The implications of biofuel production on intensive livestock production in the United States

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The United States (US) produces 13.3 billion bushels of corn and 3.2 billion bushels of soybeans annually. Sixty percent of total corn is used in livestock production, with 31% used in beef production, 27% in poultry, 24% in pork, and 15% in dairy. Current US policy dictates that 25% of fossil fuel requirements will be replaced by biofuels by 2025. The entire US corn crop used for ethanol production would replace only 12.3% of the current US fossil fuel demand. Fundamentally, the use of US grain crops will not have a *significant* impact on total fuel use in the near future. Alternative energy sources-cellulosic fermentation products, cropland conversion to sugar cane, increased use of wind, geothermal, or other energy power, or a significant reduction in prices for crude oil will diminish the demand for alternative fuels.

Ethanol and biodiesel production predominate as alternative fuels, with 124 ethanol plants using about 20% of the corn crop in the US and producing 6.5 billion gallons of ethanol. Distillers grains represent a maximum of 40% of the replacement rate of corn in beef cattle, with poultry being only about 5%. Significant costs for shipment of distillers grains from production areas to feeding areas will increase diet costs. Biodiesel production triples annually. Enough virgin soy oil and recycled restaurant grease are available in the United States to provide feedstock for about 1.7 billion gallons of biodiesel per year, or 5% of on-road diesel use. Co-products of this process include glycerol and soybean meal. There will be restrictive future need for soybean meal. Glycerol is currently under study, and studies have shown effective use in dairy cattle, replacing 10% of the corn in beef steers, up to10% of the diet in pigs, and up to 5% of the diet in chickens. Biodiesel represents the most significant source of alternative fuels in the US. The use of soybeans as the primary feedstock will be under scrutiny because of depleted value of soybean meal for livestock use from overproduction and placing glycerol in a competitive international marketplace.

For the future, use of corn to meet policy requirements for fossil fuel replacement implies 6.6 million additional bushels of corn will no longer be available. Short term implications are higher prices for feed grains as they are diverted to subsidized biofuel production. Higher costs for most livestock and dairy production, because of lower production and increased ownership costs, will make red meats, poultry, and milk less competitive to imports and substitutes. Longer term implications will be from determination of the most economical feedstock for biofuel production. This may include celulosic fermentation coming on line, and 300 million cares of grasslands could be converted to biomass production. Concentrated dairy and beef feeding operations, including that for the breeding herd, will be similar to current production systems for pork and poultry. The implications to this result on consumer acceptability will be important in the marketplace. The substitution rate of corn with co-products for the dairy and beef industries will be mandate a higher proportion of forage-based diets. Lower milk and meat production could result with reduced energy in the total diet. Complete forage diets may emerge. Supply and demand forces will need to dictate if this result is profitable in the US market since grass-fed meat and milk in the “natural” or organic form resides only in niche markets.

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Pigs: Use of biofuel co-products, economics and nutritional limitations

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It is anticipated that there will be a significant increase in the quantity of co-products available from the biofuel industry for use in animal feed. The co-products are the result of either biodiesel or bioethanol production. Biodiesel is produced from oil. One of the main sources of oil is oil seed rape but other oil seeds such as sunflower, Crambe and *Camelina sativa* (Cottrill *et al*., 2007) may be used. Bioethanol is produced from the fermentation of sugar which is either added directly to the process or obtained from the digestion of starch. The co-products produced include glycerol (glycerine or glycerin) from the production of biodiesel and dried distillers grains with solubles (DDGS) from the production of bioethanol from starch.

The process of producing biodiesel involves the hydrolysis of triglycerides using sodium or potassium hydroxide as catalysts and methanol for methylation. The glycerol produced, which is neutralised using hydrochloric acid, may therefore be limited in its inclusion level due to the high sodium or potassium content. Glycerol may contain levels of methanol but the risk of methanol toxicity is low and limited to meals since methanol will evaporate during the pelleting process. Glycerol is a sweet, high energy liquid that may be utilised by pigs as either a glucogenic or a lipogenic nutrient depending upon the energy status of the animal. During the energy dependant phase of growth glycerol would be metabolised via gluconeogenesis and have a net energy value of 14 MJ/kg. The utilisation of glycerol also requires enzyme activation which is limiting in the pig. High levels of glycerol have a lower energy value because the enzyme system becomes saturated and excess glycerol is excreted via the urine (Doppenberg and van der Aar, 2007). Including glycerol up to a level of 5% in pig diets gives optimum utilisation and increased feed intake and gain have been observed (Kijora *et al*., 1995). Glycerol has also been demonstrated to reduce carcass drip and cooking losses and increase the levels of C16:0 and C18:1 in the fat via *de novo* synthesis at the expense of polyunsaturated fatty acids.

Where oil seeds are used as the source of oil then oil seed meal is the other co-product produced from the production of biodiesel and rapeseed is often used for this process. The maximum level of inclusion of rapeseed meal in pig diets is primarily dependant upon the level of glucosinolates in the product. The glucosinolate levels may differ between processing conditions used to extract the oil and cold pressed meals have been shown to contain twice the level of glucosinolates as that subjected to heat processing. Trials have shown that '00' rape seed meal, containing 10umol glucosinolate per g, can be included at levels up to 20-25% in finishing pig feeds. It is likely that rapeseed meal will become more cost effective, if the volume of production increases, thus increasing the use of the material in pig feeds.

The main concern with the use of DDGS in pig feeds is the degree of variation in composition and digestibility of nutrients. Variation arises from differences in nutrient analyses of the incoming raw material, amount of condensed distillers solubles added to the distillers dried grains, quantity of starch converted to ethanol by fermentation process and temperature and duration of the drying process (Shurson *et al*., 2004). Heat processing reduces the availability of amino acids and this will reduce growth unless the inclusion level of DDGS is reduced or the amino acid availability is accurately assessed and accounted for. DDGS also tends to show a high degree of variation in energy content. Phosphorus however has a relatively high digestibility due to the destruction of phytate during processing. Maize DDGS has been used successfully at levels of up to 15% in finishing pig diets but soft carcass fat may be an issue due to the level of poly unsaturated fatty acids in the diet. Wheat DDGS has been used up to a level of 10% in finishing pig diets but a reduction of feed intake has been observed above this level. The use of enzymes may offer a means of increasing the utilisation of DDGS but further investigation appears necessary to determine the type and level of enzyme required. To fully exploit the economic and nutritional value of DDGS in diets for pigs either a rapid method of accurately assessing the nutrient availability is required or processes, which minimise heat damage, should be adopted to ensure the production of a consistent material.

Co-products from the biofuel industry have the potential to be important sources of raw material for the pig industry. In certain areas obtaining further knowledge of how to: 1) improve the production process, 2) rapidly measure the nutrient availability and 3) use new technology to improve the nutrient value, would allow increased utilisation and add value to the co-products produced.

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Ruminants: Use of novel co-products, economics and nutritional limitations, including new technologies for overcoming constraints

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Bio-fuels are probably the most obvious and well known recent development, but whatever the industry the term co-products is now outdated as no factory will ever be constructed without recognition of the value contribution of all products. For example the new Cargill plant in Manchester, that uses wheat as the substrate, produces, starch plus its derivatives, vital wheat gluten, potable alcohol via a joint arrangement with an adjacent company Nedalco, wheatfeed, potentially a liquid feed for pigs and ruminants, plus a ruminant moist feed C☆Traffordgold. They are all essential products to justify capital investment and profitable plant operation.

First generation bio-fuel production is split between bio-ethanol, using grains, sugar cane or beet (or sugar rich derivatives) and bio-diesel, using palm oil, rape seed, soya beans and recovered vegetable oils and tallow. Hence the feed products derived from these processes will vary widely.

In the case of grains for bio-ethanol, these will be distillers grains (with or without the solubles added as these potentially could represent a product in their own right), with a protein content and amino acid composition being a reflection of the grains used plus a contribution from the yeast the extent of which will depend on the actual fermentation process employed, batch or continuous. It is recognised that the particular bio-ethanol production process used can have a marked effect on the nutritional value of these feed products, factors such as, grain quality, grinding conditions, pre-fermentation enzyme and heat treatments to saccharify the starch, the yeast employed, plus the type of evaporation and drying processes.

In the UK wheat will be the grain of choice, and will produce a distillers grain of 32 to 34% protein, on an as received basis, and hence from a protein perspective compete directly with rape seed meal but the higher energy content will command a premium. Rumen protein degradability and digestibility of the by-pass protein, and its' amino acid profile, will impact on its value also and will be affected by the processing conditions. There is very little information on the impact of processing on the nutritional value of wheat distillers for ruminants, the majority of the studies have been undertaken on maize based products and cannot be directly extrapolated to wheat DDGS. Formation of Maillards reactions between the amino acids, especially lysine, and sugars, particularly if they form second stage Maillards will reduce digestibility. It is recognised that the levels of xylose and non starch polysaccharides in wheat DDGS are several times more than those in maize DDGS and hence the potential to form Maillards products is much greater. Current estimates for lysine as a % of metabolisable protein for wheat DDGS are ~ 4.5% compared to soya bean meal at ~ 6.8%. Clearly the feed analysis will be source specific and cannot be treated generically.

The use of sugar cane and beet for bio-ethanol production will produce liquid 'vinasses', a crude EU legal definition, that is rich in fermentation acids, glycerol, soluble protein and NPN, minerals and yeast fragments.

As with the solubles streams from grain based fermentation systems these liquid products appear to have a stimulatory effect on rumen fermentation, probably from the yeast fragments, not live yeast as the distillation process kills the yeast. These effects add to the nutritional value that is not considered in conventional matrix descriptions.

Where oil seeds are used to produce bio-diesel there will be two feed products, the respective protein meals and glycerol the purity of which will depend on the process employed. The impurities will be moisture, organic materials from the oil used that have not been methylated, sodium or potassium as a consequence of hydroxide addition plus a residual amount of methanol. Glycerol yield is approximately 10 to 11% of the oil volume. With the rising cost of cereal grains and other low protein feeds glycerol will provide a valuable means of reducing total dietary protein allow full exploitation of the high protein distillers and oil seed meals from bio-fuel production

Glycerol, a precursor of glucose, has the potential to be a significant part of ruminant rations. The fate of glycerol in the rumen is unclear, early studies indicated it was extensively fermented in the rumen to propionic acid, but more recent from Germany suggest no difference in total tract digestibilities when 15% of the concentrate was replaced with glycerol but only a slight reduction in the acetic acid to propionic acid ratio indicating the rumen may not be as important as first speculated. Our own initial studies suggest that glycerol does not behave in the rumen in a similar manner to cane molasses. Estimates of the energy content undertaken recently in Germany, have suggested an interaction between the concentrate, with high starch diets providing a lower ME than low starch diets, hinting at a rumen involvement.

The volume of rape meal will increase in the EU and with a self sufficiency for soya of only 2.5% there is a growing need to improve the nutritive value of rape meal by removing some of the anti-nutrient factors, e.g. tannins. This may become more economically viable as the differential between rape and soya meal increases.

Clearly, accurate feed material description is fundamental to the full value of the new and novel products being realised.