USE OF POULTRY BYPRODUCT MEAL AS AN ALTERNATE PROTEIN SOURCE IN SWINE STARTER RATIONS

by

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(Under the Direction of Michael J. Azain)

ABSTRACT

Three experiments were conducted to test inclusion of poultry byproduct meal (PBM) in nursery rations to replace more commonly used animal protein sources. The results of the first experiment demonstrate PBM can replace blood meal and fishmeal without affecting performance, but may not be equivalent to spray dried plasma protein (SDPP) in phase I diets. In experiment two, pigs fed 20% PBM for the first four weeks post-weaning exhibited no difference in performance as compared to those fed a more traditional starter series of diets. The third experiment was a slope ratio assay designed to determine the ability of PBM to replace SDPP. The results indicate that in the first week post-weaning pigs fed with SDPP demonstrated greater gains. However, as in experiments 1&2, there was no difference in growth over the entire four-week period. These results validate PBM as a cost-effective substitute for higher priced ingredients in nursery diets.

INDEX WORDS: Nursery diet, Pigs, Poultry byproduct meal

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CHAPTER 1

INTRODUCTION

Early weaned pigs create a management problem known as post-weaning lag time, denoted by a typical weight loss and poor feed intake. As such, nursery diets are typically formulated with highly palatable and easily digestible animal protein sources that make this phase of swine feeding the most expensive. These ingredients generally include whey, premium fishmeal, plasma protein and blood cells (or bloodmeal).

Producers are able to use milk byproducts and animal proteins to enhance the palatability and the digestibility of the diets in an attempt to match the piglet's digestive capacity. Blood products, milk products, and fishmeal are most commonly used in phase feeding systems for the weaned pig. These consist of feeding diets that have incremental decreases in nutrient levels at 2-4 week intervals that follow the pig's changing nutritional requirements. There is a current trend moving away from feeding certain animal proteins back to the same species of livestock. With growing concerns about Bovine Spongiform Encephalopathy, and Scrapie derivatives arriving in other species, there is likely to be a further banning of meat and bone meal from swine fed back to swine. As an alternative, PBM may be the next protein source used in starter diets. Poultry byproduct meal generally consists of the viscera, head, underdeveloped eggs, and the feet from poultry at slaughter, which are then either dry or wet rendered, dried, and ground into a meal.

Alternative feed ingredients are often sought after in least-cost diet formulations. While poultry byproduct (PBM) meal is high in protein and readily available in the Southeastern United States, it has not yet been readily utilized in nursery rations as a replacement protein source. There is an additional need to find an efficient use for offal processing wastes in an increasingly environmentally conscious society. As such, validation of the use of these byproducts make it possible for livestock producers and renderers to work together and create a safe alternative feed product that is affordable and nutritional for both livestock and consumers.

Finally, the continued survival of the livestock industry in the future will depend on the ability of animals to avoid competition with humans for the available food supply. With the poultry industry in Georgia accounting for more than 40% of the agricultural market in the state, it is clear byproducts from this industry are readily available for use in Southeastern swine operations to reduce overall feed costs. The aim of this series of studies was to determine the effect of substituting PBM for traditionally used feed ingredients that are used to stimulate performance of nursery pigs during early weaning.

CHAPTER 2

LITERATURE REVIEWED

Early weaned pigs create a management concern for producers who strive to minimize post-weaning lag time, a period denoted by weight loss and poor feed intake. At present, producers use milk byproducts and animal proteins to enhance palatability and digestibility of pre-starter diets. The goal is to use dietary ingredients that most nearly match the young pig's digestive capacity (Kim and Easter 2001). Since the 1980's, the pork industry has used porcine plasma as the standard by which other proteins are evaluated (Easter and Kim 2000; Gatnau and Zimmerman 1989). In monogastric nutrition, there is a current trend moving away from feeding certain animal proteins back to the same species of livestock. Already banned is the feeding of ruminant meat and bone meal products back to ruminant animals. With growing concerns about Bovine Spongiform Encephalopathy, and Scrapie derivatives arriving in other species, there is likely to be a further banning of feeding meat and bone meal to swine and/or chickens. BSE and Scrapie infected animals that are rendered and fed back to the same species are the mechanism of disease transmission (Corbin 1992). Cooking at high temperatures does not denature the infective agent (Corbin 1992). As an alternative, PBM may be used as a substitute protein source used in starter diets.

The survival of the livestock industry of the future, including the swine industry, will depend on the ability of animals to compete with humans for the available food supply. As conventional cereal grains progressively increase in demand for direct human use, alternative and byproduct feeds will become increasingly useful in livestock diets (Pond 1981). Agriculture is a major contributor of waste materials; this creates a problem for such industries during an environmentally conscious legislation (Harpster et al 1997). Since the pig is more efficient than any other farm mammal in conversion of gross feed energy to food energy for man (Cook 1977), substitution of byproduct waste feeds creates an exceptional outlet for energy conservation. In general, animal slaughter byproducts are high in moisture content and as such require the expensive process of drying, offset only by the high digestible protein and energy content these products supply to the animal feed industry (Miller and deBoer 1988). Successfully feeding byproducts may markedly extend the animal production potential of a farm by providing cheap alternative feed ingredients, ultimately benefiting the livestock producer, the environment, and the industry producing the byproduct from waste. With the poultry industry in Georgia accounting for more than 40% of the agricultural market, it is clear this industry can provide a large amount of byproducts. In particular, Southeastern swine operations that are cost-effectively competing with the Midwest for grain, find byproducts useful to reduce overall feed costs.

Feeding the Nursery Pig

With industry emphasizing increased pigs per sow per year, the trend is to decrease weaning age to as young as 14-21 days of age. Weaning pigs younger than 5 weeks old occurs prior to the time the digestive tract of the pig is physiologically mature. Without enough of the digestive enzymes needed to properly digest plant proteins, overall growth and cellular immune reactivity could be compromised, altering disease susceptibility in these young pigs (Blecha et al 1983). Additionally, feed is the major expense in the overall swine production system, representing more than 65% of the production costs (Hollis and Curtis 2001).

Undigested dietary protein is another economic loss. Plant proteins tend to move through the digestive tract of a nursery pig undigested (Maxwell and Carter 2001) causing an increase in nitrogen excretion lost into the environment. Additionally, the decrease in digestibility decreases nutrient absorption, causing both a reduction in growth and an increase in nutrients available for the micro-flora that can develop into scours, causing an overall reduction in health. This reduction in growth during the piglet's transition is commonly referred to as post-weaning "lag." The digestive system of nursing piglets is adapted to secrete the hydrolytic enzymes necessary for the digestion of milk nutrients (Maxwell and Carter 2001). Therefore, lactase activity is high and the activity of lipase and protease is sufficient to digest the proteins and fats found in sow milk. In designing nursery diets, ingredients should be compatible with the established pattern of, and capacity for, enzyme secretion to ensure digestion (Maxwell and Carter 2001). The earlier pigs are weaned, the greater the need for a complex diet containing higher levels of animal protein (which most nearly matches the digestive capacity) and lower levels of complex carbohydrates present in most plant protein to improve post-weaning performance. In addition to nutrient digestibility, there are immunological factors that induce temporary hypersensitivity responses to plant protein sources such as soybeans (Friesen et al, 1993). Soy protein is potentially antigenic with native storage globulins, particularly glycinin and β-conglycinin, in addition to other anti-nutritional factors that include protease inhibitors and lectin (Maxwell and Carter 2001). Walker et al 1986 compared SBM to milk protein (calcium caseinate) in nursery diets fed for five weeks and concluded that piglets fed the milk diets gained 13% more and were more efficient during the first two weeks post weaning, but gain rates did not differ from the pigs fed the SBM in the last two weeks of the study. Overall, efficiency and gain were higher in pigs fed calcium caseinate compared to SBM but there was no overall difference in feed intake. Li et al. 1990, 1991a, and 1991b, examined the transient hypersensitivity reaction to SBM and its effects on villus height, crypt depth and proliferative responses of the lower gastrointestinal tract. This work demonstrated that pigs fed SBM post weaning had lower villus height and xylose absorption, but higher serum anti-soy IgG titers and increased skin fold thickness in the intestinal tract. This indicates that commercial SBM may retain some antigens that cause an immunological response in these pigs (Li et al 1991b, Dunsford et al 1989).

Numerous studies have demonstrated that substituting SBM with products like plasma protein, blood meal or fishmeal reduces negative effects on growth (Maxwell and Carter 2001). The reasoning is that animal proteins, when compared to plant proteins, more nearly match the digestible amino acid patterns needed by the pig. Additionally, plant proteins generally have a lower energy value as a result of indigestible cell wall material (Miller and deBoer 1988). Management practices that promote a high health environment, such as segregated early weaning and all-in, all-out practices, facilitate excellent nursery performance by reducing pathogenic situations (Maxwell and Carter 2001). Diet complexity during the first few weeks post weaning aids in the piglet's transition to simple plant based rations. Herein lies the reason for phase feeding as the pig's nutrient requirements change rapidly. Newly weaned pigs perform well only when given a complex diet appropriate for their stage of development (Maxwell and Carter 2001). In 1985 Himmelberg et al evaluated the use of complex diets on various ages and weights of weaned pigs. Their goal was to determine if and how much an advantage a complex diet would give over a simple grain-based diet. Simple diets were composed of corn (47%), SBM (37%), and oats (10%). Sugar, dried skim milk, brewer's yeast and dried fish solubles replaced part of the corn and SBM in the complex diet. Feed intake, ADG, and feed efficiency were all improved in pigs fed the complex diets over those fed a simple diet, regardless of weaning weight. Additionally, they observed that faster initial growth in the nursery resulted in higher muscle percentage at slaughter. Similarly, Mahan et al (1998), evaluated the duration of feeding highly complex phase I (1.4% lysine) and phase II (1.3% lysine) diets on gain of weanling pigs to 105kg weights. They found feeding phase one diets (including dried whey, blood plasma, and soy protein concentrate) for two weeks post-weaning reduced the time from weaning to 105kg BW irregardless of weaning weight. However, weaning weight accounted for more of the variation in post-weaning performance than did the nursery diets (Mahan et al 1998). These first diets are typically pelleted based on pig preference patterns determined in studies such as Jensen and Becker in 1965. Their results concluded that pelleting resulted in a higher gain to feed ratio and significantly less crude fiber with an overall increase in total nitrogen. Pelleting improves starch digestibility. Pelleting also increases shelf life, improves diet uniformity and handling, reduces dust.

Commonly Used Ingredients in Nursery Rations

Animal protein byproducts that typically replace a percent of the diet in phase one and two starter rations include such products as spray dried plasma protein (SDPP), spray dried blood cells, fishmeal, lactose and dehydrated whey products. These products are expensive due to the advanced rendering facilities required to refine them into useful and nutritious feed ingredients. The benefit these products provide during this transitional phase for the pig usually outweighs the cost. Table 2-2 lists a series of common ingredients of diets for newly weaned pigs.

Dried Whey

The lactose component of dried whey is considered to be the primary cause of improved gain and feed intake responses when fed to starter pigs in addition to SBM (Mahan 1992). Nessmith et al (1997) researched substitution of dried whey with deproteinized whey and (or) crystalline lactose. They demonstrated an increase in gain and feed intake during the second week post-weaning in the pigs fed dried whey when compared to pigs fed a combination of deproteinized whey and crystalline lactose. Overall, all three products were not found to be different.

SDPP and Spray-Dried Bloodmeal

The ingredient that revolutionized nursery pig feeding is SDPP, introduced in the late eighties (Mavromichalis and Baker 2000). Plasma protein has been studied in multiple scenarios as it consistently improves growth performance when included in phase I diets at the expense of dried skim milk or SBM (de Rhodas et al 1995, Hansen et al 1993, Kats et al 1994). De Rhodas et al 1995 performed a series of studies comparing dried skim milk (DSM) with SDPP and spray dried blood meal (SDBM). Their results indicated that SDPP and SDBM are effective dietary replacements to DSM or SBM in phase one diets.

Grinstead et al (2000) tested whey protein concentrate (73% crude protein) as a replacement for varying percentages of SDPP and SBM in nursery diets. Results concluded that overall performance of weanling pigs was not different between SDPP and whey protein concentrate. During the first seven days on test, pigs fed SDPP showed improved gains over the control (SBM) and the whey protein concentrate diets. Both SDPP and whey fed pigs had gains, feed intakes and feed efficiencies greater than that of pigs fed the SBM control.

Kats, et al, 1994, did several studies examining the replacement of dried skim milk with SDPP and SDBM. Dried skim milk comprised 20% of the control diet. Treatments included substitution levels of 100% SDPP, 100% SDBM, 50-50% 75-25, and 25-75%. It was concluded that inclusion of up to 10% SDPP can be added to the phase I diet, but the greatest average daily gains (ADG) were observed when feeding a combination of SDPP and SDBM at 7.5% to 1.63%, respectively. This percentage SDBM represented substitution of 25% of the SDPP in the diets. Feed efficiency, intake and ADG were all numerically greater for this group. Gain in pigs improved ($P<.06$) with inclusion of SDPP up to 10% over the other treatments. These diets were fed for 14 days post weaning. Addition of DL-Methionine to the diets containing blood products further improved performance, as both SDPP and SDBM contain a low percentage of methionine.

Several other protein sources (fishmeal, blood meal, and spray-dried blood cells) have been used unsuccessfully to mimic the effects of SDPP in an effort to reduce cost (Mavromichalis and Baker 2000). Unfortunately, none have been able to replicate the increased feed intake during that first crucial week post weaning. However, addition of these protein sources allows a reduced percent SDPP inclusion in the diet while maintaining beneficial effects.

Dried bloodmeal, collected and processed at slaughter facilities, contains over 80% protein. When dried using ring drying techniques, the lysine availability has been calculated to be at 70% (Wahlstrom and Libal 1977). Performance of growing and finishing swine fed ring-dried blood meal was evaluated in Wahlstrom and Libal (1977). A significant decrease in feed intake was noted during the grower phase for pigs fed blood meal combined with SBM when compared to pigs fed SBM alone. No other significant differences in gain or efficiency were noted. Miller et al (1976) additionally supports these results reporting optimum growth rate and efficiency of diet utilization when starter diets contained 6% ring dried blood meal.

Fishmeal

Fishmeal, because of its excellent amino acid profile and digestibility, is also considered a standard ingredient in many starter rations. Zhang et al 1998 reported that both blood cells (spray-dried) and FM (Select Menhaden) are economical and effective protein sources in weanling pig diets. Stoner et al

(1990) conducted two trials on select menhaden FM and determined that its substitution for SBM resulted in acceptable performance indicating that FM can be used as the major protein source for early-weaned pigs. At 4% of the diet, FM can replace half the dried whey (dried whey is typically included at 20% in the diet) without altering growth or performance. Green (1989) compared the digestibilities of meat, skimmed milk, and FM in young pigs. The digestibility of essential amino acids were greater in the milk and FM than in the meat meals. A series of common starter diet compositions are listed in Table 2-1.

PBM in Monogastric Rations

Information on the use of poultry byproduct meal in nursery diets is limited. References to its use in grow-finisher swine production or other monogastric species were investigated.

Poultry byproduct meal consists of the viscera, head, undeveloped eggs, and the feet from poultry slaughter that are then dry or wet rendered, dried, and ground into a meal (Elwyn 1994). Researchers may also refer to PBM as poultry offal meal (Daghir 1975). Pet food grade PBM is a specialty product that contains remaining meat from the backs and wings, and the viscera. There are no heads, feet, undeveloped eggs or "deads" in this product. "Deads" refer to birds that died prior to processing at the farm or during shipping.

Swine

While no peer-reviewed literature has appeared on the feeding of PBM to nursery pigs, several abstracts and two departmental reports have used this product. Seddon and Smith (1997) used PBM as an added ingredient in nursery diets containing raw soybeans. They found a greater reduction in performance relative to the addition of raw soybeans alone. They attributed this reduction to potentially altered biogenic amine metabolism. Veum and Haque (1994) compared spray-dried PBM to SDPP in nursery diets and reported that during the first week SDPP fed pigs had a higher ADG and FI than the pigs fed the PBM, but overall there was not a significant difference in piglet performance. This same group repeated their initial findings in a later report (Veum et al 1999) and again showed that replacing all the SDPP with spray-dried PBM did not affect overall performance. They added in an estimated cost reduction of 28% per ton for phase I diets. It is noted that spray drying is different from conventionally rendered PBM. In the spray-drying process, moisture is removed from the blood by a low temperature evaporator (below 80 degrees Celsius) under vacuum until it contains approximately 30% solids. It is then dried by spraying into a draft of warm, dry air which reduces the blood to finely divided particles with a maximum moisture of 8% (Polin 1992). Conventional low temperature (85-100 degrees Celsius) drying techniques are less costly and more common in the rendering industry than the spray-drying techniques. The first step in the rendering process separates the solids from the fat and water using a decanter (horizontal centrifuge). The solid phase is then dried in steam heated or direct-fired dryers (Fernando 1992).

A study focusing on the use of another poultry byproduct, hydrolyzed feather meal, in grow-finisher hogs determined that it actually increased leanness when compared to SBM (Chiba 1994). Chiba further determined that a low-quality protein source could be used effectively in diets designed to enhance leanness in finisher pigs. Hydrolyzed feather meal is unbalanced in essential amino acid content when compared to PBM.

In 1981, Gruhn and Wunderlich evaluated growth of pigs over a period of 140 days (initial weight 29.4 kg). PBM replaced none, one-third, two-thirds, or all of the fishmeal and SBM in the grower diets. Results showed significantly lower intake and thus average daily gain for pigs fed the highest concentration of PBM. However performance of the pigs fed the other treatments with reduced inclusion rates of PBM were not different from the control.

In a paper published by Shelton et al in 2001, the effects of different protein sources on growth and carcass merit were evaluated in grow-finisher pigs. They made comparisons between the control pigs fed a SBM protein and pigs fed PBM as the sole source of protein. Diets were not isonitrogenous. In fact, the control diet had 20.52% crude protein (CP) and the PBM diet contained only 13.84% CP. As a result of the differences in CP, the control contained 64.26% corn and 31.98% SBM, where the PBM diet included 82.35% corn and 15.01% PBM in the grower phase (duration of feeding unknown). The manuscript indicates diet composition for the early and late finisher phase (duration unknown) differs only in lysine percentage. The results indicated a significantly lower ADG and efficiency during the grower period in pigs fed PBM, no significant differences in the finishing phases, and overall significant differences in feed intake and gain were noted. The only significant difference in carcass traits was an increase in backfat for pigs fed PBM due to a decrease in the protein/calorie ratio. No data on ether extract in diet composition was shown.

Use of PBM in Poultry

Poultry byproducts have been successfully used in broiler and layer rations for the better part of the past 50 years. Papers such as Wisman et al (1958) and Daghir (1975) have documented the acceptability of these products for commercial operations. Daghir (1975) analyzed PBM in broiler and layer rations that supplemented PBM with hydrolyzed feather meal in place of fishmeal. Results indicated a numerical decrease in weight with diminishing amounts of fishmeal and increasing PBM/feather meal; however, none of the values were statistically significant. Feed utilization was decreased ($P<.05$) with the PBM and feather meal. Feed utilization, however, was improved when crystalline amino acids were added to the diets, indicating that the digestible amino acid profile of the PBM/feather meal was not optimal. The addition of feather meal to the PBM may account for the reduction in feed efficiency due to its typically lower essential amino acid profile including histodine, lysine, and methionine when compared to the amino acid profile of PBM (Pearson and Dutson 1992). Additionally, relative to PBM, feather meal is low in calcium and potassium, and metabolizable energy value (Polin 1992).

Additional studies of the quality of various poultry byproducts as a feed ingredient have been conducted on laying hens, and have resulted in comparable or better results than seen in diets containing more typical ingredients (Vandepopuliere 1976). This study replaced varying percentages of SBM, meat and bone meal, and wheat middlings with two types of hatchery by-product meal. Eggshell production, feed conversion and shell qualities were tested in the Vandepopuliere research. They concluded that there is a potential market for poultry byproducts as effective alternative feedstuffs.

Escalona et al (1986) reported on nutritive value (protein efficiency ratio) of PBM as a protein source for chicks. It was determined in a slope ratio assay (varying protein content 2.5-30%) through several methods of protein quality assessment that SBM was superior to PBM as a protein source for chicks, when fed as the sole source of protein. A slope ratio assay is designed such that the lysine level selected is in the linear portion of the response curve. An evaluation on the linear improvement in gain is compared between the slopes of the lines. This demonstrates the ability of the ingredients to be substituted equally in diets and reveals the subsequent effect on performance.

Escalona and Pesti (1987) summarized the growth-promoting properties of PBM that were reported by Romoser (1955), Fuller (1956), Gerry (1956), and Wisman et al (1958) where the value of PBM was found to be similar to that of fishmeal. Escalona and Pesti (1987) fed seven different samples of PBM from different rendering plants in the Southeast to chicks for the purpose of testing inclusion of PBM at 5 and 10% in place of SBM in the diets. Sources differed based on day collected and individual plant sampled. Diets were designed to be is nitrogenous and isocaloric. Chicks fed the 5% PBM diet gained significantly more than chicks fed 10% PBM diet. However, neither of the two treatments differed significantly in gains from the basal diet. In a second experiment, chicks fed the basal diet may have gained significantly more than those on the 10% PBM diet, though p-values for that specific comparison were not reported. No significant differences were detected in feed efficiency across treatments.

Continued use of rendered byproducts as a SBM replacement has yielded papers validating their use in turkey rations. For example, Boling and Firman (1997) determined the efficacy of byproducts as a substitute for SBM. They fed toms diets formulated on a digestible amino acid basis with a mixture of byproducts that included PBM and determined that performance was not affected by the inclusion of PBM in starter diets. They did note a numerical (3%) decrease (not significant) in weight gain in the highest BP inclusion finisher diets. Partial replacement of SBM with a byproduct is again supported.

Use of PBM in Petfoods

Approximately 25-40% of the dry matter in premium dog diets is animal byproduct; however, due to private companies' proprietary rules, little is published regarding the composition and digestibility of ingredients used in these diets (Murray et al 1997). Murray et al (1997) studied inclusion of several meat byproducts including PBM in experimental diets fed to ileal-canulated dogs using a Latin square design. They found that diets containing animal byproducts were similar in total tract digestibility. The Murray et al (1997) paper concluded that beef and poultry byproducts are good sources of highly digestible nutrients for dogs; however, it is noted that ileal digestibility is somewhat lower for diets containing rendered byproducts over those containing fresh raw ingredients. This decrease is attributed to the origin of the raw materials and rendering techniques used to produce them.

Johnson et al (1998) tested the amino acid digestibility of several animal byproduct meals with varying ash content. The study revealed that there was no significant difference in total amino acid digestibility for cecectomized roosters fed PBM when comparing PBM sources of high (16.3%) and low (7.2%) ash content. True metabolizable energy (TME) was greatest in the low ash PBM diet, and both PBM diets were greater in TME when compared with meat and bone meal and lamb meal at varying ash contents (Johnson et al 1998). When comparing the same products in ileally canulated dogs, Johnson et al 1998 found a general decrease in digestibility compared to results seen in the roosters.

However, ileal digestion of gross energy was not different among treatments, and nitrogen digestion at the ileum was less only when comparing the PBM diets (high and low ash) to meat and bone meal cooked at low temperature. Total tract digestion was equivalent to, or greater than, that of the other diets for PBM. Again, only nitrogen digestion was greater in dogs fed meat and bone meal cooked at low (80 Celcius) temperature.

Feed tags obtained from various major pet food manufacturers revealed PBM among the top three ingredients, placing it before most plant protein sources. While not knowing exact inclusion levels, one can surmise that greater than 30% of these diets include some form of poultry meal. Because of the demands on the pet food industry to provide quality diets for selective consumers, one can be sure vast research has been performed. Both Hill's® 2000 and Purina™ 2001 list PBM among the top ingredients in their specialty diets sold exclusively at veterinary clinics. Using the dog as a model for gain and digestibility, the swine industry can similarly utilize this available byproduct resource as a more economical protein supplement.

Use of PBM in Extruded Diets

Poultry byproducts have also been used with promising results in extruded diets. In Patterson et al (1994), the extrusion process consisted of grinding fresh poultry offal through a 6mm screen, mixing with either cassava meal, ground barley, or wheat middlings, extruding the combined products at 135-163 degrees

Celsius, cutting resulting product to a one cm length, cooling, drying and finally grinding with a hammer mill to create an 89% dry matter product. These extruded poultry byproducts were fed to day-old male commercial broiler chicks for three weeks. Body weights, feed consumption, and efficiency were all statistically similar when compared to the control. Only the diet that was extruded with poultry byproduct and barley, fed at 20% of the diet, had feed efficiencies at a level below that of the control and considered to be due to a decrease in palatability (Patterson et al 1994).

Use of PBM in Fermented Products

In a desire to further reduce cost by decreasing the consumption of energy necessary during the rendering process, researchers have ensiled poultry byproducts with promising results (Tibbetts and Seerley 1988). For example, ensiling PBM with *Lactobacillus Acidophilus* did not significantly affect ADG or feed conversions when included at 10 and 20% of the diet (Tibbetts et al 1987). For these rations the poultry offal was inoculated with the, incubated for six hours and inoculated into reconstituted whey (for large quantity production) and incubated again until a specific titer of *Lactobacillus* was reached. The offal meal was ground and mixed with ground shelled corn and molasses and the *L. Acidophilus* culture and then fermented for 96 hours (Tibbetts et al 1987). Following fermentation, digestible energy, metabolizable energy, crude fiber, phosphorus and nitrogen balance values were higher for the 20% offal silage than the control diet (Tibbetts et al 1987). Average daily gains, feed-to-gain ratios and carcass merit measurements were not significantly different in grower and finisher pigs fed diets containing up to 20% fermented product. Based on their research, Tibbetts et al (1987) concluded that poultry offal silage is an acceptable feed ingredient for growing and finishing hogs. A year later, Tibbetts and Seerley (1988) published similar results using fermented viscera from broiler processing plants. Up to 20% fermented product resulted in significantly improved average daily gain and feed conversion rates. Carcasses from pigs fed visceralage had less backfat, larger loin area, and the loin was softer. The product was concluded to be a potentially useful feedstuff for swine diets if not more than 20% of the diet contained fermented byproduct. Hong et al (2001) used fermented PBM at 0, 10, and 20% levels in place of SBM for crossbred finishing pig diets over a period of 56 days. ADG, ADFI, gain/feed, BUN levels and apparent digestibility of DM and N did not differ across treatments. The authors did note an increase in backfat thickness as inclusion rate of fermented PBM increased; however, they did have increasing levels of fat in those diets to maintain an overall metabolizable energy level that was similar across treatments. While ensiling references can be found in the literature and ensiled PBM has been shown to be an acceptable protein source in swine diets, it is noted that the fermented diet can change the gut flora significantly: biogenic amine levels increase, and overall health of the animals may decrease. Additionally, non-protein nitrogen and total volatile nitrogen levels are typically very high in fermented products as a result of excessive protein and amino acid breakdown that occurs when fermenting with *Lactobacillus plantarum* and *Enteroccocus faecium* (Urlings et al 1993).

Using the resources and research from the past, one is able to hypothesize the addition of PBM to nursery diets and the economic implications with which it corresponds. Whether fermented, extruded, fed to pets, growing pigs, mink, or poultry, PBM has been proven to be an asset to feeding programs.

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Table 2-1. Primary ingredients in a typical starter diet series.*

	SEW diet <11 lb	Transition 11-15 lb	Phase II 15-25 lbs	Phase III 25-50 lbs
Corn	33	39	48	55
SBM	12	23	29	35
Whey	25	20	10	-
SDPP	6.5	2.5	-	-
SDBM	1.7	2.5	2.5	-
FM	6	2.5	-	-
Lactose	5	-	-	-
Lysine	1.7	1.6	1.4	1.35
ME Kcal/kg	3510	3440	3460	3490

*Kansas State University Agricultural Experiment Station and Cooperative Extension Service, 1997

Table 2-2. Composition of nursery diet ingredients.*

Amino Acids	Whey %	Spray-Dried Plasma Protien %	Fish Meal (Menhaden) %	Ring Dried BM %	Spray Dried Blood Cells %	SBM 48% %	PBM %
ARG	0.26	4.55	3.66	3.34	3.77	3.48	3.94
HIS	0.23	2.55	1.78	5.06	6.99	1.28	1.25
ILE	0.62	2.71	2.57	0.91	0.49	2.16	2.02
LEU	1.08	7.61	4.54	10.99	12.70	3.66	3.89
LYS	0.9	6.84	4.81	7.04	8.51	3.02	3.32
MET	0.17	0.75	1.77	0.99	0.81	0.67	1.11
CYS	0.25	2.63	0.57	1.09	0.61	0.74	0.65
PHE	0.36	4.42	2.51	5.34	6.69	2.39	2.26
TYR	0.25	3.53	2.04	2.29	2.14	1.82	1.56
THR	0.72	4.72	2.64	4.05	3.38	1.85	2.18
TRP	0.18	1.36	0.66	1.08	1.37	0.65	0.48
VAL	0.6	7.03	3.03	7.05	8.50	2.27	2.51
Dry Matter	96	91	92	92	92	90	93
Metabolizible Energy kcal/kg	3190	-	3360	2350	-	3380	2860
Crude Protein	12.1	78	62.3	77.1	92	47.5	64.1
Fat	0.9	2	9.4	1.6	1.5	3	12.6
Calcium	0.75	0.15	5.21	0.37	0.02	0.34	4.46
Phosphorus	0.72	1.71	3.04	0.27	0.37	0.69	2.41

*Based on NRC information, 1998.

CHAPTER 3

USE OF POULTRY BYPRODUCT MEAL AS AN ALTERNATE PROTEIN SOURCE IN SWINE STARTER RATIONS

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Abstract

A series of studies were conducted to evaluate pet-food grade poultry byproduct meal (PBM) as a replacement protein source for fishmeal, blood meal, and SDPP in swine nursery rations. A total of 200 crossbred pigs (initial wt = 6.5, kg) were weaned (21 d) and randomly allotted in Exp. 1 to four treatment groups in two replicates. The phase I diets (1.5% lysine) included a basal diet containing both fish meal (FM, 5%) and spray dried porcine plasma (SDPP, 3%), and three test diets made to substitute SDPP, FM, or both with PBM. Phase II diets (1.375% lysine) included a control diet with 2.5% blood meal (BM) and 2.5% FM, and three other diets replacing BM, FM, or both with PBM. In phase I, average daily gain (211 vs. 158 g/d, $P < 0.01$), body weight (7.61 vs. 7.34 kg, $P < 0.01$), and intake (205 vs. 175 g/d, $P < 0.001$) in pigs fed diets containing the SDPP were greater than those fed PBM. Average daily gain (ADG) during phase II was greater in pigs fed PBM than BM (191 vs. 152 g/d, $P < 0.01$). Overall (d 0-26), there was no difference in performance between treatments. Experiment 2 ran concurrently with Exp. 1, using control pigs from the first study to compare with 50 pigs fed 20% PBM in the ration. Feed intake during phase I was greater (207g/d vs 161g/d, $P<.005$) for pigs fed the control diet when compared to pigs fed the 20%PBM diet. No differences in performance were noted in the second phase. However, in phase III, both ADG (559g/d vs 453g/d, $P<.05$) and feed efficiency (1.34 F:G vs 1.52 F:G, $P<.05$) were greater in those fed the control

diet when compared to those fed the PBM. Overall (d 0-26) there was no difference in performance between pigs fed the high level of PBM when compared to those fed a more traditional starter series of diets. Experiment 3 was designed as a slope ratio assay to determine the ability of PBM to replace SDPP. A total of 320 crossbred terminal pigs were weaned (21 d) and allotted to five treatment groups in three replicates in a blocked design with product (SDPP or PBM) as the first factor, and lysine level (1.08%, 1.28%, 1.49%) as the second factor. There was a linear trend for growth to increase as lysine increased. There was no difference in growth for pigs fed SDPP vs PBM. These results indicate that PBM can be used in nursery rations in place of blood meal and fishmeal without affecting performance, but may not be equivalent to SDPP in phase I diets.

Introduction

In order to maximize utilization of farrowing facilities and sow productivity, pigs are typically weaned prior to physiological maturity of their digestive tract. Because of this, weaning is associated with poor growth and feed conversion. To minimize this effect, starter rations for newly weaned pigs are typically formulated with highly palatable and readily digestible animal protein sources that make this phase of swine feeding the most expensive. The goal is to use dietary ingredients that most nearly match the young pig's digestive capacity (Kim and Easter 2001). Typically included ingredients are fishmeal, plasma protein, and blood meal. Since the 1980's, the pork industry has used porcine plasma as the standard by which other proteins are evaluated because of the product's ability to stimulate feed intake during the first week post-weaning (Kim and Easter 2001). Alternative feed ingredients are often sought after in least cost diet formulations. Poultry byproduct meal is readily available in the Southeastern United States and has been widely used in other monogastric rations (pet foods and poultry rations). Poultry by-product meal consists of the viscera, head, and the feet from poultry at slaughter which are either dry or wet rendered, dried, and ground into a meal (Elwyn 1994). Pet food grade PBM is a specialty product that contains remaining meat from the backs and wings, and the viscera. There are no heads, feet, undeveloped eggs or "deads" in this product. "Deads" refer to birds that died prior to processing at the farm or during shipping. Some non-peer-reviewed reports have been published concerning the feeding of PBM to nursery pigs. Seddon and Smith (1997) used PBM as an added ingredient in nursery diets containing raw soybeans. They found a greater reduction in performance relative to the addition of raw soybeans alone. Veum and Haque (1994) compared spray-dried PBM to SDPP in nursery diets and reported that, during the first week, SDPP fed pigs had a higher ADG and FI than the pigs fed the PBM, but overall there was not a significant difference in piglet performance. They estimated a cost reduction of 28% per ton for phase I diets. Studies, which validate the use of by-products, make it possible for livestock producers and renderers to work together and create an economical, alternative feed ingredient.

Materials and Methods

The experimental protocols used in this study were approved by the Animal Care and Use Committee of the University of Georgia (UGA) (UGA Animal Care and Use, A2002-10065-0). Pet food grade PBM was provided by American Proteins, Inc. (4705 Leland Dr. Cumming, GA. 30041). An analysis of the PBM used in the following studies is listed in Table 3-1. Lot 1 of PBM was used for phase I diets in Experiment 1 and 2, Lot 2 was used for all other experimental diets.

Experiment 1

A total of 200 (100 females, 100 males) crossbred terminal pigs (HampxLandxLrgWht/DRU) (initial wt = 6.5, kg) from the University of Georgia (UGA) Swine Center herd were weaned (21 d) and randomly allotted to four treatment groups (two replicates) in a 2 x 4 factorial design using sex and dietary treatment. Pen was considered the experimental unit. The study was conducted at the Large Animal Research Facility, UGA Animal Science Complex in an environmentally controlled room with continuous artificial lighting, woven wire flooring and pits. Pens were .94m wide by 1.83m long. The temperature was maintained within 26-27 degrees Celcius. In each replicate, pigs were placed into 20 pens with five pigs per pen, based on sex, weight, and litter. Pens were analyzed as the experimental units. Treatments were designed to test inclusion of poultry byproduct meal (PBM) in place of more commonly used animal protein sources. The phase I diets (1.5% lysine) included a basal diet containing both fish meal (FM, 5%) and spray dried porcine plasma (SDPP, 3%), and three test diets replaced SDPP, FM, or both with PBM. Phase II diets (1.375% lysine) included a control diet with 2.5% blood meal (BM) and 2.5% fishmeal and three other diets replacing BM, FM, or both with PBM. The phase I pelleted diets were fed for five days, the phase II pelleted diets were fed for 14 days, and a common phase III ground diet (1.25% lysine) was fed for seven days. Diet composition and nutrient content are summarized in Table 3-2. Test diets and water were available to the pigs ad libitum through five hole self-feeders and nipple waterers. Animals were monitored daily for health and to ensure feeders and waterers were functioning properly.

Pigs were weighed at weaning and again at 5, 12, 19, and 26 days post-weaning. Feed was weighed back to determine each pen's feed intake at these same intervals. Two average pigs per pen were bled during the third week of the study to determine blood urea nitrogen (BUN) levels using a similar procedure to the Bergstrom et al 1998 study. Pigs were bled in the morning, however pigs were fed ad libitum. Six pigs across treatments were removed due to lameness, illness or death (two piglets died and were sent to necropsy, which reported no significant findings). Pen weights were adjusted accordingly.

Experiment 2

In this experiment, which ran concurrently with the first experiment at the Animal Science Complex, performance of the pigs fed the control diet was compared to that of pigs fed diets with 20% PBM in all phases. In this experiment PBM replaced 50% of the soybean meal (SBM) and all of the SDPP and FM in phase I, and 70% of the SBM and all of the BM and FM in phase II. Poultry byproduct meal replaced approximately 80% of the SBM in phase III. This experiment was analyzed as a 2x2 factorial design with sex and treatment as the parameters. There were 10 pens (50 pigs) in the control and 10 pens in the 20% PBM treatments which were allotted and weighed at intervals in the same manner as an at the same time as the pigs in experiment 1. Pigs were bled to determine BUN levels at the same time as those in the first experiment. A summary of this diet is shown in Table 3-3. Experiments one and two were conducted in July, August, and September.

Experiment 3

A total of 320 crossbred terminal pigs (HxLxLW/DRU) (initial wt = 7.32 kg) from the UGA Swine Center herd were weaned (21 d) and randomly allotted to five treatment groups in three replicates. This study was conducted at the UGA Swine Center nursery barn in a blocked design with product (SDPP or PBM) as the first factor, and lysine level (1.08%, 1.28%, 1.49%) as the second factor. Experimental diets are shown in Table 3-4. Temperature regulation was more difficult to maintain, but a 60,000 BTU heater was used to keep the barn as close as possible to 27 degrees Celcius. Continuous artificial lighting was maintained. The pens were 1.22m wide by 2.84m long and flooring was double aught woven wire. Two pit fans ventilated the pit, beneath the pigs. In each replicate, pigs were placed into 15 pens with eight pigs per pen (four gilts and four barrows), based on weight, and litter with both individual pigs and pens analyzed as the experimental units. Treatments were designed to test inclusion of poultry byproduct meal (PBM) in place of SDPP in a slope ratio design.

One basal and four treatment diets, fed for an average of 20 days, were designed at incrementally different lysine levels below NRC requirements (NRC 1988) for the purpose of producing a clear slope between diets. As incremental lysine levels are added to the rations, the slopes for growth rate of the pigs should be statistically significant. An estimate of the relative protein quality of the PBM to the established product, SDPP, can be obtained by comparing the slopes of the lines (Lindemann 2000). Feed and water were provided ad libitum via five hole self-feeders and nipple waterers. Both feed and piglets were weighed weekly. Replicates of experiment 3 were conducted in the winter months.

Statistical Analysis

All data was analyzed using the *Proc glm* procedure in SAS (SAS 1985). To evaluate the slope of the line in experiment 3, lysine dose and source (PBM or SDPP) were fit to a linear model to obtain regression equations that related ADG to lysine level.

Samples of the diets and PBM from both lots were tested for amino acid content on a Beckman 6300 (Beckman Coulter, Inc., Palo Alto, CA) following procedures used in Amos et al 1976. Diets from experiment one and two were formulated using the WUFFFDA least cost formulation software (Pesti 2001) while diets for experiment three were calculated using Excel (Froetshel 2001).

Results

Experiment 1

A summary of the data in Exp 1 is presented in table 3-5. There was no significant main effect of sex and no sex by treatment interaction. In phase I, average daily gain (211 vs. 158 g/d, $P < 0.01$), body weight (7.61 vs. 7.34 kg, $P < 0.01$), and intake (205 vs. 175 g/d, $P < 0.001$) of pigs fed diets containing SDPP were greater than those fed PBM. Average daily gain (ADG) from d 5 -12 was greater in pigs fed PBM than BM (191 vs. 152 g/d, $P < 0.01$). Overall (d 0-26), there was no difference in performance of pigs fed PBM in place of SDPP and BM. Substitution of PBM for FM in phase I or II had no effect on performance. There was a trend towards ($P < .10$) pigs fed the PBM diet to have lower BUN when compared to the other treatments (PBM only diet 15.99 mg/dL vs. 16.59mg/dL other three diets, SEM .1341).

Experiment 2

There was no sex and no sex by diet interaction. Feed intake during phase I was greater (207g/d vs 161g/d, $P<.005$) for pigs fed the control diet when compared to pigs fed the 20%PBM diet. During phase II there was no difference in body weight , ADG, feed intake or feed efficiency. However, in phase III, both ADG (559g/d vs 453g/d, P<.05) and feed efficiency (1.34 F:G vs 1.52 F:G, P<.05) were improved in pigs fed the control diet when compared to those fed the PBM. Although, overall (d 0-26) there was no significant difference in performance between pigs fed the high level of PBM when compared to those fed more traditional starter diets (Table 3-6). BUN levels were not significantly different between treatments.

Experiment 3

Both pen data and individual pig data were analyzed. Body weights and ADG, were co-varied for initial weaning weight and calculated across treatments and are reported in Tables 3-7 (individual piglet weight and ADG) and 3-8 (average pen data including feed intake and efficiency). There was a linear trend as appropriate for the experimental design. The overall ADG was analyzed to determine if the sources (SDPP or PBM) were linearly different from zero. The resulting linear model indicated the lines were different from zero (p<.005), but there is not enough evidence to detect a difference is the slopes of the two lines. During the first week, pigs fed the SDPP diets gained more than those fed the control or the PBM. There was a stepwise increase in final weight and in gain in pigs fed 0, 3, and 6% SDPP or PBM. Overall there was no difference between

PBM and SDPP. The equations of lines for overall gain were as follows: SDPP, y= .186285224 + .01446966x and PBM, y=.186285224+ .0089400x (SEM .0028).

Discussion

This series of experiments examined the use of PBM in nursery diets to replace higher cost ingredients. Differences in ADG for SDPP vs. PBM noted for phase I were negated by the end of the first week on the phase II diets. These results indicate that PBM can be used in nursery rations in place of blood meal and fishmeal without affecting performance, but may not be equivalent to SDPP in phase I diets. These results are consistent with Veum and Haque (1994) who compared spray-dried PBM to SDPP in nursery diets and reported that during the first week SDPP fed pigs had a higher ADG and FI than the pigs fed the PBM, but overall there was not a significant difference in piglet performance. It is noted that spray drying is different from conventionally rendered PBM. Additionally, results are consistent with de Rhodas et al (1995), Hansen et al (1993), and Kats et al (1994); all of which noted an increase in performance when SDPP was included in phase I diets at the expense of dried skim milk or SBM.

It has been speculated that compensatory gain and feed intake occurs following environmental or nutritional insults (Mahan and Lepine 1991) possibly including post-weaning "lag." This would in part account for the improvements in feed intake and gain seen during the second week of all three studies.

When diets are formulated to provide similar digestible amino acid levels, relatively high amounts of byproduct in both starter and finisher diets resulted in only minor adverse effects on gain (Boling 1997). Formulating on a digestible amino acid basis may enable producers to increase dietary PBM to 20% without a reduction in performance. While results support the addition of 20% PBM into the diet without adversely affecting overall performance, it is important to consider maximum inclusion at a lower level avoid the reduction in intake during the first week post weaning.

Diets in the slope ratio experiment were formulated to contain lysine levels based on results from studies such as Lindemann et al (2000) and Kim and Easter (2001). Through regression analysis, the slope of the two lines for SDPP and PBM were concluded not different from each other for overall gain, indicating the products are interchangeable.

It is concluded that PBM cannot fully replace SDPP in phase I diets. However, overall, PBM containing diets appear to be equivalent to those containing SDPP based on final nursery weights that do not differ.

Use of PBM in conjunction with SDPP in a starter ration, or to replace fishmeal and blood meal in a phase II ration is economically advantageous, reducing the cost of the diets by up to 24% based on commodity price and inclusion similar to that of the diets in experiments 1 and 2.

Implications

From a practical standpoint, PBM is an affordable alternative for the more expensive, traditionally used, animal proteins in the diets of weaned piglets. Substituting PBM for fishmeal or bloodmeal is an excellent way to reduce diet cost while not sacrificing performance. However, use of PBM in place of SDPP the first week post-weaning does not result in the stimulation of intake and gain that is routinely observed with SDPP. PBM would make a sensible and safe addition to nursery diets after the first week post weaning.

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Table 3-1. PBM analysis compared to calculated values on an as fed (AF) basis.

Amino Acids	PBM (Used for Phase 1, Exp 1 and 2) g AA/100g AF**	PBM (Used for Exp 1& 2, Phases 2 and 3, and Exp 3) g AA/100g AF**	Analysis Pet Food Grade PBM#
ASP	4.02	4.20	4.89
THR	1.94	2.01	2.34
SER	2.11	2.03	2.66
GLU	7.01	7.34	7.72
GLY	4.47	4.87	7.31
ALA	3.01	3.34	4.36
VAL	2.24	2.35	2.51
MET	1.22	1.29	1.18
ILE	2.41	2.51	2.02
LEU	4.53	4.70	4.02
TYR	2.21	2.17	1.84
PHE	1.83	1.91	2.25
HIS	1.22	1.29	1.25
LYS	3.27	3.46	3.68
ARG	3.93	4.16	4.35
PRO	2.41	2.66	4.52
CYS	0.24	0.21	0.65
	%AF*	%AF*	%AF#
Moisture	9.3	5.3	5
Crude Protein	61.9	65.6	65.1
Crude Fiber	0.5	0.2	2.2
Fat	12.95	10.84	11.5
Calcium	2.8	4	4.8
Phosphorus	1.7	2.4	2.3

*Analyzed by University of Georgia Feed and Environmental Water Laboratory

#Typical analysis as reported by American Proteins, Inc. 4705 Leland Dr. Cumming, Ga. 30131

**Analyzed using Beckman 6300, Beckman Coulter, Inc., Palo Alto, CA

Table 3-2. Summary of diets as calculated for Exp. 1.

Ingredient	Basal phase 1 Amount %	Fishmeal & PBM Amount %	SDPP & PBM Amount %	PBM Amount %	Basal phase 2 Amount %	Fishmeal & PBM Amount %	SDPP & PBM Amount %	PBM Amount %	Common phase 3 Amount %
Corn, Grain	37.81	36	37.66	36	52.53	54.66	54.26	53.9	59.31
Whey, Dried	27.5	27.5	27.5	27.5	10	10	10	10	-
Soybean Meal -48%	20.54	22.16	19.24	22.11	24.05	21.1	20.63	21.51	31.76
Plasma protein, SD	5	-	5	-	-	-	-	-	-
Menhaden Meal	3	3	-	-	2.5	2.5	-	-	-
Bloodmeal	-	-	-	-	2.5	-	2.5	-	-
Poultry BP Meal	-	6	5	9	-	6	5	9	-
Anml-Veg Fat	2.62	2.48	2.27	2.42	3.94	2.26	3.42	2.16	5.03
Dical. Phos.	1	0.81	1	0.85	2	1.33	1.84	1.33	1.85
Limestone	0.64	-	0.42	-	0.52	0.17	0.34	0.13	0.75
Common Salt	-	-	-	-	-	-	-	-	0.35
Zinc oxide	0.38	0.38	0.38	0.38	0.25	0.25	0.25	0.25	-
Swine Vit Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Swine TM Premix**	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.13	0.18	0.13	0.2	0.15	0.12	0.16	0.13	0.1
L-Lysine HCl	-	0.1	-	0.14	0.15	0.2	0.2	0.2	0.2
Antibiotic[@]	1	1	1	1	1	1	1	1	0.25

Table 3-2. Summary of diets as calculated for Exp. 1 (con't).

As Calculated									
ME Kcal/g	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.42
%CP	21.94	22.97	22.92	23.22	20.69	21.32	20.93	21.85	20.14
%EE	4.72	5.13	4.65	5.12	6.35	5.38	6.19	5.37	7.21
%CF	1.36	1.5	1.4	1.55	1.81	1.82	1.83	1.87	2.09
%calcium	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.75
%Phosphorus	0.8	0.83	0.83	0.83	0.82	0.82	0.82	0.82	0.7
%avail phos	0.65	0.67	0.68	0.66	0.61	0.63	0.63	0.63	0.45
%Lysine	1.5	1.5	1.5	1.5	1.37	1.37	1.37	1.37	1.25
Tryptophan	0.31	0.28	0.31	0.28	0.27	0.25	0.25	0.25	0.26
TSAA	0.9	0.9	0.9	0.9	0.81	0.81	0.81	0.81	0.75
Threonine	1.05	0.98	1.07	0.98	0.87	0.86	0.87	0.88	0.81

*Supplied per kg of premix: vitamin A, 4,400 IU; vitamin D, 660,000 IU; vitamin E, 17,600 IU; vitamin K, 1,760 IU; riboflavin, 3,960 mg; niacin, 22,000 mg; panothenic acid, 13,200mg; vitamin B12, 17,600 ug.

**Supplied per kg of premix: iron 110,000 mg; copper, 11,000 mg; manganese, 26,400 mg; zinc, 110,000 mg; iodine, 198 mg; selenium, 198 mg.

[@] Phase one diets contained Apralan (Elanco Animal Health, Indianapolis, IN); Phase two and three diets contained Mecadox (Pfizer, Inc., Ann Arbor, MI).

Table 3-3. Summary of diets fed in Exp 2.

	Phase I		Phase II		Phase III	
Ingredient	Basal phase 1 Amount %	20% PBM Amount %	Basal phase 2 Amount %	20% PBM Amount %	Basal phase 3 Amount %	20% PBM Amount %
Corn, Grain	37.81	38	52.53	58.08	59.31	68.13
Whey, Dried	27.5	27.5	10	10	-	-
Soybean Meal -48%	20.54	10.25	24.05	7.67	31.76	6.49
Plasma protein, SD	5	-	-	-	-	-
Menhaden Meal	3	-	2.5	-	-	-
Bloodmeal	-	-	2.5	-	-	-
Poultry BP Meal	-	20	-	20	-	20
Anml-Veg Fat	2.62	2.2	3.94	2	5.03	4
Dical. Phos.	1	-	2	0.25	1.85	0.04
Limestone	0.64	-	0.52	-	0.75	-
Common Salt	-	-	-	-	0.35	0.35
Zinc oxide	0.38	0.38	0.25	0.25	-	-
Swine Vit Premix*	0.25	0.25	0.25	0.25	0.25	0.25
Swine TM Premix**	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.13	0.17	0.15	0.12	0.1	0.08
L-Lysine HCl	-	0.08	0.15	0.2	0.2	0.2
Antibiotic[@]	1	1	1	1	0.25	0.25
L-Tryptophan	-	0.03	-	0.04	-	0.05
As Calculated						
ME Kcal/g	3.31	3.37	3.31	3.39	3.42	3.52
%CP	21.94	25.3	20.69	22.74	20.14	21.74
%EE	4.72	6.12	6.35	6.48	7.21	8.73
%CF	1.36	1.47	1.81	1.77	2.09	1.92
%calcium	0.9	1.22	0.9	1.12	0.75	0.99
%Phosphorus	0.8	0.86	0.82	0.8	0.7	0.7
%avail phos	0.65	0.75	0.61	0.67	0.45	0.56
%Lysine	1.5	1.5	1.37	1.37	1.25	1.25
Tryptophan	0.31	0.28	0.27	0.25	0.26	0.24
TSAA	0.9	0.9	0.81	0.81	0.75	0.75
Threonine	1.05	1	0.87	0.87	0.81	0.79

*Supplied per kg of premix: vitamin A, 4,400 IU; vitamin D, 660,000 IU; vitamin E, 17,600 IU; vitamin K, 1,760 IU; riboflavin, 3,960 mg; niacin, 22,000 mg; panothenic acid, 13,200mg; vitamin B12, 17,600 ug.

**Supplied per kg of premix: iron 110,000 mg; copper, 11,000 mg; manganese, 26,400 mg; zinc, 110,000 mg; iodine, 198 mg; selenium, 198 mg.

[@] Phase one diets contained Apralan (Elanco Animal Health, Indianapolis, IN); Phase two and three diets contained Mecadox (Pfizer, Inc., Ann Arbor, MI).

Table 3-4. Experimental diets as calculated, used in Exp. 3.

		SDPP,%		PBM,%	
Ingredients	BASAL	3	6	3	6
Corn	42.3	42.35	42.5	42.63	43
SBM 49%	20	20	20	20	20
Whey	23	23	23	23	23
SDPP	-	3	6	-	-
PBM	-	-	-	3	6
Cornstarch	6	3	-	3	-
Fat	2.5	2.5	2.5	2.5	2.5
Fish meal	2.5	2.5	2.5	2.5	2.5
Lysine HCL	-	-	-	0.13	0.26
DL Methionine	0.05	0.1	0.1	0.15	0.2
Threonine	-	-	-	-	0.05
Antibiotic Mecadox[@]	1	1	1	1	1
Dicalcium Phosphate	1.72	1.44	1.16	1.32	0.93
Limestone	0.57	0.72	0.87	0.37	0.18
Swine TM Premix**	0.15	0.15	0.15	0.15	0.15
Swine Vit Premix*	0.25	0.25	0.25	0.25	0.25
As Formulated					
Crude Protein	17.21	19.61	21.97	19.39	21.56
Lysine	1.08	1.28	1.49	1.28	1.49
ME kcal/g	3.29	3.30	3.31	3.30	3.32
Calcium	0.9	0.9	0.9	0.9	0.9
Phosphorus	0.8	0.8	0.8	0.8	0.8
TSAA	0.65	0.8	0.91	0.81	0.91
TRP	0.23	0.27	0.31	0.28	0.34
THR	0.78	0.92	1.06	0.85	0.97

*Supplied per kg of premix: vitamin A, 4,400 IU; vitamin D, 660,000 IU; vitamin E, 17,600 IU; vitamin K, 1,760 IU; riboflavin, 3,960 mg; niacin, 22,000 mg; panothenic acid, 13,200 mg; vitamin B12, 17,600 ug.

**Supplied per kg of premix: iron 110,000 mg; copper, 11,000 mg; manganese, 26,400 mg; zinc, 110,000 mg; iodine, 198 mg; selenium, 198 mg.

[@] Diets contained Mecadox (Carl Akey Feeds).

Table 3-5. The effects on replacing FM, BM and SDPP with PBM in Exp. 1[d].

Variables	Days Post-Weaning	Diets: SDPP/BM & FM	SDPP/BM & PBM	FM & PBM	PBM	SEM	P-values
BW (kg)	Weaning	6.56	6.55	6.54	6.56	0.03	NS
	5d	7.60[a]	7.62[a]	7.45[b]	7.23[b]	0.09	0.005
	12d	8.63	8.77	8.82	8.57	0.12	NS
	19d	10.98	11.29	11.19	11.27	0.18	NS
	26d	14.87	14.97	15.19	15.17	0.32	NS
ADG (g)	0-5d	207.5[a]	214.4[a]	182.8[ab]	133.4[b]	18.1	0.006
	5-12d	146.4[a]	157.8[ab]	195.8[b]	186.6[ab]	15.4	0.01
	12-19d	336.2	361.2	338.1	374.4	21.5	NS
	19-26d	555.3	533.5	571.7	557.8	25	NS
	0-26d	319.3	326.7	332.8	329.7	12.6	NS
FI (g/d)	Week 1	204.4[a]	205.6[a]	184.6[ab]	165.2[b]	8.3	0.001
	Week 2	270.9	277.9	300	290.1	11.7	NS
	Week 3	509.9	528	540.4	513.2	21.1	NS
	Week 4	749.1	715.7	765.9	735.2	29.7	NS
	Avg.Total	451.2	449.2	468	446	16.1	NS
F:G	0-5d	1.08[a]	1.09[a]	1.15[ab]	1.67[b]	0.20	NS
	5-12d	2.05	1.82	1.63	1.71	0.17	NS
	12-19d	1.56[a]	1.47[a]	1.70[ab]	1.41[a]	0.09	NS
	19-26d	1.36	1.35	1.35	1.34	0.05	NS
	0-26d	1.43	1.39	1.41	1.37	0.04	NS

[a-c]Means within a row lacking a common superscript differ ($P<.05$)

[d]Average weaning weight was 6.55 kg.

Table 3-6. Performance of pigs fed a high inclusion of PBM when compared to a control group Exp. 2.

Variables	Days Post-Weaning	Diet: SDPP/BM & FM	20% PBM	SEM	P-Values
Body Weight, kg	Weaning	6.54	6.52	0.03	NS
	5d	7.61	7.31	0.10	NS
	12d	8.66	8.66	0.10	NS
	19d	11.00	11.28	0.16	NS
	26d	14.92	14.46	0.25	NS
Gain, g/d	0-5d	213	159	20	NS
	5-12d	151	190	20	NS
	12-19d	334	361	20	NS
	19-26d	559^{a}	453^{b}	20	0.01
	0-26d	322	303	10	NS
Intake, g/d	Week 1	207^{a}	161^{b}	10	0.001
	Week 2	273	285	10	NS
	Week 3	511	514	20	NS
	Week 4	751	688	40	NS
	Avg. Total	452	431	20	NS
Feed:Gain	0-5d	1.06	1.25	0.08	NS
	5-12d	1.98	2.05	0.38	NS
	12-19d	1.56	1.43	0.06	NS
	19-26d	1.34^{a}	1.52^{b}	0.06	0.05
	0-26d	1.42	1.42	0.04	NS

$^{a\text{-}b}$Means within a row lacking a common superscript differ (P<.05).

Table 3-7. The effect of protein source on performance of pigs weaned at 21 days (Exp. 3)[d]

	Diet						
	Control	3% SDPP	3% PBM	6% SDPP	6% PBM		
% Lysine (as calculated)	1.08	1.28	1.28	1.49	1.49	SEM	pvalue
BW, kg Wk 1	7.671^{a}	7.946^{b}	7.803^{ab}	8.215^{c}	7.858^{b}	0.065	0.0001
BW, kg Wk 2	8.783^{a}	9.402^{b}	9.307^{b}	9.83^{c}	9.628^{bc}	0.152	0.0001
BW, kg Wk 3	10.593^{a}	11.488^{b}	11.632^{b}	12.304^{c}	12.021^{bc}	0.226	0.0001
ADG, g Wk 1	-2^{a}	51^{b}	16^{ab}	51^{b}	30^{ab}	15	0.05
ADG, g Wk 2	140^{a}	183^{b}	188^{b}	202^{b}	218^{b}	14	0.002
ADG, g Wk 3	301^{a}	348^{ab}	387^{bc}	412^{c}	399^{bc}	20	0.0004
ADG, g Overall	164^{a}	208^{b}	216^{b}	249^{c}	235^{bc}	11	0.0001

[a-c]Means within a row lacking a common superscript differ ($P<.05$)

[d]Data are means of individual pig weights. Average weaning weight was 7.32kg.

Table 3-8. Experiment 3 results for pen data.*

Variables	Control	3% SDPP	6 %SDPP	3% PBM	6% PBM	SEM	p-Value
Wean (kg)	7.45	7.31	7.36	7.50	7.46	0.05	
BW Week 1	7.79^{a}	8.18^{b}	8.4^{c}	7.86^{a}	7.9^{a}	0.06	0.0001
BW Week 2	8.97^{a}	9.51^{b}	10.08^{c}	9.3^{ab}	9.49^{b}	0.14	0.0002
BW Week 3	11.12^{a}	11.85^{b}	12.97^{c}	11.86^{b}	12.13^{b}	0.19	0.0001
Gain Week 1(g/d)	57^{a}	121^{b}	154^{c}	69^{a}	73^{a}	10	0.0001
Gain Week 2	163^{a}	184^{a}	230^{b}	196^{ab}	214^{b}	14	0.0200
Gain Week 3	335^{a}	368^{ab}	446^{d}	399^{bc}	416^{cd}	15	0.0001
Gain Avg Total	185^{a}	223^{b}	275^{c}	222^{b}	236^{b}	10	0.0001
Feed Intake WK1(g/d)	180	209	222	196	186	12	NS
FIWK2	302	335	329	306	295	14	NS
FIWK3	498	486	524	527	504	27	NS
FI Avg Total	336	350	365	350	336	12	NS
G:F WK1	0.23^{a}	0.57^{b}	0.69^{b}	0.34^{a}	0.36^{a}	0.05	0.0001
G:F WK2	0.55	0.56	0.71	0.66	0.73	0.05	NS
G:F WK3	0.69^{a}	0.76^{ab}	0.85^{c}	0.76^{ab}	0.83^{bc}	0.03	0.0020
G:F Avg Total	0.545^{a}	0.638^{b}	0.751^{c}	0.636^{b}	0.705^{c}	0.02	0.0001

$^{a\text{-}d}$Means within a row lacking a common superscript differ (P<.05)

*Data is from pen averages and is covaried for initial weaning weight. Average weaning weight was 7.32kg.

CHAPTER 4

CONCLUSIONS

Decreases in ADG for pigs fed PBM in place of SDPP noted during the first phase were negated one week later during the second phase of feeding. These results indicate that PBM can be used in nursery rations in place of blood meal and fishmeal without affecting performance, but may not be equivalent to SDPP in phase I diets. Formulating on a digestible amino acid basis may enable producers to increase dietary PBM to 20% without a significant depression in weight gain. While results support the addition of 20%PBM into the diet without adversely affecting overall performance, it is important to consider maximum inclusion at a lower level avoid the reduction in intake during the first week post weaning.

From a practical standpoint, PBM is an affordable alternative for the more expensive, traditionally used, animal proteins in the diets of weaned piglets. Substituting PBM for fishmeal or bloodmeal is an excellent way to reduce diet cost while not losing performance. PBM would make an economical and safe addition to nursery diets after the first week post weaning.

APPENDIX

Appendix 1. Actual A.A. analysis of experiment 1 and 2 diets.**

AVERAGES:

	Control 1	A1	B1	C1	D1	Control 2	A2	B2	C2	D2	Control 3	D3
AA	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**	**g AA/100g AF**
ASP	1.67	2.09	1.50	1.50	1.53	1.46	1.47	2.74	2.53	2.42	2.27	1.95
THR	0.77	0.93	0.71	0.67	0.73	0.63	0.64	1.01	0.94	0.99	0.86	0.89
SER	0.85	1.10	0.77	0.74	0.77	0.72	0.75	1.15	1.08	1.12	1.11	1.01
GLU	3.16	3.92	2.84	2.89	2.96	2.80	2.82	4.64	4.46	4.17	4.50	3.99
GLY	0.69	0.90	0.71	0.80	1.13	0.69	0.70	1.25	1.33	1.86	0.93	1.71
ALA	0.85	1.28	0.80	0.81	1.00	0.82	0.83	1.33	1.26	1.49	1.13	1.50
VAL	0.86	0.99	0.77	0.74	0.82	0.72	0.70	1.16	1.05	0.93	1.05	1.07
MET	0.44	0.49	0.42	0.45	0.53	0.44	0.44	0.50	0.46	0.54	0.23	0.30
ILE	0.91	0.85	0.83	0.87	0.91	0.81	0.79	0.89	0.84	0.71	0.87	0.81
LEU	1.91	1.68	1.74	1.68	1.82	1.73	1.74	1.95	1.81	1.80	1.82	1.85
TYR	0.89	0.72	0.80	0.76	0.80	0.76	0.76	0.81	0.78	0.77	0.76	0.73
PHE	1.02	1.03	0.92	0.91	0.96	0.92	0.92	1.30	1.20	1.16	1.08	1.02
HIS	0.54	0.49	0.48	0.46	0.48	0.51	0.50	0.68	0.59	0.53	0.57	0.52
LYS	1.59	1.32	1.24	1.08	1.15	1.10	1.09	1.70	1.57	1.58	1.34	1.32
ARG	1.22	1.33	1.11	1.16	1.27	1.14	1.15	1.56	1.51	1.56	1.42	1.42
PRO	0.81	2.16	0.78	0.78	0.92	0.73	0.73	1.21	1.53	1.67	1.41	1.68
CYS	0.11	0.02	0.09	0.08	0.07	0.07	0.08	0.11	0.12	0.13	0.13	0.12

**Analyzed using Beckman 6300, Beckman Coulter, Inc., Palo Alto, CA

A-2. Actual A.A. analysis of diets for Exp. 3.

AVERAGES:

AA	Control g AA/100g AF**	Control as calculated	3% SDPP g AA/100g AF**	3% SDPP as calculated	3% PBM g AA/100g AF**	3% PBM as calculated	6% SDPP g AA/100g AF**	6% SDPP as calculated	6% PBM g AA/100g AF**	6% PBM as calculated
ASP	1.75		2.29		2.08		2.26		2.17	
THR	0.75	0.78	1.01	0.92	0.87	0.85	1.07	1.06	0.97	0.97
SER	0.89		1.16		1.06		1.25		1.05	
GLU	3.42		4.34		3.96		4.20		4.12	
GLY	0.75		0.98		1.00		0.97		1.16	
ALA	0.90		1.14		1.09		1.18		1.17	
VAL	0.74	0.95	1.12	1.10	0.83	1.03	1.12	1.25	1.02	1.10
MET	0.28	0.35	0.35	0.43	0.40	0.49	0.35	0.45	0.46	0.57
ILE	0.62	0.91	0.89	0.99	0.69	0.97	0.84	1.07	0.85	1.03
LEU	1.39	1.57	1.84	1.80	1.60	1.69	1.87	2.03	1.70	1.82
TYR	0.56		0.79		0.66		0.82		0.71	
PHE	0.77	0.87	1.05	1.00	0.92	0.93	1.07	1.13	0.97	1.00
HIS	0.40	0.45	0.55	0.53	0.47	0.49	0.56	0.60	0.50	0.53
LYS	0.98	1.08	1.37	1.28	1.24	1.28	1.36	1.49	1.46	1.49
ARG	0.99	1.07	1.32	1.21	1.21	1.20	1.26	1.35	1.32	1.34
PRO	1.10		1.38		1.29		1.38		1.37	
CYS	0.11	0.30	0.14	0.38	0.12	0.32	0.18	0.46	0.11	0.34
	analyzed*	calculated	analyzed*	calculated	analyzed*	calculated	analyzed*	calculated	analyzed*	calculated
%CP	17.6	17.21	20.1	19.61	19.4	19.39	21.5	21.97	21.7	21.564
%EE	4.36		4.35		4.61		4.55		4.98	
%CF	1.3		1.2		1.2		1.3		1.3	
%calcium	1.26	0.90	1.13	0.9	1.09	0.9	1.1	0.9	1.13	0.9
%Phosphorus	0.83	0.80	0.84	0.8	0.83	0.8	0.8	0.8	0.89	0.8

*Analyzed by University of Georgia Feed and Environmental Water Laboratory

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