ALTERNATIVE PROTEIN SOURCES FOR THE EARLY WEANED PIG

By

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ALTERNATIVE PROTEIN SOURCES FOR

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CHAPTER I

INTRODUCTION

Weaning pigs at eighteen to twenty-one days of age is often economically advantageous to swine producers. This practice will shorten the reproductive cycle of the sow herd and allow placement of females back into productivity sooner with the expectation of rearing more pigs per sow per year and thus maximizing profit.

Subjecting a three week old pig to the distresses associated with weaning commonly results in a reduction of feed intake, little or no weight gain and often diarrhea. It is also common to observe a longer postweaning growth depression and a higher incidence of mortality in early weaned pigs when compared to those weaned at an older age. This reduction in performance has been attributed, at least in part, to the lack of enterocyte maturity of the small intestine resulting in poor utilization of the nutrients present in starter diets.

It has been well documented that young pigs perform much better on diets that contain high levels of milk proteins when compared to soybean protein. However, the use of the more complex diets has been questioned because of their high cost and because pigs are capable of compensatory gain resulting in very little change in days to market weight. Due to the excessive cost of milk proteins, soybean proteins have been supplemented with essential amino acids, digestive enzymes and treated soybean products in an attempt to improve performance and efficiency of utilization by the early weaned pig.

The etiology of lower performance of young pigs fed soybean protein has not been clearly determined but possible explanations include: 1) amino acid availability is lower in soybean protein than in milk protein in the young pig; 2) substance or substances present in soybean protein may be detrimental to the health of the intestinal villi; 3) protease or disaccharidase levels may be insufficient for optimal utilization of non milk protein or energy.

The objective of this study was to compare gain, efficiency of gain and feed intake of early weaned pigs fed an all milk protein based diet using dried skim milk as the primary source of lysine compared to two sources of soybean protein. An isolated soy protein and 50% soybean meal were used to evaluate the effect of complete replacement of the dried skim milk protein. In addition, a partial replacement of the dried skim milk protein with isolated soybean protein was also tested. All pigs were fed a common starter diet after the trial for a three week period to determine the effect of diet fed for a two week period on subsequent performance.

CHAPTER II

REVIEW OF LITERATURE

Numerous experiments have been conducted comparing the performance of the early weaned pig fed milk versus soybean protein based diets. Generally, ADG is reduced and is often accompanied with a decrease in feed intake and efficiency of gain in pigs fed soybean protein based diets when compared to pigs that have received diets containing milk protein sources. Table 1 is a summary of studies comparing various milk proteins with soybean protein as the protein source for early weaned pigs.

These studies indicate that the substitution of soybean protein in the form of isolated soy protein (ISP), soy flour (SF), or soybean meal (SBM) for milk protein in the diet of the early weaned pig generally results in a reduction in performance when compared to milk protein based protein diets. Also, pigs fed SF as the supplemental protein source exhibited lower performance when compared to either SBM or ISP. This phenomenon has been studied extensively in the pre-ruminant calf and is attributed to a gastrointestinal allergy (Kilshaw and Sissons, 1979; Kilshaw, 1981) which results in abnormal movement of digesta through the small intestine and poor

TABLE 2.1.

COMPARING PERFORMANCE OF MILK OR SOYBEAN PROTEIN DIETS FED TO EARLY WEANED PIGS[a]

Reference	Total pigs	Initial Age (d)	Initial Weight (kg)	Trial Length (d)	Type of Diet	Type of Milk Protein	Type of Soybean Protein	Trait	Response Difference from Milk Protein	P[b]
Bayley and Holmes, 1972	16	10	---	21	Dry	DSM	SF	ADG	-.02kg	*
Combs et al., 1963	12	15	3.90	42	Dry	DSM	SBM	ADG	-.17kg	**
								ADFI	-.20kg	**
								F:G	.20kg	
Hays et al., 1959	12	10	3.04	35	Dry	DSM	SBM	ADG	-.19kg	*
								F:G	.76kg	*
Leece et al., 1979	37	14	4.00	16	Liqu.	DSM	SF	ADG	-.13kg	*
								ADFI	-.009kg	
								F:G	1.04kg	
Leibholz, 1981	32	7	---	21	Dry	DSM	ISP	ADG	-.02kg	
								ADFI	.002kg	
								G:F	.008kg	
Maner et al., 1961	25	3	1.5	21	Liqu.	Casein	ISP	ADG	-.04kg	**
								F:G	.52kg	**
Newport, 1980	32	2	---	26	Liqu.	DSM	ISP	ADG	-.02kg	
								F:G	.04kg	

TABLE 2.1. (Continued)

Reference	Total pigs	Initial Age (d)	Initial Weight (kg)	Trial Length (d)	Type of Diet	Type of Milk Protein	Type of Soybean Protein	Trait	Response Difference from Milk Protein	P[b]
Newport and Keal, 1982	32	2	---	26	Liqu.	DSM	ISP	ADG	-.05kg	**
								F:G	.03kg	
Partridge, 1981	36	21	6.17	35	Dry	DSM	SBM	ADG	-.03kg	
								ADFI	-.03kg	
								F:G	.02kg	
Schmidt, 1973	32	3	1.50	21	Dry	DSM	SBM	ADG	-.06kg	*
								G:F	-.30kg	*
Sherry et al., 1978	32	2	1.60	21	Liqu. & Dry	DSM	SBM	ADG	-.03kg	
								G:F	-.02kg	*
Wilson and Leibholz, 1981a	14	7	2.43	21	Dry	DSM	ISP	ADG	-.11kg	**
								F:G	.20kg	**
								ADFI	-.05kg	*
	12	7	2.05	17	Dry	DSM	ISP	ADG	-.16kg	**
								ADFI	-.06kg	**
								F:G	.54kg	**

[a]Abbreviations for feedstuffs. DSM - dried skim milk; ISP - isolated soybean protein;SBM - soybean meal; SF - soy flour WM - whole milk; ADG - average daily gain; F:G - feed per unit of gain; G:F - gain per unit of feed; ADFI - average daily feed intake.

[b]Probability level: * - P<.05; ** - P<.01.

absorption of dietary nitrogen. Pedersen and Sissons (1984) fed diets which contained heated soybean flour to pre-ruminant calves and observed reduced villus height in the jejunum, abnormal digesta movement, and impared nutrient absorption when compared to calves fed casein diets. Likewise, these responses were attributed to an allergic reaction to the soybean protein. Sissons and Smith (1976) observed that pre-ruminant calves fed a diet containing heated soyabean flour appeared to develop a sensitivity to the flour and had significantly higher rates of ileal flow, lower small intestinal transit times and lower net nitrogen absorption values than similarly fed unsensitized calves. They attributed these disturbances in digestive function to be the result of a gastrointestinal allergy.

The effect of soybean flour on digestive processes in the young pig has not been reported but may be similar to those of the pre-ruminant calf based on the fact that pigs fed soybean flour as the supplemental protein source show reduced performance to those fed either soybean meal or isolated soy protein as the dietary protein source.

Comparison of Milk Versus Soybean Protein as the Source of Supplemental Protein

Leece et al. (1979) in trying to determine the optimal age for shifting minimally stressed piglets from a hourly, liquid feeding system to an ad libitum, dry feeding regimen observed a significant advantage in ADG in 14 to 30 d old pigs fed an all milk protein diet when compared to either an all soybean protein diet or one that contained an equal combination of the two. Although rate of gain decreased as the amount of milk protein in the diet decreased, the decrease was only significant from d 14-22. Post treatment performance was similiar when the pigs were fed a common 18% CP starter diet for a 12 d period.

Newport and Keal (1982) reported that in a 26 day trial, pigs weaned at two days of age and fed a liquid diet containing DSM showed a significant increase in ADG ($P<.05$) when compared to pigs fed a diet where there was partial replacement by a soybean isolate. ADFI was not reported for these pigs but there was no difference in F:G ratio over the same twenty-six day period.

Liebholz (1981) in a 21 day trial fed 7 day old pigs pelleted diets that used either DSM or ISP as the major protein source. The weight gains of the pigs given the ISP diets were significantly less (40%) than those of the pigs given the milk protein diets between 7 and 14 days of age. However, between 14 and 28 days of age and over the whole experiment, the differences were only 5-11% . The feed conversion ratio of the pigs given the ISP diets was significantly greater than that of the pigs fed the milk protein diets. ADFI was equivilent over the 21 d period.

Newport (1980) using 42 two day old pigs found performance was not affected at days 2 to 7 or 2 to 28 (P>.05) when half of the DSM was replaced with ISP and dried whey. However, when SBM totally replaced DSM as the primary protein source, very poor growth was observed and severe scouring was associated with the diet. Statistical analysis of this treatment was not included as only four of 21 pigs survived.

Combs et al. (1963) comparing performance data on 12 pigs weaned at an average of 15 days fed either DSM or SBM as supplemental protein sources over a 6 week period observed superior gains and feed intakes in favor of DSM over SBM (P<.01) and F:G ratio was 20% more efficient when DSM was the dietary protein source.

In a three experiment study by Sherry et al. (1978) neonatal pigs were fed isocaloric and isonitrogenous diets from 2 to 23 days of age to determine the dietary value of corn and SBM when used at different replacement levels for DSM. It was apparent that ADG and G:F decreased as the percent of the milk protein in the diet decreased. The performance of pigs fed diets containing milk protein at 25% or less of the dietary protein was severely depressed compared to pigs fed diets containing 45% or more milk protein. Subsequent performance of pigs from 23 to 65 days fed a common starter ration was also depressed in those pigs previously fed the diets which contained milk protein at 25% or less of the dietary protein.

Wilson and Liebholz (1981a) substituted SBM for milk protein to 75% of the dietary protein. This substitution resulted in a decrease of up to 85% in ADG and feed efficiency of pigs 7 to 14 d of age and up to 31% from 21 to 28 d of age. In a similiar study, Zamora and Veum (1979) compared a diet that contained dried skim milk and whey with one in which 50% of the dietary milk protein was replaced with soybean meal in pigs from 2 to 22 days of age. ADG and F:G were similar among treatments with a reported ADG of .14 kg/day for both treatments over the entire 21 day period. No significant (P>.05) differences were observed in F:G ratio or feed consumption although there was a slight advantage for the skim milk diet.

Contrary to all other studies reported here, Decuypere et al. (1981) reported that ADG and F:G over a 28 d period where 40% of the milk protein was replaced with ISP that was either soluable or easily dispersed in water was greater than that of pigs fed the all milk protein diet but differed significantly only during week 4. However, performance of pigs fed the all milk protein diet was better than pigs fed a diet where 40% of the milk protein was replaced by an ISP that was totally insoluable in water. Performance during this trial was exceptionally good for pigs this age with gains exceeding an average of 350 g/d with an average of 1.1 g feed / g gain. The high level of performance was probably due to the high level of milk protein in all of the experimental diets. Likewise, Geurin et al. (1988) observed that when 21 day old pigs were fed an isolated soy protein - whey diet that gains were not significantly different (P>.05) from those fed a dried skim milk protein diet and thus concluded that isolated soy protein can be used with whey to replace dried skim milk in pigs from 3 to 6 weeks of age.

The performance of early weaned pigs fed milk protein based diets has clearly been shown to be superior to that of pigs fed soybean protein based diets. In general, performance also decreases as the level of milk protein in the diet decreases.

Variations in Metabolic Characteristics Due to Protein Source

Researchers have observed variation in a number of parameters which may partially explain the effect that soybean protein has on performance. Differences in apparent nutrient digestability, amino acid availability, gastric pH, rate of passage, and small intestinal morphological responses of the young pig appear to be dependent on dietary ingredients.

Wilson and Liebholz (1981b) noted that total flow of digesta through the stomach was greater when pigs were fed diets containing soy protein (SBM or ISP) when compared to those fed diets containing milk protein in pigs 14 to 35 d of age. However, significantly less digesta, associated with a greater retention time was found in those pigs fed ISP. The flow of DM through the stomach, duodenum and jejunum were not different between the three protein sources, but DM intake was considerably lower for ISP. Greater amounts of DM appeared in the feces of the ISP and SBM than the milk protein diet. Maner et al. (1962) noted that a shorter time was required for an indigestable marker to appear in the feces of 4 week old pigs fed a diet containing ISP than pigs fed casein and attributed the difference to superior absorbability of diet components by pigs fed casein protein as compared to those fed soybean protein.

Protein sources vary in amino acid (AA) content and availability. Walker et al. (1986b) reported that for the early weaned pig, the apparent availability of nitrogen and AA was generally higher when protein was provided from casein than from soybean protein sources. In addition, the apparent availability of N and AA, except for cystine and glycine, increased with increasing age of the young pig.

Wilson and Leibholz (1981c) reported that the apparent and true digestability of N of 28 d old pigs is higher for pigs fed DSM and casein diets when compared to those fed either SBM or ISP. Likewise, Hays et al. (1959) and Wilson and Leibholz (1981c) reported that apparent digestability of both DM and N was reduced in pigs fed SBM diets. Both studies also reported that the apparent digestability of DM and N of the diets containing SBM protein increased with increasing age of the pig but the apparent digestability of the milk diets was not affected by the age of the pig. Mateo and Veum (1980) reported higher apparent digestibilities for DM and CP in 2 week old pigs fed casein diets compared to those fed ISP diets. However, the type of diet fed from 1 to 29 days of age had no effect on performance from 29 to 64 days of age when all pigs were fed the same diet. This is consistant with results reported by Walker et al. (1986a) who reported that DM digestability of a diet that used casein as the protein source was 2.7 and 5.2 percent higher than diets that used ISP and SBM, respectively, for pigs from 21 to 56 days of age.

The effect of protein source on gastric pH was hypothisized to be a cause of different nutrient digestabilities among different diets fed to the early weaned pig. In an unique study, Maner et al. (1962) used pigs 17 to 19 d old equiped with gastric fistulas to determine the pH of the gastric contents. This data indicted that 4 week old pigs fed casein diets had a mean gastric pH of 1.8 before feeding, a pH of 5.6 five minutes after feeding, a pH of 3.2 one hour post feeding and a pH of 1.7 two hours after feeding compared with a pH of 1.6, 5.4, 5.0 and 4.2 for the same time periods respectively when pigs were fed diets with soybean protein. The data was thought to indicate that the acidity of the gastric contents of pigs this age fed soybean proteins may be insufficient for maximal pepsin activity as Hawk et al. (1954) had reported and optimal pH of 2.0 for maximum activity. More recently though, Cornelius and Abin (1985) reported that pepsins have two pH optima, one near pH 2.0 and the other at approximately pH 3.5.

Another aspect of protein digestion in the young pig is the ability to secrete large enough quantities of acids and enzymes. Cranwell (1977) reported the young pig has a limited capicity to secrete pepsin and acid, but the quanity increases with age. Corring et al. (1978) also observed that proteinase activity of the pancreas also increases with age. These statements appear to coincide with Wilson and Leibholz (1981c) and Hays et al. (1959) who reported that nutrient digestibility increases with increased age of the pig when the diets were soybean protein based. However, Maner et al. (1961) using 24 newborn pigs to study the effect of adding pepsin and trypsin to an ISP diet and the affect on protein digestibility found that neither the addition of pepsin nor trypsin had any measurable effect on protein digestibility during the 22 day trial.

Leibholz (1981) reported chymotrypsin and trypsin activity to be similiar in pigs fed either DSM or ISP protein diets but there was a tendency for lower activity of these enzymes in the pigs fed the ISP diets. These results are consistant with the results of Newport (1980) who reported that the amounts of trypsin and chymotrypsin in the digesta from the small intestine were not affected by partial replacement of DSM by soybean protein implying that secretion was not affected by protein source. These reports support earlier work by Cunningham and Brisson (1957) and Alsmeyer et al. (1957) that the addition of proteolytic enzymes to diets containing soybean protein had no measurable effect on growth or protein digestibility and indicate that some other factor or factors besides proteolytic enzymes are responsible for the young pigs inability to utilize soybean protein.

Small Intestine Morphology

A large small intestinal surface area is important to the young, growing animal in order to have maximum digestive and absorptive capabilities. Seve et al. (1986) indicated that nutrients are allocated for digestive organ formation before other tissues in young pigs and McCance (1974) reported that small intestine length in the pig increases rapidly after birth. Similarly, Smith and Jarvis (1978) reported that the small intestine increases 80% in length and 30% in diameter during the first 10 days post natally.

The microvilli size and structure during the immediate post weaning period is also critical to the ability of the young pig to digest and utilize nutrients. Cera et al. (1988) used electron microscopy (EM) to study small intestine morphology in the young pig. They reported that in the 21 day old pig, villus height decreased dramatically and were in close apposition to each other within 3 days of weaning and persisted to day 7 postweaning. After day 7 postweaning, villi height started to increase and lengthened villi were evident by day 14 postweaning. Morphological structure changed from long, finger like projections to longitudinally flattened structures resulting in increased small intestinal surface area.

Miller et al. (1986) used 4 and 6 week old pigs in a comprehensive study of how age and weaning affects intestinal structure and enterocyte ability to digest and absorb nutrients. They observed that villus height was halved 5 days post-weaning but height did not change significantly in their unweaned contemporaries. In addition, crypt depth, which increased normally in the unweaned pig, doubled in pigs weaned at 4 weeks of age. These results vary somewhat from Smith (1984) who reported that villus height in 15 day old pigs was decreased by half during the next 5 to 6 days in both weaned and unweaned pigs. Crypth depth also increased during the period after weaning. Hampson (1986a) reports significant differences in villi height at sites between 50 and 75 percent of the small intestine when hydrolysed casein was compared to control casein tending to support the concept that hypersensitivity to antigenic parts of the diet may stimulate crypt cell production and cause reduced enterocyte maturity after weaning (Miller et al., 1984).

Hampson and Kidder (1986) reported a large and highly significant reduction in lactase activity at sites of 5, 25, 50 and 75% along the small intestine in pigs weaned at 21 days when compared to unweaned pigs of the same age. The reduction was initially thought to be a result of loss of substrate but a decrease in sucrase activity was similiar but not as large and could not be explained in the same manner. Futher investigation showed that the loss of enzyme activity was coincidental with a reduction in villus height and an increase in crypt depth in the small intestine. They attributed the increased reduction of lactase activity when compared to sucrase activity to be a result of the more apical distibution of lactase activity on the villus which makes it more susceptible to losses associated with increased cell proliferation at weaning. Hampson (1986b) reported that in unweaned pigs a gradual increase in crypt depth occured with age while villus height was not altered. In contrast, weaned pigs showed a highly significant increase in crypt depth and and increase in the complexity of villus morphology with a dramatic reduction in villus height.

Reduction of small intestinal surface area at weaning contributes to post-weaning diarrhea due to sudden changes in villus structure resulting in a larger number of immature enterocytes and a temporary reduction in the ability of villi to absorb and digest nutrients.

The rapid changes in small intestinal morphology have been attributed to diet, changes in hormone levels, and increased cell proliferation but none of these studies provide a complete explanation of the effect of diet on performance of early weaned pigs.

CHAPTER III

THE EFFECT OF PROTEIN SOURCE ON PERFORMANCE OF THE EARLY WEANED PIG

Materials and methods

Seventy-two Yorkshire pigs were used to study the effect of dietary protein source on performance of early weaned pigs. Twenty-four pigs in each of three replicates were alloted by sex, litter and weight to one of four dietary treatments after being weaned at approximately 21 days of age providing 18 pigs per treatment. During the first 14 days (period 1) diets consisted of one (table 1) that used dried skim milk (DSM) as the primary lysine source (MP), a diet where isolated soy protein (IS) replaced DSM as the primary lysine source, a diet where DSM and IS provided equal amounts of lysine (MISP), or a diet where 48% SBM served as the primary lysine source. Pigs had ad libitum access to feed and water. Calculated analysis of each diet is presented in table 2. All diets were formulated to contain 1.50% lysine, .90% Ca., and .70% P.

These pigs were individually housed in metabolism crates measuring .47 by .76m in an environmentally controlled room at a temperature of 33 to 27 °C for a period of 35 days.

The isolated soy protein (product PP500E) was provided by Protein Technologies International. The composition of the isolated soy protein is shown in table 3 and a schematic (figure 1) illustrates how the product is obtained. Isolated soybean proteins that contain over 90% protein are the most highly purified of the commercial soybean protein ingredients and are defined by Kolar et al. (1985) as the major proteinaceous fraction of the soybean, prepared from high quality, sound, cleaned, dehulled soybeans by removing a preponderance of the non-protein components. It must not contain less than 90% protein (N * 6.25) on a moisture free basis.

In the subsequent 21 day period (period 2) all pigs were fed a common 18% CP starter diet (table 4) to test for carry over effects from period 1.

During the 5 week trial, individual pig weight was recorded, feed intake was measured, and feed efficiency (G:F) was evaluated. Feed wastage was collected in pans directly under individual feeders, dried, and then standardized to 90% dry matter in order to more accurately measure as-is feed intake.

In replication 1, due to uncontrollable feed wastage, three pigs exhibited feed intake values that were more than three standard deviations away from the mean and therefore eliminated from the feed intake and feed efficiency analysis during the 14d experimental period (period 1). Also, one pig was removed from period 2 (d 14-35) analysis because of feed refusal. In replication 2, two pigs died due to starvation and dehydration, and in replication 3, one pig was removed from the analysis due to prolonged periods of feed refusal. Feeder modifications were made after replication 1 was completed in an attempt to prevent further excess feed wastage so that a more accurate measure of feed intake could be obtained.

Data were analyzed as a split plot design using least-squares analysis of variance. The model for average daily feed intake (ADFI), average daily gain (ADG), feed efficiency (FE) and weight gain included the main effects of replication, treatment, sex, litter within replication and the appropriate interactions.

Pig weight was analyzed with the main effects of treatment, replication, sex, litter within replication, week and the appropriate interactions.

Results and discussion

The effect of dietary protein source on average daily gain (ADG) during the 14d experimental period (period 1) is shown in table 5. Pigs fed the IS and MPIS grew 50.0% faster ($P<.01$) than those fed the SBM diet and 20% faster than those fed the MP diet, respectively. Differences observed in ADG were primarily the result of differences that occured during week 1 of the trial (table 5) when pigs fed the IS and MPIS out performed those fed the SBM and MP diets by .05 and .14 kg/d respectively. ADG was similar (P>.30) among all treatments during the subsequent 3 weeks (table 6) although pigs fed the SBM and MP diets during period 1 continued to show reduced gains when compared to pigs fed the IS and MPIS diets. Although significant differences were observed in ADG during period 1 and gains were similar during period 2, no treatment by week interaction (P>.75) was observed.

The effect of dietary protein source on the efficiency of feed utilization (table 7) was similar to the effect on ADG. Pigs fed the IS and MPIS diets had a higher (P<.10) gain to feed ratio (G:F) during the first week on trial than those fed the SBM diet. Also during week 1, pigs fed the SBM diet exhibited a negative G:F ratio even though feed intake and weight gain were positive. This may be explained as several pigs lost large amounts of body weight, largely due to dehydration, in proportion to the amount of feed consumed causing the average of the G:F ratios to be negative. Perhaps a method which would avoid problems resulting from means of ratios would be to use instead the ratio of the means. The ratio of the means for G:F for days 0 - 7 (from tables

5 and 9) are .86, 1.06, 1.00 and .27 kg gain/kg feed for pigs fed the MP, IS, MPIS and SBM diets, respectively. The effect of dietary protein source on the efficiency of feed utilization was similar among treatments (P>.49) during the entire 14d period even though pigs fed the MPIS gained 36% more per kg of feed than those fed the SBM diet. During week 3, pigs fed the MPIS diet (table 8) exhibited a G:F ratio that was 64, 47 and 27% higher than those fed the IS, MP and SBM diets respectively. However, this difference was significant only for those fed the IS diet. During the combined 3 week period, the magnitude of the differences decreased and the G:F ratios for the MP, MPIS and SBM diets were only 6.3, 9.5 and 11.0% higher than the IS diet.

A treatment by replication interaction was observed (P<.10) for G:F during period 2. The interaction was due to changes in rank of treatments among replications for efficiency of feed utilization.

Several workers have reported higher average daily gains and improved efficiency of feed utilization for pigs fed milk protein diets compared to those fed ISP diets (Maner et al., 1961; Leibholz, 1981; Wilson and Leibholz, 1981a; Walker et al., 1986a) or SBM (Combs et al., 1963; Sherry et al., 1978; Wilson and Leibholz, 1981a).

The .30 kg/d gain reported for pigs fed the IS diet as well as the .93 G:F ratio in this study are similar to the values reported by Decuypere et al. (1981) of .35 kg/d gain and a .93 G:F ratio but well excede the values of .12 kg/d and a G:F ratio of .54 reported by Geurin et al. (1988) when pigs were fed a similar diet. However, gains in this study of .25 kg/d by pigs fed the MP diet is somewhat less than those reported by other workers for this age pig (Combs et al., 1963; Lecce et al., 1979; Partridge, 1981; Walker et al., 1986a) which range from .33 to .42 kg/d. However, their reported G:F ratios were lower (.54 to .67) than the .84 reported here.

The effect of dietary protein source on average daily feed intake (ADFI) is presented in table 9. ADFI during period 1 was larger ($P<.01$) for pigs fed IS and MPIS than for those fed SBM. The largest difference, however, was during week 2. Pigs fed the IS diet ate 15, 27 and 47% more per day than those fed the MPIS, MP and SBM diets, respectively. During the subsequent twenty-one day period (table 10), pigs fed the IS diet ate more ($P<.01$) than those fed the SBM diet and the MP diet ($P<.05$) but was similar to pigs that received the MPIS diet.

Feed intake values reported here for milk protein based diets are less than those reported by other workers which range from .34 to .71 kg/d (Combs et al., 1963; Lecce et al., 1979; Decuypere et al., 1981; Partridge, 1981; Walker et al., 1986) but are similar to the value reported by Geurin et al. (1988) of .24 kg/d for this age pig. ADFI for pigs of a similar age fed IS based diets have ranged from .27 to .38 kg/d with an ADFI of .32 reported here. Reported feed intake levels of .58 and .54 kg/d (Lecce et al., 1979; Partridge, 1981) for pigs fed SBM protein based diets well exceed the .21 kg/d reported in this study. Decreased intake values of both DSM and SBM protein based diets may have been a result of low palatability as numerous pigs on both treatments were observed creating a slurry with available feed.

A significant replication by treatment interaction for feed intake was observed during week 2 (P<.10) and during period 1 (P<.05). Pigs fed the MPIS diet exhibited great variability in the quantity of feed consumed within repititions of the experiment. During replication 1, pigs ate 14, 43, and 69% more feed and in replication 2 consumed 30, 21, and 16% less feed than those fed the IS, MP, and SBM diets did respectively.

Initial pig weights averaged 6.08, 6.14, 6.12, and 6.07 kg for MP, IS, MPIS, and SBM treatments respectively when placed on trial. After week 1, due to superior gains by pigs fed the IS and MPIS diets, dietary protein source affected pig weights (P<.01) and by the end of week 2 (table 11) pigs fed the SBM diet weighed 8.4, 15.2, and 13.4% less than pigs fed the MP, IS, and MPIS diets respectively. Less weight variation between treatments was evident during the 3 week carryover period (table 12) although pigs previously fed the IS diet weighed more at the end of week 3 and 4 ($P<.05$) than those fed the SBM diet. Pigs fed the SBM diet weighed less at the completion of the trial (figure 2) when compared to other dietary treatments although differences were significant ($P<.06$) only for those fed the IS diet. No significant treatment by week interaction ($P>.90$) was observed and differences in weight during the final three weeks were primarily the result of differences observed in weight gain during the initial two week experimental period.

Tight supplies of milk products combined with increasing demand usually cause higher prices for milk proteins and has resulted in a search for sources of protein that can nutritionally replace milk proteins. The results of this study indicate that selected isolated soy protein will produce performance equivalent to that observed with milk protein and may be used to replace milk protein when economic circumstances allow.

TABLE 3.1.

COMPOSITION OF DIETS FED
DURING PERIOD 1 (2 WK)

Ingredient	Diets[a,b] MP	IS	MP-IS	SBM
Soybean meal	--	--	--	24.12
Isolated soy protein[c]	--	20.29	10.15	--
Dried skim milk	40.00	--	23.25	--
Whey, dried whole	40.00	40.00	40.00	40.00
Lactose	--	20.62	8.63	20.62
Cerelose	7.01	4.52	4.55	--
Soybean oil	10.00	10.00	10.00	10.00
Lysine, HCl	.21	--	--	.45
DL Methionine	.085	.115	.08	.17
Cystine	.085	.115	.08	.17
Tryptophan	--	--	--	.03
Threonine	--	--	--	.09
Lecithin	1.00	1.00	1.00	1.00
ASP 250	.25	.25	.25	.25
Calcium carbonate	.12	.70	.42	.49
Dicalcium phosphate	--	1.15	.35	1.37
Vit. TM premix[d]	.94	.94	.94	.94
Salt	.30	.30	.30	.30
	100.00	100.00	100.00	100.00

[a]As fed basis.
[b]MP: milk protein diet;IS: isolated soybean diet;MP-IS: milk protein isolated soybean diet;SBM: soybean meal diet.
[c]Product PP500E,Protein Tech. Int., St. Louis, MO.
[d]Supplies 8,800 IU vitamin A, 880 IU vitamin D, 37 IU vitamin E, 44 mg panothenic acid, 59 mg niacin, 8.8 mg riboflavin, 7.3 mg menadione, .04 mg vitamin B_{12}, 880 mg choline chloride, .2 mg selenium, .06 g manganese, .2 g zinc, .2 g iron, .02 g copper, .4 mg iodine, per kg of feed.

TABLE 3.2.

CALCULATED ANALYSIS OF DIETS FED DURING PERIOD 1 (2 WK)

	Diets[a]			
	MP	IS	MP-IS	SBM
Lysine	1.50	1.50	1.50	1.50
Crude protein	20.09	23.46	22.81	17.91
Calcium	.90	.90	.90	.90
Phosphorus	.71	.70	.70	.71
M.E. (Kcal/kg)	3582.70	3544.42	3576.76	3527.26
Tryptophan	.25	.33	.30	.26
Threonine	.92	1.04	1.02	.90
Met + Cys	.88	.88	.89	.88

[a]As fed basis.

TABLE 3.3.

COMPOSITON OF ISOLATED SOYBEAN PROTEIN

ITEM	%
PROTEIN	91.5
MOISTURE	5.5
FAT(PE.EXTRACT)	0.5
FIBER	.2
ASH	3.8

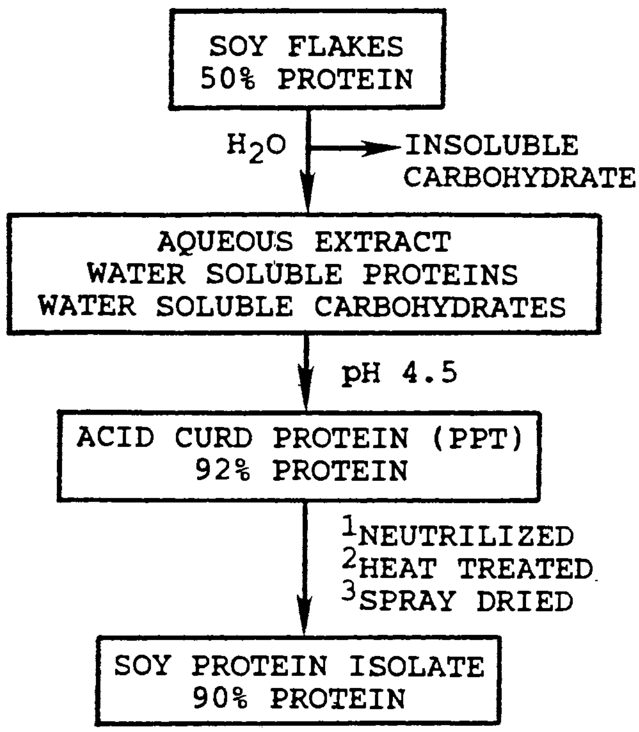

Figure 3.1. Production Process of Isolated Soy Protein

TABLE 3.4.

COMPOSITION OF DIET FED
DURING PERIOD 2 (3 WK)

Ingredient	% of Diet[a]
Yellow corn	67.30
Soybean meal (44%)	28.50
Dicalcium phosphate	1.95
Calcium carbonate	.90
Vit. TM premix	.375
Lysine - HCl	.15
Salt	.40
Copper sulfate	.075
Banmith (pyrantel Tartrate - 48 g/lb)	.1
Mecadox - 10 (Carbadox - 10g/lb)	.25
	100.00

[a]As fed basis.

Calculated Compositon of Diet:

ME, Kcal/kg.	3150.62
Lysine, %	1.10
Crude protein, %	18.48
Threonine, %	.75
Tryptophan, %	.22
Met + Cys, %	.61
Calcium, %	.85
Phosphorus, %	.70

TABLE 3.5.

THE EFFECT OF PROTEIN SOURCE ON ADG IN PERIOD 1 (kg/d.)[a]

Item	Diet MP	IS	MP-IS	SBM	SEM
No. of pigs	14	18	18	18	
d 0 - 7[de]	.12[bc]	.18[b]	.17[b]	.03[c]	.02
d 7 - 14	.39	.43	.41	.36	.03
d 0 - 14[f]	.25[bc]	.30[b]	.29[b]	.20[c]	.02

[a] LS means
[bc] Means in the same row with different superscripts differ (P<.01)
[d] Treatment 1 differs from treatment 3 (P<.10)
[e] Treatment 1 differs from treatments 2 and 4 (P<.05)
[f] Treatment 1 differs from treatments 2 and 4 (P<.10)

TABLE 3.6.

THE EFFECT OF PROTEIN SOURCE ON ADG IN PERIOD 2 (kg/d)[a]

Item	Diet				SEM
	MP	IS	MP-IS	SBM	
No. of pigs	14	18	17	18	
d 14-21	.43	.44	.52	.45	.04
d 14-35	.56	.58	.60	.56	.01

[a]LS means

TABLE 3.7.

THE EFFECT OF PROTEIN SOURCE ON FEED EFFICIENCY DURING PERIOD 1 (G:F)[a]

Item	Diet				SEM
	MP	IS	MP-IS	SBM	
No. of pigs	13	17	17	18	
d 0-7	.40[bc]	1.27[b]	2.60[b]	-9.83[c]	4.93
d 7-14	.60	.99	1.16	.60	.34
d 0-14	.84	.93	1.09	.70	.16

[a] LS means kg gain/kg feed
[bc] Means in the same row with different superscripts differ ($P<.10$)

TABLE 3.8.

THE EFFECT OF PROTEIN SOURCE ON FEED EFFICIENCY DURING PERIOD 2 (G:F)[a]

Item	Diet				SEM
	MP	IS	MP-IS	SBM	
No. of pigs	14	18	17	18	
d 14-21	.68[bc]	.61[c]	1.00[b]	.79[bc]	.10
d 14-35[g]	.67[ef]	.63[e]	.69[ef]	.70[f]	.02

[a] LS means kg gain/kg feed
[bc] Means in the same row with different superscripts differ (P<.05)
[ef] Means in the same row with different superscripts differ (P<.01)
[g] Treatment 2 differs from treatment 3 (P<.05)

TABLE 3.9.

THE EFFECT OF PROTEIN SOURCE ON FEED INTAKE IN PERIOD 1 (kg/d)[a]

Item	Diet				SEM
	MP	IS	MP-IS	SBM	
No. of pigs	13	17	17	18	
d 0-7	.14[bc]	.17[b]	.17[b]	.11[c]	.02
d 7-14[f]	.37[e]	.47[d]	.41[de]	.32[e]	.03
d 0-14[g]	.26[de]	.32[d]	.29[d]	.21[e]	.02

[a] LS means
[bc] Means in the same row with different superscripts differ ($P<.05$)
[de] Means in the same row with different superscripts differ ($P<.01$)
[f] Treatment 3 differs from treatment 4 ($P<.05$)
[g] Treatment 2 differs from treatment 1 ($P<.01$)

TABLE 3.10.

THE EFFECT OF PROTEIN SOURCE ON FEED INTAKE DURING PERIOD 2 (kg/d)[a]

Item	Diet: MP	IS	MP-IS	SBM	SEM
No. of pigs	14	18	17	18	
d 14-21	.61[bc]	.68[b]	.62[bc]	.57[c]	.03
d 14-35[fg]	.84[de]	.91[d]	.87[de]	.80[e]	.02

[a] LS means
[bc] Means in the same row with different superscripts differ ($P<.05$).
[de] Means in the same row with different superscripts differ ($P<.01$).
[f] Treatment 1 differs from treatment 2 ($P<.05$)
[g] Treatment 3 differs from treatment 4 ($P<.05$)

TABLE 3.11.

THE EFFECT OF PROTEIN SOURCE ON PIG WEIGHT IN PERIOD 1 (kg)[a]

Item	Diet				SEM
	MP	IS	MPIS	SBM	
No. of pigs	14	18	18	18	
In Wgt.	6.08	6.14	6.12	6.07	.17
Week 1	6.89[bc]	7.42[b]	7.32[b]	6.31[c]	.22
Week 2	9.65[bc]	10.41[b]	10.20[b]	8.83[c]	.33

[a] LS means
[bc]Means in the same row with different superscripts differ (P<.01).

TABLE 3.12.

THE EFFECT OF PROTEIN SOURCE ON PIG WEIGHT IN PERIOD 2 (kg)[a]

Item	Diet				SEM
	MP	IS	MPIS	SBM	
No. of pigs	14	18	18	18	
Week 3	12.61[bc]	13.46[b]	13.62[b]	12.02[c]	.49
Week 4	16.28[bc]	17.48[b]	16.95[bc]	15.70[c]	.59
Week 5	21.25	22.58	21.96	20.73	.69

[a] LS means
[bc]Means in the same row with different superscripts differ (P<.05).

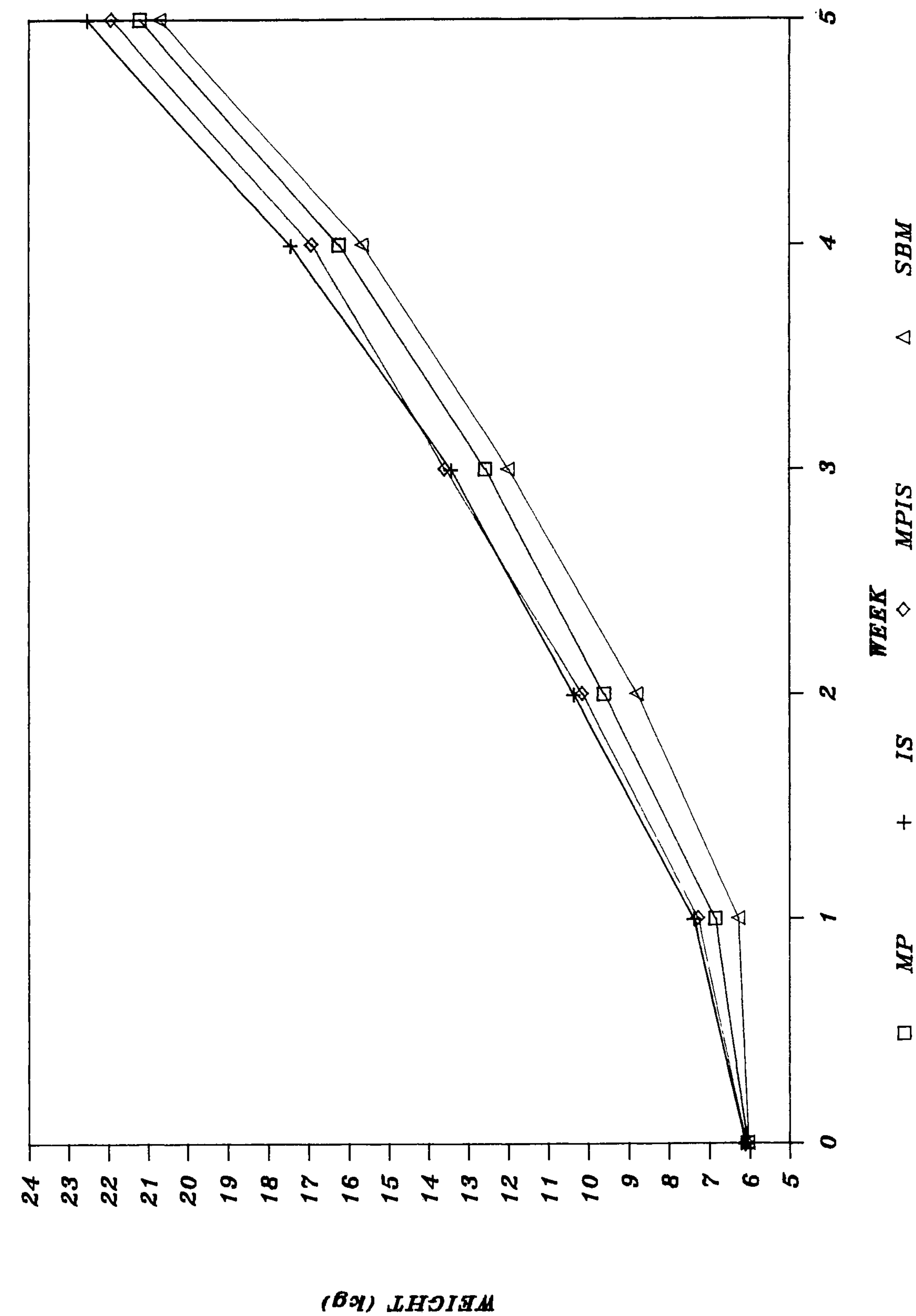

Figure 3.2. LS Means for Pig Weight by Week

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