NEW THOUGHTS ON NUTRITION OF NEWLY WEANED PIGS

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ABSTRACT

Nutrition of weanling pigs remains a key topic of interest in pig production because a good start in the post-weaning period is critical in the subsequent growth, development and survival of pigs through to market. The overriding aim of nutritional programmes is to transition pigs from relatively high-cost diets eaten in smaller quantities to less expensive diets that weaner pigs consume in greater quantities, without detriment to the health and welfare of the animals. Nutritional programmes for weanling pigs are still largely based on the inclusion of antimicrobial compounds such as antibiotics and ZnO, however there is some recognition, even in countries where these compounds are still permitted for use, that sentiment is changing and there is a need to search for other products/strategies to enable pigs to handle the post-weaning period.

INTRODUCTION

The types of feeding programmes for weanling pigs differ around the world, and the nature of these programmes predominately reflect differences in ingredient price/availability (hence diet cost), management considerations (eg. age at weaning), and the general nature of the production system (eg. restrictions on use of antimicrobials in the diet). A plethora of papers, reviews and articles have been written concerning the nutrition of newly weaned pigs, and it is not my intention to reiterate this information. There is no doubt, however, that diet formulation and ingredient selection are critical factors in the successful implementation of nursery feeding programmes, although the age and weight of pigs at weaning are major determinants of performance in the first four weeks following weaning and subsequently through to slaughter (discussed by Dritz, 2004). Similarly, the design of any feeding programme for weaner pigs needs to consider the physiological development (or underdevelopment) of the gastrointestinal tract and interactions with the resident microbiota (Pluske et al., 2004), because the processes of digestion and absorption along with microbial digestion of feed components play key roles in meeting the maintenance requirement of the newly-weaned pig and contributing to growth and, in some circumstances, the gastrointestinal health of the pig. This paper explores some alternative approaches to post-weaning nutrition.

BASIS OF NUTRIENT SPECIFICATIONS FOR WEANER PIGS

Tokach et al. (2003) listed the three major concepts when formulating diets for newly weaned pigs as:

1. Adjusting pigs to the simplest and relatively lowest cost diets as quickly as possible after weaning,
2. Maximizing feed intake to ensure that the pig consumes sufficient energy and nutrients at a time when excess mobilization of body reserves (primarily lipid) can occur, and
3. Formulating the initial diets with highly digestible ingredients that complement the pattern of digestive enzymes, and digestive enzyme development, in the gastrointestinal tract.

Therefore, weanling pig diets have been manipulated predominately to overcome the limitations or immaturity in digestive function so as to maximize the growth of the whole animal. As such, ingredient selection (in addition to cost) to meet these objectives is generally based on nutrient digestibility, amino acid density, lactose concentration, and stimulatory effects on voluntary feed intake from products such as spray-dried animal plasma. The NRC (1998), for example, list the nutrient requirements for pigs of different weights and, as has been described previously in many other papers, nutrient requirements per kg of diet (eg. lysine) and the diet complexity generally decrease with age in accordance with increased feed intake by the pigs. Inherent to changes in diet specifications after weaning is an understanding of the gastrointestinal changes that occur, and this will now be discussed.

FEEDING THE GASTROINTESTINAL TRACT AFTER WEANING

Burrin and Stoll (2003) highlighted the temporal changes in gastrointestinal development and growth after weaning, showing that early-weaned pigs (14 days in this case) have an 'acute phase' lasting about 7 days and a subsequent 'adaptive phase' in which the gastrointestinal tract recovers from the immediate post-weaning insults. Although the duration and magnitude of these phases varies according to factors such as weaning age, environment, genotype and health status, they are generally coincidental with patterns of energy intake and weight gain after weaning (Le Dividich and Seve, 2000), although the variation surrounding these indices can be enormous (Brooks and Tsourgiannis, 2003). Feeding programmes and feed budgets after weaning have evolved to accommodate these two phases and place pigs as soon as possible onto cheaper diets, but the percentage of pigs in a population that fit this generalized pattern is unknown. Indeed, what are the implications for pigs that fall outside this pattern?

In this regard, Burrin and Stoll (2003) remarked that given increases in the understanding of intestinal nutrient utilization of recent times, it is (theoretically perhaps) possible to formulate diets for weanling pigs with the specific goal of optimizing the growth, function and health of the gastrointestinal tract. Their review comprehensively describes some of the most promising candidates they believe could be used in weanling pig diets based upon their known mode(s) of action in the gastrointestinal tract and their utilization in the portal-drained viscera (PDV), the tissues of which include the stomach, pancreas, small and large intestine, and the spleen. In pigs, the PDV tissues contribute approximately 5% of body weight yet account for 20-35% of whole-body protein turnover and energy expenditure (Yen et al., 1997), which reflects their disproportionately high fractional protein synthesis rates and O_2 consumption. The high rates of metabolism and nutrient utilization in the gut are directly linked to the high rates of proliferation, protein secretion, apoptosis and desquamation of various epithelial and lymphoid cells within the mucosa (Burrin and Stoll, 2003), all of which are a key feature of the post-weaning period.

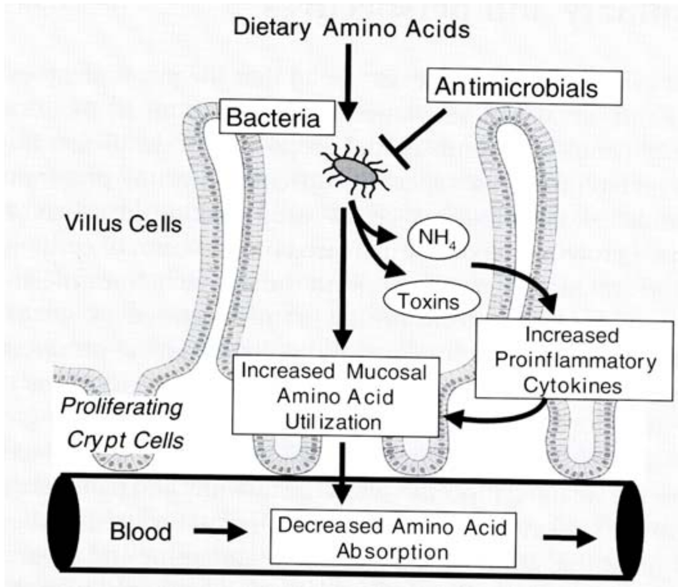
Gut specific nutrients suggested by Burrin and Stoll (2003) include the amino acids glutamine, glutamate and threonine, and the reader is directed towards this review for more extensive information. Glutamine and glutamate are not considered as “essential” amino acids in traditional diet formulations, however there is a large body of evidence in many species, including young pigs, showing some benefits to the addition of these amino acids in the immediate post-weaning period. Arginine, an essential amino acid for neonates but not for growing pigs, was shown by Wu et al. (2004) to decline markedly in plasma during suckling, and supplementation of 0.2 and 0.4% arginine to 7- to 21-day-old artificially-reared pigs increased piglet growth rates by 28 and 66% respectively. Whether there is a conditionally essential requirement for arginine after weaning has not been investigated to my knowledge, however for producers that feed pigs milk liquid diets then attention to arginine levels may be warranted. Obviously major consideration for any of these amino acids of course is the cost of such interventions.

In addition, the influence of post-weaning infections and associated inflammatory responses on aspects of gastrointestinal function warrants mention. Burrin and Stoll (2003) suggested that enteric infection increases intestinal nutrient requirements that in turn limit the availability of dietary nutrients for growth. A schematic illustration of this is shown below (Figure 1). Key questions include how an infection, such as enterotoxigenic *Escherchia coli* infection, alters the pattern of intestinal nutrient utilization, and what are the key nutrients that may either become limiting for intestinal function/body growth and/or assist with gastrointestinal repair. In the case of enterotoxigenic *Escherchia coli* infection for example, which can still be prevalent 10-12 days after weaning, it seems ironic that some pigs in a pen could be offered a lower specification diet just at the time they require a higher specification diet to boost gut repair. Economics and facility management obviously play key roles in addressing this, however from a biological perspective I think this is an interesting question and one worth discussing.

ALTERNATIVES TO ANTIMICROBIALS

Much has been written and spoken, especially in view of the EU ban from 1st January 2006 on the use of prophylactic levels of dietary antibiotic growth promotants, regarding a nutritional ‘magic bullet’ to assist pigs overcome the post-weaning growth check, even in situations where antimicrobials are still permitted for use. Debate and discussions will obviously ensue for some time and more so in parts of the world that face increasing pressure to severely limit/abolish the use of current antimicrobials. Regardless, there is a plethora of products/strategies mentioned when this topic is raised. What I have attempted to do in the following discussion is highlight some ideas that could be considered/reconsidered in this general environment.

Figure 1. Illustration of the relationship between intestinal amino acid metabolism and luminal bacteria (after Burrin and Stoll, 2003).

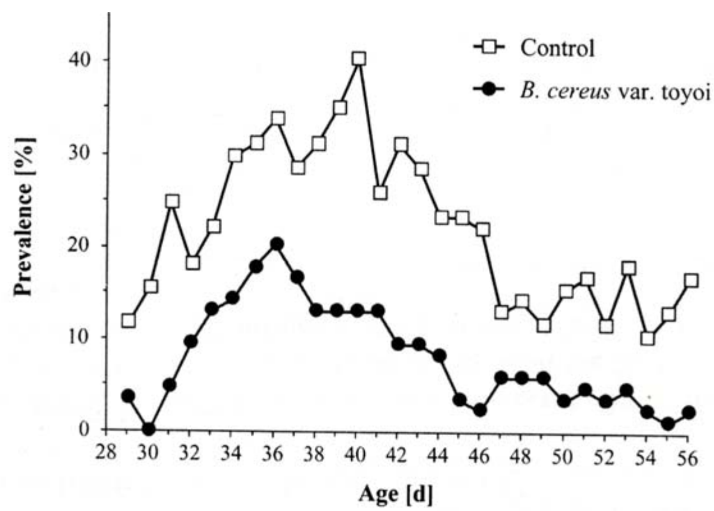


Should I Use Probiotics?

Many different and diverse nutritional strategies are being investigated, and some are being used commercially, to maintain animal performance and intestinal health in the absence of antimicrobial agents. One of these strategies is the use of probiotics, a feed additive containing bacteria that is claimed to improve the intestinal microbial balance (quite vague) and reduce gastrointestinal disturbances in the post-weaning period. Data in the literature purporting the benefits of probiotics for nursery pigs are equivocal, which is no real surprise given the different species and strains that are used and the wide array of weaning and feeding conditions that products work under. Differences in herd health status undoubtedly also contributes to the ambiguity in efficacy seen. Even if a particular probiotic has potential, its usefulness is limited by the newly weaned pig's inability to consume enough bacteria in the immediate post-weaning period, ironically when it is most susceptible to gastrointestinal insults. This lack of a constant, threshold level of probiotic bacteria in the gastrointestinal tract in the population of nursery pigs is a possible reason for the disparity seen in the overall effectiveness of probiotic preparations.

Is there a better way of delivering probiotics? Can we think 'outside the box' with regard to delivering potentially beneficial bacteria instead of relying on a stressed newly-weaned pig to do the job? Work from the UK with fermented liquid feeding (Demeckova et al. 2002) and Germany with *Bacillus cereus* var. toyoi (eg. Taras et al. 2005) has suggested that transfer between sows and newborn piglets of bacteria (or a particular species) coupled to an altered microbiota in the feces of the dam exerts a beneficial influence on both pre- and post-weaning development of the young pig. There is also some suggestion of altered milk 'quality' in sows with feeding spores of *B. licheniformis* and *B. subtilis* (Alexopoulos et al., 2004). In the study by Taras et al. (2005), one group of sows were fed for a period of 17 weeks, from day 24 after mating to day 28 after farrowing, and the piglets from these sows were fed for 6 weeks, from day 15 of lactation to 8 weeks of age. The control group of sows/piglets did not receive the probiotic strain. The *Bacillus cereus* var. toyoi was recovered from the feces of sows and piglets throughout the trial, including the period 0-14 days of age before introduction of the starter diet occurred, and there was an improvement in FCR of pigs in the post-weaning period derived from sows fed the probiotic during pregnancy and lactation. Of particular interest in the weaned pigs offered the probiotic was a significant reduction in the incidence of liquid feces (Figure 2) and post-weaning diarrhoea. Diets did not contain any antimicrobial agents, suggesting that this particular probiotic strain reduced the proliferation of enterotoxigenic *Escherichia coli* in the gastrointestinal tract of weaned piglets.

Figure 2. Prevalence of liquid feces (consistency score 4-5) during the total post-weaning period (day 29-56) of piglets in the Control (open boxes) and probiotic (closed circles) group, respectively (after Taras et al., 2005).

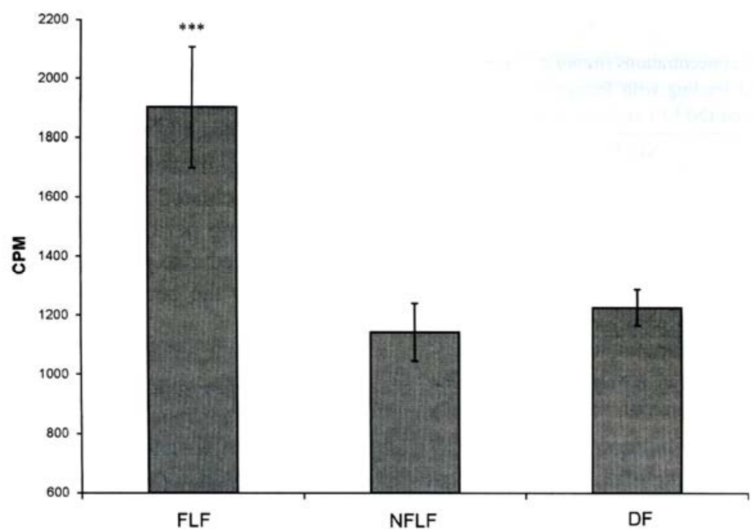


Liquid Feeding of Weanling Pigs

Liquid feeding of growing-finishing pigs is gaining popularity around the world, and in Ontario an estimated 20-30% of pigs are raised using liquid feeding systems (Braun and de Lange, 2004). Liquid feeding can involve partial fermentation of ingredients or diets, and in this instance the production of high concentrations of organic acids (especially lactic acid) and lactic acid bacteria (LAB) are seen as key aspects of the process. Liquid feeding of newly weaned pigs is less common as it is generally viewed as more problematic, but nevertheless there are numerous potential advantages such as the use of cheaper co-products and positive effects on gastrointestinal health and function. Liquid feeding research being conducted at the University of Guelph in newly weaned pigs has focused on comparisons with dry diets, the use of high-moisture corn, and phytase and phosphorus. Data will be presented during the presentation to highlight some of the results of these studies.

Feed may be fermented with wild and/or introduced LAB, and this process has been shown to reduce coliform numbers in both the feed and the gastrointestinal tract. High numbers of LAB in fermented liquid feed (FLF) have been shown to modulate the mucosal immune system (eg. Gill and Rutherfurd, 2001) that, in a sow, could potentially cause higher levels of colostral immune factors (better colostrum 'quality') and therefore contribute to a more robust piglet at the point of weaning. Demecková et al. (2002) fed sows for approximately 2 weeks before farrowing and 3 weeks after parturition on one of three diets: (i) dry pelleted feed, (ii) non-fermented liquid feed (NFLF), and (iii) FLF. A strain of *Lactobacillus plantarum* was used in the FLF. Demecková et al. (2002) showed that faeces excreted from sows fed FLF had lower numbers of coliforms, and piglets sucking from sows fed FLF excreted faeces higher in LAB and lower in coliforms than their counterparts sucking sows fed dry pellets. Of particular interest in this study though was the enhanced mitogenic capacity of the colostrum derived from sows fed liquid feed, especially the FLF. Colostrum from sows fed FLF and NFLF had a greater mitogenic activity on epithelial cells compared to dry-fed sows, but the colostrum from sows fed FLF only had the greatest effect on mitogenic activity in blood lymphocytes indicating a greater level of lymphocyte proliferation and, by association, possible enhanced immune function (Figure 3).

Figure 3. **Mitogenic activity of sow colostrum on blood lymphocytes. Data are expressed as mean counts per minute (CPM). Error bars are standard error of the mean. *** P < 0.001 (after Demecková et al., 2002).**



Collectively, the data presented in the studies by Taras et al. (2005) and Demecková et al. (2002) suggest an alternative means whereby the overall robustness of the neonatal and weaned pig could be improved, i.e. through the sow. Such an approach could circumvent the issue of low feed intake in the post-weaning period, and hence the low intake of additives/compounds reputed to be beneficial to the newly weaned pig. The data of Demecková et al. (2002) suggest that neonatal defence may be enhanced by manipulating the immune status of farrowing/lactating sows because of the provision of colostrum/milk of greater immunological and nutritional quality. The question remains to be seen, however, whether any benefits bestowed on sucking piglets can be transferred to the period after weaning.

GASTROINTESTINAL HEALTH, CARBOHYDRATE AND PROTEIN IN DIETS

Data presented nearly 40 years ago by Smith and Halls (1968) showed clearly that providing a source of insoluble dietary fibre in diets for weanling pigs reduced the incidence of enterotoxigenic diarrhea after weaning. The widespread use of antimicrobial agents coupled with advances in feed processing, diet formulation and production systems since this time virtually consigned the word ‘fibre’ to the sin bin with regard to its usefulness in modulating the gastrointestinal environment of the young pig. The wheel has seemingly turned full circle in some parts of the world because some nutritionists again view dietary fibre as a key weapon in their arsenal to combat post-weaning enteric problems in the absence of antimicrobials.

A large body of information is available on dietary fibre and its effects in pigs, and I will not add to the mound. Rather, I think it is important to discuss dietary fibre, or specifically components of dietary fibre (eg. non-starch polysaccharides and resistant starch), in relation to other dietary components such as crude protein where the gastrointestinal health of the weaned pig is concerned. It appears that an appropriate balance between the ‘carbohydrate’ content of the diet and the ‘protein’ content (or undigested protein content) of the diet might play a role in gastrointestinal health and function that in turn impinges upon growth efficiency. Such a concept might not neatly be accommodated with a least-cost diet formulation philosophy, but in situations where, for example, legislation restricts the use of pharmacological levels of minerals and/or antibiotic growth promotants are banned, then such a concept becomes more attractive.

In broilers for example, de Lange (2005) presented data showing a positive linear relationship between FCR and the amount of undigested crude protein in the diet, with the nature of this relationship being different with or without antibiotic growth promotants. The presence of more undigested crude protein in the distal part of the gastrointestinal tract caused deterioration in FCR, with this author suggesting that the end-products of proteolytic fermentation were harmful to the host and stimulated the growth of sulphite-producing bacteria and some LAB that further impaired FCR. More recently in Quebec, Cardinal et al. (2006) examined 34 herds with a weaning age less than 22 days in which 17 herds did not have post-weaning *E. coli* diarrhoea (PWECD) and 17 herds were affected by PWECD. Risk-factor analysis for PWECD showed that the affected herds used higher levels of soybean meal and canola products, and had higher Ca (and Mg) levels and lower Zn and electrolytic balance (EB) levels, than non-affected herds. Cardinal et al. (2006) recommended that to prevent/reduce PWECD, protein of animal origin should be included in the feed for the first 3 weeks post-weaning without high Ca levels.

In somewhat of a contrast, we (Kim et al. 2005) have shown that adding 20 g oat hulls per kg diet to a diet containing cooked white rice as the only cereal (where the starch is 98% apparently digestible at the ileum) and animal protein sources (most likely of varying ileal digestibility) reduced the incidence of post-weaning diarrhoea and the number of antibiotic treatments. The levels of blood urea nitrogen and concentrations of some biogenic amines were also reduced in pigs given the diet with oat hulls, suggesting that oat hulls changed fermentation characteristics in the hindgut, possibly by altering the balance of the microbiota. Jeaurond and de Lange (2005) reported similar changes in biogenic amine contents using poultry meal and sugar-beet pulp.

It is recognized that the 'quality' of animal protein sources varies enormously (eg. Hendriks et al., 2004 showed enormous variation between manufacturing plants in the 'quality' of New Zealand meat-and-bone meal), so it is of little surprise that there is disparity between studies. Greater attention to the indigestible component of some protein sources coupled to greater awareness of dietary fibre sources could impact positively on post-weaning pig performance and health, although obviously account needs to be taken of the specific situation in question.

CYTOKINES AND FATTY ACIDS

Interactions between nutrition and immunity are diverse and can have profound implications for pig growth and productivity. Pro-inflammatory cytokines released from macrophages act to both amplify the cellular immune response following immunological challenge and act systemically to change behavior, metabolism and neuroendocrine secretions (Johnson, 1997). The pro-inflammatory cytokines are important mediators of the inflammatory response, and one of the consequences of the weaning process sometimes observed is an elevation in indices of inflammation (King et al., 2003). Transient anorexia in the immediate post-weaning period impairs the integrity of the mucosal epithelium and elevates markers of the inflammatory response (Pie et al., 2004).

Grimble (1998) reviewed the effects of nutrients, predominately antioxidants, proteins and amino acids and fats, influencing the ability of cells to produce cytokines and affecting the ability of target tissues to respond to cytokines. With respect to fats, there is now sufficient evidence both in the literature and commercially advocating the use of some fatty acids in diets modulating both immune and anti-bacterial responses in pigs. In the weaned pig the notion of using specific fatty acids is obviously attractive because they can simply be added to the diet often at little cost and are sometimes as effective as antimicrobial agents. For example, research from Belgium by Dierick et al. (2002) shows strong *in vitro* and *in vivo* anti-bacterial effects of medium-chain fatty acids on the pig proximal small intestine in the absence of traditional antimicrobials.

FEED MANUFACTURING AND QUALITY

Issues including grinding and particle size and pellet 'quality', whether or not to use cooked cereals, and pellets versus meal, are always of keen interest to feed manufacturers and producers. Pelleting of diets for young pigs is generally regarded as providing better performance and feed conversion efficiency than meal diets, although attention needs to be paid to the percentage of fines because an increased concentration of fines can bridge feeders and hence decrease performance (Table 1). Another possible advantage of pellets over meals relates to flow ability of diets. Research using the angle of repose [a measure of the maximum angle (º) at which a pile of ingredients retains its shape] showed greater flow ability in meal diets with granulated specialty protein or coarsely ground lactose sources (Carney et al., 2005).

Table 1. The effect of fines in nursery diets on pig performance (after Stark et al. 1994)[A].

	Minimum fines	300g fines added/kg of diet	Difference, %
Weight gain, g/day	469[a]	454[b]	-3
Feed intake, g/day	772	771	0
Feed:gain (g:g)	1.65[a]	1.70[b]	+3

[A]Trial conducted between 7-21 days after weaning.
[a,b]Values in a row with a different superscript are significantly different ($P < 0.05$).

A topic that is always of interest is pellet size, yet there is little empirical evidence to make a formed decision. In a factorial study, Edge et al. (2005) offered sucking pigs a creep feed with a diameter of either 5.0 mm or 1.8 mm followed by pellets of either 1.8 mm, 2.4 mm or 5.0 mm diameter after weaning. These authors failed to find any long-lasting effects of pellet diameter on production in the peri-weaning period. Earlier, Traylor et al. (1996) presented data showing that pellets to 12 mm in diameter had no influence on post-weaning performance, as did the provision of a meal-based diet. Nevertheless, details are lacking as to whether manufacture of a smaller pellet influences nutrient (eg. amino acid) availability.

CONCLUSIONS

This paper has attempted to outline some different/alternative philosophies or approaches to nursery pig nutrition. The perennial problem of low feed intake in the immediate post-weaning period, by implication, means that potentially useful compounds are delivered irregularly and/or in suboptimal concentrations to evoke a positive response. Obviously there are many other strategies that could be pursued as ‘new thoughts’ on weaner pig nutrition, but the cost and overall acceptance by producers of such strategies must be taken into account.

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