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RECENT DEVELOPMENTS IN STARTER PIG NUTRITION

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INTRODUCTION Technology on the feeding and care of the early weaned pig has improved immensely in the last 10 years. As producers have moved to weaning at a younger age, the industry has evolved from feeding simple corn-soybean meal diets from weaning to market to a phase feeding system utilizing numerous diets tailored to the changing needs of the pig (Nelssen, 1986). However, due to the differences in diet cost, many producers still have difficulty determining whether to use less expensive simple diets or a complex, phase feeding system. The purpose of this paper is to aid nutritionists in making that decision by: 1) presenting the theory behind the simple vs complex diet controversy including the advantages and disadvantages associated with each system, 2) describing a nutritional program that can be tailored to weanling pigs of different ages and weights, and 3) providing an update of recent nutritional research on the appropriate protein, carbohydrate and fat sources and levels for the young pig. However, before we can confidently select a particular feeding program, we must understand the biology and stressors facing the pig we are trying to feed.

THE EARLY WEANED PIG - WHAT ARE WE DEALING WITH? The young pig is rapidly undergoing many digestive, metabolic and immunological changes during the first few weeks of life. As shown in Figure 1, lactase, the enzyme associated with the digestion of milk carbohydrate, peaks in activity two to three wk after birth and rapidly declines. The immunological status, shown in Figure 2, is also rapidly changing, as passive immunity from the colostrum is high on day one, but rapidly declines by three wk of age. Active immunity doesn't start building to any extent until after three wk of age and only begins to function effectively at 4 to 5 wk of age (Pond and Maner, 1984). There is also evidence that certain metabolic pathways need time to become fully functional in the young pig.

As seen in Figures 1 and 2, the young pig is rapidly changing and, thus, his ability to handle different dietary ingredients and environmental stressors is also changing. It is imperative that diets are designed to match digestive capabilities of the pig and to reduce unneeded strain on the immune system. Therefore, nutritional programs must be tailored to the age and weight of the pig that is being weaned.

Weaning also provides many changes that must be considered. Prior to weaning, piglets are provided approximately 24 equally spaced meals per day. On a dry matter basis, each of these meals contains approximately 35% fat, 30% protein and 25% lactose. The diet is provided in a highly digestible liquid form and all piglets are conditioned to eating at the same time and only when the sow tells them to eat. After weaning, piglets are often expected to adjust to a dry diet with a vastly different composition. They are also supposed to tell themselves when, how much and how often to eat. Usually, there is not enough feeder space available for all pigs to eat at once. Management practices, such as frequent feeding, use of feeding boards and providing highly digestible diets, can limit some of these potential stresses.

SIMPLE VS COMPLEX DIETS

The key behind the use of simple corn-soybean meal starter diets is the concept of compensatory growth during the grower and finisher phases. Advocates of simple starter diets stress minimizing feed cost during the starter phase. They are willing to accept reduced performance and slower growth in the starter phase as they believe the pig will compensate by growing faster in the subsequent grower and finisher phases. The obvious advantages of this system are reduced diet cost and less management input as fewer diet changes are required. The disadvantages of poor performance and the postweaning lag are the reasons the phase feeding system was developed.

Proponents of complex diets in a phase feeding starter program dispute compensatory growth claims. They believe postweaning lag can be avoided and optimal growth from weaning to 22-23 kg can be achieved by finding the proper balance between diet cost and pig performance. They believe the enhanced gain in the starter phase will be maintained to market weight. The major disadvantage of complex diets in a phase feeding system is the immediate diet cost. However, these diets are highly digestible, palatable and can be matched to the rapidly changing nutrient requirements and digestive capabilities of the young pig. The improvements that this program offers in pig performance are especially important in intensively managed production units, where maximizing pig throughput is critical.

The key to settling the dispute in determining which program is most cost-effective appears to center on whether compensatory gain occurs? In other words, is the additional weight gain achieved from feeding complex diets during the starter phase lost during the subsequent grower and finisher phases? We must determine if the postweaning lag normally found when feeding a simple corn-soybean meal diet to early weaned pigs affects pig performance to market weight?

To answer the compensatory gain question, reseachers conducted an experiment (Tokach et al., 1991a) to determine whether the growth response gained from feeding a high nutrient density starter diet was lost during the grower and finisher phase. A total of 240 pigs (initially 5.4 kg and 21 d of age) were allotted to four dietary treatments. Treatments were imposed during the starter phase with all pigs receiving the same grower and finisher diets. During the first two wk (Phase 1) following weaning, diets contained 0 or 40% milk products

(20% dried whey, 20% skim milk) and either 0 or 6% soybean oil. During wk 3-5 postweaning (Phase 2), the skim milk was removed. Addition of milk products to the starter diet improved (P<.01) ADG (.12 vs .19 kg) and feed utilization (F/G; 1.9 vs 1.24) during Phase 1 and daily gain (.42 vs .46 kg) during Phase 2. Adding fat to the diet did not affect growth performance during Phase 1, but improved ADG and F/G during Phase 2. However, overall pig performance to market weight was not improved by adding fat to the starter diet. Advantages gained from milk products during the starter phase were not lost during the subsequent grower and finisher phase, indicating that compensatory gain did not occur. Pigs fed the diet containing 40% milk products during the initial 2 weeks postweaning were 5 kg (104.5 vs 99.5 kg) heavier at market compared to those fed the simple starter diet without milk products. Recently, another University of Minnesota experiment (Stairs et al., 1991) confirmed compensatory gain does not occur and that adding milk products to the starter diet not only maintains, but actually improves subsequent performance in the grower and finisher phase. Thus, the economic advantages of a phase feeding starter program must include both the improvements gained in performance during the starter phase and advantages in subsequent performance to market.

Recent research at Kansas State University confirms that postweaning lag affects pig performance all the way to market weight. In our experiment, pigs were placed in four categories based on ADG during the first wk after weaning (<0, 0-150, 150-225, >225 kg). Days to market were monitored for the four groups. The results shown below illustrate that the postweaning lag can have a prolonged effect on pig performance, substantially increasing days to market.

	Wt (kg) on d			
Wk 1 ADG, g	28	56	156	d to MKT
≤ 0	14.7	30.1	105.3	183.3
0 - 150	16.0	31.8	108.1	179.2
150 - 225	16.9	32.5	111.2	175.2
> 225	18.2	34.7	113.3	173.0

Bottom line cost comparisons between the simple diet and phase feeding programs are difficult to make due to the rapid changes in ingredient prices, differing importance of increased throughput from operation to operation, and varying feeder pig and market hog prices. However, feed cost per pig from weaning to 22 kg is usually $1.25 to $1.50 higher for the phase feeding program than a traditional corn-soybean meal system. I believe the decreased postweaning lag, improved performance and lowered days to market offset the increased diet cost and, thus, recommend a phase feeding program for the early weaned pig.

NUTRITIONAL PROGRAM FOR THE WEANED PIG

In the 1980's, the swine industry moved towards earlier weaning and "all-in-all- out" production systems. As explained previously, early weaning often leads to a lag in performance, including decreased gain and feed intake and increased morbidity and mortality. Researchers were challenged to devise an economical, nutritional regimen that would eliminate the postweaning lag and provide uniform rapid pig growth to maximize throughput and allow adoption of "all-in-all-out" technology. This led swine nutritionists at Kansas State University to introduce the high nutrient density diet (HNDD) diet to the commercial swine industry in 1985. This was followed by the development of a three phase starter program for early weaned pigs as a management practice to optimize pig performance and minimize product cost. This program was outlined in detail by Nelssen (1986). One of the major advantages of the phase feeding system is that guidelines presented allow it to be adapted to a wide range of weaning ages. Suggested composition characteristics of the phase feeding diets are listed in Table 1. Phase 1 involves feeding a HNDD diet (1.5% lysine, 40% milk product, pelleted dry diet) until pigs reach 6.8 kg body weight. Phase 1 has recently been amended to include diets with 8-10% spray-dried porcine plasma replacing the skim milk. From 6.8 to 11.4 kg (Phase 2), a 1.25% lysine, grain-soybean meal diet containing dried whey and another high quality protein source (spray-dried blood meal or fishmeal) is fed. The last phase (Phase 3) is a 1.10% lysine, grain-soybean meal diet to be fed from 11.4 to 22.7 kg.

The three-phase program was devised as a means of gradually converting the young pig from a high fat, high lactose, liquid, milk diet prior to weaning to a low fat, low lactose, high carbohydrate, dry diet composed of cereal grains and soybean meal. The Phase 1 and 2 diets are designed as a compromise between maximal digestibility and performance and economics. The real objective of Phase 1 and 2 is to entice the young pig to start eating dry feed. Once nursery pigs have started consuming a considerable amount of feed, the goal is to lower diet cost as quickly as possible while insuring optimal pig performance is maintained. Thus, in Phase 3, highly palatable, but expensive ingredients, can be removed from the nutritional program to lower diet cost. An important and critical aspect of the three-phase program is that the Phase 1 and 2 diets should not be fed too long. Producers are often so impressed with the performance of pigs consuming these diets that they feed them past the recommended weight. Unfortunately, this practice unnecessarily increases total feed cost and, thus, cost of production. Thus, the expensive phase 1 diet may not be needed by pigs weaned at 4 weeks or later.

NEW RESEARCH ON PROTEIN, CARBOHYDRATE AND FAT SOURCES

Although the Phase 1 and 2 diets are only fed for a short period of time and consumed in the smallest amount of any of the diets on the farm, the formulation and composition of these diets are extremely important for a number of reasons. First, they are fed during the most critical time, when converting the immune-deficient, enzymatically-immature pig from a liquid to dry diet immediately after weaning. Second, they help prepare the pig to handle the less digestible Phase 3 diets while eliminating the postweaning lag. Third, they are the most expensive diets. Therefore, considerable research in recent years has focused on refining and lowering the cost of the phase 1 and 2 diets. In this section, recent research concerning protein, carbohydrate and fat sources and levels for early weaned pig diets are presented.

PROTEIN SOURCES

Phase 1 and 2 diets are typically based largely on milk products, which are expensive, difficult to pellet and often not available in reliable quantities. Thus, there is considerable interest in finding alternative protein sources for starter diets. Alternative sources that have been investigated recently include soybean proteins, cheese by-products and spray-dried blood products.

Soybean protein in the form of soybean meal has long been the predominant protein source in swine diets. Unfortunately, soybeans contain many anti-nutritional factors such as trypsin inhibitors, lectins, and complex carbohydrates and proteins which impair the pigs ability to utilize them. Heat treatment of the soybeans in the process of making soybean meal removes much of the trypsin inhibitor; however, complex proteins and carbohydrates are not removed. Complex proteins in soybean meal have been suggested as the cause of a transient hypersensitivity response in the early weaned pig. Before weaning, pigs can consume soybean proteins by eating small quantities of sow feed or creep feed and become exposed or "sensitized" to the soy proteins. Bourne (1986) explains that prior to building up a tolerance to an antigen such as those in soybean proteins, the pig goes through a period of heightened responsiveness. Feeding the soybean protein during this period can result in damaging hypersensitivity responses, such as increased crypt cell division and the appearance of immature enterocytes on the villus, resulting in reduced digestive and absorptive capacity and an increased susceptibility to enterotoxins.

Kansas State research (Li et al., 1990c) found that pigs dosed with soybean meal preweaning and then fed diets containing soybean meal postweaning showed a transient hypersensitivity response to soybean proteins. This response appeared to be caused by antigenic proteins present in soybeans, such as glycinin and beta-conglycinin. The transient hypersensitivity is measured experimentally as higher immunoglobulin G titers to soybean protein resulting from the pig's attempt to mount an immune response against the antigenic proteins. However, the end result is that digestive abnormalities, including disorders in digestive movement and inflammatory responses in the intestinal mucosa, can occur (Nelssen, 1990). Villi are sloughed from the small intestinal mucosa and absorptive capabilities are reduced.

Further research (Jones et al., 1990a,b; Li, 1990a,b) was conducted at Kansas State University to determine if further processing soybean protein products would lower their antigenic properties and, thus, reduce or eliminate the transient hypersensitivity response seen in the young pig. A number of further processed soy protein products are available on the market including soy flour, soy protein concentrate and isolated soy protein. The results of these trials revealed that further processing of soy proteins decreases transient hypersensitivity and increases villus height, nutrient digestibility and growth performance as compared to soybean meal. Li et al. (1990a,b) also demonstrated that moist extrusion further increases the value of soy protein concentrate. However, pigs fed milk based diets still had longer villi and higher nutrient digestibility than pigs fed the further processed soy proteins. This research reveals that processing method significantly affects the utilization of soy proteins by nursery pigs. However, further research is needed to establish the proper processing (moist extrusion conditions) necessary to provide a highly digestible soy protein product that can replace skim milk in the HNDD diet.

Recent research at Kansas State (Friesen et al., 1991) has revealed that moist extrusion of soy flour greatly improves its nutritive value for weanling pigs. In fact, pigs fed diets containing moist extruded soy flour performed as well as pigs fed diets containing moist extruded soy protein concentrate. Moist extrusion appears to be an effective means of improving the value of less expensive soy protein products.

Cheese food, a by-product of the cheese processing industry, has been proposed as a possible substitute for milk products in the phase 1 and 2 diets. Cheese food is a blended, dry product composed of dehydrated cheeses (not passing quality standards in the human sector), cheese trim, and soy flour. Current market prices make cheese food appear to be an attractive alternative for dry skim milk in early weaned starter pig diets. Unfortunately, research conducted at the University of Minnesota (Lohrmann et al., 1991a) discovered that substituting cheese food for dried skim milk reduced diet acceptability, nutrient digestibility and growth rate. In another trial (Lohrmann et al., 1991b), cheese food additions up to 10% improved performance over simple corn-soybean meal diets. However, other less expensive milk products (edible grade dried whey) provide similar advantages in performance and have more consistent quality standards.

Spray dried blood products have renewed the faith of the swine industry in animal protein products. Spray-dried porcine plasma (SDPP) and spray-dried blood meal (SDBM), by-products of blood obtained from pork slaughter plants, are the most exciting protein sources to become available to the swine industry in recent years. Previously, SDPP has been used as a supplement for cereal protein in bakery products as well as an emulsifying agent in meat products and pet foods. It is made up of the albumin, globin and globulin fractions of blood and contains 68% protein and 6.1% lysine. The blood is collected in refrigerated tanks and prevented from coagulating by adding sodium citrate. The plasma fraction is separated from the blood cells by centrifugation, and stored at 25 F until the product is spray dried. This process consists of preheating (25 min at 90 F), spray drying (1 to 2 min at 405 F) and evaporation of moisture (1 to 2 min at 200 F), resulting in a fine grained powder as the finished product. Spray-dried blood meal is processed similarly, except it contains the plasma and red blood cell fractions.

Kansas State University conducted two experiments (Hansen et al., 1990) to determine whether SDPP could replace dried skim milk (DSM) and/or dried whey (DW) in early weaned pig diets. The results of the first trial indicated that SDPP and lactose can replace DSM in the HNDD Phase 1 diet and DW in the Phase 2 diet. The second experiment was conducted to further define the growth response to SDPP and determine the need for the lactose addition. Experimental treatments fed during the first two wk postweaning were 1)control (HNDD), corn-soybean meal + 20% DSM + 20% DW; 2)casein (CAS), as 1 with

7.5% casein replacing soybean meal; 3)SDPP-lactose-whey (PLW), as 1 with 10.3% SDPP and 10% lactose replacing DSM; 4)SDPP-starch-whey (PSW), as 3 with corn starch replacing lactose; 5)SDPP-lactose (PL), as 1 with 13.4% SDPP and 24.4% lactose replacing DSM and DW; 6)SDPP-starch, (PS) as 5 with corn starch replacing lactose; 7)dried whey (DW), corn-soybean meal + 20% DW. During wk 3, 4 and 5 postweaning, all pigs were fed a common 10% DW, 4% fishmeal, corn-soybean meal diet. A total of 204 pigs (initially 21 d and 5.9 kg) were blocked by weight and randomly assigned to the 7 experimental treatments for a total of 5 replicates. On day 6 postweaning, pigs were injected intradermally in the flank with protein extracts of soybean meal, SDPP, dried skim milk and saline. Changes in skin fold thickness were measured 24 h post-injection to determine transient hypersensitivity to each protein source.

The results of this trial are presented in Table 2. Pigs fed diets containing SDPP gained 30% faster (P<.05) and consumed 20% more feed (P<.05) during wk 1 and the 0 to 2 wk period than pigs fed the HNDD or DW diets. Growth and feed intake responses appeared to be maximized when SDPP and lactose were substituted for DSM (PLW diet), illustrating the need for lactose in these diets. The skinfold thickness test revealed that pigs had little immune response to dried skim milk or SDPP; however, there was an increase in skin fold thickness due to soybean protein extracts. This indicates that antigenic factors in soybean proteins cause significant immunological changes in the young pig.

These results are evidence that SDPP and lactose can effectively replace the milk products in the Phase 1 and 2 diets. Gatnau et al. (1991) concluded that 6% SDPP was the optimal inclusion level for early weaned starter diets. Unfortunately, methionine concentration was not equalized in all diets in their experiment. Synthetic methionine must be added to the diet when SDPP is included at greater than 6% to maintain concentrations above NRC (1988) requirements. Therefore, it is possible that pigs would have responded to higher inclusion levels of SDPP if sufficient synthetic methionine was added to the diet.

Recent research has also compared porcine to bovine plasma, porcine blood meal and meat extract (Hansen et al., 1991) and porcine plasma to porcine blood meal (Sohn et al., 1991). In the first experiment conducted at Kansas State University, porcine blood meal and bovine plasma were effective in replacing skim milk in a high nutrient density diet during the first two weeks postweaning. However, pigs fed diets containing porcine plasma gained faster and consumed more feed during the same period. These results indicate that specie specific responses may be important when comparing plasma protein products. Additionally, porcine plasma is superior to porcine blood meal for the first week postweaning for early weaned pigs. Meat extract was inferior to bovine plasma, porcine plasma and porcine blood meal as a protein source for the early weaned pig.

In the second trial conducted at Oklahoma State University, dried skim milk was compared to SDPP and SDBM. Results in Table 3 indicate that SDPP was superior to SDBM during the first two weeks postweaning. However, pigs fed diets containing SDBM had higher daily gains and feed intakes during the first two weeks postweaning than pigs fed diets containing dried skim milk. Additionally, at the conclusion of the trial, after all pigs were fed a common diet for phase 2 (14 to 35 d postweaning), there were no differences in gain or feed intake between pigs receiving SDBM or SDPP. It is important to recognize that a spray-dried rather than vat- or flash-dried blood meal was used in this study. Spray drying is important to prevent denaturing of the protein. Since SDBM is much less expensive than SDPP, it provides an economical means of including co-products of the slaughter industry in both the phase 1 and 2 diets.

A recent trial was conducted to compare several protein sources in phase II starter diets (Tokach et al., 1991b). A total of 432 weanling pigs (initially 6.9 kg and 21 d of age) was used in a growth trial to compare various protein sources in the Phase II starter diets (Table 4). During Phase I (0 to 7 d postweaning), all pigs were fed a common high nutrient density diet containing 1.5% lysine, 10% porcine plasma, 10% lactose, and 20% dried whey. During Phase II (7 to 28 d postweaning), pigs were fed one of six experimental diets. All Phase II diets contained 10% dried whey and were formulated to 1.18% lysine. The positive control diet contained 4% menhaden fish meal (FISH). Synthetic amino acids were used to replace fish meal to form an ideal protein, negative control diet (AA). Spray-dried porcine plasma (SDPP), spray-dried blood meal (SDBM), soy protein concentrate (SPC), and extruded soy protein concentrate (ESPC) replaced fish meal on a lysine basis to form the other four diets. During the grower phase (28 to 56 d postweaning), all pigs were fed a common 1.1% lysine, milo-soybean meal diet. Average daily gain (kg), AFDI (kg), and F/G during Phase I were .18, .24 and 1.41, respectively. During Phase II, SPC and ESPC effectively replaced fish meal as a protein source; however, pigs fed diets containing the spray-dried blood products (SDPP or SDBM) gained faster than pigs fed the other four diets. Pigs fed the diet containing synthetic amino acids had poorer feed conversion than pigs fed diets containing the intact protein sources. Pigs fed the diet containing SDBM during Phase II gained faster during the subsequent grower phase than pigs fed the other diets.

These results have led to an amendment in our phase 1 and 2 diet recommendations. In order to achieve maximal performance, current recommendations include replacing skim milk with SDPP in phase 1. Additionally, SDBM may replace fish meal in phase 2. Economical analysis prevents recommending the inclusion of SDPP in phase 2 diets other than for tag dressing purposes.

Spray-dried porcine plasma and blood meal appear to have promising futures as alternatives to milk protein sources in the phase 1 and 2 diets. These products may be used to decrease diet cost without sacrificing pig performance. Cheese food quality aspects may need to be controlled more closely before it can be recommended for starter pig diets. Further research is needed to determine the optimal staging of new protein sources in a phase feeding program.

CARBOHYDRATE SOURCES

Lactose is the carbohydrate fraction of milk. Dried skim milk and dried whey are extremely high in lactose containing 50 and 70%, respectively. Since these milk products improve starter pig performance, pigs would be expected to respond favorably to lactose additions to the diet. In addition, as discussed above, lactase is much higher than amylase at three wk of age. Thus, pigs should be able to digest lactose more easily than starch carbohydrates.

Tokach et al. (1989c) demonstrated that adding lactose to the starter diet increases gain and feed intake. Giesting et al. (1985) also reported that lactose was superior to other carbohydrate sources for the weanling pig. It appears that lactose improves early acceptance of dry diets by the young pig. Turlington et al. (1989) suggested that lactose will improve nutrient digestibility by slowing digesta flow rate as compared to dextrose as a carbohydrate source for 3 to 5 wk old pigs.

Extruding soy proteins may also improve digestibility of the complex carbohydrates present in soybeans. This may contribute to the advantage that extruded products display over conventionally processed soybean products (Li et al., 1990a,b).

In summary, lactose is an excellent carbohydrate source for the young pig. Adding lactose to the diet increases nutrient digestibility by slowing digesta flow rate and/or by matching carbohydrate source with the available digestive enzymes. Research with SDPP (Hansen et al., 1990) and soybean proteins (Jones et al., 1990a) indicate that lactose is an important component of the phase 1 diet.

FAT LEVELS AND SOURCES

The original HNDD diet was designed to contain 8 to 10% supplemental fat, (Nelssen, 1986). Since the introduction of this diet, numerous trials have been conducted to examine the young pig's ability to utilize fat. Nelssen (1990) explained that fat was added to the original HNDD diet for two reasons: 1)to increase dietary energy density, and 2) to improve pellet quality and efficiency in the pellet mill. However, early research examining the response to supplemental fat in HNDD diets failed to consider the importance of fat in maintaining pellet quality. Diets containing high levels of milk products without supplemental fat are extremely difficult to pellet and may even lodge in the pellet mill. The diet will thus have a longer residence time in the die and may be scorched, lowering lysine availability and milk product quality. Adding high levels of fat to the diet prevents the scorching. Thus, a response that was attributed to added fat in early research may have been due to an improvement in pellet quality rather than a response to fat per se.

When carefully monitoring pellet quality, University of Minnesota (Tokach et al., 1989a, 1989b) and Kansas State University (Li et al., 1989) researchers have failed to show an improvement in performance when adding 10% fat to HNDD diets. However, the "pellet quality factor" must be considered when adding fat to a HNDD diet. Thus, levels of 4 to 6% supplemental fat may be warranted in HNDD diets to improve pelleting efficiency. However, the 8 to 10% fat addition often used in the feed industry certainly appears unjustified.

Considerable research has been conducted in recent years to determine the appropriate fat source for the early weaned pig. Cera et al. (1988) found corn oil to be more digestible than lard or tallow, but differences among fat sources narrowed from wk 1 to 4 postweaning. Turlington et al. (1987) reported that pigs fed soybean oil had higher growth rates than those fed choice white grease, coconut oil or tallow during the first two wk postweaning. During three subsequent wk and over the entire 5 wk study, pigs fed choice white grease or soybean oil grew faster and more efficiently than pigs fed other fat sources. Tokach et al. (1990a) found no difference in performance when comparing corn oil and soybean oil. Tallow has consistently been found to be the least desirable fat source for nursery diets.

Kansas State University recently completed a series of experiments to evaluate whether combining various fat sources would improve the pig's ability to utilize the fat. Thaler et al. (1988) found pigs gained numerically faster and more efficiently with a combination of soybean oil and coconut oil in the diet than when diets contained soybean oil, coconut oil, choice white grease or a combination of coconut oil and choice white grease. In a follow-up study, Li et al. (1989) found pigs fed a combination of soybean oil and coconut oil had increased villus height and decreased crypt depth compared to those fed soybean oil or coconut oil alone. In a third experiment, Li et al. (1989) evaluated the addition of soybean oil, coconut oil, 50% soybean oil:50% coconut oil, 75% soybean oil:25% coconut oil, and 25% soybean oil:75% coconut oil on starter pig performance. The 50% soybean oil:50% coconut oil combination maximized performance. These results indicate that a mixture of soybean oil and coconut oil is a superior fat source for the early weaned pig. Unfortunately, the cost of coconut oil severely limits its use in swine diets.

When fat is added to the starter diet, a high quality, stabilized fat source must be used. Obviously, a constant ratio of nutrients to energy must be maintained when adding fat to the diet. The importance of fat in maintaining pellet quality in a high milk, dry diet should not be underestimated.

SUMMARY

Important breakthroughs in nutritional programs for the early weaned pig have occurred in the 1980's. The introduction of the high nutrient density diet and three phase starter program have provided a means of economically eliminating the postweaning lag often found when feeding simple corn-soybean meal diets to the young pig. Recent research has demonstrated that subsequent performance in the grower and finisher phase must also be considered when evaluating the economics of different nutritional programs for the nursery pig. The basic premise of the three phase starter program remain unchanged since its introduction by Nelssen (1986); however, the individual diets are continually being refined as new research becomes available.

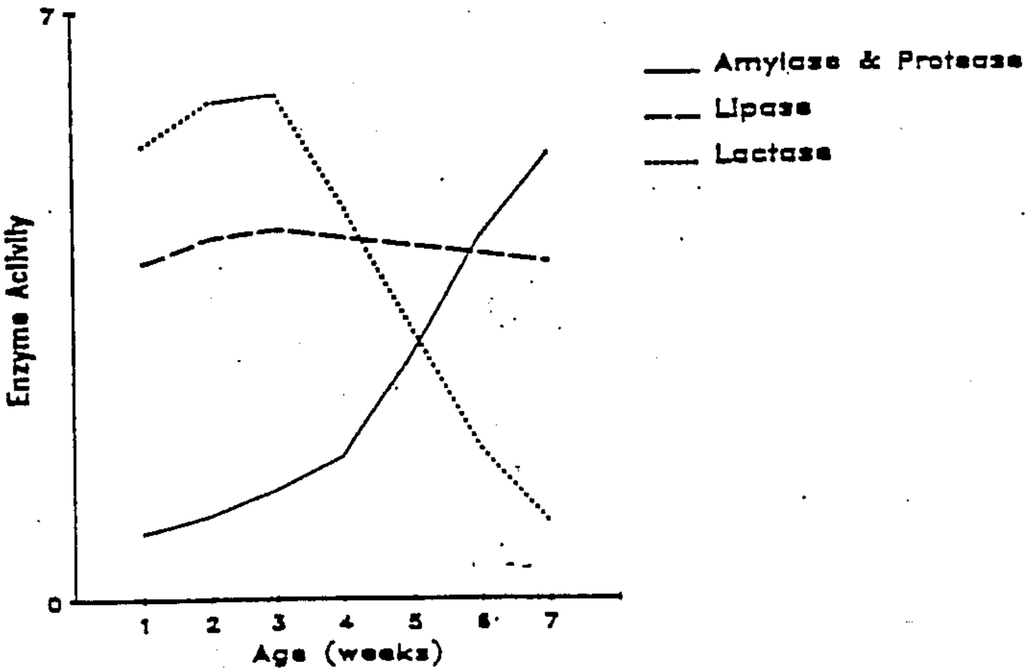

Figure 1. Digestive enzyme activity in young pigs.

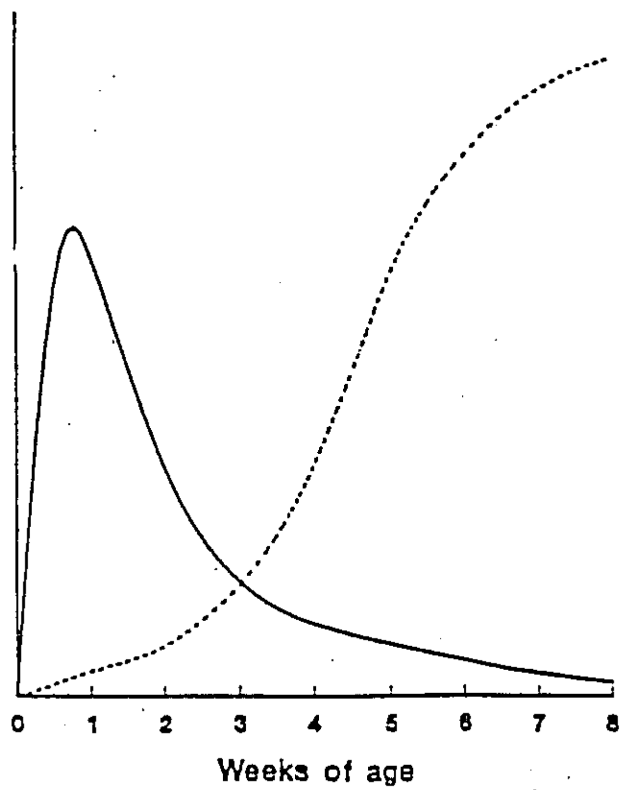

Figure 2. Development of passive (———) and active (——) immunity in young pigs.

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TABLE 1. SUGGESTED COMPOSITION CHARACTERISTICS OF THREE-PHASE STARTER DIETS

Item	Phase 1: HNDD	Phase 2: Whey Starter	Phase 3: Corn-soy
Protein, %	20-22	18-20	18
Lysine, %	1.5	1.25	1.10
Fat, %	4-6	3-5	----
Spray-dried Edible Grade Whey, %	15-25	10-20	----
Spray-dried Skim Milk, %	0-5	----	----
Spray-dried Porcine Plasma	6-8	----	----
Spray-dried Blood meal[a]	1-3	2-3	----
Copper, ppm	190-260	190-260	190-260
Vitamin E, IU/ton	40,000	40,000	40,000
Selenium, ppm	.3	.3	.3
Antibacterial or Antibiotic	+	+	+
Physical Form	1/8" pellet	pellet or meal	meal

[a] Spray dried blood meal (2.5%) can be replaced by select menhaden fish meal in the phase II diet.

TABLE 2. EFFECT OF SUBSTITUTING SPRAY DRIED PORCINE PLASMA AND LACTOSE OR STARCH FOR MILK PRODUCTS IN STARTER PIG DIETS[a,b]

Item	HNDD	CAS	PLW	PSW	PL	PS	DW	CV
WK 0-1								
ADG, kg[cdef]	.30	.33	.40	.38	.37	.31	.26	9.8
ADFI, kg[cdef]	.30	.30	.40	.34	.35	.30	.28	8.1
F/G	.98	.89	.99	.93	.97	.97	1.08	7.5
WK 0-2								
ADG, kg[cde]	.31	.33	.45	.42	.41	.38	.33	8.9
ADFI, kg[cde]	.39	.37	.54	.49	.48	.44	.42	8.2
F/G	1.24	1.12	1.21	1.16	1.17	1.15	1.27	4.7
WK 2-5								
ADG, kg	.59	.54	.61	.59	.61	.60	.60	6.4
ADFI, kg[e]	1.05	1.01	1.13	1.10	1.15	1.15	1.13	6.3
F/G[e]	1.77	1.86	1.86	1.88	1.90	1.98	1.88	5.6
WK 0-5								
ADG, kg[e]	.48	.46	.54	.52	.53	.51	.50	6.1
ADFI, kg[e]	.78	.75	.89	.86	.89	.87	.85	6.3
F/G	1.63	1.64	1.65	1.64	1.67	1.68	1.72	4.3

[a] From Hansen et al. (1990).
[b] HNDD=control; CAS=casein; PLW=SDPP-lactose-whey; PSW=SDPP-starch-whey; PL=SDPP-lactose; PS=SDPP-starch; DW=dried whey.
[c] Main effect of lactose (P<.10).
[d] Main effect of SDPP level (P<.05).
[e] SDPP vs control (P<.05).
[f] Control vs dried whey diet (P<.05).

TABLE 3. EFFECT OF SUBSTITUTING PORCINE PLASMA OR PORCINE BLOOD MEAL FOR SKIM MILK IN STARTER PIG DIETS[a]

Item	Skim milk	Plasma	Blood Meal
Wk 0-2			
ADG, kg	.28[b]	.36[c]	.32[d]
ADFI, kg	.33[e]	.41[f]	.37[g]
F/G	1.16	1.15	1.15
Wk 2-5			
ADG, kg	.53	.55	.56
ADFI, kg	.95	.99	.99
F/G	1.79	1.79	1.75
Wk 0-5			
ADG, kg	.43	.47	.46
ADFI, kg	.70	.76	.75
F/G	1.63	1.61	1.61

[a] Adapted from Sohn et al. (1991).

[b,c,d] Means within same row with different superscripts differ ($P < .05$).

[e,f,g] Means within same row with different superscripts differ ($P < .01$).

TABLE 4. INFLUENCE OF PHASE II PROTEIN SOURCE ON PIG PERFORMANCE[a]

Item	Phase II Treatment[b]						
	AA	Fish	SDPP	SDBM	SPC	ESPC	CV
d 7-14							
ADG, kg[cde]	.20	.25	.30	.27	.21	.26	17.1
ADFI, kg[cf]	.38	.37	.45	.41	.40	.40	9.2
F/G	2.00	1.64	1.55	1.59	2.14	1.67	24.6
d 7-28							
ADG, kg[g]	.40	.40	.43	.42	.40	.40	7.4
ADFI, kg[h]	.63	.60	.64	.64	.61	.62	6.3
F/G[e]	1.61	1.52	1.51	1.53	1.56	1.53	4.4
Phase II							
Total Gain, kg[g]	8.3	8.3	9.0	8.8	8.3	8.5	7.4
Grower phase							
ADG, kg[i]	.55	.55	.56	.60	.57	.55	7.0
Total gain, kg[i]	15.4	15.3	15.7	17.0	15.9	15.6	7.0
Pig wt. kg							
d 28[g]	16.5	16.5	17.2	17.0	16.5	16.7	3.8
d 56[gi]	31.9	32.0	32.9	34.0	32.4	32.3	3.5

[a]All pigs were fed a common diet from d 0 to 7 postweaning. Values are means of six pens containing 12 pigs per pen.
[b]AA = amino acids, Fish = fish meal; SDPP = spray-dried porcine plasma, SDBM = spray-dried blood meal, SPC = soy protein concentrate, ESPC = extruded soy protein concentrate.
[c]Blood products vs others, (P<.01).
[d]SPC vs ESPC, (P<.08).
[e]Amino Acids (AA) vs others, (P<.02).
[f]Fish meal vs others, (P<.07).
[g]Blood products vs others, (P<.06).
[h]Blood products vs others, (P<.14).
[i]SDBM vs others, (P<.03).

PHASE I STARTER DIET

Complete list of ingredients and levels for Phase I diet:

Ingredient	Percent	lb/ton
Extra-grade dried whey	20.0%	400
Spray-dried skim milk	2.5%	50
Spray-dried porcine plasma	7.5%	150
Spray-dried blood meal	1.75%	35
Corn	44.25%	885
Soybean meal, 46.5% protein	14.5%	150
Soybean oil	5.0%	100
Monocalcium phosphate (21% P)	1.85%	37
Apralan	1.0%	20
Limestone (38% calcium)	.66%	13.2
L-lysine HCL	.1%	2
DL-methionine	.1%	2
Remainder will be:		
- Vitamins and trace minerals*	.79%	15.8
Total	100.0	2000.0

* After vitamins and trace minerals are added, any remaining portion of the diet should be filled with corn to acheive 100%.

All vitamin and trace mineral levels are listed on the following page.

This diet must be pelleted in 1/8 or 5/32" pellet.

Diet must be provided in 50 lb bags.

PHASE I STARTER DIET

The diet must meet ingredient specifications listed on the preceding page.

Total levels and sources of vitamin and trace minerals that must be <u>added per ton of complete diet</u> are listed below:

Nutrient	Amount added per ton	Source	
Vitamin A	10,000,000 USP Units	A	650
Vitamin D_3	1,000,000 USP Units	D_3	400
Vitamin E	40,000 Int Units	E	50%
Vitamin K (as Menadione)	4,000 mg	MSBC	100%
Vitamin B_{12}	180 mg	B_{12}	600
Riboflavin	7,500 mg	Riboflavin	95%
Pantothenic Acid	26,000 mg	Cal Pan	100%
Niacin	45,000 mg	Niacin	99.5%
Choline	150,000 mg	Choline Cl	60%
Zinc	150 g	Zn oxide or sulfate	
Iron	150 g	Ferrous sulfate	
Manganese	60 g	Mn Oxide	
Copper	186 g	Cu sulfate	
Iodine	450 mg	Ca Iodate	
Selenium	450 mg	Na selenite	

Ingredient quality is imperative for this diet. Therefore, the following guidelines must be followed as sources for the major ingredients listed for the phase I diet.

Ingredient	Percent	lb/ton	Source
Extra-grade, edible-grade, spray-dried whey	20.0%	400	Land-O-Lakes
Spray-dried skim milk	2.5%	50	Land-O-Lakes
Spray-dried porcine plasma	7.5%	150	Merrick's or American Proteins
Spray-dried blood meal	1.75%	35	California Spray Dry or American Proteins

Product Name...STARTER 1 < 15 LB
Comments...... PHASE 1 SPECIFICATIONS
Date/Time......02-06-1992 11:37:24 # 5381

ROUNDED AMOUNT	INGREDIENT NUM	NAME	PERCENT OF MIX	COST/ 100LB	LOW RANGE	HIGH RANGE	REST.$/ 100LB	INGREDIENT MIN.	MAX.	NUM	NUTRIENT RESTRICTION	NUTRIENT MINIMUM	ACTUAL	MAXIMUM	COST
891.08	112	CORN GR YL	44.554	4.45		5.11				1	WEIGHT	1.00	1.00	1.00	
400.00	11	DRIED WHEY	20.000	20.00				20.000	20.000	4	MET ENERGY S		1418.03		
290.26	381	SBM 46.5%	14.513	9.80	9.18	999999				5	DIGESTIBLE E		1485.12		
150.00	31	APC PLASMA	7.500	140.00				7.500	7.500	10	CRUDE PROTEI		21.04		
100.00	9	SOY OIL	5.000	30.57				5.000	5.000	14	LYSINE	1.50	1.50	1.50	
50.00	12	DRIED SKIM	2.500	90.00				2.500	2.500	15	METHIONINE	0.37	0.39		
36.99	8	MONOCALCIUM	1.850	21.80	2.52	55.69				16	METH & CYSTI	0.73	0.84		
35.00	98	APC BLOOD M	1.750	60.00				1.750	1.750	17	TRYPTOPHAN	0.21	0.30		
20.00	33	APRALAN	1.000	188.25				1.000	1.000	21	ISOLEUCINE	0.81	0.83		
13.17	281	LIMESTONE	0.658	1.00		40.59				24	THREONINE	0.86	1.02		
5.00	5	KSU HT VIT	0.250	80.00				0.250	0.250	26	CRUDE FAT		7.25		
3.00	6	KSU HT TRAC	0.150	40.00				0.150	0.150	27	CRUDE FIBER		0.94		
2.00	401	LYSINE	0.100	130.00		147.69	-17.69		0.100	30	CALCIUM %	0.90	0.90	0.90	
2.00	422	METHIONINE	0.100	208.00				0.100	0.100	31	AV PHOSPHORU		0.47		
1.50	17	COPPER SULF	0.075	53.00				0.075	0.075	32	PHOSPHORUS-T	0.80	0.80		0.924
										33	SALT		1.01		
										36	MN, mg		18.00		
2000.00				$513.27 PER TON			$25.66								
PER 100LB										37	ZN, mg		75.00		
										38	FE, mg		75.00		
										39	CU, mg		93.11		
										41	I, mg		0.14		
										44	VIT A IU/LB		5000.00		
										45	SE, mg		0.14		
										46	VIT D IU/LB		500.00		
										47	VIT E IU/LB		20.00		
										48	VIT K, mg		2.00		
										50	RIBO, mg		3.75		
										51	NIACIN, mg		22.50		
										52	PANTO, mg		13.00		
										53	CHOLINE, mg		75.00		
										57	VIT B12, mg		15.00		

STARTER BASEMIX

Guarenteed Per Pound of Basemix

		Source	
Vitamin A	112,000 USP Units	A	650
Vitamin D_3	11,200 USP Units	D_3	400
Vitamin E	450 Int Units	E	50%
Vitamin K (Menadione)	45 mg	MSBC	100%
Vitamin B_{12}	0.36 mg	B_{12}	600
Riboflavin	90 mg	Riboflavin	95%
Pantothenic Acid	290 mg	Cal Pan	100%
Niacin	535 mg	Niacin	99.5%
Choline	1,700 mg	Choline Cl	60%
Zinc	1,800 mg	Zn oxide or sulfate	
Iron	1,800 mg	Ferrous sulfate	
Manganese	400 mg	Mn Oxide	
Copper	2,070 mg	Cu oxide	
Iodine	3 mg	Ca Iodate	
Selenium	3 mg	Na selenite	
Calcium	15.2%	Limestone, Dical or Monocal Phosphate	
Phosphorus	9.3%	Dical or Monocal Phos	
Lysine	2.66%	Lysine-HCl	
Methionine	1.11%	DL-Methionine	
Carbadox	.55 g	Mecadox	

Feeding rates for this basemix: Phase II or III Starter diets: 90 lb/ton

This basemix must be provided in 45 lb bags.

Mixing directions are as follows:

Phase II:	44% SBM	46.5% SBM
Corn or milo	1200	1220
Soybean meal	460	440
Starter Basemix	90	90
Edible-grade, dried Whey	200	200
Spray-dried Blood Meal	50	50
	2000	2000

Phase III:	44% SBM	46.5% SBM
Corn or Milo	1343	1368
Soybean meal	560	535
Starter Basemix	90	90
Salt	7	7
	2000	2000

Fat (20 to 60 lb/ton) can be substituted for the grain source.