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FEED CONFERENCE

ABSTRACTS

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46th University of Nottingham Feed Conference. 24-25 June 2014 www.nottingham.ac.uk/feedconf
Managing nutrition to improve metabolic health and reproduction of dairy cows

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Nutrition is one of the keystones of dairy farming, next to genetics and management. When nutrition is not optimal, the farm will lose money. Nutrition errors may be in the area of quality and quantity of feedstuffs or nutrients, and/or in the area of general and daily nutrition management. The occurrence of a negative energy balance (NEB) in higher yielding cows has become a serious issue. Although in truly high yielding cows NEB may partly be physiological, in most other cases NEB represents a patho-physiological situation. These cows have physiologically not been able to adapt to the situation of an increasing milk production around and/or after calving with high energy demands while demands for fibres remain. Triacylglyceride levels increase from 12.4 mg/g at 4 days pp to 61.8 mg/g at 1 week pp and 82.1 mg/g at 2 weeks pp; NEFAs increase from 0.4 mmol/L at 4 days ap to 1.25 mmol/L (1 wk pp) and 1.60 mmol/L (1.5 wk pp). Rumen function is often hampered. The process of adaptation is influenced by different factors: poor housing and barn climate rendering adaptation much more difficult; stress conditions like in lactating heifers competing for feed with adult cows, or during heat stress; genetic variation between cows: some can adapt more easily than others; nutritional issues such as ad libitum feeding or TMR feeding which is not adequate for a particular lactation group; poorly composed rations (cheap rations – poor commodities); feeding a too ketogenic or acidogenic ration; poor frequency of distribution of feed; poor TMR handling causing fibres too small for optimal rumen function; all factors leading to stress in cows and hence an impairment of the immune response; all factors causing a decrease in feed intake (e.g. sickness; overcrowding; overcondition; poor bunk space; poor resting space; poor cow comfort).

The first result of a poor adaptation is the occurrence of NEB. Cows are ‘not doing well’ after calving. This is shown in a reduced feed intake (poor rumen fill score; deviating faeces quality scores; loss of body condition, BCS) and a loss of milk yield. The energy demands are higher than the cow can supply through its rations. Fat is mobilized to counteract the latter, resulting in large amounts of fatty acids circulating (non-esterified fatty acids, NEFA; triacylglycerides). The latter will end up in the liver and could be used as an energy source, but in surplus they affect liver function (fatty liver disease) and metabolites like betahydroxybutyrate, BHB, and other ketone bodies will circulate. NEB hence often results in ketosis (and possibly acetonemia) and even rumen acidosis. A prevalence of 30% (variation from 10 to 60%) has been reported in a UK based 2013 study, against 0.5% acetonaemia, the clinical form. Ketosis can –next to detection by cow-side tests on milk or urine— be checked in blood samples: betahydroxybuturate (BHB); the accepted target threshold is at < 1200 µmol/dL. Furthermore, NEFA are circulating in NEB affected cows; their target threshold in blood is at < 0.6 mEq/L. Ketosis can also be detected by checking milk recording forms over subsequent dates of fresh cows. Parameters to look for are milk yield per cow, milk fat content, milk protein content, the milk-fat-to-milk-protein-ratio. In ketotic cows, milk yield often drops, milk fat increases or remains stable, milk protein decreases, and the ratio is > 1.5. A disturbed liver function is reflected by the fact that in this
case the conversion from ammonia NH3, from proteolysis, to urea is hampered; milk or blood urea levels are hence an indirect indicator for NEB-ketosis (high urea) and acidosis (low urea) problems in the herd. In the case of **rumen acidosis** (most often it is the subacute form in dairy cows, **SARA**) the rumen papillae which are shorter and less functional in the dry period have not been able to adapt to a new nutrition situation; rumen flora is of the cellulolytic type which should change to amylolytic; protozoa may die; digestion is poor; the pH decreases at levels below 5.6. SARA herd prevalence of 19 - 26% has been reported; over 50% of the herds may be affected. Economic losses of around €15,000 for a 500 cattle herd have been described. A major cause is feeding high levels (> 50%) of maize or cereals, or too much (>30%) easily fermentable glucosides (pectines) and/or too few fibres (< 18% DM) to freshly calved cows with poor rumen function. Acidotic cows often show a decreased milk fat content, a stable or increased milk protein content, and a ratio of < 1.2 in milk recording forms. Milk fat content may be even less than milk protein content (called **inversion**). Possibly too much by-pass starch was supplied. In general, NEB problems can be expected in cows with milk fat content > 4.8% or < 3.5%, and a milk protein < 2.9%. Ketosis and acidosis may sometimes occur in the same cows.

Next to milk production problems, further **consequences of NEB, ketosis and SARA** are cattle health and reproduction. Ketosis leads to immune suppression (downregulating pro-inflammatory and anti-inflammatory responses) and then to an increased risk of mastitis, infectious claw lesions and other infections. Cows with ketosis in a study by van Holder (2013) showed an increased risk of other disorders such as dystocia (OR 1.7), retained placenta (OR 2.2), milk fever (OR 1.8), other metabolic disorder like SARA (OR 4.5), mastitis (OR 2.3), abomasal displacement DA (OR 2.7), acetonaemia (OR 11.5). These disorders represent huge economic losses for a dairy farm. The first two disorders hence even before calving. With respect to reproductive problems one may notice a poor oocyte development and quality, poor oestrus expression, poor pregnancy results, metritis, cystic ovarian disease. Too high rumen degradable protein levels have been associated with early embryonic death.

**Treatment and prevention** of forenamed problems are in the domains of nutrition and management. Management should allow cows to adapt properly (group feeding; gradual increase of concentrates pp; frequent feeding on the day). Furthermore the farmer should eliminate risk factors in housing, barn climate, social stress, heat stress, overcrowding, or at least reduce their impact on cows; cow comfort should be optimized. The farmer should observe his cattle more closely to detect pending problems early. Forenamed issues are centered around an optimal cow comfort, optimal immune responsiveness, and the best possible benefits from high quality nutrition and nutritional management. With regard to nutrition, the fibre content should be > 18% in DM and the butyric acid level < 15% (acidosis). Antibiotics, ‘positive’ bacteria and yeast have been proposed as treatment; effects are however hardly conclusive. The farmer should envisage the composition of specific rations for specific lactation stages to optimally accommodate the transition from lactation to dry period, from dry period to lactation, and up to the peak milk yield. Especially for these cows feed quality should be the highest. A high insulin ration around calving and a low insulin (low carbohydrate and/or high fat) ration to start up follicle development would be a good option, although contradictory and hence difficult to realize. Fat source is important (avoid polyunsaturated fatty acids). Fish meal supplies (eicosapentaenoic acid; docosahexaenoic acid) could be beneficial to maintain pregnancy through corpus luteum.
viability increase. Supply of minerals (Ca, Se, Cu, Zn, Mn) and vitamins (A-D-E) in a balanced way is a must, if pretestings have shown deficiencies in forages and or in cows. At all times, energy contents in the rations should be controlled at each stage of lactation.
Physiological role of carnitine in energy metabolism, possible interplay with inflammation and potential benefits for dairy cows

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Carnitine is a naturally occurring substance. It was detected in 1905 as an ingredient in the muscle. In contrast to the D-isomer, the L-form plays an essential and crucial role in the energy metabolism of human and animal organisms. The main function is to shuttle long chain fatty acids into the mitochondria for β-oxidation and finally to drive the citric acid cycle. This role is well known and published in literature. However, the crucial role of carnitine in regulating carbohydrate- and fatty acid metabolism is rarely considered. Carnitine is defined by many scientists as conditionally essential.

Positive impacts of L-carnitine as a supplement to diets in humans and livestock are well documented. Extensive research in sows proved the benefits of a carnitine supplementation during pregnancy and lactation. Metabolic load in the transition period of cows could be repeatedly reduced through carnitine supplementation in many trials. Carlson et al. (2007) showed significant beneficial impacts of different carnitine supplementations on liver lipid accumulation, hepatic nutrient metabolism, and lactation in multiparous cows during the periparturient period. The authors thus conclude that by decreasing liver lipid accumulation and stimulating hepatic glucose output, carnitine might improve glucose status and diminish the risk of developing metabolic disorders during early lactation. Scholz et al. (2014) divided 262 HF dairy cattle into two groups according to their lactation number. The trial group (CP) received 10 g of a rumen-protected carnitine product i.e. 2 g pure carnitine per cow and day. The control group (C) was fed 10 g barley instead. Carnitine lowered the content of non-esterified fatty acids in the blood by trend, improved fat/protein ratio in milk and reduced milk somatic cell count. Moreover, it is worth mentioning that L-carnitine improved the health status and fertility of the cows (table 1).

<table>
<thead>
<tr>
<th></th>
<th>Control group</th>
<th>Carnitine group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days open</td>
<td>75</td>
<td>74</td>
</tr>
<tr>
<td>Insemination ratio</td>
<td>2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>pregnancy rate *)</td>
<td>71</td>
<td>86</td>
</tr>
<tr>
<td>Total treatments</td>
<td>1.64</td>
<td>1.17</td>
</tr>
<tr>
<td>Fertility treatments</td>
<td>0.28</td>
<td>0.17</td>
</tr>
<tr>
<td>Udder treatments</td>
<td>1.32</td>
<td>0.93</td>
</tr>
</tbody>
</table>

*) % pregnant cows at day > 200, not pregnant cows were culled

Table 1: Impact of carnitine on fertility and veterinary treatments (Scholz et al, 2014)

Endogenous Biosynthesis

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. Certain physiological conditions may lead to insufficient biosynthesis of carnitine especially under anabolic conditions due to reduced protein degradation. This in turn leads to a lack of TML. Moreover, the demand for carnitine
increases during negative energy balance due to increasing fatty acids stemming from mobilized body fat (table 2).

<table>
<thead>
<tr>
<th>condition</th>
<th>Cause of impaired carnitine synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>pregnancy</td>
<td>Anabolic condition: reduced release of TML from muscle</td>
</tr>
<tr>
<td>Obesity</td>
<td>Metabolic syndrome / chronic inflammation ?</td>
</tr>
<tr>
<td>High fat diet</td>
<td>Increased levels of free fatty acids / chronic inflammation ?</td>
</tr>
<tr>
<td>Inflammation ?</td>
<td>Reduced carnitine synthesis / function ?</td>
</tr>
</tbody>
</table>

Table 2: Conditions probably leading to an insufficient endogenous carnitine synthesis (Eder 2013)

*Functions and mode of action of L-carnitine*

The most important functions of L-carnitine in the endogenous metabolism are as follows:

shuttle medium- and long-chain fatty acids into the mitochondria (shuttle)

modulate the acetyl-CoA : CoA ratio and thereby regulate carbohydrate- and fatty acid metabolism (buffer)

*Shuttle function*

Fatty acids must first be transported into the mitochondrial matrix for β-oxidation to serve as a fuel for energy metabolism. In a first step the fatty acids must be activated by the cofactor CoA. As the matrix is impermeable for these activated fatty acids the cofactor CoA is substituted by carnitine. Acetyl-carnitine can now permeate the mitochondrial matrix. Once inside carnitine is in turn replaced by CoA. Acyl-CoA is now available for β-oxidation and carnitine leaves the matrix for another round (fig 2).

*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 showed that with increasing performance or energy deprivation the excretion of Acetyl-carnitine via urine and milk is increased. Schlegel et al. (2012) showed that the loss of carnitine via milk in early lactation of dairy cows was 215.5 mmol/l in week 1. By week 14 carnitine content in milk had decreased to 101.5 mmol/l. It is noteworthy that the ratio free carnitine : acetetyl carnitine was inverted from 84.5 : 131.1 to 60.2 : 41.3. These relations correspond very well with the carnitine blood parameters which were analyzed simultaneously. Also in humans the renal excretion of carnitine esters increases when fasting or performing endurance sports. These results can be explained by the modulation of the acetyl-CoA/CoA ratio.

Following β-oxidation acetyl-CoA condenses with oxaloacetate to form citric acid and drive the citric acid cycle. In the negative energy balance during early lactation the animals start to mobilize body fat leading to an increasing quantity of acetyl-CoA. At some point this will exceed the capacity of the mentioned pathway to the citric acid cycle. In ruminants the situation is aggravated due to a lack of oxaloacetate which is needed for gluconeogenesis. Consequently ketogenesis accelerates. More and more ketone bodies are built up, leading to considerable metabolic disorders, especially in dairy cows.
In such a metabolic situation most of the CoA in the mitochondria is fixed to the activated fatty acids and thus not available for other metabolic functions. The enzyme pyruvate dehydrogenase in particular plays a crucial role here. This enzyme catalyzes the reaction of pyruvate and its precursors, glucose and glucoplastic substances, with fatty acids.

If sufficient free carnitine is available in the mitochondrial matrix carnitine again replaces the CoA in the surplus acetyl-CoA. CoA is released and acetylcarnitine removed from the mitochondrial matrix in return with free carnitine from the blood. If the capacity of this converse metabolism is exceeded acetylcarnitine is excreted via urine and milk. The simultaneously increasing pool of free CoA in the mitochondrial matrix is essential to activate the PDH (fig 1).

Fig. 1: Function of carnitine in the transport of mitochondrial long chain fatty acid oxidation and regulation of the mitochondrial Acetyl-CoA : CoA ratio (Vaz and Wanders, 2002)

**Effects of carnitine in the Randle cycle**

The main fuels for energy metabolism in the organism are glucose and fatty acids reaching the mitochondria, the energy factory of the cells, via separate pathways. In 1963 Randle already described the competition between these two pathways. Increasing glucose oxidation occurs at the cost of the fatty acids and vice versa. This "glucose-fatty acid cycle" or "Randle cycle" does not describe a metabolic cycle like the citric acid cycle but dynamic interaction between substrates. Competition between the substrates glucose and fatty acids explains why excessive fatty acid oxidation inhibits use of glucose or glucoplastic substances and thereby reduces insulin sensitivity (Fig. 2).
Fig. 2: Mechanism of inhibition of glucose utilization by fatty acid oxidation. The extent of inhibition is graded and most severe at the level of PDH. PDH inhibition is caused by acetyl-CoA and NADH accumulation resulting from fatty acid oxidation (Hue and Taegtmeyer, 2009).

Modulation of acetyl-cCA/CoA ratio by carnitine as described above already implies that carnitine – if available in the mitochondria – can influence this competition of the substrates in favour of glucose (Ffig. 3). Carnitine in general plays an important role in glucose homeostasis.
Carnitine and inflammation

Research shows that subclinical and chronic inflammation in the transition period of farm animals is a serious problem. Trevisi et al. conclude that feed intake and energy efficiency postpartum is significantly reduced due to an inflammatory response (2013). As described by Liu et al. (2012) the initiating pro-inflammatory phase is anabolic and needs glucose as a fuel while the adaption phase is catabolic requiring fatty acid oxidation. This is in accordance with the transition period shifting from anabolic to catabolic at parturition. Steinberg et al. (2009) explained how energy metabolism is steered by inflammatory agents, for example the cytokines TNF-α, IL-6, resistin. Ye et al. (2011) described the regulation of energy metabolism by inflammation as a feedback response of the body to get rid of the energy surplus stored in the body fat. Carnitine biosynthesis and carnitine uptake into the cell are probably impaired by inflammation, which thus may aggravate the problem.

Conclusion: Carnitine supplementation beneficial

Physiological functions of carnitine are manifold. Biosynthesis is reduced under anabolic conditions, as e.g. in pregnancy. Carnitine demand is increased in catabolic metabolism like negative energy balance after parturition. Subclinical and chronic inflammation may aggravate the problem by inhibiting carnitine biosynthesis. Consequently, it would seem appropriate to supply additional exogenous carnitine to dairy cows in the transition period.
Considerations for Feeding Starch to High-Yielding Dairy Cows

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Why feed starch?

Dairy farmers are paid for the amount and quality of the milk they sell, thus through genetic selection and advances in management there have been long-term and sustained increases in average milk yield of dairy cows. Feed intake capacity has increased along with milk yield, but body energy loss in early lactation appears to be an unavoidable consequence of high milk energy output that drives high levels of feed intake. However, excessive body energy loss can have negative effects on health, reproduction, and longevity. To maximize milk solids yield and minimize body energy loss diets for high-yielding dairy cows are typically formulated for maximal intake of absorbable nutrients and energy using available feed resources. In practical terms, this has been accomplished through the addition of more digestible concentrate feeds containing starch from cereal grains. Diets are formulated on the basis of concentrations and characteristics of carbohydrates, fats, and proteins (as well as minerals and vitamins), with the carbohydrate fractions characterized through available analytical methods into neutral detergent fibre (NDF) and neutral detergent solubles or non-NDF carbohydrates (non-fibre carbohydrates or NFC), which include starch, sugars, and pectin. In simple terms, specific recommendations are given for NDF and NFC to maximize intake of digestible, rumen fermentable substrates without negative effects of excess fermentation end products. These recommendations are adjusted for specific sources of NDF and NFC.

Benefits and risks of feeding starch

Dairy cows typically derive the majority of their metabolizable energy (ME) and metabolizable protein (MP) from rumen microbial production of volatile fatty acids (VFA) and protein, respectively. Benefits of feeding starch include increased ME and MP supply and thus greater milk and milk protein yield compared to feeding less digestible NDF. Other benefits include reduced enteric methane production and improved glucogenic nutrient supply. The latter may lessen the severity of negative energy balance in early lactation and prevent ketosis. In addition to being more digestible and having a greater ME concentration, it has long been known that the efficiency of using ME from starch is greater than for ME from forages. However, the rumen has evolved to digest forages, and a risk of feeding starch is production of excess VFA by microbes in the rumen, reduced milk fat concentration, and associated effects of low rumen pH on rumen function, NDF digestion, and cow health.

Site of starch digestion

Ruminants normally absorb little if any glucose from their small intestine and rely on glucose synthesis from propionate and other precursors to meet their glucose requirements, which are substantial in high-yielding dairy cows. Propionate from rumen fermentation is the major
glucose precursor and increased rumen digestion of starch will generally shift VFA patterns in the rumen towards a higher ratio of propionate to acetate, which is used for fat synthesis in mammary and other tissues (lipogenic). Rate of starch degradation is determined by a number of factors, including source and processing. Predicting the rate and extent of starch digestion in the rumen is essential for predictions of ME and MP supply, but predictions based on nylon bag degradability may under predict rumen degradation and thus refinements to estimates are needed. Absorbed propionate is an important regulator of feed intake in ruminants, thus one potential disadvantage of increased starch digestion in the rumen is a reduction in feed intake. This reduction may also be attributable to reduced NDF degradation in the rumen due to lowered rumen pH. In addition, it is energetically more efficient to digest starch directly to absorbable glucose in the small intestine, rather than digesting the starch in the rumen to VFA and other products, of which the propionate can be converted to glucose in the liver. For this reason there has long been interest in the potential benefits of rumen escape starch for high-yielding dairy cows, particularly during early lactation when glucose requirements are high relative to ME intake. The capacity for starch digestion in the small intestine of lactating dairy cows is high, but starch reaching the small intestine is by nature less digestible than starch digested in the rumen, thus with increasing flow of starch to the small intestine more starch digestion in the hindgut also occurs. In published studies increased supply of glucose from the small intestine or propionate from the rumen increased milk yield and protein concentration, but reduced milk fat concentration such that milk energy yield only increased at higher levels of provision and the majority of the increased energy supplied was used for body tissue energy and protein retention. These effects have been associated with more positive body energy balance and improved fertility in early lactation, but increased glucose supply may also suppress intake, limiting milk yield response.

**Rumen acidosis**

There has long been concern regarding the potential negative effects of feeding rumen degradable starch, and other NFC substrates, arising from acid accumulation and reduced pH in the rumen. The extent of the pH reduction depends on a number of factors, including rate and extent of rumen carbohydrate degradation, pattern of intake, forage characteristics, and stage of lactation. Clinical rumen acidosis is a serious condition with major implications for welfare and health, but another concern is so-called sub-clinical rumen acidosis (SARA). In addition to measurement of rumen pH, indicators of SARA include decreased milk fat concentration, variable intakes, and abnormal faeces. The problem reflects an imbalance between the amount of fermentable substrate in the diet and NDF that is ‘effective’ at promoting rumination and saliva production, thus the physical structure of NDF is important. Continuous monitoring of rumen pH shows variability in the postprandial patterns of rumen pH among cows, with some cows classed as having SARA, whilst other cows consuming equal amounts of the same diet classed as having normal rumen pH patterns. These differences in rumen pH between cows may relate to differences in intake pattern, milk yield, VFA absorption, and rate of digesta passage. It appears that SARA may be ‘normal’ in early lactation cows with high levels of intake and milk yield, but cows exhibiting variability in their day to day patterns of rumen pH are more of a concern. In the USA, diet concentrations of NDF and NFC recommended for lactating dairy cows seem low and high, respectively, relative to diets typically fed in Northern Europe. However, recommendations for the US are based on feeding maize grain, which is less degradable than wheat or barley starch and therefore reduces the requirement for physically effective NDF.
**Feeding food to cows?**

Concerns regarding future food security have fuelled discussion regarding the perceived competition between cereal grain use for milk and meat production by animals and human grain consumption, leading some to suggest that in future ruminants should be ‘fed no food’. In reality, much of the cereal grain fed to ruminants is not of milling quality, and supply, demand and cost are and will be a major determinant of amounts of grain fed in rations for dairy cows. In recent years ethanol production has limited maize grain use in US dairy rations where the focus has shifted to feeding distillers grains and other co-products, thus ‘low starch’ diets for high-yielding dairy cows have already become a reality. It is likely the future will see further shifts away from cereal grains and towards greater use of co-products from bioenergy production and human food processing in rations for high-yielding dairy cows.

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Nitrogen efficiency and amino acid requirements in dairy cattle

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Although ruminants are less efficient in feed protein use than monogastric livestock animals, their human edible protein efficiency is substantially higher than for monogastrics and is usually larger than 1.0. However, ruminant animal protein production is also characterised by high manure nitrogen (N) excretion and relatively low N use efficiency and by the environmental impact of manure N and from land use changes for feed production. This presentation will focus on new developments and perspectives in protein and amino acid (AA) metabolism in the dairy cow that affect the efficiency by which feed N is secreted into milk N.

Summarising data from various studies has shown that an increase in N intake increases milk protein secretion. However, the relationship between N intake and milk protein secretion is influenced by the research treatments employed in the studies reported, where animals are typically fed to meet requirements. In experiments, marginal efficiencies by which additional dietary protein is secreted in milk protein are 38% or lower, being much lower than assumed in various protein evaluation systems (64 to 68%) and also much lower than theoretical maximum efficiency (85%).

Because surplus feeding of protein has only a marginal effect on animal performance, but a significant effect on urinary N excretion and hence emissions of NH$_3$ and N$_2$O, the question has arisen as how to define the optimal protein level for dairy cattle. This was recognised many decades ago resulting in the development of new protein evaluation systems based on the rumen digestive processes and aiming to predict the supply of absorbable and metabolisable protein (MP) and minimising N losses in the rumen. These new protein evaluation systems aim to enable nutritionists to use smaller safety margins at feed formulation, which should result in a reduction in dietary N levels. Strategies to reduce N losses and improve N efficiency should focus on an optimal supply of rumen degradable N and on an optimal utilization of absorbed AA for milk protein synthesis.

**Inefficiency of microbial protein synthesis**

The ruminal microbial population not only converts dietary protein and non-protein-N into digestible microbial protein, but also into other N components, such as nucleic acids, which are not used for milk protein synthesis. Moreover, the levels of ammonia-N and amino acid or peptide-N in the rumen required for maximal microbial protein synthesis give rise to a net unavoidable N loss in urine. Minimising such losses requires protein evaluation systems that adequately represent the dynamics of microbial protein synthesis. Unfortunately, such dynamic systems have not yet been implemented.

One source of non-protein N for ruminal microorganisms is urea being recycled via saliva and the rumen wall. Studies have shown that dietary crude protein (CP) level has no effect on the total amount of urea N recycled into the rumen. It was concluded that dairy cattle appear largely unable to up-regulate urea-N transport sufficiently to fully compensate for reductions in dietary CP supply and maintain milk N production.

Synchronising the availability of energy (carbohydrates) and N compounds (ammonia, AA) gave less positive results in practice than expected. Synchronising the availability of energy...
and RDN may be important for rapidly degradable substrates, but an extra need for more slowly degradable CP can be disputed, because the slow growth rate of cell wall degrading micro-organisms will require only small amounts of available N, which can be met by the reflux of urea N.

**Inefficiency of utilisation of absorbed AA**

Modifications in protein evaluation systems have mainly focused on improvements to estimate the supply of MP or AA that are absorbed and/or available to the mammary gland; less attention has been given to optimum AA requirements and their relationship with the supply of other nutrients. An excess of absorbed AA should be avoided, because surplus AA will be deaminated (contributing to urinary N secretion) and oxidised in liver and portal drained viscera. Their carbon chains can also be utilised for gluconeogenesis, although any additional glucose supply will, in general, not increase milk production.

Various reasons for a suboptimal AA uptake by the mammary gland have been postulated, such as (1) a suboptimal profile of the AA supplied to the mammary gland; (2) a suboptimal synchronisation of available energy and AA for the mammary gland and (3) asynchrony between available nutrients and the activity of anabolic pathways in mammary cells. A shortage of one or more essential AA (EAA) in relation to the other EAA has been postulated for many years and appears the main driver for including rumen-protected AA considered as first-limiting, especially at a low dietary CP content. This theory is often presented as a barrel made of staves with different lengths, which represents the supply of an AA relative to the ideal AA profile based on the AA profile of milk protein. Met and Lys are generally considered to be the first limiting AA for milk production and a large number of studies on the effect of supplementing these AA have been reported.

A shortage of ATP yielding nutrients is another possible reason for an inefficient utilisation of AA by the mammary gland. In this regard a relationship between energy and MP supply has been incorporated in the INRA protein evaluation system.

Protein synthesis is regulated by many mechanisms and pathways related to, amongst others, AA transport into the epithelial cells, activation through phosphorylation, transcription of DNA and RNA, and elongation, with the “mTOR pathway” in a central role. Nutrients may influence these processes at different levels. Glucose (directly and indirectly through insulin), Leu, Ile, Lys and Lys+Met have been identified as regulatory nutrients of the mTOR pathway.

To reduce the environmental impact of N excretion by dairy cattle, mitigating N intake should be the main nutritional strategy. Although new protein evaluation systems enable a reduction in safety margins, these systems are not yet fully exploited. Exchanging a MP system into a metabolisable AA system would enable a further reduction in dietary N, but at this stage requires more insight into the regulation of AA use for milk protein synthesis in mammary cells. Supplementing individual (rumen-protected) AA based on the “barrel concept” needs to be reconsidered, as positive effects of supplemental EAA may be attributed to specific regulatory functions of these AA resulting in activation of the protein synthetic pathways.
Manipulating rumen fermentation to improve efficiency and reduce environmental impact

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Introduction

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

- The 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.

Targets for manipulation

In 2001 we noted that “The targets for manipulation are also changing and no longer can the productivity of the animal be considered in isolation. There is a growing awareness of the health, safety and environmental issues associated with animal agriculture” (Newbold, Stewart, Wallace, 2001). These remarks remain valid.

However the predicted increases in human population, the need not to compete for human edible feed resources (Gill et al., 2010) and the rise in both demand and ability to pay for highly quality ruminant products in developing economy’s (Scollan et al., 2011) has perhaps added an increased urgency to these challenges. Indeed in the last few years’ the term “sustainable intensification” or producing more from less has come into common usage. Whilst we would agree with many that the term “sustainable intensification” is intrinsically contradictory the underlying concept remains valid and we find the definition provided by Smith (2013):

“The process of delivering more safe, nutritious food per unit of input resource, whilst allowing the current generation to meet its needs without compromising the ability of future generations to meet their own needs”.

a useful starting point from which to refine our original statement and from which to base our evaluation of targets and approaches to rumen manipulation. However, perhaps missing from our initial considerations and that of Smith (2013) is the ethical and welfare issues associated with ruminant production and it seems likely that with both the increasing wealth and sophistication of developing markets this may well become an increasing concern. The
nascent debate within developed economies of the need for change in demand side drivers as well as production side changes in response to concerns over the role of livestock as a driver of climate change will inevitably drive increased discussion about the ethical and welfare aspect of production systems (Ripple et al., 2014).

**Approaches to manipulation**

In 2001 we noted that “There is growing resistance to the use of antibiotic growth promoters within the food chain and the short-term possibility of using genetically modified organisms either by modifying the plants which the animal eats or by introducing modified “superbugs” into the rumen seems unlikely in the face of current consumer concern. Indeed the technologies most likely to be adopted are those that are perceived to be based on natural or green products” (Newbold, Stewart, Wallace, 2001). Again these remarks remain valid however there has been significant advances in developing such approaches in the areas of:

1] A significant increase in both research and new products based on plant extracts and probiotics designed to increase productivity whilst decreasing greenhouse gas emissions, improving product quality/safety and improving animal welfare (Hart et al. 2008).

2] An increasing use of molecular biological techniques both to characterise changes in the rumen microbial population in response to additives and to understand the metabolism of rumen microbes thus allowing new additives to be developed (Pinloche et al., 2013, Leahy et al., 2013).

3] A renewed awareness of the role that the plant plays in rumen fermentation and the use of plant breeding as a means to manipulate rumen fermentation. (Kingston-Smith, Marshall, Moorby, 2013).

4] The developing understanding of the importance of the host in helping determine the microbial population in the rumen, both in terms of the importance of paternal genetics (Pinares-Patiño et al., 2013) and the importance of early life nutrition in programing the rumen microbial population in later life. (Yáñez-Ruiz et al 2010).

**Conclusions**

New ways by which the rumen microbes might be manipulated continue to be identified, whilst the targets for manipulation continue to be refined by the changing societal views and concerns regarding the role of ruminant livestock within food production systems.

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Yáñez-Ruiz DR, Macías B, Pinloche E, and Newbold CJ (2010) *The persistence of bacterial and methanogenic archaeal communities residing in the rumen of young lambs* *FEMS Microbiology Ecology* 72 272-278
Dairy calf and heifer rearing for optimum lifetime performance

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Feeding methods and management practices applied to today’s dairy replacements will influence the performance (and economic returns) of dairy herds in 2016 onwards. Due to this relatively long lag, most producers and dairy consultants tend devote less-than-desirable efforts and attention to calf and heifer rearing. Contrarily 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. However, 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 as well as changes in performance, body composition, and metabolic function of the offspring of livestock. In fact, the results from a meta-analysis concluded that about 225 kg of additional milk in the first lactation could be expected for each additional 100 g/d of growth during the first 2 months of life.

Achieving rapid growths (>750 g/d) early life demands feeding more than 4 l/d of milk replacer (MR) or milk. However, feeding 8 l/d may compromise intake of starter and if MR is offered only twice daily it may foster insulin resistance in calves. In addition, calves fed high milk allowances tend to struggle during transition onto solid feed, and part of the growth advantage achieved before weaning may be lost due to (1) diminished consumption of nutrients, and (2) reduced digestibility. Therefore, promoting solid feed intake is of pivotal importance when feeding more generous milk allowances (i.e., 6 l/d) to calves. Starter feed consumption can be improved by including ‘palatable’ ingredients in the formulation of the starter. Also, an effective method to foster solid feed intake of calves, contrary to what it has been traditionally recommended, is to provide ad libitum access to poor quality (nutritionally) chopped straw or chopped grass hay. This practice has been shown to increase solid feed by 23% (and consequently growth also increases). Furthermore, forage provision to calves increased almost 4-fold the number of volatile fatty acid transporters in the rumen, a condition that should minimize rumen acidosis by actively removing acid from the rumen fluid.

It is commonly recommended to wean calves when they consume about 1 kg/d of starter for three consecutive days. However, if an average daily gain (ADG) of about 1 kg/d is sought around weaning time, calves should not be weaned until they consume at least about 1.5 kg of dry feed. Weaning with intakes below 1.5 kg/d is totally possible, but growth, and potentially health, will be compromised. With a proper nutritional scheme, transition calves (few days before and few weeks after weaning) can easily grow about 1.2-1.3 kg/d and do it very efficiently (about 40% feed efficiency) resulting in the most profitable development stage that calves or heifers will undergo during their entire growing period. Last, weaning has usually been associated with a moment of stress. To minimize the stress around weaning, it is commonly recommended to keep calves individually housed for an additional 1 or 2 weeks following weaning. However, recent studies have shown that commingling calves in small groups before pre-weaning (reducing RM allowance) has beneficial effects on solid
feed intake and incidence of bovine respiratory disease (BRD). Also, the way these groups are formed (mixing animals with and without previous history of BRD will have a great impact on the incidence of BRD. Furthermore, recent evidence from our research group indicates that productive life of cows is negatively correlated with the number of BRD episodes experienced by the cow as a calf or heifer.

An optimum ADG between weaning and breeding time should be around 900 g/d. However, there is some generalized concern that growing excessively, above 700 g/d, during the pre-pubertal period might compromise mammary development and milking potential, but there are several studies that show that rapid growth rates (up to 1 kg/d) achieved without inducing fattening of the animals does not compromise future milk yield, and if any thing, they might actually increase it. However, contrarily to the observations that indicate that rapid growth rates during the pre-pubertal period are not detrimental (provided fattening does not occur), rapid ADG during pregnancy seem to be associated with impaired milk production. The metabolism of the pregnant heifers is modulated by progesterone, which will tend to foster fat disposition in preparation for lactation. Data collected from our research department indicate that rapid growth rates post-breeding are correlated with decreased milk performance.

Last, rations fed to heifers during the 2 months preceding calving should provide sufficient nutrients to ensure an ADG of 750 g/d. Typically, pre-calving heifers are grouped and fed with pre-calving adult cows, which traditionally are fed high-energy rations in an attempt to minimize body fat mobilization, ketosis, and fatty liver after calving and adapt rumen microflora to high energy levels as those fed during lactation. However, recent studies have shown that allowing ad libitum access to high-energy diets during the dry period results in pressed feed intake before parturition and a decreased feed intake postpartum and thus cows may be placed at greater risk for peri-parturient health problems when fed this high-energy diets before calving. Thus, it is recommended to keep pre-caving heifers (as adult cows as well) on low-energy, high-fiber diets until calving date.
Recent developments in feed enzyme technology

HV Masey O'Neill, MR Bedford and N Walker

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 feed enzymes for non-ruminants

In 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). As phytate is converted to various lower phosphate esters by sequential removal of phosphate groups, the anti-nutritional effect is reduced, but recent evidence suggests that many phytases, particularly when used at a standard dose, struggle to convert IP4 to IP3 and as a result IP4 accumulates, particularly in the small intestine (Pontopiddan, 2012). This phosphoester is still very effective in precipitating Zn at pH5 and above and as a result can interfere with small intestinal digestion of protein as many intestinal proteases are Zn dependent. Finally, if phytate is completely dephosphorylated, the end product is inositol, which has been found in many studies to be a growth stimulant in broilers.

It is well understood that NSP enzymes improve performance by eliminating the nutrient encapsulating effect of the cell wall and ameliorating viscosity problems particularly with arabinoxylans and mixed-linked β-glucans. However, NSP enzymes may result in large performance benefits in diets containing maize (Masey O'Neill et al., 2014) and low viscosity wheat (Persia et al. 2002). 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. 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.

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. There is therefore an argument for greater development in the understanding of oligosaccharides produced in vivo by enzyme action in production animals.
Advances in the use of exogenous fibrolytic enzymes (EFEs) in ruminant feeds.

Only very limited use has been made of exogenous fibrolytic enzymes (EFEs) for ruminants. Although the ruminant is inherently more efficient than a monogastric animal at breaking down plant cell walls, it has been estimated that plant cell wall digestibility in the total tract of ruminants is still less than 65% (Van Soest, 1994). Therefore there is potential to improve fibre digestion, even in the ruminant animal. In the late 1990s scientists investigated the potential of using EFEs derived from concentrated fungal fermentation extracts from Trichoderma as a means of further improving feed digestibility in the rumen. However, at that time, it was not considered a commercially viable proposition due to the high costs of producing these EFEs relative to low feed prices and milk and meat price returns. Today, with escalating feed costs combined with higher milk prices and better return on investments for dairy and beef, the potential use of EFEs in ruminant diets is being re-evaluated.

Recent work using NIR has demonstrated that the predicted digestibility of a range of different forages could be significantly increased by spraying fungal fermentation extracts onto the surface of the fibre (Walker et al., unpublished data). Due to the high levels of hemicellulase and cellulase activity, the fibre starts to be pre-digested before the animal consumes it, as demonstrated from changes in NIR spectral analyses, leading to pre-digestion of the NDF and ADF component and increases in predicted D-value of up to 15% and predicted ME of up to 1.5 MJ/kg DM. It was hypothesised that this sugar release would act as a chemo-attractant for the rumen flora (Forsberg et al., 2000) and as a source of readily available carbohydrates, enabling rapid microbial growth, thus explaining the reduction in the lag time to digestion observed in several in situ studies. However, this sugar release would only represent a very small portion of the total carbohydrates potentially available and it is likely that several other factors are involved, leading to better feed digestibility. By action of the hemicellulose and cellulose degrading properties of the EFEs, pits are quickly formed in the surface of the fibre (McAllister et al., 2001), leading to a roughened surface. When the treated forage is then consumed by the animal, this allows faster attachment and greater surface area colonisation by the fibrolytic rumen microflora (Morgavi et al., 2000). As a consequence, the lag time to digestion is decreased and overall DMd, NDFd and ADFd are increased, as demonstrated by both rumen in vitro and in situ measurements (Walker et al., 2012; Holthausen et al., 2011).

A recent meta-analysis (Eun et al., 2011) of 10 published studies in dairy cows demonstrated that using these EFEs significantly increased DMI (+0.5 kg/d, P=0.05) and milk yield (+2.3 kg/d, P<0.01), leading to significant improvements in feed efficiency (kg milk yield/kg DMI) from 1.52 to 1.59 (P=0.01). Therefore, even though different dose rates and a range of different diets were used and fed to cows during the early stages of lactation, overall dairy cow performance was significantly improved.

Although it would seem logical that the greatest effects of EFEs would be on dairy diets which contain a higher proportion of fibre, positive results have also been seen in beef production systems, both in the growing period and in the finishing period where the fibre content is more limited. Beauchemin et al. (1999) showed that addition of EFEs to rolled barley grains, which comprised 90% of the diet fed to finishing cattle in a commercial feedlot, significantly increased ADG (1.40 vs 1.53 kg/day, P<0.01) and numerically increased feed to
gain by 10% (7.75 vs 6.92 kg DM/ kg gain). Two recent studies (He et al., 2014a, b) examined the effects on in situ feed digestibility of adding a similar EFEs mixture at two different levels to fistulated animals fed backgrounding and then intensive finishing diets. The backgrounding diet contained 50% barley silage, 25% barley, 15% wheat DDGS and 10% hay; the finishing diet contained 60% rolled barley, 30% wheat DDGS and 10% barley silage. In the backgrounding diet, increasing the amount of product applied to the diet quadratically changed in situ DMd of wheat DDGs (61.1, 63.1 to 59.3%) and increased linearly in situ NDFd of barley silage (14.9 to 18.9%). Crude protein digestion was also significantly increased in a linear manner. In the finishing diet, starch digestibility was significantly increased with increasing dosage treatment; however, no differences in digestibility of other nutrients were observed, nor were there any differences in ruminal pH or VFA production.

In conclusion, the potential benefits of using EFEs high in hemicellulase and cellulase activity in ruminant production are becoming obvious, especially as more trials data is collected. Further work is needed to understand the exact mechanisms involved, and perhaps why there is sometimes some variability in the responses seen. However, with the advent of low cost, consistent, high quality EFE products, and the need to improve feed digestibility, utilisation and efficiency, it is certain that more research efforts will be directed at this interesting and new application.
USING ANIMAL-ORIENTED INDICATORS AND BECHMARKING FOR CONTINUOUSLY IMPROVING ANIMAL HEALTH AND WELFARE

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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.

The current attitude of the society toward food of animal origin is characterized by the fact that especially activist groups demand more and more animal welfare and organic or more natural production systems (e.g. free-range and out-door husbandry), but the production and consumption of food is still oriented towards “cheap” food. Another characteristic is that there are several popular misperceptions about especially animal production: e.g. it is simply not true that big animal units mean necessarily cruelty to animals and that small animal holdings mean always happy animals.

The result of this development is that there is a widening gap between on the one hand what critical parts of the population and sophisticated well-to-do consumers expect regarding the husbandry systems and the handling of animals for food production and on the other how farmers (have to) raise and handle their animals. Traditionally, such situations call for new regulations and laws and/or for raising the minimal standards set by existing regulations and laws. However, even in countries with very strict regulations experience: the gap remains more or less as wide as it was before the raise of the minimal standards.

Figure 1 illustrates this: the red line shows that the increase of the societal expectations is quite a steady process, whereas the black line shows that the increase of the legal minimal standards goes only upwards like a stair case, and thus, stays always behind the expectations.

![Fig. 1: The varying gap between the steadily increasing societal expectations and the “limping behind” of the raising of legal minimal standards that can only take place in a “staircase” manner](image)
This means that closing the gap or keeping it as narrow as critical people feel almost content with the conditions, under which our food animals live, needs an additional process, which is a systematic approach to implementing the **principles of continuous improvement**, which many industries have already adopted. One of the basic principles in the realm of quality assurance and quality management in whichever area of human activities is that “you can only improve what you measure”. Therefore, animal-oriented indicators per herd or flock such as frequency of disease, frequency of injuries, lameness, mastitis in cows, food lesions in poultry and turkey etc. are needed to assess the quality of the animals’ life in question and of the quality of the stockmanship and the empathy for animals of the animal caretakers. The basic principle for any system that uses animal-oriented indicators for implementing continuous improvement processes to better the animal health and welfare status of food animal herds and flocks are: **record standardized findings** related to animal health and welfare per animal population, **calculate a Herd-Health-Welfare-Index** (HHWI), e.g. in points per criterion and sum the points up to an index, and **benchmark** those herds or flocks, the HHWI of which is calculated in the same manner. Figure 2 demonstrates the principle of benchmarking pig herds using the criteria listed above plus the 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).

Animal-oriented indicators can be **recorded at farm level** (e.g. mortality rate and antibiotic use expressed in days that statistically all animals of the herd or flock are treated with any antibiotic substance, which is expresses as Animal-Treatment-Index (ATI), and **at abattoir level**. This process of continuous improvement will not lead to a complete stop of the current societal criticism with food animal production, but it will considerably contribute to a demonstrable improvement of the conditions, under which we keep our food animals and, most of all, how we effectively prevent any suffering of animals and improve their well-being.
Enabling the exploitation of Insects as a Sustainable Source of Protein for Animal Feed and Human Nutrition.

Fitches, E.C., Kenis, M., Charlton, A.C., Bruggeman, G., Muys, B., Melzer, G., Smith, R.

A growing global population and a rise in per-capita meat consumption place increasing pressures on the need to increase the production of protein from sustainable sources. 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 the exploitation of insects as an alternative protein source for animal feed. Currently more than 80% of the 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 the final products. The UK alone currently imports approximately 2.5 million tonnes of soya per year, the majority of which is destined for animal feed, principally that for pigs and poultry. The incorporation of insects in animal feed could help to reduce the dependency of the EU upon external protein sources to feed its livestock.

Focus in PROteINSECT is placed on two fly species, the common housefly *Musca domestica* and the black soldier fly *Hermetia illuscens*. Fly larvae are a natural component of the diets of certain animals and are able to grow rapidly on a range of organic wastes, reducing waste volumes by up to 60%. Thus flies offer both a new source of feed protein and a means of reducing wastes produced by agriculture and food industries. PROteINSECT has established new fly production systems in Europe, China and Africa utilising manures as the major substrate for larval growth. A number of factors including the optimisation of rearing substrates, designs for prepupal collection, determination of oviposition attractants and the control of natural enemies are being investigated in order to improve production efficiency and potential for scale-up. Potential solutions to bottlenecks in the different rearing systems, such as the maintenance of adult cultures and supply of eggs to maximise larval yields, are being explored. In all systems larvae are harvested at the pre-pupal stage and supplied as crude dried insects for further studies.

Whilst the potential use of insects as a source of nutrition for domestic animals/fish has been recognised for several decades (e.g. Bondary and Sheppard, 1987; Newton et al., 2005; Hem et al., 2008) this has not yet led to any significant replacement of traditional plant/fish-based protein used for livestock production. This is largely due to systems being explored and developed on a local, isolated level with no integration or co-ordinated development of know-how to enable adoption at national and international levels. A recent study comparing nutritive characteristics of a range of insects has shown that the amino acid profile of dipteran insects is superior to soybean meal and more similar to fishmeal (Barroso et al., 2014). In PROteINSECT the nutritional quality of crude larval extracts (e.g. protein content, amino acid profiles, ileal digestibility) will be determined allowing comparative analysis of fly larvae produced using different production systems and under widely differing environmental conditions. Much of the work to date has made little or no attempt to process the produced insect material, in PROteINSECT processing options for improving the nutritional status of insect protein are being investigated and nutritional analysis will provide key information enabling feed formulation and the design of appropriate animal feeding trials. Where possible feeding trials will be conducted using both crude and refined material to enable the benefits of protein refining to be evaluated. Fish feeding trials will be carried out using representative species in China, Mali, Ghana (such as Tilapia *Oreochromis* sp.) and in the UK (Atlantic Salmon; *Salmo salar*). Poultry is globally a major animal protein source and chicken feeding trials will be conducted in China, Mali and in Belgium. Pigs constitute a
major protein source for human consumption in Europe and as such trials will be carried out in Belgium.

A major consideration in the use of any novel feed product is to demonstrate safety, particularly given that the larval rearing substrates are waste products. Little published data is available in relation to the risks of using insects in feed and how these risks might be mitigated. Chemical and microbiological safety testing will include analysis of heavy metals, pesticides, dioxins, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), veterinary medicines and mycotoxins. Microbiological risks, such as the potential for the persistence of salmonella and Hepatitis E, and for allergenicity of larval samples will be evaluated. Downstream analysis of meat derived from insect reared animals will also be undertaken in relation to safety and quality (eg. taints). Possibilities for obtaining valuable by-products from the insects such as oils, vitamins, minerals and chitin as well as fertilisers from the digested substrates are also being considered.

Data obtained from insect production scenarios, quality and safety analysis, and feeding trials will form the basis for assessments of environmental, social and economic life cycle impacts of insect based animal feed production systems. The overall objective of this component of PROteINSECT is to facilitate the design of optimised and sustainable production systems suitable for adoption by both small and large-scale operations in different geographical locations. Following a general life cycle assessment (LCA) framework different impacts (eg. substrate collection, production efficiency) will be quantified and compared to conventional feed assessments. Experimental data from feeding trials will be used to conduct assessments for fish, pigs and poultry that will be evaluated under different production scenarios. Ultimately LCA analyses will enable policy and technical recommendations to be provided for the establishment of economically viable and efficient fly rearing systems in different locations.

Consumer acceptance is key to the successful adoption of insects as a source of protein for livestock. As such focus is also placed on activities such as monitoring of relevant media coverage and gauging consumer attitudes. An initial consumer survey conducted in 2014 by PROteINSECT has highlighted the need for more information to be made available, but has suggested that the public are generally accepting of the use of insects in animal feed. The use of insects in animal feed is not currently recognised or specified in European legislation or regulation and this presents a major barrier to the development of industrial insect-rearing plants. PROteINSECT is engaging with policy makers in order to support the introduction of enabling legislation and a recent report mapping current EU legislation has identified key challenges that need to be addressed (available at www.proteinsect.eu). These include the authorisation of insect processed animal protein for use in non-ruminant feed, the need for solid scientific evidence of the safety of products to permit the rearing of insects on animal manures and legislation to address novel issues associated with mass production. PROteINSECT is consulting with key stakeholder groups (eg. producers of feed and feed ingredients, consumers, government) to generate a core ‘business case’ for the use of insects in animal feed. Ultimately the presentation of a White Paper to the European Parliament will ensure that regulatory aspects and consumer issues are brought to the political arena. Our aim is to build a pro-insect platform in Europe to encourage the adoption of sustainable protein production technologies in order to alleviate the reliance of the feed industry on plant/fish derived proteins.

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Porcine reproductive and respiratory syndrome virus and pig feed efficiency and tissue accretion

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In pork production, the largest use of natural resources is through the production and consumption of feed. Health challenged pigs can be a burden on production and pork quality. Therefore, improving feed efficiency and health of swine is an important goal for sustainable and profitable pork production. The pig is under constant pathogenic challenge which can have adverse effects on intestinal and respiratory health and function, as well as on anabolic processes in peripheral tissues such as skeletal muscle (Escobar et al., 2004; Williams et al., 1997a, b). Of the health challenges the swine industry face, Porcine Reproductive and Respiratory Syndrome (PRRS) and now Porcine Epidemic Diarrhea (PED) viruses are arguably the two most economically costly viruses to U.S. and world pork production. Alone, PRRS virus infections are estimated to cost the U.S. swine industry more than USD $664 million annually (Holtkamp et al., 2013). In addition to mortality losses and costs of interventions, these viruses may reduce lean tissue accretion and feed efficiency in growing pigs from weaning to market. These reductions may be caused by the innate and adaptive responses to intense, prolonged or poorly contained immunological or stress stimuli. However, single infection alone often fails to induce overt disease; yet they are still recognized individually as important etiological agents in multi-factorial disease of swine and can negatively impact pig performance. Although we clearly know that PRRS virus impacts sow reproduction and attenuates ADG of production pigs, its direct impact on feed efficiency, nutrient and energy digestibility, metabolism and whole body lean and fat accretion in grow finisher pigs has been poorly characterized.

Classically, pigs infected with PRRS virus exhibit a peak serum viremia within 4 to 8 day post inoculation (dpi) and all have serum convert by 14 to 28 dpi (Figure 1). Pigs exposed to PRRS virus have prolonged viremia, often accompanied by persistent infection and virus shedding, and are prone to re-infection and secondary infections.

Although we know that pigs reared in high inflammatory, poor health and dirty conditions can exhibit decreases in protein deposition and growth performance, surprisingly there is still little data available that quantifies the true impact PRRS virus has on feed efficiency and tissue accretion in nursery-finisher pigs. Interestingly, there has only been one study to examine the impact of PRRS virus infection on tissue accretion rates. We also reported a significant reduction in ADG, ADFI and feed efficiency in PRRS virus infected pigs. These reductions are particularly evident within the first four weeks of infection (Figure 2). However, these negative insults on grower-finisher pig production parameters can have a significant effect on lifetime performance (Table 1).

In summary, our ongoing project is clearly demonstrating that PRRS virus infection reduces not only ADG, but also ADFI, coefficients of apparent total tract digestibility, and feed efficiency in grow-finisher gilts. Furthermore, lean/protein and fat accretion rates all appear to be affected to a similar extent. Additional blood analysis and carcass data from this project will allow us to better understand the metabolic impact of PRRS virus in pigs and to calculate the economic impact of this health challenge in a grow-finisher production setting. Based on
this data set, overall we conservatively estimated the economic impact of PRRS virus to cost the producer between USD$6.14 - USD$12.85 per head.

**Table 1.** Performance of gilts infected with PRRS virus or without (CONT) from 35-127 kg BW.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CONT</th>
<th>PRRSv</th>
<th>SE</th>
<th>P-value</th>
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<td><strong>1 Performance, 0-112 dpi</strong></td>
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<tr>
<td>Feed:Gain</td>
<td>2.30</td>
<td>2.41</td>
<td>0.026</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td><strong>2 Tissue Accretion, 0-80</strong></td>
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<tr>
<td>Lean, g/d</td>
<td>657</td>
<td>568</td>
<td>13.9</td>
<td>&lt;0.001</td>
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<tr>
<td>Protein, g/d</td>
<td>131</td>
<td>112</td>
<td>2.89</td>
<td>&lt;0.001</td>
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<td>Fat, g/d</td>
<td>230</td>
<td>184</td>
<td>9.22</td>
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</tr>
<tr>
<td>Bone, g/d</td>
<td>27.8</td>
<td>26.0</td>
<td>0.94</td>
<td>0.063</td>
</tr>
<tr>
<td><strong>3 Apparent total tract digestibility, 19-21 dpi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter, %</td>
<td>83.9</td>
<td>81.3</td>
<td>0.54</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nitrogen, %</td>
<td>81.8</td>
<td>77.3</td>
<td>0.84</td>
<td>&lt;0.001</td>
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<tr>
<td>Energy, %</td>
<td>81.0</td>
<td>77.8</td>
<td>0.64</td>
<td>&lt;0.001</td>
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<tr>
<td><strong>2 Carcass yield, %</strong></td>
<td>76.7</td>
<td>75.4</td>
<td></td>
<td></td>
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<tr>
<td><strong>2 Carcass lean, %</strong></td>
<td>55.4</td>
<td>56.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>**2 Carcass backfat depth, cm</td>
<td>1.85</td>
<td>1.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>**2 Carcass loin depth, cm</td>
<td>7.00</td>
<td>7.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 n=6 gilts per treatment  
2 n=30 gilts per treatment  
3 n=15 gilts per treatment

**Figure 1.** Typical PRRS viremia and antibody response in growing pigs (adopted from Greiner et al., 2000; Van Gucht et al., 2004; Boddicker et al., 2012; and Gabler et al., 2013)
**Figure 2.** Within period changes in ADG, ADFI and Gain:Feed of PRRS virus infected and naïve gilts. n=5 pen/trt, * P < 0.05 within period.
More pigs born per sow per year – Feeding and management of the bottom 20% of the pig population

Pete Wilcock, AB Vista, UK and Ian Wellock – Primary Diets

*Increased litter size and impact on small pig performance*

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.

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. 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 t 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 and improve pre-weaning performance and thereby weaning are important in maximising the full value pigs marketed in the production system. Furthermore post-weaning applications can be used to improve small pig performance through the first three weeks post-weaning.

*Pre-weaning intervention strategies via the piglet*

It is recognised that impacting the sow in terms of improving litter weaning weights is a key component of maximising litter weight and that will be discussed later. However are there intervention production strategies that can be used to improve pre-weaning performance directly through the piglet? Two strategies that have been used are creep feeding and milk replacer and the following will highlight some of the benefits and issues these may have in terms of improving weaning and subsequent pig performance.

Traditionally creep feeding has been targeted for improving weaning weights especially in later weaned pigs where results are more consistent. However there may be a greater opportunity with higher litter sizes in terms of using creep feed to maintain a greater weaning weight. There is research that suggests use of creep feeding in litter sizes greater than 9 pigs per litter can improve weaning weights when compared to those litters fed no creep. Although improving weaning weights would be advantageous the use of creep feeds for improvements in pre-weaning mortality and lifetime performance is now more of a focus of creep feeding. Both European and USA studies in late and early weaned pigs respectively.
have shown benefits in the post-weaning nursery performance of those pigs that consume creep compared to pigs not eating or fed no creep at all. Hence, any strategies to increase the percentage of pigs eating creep feed would be advantageous. This can include feeding creep feed early, the use of a specific feeder, using a higher digestible creep feed as well as keeping product fresh and not over feeding and letting product go stale. The importance of gut microflora on the pig’s performance is also an area of interest as it has been shown in certain studies that piglets from outdoor sows do better immediately post-weaning than indoor reared piglets. The gut microflora from these piglets is different. The outdoor reared piglets show a higher level of lactobacillus compared to the indoor reared piglets. In addition the outdoor reared piglets have reduced microflora diversity when older and this has been associated with a lower level of immune stimulus in the outdoor reared pigs. Australian work has indicated that the use of outdoor organic matter in an indoor system can improve hot carcass weight and carcass composition when compared to pigs fed a standard creep. This opens the possibility that there may be a substrate, microflora interaction and opens the possibility of more research in this area.

The design of creep feed can be important and recent work has shown that the use of a specialist creep feed can improve not just pre-weaning performance (higher weaning weight and lower mortality) but also lifetime performance. Recent studies have shown that the use of a specialist creep feed (all pigs fed the same diets from weaning to slaughter) pre-weaning can improve live-weight at slaughter by 3 to 4 kg when compared to pigs fed a standard high specification phase 1 starter feed as a creep feed. This suggests that the traditional use of taking the phase 1 post-weaning diet on farm and using it as a creep feed although acceptable and will assist pig performance may be improved upon by using a more specialist diet for that specific pre-weaning phase.

Another management tool for improving weaning weight is the use of milk replacer. It has been known since the 1990’s that the sow’s milk is limiting in terms of piglet performance and if pigs are fed a milk replacer (post 24 hours to ensure pigs have consumed colostrum) they can perform significantly better that sow reared pigs.

Milk replacer can be supplemented to piglets through each farrowing pen using cups that are tapped into the milk replacer tank (mixed daily) within the farrowing house. Alternatively a crate that is positioned above the farrowing pens can be used whereby the smallest pigs within the room are removed from the sow after 24 to 48 hours and placed into the crate. Each crate typically has a maximum of 12 pigs per crate. These crates are then supplemented with milk replacer and unlike the supplementary milk replacer the pigs do not have access to the sow. Dry feed is added normally when the pigs have been in the crate for approximately 4 days.

The use of milk replacer is consistent in terms of response and supplementary milk replacer research has shown an average weaning weight response of 19% compared to pigs not fed milk replacer. In addition milk replacer typically reduces pre-weaning mortality.

As a tool, milk replacer could be used to improve the mean weaning weights as well as reducing both pre-weaning mortality and weaning weight variation. Each production system is specific and it is vital to target milk replacer technology to specific piglets and management practices to achieve improvements in survivability and weight gain of selected piglets with non-impaired growth competencies. Milk replacer typically should be used with
large litter sizes (> 12 pigs born alive). Notice should however be taken of the extra management time and costs associated with the use of milk replacer. For example in the use of supplementary milk replacer it has been shown to be more cost effective to use milk replacer up to 4 days pre-weaning and then switch off the access to milk replacer. This practice saves almost 50% of the milk replacer consumption that would otherwise have been consumed to weaning, thereby saving 50% of the cost, while not negatively impacting the benefit milk replacer has on pre-weaning performance.

**Pre-weaning intervention strategies via the sow**

The obvious key to improve weaning weight is by targeting increased feed intake and water intake by the lactation sow especially in summer when intakes traditionally drop. To optimise lactation intake it is necessary to ensure that pregnant sows are not overfed and over conditioned; ideally they should be in the 3 to 3.5 range on a scale of 1 to 5. Prior to farrowing feed intake should be dropped to approximately to approximately 2 kg to ensure early lactation feed intake is maximised and thereby minimising health issues in lactation. Feed intake will not be maximised without sufficient water intake and so sows should have access to fresh water with good flow (2 liters per minute for a bite drinker) or even liquid or wet feeding to stimulate intake. Feed intake has also been stimulated by two management practices; the introduction of self-feeders has stimulated lactation feed intake over the traditional hand feeding system by 7% while the use of low level increment of feed intake in the first 4 days post-farrow (1.8 kg, 1.8 kg 2.7 kg and 2.7 kg respectively) before going to *ad libitum* feeding has helped stimulate overall lactation feed intake. The impact of temperature is important in lactating sows as with an increased level of feed intake the sows’ temperature requirement drops and so if the room is too warm the sows will lower feed intake. It is therefore important to target the sows thermal neutral zone (between 12 to 20°C) to maximise intake with most units tending to typically target 18 to 20°C. Obviously this is the reason for sow intake drop during summer when room temperatures are difficult to control. The importance of stimulating feed intake is the same for all lactating sows and the generalities described all play a role in achieving this, However it must be remembered specific responses and guidelines will depend on the genetics used in the production system and so working with your genetic supplier is important in the optimal management of the lactating sow.

The importance of focusing on high intake coupled with a high nutrient dense diet will maximise the nutrient intake to the sow, increasing milk production and improving weaning weights. However are there any feed ingredients that can also be used to further improve piglet performance on the sow?

In the pig, use of live yeast has mainly been focused in more of the stressful periods of pork production such as lactation and nursery pigs. The use of a live yeast in lactation has shown benefits in terms of weaning weight improvement and pre-weaning mortality A series of studies has shown that the use of a live yeast in lactation can improve weaning weights by an average of 7.95% and reduce pre-weaning mortality by an average of 2.73% (for example 15% to 12.23%).

The synthesis of carnitine can be synthesised by the body from protein bound lysine and methionine and so does not need to be an essential component of the diet. However in the young neonate the ability to synthesise carnitine is limited and so supplementing the early
weaned pig with carnitine may be beneficial in terms of pre-weaning performance. L-carnitine is essential in the transportation of long and medium chain fatty acids across the mitochondrial membrane for B-oxidation and therefore low levels of carnitine may lead to suboptimal usage of fatty acids. The use of carnitine in both dry and lactating sows is well documented and studies have shown the use of carnitine in dry and lactating sows improves birth and weaning weights (0.55 kg).

The use of bacillus species as probiotics is well established in post-weaning pigs with good evidence of improved performance. However the use of bacillus in the sow is a more recent application and similar to live yeast it acts as a probiotic whereby it improves nutrient utilisation resulting in improved milk protein and milk fat. One study showed that this can lead to an improved weaning weight (0.38 kg) and reduced pre-weaning mortality (5.1%) while those sows fed the probiotic had less weight loss at weaning.

**Post-weaning intervention**

The benefit of improving 20 day and nursery post-weaning growth on lifetime performance and improving the bottom 20% of the light pigs is another key determinant of lifetime performance. Improving this post-weaning performance can be a result of many different factors such as management, nutritional or environmental.

Starter regimes are critical to maximise pig performance during the nursery phase as pigs’ transition from liquid to solid feed. However it may be necessary to feed pigs differently depending on their birth and weaning weight in order to improve the small pig performance post-weaning. It has been shown in a number of different studies that using a high specification, high digestible and higher cost feeding program coupled with a longer feeding duration it may be possible to take pigs that were categorised as light weight birth pigs to the same level of performance at the end of the nursery as the normal birth weight pigs. More importantly this improved performance was achieved while delivering an extra margin over feed showing that this may be a cost effective solution to improve small pig performance.

Traditionally the use of phytase in starter feed has been limited due to the presence of pharmacological levels of zinc. However this was based on work using an older generation phytase and at standard levels of inclusion targeting P release. Recent work in piglets however has looked at the use of superdose (> 2000 FTU/kg) levels of phytase, to breakdown phytate as an anti-nutrient in starter feeds containing pharmacological zinc levels, to improve performance. Through phytase superdosing it is possible to minimise the anti-nutrient effects of phytate and improve energy, amino acid and mineral utilisation thereby eliciting a response in the newly weaned pig. A secondary more recent explanation of the benefit of superdosing phytase has been linked to the production of inositol. Inositol plays a role in many metabolic functions within the animal including lipid and phospholipid metabolism, secondary messengers and re-phosphorylation within the cell to phytate which is known to be an antioxidant. Inositol has been shown to improve animal performance and recent work in pigs and broilers has shown there is a positive correlation between increasing the dietary dose of a modified *E. Coli* phytase with increased inositol measured in the stomach/gizzard of the animal and improvement in gain and feed conversion.

A series of studies have been conducted looking at the impact that high levels (> 2000 FTU/kg) of a modified *E. Coli* phytase can have on post-weaning pig performance in diets with pharmacological levels of zinc. The outcome of these studies showed that the use of
superdosing phytase from weaning to 21 days post-weaning improved ADG by 7.2% and FCR by 4.2%. As all diets were designed to meet the requirements of the animal this data suggests that the response to the superdosing phytase was associated with phytate breakdown and not phosphorus provision. This new application of using superdosing levels of phytase in starter feeds that contain pharmacological levels of zinc, to breakdown phytate as an anti-nutrient could potentially be used to improve post-weaning performance and minimise the impact of the small pig effect.

**Conclusion**

The current swine market continues to target an increased litter size thereby maximising the amount of pork output per annum at a lower cost base. However with the hyper-prolific sows there is a concern that intrauterine crowding is having a negative impact on birthweight and subsequent performance. This has led to greater litter sizes and a higher percentage of smaller pigs to manage and it is these pigs that are the issue in the production system with higher mortalities/morbidity and less full value pigs going to market. Moving forward there are strategies that can be used to improve the small pig effect such as the pre-weaning use of specialist creep feeding and the use of milk replacer, the post-weaning use of different feeding programs and new applications of enzymes. These pre-weaning applications may take up more labour and management time but the performance benefits may be warranted. In addition a greater focus on the sow in terms of selecting for increased uterine capacity may be advantageous as well as ensuring the lactating sow is managed and fed correctly to maximise milk production.
Fermented products and diets for pigs

Hanne Maribo, Anni Øyan Pedersen, Thomas Sønderby Bruun

Pig Research Centre, DAFC, Axeltorv 3, 1609 Copenhagen V, Denmark

Fermenting diets and grain and other sources demonstrated:

1. Fermented liquid feed can reduce growth of weaners.
2. Fermenting diets or soy protein can reduce growth of finishers.
3. Fermenting grain increases the energy value and increases lactic acid.
4. Fermenting rape seed should - according to the producer - improve the digestibility of the protein and reduce the content of glucosinolates.

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 for example reduce the level of diarrhoea. However, the results showed that if the total diet is fermented, productivity drops as the feed intake is reduced; Pedersen (2001), Pedersen et al. (2002b), Pedersen et al., (2002c). Fermenting grain and soy bean meal to which inoculums are added also showed a negative effect on the productivity; Pedersen and Lybye (2012). Therefore, we do not recommend fermenting either diets or soy bean meal, but fermenting the grain (wheat and/or barley) increases the feed utilization as the digestibility of energy; Pedersen (2006), Pedersen et al., (2009), Pedersen et al., (2010), Pedersen and Canibe (2011). Phosphorus in grain increases during fermentation; Pedersen et al (2010)

When the complete feed is mixed in the tank, it should be fed to the pigs immediately to avoid loss of pure amino acids. However, residuals in the pipes will lead to loss of pure amino acids: it is assumed that 8 hours in pipes will lead to total loss of pure lysine; Pedersen and Jensen (2005). Consequently, Danish farmers are recommended to add more protein and pure amino acids to the 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

Fermenting grain was investigated in 3 trials with finishers and 1 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; Peders

Fermenting grain degrades the fibre that is indigestible for the 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 the fermented grain is approx. 100 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.

The 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 meal must be approximately 11% cheaper than diets with regular rapeseed meal or soybean meal. Fermented rape seed cake for weaners showed a reduction in productivity of approx. 7-9% compared to soybean meal or traditional rapeseed cake. This was attributed to a lower feed intake and reduced feed utilization (table 1). The reduced productivity was attributed to two factors: 1) the producer of the product had set the digestibility of protein too high (9% higher than traditional rape seed meal), and 2) probably a higher content of degradation products of glucosinolates due to either the fermentation process or the drying process after fermentation; Maribo and Sauer (2012).

Table 1

<table>
<thead>
<tr>
<th>Diet</th>
<th>Control</th>
<th>Fermented rapeseed meal</th>
<th>Traditional rapeseed meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of pigs</td>
<td>546</td>
<td>559</td>
<td>551</td>
</tr>
<tr>
<td>Replicates</td>
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<td>Results</td>
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<tr>
<td>Feed intake, feed units/day</td>
<td>1.04</td>
<td>1.02</td>
<td>1.03</td>
</tr>
<tr>
<td>G per day</td>
<td>531a</td>
<td>509b</td>
<td>533a</td>
</tr>
<tr>
<td>Feed utilisation FEsv/kg</td>
<td>1.96a</td>
<td>2.00b</td>
<td>1.94a</td>
</tr>
<tr>
<td>Index of productivity</td>
<td>100</td>
<td>93</td>
<td>102</td>
</tr>
</tbody>
</table>

Digestibility of fermented rape seed

To confirm these results, fermented rape seed EP 100 was tested in a digestibility trial with weaned pigs. The trial comprised seven soybean and rapeseed protein products and the outcome formed the basis of a revision of table values for raw materials. Data presented here only include crude protein in dehulled soybean meal, Scanola rapeseed expeller and EP 100.

Fermented rapeseed meal (EP 100) had a significantly lower protein quality than traditional rapeseed cake and soy protein (table 2), which explains the reduced productivity value for weaners.

Table 2

<table>
<thead>
<tr>
<th>Product</th>
<th>Dehulled soybean meal</th>
<th>Scanola rapeseed meal</th>
<th>Fermented rape seed (EP 100 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein digestibility</td>
<td>88.0a</td>
<td>79.5b</td>
<td>70.6c</td>
</tr>
</tbody>
</table>

a-c Means with different superscripts differ significantly (P < 0.05).

1 Data are least square means of 15 observations for all treatments.
Conclusion

It is recommended to use fermentation of grain for finishers to increase the digestibility value. Fermenting soy protein or complete diets is not recommended for either finishers or weaners as it leads to lower feed intake and feed utilisation. Fermenting rapeseed meal has not shown to result in a protein digestibility that is higher than when using traditional rapeseed meal; the productivity was actually lower leading to a reduced value for diets to which fermented rape seed was added.


Highlights of the 2012 SWINE NRC

Brian J. Kerr - On behalf of the Swine NRC 2012 Committee

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The 11th edition of the Nutrient Recommendations for Swine (NRC, 2012) was released in July 2012. A committee consisting of 10 scientists worked from the basis that scientific literature would provide the foundation for revising concepts, ingredient composition, and ultimately nutrient requirements from the previous publication (NRC, 1998). Furthermore, information on several topics of interest was also added to the publication. In a few instances, discussion and requirements were not changed from the previous publication, because no new information had been published during the preceding 15-year period. In the end, however, the 2012 NRC represents a major revision of the previous publication, including an additional 6 chapters and approximately 200 pages of text/tables. Several key revisions are worth mentioning. Discussion of net energy (NE) concepts was broadened and NE values presented in the ingredient composition tables were predicted from chemical composition and digestible energy (DE). Estimates of amino acid availability were updated, with the 2012 NRC utilizing standardized ileal digestibility (SID) instead of true ileal digestibility, with total and apparent ileal digestibility (AID) values presented as before. Phosphorus requirements also changed dramatically, where phosphorus requirements were expressed on an apparent and standardized total tract digestible basis (ATTD and STTD, respectively) instead of available phosphorus. The models developed in conjunction with the NRC 2012 are a major emphasis of the publication and are a significant refinement of those from the NRC 1998. Biological principles used in the models are described in detail in the respective chapters (energy, amino acids, minerals, etc.). Overall, the models are dynamic, mechanistic, and deterministic in terms of the representation of pig biology. The growing-finishing, gestation, and lactation models were heavily scrutinized and revised relative to a number of critical empirical data sets, with those data sets and comparisons provided in their respective chapters. As in previous publications, requirements (e.g., amino acids, nitrogen, calcium, and phosphorus) are presented in tables, which for the 2012 NRC were generated from their respective models. A new chapter, Chapter 15, outlines a number of research priorities identified by the committee with the intention that these priorities be considered in future research to help overcome limitations of available data needed to develop/challenge the biological concepts defining the models and more accurately describe feed ingredient nutrient composition. Chapter 17 provides feed ingredient composition tables that were revised extensively. Actual ingredient compositions were derived directly from the scientific literature and whereupon an individual page is dedicated to each ingredient at the end of the book.
Feed processing technology to improve feed efficiency in pigs and poultry.

Charles Stark, Ph.D.

Department of Grain Science and Industry, Department of Animal Sciences and Industry,
Kansas State University, USA

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.

Every feed mill, whether commercial or integrated, must decide what technology best fits their business model. Every company has as different set of criteria for determining return on investment and risk based on the company’s business philosophy. In general, large integrated animal production systems focus on manufacturing large amounts feed with very few formulas. These systems are looking for technologies that can reduce labor, increase throughput, and reduce maintenance time and costs. Producing a safe feed with the precise nutrients required for optimal performance is a top priority for integrated systems. While the physical quality of the feed (i.e. pellet quality and fines) is important, not as much emphasis is placed on physical form. However, the effect of particle size significantly affects the performance of both swine and poultry. Research has demonstrated a linear improvement in feed conversion as the particle size of the cereal grain is reduced in swine. Conversely, the data has suggested that broilers need larger particles to stimulate the gizzard, which in return improve the digestion of the nutrients due to reverse peristalsis in the digestive tract of the bird. Commercial feed mills, on the other hand, must focus on feed that is not only safe and nutritious, but also meets customer expectations. Customers most often evaluate the quality of the feed based on its visual appearance and physical characteristics. The return on investment of new technology is driven by many different factors, ranging from safety, governmental regulations, business continuity, expansion of market share, and customer demands. In some instances new technology will be implemented to meet customer demands and government regulations regardless of the return on investment. Since the production of a safe feed and food supply is paramount to the success of both business models, companies need to continually evaluate technology that will improve animal performance, increase efficiency, and produce a safe, high quality feed.

The risk of any new technology is capturing its full value. Technology that is not correctly implemented could be underutilized by the feed mill employees. Senior management must recognize the fact that new technology may require additional training related to its operation and maintenance upon installation. The simple fact still remains that great technology often fails due to poor implementation or the lack of understanding of the feed manufacturing process.

The technology that has the greatest potential to reduce the cost of raising swine and poultry in the feed mill industry is automation. New technology such as NIR in-line analysis of ingredients, linear roll adjustments on pellet mills, and lot tracking of ingredients and feed all rely upon computer automation. The automation system not only controls equipment but
also collects process data and then generates charts and reports that can be used to improve the efficiency of the feed mill and quality of the feed. However, a challenge for the feed mill manager, whether commercial or integrated, is determining the data that has the greatest economic impact on animal performance. Often times, the feed mill does not fully appreciate or understand the effect that processing has on the swine and poultry performance. Changes in moisture content of ingredients, the particle size of cereal grains, or amount of fines in the feed can have a significant impact on animal performance. Unfortunately, many times these changes occur without the knowledge of the feed mill due to the lack of real time feedback about the process. However, new technology such as in-line NIR that measures the particle size of grains and nutrient content of finished feed is providing more real-time information and solutions that can help manage the process.

Automation systems provide enhanced control of the grinding, batching, mixing, and pelleting processes. Maintenance personnel can be alerted to change hammers, screens, or rolls in grinding equipment when the efficiency of the equipment drops below a predetermined limit based upon maintenance and electrical costs. Batching data can be exported to statistical process control (SPC) software, which can generate process charts that help operators make the appropriate changes in free fall, jog times, and cut-off limits to reduce ingredient shrink or prevent nutrient deficiencies in the feed. While data collection is important for managing the process, the increased volume of data that is now captured during the manufacturing process has become overwhelming and often difficult to analyze. For this reason the feed mill manager and plant engineer should systematically evaluate each process within their feed mill and look for technology that can be implemented from the time ingredients are purchased to when feed is delivered to the farm. This evaluation must be a coordinated effort between the purchasing agent, nutritionist, and feed mill manager while working with the animal producer to understand their feeding requirements. Whether the feed mill is manufacturing feed to support an integrated production system or selling commercial feed, the objective should be to produce a safe, high quality feed that optimizes the production of meat, milk, and eggs.
Gilt management and nutrition: an overview

Lia Hoving MSc PhD

EMEA, Provimi B.V.: a Cargill company

Due to genetic progress sow production has increased dramatically over the past decade. As an example, the number of piglets born alive has increased with 1.0 - 2.0 piglets per litter resulting in an increase of 2.0 to 4.5 piglets weaned per sow per year (Table 1). The increased production levels put more and more pressure on the sow as a producer of milk and meat. As a result, sow feeding management needs to keep evolving constantly. Besides optimal gestating and lactation feeding strategies, nutritional management of the rearing gilt also has a large influence on sow productivity and longevity. Since gilts are the future of a sow herd, optimising gilt rearing, but also management of the young pregnant gilt, are crucial for a long productive life.

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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom*</td>
<td>10.9</td>
<td>11.9</td>
<td>21.5</td>
<td>23.6</td>
</tr>
<tr>
<td>Ireland</td>
<td>11.0</td>
<td>12.6</td>
<td>22.8</td>
<td>25.7</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>11.6</td>
<td>13.9</td>
<td>23.3</td>
<td>27.9</td>
</tr>
</tbody>
</table>

Age, body weight and body composition at first insemination are well established factors affecting sow reproductive performance and longevity (Schukken et al., 1994; Challinor et al., 1996; Tummaruk et al., 2001). From the literature one can conclude that age by itself is not a good predictor for future reproductive performance and longevity. Age at first insemination should therefore be combined with back fat, protein content and body weight at first insemination. For a long time it has been thought that fat reserves, often measured as back fat, at first insemination were the key factor in puberty attainment and gilt fertility. However, due to the leaner phenotype of the modern sow, this parameter is probably of lesser importance. Weight at first insemination, if possible combined with back fat, is the preferred parameter to assess gilt development at first insemination. As an example, Williams et al. (2005) showed that gilts inseminated at a weight of 135 kg or higher, had 1.5 to 2 more piglets born in the first 3 parities compared to gilts inseminated at a weight of less than 135 kg. In order to have a gilt with the recommended weight at a certain age (Table 2) one should control the growth rate during the rearing phase. From the literature it can be concluded that gilts with a growth rate of around 600-800 g/day show puberty at a younger age with more developed follicles than gilts growing less than 600 g/day. Effects on future reproductive performance or longevity are less clear, although a growth rate of more than 800 g/day should be prevented since this can cause locomotion problems later in life.
Table 2 General recommendation for weight, age, daily live weight gain (DLWG) and back fat at first insemination. Recommendation can differ per breed and should be checked with consultants before applying

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>135-155</td>
</tr>
<tr>
<td>Age (days)</td>
<td>230 [range 210 – 260]</td>
</tr>
<tr>
<td>DLWG (birth to insemination, gr/day)</td>
<td>600-800</td>
</tr>
<tr>
<td>Back fat (P2, mm)</td>
<td>15-17</td>
</tr>
</tbody>
</table>

Nutrition, feeding schedules as well as feed composition, is a strong tool to influence gilt growth and development during rearing. Nutrition should meet the demands of the developing gilt, but also prepare her for a long and reproductive successful life. Historically replacement gilts have been raised on finisher diets or gestation diets, neither of which is formulated to meet the nutrient requirements of the developing gilt.

A finisher diet is designed for fast growing animals with high lean meat deposition. Excessive growth rates in gilts, however, may lead to future production problems such as osteochondrosis and leg weakness which increase gilt replacement rates within a herd. Furthermore, the vitamins and trace element level in finisher feed do not support bone development and development of the reproductive tract needed for replacement gilts. Young animals are often culled due to locomotive problems such as lameness, osteochondrosis and poor claw health. This can be associated with poor mineral supplementation during the rearing period. The 2012 NRC recommendations show that the requirements for calcium (Ca) and phosphorus (P), in order to maximize bone strength and bone ash are 1 g/kg higher than requirements for optimal gain for finishers. Besides Ca and P, Vitamin D and magnesium (Mg) are needed to optimize calcium metabolism and thereby support bone development. Additional Vitamin E, antioxidants and biotin are required to improve hoof development and immune function, while vitamin B6 and Folic Acid are involved in embryo survival and reproductive performance. Supplemented zinc and manganese assist with the formation and maintenance of cartilage and bones.

A gestation diet is designed for a sow that has finished growing and will not meet the amino acid or the energy requirements of the developing gilt during rearing. Protein (lysine) and energy values of diets are important for optimal gilt development. Since gilts are growing animals they will need more lysine than gestating sows but less than fatteners. Energy values should be at such levels that they optimise development without the risk of making the gilt too fat. Manipulating lysine to energy ratios can affect the ratio of lean to fat growth in gilts, which determines the body composition at first insemination and thereby reproductive performance of gilts and longevity of sows. Finally, the use of fibre in developer diets also stimulates gut development which is important for the transition to gestating diets which often contain substantial amount of fibre. In addition, fermentable fibre in developing diets can increase satiety and therefore reduce the risk on stereotypic behavior and competition for feed when animals are fed below ad libitum.
To conclude, in order to get the most out of a gilt, rearing should aim to optimise body development. Considering the high productive and lean gilts, ‘old’ gilt rearing strategies should be revised. Gilt rearing is a key driver of sow herd productivity. A specific gilt developer feeding programme should be followed, only then will the gilt have the start she needs for a long and productive life.
SPONSORS

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