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ABSTRACTS

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Monitoring nutritional status of transition cows to improve health and fertility

R.L. Cooper and J.A. Husband

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Introduction

How we choose to manage dairy cattle during their non-lactating period and in the few weeks following calving (the transition period), can have extremely significant effects on their subsequent production, health and fertility. The main nutritional goals of transition cow management are:

- Prevention of excessive negative energy balance (NEB) and fat mobilisation, including subclinical or clinical ketosis and severe 'fatty liver'.
- Prevention of clinical and subclinical periparturient hypocalcaemia.
- Prevention of micronutrient deficiencies and additional supplementation of certain micronutrients where evidence suggests positive health benefits.
- Adaptation to the milking cow diet in a manner that encourages rumen health

The aims of monitoring transition management are to see if the above goals are being achieved and to allow identification of an emerging problem within a timescale that allows interventions to circumvent or reduce the risks of a negative event occurring.

Monitoring- key points

- Both direct and indirect measurements can be used. Direct measurements are better but indirect measurements can be used as a 'proxy' e.g. using milk fat:protein ratios (FPRs) as a proxy for energy balance. The data can be useful but are not as robust as a direct measurement.
- In smaller herds especially, examination of data from closely defined groups of animals e.g. those in the first 3 weeks after calving, will be potentially very inaccurate. If there are insufficient cows in the monitored group increasing the time period to include extra cows will add 'momentum'. There is a constant trade-off between momentum and statistical robustness.
- High sensitivity tests are best used for initial screening tests but can suffer from poor specificity i.e. can lead to higher numbers of false positives. It is important to know the limitations of the tests being used.

- When examining data that have a uni-directional negative impact on cow health or are compared to threshold values, the proportion of animals above a threshold should be described, rather than just using the mean e.g. if animals are sampled for blood betahydroxybutyrate (BHB) concentrations, results should be expressed as the proportion of animals above the 1.2mmol/l cut-off, rather the mean BHB concentration for the group. For measurements that have a bi-directional negative effect on cow health (i.e. can be too high or low), then the mean or median may be more appropriate.

- Techniques must be convenient and cost-effective and the results examined and acted upon if intervention is necessary.

Key monitoring targets

1. Body condition score (BCS) - an indirect measurement of NEB. Should be done very regularly on farm even if there is no formal recording of the data. Absolute BCS at drying off and calving and loss post calving are the main targets and should be 2.5 -3 and <0.5 respectively.

2. NEB will be the primary target for monitoring in most herds due to the negative effects excessive NEB has on health and fertility. The two most commonly employed biochemical measurements of energy status for monitoring purposes are the ketone bodies (usually BHB) and non-esterified fatty acids (NEFAs). Ketone testing can be done using blood (using hand-held meters even), milk and urine; in general urine testing is very sensitive but has low specificity (lot of false +ves), whereas milk testing has lower sensitivity but higher specificity. There are some new milk tests for BHB becoming available in the UK that have better performance. High FPRs can be associated with NEB and low FPRs with ruminal acidosis, but correlations with metabolic disease and fertility parameters are generally weak. Milking parlours are starting to incorporate technology for monitoring energy balance on a daily basis- some of these examine FPRs whilst others directly detect ketones.

3. Urine pH and macromineral excretion can be used as a predictor for milk fever. The dietary cation-anion balance/difference (DCAB/D) in the pre-calving transition relates to the acidogenic/alkalogenic potential of the diet and has a strong effect on the likelihood of milk fever as does Mg status. Urine pH >8.25 is high risk but pH is generally not very useful on its own apart from when monitoring full DCAB systems where target pH is 6-7.

4. Rumen pH- rumenocentesis is the current gold standard for diagnosing ruminal acidosis but is invasive and not an appropriate test for frequent monitoring. Indirect evidence can be gained from faecal and dietary analysis and milk component analysis but is of

questionable accuracy. In situ boluses which record pH for a few months are now becoming more available.

Selecting the cohort of animals to test

Choice of animals is crucial because reference ranges change for animals at different stages of the production cycle and at different times of the year. This is especially true for beta carotene and vitamin E status which can be very poor at the tail end of winter before turnout in maize fed herds.

Choice of animals is very important when diagnosing or monitoring a herd for types 1 and 2 ketosis.

	Target group relative to calving	Biochemical substrate	No. animals to sample
Pre-calving	-7 to -1 days	NEFA	12
Post calving			
‘Type 2’ ketosis	+1 to +15 days	BHB + NEFA	12
‘Type 1’ ketosis	+25 to +45 days	BHB +/- NEFA	12

Feed intake and reproduction in cattle

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The importance of nutrition for animal reproduction has been known to producers and researchers for a long time. However, contemporary studies have brought new perspectives and further details of this relationship, allowing fine-tuning of diet formulation in order to increase production and reproduction in ruminants. Nevertheless, especially in high-producing dairy cows, there are still serious multifactorial fertility problems, with a heavy nutritional involvement. High feed intake, for example, affects reproductive physiology in several manners; by increasing the metabolism of steroid hormones, or by affecting the response of cells to other hormones. These changes result in increased size and number of ovarian structures; however, the changes also reduce circulating steroids, potentially compromising oocyte and embryo quality. High circulating insulin due to long-term high feed intake may also contribute to reduction in oocyte quality. Although changes in feed intake affect ovarian function in Bos taurus and Bos indicus cattle, it seems that overfeeding may more profoundly affect oocyte/embryo quality in Bos taurus than Bos indicus cows and heifers. Thus, this article presents and discusses results of some relevant studies on these subjects, especially those related to the influence of feed intake on reproduction.

Supplemental antioxidants to improve reproduction in dairy cattle – why, when and how effective are they?

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The transition dairy cow is potentially at risk from oxidative stress because of decreased feed consumption, neutrophil activation associated with parturition, inflammation in the uterus in the early postpartum period, and a large increase in oxygen consumption caused by lactation. Accordingly, provision of antioxidants during this time might be expected to improve health and performance of the lactating cow. There have been two approaches for increasing antioxidant status of the transition dairy cow. The first has been to provide metal cofactors of enzymes that facilitate electron donation to reactive oxygen species. Most efforts have focused on selenium and copper because there are deficiencies in amounts of these metals in many soils. The second approach has been to increase availability of antioxidant molecules that directly react with reactive oxygen species and cause their elimination. The most important of these free-radical scavenging molecules for dairy cattle nutrition have been vitamin E and β-carotene. These have been fed as supplements or provided through injection. There are also commercial products that combine vitamin E with selenium.

The most consistent benefit to antioxidant supplementation for dairy cow reproduction is a reduction in retained placenta. This is an important effect of antioxidants because occurrence of retained placenta is associated with subsequent endometritis, metritis, and reduced fertility. In contrast to the effects of antioxidants on reducing the incidence of retained placenta, benefits of antioxidant supplementation on uterine health, resumption of cyclicity, and fertility have been highly variable. Some of this variation probably reflects differences in chemical structure, route, and dosage of the antioxidant tested. It is likely, however, that much of the variation in effectiveness of antioxidant treatments reflects variation in the antioxidant status of un-supplemented cows. Depending on diet and physiological and immune status, innate antioxidant defences of the cow are probably sufficient in many cases to protect cells involved in reproductive processes from the oxidizing actions of reactive oxygen species. In those cows, additional antioxidants are not required. One way to improve the efficacy of antioxidant supplementation for the dairy cow is to assess which cows are at risk for oxidative stress and whether the incidence of these cows in the herd is sufficiently high to warrant intervention with supplemental antioxidants. Analysis of feed composition to determine levels of vitamins and minerals involved in antioxidant defence can be one tool for assessing risk for oxidative stress. It is also likely that blood metabolites can be used to assess the oxidative status of individual cows and groups of cows. To date, there are insufficient data to establish benchmark values of key metabolites that predict cow response to antioxidant supplementation.

Rumen lipid metabolism and its impacts on milk production and quality

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Introduction

Ruminants have evolved an efficient compartmentalised digestive system enabling them to utilise fibrous feedstuffs. About 95% of neutral detergent fibre digestion occurs in the rumino-reticulum due to the activity of numerous species of bacteria, protozoa and fungi. Digestion of dietary carbohydrate and protein in the rumen and reticulum results in the production of volatile fatty acid fermentation products (principally acetate, propionate and butyrate), microbial protein and ammonia. Specific populations of rumen bacteria, and to a lesser extent protozoa and fungi, are also capable of biohydrogenation, a process which converts unsaturated (UFA) to saturated fatty acids (SFA) and thereby minimises the toxic effects of UFA containing 18 or more carbon atoms on the growth of bacteria involved in ruminal carbohydrate digestion. On most diets, ruminal biohydrogenation of *cis*-9 18:1, 18:2n-6, 18:3n-3, 20:5n-3 and 22:6n-3 varies between 58-87, 70-95, 85-100, 49-97 and 74-99 g/100 g, respectively.

Even though forages alone can support moderate milk yields, additional energy and protein from supplementary sources are required to meet the nutrient requirements of high yielding dairy cows. Dietary fat supplements are often used to increase the energy density of the diet to support higher milk yields. Provided that there is no excessive decrease in dry matter intake, fat supplements increase energy intake with expected benefits on milk production as well as energy balance, body condition and reproduction. Use of fat in compound feeds also has the advantage of minimising dust and improving pellet quality. Despite raising gross energy content, feeding fat supplements has variable effects on milk yield and milk fat content, but typically lowers (1-4 g/kg) milk protein concentration. Decreases in milk protein content caused by fat supplements may not simply be due to dilution, but may represent a true physiological response, possibly due to deficiencies in glucose supply, insulin resistance, improved energetic efficiency of milk production or reduced somatotrophin production. Changes in milk and milk fat yields due to dietary fat supplements are dependent on several inter-related factors including inclusion rate, degree of unsaturation, physical form and composition of the basal diet. In high amounts, plant oil and oilseed supplements decrease dry matter intake and organic matter digestion in the rumen, shift rumen fermentation towards higher proportions of gluconeogenic precursors, and lower milk yield.

In addition to increasing energy intake, adding specific fat sources to the diet has often been used in attempts to alter milk fat composition, improve fertility, decrease the incidence of metabolic diseases in early lactation, enhance immune competence or lower enteric methane production. Milk fat contains a high proportion of saturated fatty acids, some of which are known risk factors for cardiovascular diseases and insulin resistance. Therefore, there has been increased interest in lowering the medium-chain SFA and increasing the concentration of specific UFA in milk, either for the production of added value products or in an attempt to improve the public perception of the nutritional value of milk and dairy products. Supplementing the diet with plant oils, oilseeds, fish oil, marine algae and rumen protected lipid supplements can be used to influence milk fat composition. However, the extent to which it is possible to enrich specific dietary UFA in milk is largely dependent on the extent of biohydrogenation in the rumen. Often attempts to alter milk fatty acid composition, particularly using marine lipids and fat supplementation of low forage-high concentrate diets, is associated with milk fat depression. At least part of the decrease can be explained by changes in the major pathways of ruminal biohydrogenation resulting in the formation of certain fatty acid intermediates which have a direct inhibitory effect on milk fat synthesis.

Ration formulation for dairy cows: least cost versus least environmental cost

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Governments have made international commitments to reduce greenhouse gas emissions (GHGE) and the United Kingdom government has set a target of an 80% reduction in emissions of GHGE by the year 2050 compared to the baseline of 1990. In the context of food production at the farm level, this largely involves reducing emissions of nitrous oxide from agricultural soils and manures, and methane from enteric fermentation and manures. Globally, the dairy sector is estimated by FAO to contribute 4% (±26%) of anthropogenic greenhouse gas emissions. At the EU level, dairy cows contribute more than 30% of total nitrogen excretions from livestock.

In the face of such environmental concerns, it is vital to stress the tremendous positive contributions of the dairy industry to Global Food Security. The dairy cow is the most efficient animal at converting feeds unsuitable for human consumption into highly nutritious animal products. The ability of dairy cows to convert grassland herbage and forage crops into milk is likely to become of greater significance in terms of global human food production as the population of the planet increases. Because grass and forage alone cannot support high levels of milk production per cow, it is usual to provide supplementary feeding in the form of compound feeds or straights. In recent years, therefore, diets for highly productive dairy cows included raw materials such as cereal grains and soyabean meal, which potentially could be eaten directly by humans. This leads to debate about the competition between livestock and humans for land and other resources needed to grow crops. It is possible to feed dairy cows on a diet that is composed entirely of ingredients that are not suitable for human consumption, by using co-products from other industries to supplement grass and forages. The debate then transfers to the economics and relative environmental impacts of such strategies.

Least cost ration formulation is the most common approach to dairy cow nutrition adopted by the animal feed industry. An understanding of relationships between the economic cost of rations and their environmental cost is essential in order to develop new approaches to dairy cow feeding which are both economically and environmentally robust. Cereals and soya have appeared in dairy rations mainly on the basis of their cost per unit of energy and protein. Thus, for example, recent rises in the price of wheat have reduced its inclusion level as it is replaced by cheaper energy sources, although the need for high quality protein still favours soya.

In this paper the effects on nitrogen use efficiency (NUE) and GHGE per kg milk of implementing theoretically a range of nutritional strategies relevant to conventional systems of milk production operated on farms in northern Europe and America are explored using the Ultramix ration formulation programme. Ration formulations for cows giving a range of daily milk output are considered in terms of N losses as nitrous oxide, nitrate, and ammonia with emphasis on differences between urine and faecal excretion routes. Carbon footprints associated with production of feed materials are also taken into account. Factors affecting methane emissions are also discussed together with interactions between methane and N emissions. Feed conversion efficiency (kg milk per kg feed DM, ME and MP) is explored in terms of both gross efficiency and human-edible efficiency. Finally, implications are discussed in terms of predicted impacts on cow fertility and longevity via likely dietary effects on levels of insulin and progesterone in blood.

The main finding of the study is that equations to predict nitrogen excretion, carbon footprint of raw materials, methane emissions and proportions of human-edible feed ingredients can all be incorporated into models for least cost diet formulation. A range of values were predicted for each measure of environmental impact, which were within the normal ranges observed in research trials and commercial practice. Changes in impact measures are linked across scenarios (through changes in efficiency), so an improvement in one measure is often accompanied by improvements in other measures. Each of the impact measures can be used as a constraint to iteratively reduce the environmental impact of milk production. Any constraint will, however, increase the cost of the resulting diet. In general, therefore, reductions in environmental impacts are likely to require price incentives to achieve widespread uptake.

Animal Nutrition: Challenges & strategies for success in a competitive market

Bernd Springer

Feed Magazine/Kraftfutter, Germany

Structure of animal husbandry in Germany

The regional centres of dairy cattle farming in Germany lie in the south and the north-west of the country. Of the total 4.2 million cows, nearly 30 percent (1.25 million) are kept in Bavaria in the south and almost 20 percent (0.8 million) in Lower Saxony in the north. Movements on the milk quota exchange show that production is migrating from some locations in South Germany and increasing in the federal states of Lower Saxony and North Rhine-Westphalia.

German pig farmers are situated mostly in Lower Saxony and North Rhine-Westphalia, where nearly 60 percent of the 11.2 million fattening pigs in the country are to be found.

Numbers of layer hens and egg-producing poultry farms have shrunk considerably in Germany in the last three years (35.3 million layer hens in 2010). By contrast, the number of broilers has risen to 67.5 million. Altogether poultry farming for meat production has increased by over 90 percent since 1990, driven by turkey production that has grown by 125 percent.

Structure of the compound feed industry in Germany

The compound feed industry is tied to the location of its customers and experiences any changes in the structure of livestock and poultry farming at first hand. This pressure to adapt generates a sustained process of concentration in the compound feed industry. In 2002 there were 420 business establishments in Germany, but by 2010 the number was 332; in other words 21 percent fewer. The main reason for the decline in the number of business establishments is the growing pressure of competition due to surplus capacities – despite the growing number of animals and Germany's rising level of self-sufficiency in processed animal products. In recent years this structural change has been aggravated chiefly by tight competition on the commodities market. Extreme price fluctuations – both upward and downward – represent an enormous increase in the risk potential for feed producers. Accordingly the process of concentration is likely to continue in the next few years and lead to further decline in the number of plants producing compound feed.

Over the past 20 years there have been distinct shifts between size categories, and a growing concentration of compound feed production among the major producers is becoming apparent. The growth threshold for business establishments currently lies at an annual production level of 100,000 t and more. In the business year 2009/2010 the 34 establishments in the size category above 200,000 t produced 45 percent of the total volume of compound feed; in the business year 1991/1992 this figure was below 30 percent. One side effect of the structural adjustments in the compound feed industry is that the small plants remaining have become more strongly oriented to producing special compound feed varieties, while the larger producers primarily supply the market with compound feed ranges for the key productive livestock and poultry species.

Inhomogeneous customer needs

Apart from the different forms of animal husbandry, the compound feed suppliers also have to cater to a broad spectrum of customer characters. These range from "production technicians" possessing a high level of feed know-how who expect high-level expert consultancy on feeding issues, to pure "users" who want to be presented with the right solution so that everything "simply works", without going into any great detail themselves. Accordingly the competition on the compound feed market is to a great extent a competition between sales forces, whose recipe for success lies in addressing customers the right way.

Where are the returns?

Even in times of relatively high food prices, the margins at the individual stages of the food chain are low. This holds true especially for the actual production stage and the directly upstream feed industry, which is a partner of agriculture on two fronts. It absorbs raw materials from the field and supplies farms with efficient feedstuffs. Germany's feed industry has consolidated and perfected its role as partner in recent years. There are admittedly repeated and even cut-throat price wars at sales team level that slash the margins for the compound feed producers. However, stable, problem-oriented customer relations predominate, in which the feed adviser who knows his customer farms well can help to stabilise their incomes. The playing field covers the right balance between selling crops and taking farm-produced feedstuffs into storage, solving sub-acute health problems in the animal populations, developing special feeding concepts geared to specific farms, supporting choice of the right genetics and exploiting them optimally by diets designed to suit, and much more besides.

While 10 to 20 years ago compound feed plants located close to ports enjoyed an advantage in procuring raw materials (sites such as Hamburg, along the Rhine and the Main), this plays a lesser role today because compound feed now contains up to 50 percent grain. This raw material is largely produced and provided on the domestic market. However, in the face of foreseeable rising competition with the human food market, raw materials not suitable as human foods will become more important for compound feed production again and port locations will regain their advantage.

Challenges encountered in feeding animals

Present and future challenges in feeding animals that feed producers and animal farmers will need to solve in a spirit of partnership include:

- reducing the use of medicines and at the same time improving the health status of high-performing animal populations,
- harnessing fibre as digestible energy,
- using more by-products in the rations,
- increasing energy efficiency,
- conveying nutrients to the crucial sections of the digestive tract to boost their efficiency and avoid stresses,
- researching and making effective use of the active mechanisms of phytogenic additives.

In addition, compound feed producers must continue to invest in technologies that increase working precision and reduce labour needs (e.g. automation).

EU feed additive registration and review processes: impact on new product development

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Meeting current and future EU regulatory requirements for feed and feed additives is a major challenge for businesses operating in this sector. This presentation will review the legislation, examining both procedures and data requirements and discuss the main issues that confront companies in this important industry sector.

As a result of the EU White Paper on Food Safety, published in 2000, there have been sweeping changes to legislation concerning the food chain, especially feed and feed additives. The 2003 EU feed additive regulation (Regulation EC Nº 1831/2003) replaced the "old" 1970 feed additive Directive 70/524/EEC and introduced a new system for assessing feed additive dossiers.

The current evaluation procedure involves the EU Commission and the EURL (European Union Reference Laboratory), EFSA (European Food Safety Authority) and the Standing Committee on the Food Chain and Animal Health, which includes delegations from 27 EU Member States ("Comitology").

Regulation (EC) Nº 1831/2003 re-categorised feed additives and created new functional groups such as amino acids, silage agents and urea. Technological feed additives have been expanded to include mycotoxin inactivators.

The ban on antibiotic growth promoters in the EU was completed in January 2006, although coccidiostats and histomonostats remain as feed additives. Maintaining approvals under current legislation presents considerable challenges for all operators in this business sector.

November 2010 was the re-evaluation deadline for many feed additives, and resulted in the submission of around 450 re-evaluation dossiers, many still under EFSA scrutiny. Most of these feed additives had never been subjected to an EU assessment according to current standards of safety, quality and efficacy.

A new feed additive register was first published in November 2005, and is regularly updated. The EU Commission has started to delete a large number of active substances from this register since no re-evaluation dossiers were submitted and has recently published a regulation withdrawing many silage additives.

The pioneering feed regulation, published in 2009, allows certain nutritional and physiological claims on feed materials and provides for an informal, web-based feed material register, as well as a formal community catalogue of feed materials, which is updated by EU regulation from time to time

This presentation will cover the main elements of the legal environment for feeds and feed additives in the EU, and will illustrate the key elements of a successful feed additive dossier. Creative marketing strategies will be illustrated with examples, showing how an understanding of the legal environment affects new product development.

The impact of bio fuels on the supply of animal feed raw materials

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Much has been written and discussed concerning the various effects of Bio fuels production, in particularly the effect on Animal Feed raw materials supply. The global Bio fuel industry has developed over the past couple of decades at differing speeds and on different scales in each continent for a number of reasons, including Economic, Environmental and Political. The outlook for further development in the Bio fuel industry requires further clarity but activities resulting from development to date have had an impact on the availability of Animal Feed raw materials and although legislation has been drafted to promote the production of sustainable energy through subsidy support and mandatory schemes, the effect on supply to the animal feeding sector in the form of tighter raw material supply lines, lower global stocks, broader demand for the portfolio of animal feed products and increased price volatility is worthy of assessment.

Bio fuels have been in use since man discovered wood as a fuel source. Liquid bio fuel has been used from the earliest days of automotive industry development with ethanol and peanut oil being used to run petrol and diesel engines. In the main, bio fuels development has taken place in a reactionary way. The Ethanol industry developed in Brazil during the 1970s as a result of the 1970s Oil crisis. More recently, energy security drove the US Ethanol industry and greenhouse gas reduction targets became a significant driver for EU Bio fuel growth. Large scale biodiesel production grew first in Europe, although US production in 2011 was greater than that of Germany; Europe's biggest producer and Argentina is increasing Biodiesel production from Soybean annually. Alongside this, Biogas and Co-firing also utilise Animal Feed Raw Materials.

It is false to assume greater demand for grain and vegetable oil into bio fuels is the main driver for increased volatility and higher prices. Bio fuels have been developing globally for many years. It is only in the past 5 years that world prices have become very volatile. There has been greater volatility in both the costs of inputs and the value of co-products from bio fuels which come mainly in the form of feed proteins even though production of the co-products has increased significantly. Significant changes and improvements in global dietary requirement have increased demand for all raw materials and have driven price rises and have come into focus for investment fund holders whom thrive on volatility. Extra demand for the global supply of feed raw materials may be a driver for further improvement in efficient/targeted nutrition, particularly in ruminant animals, with focus on better feed conversion rates. In Europe the drive toward increased feed self sufficiency and the resultant decrease in reliance on imports including, in particular protein products, will become more focused as the retailer drives the better utilisation of domestically produced co-products.

Whether competing for raw materials for feed or for Bio fuel, the world market has evolved into one with very few regional anomalies and as such the cost of raw material into feed and Bio fuel looks set to be price consistent only in so far that prices between continents are level and transparent but at prices far higher and with markets more volatile than those familiar prior to 2007.

Global Food Security in an era of climate change: impact upon animals and their utilisation

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Introduction

At the Food Summit in 1996, the UN defined food security as:

"*Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*"

One of the greatest challenges in identifying actions to achieve global food security as so defined, is how to increase food production with minimal damage to the environment and in particular, with reduced greenhouse gas emissions. This is especially true for livestock. Ruminants are notorious for the amount of methane they produce, yet they have played a key role in human history in converting grass and other biomass which has negligible nutritive value for humans, into high quality protein for humans. Monogastric species on the other hand, produce relatively little methane, yet eat dietary components grown on land which could produce human food. Decision makers (from farm to national level) thus have a huge challenge in trying to optimise the net contribution of livestock to food production while minimising greenhouse gas emissions. This paper analyses historical trends in the production of different livestock species at global and UK level, to highlight how animal scientists could help to ensure that the right decisions are made, for example, by ensuring that the evidence accessible to decision makers is appropriate to their needs.

Food security: looking back in time

In some respects, agricultural research has been a success story; during the period from 1969-71 through to 2005-07, global food supply per person increased by 17% (Table 1).

Table 1 Global food supply in kJ and g protein /capita comparing 1969-71 with 2005-07 (FAOSTAT, 2012 accessed May 2012)

	1969-1971	**2005-2007**
Global food supply kJ/capita	9.93	11.63
Global food supply protein/capita	64.3	76.6

This increase did not, however, result in food security. In 1990/92 840 million people were suffering from severe malnutrition, and after the food price spikes of 2007/08, the number of people suffering from severe malnutrition peaked at over 1 billion in 2009, falling back to 925 million in 2010. It did, however, result in many negative impacts on the environment (see e.g. Hazell and Wood, 2008), with livestock production attracting particular attention (Steinfeld et al 2006). Such figures understandably make livestock production a target for greenhouse gas emission reduction, but livestock make a major contribution to food security by providing human edible food from the 3.4 billion ha of grazing land (FAOSTAT, 2012) and are an integral part of some existing ecosystems, which may in turn have an impact on wider environmental health and thereby on the sustaining of crop yields in the longer term.

Historical trends in global supply of livestock products

In 2007, animal products in total supplied 0.39 of total protein supply at a global level, of which 0.45 (0.175 of total protein) was in the form of meat, but this average hides a very large geographical diversity, with 47 countries where meat supplied <0.1 of the dietary protein and 19 where it supplied >0.4. Of the top 19 meat eating (per capita) countries, beef provided < 0.25 of the meat protein in 6 and over 0.5 in only one (Argentina). Trends in the supply of meat from different species are illustrated in Figure 1.

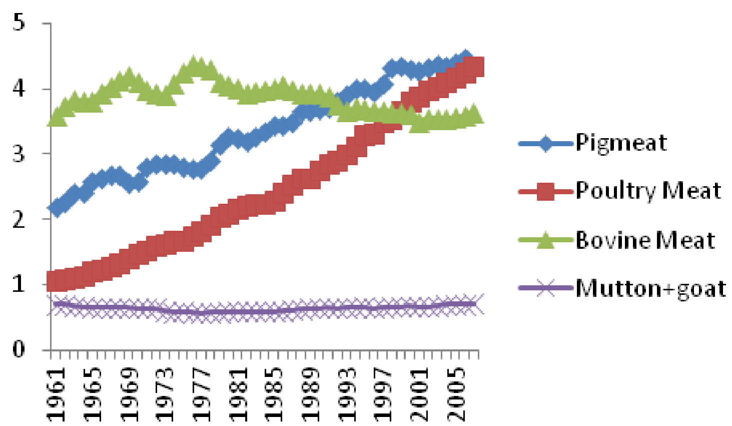

Figure 1 Trends in meat consumption (g protein/capita/day) at a global level between 1961 and 2007 (FAO STAT accessed April and May 2012).

This increasing demand for meat from monogastric species (ratio of monogastric:ruminant meat has changed from 0.75 in 1961 to 2.0 in 2007) has implications for feed supply given the greater dependence of monogastrics on grain. The CAST report on Animal Agriculture and Global Food Supply published in 1999 gave illustrative diets for beef cattle in the US with significant (47% for California) amounts of components which would not be used for human food, compared to only 18% for pig diets and 32% for broilers. The report also illustrated example components of diets from South Korea, where the use of by-products was considerably higher, resulting in higher efficiencies of both energy and protein use when expressed purely in terms of the efficiency of use of those feed dietary components which could have been used directly by humans for food (Table 2).

Table 2 Efficiencies of feed protein use by different species in the US and South Korea (from CAST, 1999)

	USA		South Korea	
	Gross efficiency	Human edible efficiency	Gross efficiency	Human edible efficiency
Beef	0.08	1.19	0.06	6.57
Pigs	0.19	0.29	0.16	0.51
Poultry	0.31	0.62	0.34	1.04

What Table 2 shows is the increasing risk for competition with humans for feed components as the trend towards greater consumption of pig and poultry meat continues, with the potential for decreasing dependence if the use of by-products and other non-human edible components of feeds can be increased. The benefits of ruminants in relation to less use of grain, need to be balanced, however, against their greater production of the greenhouse gas methane per kg of meat produced (see e.g. Gill et al., 2010).

Historical trends in the supply of meat within the UK

The trends for supply of meat at UK level (Fig. 2) are somewhat different from those at global level, with pigmeat supply having relatively little variation, although poultry meat does reflect the trend at global level. Pigmeat now (2007) comprises 0.28 of the 3 main meats, with cattle at 0.29 and poultry at 0.43. This compares with world average values of 0.35 each for pig and poultry meat and 0.29 for cattle meat.

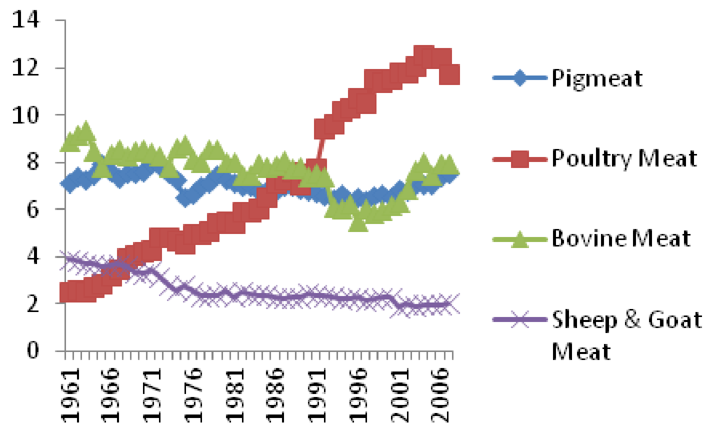

Figure 2 Supply (g protein/capita/day) of meat from cattle, poultry, pigs and sheep and goats in the UK between 1961 and 2007 (FAOSTAT accessed April and May 2012)

The CAST report (CAST, 1999) did not estimate efficiencies for UK livestock systems, but Wilkinson (2011) estimated feed conversion ratios for several UK systems using CAST methodology and these have been re-calculated into efficiencies in Table 3.

Table 3 Gross and Human-edible efficiencies of feed protein use for a range of UK livestock systems

	Gross efficiency	Human-edible efficiency
Upland beef	0.04	1.09
Cereal beef	0.12	0.33
Pig	0.23	0.36
Poultry	0.33	0.48

Table 3 illustrates that in terms of net food production, upland beef replaces poultry as the most protein efficient system when efficiencies for human edible protein are calculated. The trade-off, however, is increased greenhouse gas emissions. The variation in greenhouse gas emissions per kg product from 18 kg CO_2e/kg human edible protein in product for poultry to 93 for beef and sheep (Gill et al., 2010) therefore needs to be brought into considerations of trade-offs and indeed to trade-offs between environmental impacts and health benefits.

Feed supply

Another missing part of the evidence required by decision-makers relates to risks to the supply of feed protein. Concern about sources of protein to meet the increasing demand for livestock is not new (see e.g. FAO, 2004), but significant economic alternatives to soyabean cake have not been identified as yet. The need for this research may become yet more urgent, however, as data on the vulnerability of the soya crop to climate change becomes available. Recent work (Rose et al. Personal communication) illustrates the potential for yield decreases in some soya-growing areas in response to temperature rises of even 1.4 °C, with additional indications that these yield drops cannot be compensated for by using adapted varieties.

Conclusions

This paper emphasises the growing urgency for decision-makers to understand the trade-offs between increasing livestock production while minimising negative impacts on the environment, particularly greenhouse gas emissions, and has also highlighted the risk of protein resources becoming limiting. It is likely that at some point, governments may be compelled to include the economic costs of the negative environmental effects in the price of agricultural products, but to ensure that any such policies are effective and do not inadvertently have an undue negative effect on livestock, there is a need for data to enable estimation of these trade-offs to be readily accessible.

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The Future of Animal Production - Improving Productivity and Sustainability

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Although population growth in the developed nations has reached a plateau, no slowdown is predicted in the developing world until about 2050. The UN recognises that to meet the global food demand will require that we nearly double our current agricultural output from the same amount of, or less agricultural land. As fossil fuels stocks continue to decline, there is additional pressure on land to supply not only our needs for food, but also for energy and chemical feedstock. The global challenge is to develop sustainable systems to meet these demands each year from one year's worth of sunshine. Others, including members of the U.K. Government Office for Science's Foresight Project on Global Food and Farming Futures have ably summarised the Food Security challenge.

With the emphasis placed upon the success of the green revolution, the animal sector of the agrifood industry has also produced major successes in delivering improved productivity to meet demand. In this talk I will discuss the ways in which the growing demand for animal products can be met through a combination of continuing incremental improvements in productivity and the adoption of new genome-based technologies with the potential to deliver step changes in productivity.

There are many cultures, or individuals within cultures, who live relatively healthy lives consuming relatively little or no animal protein and many would argue that the challenge of feeding the human population would best be met by reducing livestock production. Livestock themselves consume energy derived from plants that might otherwise be consumed directly by humans; although swine, poultry and cultivated fish are the fastest growing sectors of livestock production, ruminant animals remain important. Small ruminants are especially important in the developing world, and together with poultry, provide the major route out of property for the poorest farmers. In traditional pasture grazing, ruminants consume feed that would not be available to humans. This may become more important as more land becomes marginal for arable agriculture.

The demand for animal protein will probably continue to grow over the next 20 years, especially in developing countries as they become more affluent. There is little likelihood that vegan diets will be acceptable or prevalent in the medium term, and the dairy and poultry (egg) sectors, which provide acceptable animal protein sources to vegetarians, especially the poultry sector, are currently highly dependent upon grain. It would be unwise to build strategies for achieving food security upon assumptions of altruistic or government advised changes in eating behaviour.

Thus, we need to plan for increased production of animal products. In the past 40 years, there have been major productivity gains in dairy cattle, pigs and poultry. Perhaps surprisingly, given how much has been said about the environmental impact of livestock production, there have also been significant reductions in the greenhouse gas emissions and global warming potential per tonne of animal product. These gains have been achieved through a combination of genetic improvement and better husbandry, nutrition and disease control. The dairy, swine and poultry sectors are highly structured with a small number of international companies controlling large proportions of the breeding and production. The sheep, goat and beef cattle sectors are less highly structured and for these species together with others (e.g. buffalo, deer, llama, alpaca, camel) there remains considerable scope for improvements in productivity. By contrast to land-based agriculture, we are at early stage in fish domestication, and there are likely to be potential productivity and feed efficiency gains to be had.

Within an overarching aim of improving the sustainability of animal production systems, including minimising their environmental footprint there are three objectives that need to be addressed:

- To maximise the number of productive offspring per breeding male and female
- To maximise the efficiency of converting feed (or solar energy) and water into useful animal product
- To minimise waste and losses through infectious and metabolic disease and stress

Some of the major targets for the future of livestock production are to:

- Maximise the number of offspring produced by each female animal that are also fit for purpose
- Minimise losses of production due to environmental variables including disease and stress
- Maximise the welfare of the animals (at least in Western agriculture)
- Maximise the efficiency of energy utilisation in the generation of animal protein

- Minimise wastage of animal protein at every stage of production and utilisation

- Minimise the impact of livestock production on the environment in terms of both inputs and outputs.

- Add value to livestock by producing desirable outcomes in addition to food.

The completion of high quality genome sequences for all the major livestock species, the rapidly-decreasing cost of genome analysis, the increasing sophistication of functional genomics, and the advent of targeted genetic modification in animals, will all provide new avenues to increase the productivity of animals and improve the feed conversion efficiency of the sector.

Genetic selection of poultry based on digestive capacity – impact on gut microbiota

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Feed efficiency is the main objective of genetic selection, but does not lead to optimal digestive efficiency, which becomes more important due to increase in cost of feedstuffs and need to decrease animal wastes. As digestive efficiency was highly heritable (h^2 >0.30), a divergent selection program for high (D+) or low (D-) digestive efficiency started at INRA in 2002, using AMEn to evaluate digestive efficiency, and a wheat-based diet, resulted in large variability between animals. These divergent lines represent a unique model to understand physiological mechanisms implied in digestion.

These two lines have been characterized for digestive efficiency parameters, performance and anatomy of the digestive tract in the upper and middle part which are implicated in host digestion. Studies have also been undertaken on their digestive physiology, and some analyses have been performed on the lower part of the digestive tract such as the caeca, the site of bacterial fermentation that may contribute to energy extracted from the feed for the host. More recently digestive microbiota was also studied.

After 8 generations of selection, AMEn was 30-40% higher in D+ than D- birds, the difference was larger with a wheat diet (+33.5%) than with a maize diet (+6.7%). D- birds showed limited capacity to digest an easily digestible diet, and had greater difficulty in adapting to a wheat-based diet. As for AMEn, the D+ birds were characterized by higher total tract faecal digestibilities of lipid, starch, and protein, with the biggest difference being for lipid with the wheat-based diet, and for protein with a maize-based diet. The limiting factor for digestibility in D- birds is therefore dependent on the cereal source.

When fed a wheat-based diet, D+ birds were heavier at 3 weeks of age (+14.5%), had a greater weight gain (+13.7%), lower feed intake (-21.5%) and improved feed efficiency (+58.0%). The latter is probably the cause for the higher feed intake of D- birds, to compensate for the lack of energy obtained from the diet, but it has been shown that it is not the only cause of difference between the lines.

Selection based on AMEn had an impact on all regions of the gastrointestinal tract, but it is thought that the difference between lines is mainly due to the difference in the upper region, with higher relative weight of the gizzard (h^2=0.53) and proventriculus and higher mean retention time of the digesta in D+ than D- birds. This characteristic is thus proposed as a major limiting factor for digestion efficiencies in chickens. The differences in the upper region may be responsible for the differences in the small intestine, with higher relative intestinal tissue weight in D- birds (h^2= 0.33 to 0.44) and increased digestive contents and, conversely, higher caecal content and tissue weight in D+ birds. These differences imply modifications of the biotope of digestive bacteria, both in the contents and in mucosa.

In the contents of the ileum, a small difference was detected between the two bird lines by comparison of molecular fingerprint. Moreover, a greater importance of a *Clostridium* strain was observed for D+ birds and, conversely, a greater importance of a Lactobacillus strain in D-. Quantitative PCR did not show a difference in the total bacteria load per gram of fresh weight (4.28×10^{10} copies of 16S rDNA/g). However a higher small intestinal content in D- birds compared to D+ birds (+50%) and, conversely, lower caecal content (-40%), may lead to a total bacterial biomass in the small intestine similar or slightly higher to that of the caecal biomass in D- birds, in contrast to a lower importance in D+ birds. Moreover, qPCR analysis showed more *C. coccoides* in D+ birds and more E. coli in D- birds. These microbiota differences may be linked to differences in digestive physiology. In D+ birds, the pH of the gizzard content was lower and retention time longer, favouring the acidic gate of this organ. Similarly, in the small intestinal contents, conditions of bacterial growth are not the same in both lines, especially regarding pH and bile acid contents. Moreover, available substrates are not the same between the two lines with a higher concentration of protein in D+ birds and of starch in D- birds fed with wheat, which may explain the higher content of *Clostridium* in D+ birds and of *Lactobacillus* in D- birds. Moreover, the origin of available substrates (undigested feedstuffs and endogenous components) and thus their hydrolytic susceptibility may vary. The endogenous components may be more present in D- birds which have more goblet cells in villi and deeper crypts, suggesting higher mucus production and cell turnover rate.

Similarly, in the caecal contents, the total bacteria load per fresh weight did not differ between the lines (4.36×10^{11} copies of 16S rDNA/g), however a difference appeared as shown by the more developed caeca and thus a higher fermentative activity in D+ birds. Moreover D+ birds showed a higher amount of *C. leptum*, and D- birds a higher amount of *Lactobacillus* and *E. coli*. Significant relationships were observed between the concentration of caecal bacteria and fecal starch content, with a positive link with *Lactobacillus*, and the ratios "*L. crispatus*/*C. leptum*" and "*L. salivarius*/*C. leptum*", and conversely a negative link with the ratio "*C. leptum*/*Lactobacillus*". As in the small intestine, the relatively high protein concentration for D+ birds and conversely relative high starch concentration for D- birds fed with wheat may be responsible for the preferential development of *Clostridium* in D+ birds, and *Lactobacillus* in D- birds. Moreover, significant heritabilities were observed for bacterial concentration and higher for bacterial ratio, the highest value being obtained for "*C. coccoides*/*Lactobacillus*" (h^2=0.34) implying that host genetics can control up to a third of variability in bacteria development.

In the mucus layer of the digestive mucosa, lines did not differ for total bacteria amounts (2.49×10^9 and 7.66×10^9 copies of 16S rDNA/segment, in the ileum and the caeca respectively). However bacterial composition differed, mainly in the caeca. Indeed, only *L. salivarius* was more frequent in D- ileum mucosa, whereas in the caecal mucosa, D+ birds presented more *E. coli* and D- birds more *Lactobacillus* as well as *L. salivarius* and *L. crispatus*. These differences may be due to the difference of substrate in the mucous gel able to go through this matrix, due to a difference in animal digestion and to different bacterial fermentation in the digestive lumen.

If differences in digestive tract biotopes between the two lines may explain some differences in microbiota, reciprocally bacteria have numerous effects on host digestive and non digestive physiology. For example, a higher total load of bacteria as suspected in the small intestine of D- birds may be responsible in part for the higher number of goblets cells in the villi. It may also contribute to the higher relative weight and density of their small intestine, by stimulating the development of the epithelium, and maybe the intestinal immune system. More bacteria may lead to higher amounts of harmful products that need to be detoxified and may contribute to a heavier liver in D- birds. Moreover the low level of bile acids in the small intestine of D- birds may be partly due to deconjugation by bacteria such as *Lactobacillus*, which has consequences for lipid digestibility and AMEn. Moreover it cannot be excluded that the commensal bacteria lead to modifications of hepatic metabolism and thus synthesis of biliary acids. All these extra syntheses in D- birds may contribute to their lower feed efficiency.

Commensal bacteria may have positive effects such as some strains of *Clostridium* in the digestive tract of D+ birds. In addition to their beneficial effect on intestinal functionality, their fermentation products may increase energy extracted from the diet for the host. On a F2 cross between D+ and D- lines, a significant amount of variability of AMEn could be explained with some components of caecal microbiota : 9% could be attributed to *L. salivarius* and 13% to the ratio "Log *L. salivarius*/Log *C. leptum*". Multifactorial analyses also showed association between high AMEn and low amounts of *E. coli* (in absolute values or relative to other bacterial groups). On the other hand, low AMEn was associated with high amounts of *E. coli* (in absolute value and relatively to *Clostridium*) and of *L. salivarius* (in absolute value and relatively to *Lactobacillus* and *Clostridium*).

The results obtained with these bird lines, showed that bacterial ratios are more important than bacterial concentrations, which can be explained by the fact that the effect of microbiota is not due to a group of bacteria, but to their interactions. Indeed, digestive microbiota is a complex equilibrium between numerous bacterial strains, their biotope, and their host. The host phenotype is the result of a balance state between the genetics of the host, environment, one of which dietary compounds, and the digestive microbiota.

As these relationships between bacterial groups and animal phenotype have been obtained in specific conditions of diet and environment, we need to extend these initial studies to conditions closer to production conditions.

Progress on the English Pig Industry Environment Road Map

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A definition for sustainability; "*Meeting the needs of the present generation without compromising the ability of future generations to meet their needs*."

The English Pig Industry launched its Roadmap; "Advancing Together" in May 2011. This document is a clear statement of intent outlining how the industry will further develop improved sustainability and environmental responsibility. Delivery is taking place by improving performance throughout the whole industry from production to marketing of products. An integrated approach is taken joining all the pieces of the Jigsaw to make a complete picture, there is no one magic bullet. Producing pig meat sustainably in order to provide a growing world population with safe, affordable, highly desirable meat protein and other products of pig origin when faced with diminishing resources requires team effort.

Feed and nutrition is a crucial key piece of this Jigsaw. Besides the challenge of delivering to farmers rations meeting the production needs of their pigs at an affordable price, high metabolic efficiencies are required to reduce emissions and pressures on the environment. Last, but not least, are the ethical questions about the origin of ingredients, and even if we should feed them to animals at all?

Feed is the largest single component of the cost of pig production on the farm. It also is the largest contributor to the Carbon Footprint and environmental burdens of production. Co-product use is a good news story, but food manufacturers are under similar pressures to maximise returns from sales as well; therefore established products may change and new ones emerge. Feeding catering waste and processed animal protein is on the political radar, and supported by some environmental NGOs; will it become acceptable?

The Pig Industry has travelled a rough road since the late 1990s. "Advancing Together", is a continuation of the journey which commenced in 2002 when BPEX first launched its Road to Recovery strategy; Part 2 followed in 2006. Within this umbrella of activity came the BPEX Pig Health Scheme (BPHS), 2003, the Pig Industry Professional Register (PIPR), 2007 and the appointment of BPEX Knowledge Transfer Managers to empower farmers.

To lead the debate and industry, the Pig Environment Partnership (PEP) was developed in 2007. Unfortunately, this coincided with a period of rapidly falling farm-gate pig prices. It was not seen as a priority by an industry fighting for economic survival; the background delivery work continued, but with a lower public profile. The Pigmeat Supply Chain Task

Force, instigated in 2009 and chaired by Government Ministers, largely took over the function of PEP.

Despite implementation of the various schemes and strategies, the English industry continued to lag behind other European countries in terms of pig performance and cost of production. Thus in 2010, the simple concept of the Two Tonne Sow (2TS) was born. The aim was to focus on raising the industry average of 1.6 tonnes of pig meat per year to 2.0 tonnes by 2014, a substantial and theoretically achievable increase, but still behind the levels of production being achieved elsewhere in Europe, most notably Denmark. 2TS is again a holistic strategy with key focus on six areas, or pillars as they are named. The Pillars are; breeding, finishing, health, nutrition, buildings and training.

The Pillars are the front line activity with BPEX leading work on improving farm performance, concentrating on one at time with the possible exception of health which is a continuous work stream. BPEX KT Managers are engaging directly with producers through targeted and co-ordinated meetings, events, workshops and conferences backed up by a professional communications team. This approach means messages are disseminated effectively and by different means. The 2012 BPEX Customer satisfaction survey results showed an increase in the last year in the use of BPEX services from 71% to 76% by respondents in the producer category.

Endemic disease has been a burden to our industry for too long, pulling down productivity and limiting advances perhaps most dramatically in nutrition and genetics where the UK is a recognised world leader and exporter. Thus investment in Health is a fundamental of success for the Roadmap.

In August 2011 a new strategy was launched; “20:20 Pig Health and Welfare” with cross-industry support. The strategy is presented in a sister document to “Advancing Together”, sharing a common holistic approach to solving problems and placing the industry in a better position to face challenges of the future. The Pig Health Improvement Programme (PHIP) is partnership working. Focused cluster groups of farmers are working with veterinary practitioners utilising Defra grants carrying out on-farm activity to improve pig health status. Just looking at disease and health is not enough; the housed environment is important, housing and ventilation are also receiving attention.

Research and development is providing evidence and answers supporting progress. Projects investigating the use of home grown protein crops, reducing levels of protein and phosphorous in diets are part of the process. BPEX is currently revising its priorities and objectives for the next stage in the journey. Resource efficiency will no doubt feature strongly together with health and welfare. Environment and welfare improvements often conflict.

Activity continues beyond farm gate; processing industries have been adopting “lean” production techniques reducing operating costs, energy, water use and waste. Meat waste and maximising the whole carcase either through export of products or developing novel processes such as bio-oil extraction still offer further opportunity.

A long, challenging complex path towards our joint destination.

Aspects of amino acid digestibility in feed ingredients fed to pigs

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Most feed ingredients used in practical feed formulation contain protein, which needs to be digested because only free amino acids can be absorbed into the portal blood of the animal. Protein digestion starts in the stomach where pepsin hydrolyses some of the peptide bonds in the feed proteins. Hydrolysis of the majority of the remaining peptide bonds takes place in the small intestine where the pancreatic enzymes trypsin, chymotrypsin, elastase, and carboxypeptidate A and B are secreted into the intestinal lumen and amino peptidase is secreted by the small intestinal brush border. In combination, these enzymes hydrolyze the majority of the peptide bonds in the peptides, and free amino acids, dipeptides, and tripeptides will be absorbed into the enterocytes. Dipeptidases and tripeptidases will do the final hydrolysis inside the enterocytes and free amino acids are released over the basolateral membrane and absorbed into the hepatic portal vein. Any amino acids that are not absorbed by the end of the small intestine will enter the large intestine where they will metabolized by the microbes and excreted as microbial protein. To estimate the quantities of amino acids that are available for protein synthesis in the pig, an estimate of the amino acids that disappeared in the small intestine is, therefore, necessary.

For practical purposes, availability of amino acids is usually estimated as the digestibility of amino acids. The apparent ileal digestibility (AID) of amino acids is often determined, but values for AID of amino acids are not always additive in mixed diets because the contgributions of endogenous amino acids to the ileal output of amino acids changes with dietary protein level. It is, therefore, necessary to determine the basal endogenous flow of amino acids, which is usually accomplished by collection of ileal digesta from pigs fed a protein-free diet. By correcting AID values for basal endogenous losses, values for the standardized ileal digestibility (SID) are determined and these values are additive in mixed diets. Because practical diet formulation assumes additivity among dietary ingredients, SID values are usually used in diet formulations. It follows from this that pig amino acid requirements need to be expressed as SID amino acids.

The level of feed intake may influence SID values for amino acids because the basal endogenous losses of amino acids are influenced by level of feed intake. Gestating sows fed a restricted amount of feed, therefore, have different levels of basal endogenous losses than pigs allowed ad libitum access to feed. However, if pigs are fed at a level of approximately 3 times the maintenance requirement for energy, they will have SID values that are similar to SID values obtained in pigs allowed ad libitum intake of feed. It is, therefore, recommended that pigs used to determine SID values are provided feed on an ad libitum basis or at a level of approximately 3 times the estimated requirement for energy. The only exception from this will be gestating sows, where restricted feeding is recommended.

Several anti-nutritional factors including gossypol, phytate, trypsin inhibitors, and glucosinolates may negatively impact the SID of amino acids. The detrimental effects of free gossypol on pig performance may be reduced if ferrous sulfate is added to diets in a 1:1 ratio. Heat treatment will reduce the concentration of trypsin inhibitors in feed ingredients and use of low-glucosinolate varieties of canola meal or rapeseed meal will reduce the impact of glucosinolates on amino acid metabolism.

Processing of feed ingredients involving heat will often result in Maillard reactions, which involves the condensation between the amino group of Lys or other AA, and the carbonyl group of reducing sugars. Consequently, Lys becomes unavailable to pigs, thus reducing the digestibility of this AA. For practical feed formulation it is recommended that standards for the lysine to crude protein ratio be calculated and these standards should then be used to predict degree of heat damage in feed ingredients.

Sow nutrition - hormonal manipulation via nutrition

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The number of piglets weaned per sow per year is one of the most important factors that determine the income of the farmer. Litter size of modern sow lines has increased, mainly due to genetic selection. The limited uterine capacity has reduced birth weight. It is known that low birth weights are negatively correlated with piglet mortality. Furthermore, the selection for higher lean meat content has also altered the body composition of breeding sows. Consequently, the feed industry is faced with the following challenges regarding sow nutrition:

1. How to feed modern genotype sows with high reproductive performance according to their requirements

2. How to feed modern genotype sows to improve piglet survival, birth weight and homogeneity of the litter

Recently, studies have shown that fine tuning during the end of lactation and the weaning to oestrus interval can affect birth weight and homogeneity of the litter. In both cases the nutritional measures taken in order to improve piglet quality have their effect via hormones. The most important hormone is insulin. How insulin is affected by feeding measures such as feeding level and diet composition as well as how insulin affects birth weight and homogeneity of the litter will be discussed in this paper.

Both insulin and IGF-1 play a role in follicle development and oocyte quality. The effects of insulin seem to work via interactions with LH and on medium and large sized follicles, whereas their effect on smaller follicles is minor. It is suggested that insulin elevates the concentrations of steroid hormones in the follicular fluid of larger follicles but not in small ones. A better quality oocyte may also have beneficial effects on birth weight and homogeneity of the litter and a higher conception rate.

Piglets need glucose and lactate as energy sources for their development. During the last month of the pregnancy the sow develops a reversible form of insulin resistance, resulting in higher blood glucose levels and therefore a larger supply of glucose to the foetuses, enabling the piglet to deposit more glycogen reserves, which may support piglet survival during the first days after birth. This insulin resistance is gradually reduced during lactation.

The next reproductive cycle already starts during the lactation of the previous litter. Higher levels of glucose in the blood not only stimulate milk production but also stimulate the start of the next reproduction cycle. During the weaning to oestrus interval (WOI) high feed intake levels will via insulin stimulate the production of LH. It is suggested that it stimulates follicular development and thus the reproductive performance of the sows. The effect of feed intake on the insulin response was larger when the animals were fed twice a day than if the feed was supplied in various small portions. Additionally the energy source in the diet is of relevance. Studies showed that the glucose and glucose precursors (amino acids and propionate) had a positive effect on insulin levels during WOI, stimulating follicle development, which resulted in more homogeneous or larger follicles leading to more homogeneous but not larger litters. The effect was particularly evident if the sows were still in a catabolic state at weaning.

Insulin resistance at the end of gestation can be stimulated by saturated fats in the diet whereas unsaturated fatty acids may have the opposite effect. Positive effects of MCT or fat sources rich in MCTs , like coconut oil, on glycogen reserves and piglet survival the first 3 days post farrowing, have been observed in several studies. The effect was especially found in piglets with a low birth weight. It is not clear whether this effect is related to insulin resistance or that these fatty acids are better available to the foetuses.

In conclusion, sow reproductive performance can be affected by manipulating metabolic hormones via nutrition. Most interesting is manipulating during the WOI, but this optimisation is only effective when other factors on the farm such as feed management are not limiting.

Extra-phosphoric effects of phytase – low phytate nutrition in non-ruminants

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The vast majority of phytase use to date has been with reduced supplementation of inorganic phosphates in poultry and pig rations in mind. Such an application saves considerable costs whilst at the same time providing a benefit to the environment with regards to reduced phosphorus (P) pollution. Phytases deliver the P of interest through de-phosphorylation of phytic acid, and it is the destruction of the phytic acid per se, not the provision of phosphate which is the focus of this paper. Considerable quantities of P are delivered at commercial phytase dosage rates, but such dosages are insufficient to consistently destroy more than 60% of the phytic acid in the diet. Phytic acid has several anti-nutritive properties, not least the ability to chelate minerals (Adeola et al., 1995; Kies et al., 2006), rendering them unavailable, which in some cases may precipitate deficiency. However such effects are well understood and circumvented by supplementation with the appropriate mineral premixes. Indeed current mineral requirements for non-ruminants more than likely have taken this anti-nutritive phytate effect into account so the advent of phytase may justify a review of all mineral requirements. However, recent work has suggested a more profound anti-nutritive effect of phytic acid (Cowieson et al., 2004; Cowieson and Ravindran, 2007; Onyango et al., 2004), and that more complete destruction of phytic acid per se can yield benefits which are unrelated to P release. Whereas the mechanism has been well described as to how phytic acid may detract from energetic efficiency of the animal, there is little information on the potential scale of response attainable if the target for phytase use was specifically phytic acid destruction rather than P release. This is because the vast majority of work where very high dosages of phytases have been used has employed diets which are deficient in P (Augspurger and Baker, 2004; Cowieson et al., 2006; Pirgozliev et al., 2011). As a result, it is not possible to ascertain when the response to incremental phytase dosage switches from meeting the P requirement to phytic acid destruction, if indeed phytic acid is involved at all in the work reported. However, recently several trials have been conducted which do indeed suggest that benefits beyond P release are attainable. This effect however, requires use of phytase dosages which are well in excess of current practice. If such an effect proves to be consistent then it may profoundly alter the way this enzyme is used in the future.