# Recent Advances in Animal Nutrition

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# Managing Nutrition to Improve the Metabolic Health and Reproduction of Dairy Cows

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## Introduction

Transition cow management is currently considered as the key factor for subsequent adequate milk productivity, dairy cow health and reproduction. Transition cow management is a container term. It comprises different aspects of farm management, even including the nutrition at the end of lactation and during the dry period, as well as the cows' health status during the latter periods, but most of all it comprises the nutrition during about the last 20 days antepartum and the first 30 days postpartum, the health status of the cows during these weeks, and husbandry factors such as housing and barn climate, as well as cow comfort elements. Transition cow management should prepare the cow in such a way that she would be able to adequately counteract the different periods of high risk between calving and day 100 postpartum. In this context, risks refer to metabolic, other health and reproductive disorders during the transition period. Inadequate transition management leads to a whole spectrum of subclinical and clinical health, reproduction and milk production disorders.

This paper addresses issues of transition cow management and the respective risk periods after calving. These risk periods comprise health and fertility disorders. Ultimately, management measures to better control and possibly prevent disorders in the period between calving and day 100 postpartum are discussed.

## Transition cow management

The transition period is schematically described in Figure 1. This Figure illustrates the different physiological and pathophysiological processes, major events in this period, and the respective relevant hazards. The transition period comprises 20 days close-up, the calving event, and the first 30 days in milk. The ultimate objective of

The different domains and factors, as listed in Table 1, point to the complexity of transition cow management which is possibly the explanation for the phenomenon that some farmers are very successful in this management while others are not. Several of these domains and factors have 'read out' parameters in the field. Body condition score is one example; at end of lactation 3.0 to 3.5, in the dry period 3.5 to 3.0. Others are rumen fill score (RF), faeces consistency score (FC), undigested fibres in faeces (UF) (Zaaijer & Noordhuizen, 2003). Feed bunk space should be 75 cm per cow; for high yielding cows even 90 cm. Total width of available drinking place in the barn or pasture should be 450 cm for 100 cows, and may be double in warm summer seasons, and troughs must be well positioned throughout the barn and in pasture. Rumination frequency in the herd should be > 75% of the cows (if not eating). The diurnal feeding pattern in cows is influenced mostly by time of feeding, and less by feed push-ups or milking (DeVries, 2011). Giving smaller but

**Table 1. Overview of domains and factors per domain which may impact on the extent of feed intake reduction before and after parturition (adapted after Interact AgriManagement, 2004, in Noordhuizen, 2012)**

| Domain | Factors |
|---|---|
| Dry period management | Manner of preparation of cows (BCS 3.0-3.5 max) |
| | Presence/absence of far-off and close-up cow groups |
| | Cow comfort conditions (see below) |
| Feeding | Palatability of grass/maize (silage) |
| | Fibre content in grass/maize (silage) |
| | Other feed (by)products |
| Feeding management | Feeding according to standards |
| | Freshness and quality of rations fed |
| | Rations based on forage analysis |
| | Total Mixed Ration (TMR) mixing and mixing time |
| | Supply of feed over the day |
| | Speed of increase in concentrates supply after parturition |
| | Feed bunk space per cow and heifer |
| | Animal density (< or > 100%) and presence of cow groups |
| Claw and leg health | Presence of infectious & non-infectious claw lesions |
| | Presence of hock lesions |
| Cow comfort | Barn ventilation conditions |
| | Barn light regimen applied |
| | Conditions and surface of exercise area behind feed rack |
| | Cubicle design and maintenance, including bedding |
| | Competition for cubicles, feeding places, escape |
| | Drinking water troughs (barn/pasture) number, position |
| | Water quality (chemical; micro-biological) |
| | Water cleanness |
| | Water distribution system (adults one; youngstock one) |

# 2

# Physiological Role of Carnitine in Energy Metabolism, Possible Interplay With Inflammation and Potential Benefits for Dairy Cows

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## Introduction

Carnitine is a naturally occurring substance. It was detected in 1905 as an ingredient in muscle. In contrast to the D-isomer, the L-form plays an essential and crucial role in energy metabolism of human and animal organisms. The function of shuttling long chain fatty acids into the mitochondria for β-oxidation and finally driving the citric acid cycle is well known and published in literature. However, the crucial role of carnitine in regulating carbohydrate and fatty acid metabolism by modulating the acetyl-CoA/CoA ratio in the mitochondria and the consequences for energy metabolism, as well as the link to inflammation, is rarely considered. Carnitine is defined by many scientists as conditionally essential. The aim of this chapter is to elucidate the physiological role of carnitine, the possible interplay with inflammation, and potential benefits for dairy cows.

## Endogenous biosynthesis

The chemical structure of L-carnitine is similar to that of amino acids. Endogenous biosynthesis is performed in the liver and kidney. The first metabolite is trimethyllysine (TML). Although lysine and methionine deliver the backbone of this source, the nutritional supply of these amino acids has no impact on the biosynthesis of carnitine. The precursor TML must be provided from body protein following degradation within the scope of protein turnover. Endogenous biosynthesis starts with release of TML from lysosomal protein breakdown (Vaz and Wanders, 2002). Certain physiological conditions (Table 1) may lead to insufficient biosynthesis of carnitine especially under anabolic conditions due to reduced protein degradation. This in

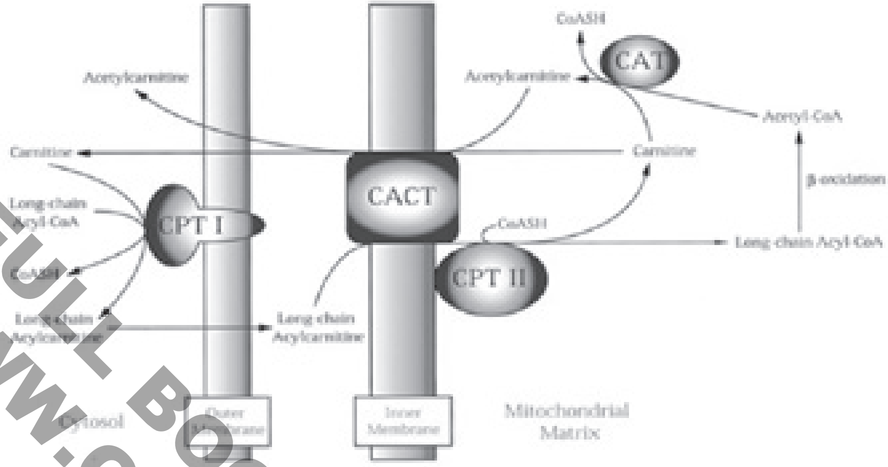

**Figure 1.** Function of carnitine in transport of mitochondrial long chain fatty acid oxidation and regulation of the mitochondrial acetyl-CoA/CoA ratio (Vaz and Wanders, 2002).

## Modulation of Acetyl-CoA/CoA ratio

A shuttle can work repeatedly without being wasted. Hence, the shuttle function of carnitine cannot explain the need for carnitine supplementation. Nevertheless, research in humans and animals has shown that with increasing performance or energy deprivation, the excretion of acetyl-carnitine via urine and milk is increased. In humans renal excretion of carnitine esters increases when fasting or performing endurance sports. These results can be explained by the buffer function, i.e. the modulation of the acetyl-CoA/CoA ratio (Luppa, 2004).

Activated acetic acid at the end of the β-oxidation condenses with oxaloacetate to form citric acid and to fuel the citric acid cycle. Under certain metabolic conditions and diseases, e.g. malnutrition, fasting, diabetes mellitus (Flanagan, Simmons, Vehige, Willcox and Garret, 2010) this metabolic pathway can be overstrained due to excess of fatty acids stemming from the diet or mobilized body fat, leading to a surplus of acetyl-CoA. Most of the CoA in the mitochondria is fixed then to the activated fatty acids and thus not available for other metabolic functions. The enzyme pyruvate dehydrogenase (PDH) in particular plays a crucial role here. This enzyme catalyzes the reaction of pyruvate and its precursors, glucose and glucoplastic substances, with fatty acids. The activity of the PDH depends on free CoA (Luppa, 2004).

If sufficient free carnitine is available in the mitochondrial matrix, carnitine again replaces the CoA in the surplus acetyl-CoA. CoA is released and acetyl-carnitine removed from the mitochondrial matrix in return with free carnitine from the

## 3

# CONSIDERATIONS FOR FEEDING STARCH TO HIGH-YIELDING DAIRY COWS

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## Introduction

There has long been interest in the potential benefits and risks of feeding starch to lactating dairy cows (e.g. Henderson and Reaves, 1954; Armsby, 1922) and there have been numerous reviews published on the utilization of starch by ruminants for production (e.g. Waldo, 1973; Owens *et al*., 1986; Nocek and Tamminga, 1991; Huntington, 1997; Firkins *et al*., 2001). In a previous publication for the 31st University of Nottingham Feed Manufacturers Conference the effects of feeding starch to lactating dairy cows on nutrient availability and milk production and composition were reviewed, including the effects of altering site of starch digestion within the digestive tract (Reynolds *et al*., 1997). In recent years there has continued to be research into effects of starch type and site of starch digestion on production and metabolism of lactating dairy cows (e.g. Reynolds, 2006), along with a pervasive concern over the potential negative effects of sub-acute ruminal acidosis (SARA), the future demand for food for a growing human population, and the ethics of feeding starch to ruminants. Our objective is to revisit key points raised in these previous reviews in light of more recent research, the sustained increase in milk yield and nutrient requirements of lactating dairy cows, and concerns regarding the future role of ruminants in sustainable food production systems.

### Why feed starch to dairy cows?

Dairy farmers are paid for the amount and quality of the milk they sell, which has been incentive for increasing milk yield per cow through genetic selection and

**Table 1. Effect of silage quality and supplementing steam-flaked maize (SFM) starch on ruminal pH and ruminal NDF kinetics**

| | Grass silage quality | | | |
|---|---|---|---|---|
| | Early maturity (394 g NDF/kg DM) | | Late maturity (464 g NDF/kg DM) | |
| Item | Control | SFM | Control | SFM |
| Starch intake, kg/d* | 0.1 | 3.6 | 0.1 | 3.2 |
| Average ruminal pH† | 6.2 | 5.9 | 6.2 | 6.2 |
| NDF intake, kg/d* | 5.8 | 5.3 | 7.0 | 6.0 |
| NDF Ruminal pool size, kg* | 3.7 | 4.5 | 4.6 | 4.8 |
| NDF fractional ruminal degradation rate, /hr* | 0.058 | 0.039 | 0.053 | 0.038 |

*van Vuuren *et al.*, 1999; †unpublished observations.

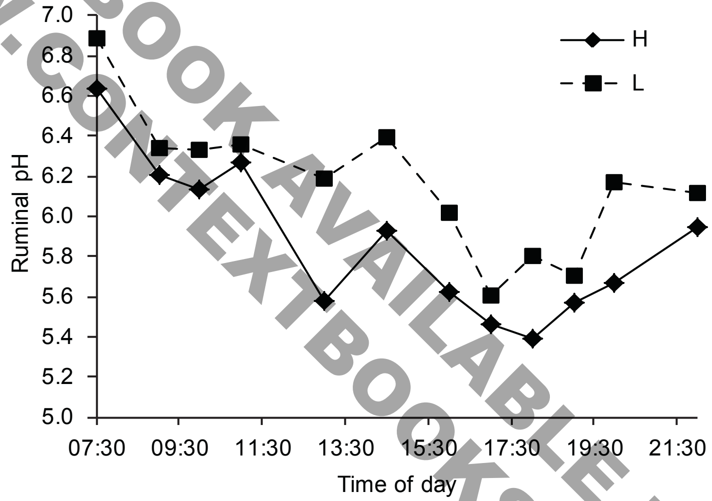

**Figure 4.** Ruminal pH in high (H) and low (L) yielding dairy cows at similar intakes of the same diet (D. J. Humphries, unpublished observations).

These differences in ruminal pH between cows were associated with differences in ruminal propionate concentration (Figure 5) and may relate to differences in intake pattern, milk yield, VFA absorption, and rate of digesta passage. It appears that some degree of SARA may be 'normal' in early lactation cows with high levels of intake and milk yield that are compensated for by adequate rumination, saliva production, and VFA absorption. However, cows exhibiting variability in their day to day patterns of ruminal pH may be more of a concern. For example, continuous monitoring of ruminal pH using rumen bolus technology in a group of cows fed the same diet in early lactation found that individual cows within the group with higher DMI and milk yield had more regular patterns of ruminal pH decline and recovery from day to day, whilst cows with lower milk yields had more erratic patterns of DMI and

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# NITROGEN EFFICIENCY AND AMINO ACID REQUIREMENTS IN DAIRY CATTLE

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## Introduction

For more than 40 years, protein nutrition and metabolism in livestock animals has been a major subject for research. The beneficial effect of dietary protein on livestock performance and the relatively high value of protein-rich ingredients were main reasons to assess the optimum dietary protein level. Scientists have long been aware of the high manure nitrogen (N) excretion and relatively low N use efficiency of livestock and the impact of manure N on the environment. In more recent years, public concerns over the impact of land use changes for feed protein production in combination with predicted increase in the demand for animal protein have become another stimulus to assess the optimum dietary protein level balancing animal performance and the ecological footprint of livestock production.

Although ruminants are less efficient in feed protein use than monogastric livestock, the human edible protein efficiency is substantially higher than for monogastrics and is usually greater than 1.0, indicating that ruminants add to the total human food supply (Dijkstra *et al.*, 2013b). This protein gain by ruminants results from the nature of plant proteins consumed by ruminants. Plant proteins for ruminants are often embedded in high-fibre forages (e.g. grass, clover) and high-fibre, inedible residues of the food industry (e.g. expellers, brewer's grains, gluten feeds) that are not potential foods for humans.

However, competition for arable land between crop and forage production may affect the overall sustainability of cattle operations. Although high-producing dairy cattle have a relatively high protein use efficiency by diluting maintenance requirements over more milk (Dijkstra *et al.*, 2013b), the required production of highly-digestible home-grown forages to enable high levels of milk production typically requires high levels

**Table 1. Maximal net contributions of glucose precursors (excluding amino acids other than alanine) removed to glucose released (% of total) by the liver of transition dairy cows (Reynolds *et al.*, 2003)**

|  | Average day relative to calving |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
| Item | -19 | -9 | 11 | 21 | 33 | 83 | SEM |
| Propionate | 55.2 | 43.5 | 55.8 | 49.0 | 57.6 | 66.4 | 7.0 |
| Lactate | 18.5 | 22.7 | 21.1 | 16.9 | 15.6 | 8.0 | 2.7 |
| Alanine | 3.1 | 2.3 | 5.5 | 3.0 | 1.5 | 1.7 | 0.6 |
| Glycerol | 2.3 | 3.0 | 3.6 | 2.4 | 1.5 | 0.4 | 0.7 |
| Triglyceride glycerol | -0.2 | 1.5 | 0.2 | 0.0 | 0.1 | -0.1 | 0.5 |
| i-Butyrate | 1.7 | 1.4 | 1.3 | 1.1 | 1.4 | 1.6 | 0.5 |
| n-Valerate | 2.8 | 2.4 | 3.3 | 2.3 | 2.8 | 3.0 | 0.6 |
| Total | 83.4 | 76.8 | 88.9 | 74.7 | 80.5 | 81.8 | 7.5 |

suggesting reduced Cori cycling of glucose and lactate between peripheral tissues and the liver (Reynolds, 2002).

Thus, the question remains how uptake of AA by the mammary gland can be optimized to avoid an undesirable surplus of AA and minimize excretion of urinary N. Various reasons for suboptimal AA uptake by the mammary gland have been postulated, such as a suboptimal profile of AA supplied to the mammary gland; suboptimal synchronisation of available energy and AA for the mammary gland and asynchrony between available nutrients; and the activity of anabolic pathways in mammary cells (Arriola Apelo *et al.*, 2014a), resulting in suboptimal uptake or cellular utilisation of AA.

## Amino acid profile

A shortage of one or more EAA in relation to the other EAA and their requirements has been postulated for many years as a limit for mammary protein synthesis and appears the main driver for including rumen-protected AA considered as first-limiting, especially when reducing dietary CP content (e.g.Broderick *et al.*, 2009). This theory is often presented as a barrel made of staves with different lengths, which represent supply of an AA relative to the ideal profile (see Cant *et al.*, 2003), where the ideal AA profile refers to the AA profile of milk protein. Methionine and lysine are considered to be the first limiting AA for milk production and a large number of studies on the effect of supplementing these AA, protected from rumen fermentation, have been reported. A recent meta-analysis of effects of rumen-protected methionine (RPM) included 36 studies (Patton, 2010). Adding RPM to rations of dairy cows overall resulted in an increase in true milk protein content of 0.7 g/kg of milk and an increase in true milk protein yield of 27 g/d. These and other responses to RPM were not influenced by supply of lysine or by other dietary factors (levels of NDF and CP, and energy balance); but of considerable interest is the observation that

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## 5

# MANIPULATING RUMEN FERMENTATION TO IMPROVE EFFICIENCY AND REDUCE ENVIRONMENTAL IMPACT

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## Introduction

Microbial fermentation in the rumen plays a central role in the ability of ruminants to utilize fibrous substrates; however rumen fermentation also has potential deleterious environmental consequences as it ultimately leads to the emission of greenhouse gases and breakdown of dietary protein leading to excessive N excretion in faeces and urine. Given the importance of rumen fermentation, it is perhaps not surprising that a great deal of effort has been devoted to investigating methods for manipulating this complex ecosystem.

Some thirteen years ago a paper was presented at the Nottingham Feed Conference on "Developments in rumen fermentation-The scientists view" (Newbold, Stewart and Wallace, 2001); given the passing of time and advances in the subject area it seems appropriate to revisit the topic and specifically to consider:

- Targets for manipulation: i.e. what are the main drivers in terms of altered outputs that are informing research in the area?

- Approaches to manipulation: i.e. what are the prominent approaches to manipulation that are being investigated?

As with the initial article this review is by design a personalised view informed by the opinions and knowledge of the contributors and is not designed, nor should it be viewed, as a complete review of the subject area.

# 6

# DAIRY CALF AND HEIFER REARING FOR OPTIMUM LIFETIME PERFORMANCE

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## Introduction

Feeding methods and management practices applied to today's dairy replacements will influence the performance (and economic returns) of dairy herds in 2016 and onwards. Due to this relatively long time lag, most producers and dairy consultants tend devote less-than-desirable efforts and attention to calf and heifer rearing. In contrast to the situation in lactating cows, where management is typically based on records of milk yield, milk composition, feed intake, body condition, etc., heifers are managed based on "feeling" rather than being based on methodical data collection and record keeping. This chapter will review several nutritional aspects aimed at improving performance of calves and heifers, minimizing health disorders, and setting the stage to achieve first calving at 23-24 months of age with a body weight (BW) above 650 kg (before calving), which should result in optimum milk production and longevity.

## Setting the stage for the future

Nowadays, it is clear that nutrient supply and hormonal signals at specific windows during development (both pre- and early post-natal) may exert permanent changes in the metabolism of humans (Fall, 2011), as well as changes in performance, body composition, and metabolic function of the offspring of livestock (Wu *et al*., 2006) through processes generically referred to as foetal programming and metabolic imprinting. Thus, it is likely that today's cow, with high milk yield but also reproductive and metabolic challenges, is not only a consequence of genetic selection, but also the result of the way her dam was fed and the way she was fed early after birth as a calf and later as a heifer (Bach, 2012).

The first weeks of life seem to have long-lasting consequences on the physiological function of neonates. The pioneering work of McCance (1962) illustrated that is decreased) improves calf performance and diminishes BRD incidence. In beef production systems, evidence exists that the health status and origin of calves being commingled seems to be important in determining BRD incidence (Step *et al.*, 2008), and, thus, grouping calves according to origin and BRD history may diminish morbidity after grouping. In fact, Bach *et al.* (2011) showed that that forming groups of animals with a BRD history should minimize the incidence of respiratory cases in those groups of calves formed by animals without a history of respiratory disease. Taking measures to minimize BRD incidence will not only have a short-term impact on growth and economic returns (i.e., less drug expenses), but will also have long-term return. Bach (2011) described a negative linear relationship between productive life and the number of BRD episodes that a cow experienced as a heifer (Figure 4).

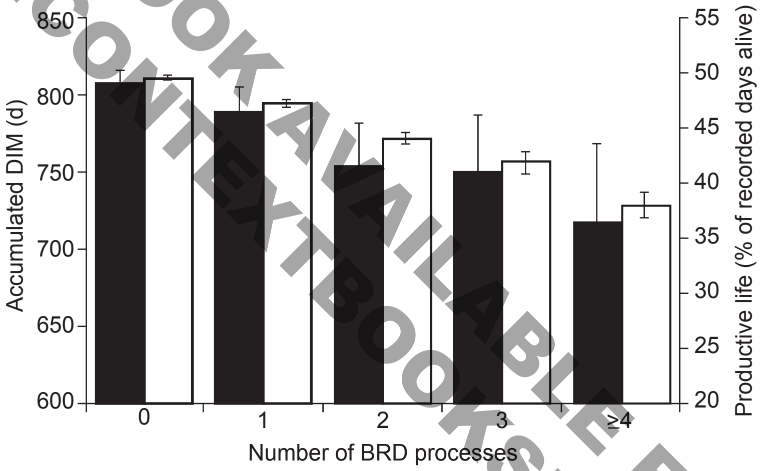

**Figure 4.** Accumulated productive life (days in milk (DIM); black bars) and productive life (as a percentage of productive days out of those recorded as alive; white bars) of cows as affected by the number of bovine respiratory disease (BRD) episodes experienced before first calving. Adapted from Bach (2011).

## Nourishing and managing heifers

Once target age and BW at first calving have been set, the rate of growth at different stages of development should be defined. Assuming a calf is weaned at 63 d of age weighing 92 kg, for her to reach 650 kg (after calving) at 23 months of age she needs to grow at an average of 870 g/d. Because BW accretion is more efficient early in life than in later stages of growth, it makes economic sense to aim for fast growth rates before breeding. The recommendation is that heifers should be bred at 400 d of life

## 7

# RECENT DEVELOPMENTS IN FEED ENZYME TECHNOLOGY

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## Introduction

Over the last twenty years feed enzyme use has developed far beyond the use of carbohydrases to combat viscosity. More targeted application is now possible with a better understanding of mechanisms both in degrading phytate and non-starch polysaccharides (NSP). This is invaluable when applying enzymes in diets containing novel ingredients and has dramatically increased the potential return on investment. It has also allowed the recent development of the use of NSP enzymes in high-fibre ruminant diets.

## Advances in the use of phytase for non-ruminants

Many hundreds of trials show the efficacy of various phytase products at standard doses in releasing phosphorus and allowing reduction of inorganic phosphorous in non-ruminant diets. Certainly the long held understanding is that of phosphate release from the plant storage form of phosphorous, phytate. In more recent years, the concept of superdoses of phytase has arisen. This involves the consideration of phytate not only as a source of phosphorus, but also as an anti-nutrient. In this regard the target is almost complete de-phytinisation of the diet (as opposed to 50-70% destruction, which is the outcome with standard usage). In cereals such as wheat and maize, phytate is likely to be present at around 0.7%, and in by-products such as rice bran, as much as 5% (Selle *et al.*, 2007). Phytate, or IP-6, is considered an anti-nutrient as it interferes with gastric protein digestion through co-ordination with both pepsin and dietary proteins and thus provokes a compensatory increase in HCl and pepsin. This is not only a loss of potential net energy of gain but irritates the stomach and stimulates additional secretion of protective mucin and therefore increases endogenous loss. Phytate also sequesters valuable nutrients such as minerals, which are then excreted.

Murphy *et al*. (2005) and others have shown that xylanase can improve gastric digestion of nutrients and used microscopy to visualise the breakdown of cell wall material, *in vivo*, with the use on an enzyme (Le *et al*., 2013). It is suggested that the enzyme works directly to degrade the cell wall, releasing the contents for digestion by the animal. However, scanning electron micrographs taken during work by the authors (Masey O'Neill *et al*., 2014) clearly shows the release of starch granules from the surface of maize particles but only little evidence of systematic breakdown of endosperm cell wall material with the use of a xylanase in an *in vitro* system (Figure 1). It appears that the enzyme has been more effective in de-anchoring starch from the cell wall material than breaking down cell wall material per se. This is a novel finding in that it suggests that there may be some xylan component involved in holding starch granules in place within an endosperm cell. Thus it appears the 'de-caging effect' is unlikely to explain the mode of action fully, particularly since the gastric phase conditions, particularly pH, limit the ability of the enzyme to act directly.

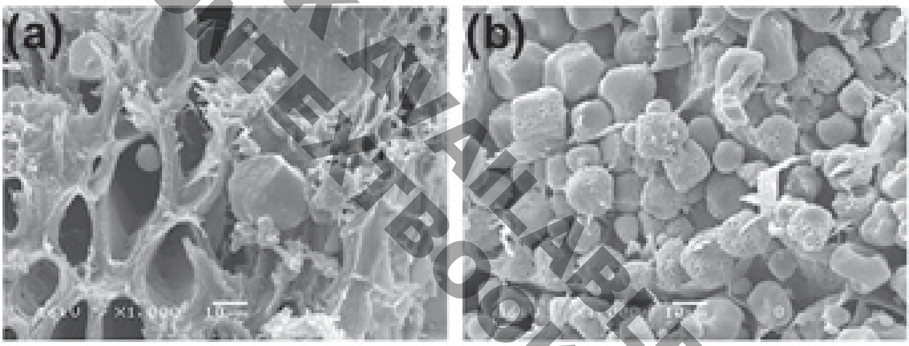

**Figure 1.** Ground maize incubated with a solution including (a) or excluding (b) xylanase (Econase XT, AB Vista Feed Ingredients, Marlborough, Wiltshire, UK). Reproduced from Masey O'Neill *et al*., 2014

Following a large body of work in allied industries, the breakdown products of NSP enzymes are quite clear and can be identified. Accepting that the de-caging and viscosity reduction effects cannot alone explain the effects of NSP enzymes, it is suggested that there may be a prebiotic route by which the *products* of NSP enzyme degradation may themselves exert a beneficial effect. Courtin *et al*. (2008) showed that feeding wheat bran xylo-oligosaccharides, derived *in vitro* using a xylanase, to broilers resulted in the same performance effect as feeding a xylanase directly. Furthermore, in various species the fermentation of such fibre may exert systemic, hormonal effects on the gastric phase. For example, Goodlad *et al*. (1987) suggested that increased colonic fermentation in rats induced the release of Peptide YY (PYY), which leads to increased gastric retention time. Presumably, this leads to increased gastric digestion of nutrients such as protein, not only through longer exposure to

## 8

# Enabling the Exploitation of Insects as a Sustainable Source of Protein for Animal Feed and Human Nutrition

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## Introduction

A growing global population and a rise in per-capita meat consumption is placing increasing pressure on the need to increase production of protein from sustainable sources. World population is expected to reach 9.6 billion by 2050, whilst the demand for meat, driven by an emerging global middle class is projected to grow by 73% from the level in 2010 (FAO, 2011). Protein is an important component of animal feed. Currently more than 80% of protein sources required for livestock rearing in the EU, such as soya and fishmeal, are imported from non-EU countries. This is problematic, as it can lead to market fluctuations and price rises in final products. Sustainable production of these protein sources is also a matter of debate. The UK alone currently imports approximately 2.5 million tonnes of soya per year, the majority of which is destined for animal feed, principally for pigs and poultry. Insects offer a promising alternative to conventional protein sources for animal feed. PROteINSECT is an international and multidisciplinary EU funded project that aims to facilitate exploitation of insects as an alternative protein source for animal feed. Incorporation of insects into animal feed could help to reduce the dependency of the EU upon external protein sources to feed its livestock. However, there are several areas of research that need to be undertaken before use of insect protein can be achieved at commercial levels. In addition, changes to the legislation that regulates animal feed in the EU would be needed before insect protein in animal feed is permitted. The research undertaken within the PROteINSECT project will advance knowledge in these key areas.

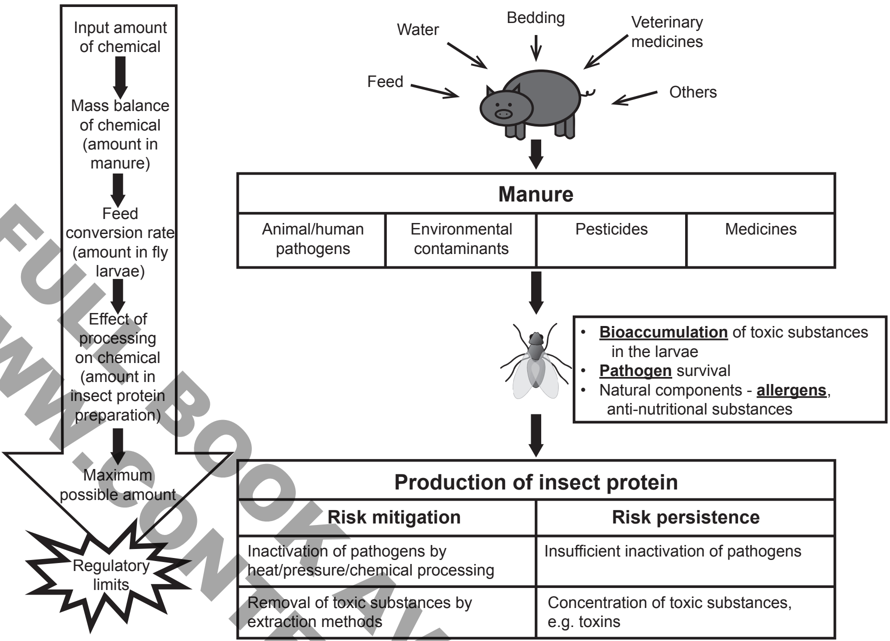

**Figure 4.** Potential for safety risks in the insect production chain

(17 compounds), polychlorinated biphenyls (PCBs) (25 compounds), polycyclic aromatic hydrocarbons (PAHs) (28 compounds), veterinary medicines (68 EU regulated compounds and a further 492 compounds including those known to be used worldwide) and mycotoxins. Microbiological risks, such as potential for persistence of *Salmonella* spp, *Campylobacter*, *Listeria monocytogenes* and Hepatitis E, will be evaluated. Initial studies on nine samples of larvae of different fly species using a recently developed and validated loop mediated isothermal amplification (LAMP) assay have all been shown to be negative for *Salmonella* species. Allergenicity is also a potential problem for insect protein. Allergenicity may occur in animals consuming feed in which insect protein is incorporated or in humans who subsequently consume fish or meat derived from these animals. There is little published information on insect allergens, but potentially allergenic proteins include tropomyosin. This is the main allergen found in shellfish and the protein sequence is similar to that found in insects. PROteINSECT will examine the potential for allergenicity of protein from larvae of the fly species used in the project. Downstream analysis of meat derived from insect reared animals will also be undertaken in relation to safety and quality (e.g. taints).

Much of the work to date on insect protein in animal feed has made little or no attempt to process the insect material produced. In PROteINSECT processing

E.C. Fitches *et al.* **111**

## 9

# Using Animal-Oriented Indicators and Benchmarking for Continuously Improving Animal Health and Welfare

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## Societal changes

The intensification of agriculture as basis for feeding the human population has been regarded as progress for centuries, since the fewer people of a population are needed to produce the necessary food for all people, the more human resources are available for industrial and cultural progress. This platitude has been true as long as the food supply has been staying behind the demand for plenty and high-quality food for everybody, but this societal consensus is almost abruptly changing, when there is an oversupply of food, even if this is only perceived by the affluent parts of the population in question: agriculture, and especially producing food from and with animals is increasingly questioned and criticized.

This very rough pattern of agricultural development and the change of its societal acceptance can be exemplified by the relatively short period from World War II until today. Regarding the area of agriculture and food supply, three phases of the post-war development can be differentiated: “Shortage”, “Risks” and “Guilt”.

**Shortage**: During the war and particularly afterwards, the shortage of food was ubiquitous and agriculture was almost everywhere characterized by a small-scale structure. The need for food was enormous and aggravated by the growing urbanization and industrialization that started in the 1950s. In the “West”, farmers benefited from the demand and a process of “growing or vanishing” started the intensification of agriculture: efficient farms grew, less efficient farms died away. In the “East”, totalitarian regimes decided to become politically and economically independent of the “West”, which resulted in an agricultural development that was designed to guarantee self-sufficiency, at least in the area of food. The Eastern communistic states developed in the early 1970s huge agriculturally used fields for crop production and likewise huge units for food animals (e.g. in East Germany sow units up to 5,000 sows

*Recorded by the official veterinarian in the ante-mortem inspection:*

- number of lame animals (broken bones, arthritis)
- number of unthrifty and cachectic animals
- number of animals with injuries (acute = transport, and chronic = negligence at farm level)
- number of animals that are not fit for being slaughtered (only due to disease is meaningful)

*Recorded by the official veterinarian in the post-mortem inspection:*

- number of animals with lesions due to cannibalism (tails, ears)
- number of animals with lesions due to animal cruelty (welts, bruises)
- number of animals that are not fit for consumption due to disease

It is obvious that the criteria listed would change for poultry (food lesions, feather pecking signs, polyserosits etc.), turkey (food lesions, breast blisters, bone deformities etc.) and cattle (mastitis, neglected claws, poor body condition etc.).

Figure 2 demonstrates the principle of benchmarking pig herds using the criteria listed above plus mortality rate and the Antibiotic Treatment Index (the ATI = number of treated animals multiplied by the days of treatment divided by all animals in the herd or flock). Assigning points to each criterion according to the severity of each of the health or welfare impairment will provide the opportunity to calculate for each herd or flock an index that semi-quantitatively measures the quality of the animal health and welfare status. As an example, the mortality rate of finishing pigs could

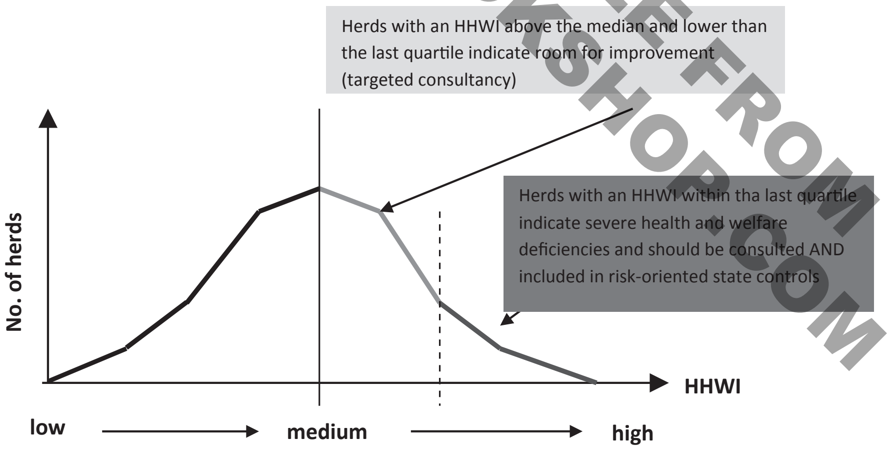

**Figure 2.** Benchmarking pig herds by measuring their animal health and welfare status by calculating their Herd-Health-Welfare-Index (HHWI) using the same criteria and point system in each of the benchmarked herds.

## 11

# More Pigs Born Per Sow Per Year – Feeding and Management of the Bottom 20% of the Pig Population

PETE WILCOCK[1] AND IAN WELLOCK[2]

[1]*AB Vista, UK;* [2]*Primary Diets*

There is a current focus on increasing pork output per sow per year and this is resulting in a greater emphasis on targeting more pigs per sow per year. This is mainly being driven by an increase in litter size which can have negative effect on birth and weaning weights as well as subsequent pig performance. This paper will look at the implications that litter size has on birth and weaning weights and subsequent pig performance. In addition it will review some of the main nutritional and management practices that can be used to assist weaning and post-weaning performance. It is not within the scope of this paper to do a detailed review of this whole topic but rather focus on some key elements of improving the bottom 20% pig performance.

## Increasing litter size

In most key markets there has been a large increase in the number of pigs born alive per litter and in Denmark they are now targeting 35 pigs weaned per sow per year. In the USA there has been a mean litter size increase of 1.2 pigs born alive since 2005 with the top ten percent of the market increasing litter size by almost 1.5 pigs born live (Figure 1). This drive for greater litter size improves financial return as the pork marketed per sow per year increases while the cost per weaned pig is reduced. Indeed a combination of greater pigs weaned per sow and heavier slaughter weights make the 4 tonne per sow target already achievable in some of the top units in the USA. This increased litter size can however come at a cost with smaller birthweights leading to an increased level of mortality (pre-weaning and lifetime) as well as poorer growth performance post-weaning. Management and nutritional practices that can assist the small piglet performance have become more important in maximizing pork output per sow.

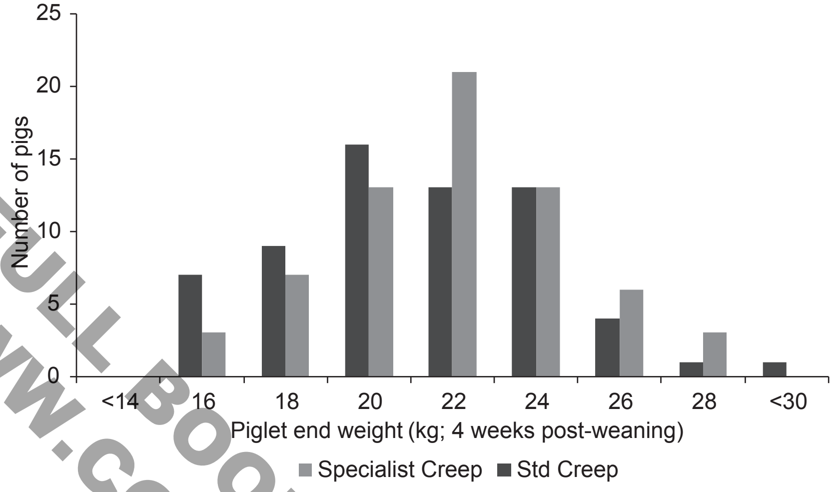

**Figure 6.** Impact of creep feeding on variation in pig weight at 28 days post-weaning (Personal Communication: Almond, 2013)

One of the aforementioned studies was conducted at Harper Adams University. In this study pigs were fed a standard creep or specialised creep pre-weaning after which all pigs were fed a common feeding regime to slaughter. The results showed that pigs that had been fed the specialist creep pre-weaning had an extra 4.3 kg at slaughter (Figure 7). This series of studies confirm the importance that creep feeding can have on pre-weaning and lifetime performance whereby the percentage of small pigs are reduced and that different creep feeds can impact performance differently.

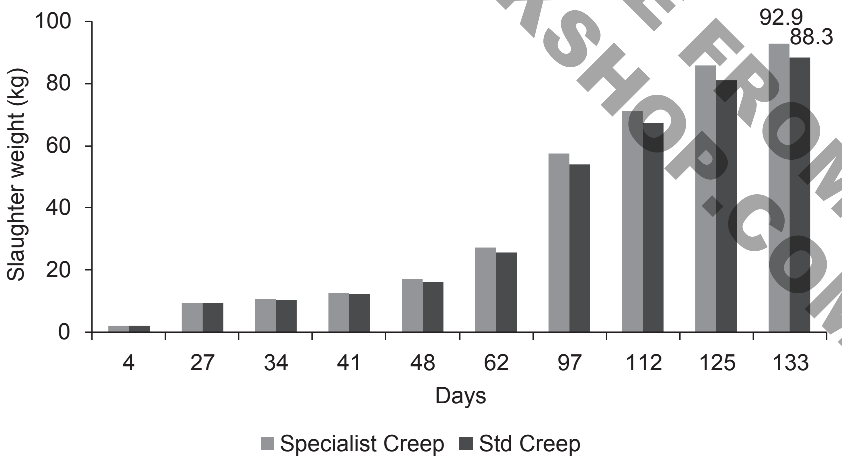

**Figure 7.** The effect of feeding a specialist creep on lifetime performance. (Creep was fed until weaning at 27 d after which all pigs were fed the same feed programme) (Personal Communication: Almond, 2013)

# 12

# FERMENTED PRODUCTS AND DIETS FOR PIGS

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## Fermenting diets

Fermenting diets under optimum conditions should increase the content of microorganisms in the diet, particularly the content of lactic acid bacteria. If the fermentation is successful, it may also affect the microbiological balance in the gut and also reduce the level of diarrhoea. However, results have shown that if the total diet is fermented, productivity drops as feed intake is reduced (Pedersen, 2001; Pedersen *et al*., 2002b; 2002c). Fermenting grain and soya bean meal to which inoculums are added also showed a negative effect on productivity (Pedersen and Lybye, 2012). Therefore, it is not recommended to ferment either diets or soya bean meal, but fermenting the grain (wheat and/or barley) increases feed utilization as digestibility of energy improves  (Pedersen *et al*., 2002a; Pedersen, 2006; Pedersen *et al*., 2009; Pedersen *et al*., 2010; Pedersen and Canibe,2011) and digestibility of phosphorus in grain increases during fermentation (Pedersen *et al*., 2010).

The reason for the reduced feed intake of fermented complete diets is not clear, but the level of biogenic amines and organic acids increases through fermentation and may affect palatability of the feed. The pH value of the diet fed to pigs should never be below 4.5. A pH below this is an indication of excessive fermentation of the diet leading to production of compounds that affect feed intake.

When a complete feed is mixed in a tank, it should be fed to the pigs immediately to avoid loss of synthetic amino acids. However, residuals in the pipes will lead to loss of synthetic amino acids; it is assumed that 8 hours in the pipes will lead to total loss of synthetic lysine (Pedersen and Jensen, 2005). Consequently, Danish farmers are recommended to add more protein and synthetic amino acids to diets if they have residuals in the pipes. Loss of amino acids through fermentation can be avoided by adding formic acid (0.2%) or by using liquid feeding systems without residuals in the pipelines.

## Fermenting grain

The optimum process is achieved if the grain is fermented in a separate tank. Grain and heated water (approximately 20°C) are mixed and left for five days before being fed to pigs in order to start the fermentation process. When diets are produced, 50% of the fermented grain is used daily, and new grain and hot water should be added once a day (Figure 1).

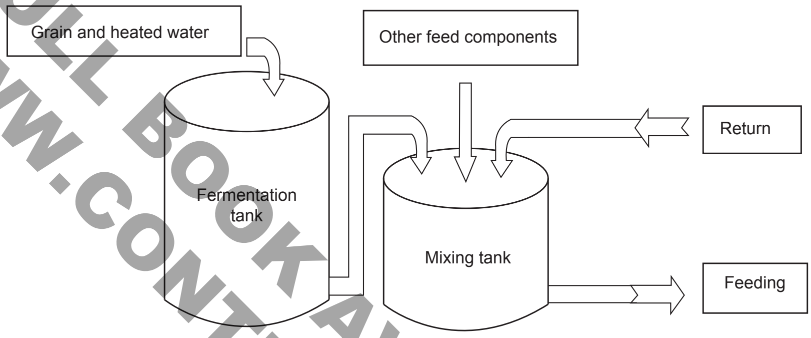

**Figure 1.** Liquid feeding system with fermentation of grain.

Fermenting grain was investigated in three trials with finishers and one with weaners in different herds. The results demonstrated that feeding weaned pigs fermented grain reduces productivity (Pedersen *et al.*, 2009) probably due to excessive fermentation of the complete diet the pipeline, but improves productivity among finishers (Pedersen *et al.*, 2002a; Pedersen, 2006;Pedersen and Canibe, 2011).

Fermenting grain degrades the fibre that is indigestible for pigs, particularly Non Starch Polysaccharides (NSP), leading to a reduction in dry matter of about 1% and increasing the content of lactic acid. The content of lactic acid in fermented grain is approximately100 mmol per kg liquid feed. Fermenting grain leads to a reduction in the use of grain by 2-3% in the diet as the energy value of fermented grain is higher compared to unfermented grain. Digestibility of phosphorous in grain is also increased by fermentation.

## Fermentation of rape seed

The nutritional value does not improve when rapeseed cake is fermented – quite the contrary. Weaner diets (from 9 kg) with fermented rapeseed cake must be approximately 11% cheaper than diets with regular rapeseed cake or soyabean meal. Fermented rape seed cake for weaners showed a reduction in productivity

## 13

# Highlights of the 2012 Swine NRC

BRIAN J. KERR - ON BEHALF OF THE SWINE NRC 2012 COMMITTEE

*USDA-ARS-National Laboratory for Agriculture and the Environment, Ames, IA, USA*

## Introduction

In conjunction with the Animal Nutrition Series developed by the National Research Council of the National Academies, a committee at the end of 2009 was appointed and initiated efforts towards the revision of the 1998 Swine NRC, beginning in January 2010. It had been approximately 14 years prior to the last revision (10th edition, NRC 1998) and even longer since the literature review included in 1998 revision. The committee was comprised of: L. Lee Southern, Chair, Louisiana State University Agricultural Center, Baton Rouge; Olayiwola Adeola, Purdue University, West Lafayette, Indiana; Cornelis F. M. de Lange, University of Guelph. Ontario; Gretchen M. Hill, Michigan State University, East Lansing; Brian Kerr, Agricultural Research Service, U.S. Department of Agriculture, Ames, IA; Merlin D. Lindemann, University of Kentucky, Lexington; Phillip S. Miller, University of Nebraska, Lincoln; Jack Odle, North Carolina State University, Raleigh; Hans H. Stein, University of Illinois, Urbana-Champaign; and Nathalie L. Trottier, Michigan State University, East Lansing.

The committee was charged with a specific statement of task to tackle the process of the revision. The statement highlighted the need to: incorporate information documenting amino acid (AA) needs for modern lean genotypes, identify new knowledge relative to energy utilization especially related to net energy, include description of novel ingredients from the biofuel industry, estimate digestible phosphorus requirements and concentrations in feed ingredients, review the role of feed additives in swine diets, document effects of feed processing on nutrient utilization, identify strategies to increase nutrient retention and thereby reduce nutrient excretion, consider (based on the current status of available information) development of a computer model to estimate nutrient requirements; and expand/refine feed composition tables. In addition, the committee was instructed to highlight future research needs.

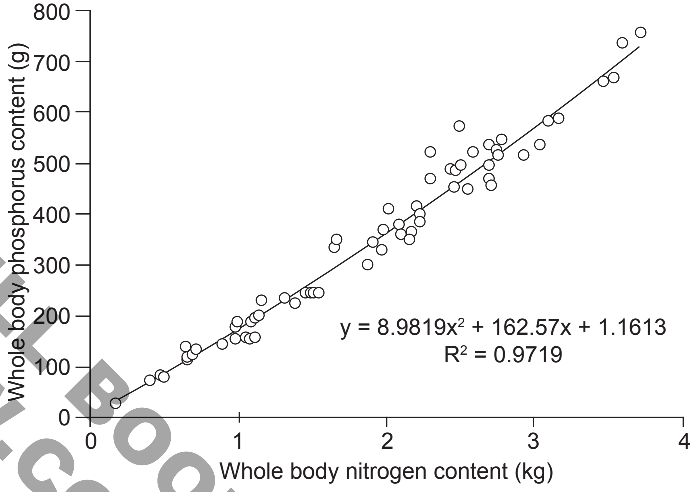

**Figure 2.** Relationship between whole-body phosphorus and whole-body nitrogen content in growing-finishing pigs, NRC (2012).

Models were then used to establish STTD P and total Ca, with factorial estimates of requirements for STTD P and total Ca are provided in tables for starting, growing-finishing, gestating and lactating pigs. Calcium requirements are based on P deposition and assumed to be a fixed conversion based on physiological state and tissue needs.

A factorial approach similar to that used for growing-finishing pigs was used to estimate STTD P and total Ca requirements for gestating and lactating sows. In general, protein deposition in fetal (including placental fluids), milk, and maternal tissues (including mammary) was the factor driving P content and retention.

## Models

A number of the key model elements (growing-finishing, gestation and lactation) have been discussed previously. The three NRC (2012) models to estimate nutrient requirements of growing-finishing pigs, gestating sows and lactating sows are dynamic, mechanistic and deterministic. The models are dynamic because changes in energy utilization and nutrient requirements are represented on a daily basis. This is in contrast to the NRC (1998) sow model in which only mean values across entire gestation or lactation periods were considered. As a result, daily changes in nutrient requirements can be assessed for the development of phase feeding programs for specific groups of pigs, especially growing-finishing pigs and gestating sows.

## 14

# FEED PROCESSING TECHNOLOGY TO IMPROVE FEED EFFICIENCY IN PIGS AND POULTRY

CHARLES STARK, PH.D.

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## Introduction

Producing meat, milk, and eggs to feed 9 billion people by 2050 will be a challenge for the feed and livestock industries worldwide. This challenge will require feed mills to evaluate new technology that will process more by-products from the food and bio-fuels industries into animal feeds. While there have been significant technological changes in feed mills over the last 100 years, the core feed manufacturing processes of grinding, batching/dosing, mixing, and pelleting have withstood the test of time.

The objectives of pig and poultry feed manufacturing are to grind cereal grains to improve digestion, and to combine by-product ingredients from food processors, renders, and bio-fuels industries to create a safe, high quality feed that optimizes animal and bird performance. The adoption of new technology in the feed industry has occurred at a much slower rate as compared to the food industry. The greatest opportunity for improvement may be in the area of data management, specifically the application of statistical process control (SPC) to the feed manufacturing process. Feed mills continue to get larger with more processes being monitored and controlled through the automation system. Koeleman (2014) stated, "More and more things are measured in the feed mill (such as) temperature and moisture content of raw materials before and after they go into the conditioner or extruder. But the challenge is how to deal with the data, otherwise it has no value." The slower rate of adoption may be due in part to the lower profit margins associated with commercial feed sales or the fact, that within an integrated animal production system, the feed mill is simply a cost center charged with delivering nutrients to animals.

Development of new technology or adaption of technology from other industries is often driven by consumer demands and government regulations. Feed mills must often compete for capital expenditures in large corporate environments, which is difficult when the return associated with improved animal performance or increased feed sales is sometimes difficult to measure.

# 15

# GILT MANAGEMENT AND NUTRITION: AN OVERVIEW

LIA HOVING[1], SIMON TIBBLE[2] AND PATRICIA BECKERS[3]

*[1] Species solution manager swine EMEA, Provimi B.V., Cargill; [2] Global Swine Nutrition Manager, Provimi, Cargill; [3] Global Swine Technology leader, Cargill*

## Introduction

Due to genetic progress sow production has increased dramatically over the past decade. Depending on country, the number of piglets born alive has increased by 1 to 2 piglets per litter resulting in an increase of 2.0 to 4.5 piglets weaned per sow per year (Table 1). Increased production levels put more and more pressure on the sow as a producer of milk and meat. As a result, sow feeding and management practices need to keep evolving constantly, not only to support optimal piglet growth, but also to maximise sow longevity.

**Table 1. Increase in number of piglets born alive and weaned per sow per year over the past decade for the United Kingdom, Ireland and The Netherlands. Source: Bpex, Aetagc, Agrovision B.V.**

| Country | 2003<br>Born alive/litter | 2012<br>Born alive/litter | 2003<br>Weaned/sow/year | 2012<br>Weaned/sow/year |
|---|---|---|---|---|
| United Kingdom | 10.9 | 11.9 | 21.5 | 23.6 |
| Ireland | 11.0 | 12.6 | 22.8 | 25.7 |
| The Netherlands | 11.6 | 13.9 | 23.3 | 27.9 |

Besides optimal gestating and lactation feeding strategies, (nutritional) management of the replacement gilt has a large influence on sow productivity and longevity. Since gilts are the future sow herd, optimising gilt rearing, and also management of the young pregnant gilt, are crucial for a long productive life.

This chapter describes management and nutritional factors related to replacement gilt rearing. The authors are aware that most studies are from the 1990s and early 2000s; however, only a limited amount of research has been done with modern genetics. Wherever possible, the literature will be related to practical recommendations while taking into account recent trends in improving sow genetic potential.

the benefit of a specific gilt developer programme, designed to meet the nutritional requirements of the rearing gilt, compared to standard finisher and gestation sow programmes. The trial comprised 100 gilts selected at 55 kg live weight, to determine the effect of three gilt nutritional programmes on gilt performance (Table 4).

**Table 4. Feeding programmes tested by Teagasc (Ireland)**

| Weight Range | Gilt developer* | Finisher diet | Gestating sow |
|---|---|---|---|
| 65-100 kg | Developer (restricted**) | Finisher (ad lib) | Finisher (ad lib) |
| 100-130 kg | Developer (restricted**) | Finisher (ad lib) | Gestating (restricted**) |
| 130-140kg*** | Developer (ad lib) | Finisher (ad lib) | Gestating (ad lib) |

* Gilt developer diets were fortified with organic trace minerals, such as zinc, copper and manganese;
** Restricted = 2.25 kg/day; *** Gilts were slaughtered at 12 weeks of age.

General gilt performance parameters, as well as additional parameters such as locomotory ability, joint abnormalities and bone density at 12 weeks, were recorded. The gilt developer programme significantly reduced lameness (Table 5), as well as claw lesions, claw size and surface lesions on the cartilage of elbow joints.

**Table 5. Gilts (%) affected by lameness during the trial period Teagasc (Ireland)**

| Period | Gilt developer | Finisher diet | Gestating sow |
|---|---|---|---|
| Day 0 | 0 | 0 | 0 |
| Wk 1-4 | 0 | 2.2 | 2.1 |
| Wk 5-8 | 0 | 9.1 | 20.8 |
| Wk 9-12 | 0 | 17.7 | 14.6 |

## Vitamins and minerals

Next to reduced fertility, a major cause of culling in the 1st two parities, representing 25% of total culled sows in a herd, is caused by locomotive problems as defined by lameness, osteochondrosis and claw health. This could be associated with poor mineral supplementation during the rearing period.

The 2012 NRC recommendations show that requirements for calcium (Ca) and phosphorus (P), in order to maximize bone strength and bone ash, desired for replacement gilts, are 0.1 percentage units higher than requirements for optimal gain, wanted for finishers. Besides C and P, Vitamin D and magnesium (Mg) are needed to optimize calcium metabolism and thereby support bone development. Besides the direct effects on culling, lameness has indirect consequences on reproductive performance since it negatively affects production and release of reproductive hormones, apart from the obvious direct causes such as poor lactation, feed intake and physiological changes associated with infection and inflammation.

Although there is limited research on the effect of vitamin and trace mineral supplementation on gilt development, those associated with fertility and immunity

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