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Weaning a pig with a healthy gut: Nutrition

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We adhere to three key concepts when formulating nutrition programs for the nursery pig. First, the economics of today's swine industry dictate that we must adjust pigs to the simplest and relatively lowest cost diets (i.e., grain and soybean meal) as quickly as possible after weaning. Second, we must remember that the newly weaned pig is in an extremely energy dependent stage of growth and that maximizing feed (energy) intake is essential. Third, we must remember the digestive physiology of the nursery pig and formulate the initial diets with highly digestible ingredients that complement the pattern of digestive enzymes secreted at weaning.

One example emphasizing all three of these concepts is the practice of using soybean meal in diets fed immediately after weaning. The source and percentage of soy protein in diets for early-weaned pigs have been controversial subjects among swine nutritionists because of the implication that soybean protein causes an immune-mediated pathology leading to decreased growth performance (Li et al., 1990; Engle, 1994).

Briefly, some nutritionists believe that weanling pigs should be fed diets with no or very little soybean meal immediately after weaning and that the level should be steadily increased over time. This slow and very gradual introduction of soybean meal into the pig's diet will minimize the potential for delayed-type hypersensitivity to the soy proteins, conglycinin and beta-conglycinin (Li et al., 1990a,b; 1991a,b) and, thus, generally results in excellent growth performance initially after weaning. However, it also leads to very high nursery feed cost.

A second option is to feed a diet with a moderate level (10 to 15% of the diet for pigs weaned between 15 and 21 days of age) of soybean meal as a partial replacement for more expensive specialty protein sources (Friesen et al., 1993). This approach is a compromise between feeding extremely expensive all milk- and animal specialty protein-based diets and too simple grain-soybean meal-based diets. As a result, the pig's feed intake is stimulated by the lactose and specialty protein sources, which are highly digestible and palatable and, thus, increase energy intake. At the same time, the pig becomes exposed to the moderate amount of soybean meal protein, minimizing the negative effects of a delayed-type hypersensitivity response. As a result the amount of soybean meal in the diet can be

quickly increased in a phase feeding program to decrease the need for the more expensive specialty protein sources.

The net result of using soybean meal in this fashion is that we can still provide a highly digestible complex diet that stimulates feed intake immediately after weaning, and then quickly reduce diet complexity by increasing the amount of soybean meal protein (Dritz et al., 1996). This strategy takes advantage of the fact that the impact of diet complexity on feed intake and pig performance decreases rapidly after weaning, especially in high health pigs. Thus, a feeding program can be developed that nutritionally allows for maximum growth performance and yet will be economically competitive.

Ingredient selection based on digestive capacity

Selection of different types and amounts of other feed ingredients also should be based on the three primary criteria of quickly reducing diet complexity to lower feed cost, maximizing feed (energy) intake, and physiology of the digestive system. Indeed, ingredient selection in addition to cost, should be based on factors including nutrient digestibility, amino acid density, lactose concentration, and stimulatory affects on feed intake or growth. Another consideration is how an ingredient or combination of ingredients will react under various feed processing methods. The use of added fat is an example of this latter consideration. Although added fat is not well utilized by the pig immediately after weaning, its inclusion is essential if diets containing high levels of milk and other specialty protein sources to lubricate the pellet die during feed manufacturing.

The newly weaned pig's digestive system is relatively immature but, at the age of weaning, well adapted to digest the proteins, lactose, and lipids secreted in sow's milk. It has been well established that inclusion of lactose containing ingredients assists in the transition at weaning from sow's milk to a dry diet (Nessmith et al., 1997). However, evidence may suggest that despite our best attempts to mimic the nutrient composition of sow's milk in a dry diet, there are dramatic changes that take place in the size, shape, and functioning of the villi in the small intestine (Xu and Cranwell, 2003). The anatomical changes in the

villi after weaning may be a possible cause for poor utilization of some ingredients. For example, the anatomical changes in the villi may cause the reduction in secretion of fatty acid binding protein, which correlates with poor fat utilization by pig for approximately 10 to 14 days after weaning (Reinhart et al., 1990). Ingredient selection also can change the degree to which these changes in the structure and functioning of the villi take place. An example is the shearing of villi caused by the delayed-type hypersensitivity reaction to excessive soybean meal fed immediately after weaning (Li et al. 1990a,b). Certain ingredients, such as spray-dried animal plasma also may have a positive effect on intestinal development (Jiang et al., 2000). Although our understanding of the influence of ingredient selection on structure and functioning of the villi has improved, the rapid change in function of the villi at weaning still seems to be a primary challenge in weanling pig nutrition.

Energy

Maximizing feed intake after weaning reduces stress and increases growth rate by decreasing the mobilization of lipid stores to provide energy for protein deposition (Whittemore et al, 1978). Weanling pigs simply do not eat enough feed to maximize their potential for protein deposition. Thus, any increase in feed (energy) intake will result in a further increase in growth rate provided proper nutrient to calorie ratios are maintained. In order to maximize energy intake, ingredients must be highly palatable to stimulate feed intake; highly digestible, and contain a high net energy concentration. When selecting protein and energy sources, their impact on feed intake must be carefully considered. Also as discussed earlier, newly weaned pigs lack the digestive capacity to effectively absorb energy from fat sources. Thus, use of increased added fat will not effectively increase caloric intake to drive growth rate. Finally, increased feed intake in the first week after weaning has been shown to clearly reduce the risk of enteric disease (Madec et. al, 1998).

Amino acids

Because of dramatic improvements in our understanding of the environmental requirements of weanling pigs as well as management and pig flow practices that result in minimizing exposure to disease antigens, protein deposition and, thus, amino acid requirements have increased over the past 10 years. Although the lysine requirement estimate for the weanling pig has increased in recent publications (NRC, 1998), many would argue that these requirement estimates may still be too low for the high-health, high lean growth potential pigs in commercial production systems. A detailed discussion of amino acid requirements is beyond the scope of this paper, but with availability of lower cost synthetic amino acids high amino

acid levels can be economically fed while lowering the levels of soybean meal.

Vitamins

Conducting and interpreting research evaluating vitamin requirements of weanling pigs is frustrating because of the tremendous variation in response between trials. These often-conflicting results appear to be somewhat characteristic of studies conducted on vitamin requirement estimates. It is likely that factors, such as age, health, environment, lean growth potential, and diet may influence responses to added vitamins. While it seems there is trial-to-trial variation in pigs' response to vitamin supplementation, one observation is certain: current NRC (1998) vitamin requirement estimates are too low for pigs in commercial production. Vitamins that should be routinely supplemented in nursery diets include the fat soluble vitamins A, D, E, and K and the water soluble vitamins B₁₂, niacin, pantothenic acid, and riboflavin. Of the fat-soluble vitamins, the majority of research has been conducted on vitamin E because it is generally one of the most expensive vitamins to add to a diet. Data would indicate that if the sow has adequate supplemental vitamin E and selenium in gestation and lactation diets (44 IU/kg and 0.3 ppm, respectively; Mahan, 1994), supplementing nursery diets to 44 IU/kg of added vitamin E should be adequate (Moreira and Mahan, 2002). However, if breeding herd diets contain less than 44 IU/kg, greater than 44 IU/kg of feed added in nursery diets may be needed in some herds to minimize the incidence of mulberry heart occurrence post weaning. Detailed specifications for vitamin levels can be found at the following web site: http://www.oznet.ksu.edu/dp_ansi/swine/swine.htm.

Minerals

Nursery pig diets should be supplemented with the macro minerals calcium, phosphorus, sodium and chloride and the trace minerals copper, iodine, iron, manganese, selenium, and zinc. As for the macro minerals, because of their relative abundance and availability in milk and other specialty protein sources, providing a wide margin of safety above the pig's actual requirements is neither difficult nor costly. Because of the importance of bone growth early in the pig's life, calcium and available phosphorus concentrations should range from 0.90 to 0.75 and 0.48 to 0.40 from weaning to 20 kg, respectively. The other macro minerals that appear to improve pig growth performance are sodium and chloride (Mahan et al., 1996). Despite the relatively high concentrations of sodium and chloride in dried whey and spray-dried animal plasma, studies show improved growth performance when salt is supplemented to diets containing high levels of these ingredients (Mahan et al., 1996). The sodium and chloride

requirement of nursery pigs initially after weaning is clearly higher than recommendations of NRC (1998).

Copper and zinc are the two trace minerals that have received the most attention due to their potential as growth promoters. The basal requirement for copper and zinc is approximately 10 and 100 ppm, respectively. Data on the addition of high levels of copper (100 to 250 ppm) to starter diets as a growth promoter was summarized well by NRC (1998). In recent years, numerous experiments have demonstrated that adding high levels of zinc oxide (3,000 ppm) to nursery diets improves pig performance (Hill et al., 2001) immediately after weaning and to a greater extent than copper sulfate (Smith et al., 1997). Most commercial diets now use 2,000 to 3,000 ppm of zinc oxide as a growth promoter immediately after weaning and 100 to 250 ppm of copper sulfate or no supplemental copper or zinc in the late nursery diets.

Post-weaning diarrhea and Zinc Oxide. Post weaning diarrhea associated with hemolytic *Escherichia coli* is a common. Supplementing nursery diets with 3000 ppm ZnO post-weaning has also been observed to have beneficial effects in helping control post-weaning *E. coli*-associated challenges under field conditions (Holm and Poulsen, 1996, Tokach et al., 2000).

A case study by Tokach et al. (2000), clearly illustrated the clinical and economic impact zinc oxide can have in controlling post-weaning diarrhea. When diet formulations were reviewed, it was discovered that the first two diets fed to the weaned pigs in the case herd contained 612 ppm zinc from zinc oxide, instead of the specified 3,000 ppm. Comparable diets for the pigs in the other two locations did contain 3,000 ppm zinc. The diet formulation error was corrected, and performance of the next groups of pigs improved. The economic loss was calculated as \$3.13 to 5.88 per weaned pig.

In a challenge study, Jensen-Waern et al. (1998) found that adding 2500 ppm of zinc from zinc oxide to the diet prevented postweaning diarrhea without affecting the numbers of *E. coli* excreted in the feces. In another challenge study (Mores et al., 1998), high concentrations of zinc from any of four zinc oxide sources reduced the occurrence of *E. coli* diarrhea without affecting fecal shedding of the *E. coli*. In these experiments, a high prevalence of diarrhea occurred in pigs that did not receive high concentrations of zinc oxide when challenged. Another study, demonstrated that pigs supplemented with ZnO at 3,000 ppm had a reduced translocation of bacteria to the ileal-mesenteric lymph node (Huang et al., 1999). Other work has indicated that ZnO may protect intestinal cells from *E. coli* infection by inhibiting the adhesion and internalization of bacteria, preventing the increase of tight junction permeability (Roselli et al, 2003). Therefore, it appears that ZnO is facilitating a barrier function rather than an antibacterial effect. Thus, implications for ZnO

addition to the nursery pig diet seem to indicate that it will minimize clinical effects of disease but will have little effect on shedding and environmental contamination.

Nonnutritive feed additives

The NRC (1998) has provided excellent background information on many of the nonnutritive feed additives that have been used in nursery pig diets including, microbial supplements, oligosaccharides, enzymes, acidifiers, flavors, and pellet binders. Although microbial supplements or probiotics have been reported to improve performance under some field conditions, most controlled experiments have failed to show consistent, beneficial responses (NRC, 1998). Oligosaccharides, such as mannan oligosaccharide also have been reported to improve pig performance (Miguel et al., 2004). But, the response is modest and inconsistent and research is needed to determine the conditions (diet, environment, pathogen load, etc) necessary to demonstrate a consistent benefit. Other additives include various plant extracts and spices (Turner et al, 2001). Many of these additives are being advocated as a replacement for antimicrobials. However, the supporting data for their usage is limited and inconsistent. Therefore, we believe implementation of sound production practices such as improved hygiene is a more cost effective investment than many of these types of additives.

The challenges for feeding early-weaned pigs extend beyond diet formulation and nutrient requirements including carefully selecting ingredients to maintain the mucosal function of the small intestine. Recognizing that many of these challenges are interrelated areas will lead to successful nursery pig nutrition programs.

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