, C.S. (1998). *Proceedings of the British Society of Animal Science*, Winter Meeting 1998. Paper No. 50

Ferris, C.P., McCoy, M.A., Lennox, S.D., Catney, D.C. and Gordon, F.J. (2000). Fertility in the High-Producing Dairy Cow. *Proceedings of an Occasional Meeting of the British Society of Animal Science*, Galway. In Press.

The effect of feeding forage maize ensiled with sugar beet pulp ('Pulp'n'Maize') to dairy cows

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Introduction An increasing acreage of forage maize is being grown in the north of England and south of Scotland as an alternative to grass silage for dairy cows. Previous work has shown that molassed sugar beet pulp (MSBP) can be ensiled with maize to minimise effluent production and ensiling losses (Hameleers *et al*) from low dry matter (DM) maize. This experiment was designed to evaluate the effects of feeding 'Pulp'n'Maize' on intake, milk yield and milk composition in dairy cows.

Materials and methods 'Pulp'n'Maize' was made by ensiling MSBP with maize at 10% freshweight. Twenty-four early lactation Holstein/Friesian cows (on average 60 days in milk, with an average milk yield of 29 kg/d) were allocated to four treatments in a Latin Square design. Treatment (T) 1: Grass silage *ad* lib; T2: 4.4 kgDM/d grass silage, *ad lib* 'Pulp'n'Maize'; T3: 4.4 kgDM/d grass silage, *ad lib* maize silage with MSBP mixed in at time of feeding; T4: 4.4 kgDM/d grass silage, *ad lib* maize silage. All cows were, in addition, fed 0.87kgDM/d extracted soya bean meal, and 4.3kgDM/d of a standard dairy compound concentrate with the composition: DM 862g/kg, crude protein 219g/kg DM, starch 244g/kg DM and metabolisable energy (ME) 13.2MJ/kg DM. Milk samples were collected on the last four days of each period and analysed for fat, protein and lactose content by Milkoscan. Milk yield was recorded daily by computer. Forage and concentrate samples were collected weekly and bulked into one sample of each per period for chemical analysis.

Results The performance results are shown in Table 1. Yield of milk, fat, protein and lactose were significantly different ($p<0.05$) between cows on different treatments. Both concentration of milk protein and forage dry matter intake (DMI) was significantly higher for cows fed T2 and T3 than for the animals on the other treatments ($p<0.001$). With the maize DM of 201g/kg and that of the MSBP 871g/kg, the DMI of the maize and MSBP components of T2 and T3 could be calculated and compared to the DMI of the other treatments (Table 2). The intakes of maize were constant for animals fed T2, T3 and T4, with the higher overall intakes apparently due to the MSBP in T2 and T3 diets. There was no substitution of MSBP for maize at this inclusion rate.

Table 1 *Performance data of cows*

	T1	T2	T3	T4	s.e.d	P
Milk yield (kg/d)	23.2^{b}	24.7^{a}	24.3^{ab}	23.1^{bc}	0.56	<0.05
Fat (g/d)	998^{b}	1091^{a}	1070^{a}	999^{b}	20.88	<0.001
Protein (g/d)	780^{b}	849^{a}	823^{a}	758^{b}	17.92	<0.001
Lactose (g/d)	1072^{b}	1148^{a}	1109^{ab}	1060^{b}	28.63	<0.05
Constituent concentration						
Fat (g/kg)	44.4	44.0	44.5	43.5	1.19	NS
Protein (g/kg)	33.9^{a}	34.1^{a}	34.1^{a}	32.9^{b}	0.33	<0.001
Lactose (g/kg)	45.9	46.0	45.6	45.7	0.34	NS
Forage DMI (kg/d)	12.1^{b}	13.9^{a}	13.9^{a}	11.3^{c}	0.30	<0.001

Within rows, values with different superscripts are significantly different

Table 2 *Estimated forage dry matter intakes (kg/head/day)*

Treatment	Total forage intake	Grass silage	Maize 'mix'	Component of maize 'mix'	
				Maize	MSBP
1	12.1	12.1	-	-	-
2	13.9	4.4	9.5	6.7	2.8
3	13.9	4.4	9.5	6.7	2.8
4	11.3	4.4	6.9	6.9	-
s.e.d.	0.30	-	-	-	-

Conclusions 'Pulp'n'Maize' is an effective product to ensile with low DM maize, as an absorbent to contain effluent, and with production benefits over grass silage, and grass silage plus maize silage, when fed to dairy cows.

References

Hameleers A., Leach K.A., Offer N.W. and Roberts D.J. The effects of incorporating sugar beet pulp with forage maize at ensiling in silage fermentation and effluent output using drum silos. *Grass and Forage Science*, in press.

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Milk production from dairy cows offered pea-wheat bi-crops containing different ratios of peas to wheat and harvested at two maturity stages.

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Introduction As more farmers try to improve the efficiency of their production systems by sourcing safer and cheaper dietary energy and protein from home grown feeds, the importance of cereal-legume bi-crops for winter-feeding of UK livestock may increase. However, little is known about the production, conservation, feeding value and animal performance from such bi-crops in the UK. This study measured the feed intake and milk production from dairy cows fed pea-wheat bi-crop silages.

Materials and methods Spring varieties of peas (cv. Magnus) and wheat (cv. Axona) sown with either a high (HP) or low (LP) pea inclusion rate were harvested at 2 growth stages and conserved in clamp silos. The 1st and 2nd cuts were respectively taken at 13 and 15 weeks after sowing, when the mean dry matter (DM) content was 301 g/kg (cut 1) or 333g/kg (cut 2). The ratios (total plant DM) of peas to wheat in the bi-crops mixture were 2:1, 3:1, 2:3 and 2:3 respectively, for HP CUT1, HP CUT2, LP CUT1 and LP CUT2. The bi-crops were evaluated against a grass silage (GS) control using eighteen multiparous cows that were between weeks 9 and 10 of lactation in a cyclical changeover design with three 28-day periods. The bi-crops were supplemented with 6 kg/day of a 240 g crude protein (CP)/kg DM concentrate and the grass silage was supplemented with either 6 (GS6) or 9 (GS9) kg/day of the same concentrate. The last week of recording before the commencement of the study was used as covariance. Individual cow feed intake, daily milk yield and weekly milk composition were measured. The data were analyzed by analysis of variance using the method of residual maximum likelihood (Genstat 5, Lawes Agricultural Trust, 1995).

Results The pH, DM, CP and neutral detergent fibre (NDF) content of the GS were 4.0, 227 g/kg, 142 and 593 g/kg DM respectively. The bi-crops (HP CUT1, HP CUT2, LP CUT1 and LP CUT2) respectively contained 284, 299, 308 and 386 g/kg of DM, 170, 197, 159, 152 g/kg DM of CP and 494, 529, 520 and 569 g/kg DM of NDF. The DM intake, milk yield and composition of cows on bi-crops or GS are presented in Table 1. Forage DM intake was significantly higher for the bi-crops than for GS irrespective of the level of concentrate intake. When the concentrate intake was considered, the total DM intake was only higher ($P<0.001$) than for GS6. Between the bi-crops, intake was lowest ($P<0.01$) for the HP CUT1 treatment. Milk yield was higher ($P<0.01$) from all the bi-crops than from GS6 but lower than from GS9. Similarly, the fat corrected milk yield (CMY) was higher ($P<0.001$) for GS9 than for all other treatments. Compared to both GS treatments, feeding the bi-crops depressed ($P<0.05$) milk fat content but did not affect ($P>0.05$) milk lactose. Milk protein content was however higher ($P<0.01$) for GS9 than for other silages. Feeding GS9 significantly increased the yield of fat, protein and lactose in comparison with other silages. Compared to GS6, the bi-crops gave comparable milk fat yield and higher ($P<0.01$) milk protein and lactose yields.

Table 1: Dry matter intake (kg/d), milk yield (kg/d) and milk composition of dairy cows (DF = 48)

	HP CUT1	HP CUT2	LP CUT1	LP CUT2	GS6	GS9	SED	F-Prob.
Forage DM intake	10.3	11.0	11.2	11.4	8.57	8.57	0.48	<0.001
Total DM intake	15.4	16.3	16.1	16.5	13.7	16.3	0.48	<0.001
Milk yield	21.9	23.4	21.8	22.4	20.8	23.7	0.45	<0.001
4% Fat CMY	26.3	27.1	25.8	26.2	26.5	29.6	0.91	<0.001
Composition (g/kg)								
Milk fat	48.2	46.6	47.9	47.1	51.4	50.2	1.70	<0.05
Milk protein	30.4	30.4	30.7	31.0	30.6	31.7	0.30	<0.01
Milk lactose	47.1	47.0	47.2	47.4	46.7	46.6	0.40	NS
Yield (g/d)								
Milk fat	1050	1085	1030	1047	1061	1184	36.4	<0.001
Milk protein	665	709	664	689	632	748	17.0	<0.001
Milk lactose	1030	1102	1027	1061	970	1102	25.1	<0.001

HP: High pea; LP: Low pea; GS6: grass silage+6kg concentrate; GS9: grass silage+9kg concentrate; CMY: corrected milk yield; NS: not significant.

Conclusions This study shows that conserved pea-wheat bi-crops, can give higher feed intakes and milk yields than grass silage when both are supplemented with similar levels of concentrate. Increasing the proportion of peas above 40% did not significantly influence the performance of the cows. However, milk production was generally better with the second cut bi-crops.

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Effects of silage fermentation on milk protein and fat content and yield

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Introduction The extent and type of in-silo fermentation has a profound influence on the composition of nutrients absorbed from the digestive tract of dairy cows (Choung & Chamberlain, 1993; van Vuuren *et al.* 1995). The amount of amino acids absorbed from the small intestine decreases when the extent of in-silo fermentation is increased due to reduced efficiency of microbial protein synthesis. The ratio of lipogenic to glucogenic VFA increases when in-silo fermentation is restricted, since silage lactic acid generally increases propionate in rumen VFA, whereas WSC in silage increases acetate, butyrate or both. The purpose of this study was to estimate quantitative relationships between silage fermentation characteristics and milk production using data based on mean treatment values of production parameters and silage fermentation characteristics.

Material and methods Relationships between silage fermentation and milk production parameters were estimated using the PROC MIXED procedure of SAS and data from 53 experiments (n = 260). Grass silages within each experiment were prepared from the same sward using different ensiling techniques. Wilted silages (DM content > 300 g/kg) were excluded from the data. The model included experiment as fixed factor and concentrate treatments within experiment as a random factor.

Results Milk fat content and yield decreased ($P<0.001$) when the extent of in-silo fermentation increased. Fat content decreased by 0.033±0.0035 g/kg ($R^2 = 0.929$; residual mean square (RMS) = 1.14) and fat yield by 1.06±0.12 g/d ($R^2 = 0.971$; RMS = 38.3) per 1 g/kg DM increase in total acid (TA) concentration. The effects of total acid and lactic acid concentration on milk fat content were similar. Milk fat concentration also decreased with increasing ammonia N, but because of positive correlation between ammonia N and TA two factor model did not explain more of the variation in milk fat content than TA alone. The effect of TA on fat yield (0.47±0.13 g per g/kg DM increase in TA) remained significant ($P<0.001$) when silage DM intake was included in the model.

Milk protein content was best predicted by model including lactic acid (LA) and VFA, with the decrease being greater for VFA than LA (0.011±0.002 *v.* 0.033±0.005 g/kg per 1 g/kg DM; $R^2 = 0.948$, RMS = 0.56). A model including TA and ammonia N explained the variation in milk protein content almost as accurately as LA and VFA both factors having similar coefficients (ammonia N: 0.011±0.003, $P<0.001$; TA 0.010±0.002, $P<0.001$). This suggest that both increasing extent of in-silo fermentation and increased proteolysis have an adverse effect on milk protein content. Milk protein yield (PY) was best predicted by the model: PY = 755(±20.9) - 0.35(±0.09) TA (g/kg DM) - 0.36(±0.13) ammonia N (g/kg total N) ($R^2 = 0.980$; RMS = 23.2). Inclusion silage DM intake into the model indicated that silage fermentation had no significant effect on PY.

Conclusions The results of the present study demonstrate that milk fat and protein content decreases when the extent of in-silo fermentation increases with secondary fermentation having a more detrimental effect on milk protein content than lactic acid fermentation. Increased in-silo fermentation also decrease fat and protein yield. The effects on protein yield were mainly associated with reduced silage DM intake, but for fat yield, silage fermentation also had a direct effect. Increased propionate production in the rumen with extensively fermented silages probably increases glucose supply compensates for the reduction in amino acid supply.

References Chamberlain, D.G. and Choung, J.-J. 1993.The nutritional value of grass silage. In: O'Kiely P. et al. (eds.). *Silage Research 1993*. Proceedings of the 10th International Conference on Silage Research. p. 131-136.
van Vuuren, A.M., Huhtanen, P. and Dulphy, J.-P. 1995. Improving the feeding and health value of ensiled forages. In: Journet, M et al. (eds.). *Recent Developments in the Nutrition of Herbivores*. INRA, Paris. p. 297-307.

The effect of feeding whole cracked rapeseed and vitamin E on dairy cow performance and milk fat composition

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Introduction Current thinking suggests that the saturated fatty acids myristic (C14:0) and palmitic (C16:0) are major risk factors in cardiovascular disease compared to longer chain fatty acids such as stearic (C18:0) and oleic (C18:1). Milk fat is rich in C14:0 and C16:0 because these fatty acids can be manufactured in the bovine mammary gland from glycerol and free fatty acids. Rapeseed oil is a rich source of oleic acid, and feeding whole rapeseed to dairy cows has been shown to increase the C18:1 content of milk fat (Murphy *et al*, 1995). However, increasing the unsaturated fat content of milk has led to suggestions that oxidative stability may be effected. Feeding high levels of a natural antioxidant such as vitamin E may enhance milk stability and improve its' nutritive value. This study investigated the effect of feeding various amounts of whole cracked rapeseed and vitamin E on animal performance, and the levels of fatty acids and vitamin E in milk fat.

Materials and methods In a 3x3 factorial design, three levels of whole rapeseed (0 (NR), 135 (MR) and 270 (HR) g DM/kg diet DM) and three levels of vitamin E (25 (L), 80 (M) and 140 (H) mg dl α-tocopherol acetate / kg diet DM) were fed to 90 multiparous Holstein cows (10 animals per treatment) in early lactation for 7 weeks. Diets were fed as total mixed rations containing maize silage (430 g DM/kg diet DM), grass silage (145 g DM/kg diet DM),various amounts of wheat, sugar beet feed, soya bean meal, rapeseed meal and a standard amount of a mineral/vitamin mix. Diets were formulated to supply sufficient metabolisable energy and protein for maintenance + 35 litres with 0.5 kg/d weight loss (AFRC, 1993). Dry matter intakes and milk yields were recorded daily, and milk samples (taken in weeks 3 and 7) analysed by the National Milk Records laboratory for NIRS prediction of fat and protein. Fatty acid composition of the milk was determined by high-pressure gas-liquid chromatography. Data were analysed using ANOVA and analysed for treatment and linear effects.

Results There were no significant interactions between whole cracked rapeseed and vitamin E level. Animal performance and milk composition results are presented in Table 1. Feeding whole cracked rapeseed reduced DM intake, daily milk yield and milk fat content, but had no effect on milk protein content. Increasing the dietary concentration of Vitamin E had no effect on any performance parameter, or on fatty acid concentration. Milk vitamin E levels increased as both whole cracked rapeseed and vitamin E levels increased in the diet. The concentration of milk C14:0 and C16:0 decreased, while C18:0 and C18:1 (n9) increased with increasing levels of whole cracked rapeseed.

Table 1 *The effects of level of whole cracked rapeseed and vitamin E on animal performance and milk fatty acid content*

	Whole cracked rapeseed level					Vitamin E level				
	NR	MR	HR	s.e.	Lin	L	M	H	s.e.	Lin
Intake (kg DM/d)	20.6	18.9	15.2	0.32	***	18.3	18.2	18.2	0.32	ns
Milk yield (kg/d)	22.9	19.3	13.2	0.76	***	18.0	18.1	19.2	0.76	ns
Milk fat (g/kg)	42.1	33.5	33.4	1.18	***	37.5	34.6	36.8	1.20	ns
Milk protein (g/kg)	36.1	37.9	38.4	0.77	ns	38.7	37.1	36.5	0.77	ns
Milk vitamin E (mg/kg)	1.36	1.57	1.57	0.055	**	1.28	1.54	1.69	0.055	***
Milk fatty acids (g/100g total fatty acids)										
C14:0	11.6	7.9	6.0	0.20	***	8.6	8.3	8.6	0.20	ns
C16:0	30.5	19.6	17.9	0.37	***	22.6	22.6	22.8	0.37	ns
C18:0	8.3	14.1	15.8	0.38	***	12.8	12.8	12.6	0.38	ns
C18:1 (n9)	18.1	34.7	39.3	0.53	***	30.2	31.4	30.4	0.53	ns

Conclusion Feeding high levels of whole cracked rapeseed to dairy cows, dramatically altered the fatty acid composition of milk fat by increasing C18 fatty acids at the expense of C14:0 and C16:0. However, feeding rape oil in the form of whole cracked rapeseed reduced DM intake, milk yield and milk fat content. Supplementing the diet with vitamin E, increased its level in the milk, but had no effect on animal performance or milk fatty acid composition.

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References

AFRC, 1993. *Energy and protein requirements of ruminants.* CAB International, Wallingford, Oxon, England.

Murphy, J.J., Connolly, J.F. and McNeill, G.P., 1995. Effect on milk fat composition and cow performance of feeding concentrates containing full fat rapeseed and maize distillers grains on grass silage based diets. *Livestock Production Science* **44**: 1-11.

Effect of untreated and formaldehyde treated whole linseed on the performance and fatty acid composition of milk produced by Friesland ewes

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Introduction: Increasing the *n-3* polyunsaturated fatty acid (PUFA) content of ruminant products is widely accepted as a potential means of reducing the incidence of cardio-vascular disease in man. However, after ingestion dietary PUFAs are extensively hydrogenated in the rumen. Whole linseed is particularly high in a-linolenic acid (C18:3 *n-3*) and the feeding of whole seeds with an intact seed coat has been reported to double the duodenal supply of C18:3 in wether lambs (Wachira *et al.* 1998). This supply may be further enhanced by treating the whole seed with formaldehyde (Gulati *et al.* 1997). The objective of the experiment was to investigate the effect of untreated and formadehyde treated whole linseed on the performance and fatty acid composition of milk produced by Friesland ewes.

Materials and Methods: Eighteen multiparous Friesland ewes weighing 64 kg (s.d.7.8) in week 4 of lactation were housed individually on sawdust and kept under continuous lighting with free access to water. Three diets were formulated to supply similar levels of metabolisable energy (12.2 MJ/kg DM), crude protein (185 g/kg DM) and fat (64 g/kg DM), but fatty acids from either Megalac (M, palmitic acid: C16:0), untreated whole linseed (UL, C18:3) or formaldehyde treated whole linseed (FL). All diets contained 350 g chopped hay, 60 g molasses and 30 g/kg mins/vits. However, diet M contained 273 g barley, 52 g Megalac and 235 g/kg soya bean meal, whereas diets UL and FL contained 243 g barley, 143 g whole linseed and 174 g/kg soya bean meal. The diets were offered *ad-libitum* daily at 0900h as course mixes in a 3 x 3 latin rectangle design consisting of 3 periods of 4 weeks duration and the refusals were weighed back twice weekly. The ewes were milked twice daily at 0730h and 1530h and during the last two weeks of each period milk and blood samples were taken for analysis. The results were analysed by analysis of variance.

Results Ewes offered diets UL and FL had a significantly lower (P<0.001) DM intake, and ewes offered diet UL had a significantly lower (P<0.05) milk yield than those offered diet M. Additionally, ewes offered diets UL and FL produced milk with a significantly lower (P<0.01) content of fat, but a significantly higher (P<0.01) content of protein and lactose than those offered diet M. There was no significant effect of diet on the C4:0-C14:0 saturated fatty acid content of milk fat. However, ewes offered diet M produced milk fat with a significantly higher (P<0.001) content of C16:0 than those offered diets UL and FL Ewes offered diet FL produced milk fat with a significantly higher (P<0.001) content of C18:3 than those offered diet UL, which produced milk fat with a higher content of C18:3 than those offered diet M. Similarly, ewes offered diets UL and FL produced milk fat with a significantly higher (P<0.001) content of C18:2 *trans* and C18:0 than those offered diet M. Ewes offered diet M had a significantly higher (P<0.001) plasma beta-hydroxybutyrate content than those offered diets UL and FL.

Table 1 *Food intake, yield and composition of milk produced by ewes offered untreated and formadehyde treated linseed*

	M	UL	FL	s.e.d.	P
Dry matter intake (g/day)	2949	2503[a]	2637[a]	105.0	***
Milk yield (g/day)	2051[b]	1821[a]	1902[ab]	85.3	*
Milk composition (g/kg)					
Fat	46.1	38.5[a]	36.2[a]	2.63	**
Protein	42.4	45.8[a]	46.1[a]	0.74	***
Lactose	48.5	49.2[a]	49.4[a]	0.27	**
Fatty acids (g/100g fat)					
C16:0	38.4	21.7[a]	19.3[a]	2.15	***
C18:0	7.5	13.2[a]	12.9[a]	1.16	***
C18:1 *trans*	1.9	3.4	4.8	1.18	NS
C18:1 *cis*	19.3	21.1	20.9	1.52	NS
C18:2 *trans*	0.4	1.9[a]	2.1[a]	0.39	***
C18:2 *cis*	2.9	3.1	3.7	0.35	NS
C18:3	0.8	2.7	4.6	0.28	***
Blood composition (mmol/l)					
Beta-hydroxybutyrate	0.527	0.267[a]	0.277[a]	0.0284	***

Means with the same superscripts are not significantly different (P<0.05)

Conclusions: Compared to Megalac, dietary inclusion of whole linseed reduced the dry matter intake and milk yield of ewes but increased milk protein and lactose content. Formaldehyde treated whole linseed was more effective than untreated linseed at reducing the C16:0 content, but increasing the C18:3 content of ewes milk fat.

References Gulati, S.K., Byers, E.B., Byers, Y.G., Ashes, J.R. and Scott, T.W. (1997). Effect of feeding different fat supplements on the fatty acid composition of goat milk. *Animal Feed Science and Technology* **66**: 159-164.
Wachira, A.M. *et al.* (1998). Rumen biohydrogenation of poly-unsaturated fatty acids and their effect on microbial efficiency in sheep. *Proceedings of the British Society of Animal Science*, 36.

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