UTILIZATION OF PROTEINS OF VARIOUS SOURCES BY THE EARLY WEANED PIG

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CHAPTER I

INTRODUCTION

Weaning pigs as early as eighteen to twenty-one days of age has long been recognized as a means to improve sow productivity. This practice allows swine producers to wean more pigs per sow per year, thus maximizing profit by marketing more pigs per sow per year.

Subjecting the three week old pig to the distresses of weaning is commonly followed by a check in growth rate and feed intake. Also, it is 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. At least some of the problems associated with early weaning could arise from the failure of a developing gastrointestinal tract to efficiently adapt to the sudden change in diet.

Numerous studies have demonstrated that growth rate and efficiency of feed utilization of early weaned pigs are superior with milk protein diets when compared to soybean protein diets. Also, milk protein used in the prestarter diet is more effective in minimizing the effects of the postweaning lag which lasts from five to ten days, and is characterized by low feed intake, little or no gain, and frequently diarrhea. However, milk proteins are expensive relative to soybean proteins, and in some instances are not economically feasible. Due to the high cost of milk proteins, and the fact that pigs are capable of compensatory gain resulting in very little change in days to market weight, soybean proteins have been supplemented with essential amino acids, digestive enzymes, and soybean products in an attempt to improve performance and efficiency of utilization by the early weaned pig.

The etiology of the unfavorable response to soybean proteins have not been clearly determined in the early weaned pig, but possible explanations include: 1) amino acid availability is lower in soybean protein than in milk protein in the young pig; 2) soybean proteins may cause changes in the intestinal environment such as pH and flow rate of digesta; 3) a reduction in proteolytic activity probably contributes to the poor digestibility of soybean proteins; 4) soybean proteins may induce morphological changes of the small intestine.

The objective of this study was to compare feed intake, gain, and efficiency of gain of early weaned pigs fed diets in which fifty and one hundred percent of the dried skim milk and whey in a complex starter diet was substituted with isolated soy protein, and to separate the effects on performance of isolated soy protein substitution for milk proteins per se from the lactose effect of milk products. The lactose effect on pigs fed a corn-SBM diet was also investigated. In addition, all pigs were fed a common starter diet for a period of three weeks to determine the effect of diet fed the previous two week period on subsequent performance.

CHAPTER II

REVIEW OF LITERATURE

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

Numerous studies have been conducted directly comparing the performance of the early weaned pig fed diets containing either milk or soybean protein sources. Several of these studies have been summarized by Walker (1984) and Dietz (1988) and are presented in Table 1. These studies indicate a reduction in average daily gain (ADG) associated with the replacement of dietary milk proteins with various sources of soybean protein. The range in reduced gain was from .02 to .18 kg per day with a weighted mean (weighted by the number of pigs in each study) of .07 kg per day for pigs weaned between 2 and 14 days of age. The weighted mean reduction in average daily feed intake (ADFI) resulting from the replacement of milk proteins with soybean proteins was .08 kg and ranged from .002 to .15 kg. In addition, the kg of feed required to produce 1 kg of gain (F:G) was increased by a weighted average of .44 kg and ranged between .03 and 1.04 kg. In some studies the kg of gain produced from 1 kg of feed (G:F) was reported, and was reduced by a weighted

TABLE 2.1.

COMPARISON OF THE PERFORMANCE OF EARLY WEANED PIGS FED EITHER MILK OR SOYBEAN PROTEIN SOURCES.[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[b]	Response Difference from Milk Protein	P[c]
Bayley and Holmes, 1972	16	10	---	21	Liq.	DSM	SF	ADG	-.02kg	*
Coalson et al., 1972	---	21	---	21	Liq.	MS	SF	ADG	-.01kg	
								F:G	.47kg	*
Combs et al., 1963	12	15	2.13	42	Dry	DSM	SBM	ADG	-.17kg	**
								ADFI	-.20	**
								F:G	.43	*
Hays et al., 1959	36	10	3.04	35	Dry	DSM	SBM	ADG	-.18	*
								F:G	.82kg	*
							SBM + Met	ADG	-.09kg	*
								F:G	.27kg	*
Kellogg et al., 1964	24	20	5.10	28	Dry	DSM	SBM	ADG	-.06kg	
								F:G	.24kg	
	18	16	6.30	28	Dry	Casein	ISP	ADG	-.09kg	
								F:G	.48kg	
Leece et al., 1979	37	14	4.00	16	Liq.	DSM	SF	ADG	-.13kg	*
								ADFI	-.15kg	

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[b]	Response Difference from Milk Protein	P[c]
								F:G	1.04kg	
Leibholz, 1981	32	7	---	21	Dry	DSM	ISP	ADG	-.02kg	
								ADFI	-.002kg	
								G:F	.008kg	
Leibholz, 1982	32	7	2.00	21	Dry	Casein	ISP	ADG	-.03kg	*
								ADFI	.03kg	*
								F:G	.32kg	*
							SBM	ADG	-.02kg	
								ADFI	.03kg	*
								F:G	.26kg	*
Maner et al., 1961	25	3	1.51	21	Liq.	Casein	ISP	ADG	-.04kg	**
								F:G	.55kg	**
							ISP + Met	ADG	-.03kg	**
								F:G	.48kg	**
Newport, 1980	32	2	---	26	Liq.	DSM	ISP	ADG	-.02kg	
								F:G	.04kg	
Newport and Keal, 1982	32	2	---	26	Liq.	DSM	ISP	ADG	-.05kg	**
								F:G	.03kg	
Partridge,	36	28	6.17	35	Dry	DSM	SBM	ADG	-.03kg	

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[b]	Response Difference from Milk Protein	P[c]
1981								ADFI	-.03kg	
								F:G	.02kg	
Schmidt et al., 1973	32	3	1.50	21	Dry	DSM	SBM	ADG	-.06kg	*
								G:F	-.30kg	*
Sherry et al., 1978	32	2	1.50	21	Liq. & Dry	DSM	ISP	ADG	-.06kg	*
								G:F	-.26kg	*
Wilson and Leibholz, 1981	14	7	2.43	21	Dry	DSM	ISP	ADG	-.11kg	**
								ADFI	.20kg	**
								F:G	-.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; MS - milk solids.

[b]Trait. ADG - average daily gain; F:G - feed per unit of gain; G:F - gain per unit of feed; ADFI - average daily feed intake.

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

average of .28 kg when milk protein was replaced with soybean protein, and ranged from .26 to .30 kg. For 13 of the 15 studies with pigs weaned between 2 and 14 days of age, ADG, ADFI, F:G, or G:F was significantly reduced when soybean proteins were fed in comparison to milk proteins.

For pigs weaned between 15 and 28 days of age, those fed soybean proteins had a reduction in ADG ranging from .01 to .17 kg with a weighted mean of .07 kg less than pigs fed milk proteins. In addition, there was a decrease in ADFI ranging from .03 to .20 kg with a weighted mean of .07 kg, and the F:G was increased by a weighted average of .26 kg with a range of .02 to .48 kg. Significant differences occurred for ADG, ADFI, or F:G in 2 of the 6 studies in which probabilities were reported for this age pig.

These studies also indicate that replacement of milk protein in the diets of early weaned pigs with either soybean flour (SF), soybean meal (SBM), or isolated soybean protein (ISP) results in a reduction (weighted average) in ADG of .09, .08, and .05 kg, in ADFI of .15, .03, and .03 kg, and an increase in F:G of 1.03, .34, and .29 kg for SF, SBM, and ISP, respectively. In addition, pigs fed diets with SF as the sole supplemental protein source showed a larger reduction in performance than those fed either SBM or ISP. Kilshaw and Sissons (1979) and Kilshaw (1981) observed simular results in the pre-ruminant calf and attributed it to a gastrointestinal allergy which results in abnormal movement of digesta through the small intestine and poor absorption of dietary nitrogen (N). Pedersen and Sissons (1984) fed diets containing heated SF to pre-ruminant calves and observed reduced villus height in the jejunum, abnormal digesta movement, and impaired nutrient absorption when compared to calves fed casein diets, and attributed these responses to an allergic reaction to the soybean protein. Likewise, Sissons and Smith (1976) reported that pre-ruminant calves fed a diet with heated SF appeared to develope a sensitivity to the flour and had significantly higher rates of ileal flow, lower small intestinal transit times, and lower net N 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 SF on digestive functions in the early weaned pig has not been reported, but may be similar to those of the pre-ruminant calf as pigs fed SF as the supplemental protein source showed reduced performance when compared to those fed SBM or ISP as the dietary protein source.

In contrast to the previous studies, Decuypere et al. (1981) reported that ADG and F:G over a 28 day period where 40% of the milk protein was replaced by an ISP that was totally dispersed in water or easily dispersed in water tended to be greater than that of pigs fed an all milk protein diet, but this difference was significant only during week 4. However, ADG and F:G of pigs fed the all milk protein diet was greater than that of pigs fed a diet where 40% of the milk protein was replaced by an ISP that was totally insoluble in water. Allee and Hsu (1981) also reported similar weight gains and feed efficiency with a decreased incidence of scours in young pigs fed a diet where 25% of the milk protein was replaced by modified soybean protein.

More recently, Geurin et al. (1988) found that 3 week old pigs fed an ISP-whey diet had gains that were not significantly different from those fed a dried skim milk (DSM) protein diet, and concluded that ISP can be used with whey to replace DSM in diets for pigs from 3 to 6 weeks of age. Similarly, Dietz et al. (1988) observed that pigs weaned at 21 days of age and fed diets where the primary lysine source was provided by DSM, ISP, or equal amounts of lysine provided by DSM and ISP had higher ADG and G:F than pigs fed a diet where 50% SBM was the primary source of lysine. Performance during a subsequent 3 week period where all pigs were fed a common 18% CP starter diet was not affected by treatment.

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

Variations in Metabolic Characteristics Due to Protein Source

In addition to the pronounced performance differences noted between young pigs fed either milk or soybean protein sources, researchers have also observed variation in a number of metabolic characteristics which may partially explain the effect that soybean protein has on performance. Differences in rate of passage, gastric pH, apparent nutrient digestibility, amino acid availability, proteolytic enzyme secretion, and small intestinal morphological responses of the early weaned pig appear to be dependent on dietary ingredients.

Wilson and Leibholz (1981a) reported that the total flow of digesta through the stomach in pigs 14 to 35 days of age was greater when they were fed diets containing soybean protein (SBM or ISP) when compared to those fed diets containing milk protein. 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 pigs fed ISP. Greater amounts of DM appeared in the feces of the ISP and SBM diets than the milk protein diet. Similar results were noted by Turlington et al. (1989) who found that pigs fed SBM tended to have a faster flow rate in the ileum than pigs fed casein, and that digesta flow rate in the colon was also greater for pigs fed SBM. Maner et al. (1962) found that the rate of passage through the gastrointestinal tract of 4 week old pigs was 14 to 24 hours in pigs fed semipurified soybean protein diets compared to 36 to 48 hours in those fed casein diets, and attributed the difference to superior absorbability of diet components by pigs fed casein protein as compared to those fed soybean protein.

Maner et al. (1962) utilized 17 to 19 day old pigs fitted with gastric fistulas to determine the pH of gastric contents in pigs fed casein or ISP. They reported that 4 week old pigs fed casein 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 after feeding, a pH of 1.7 two hours after feeding, a pH of 1.0 three hours after feeding, and a pH of 1.1 four hours after feeding compared to a pH of 1.6, 5.4, 5.0, 4.2 2.9, and 1.3 for the same time periods, respectively, when pigs were fed a diet containing ISP. These data were thought to indicate that the acidity of the gastric contents of pigs this age fed ISP may often be insufficient for maximal pepsin activity as Hawk et al. (1954) had reported an optimal pH of 2.0 for maximum pepsin activity. However, more recently Cornelius and Abin (1985) reported that pepsins have two optimal pH, one near pH 2.0 and the other near pH 3.5. Smith and Jones (1963) and Hamilton and Roe (1977) reported that pH values along the intestine of young pigs did not differ with the source of dietery protein, and that the pH values showed a gradual increase from the duodenum to the ileum.

Protein sources vary in amino acid (AA) content and availability measured either at the ileum or in fecal samples of growing-finishing pigs (Holmes et al., 1974; Taverner and Farrell, 1981; Jorgensen et al., 1984). The effect of protein source on AA availability in the early weaned pig may explain some of the variability observed in performance, but studies of AA availability in early weaned pigs have not been reported.

Walker et al. (1986a) suggested that for the early weaned pig, the apparent availability of N and AA was generally higher when the protein was provided from casein than from soybean protein sources. Also, the apparent availability of N and AA, except for cystine and glycine, increased with increasing age of the young pig. Similarly, Wilson and Leibholz (1981c) observed that the apparent digestibility of AA of pigs weaned at 7 days of age was highest in those fed the milk protein diet, intermediate in those fed the ISP diet, and lowest in those fed the SBM diet. The apparent digestion of AA to the ileum of pigs given ISP increased with increasing age of the pigs. This is consistent with the results reported by Hays et al. (1959) and Wilson and Leibholz (1981b) who found that the apparent digestibility of both DM and N was reduced in pigs fed SBM diets, and that the apparent digestibility of DM and CP of the diets containing SBM increased with increasing age of the pig. However, these authors reported that the utilization of milk proteins did not change with increasing age of the pig.

Mateo and Veum (1980) reported higher apparent digestibilities for DM and CP in pigs fed casein from 1 to 29 days of age when compared to those fed ISP diets. However, the type of diet had no effect on performance from 29 to 64 days of age when all pigs were fed the same diet. This is consistent with the results reported by Walker et al. (1986a) who noted that DM digestibility of a diet which contained casein as the protein source was 2.7 and 5.2% higher than diets that used ISP and SBM, respectively, for pigs from 21 to 56 days of age.

The ability of the young pig to secrete large enough quantities of acids and enzymes is another important aspect of protein digestion. Lewis et al. (1957) attributed the poor utilization of soybean protein to a proteolytic enzyme deficiency and insufficiently developed enzyme system in the young pig. Efird et al. (1982) studied the digestive capacity development in pigs from 1 to 22 days of age. They found that protetolytic enzyme activity in the stomach decreased from 1 to 22 days of age at which time an increase in activity occurred. Similar results were found by Cranwell (1977) who reported that the young pig has a limited capacity to secrete pepsin and acid, but the quantity increases with age, and Corring et al. (1978) who observed that proteinase activity of the pancreas also increases with age. However, Maner et al. (1961) found that neither the addition of pepsin nor trypsin to an ISP diet had any measurable effect on protein digestibility during the 22 day trial utilizing 24 newborn pigs.

Newport (1980) reported that the amounts of trypsin and chymotrypsin in the digesta from the small intestine were not affected by the partial replacement of DSM by soybean protein. Similarly, Leibholz (1981) found chymotrypsin and trypsin activity to be similar in pigs fed either DSM or ISP diets, however, there was a tendency for lower activity of chymotrypsin and trypsin in pigs fed the ISP diet. These reports further support the earlier work by Alsmeyer et al. (1957) and Cunningham and Brisson (1957) who reported that the addition of proteolytic enzymes to diets containing soybean protein had no measurable effect on growth or protein digestibility.

Small Intestinal Morphology

A large small intestinal surface area is important to the young, growing animal in order to maximize digestive and absorptive capabilities. Therefore, alterations which occur in the small intestine after early weaning may be related to subsequent poor performance.

The basic functional unit of the intestine is the crypt-villus unit. Cera et al. (1988), using electron microscopy to study small intestine morphology in the young pig, 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.

Hampson (1986) reported that weaned pigs showed a highly significant increase in crypt depth and an increase in the complexity of villus morphology with a dramatic reduction in villus height when compared to unweaned pigs. Miller et al. (1986) used 4 and 6 week old pigs to study the effects of age and weaning on intestinal structure and enterocyte ability to digest and absorb nutrients. They observed that villus height was halved 5 days postweaning, but height did not significantly change in their unweaned contemporaries. Also, crypt depth, which increased normally in the unweaned pig, doubled in pigs weaned at 4 weeks of age. These reports are somewhat contradicted by 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, but crypt depth also increased during the postweaning period.

Dietary constituents are also important in modifying the developement pattern of intestinal and pancreatic enzymes. Weaning is associated with a change from a relatively high fat, low carbohydrate diet of milk, to the relatively low fat, high carbohydrate diet of solid foods. Hampson and Kidder (1986) reported a large and highly significant reduction in lactase and sucrase activity along the small intestine in pigs weaned at 21 days of age when compared to unweaned pigs of the same age. Further 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.

Seegraber and Morrill (1986) reported that villi were long, tapering, and uniform in calves fed milk; however, gradual deterioration in villus integrity was seen in calves fed soybean proteins. Also, Li et al. (1989) found that pigs weaned at 21 days of age and fed SBM had shorter villus height and greater crypt depth than pigs fed either DSM, soy protein concentrate, extruded soy protein concentrate, or soy protein isolate. They also reported that pigs fed SBM had less villus area than pigs fed either DSM or the other soybean products tested.

The reduction in small intestinal surface area and the appearance of a less mature enterocyte population help to explain the increased susceptibility of the pig to diarrhea and growth checks in the postweaning period.

The rapid changes in the small intestine of the early weaned pig have been attributed to age, protein source, changes in hormone levels, and increased cell proliferation. However, none of these studies provide a complete explanation of the effect that diet has on the performance of the early weaned pig.

Lactose Utilization

The digestive enzymes of the young pig change dramatically the first few weeks of life. Lactase, the enzyme that breaks down lactose, the carbohydrate present in milk, is high at birth and decreases with age. The enzymes amylase, sucrase, and maltase, necessary to break down the carbohydrate in cereal grains, are low at birth and increase with age. Numerous studies have demonstrated that milk protein is more efficiently utilized by young pigs than protein from SBM until the pig is about 5 weeks of age.

After weaning, carbohydrates usually comprise approximately 70% of the diet. Cunningham (1959) and Sewell and Maxwell (1966) reported that the ability of the young pig to utilize carbohydrates depends on the form and source. Sewell and West (1965) found that pigs receiving diets containing additions of lactose gained weight at a significantly faster rate than pigs consuming diets containing ISP without lactose. Also, pigs fed diets containing ISP plus lactose required less feed per pound of gain than pigs receiving a diet containing soybean protein without lactose. Giesting et al. (1985) reported that pigs consuming lactose supplemented diets had significantly greater daily gains and feed intakes than pigs fed cornstarch or hydrolyzed cornstarch supplemented diets.

Similar results were noted by Dietz et al. (1988) who found that pigs fed diets containing ISP plus lactose had a higher performance when compared to those fed diets containing DSM. In contrast, no difference in pig performance due to carbohydrate source was reported when pigs between 1 and 29 days of age were fed diets containing either lactose or wheat starch (Wilson and Leibholz, 1979) or diets containing either lactose or glucose (Mateo and Veum, 1980).

The improvements in performance of early weaned pigs fed diets containing milk products are apparently due to the ability of the young pig to utilize the carbohydrate and protein fractions of milk more effectively than the carbohydrate and protein components of plant feed ingredients. Turlington et al. (1989) conducted a study to compare combinations of protein and carbohydrate sources from milk and plant origin and determine their effects on nutrient digestibilities of early weaned pigs. These authors noted that energy and nutrient digestibilities for weaned pigs were greater when diets contained casein or lactose rather than SBM or dextrose. Similarly, Sewell and West (1965) reported significant increases in apparent protein digestibility were obtained for diets containing lactose when compared with the basal diet containing soybean protein without lactose. Digestibility of the ether extract fraction of the diets was likewise improved by supplementation with lactose.

Wilson and Leibholz (1981b), Leibholz (1982), and Woodard and Carroll (1985) reported that nutrient digestibilities were lower when diets contained SBM, indicating that milk protein plays a major role in improving nutrient digestibilities; this is similar to the results noted by Turlington et al. (1989). Although the carbohydrate sources had little effect on digestibility, the carbohydrate fraction of the diet may account for some of the effects observed among the digestibility coefficients. The SBM treatments had a greater portion of their carbohydrates coming from SBM, particularly structural carbohydrates (NDF). These nondigestible carbohydrates may play a role in limiting the protein availability from SBM (Jones et al., 1977; Walker et al., 1986).

Different rates of passage may explain different nutrient digestibilities caused by feed ingredients. Several studies have shown that soybean proteins cause faster digesta flow than milk protein (Maner et al., 1962; Wilson and Leibholz, 1981a). Buraczewski et al. (1971) reported that lactose is more effective in delaying stomach emptying than corn dextrin. These observations are supported by the data reported by Turlington et al. (1989) which suggests that milk protein and milk carbohydrates reduce digesta flow rate.

These data reported support a 5 to 10% improvement in digestibility for the early weaned pig when milk products are fed. Also, milk carbohydrates appear to have less effect on improving nutrient digestibility than milk protein for pigs weaned at an early age.

CHAPTER III

THE EFFECT OF ISOLATED SOY PROTEIN SUBSTITUTION FOR MILK PROTEINS WITH AND WITHOUT MAINTAINING CONSTANT LACTOSE ON PERFORMANCE OF EARLY WEANED PIGS

Introduction

Subjecting the 3 wk old pig to the distresses of weaning is commonly followed by a check in growth rate and feed intake. Also, it is 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.

Numerous studies have demonstrated that growth rate and efficiency of feed utilization of early weaned pigs are superior with milk protein diets when compared to soybean protein diets (Hays et al., 1959; Coalson et al., 1972; Sherry et al., 1978; Wilson and Leibholz, 1981; Leibholz, 1982). However, milk proteins are expensive relative to soybean proteins, and in some instances are not economically feasible. Due to the high cost of milk proteins, and the fact that pigs are capable of compensatory gain resulting in very little change in days to market weight, soybean proteins have been supplemented with essential amino acids, digestive enzymes, and soybean products in an attempt to improve performance and efficiency of utilization by the early weaned pig.

The etiology of the unfavorable response to soybean proteins have not been clearly determined in the early weaned pig, but possible explanations include: 1) amino acid availability is lower in soybean protein than in milk protein in the young pig; 2) soybean proteins may cause changes in the intestinal environment such as pH and flow rate of digesta; 3) a reduction in proteolytic activity probably contributes to the poor digestibility of soybean proteins; 4) soybean proteins may induce morphological changes of the small intestine.

Recently, two studies (Dietz et al., 1988; Geurin et al., 1988) indicate that sources of refined soybean protein will support a suitable replacement for milk protein in the diets of early weaned pigs. Also, several workers have reported that pigs fed ISP diets with added lactose had improved gain and efficiency of gain when compared to those receiving ISP diets without added lactose (Sewell and West, 1965; Giesting et al., 1985; Dietz et al., 1988).

The objective of this study was to evaluate the effect on performance of 50 and 100% replacement of dried skim milk and whey with isolated soy protein, with and without lactose maintained at a constant level. The lactose effect on pigs fed a corn-SBM diet was also investigated. All pigs were fed an 18% CP starter diet for an additional 3 wk period to determine the effect of diet fed for the 2 wk experimental period on subsequent performance.

Materials and Methods

Two hundred fifty-two Yorkshire, Hampshire, and Yorkshire x Hampshire crossbred pigs were used to study the effect on performance of replacing 50 and 100% of the dried skim milk (DSM) and whey in a complex starter diet with isolated soy protein (ISP), and to seperate the effects on performance of ISP substitution for milk proteins per se from the lactose effect of milk products.

Eighty-four pigs in each of three replicates were randomly allotted by sex, litter, and weight to one of 14 pens with 6 pigs per pen in each replicate after being weaned at 21 to 28 d of age. Pens within each replicate were randomly allotted to 1 of 7 treatments for a total of 6 pens per treatment in the experiment.

Diets fed during the first 14 d (Period 1) were formulated to contain 1.30% lysine, .90% Ca, and .70% P. Composition of the diets are presented in Table 3.1 and are as follows: 1) Control diet containing 10% DSM and 20% of an edible grade of dried whey with limited use of 50 percent soybean meal (SBM); 2) and 3) 50 and 100% substitution of DSM and whey on an equal weight basis with ISP (Nurish 2000) with lactose maintained at the level present in the control diet; 4) and 5) 50 and 100% substitution of DSM and whey with ISP (Nurish 3000 replaced protein from Nurish 2000 on an equal crude protein basis) with no correction for differences in lactose; 6) Corn-SBM based diet with lactose maintained at the level present in the control diet; 7) Corn-SBM diet of treatment 4 without lactose. Pigs had ad libitum access to feed and water. Calculated analysis of each diet is presented in Table 3.2.

The pigs were housed in an environmentally controlled nursery in pens measuring 1.17 by 1.52 m with 6 pigs per pen. A temperature of 32°C was maintained during the first wk and was decreased 1°C per wk for the remainder of the trial.

The ISP (Nurish 2000 and Nurish 3000) were provided by Protein Technologies International. The composition of the ISP is shown in Table 3.3 and Table 3.4. Figure 3.1 illustrates how the products are obtained. Nurish 3000 is a protein source designed to be used in the production of high fat powder as a replacement for casein or caseinates for animal feeds. At over 90% protein, it is one of the most highly purified of the commercial soybean protein ingredients which 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 that shall contain not less than 90% protein (N * 6.25) on a moisture free basis. Nurish 2000 is an optimal combination of highly digestible proteins and milk based carbohydrates containing the same ISP as Nurish 3000, DSM, sweet dried whey, and added minerals, vitamins, and amino acids. Containing 35% protein, Nurish 2000 is similar to DSM in nutrient composition, digestibility, feeding performance, and it offers an economic alternative to DSM.

In the subsequent 21 d period (Period 2) all pigs were fed an 18% CP corn-SBM starter diet (Table 3.5) to determine the effect of diet during period 1 on subsequent performance. Both feed and water were available on an ad libitum basis.

During the 35 d trial, individual pig wts and pen feed intake was measured weekly, and pen feed efficiency (G:F) was evaluated.

Data were analyzed by least squares analysis of variance using the General Linear Models procedure of the Statistical Analysis System (SAS, 1984). Orthogonal polynomial contrasts were used to test for linear and quadratic changes in average daily gain (ADG) and feed efficiency (G:F) in response to increasing levels of ISP substitution for milk protein, with and without lactose. Bonferroni's t-test was used to make nonorthogonal comparisons to test for changes in ADG and G:F using the corn-SBM diets, with and without lactose. The model for ADG, G:F, average daily feed intake (ADFI), the polynomial contrasts, and the nonorthogonal comparisons included the main effects of replication, treatment, sex, and the treatment by replication interaction. All other interactions had probability levels greater than .20 and were removed from the model.

In replicate 1, one pig died during wk 2 of the experiment for an unknown reason. Similarly, one pig died in replicate 2 during wk 5 of the experiment. Data collected on these two pigs up to the time of death was included in the statistical analysis.

Results and Discussion

Average daily gain data for wk 1, wk 2, and period 1 will be presented within replicate since a treatment by replicate interaction ($P<.01$) was observed. During wk 1 of the experiment (Table 3.6) the overall treatment effect was not significant, but a significant replicate effect ($P<.001$) was observed. Average daily gain of pigs fed increasing levels of 0, 50, and 100% of ISP (Nurish 2000) at the expense of DSM and whey where lactose was maintained constant (Treatments 1, 2, and 3) tended to increase with 50% substitution (Treatment 2) followed by a decline in gain with 100% substitution (Treatment 3) in two of the three replicates (Replicates 1 and 3), but the quadratic response was only significant ($P<.05$) in replicate 3. Average daily gain in pigs fed increasing levels of 0, 50, and 100% substitution of ISP (Nurish 3000) without lactose (Treatments 1, 4, and 5) was similar in two of the three replicates (Replicates 1 and 3), whereas, a linear decrease (P<.01) in ADG in response to increasing level of ISP substitution was observed in replicate 2. This study suggests that ADG in wk 1 was improved in pigs fed diets where ISP replaced 50% of the DSM and whey with constant lactose, and that gain was maintained when ISP replaced 50% of the milk protein in diets formulated to contain no lactose.

A lactose effect was also indicated during wk 1 in pigs fed the standard corn-SBM diets (Table 3.7). The addition of lactose to a corn-SBM diet (Treatment 6) resulted in ADG comparable to that observed in pigs fed the control diet (Treatment 1) in two of the three replicates (Replicates 1 and 3), whereas gain was reduced in pigs fed a corn-SBM diet without lactose (Treatment 7) in two of the three replicates (Replicates 1 and 2). However, significant differences were only observed in replicate 2 where gains in pigs fed both the corn-SBM diet with lactose (Treatment 6) and the corn-SBM diet without lactose (Treatment 7) were lower (P<.05) than the gains observed in pigs fed the control diet (Treatment 1).

During wk 2 of the experiment (Table 3.8) a significant replicate effect was observed (P<.001) but the overall treatment effect was not significant. Gains were similar in pigs fed increasing levels of ISP (Nurish 2000) at the expense of milk proteins with constant lactose (Treatments 2 and 3) when compared to the control diet (Treatment 1). In pigs fed diets where DSM and whey was replaced with increasing levels of ISP (Nurish 3000) without the addition of lactose (Treatments 1, 4, and 5), ADG increased at the 50% substitution level (Treatment 4) followed by a decrease in gain with 100% substitution (Treatment 5) in two of three replicates (Replicates 1 and 2). However, in replicate 3 a significant quadratic response ($P<.04$) was observed in which gain was reduced at both levels of ISP substitution. Gain during wk 2 was similar in pigs fed the control diet, and the corn-SBM diets with and without lactose (Treatments 1, 6, and 7; Table 3.9).

Average daily gain data for the 14 d experimental period (Period 1) is shown in Table 3.10. The overall treatment effect was not significant, but a replicate effect ($P<.001$) was observed. In pigs fed increasing levels of ISP (Nurish 2000) at the expense of DSM and whey with constant lactose (Treatments 1, 2, and 3), gain was enhanced at the 100% substitution level (Treatment 3) in two of the three replicates, but neither the linear nor the quadratic contrasts for the experimental period were significant. Gains in pigs fed increasing levels of 0, 50, and 100% substitution of ISP (Nurish 3000) without lactose (Treatments 1, 4, and 5) appears to increase at the 50% substitution level (Treatment 4) followed by a decline in gain at the 100% substitution level (Treatment 5) in two of the three replicates (Replicates 1 and 2), but the quadratic response was only significant ($P<.05$) in replicate 2. The addition of lactose to a corn-SBM diet (Treatment 6; Table 3.11) resulted in gains comparable to that observed in the control diet (Treatment 1) in two of the three replicates (Replicates 1 and 3), whereas, ADG in the corn-SBM diet without lactose (Treatment 7) tended to be reduced in two of the three replicates (Replicates 2 and 3). However, no significant differences were observed.

Average daily gain during the subsequent 3 wk period (Period 2; Table 3.12) was not affected by previous treatment, although a significant replicate effect ($P<.001$) was observed.

Feed efficiency (G:F) during wk 1 (Table 3.13) followed a pattern similar to that observed for gain. Data are presented as treatment means since the treatment by replicate interaction was not significant ($P>.09$). The substitution of 0, 50, and 100% of protein from DSM and whey with ISP (Nurish 2000) with constant lactose (Treatments 1, 2, and 3) resulted in a slight improvement in G:F at the 50% substitution level (Treatment 2) followed by a decline at the 100% substitution level (Treatment 3). Both, the linear and quadratic contrasts approached significance ($P<.06$ and $P<.10$, respectively). The substitution of 0, 50, and 100% of milk protein with ISP (Nurish 3000) without lactose addition (Treatments 1, 4, and 5) resulted in a linear decrease ($P<.04$) in G:F with increasing level of ISP. This study suggests that, as was observed for gain in wk 1, G:F was improved by 50% substitution of milk protein with ISP when lactose was maintained constant while G:F tended to decrease in pigs fed a diet where 100% of the DSM and whey was replaced with ISP when lactose was maintained constant. Also, G:F was reduced in pigs fed diets where 50% and 100% of the milk proteins were replaced with ISP without lactose addition.

A lactose effect on G:F was also evident in pigs fed the corn-SBM diets during wk 1 (Table 3.14). The efficiency of feed utilization tended to be reduced in the corn-SBM diets with and without lactose (Treatments 6 and 7), with the greatest reduction in the corn-SBM diet without lactose (Treatment 7). However, no significant differences were observed.

During wk 2 of the experiment (Table 3.15), the overall effect of treatment on efficiency of feed utilization was not significant (P>.35). Data are presented within replicate since a treatment by replicate interaction (P<.03) was observed. In pigs fed increasing levels of ISP (Nurish 2000) at the expense of milk protein with constant lactose (Treatments 1, 2, and 3), G:F tended to increase linearly with increasing levels of ISP, however, this was significant (P<.02) only in replicate 2. The substitution of increasing levels of ISP (Nurish 3000) for DSM and whey without lactose (Treatments 1, 4, and 5) resulted in an increase in G:F at the 100% level of substitution in two of the three replicates (Replicates 1 and 2). However, in replicate 3 a significant quadratic response (P<.02) was observed in which

G:F was reduced at the 50% level of ISP substitution (Treatment 4) followed by an increase at the 100% substitution level (Treatment 5). The effect of lactose in the corn-SBM diets (Treatments 1, 6, and 7; Table 3.16) was not as evident during wk 2. Efficiency of feed utilization was enhanced in two of the three replicates (Replicates 1 and 2) in pigs fed the corn-SBM diets either with or without lactose (Treatments 6 and 7), whereas, in replicate 3 G:F was reduced in pigs receiving corn-SBM diets either with or without lactose when compared to those fed the control diet (Treatment 1).

The overall treatment effect on G:F was not significant, but a replicate effect (P<.001) was observed. For the 14 d experimental period (Period 1; Table 3.17) data are presented within replicate as a treatment by replicate interaction was observed (P<.01). In pigs fed increasing levels of 0, 50, and 100% substitution of ISP (Nurish 2000) for milk proteins with constant lactose (Treatments 1, 2, and 3), there was a quadratic tendency in two of the three replicates (Replicates 1 and 3) with increased G:F at the 50% substitution level (Treatment 2) followed by a decline at the 100% level of substitution (Treatment 3). However, in replicate 2 there appeared to be a linear increase in response to increasing levels of ISP substituion with lactose. Nonetheless, it should be noted that neither the linear nor the quadratic components were significant. The response on G:F of pigs fed increasing levels of ISP (Nurish

3000) without lactose (Treatments 1, 4, and 5) substituted for milk proteins appeared to be quadratic in replicates 1 and 2 with G:F enhanced at the 50% substitution level (Treatment 4) and then reduced at the 100% substitution level (Treatment 5). In replicate 3, G:F was reduced at both the 50% and 100% level of ISP substitution without lactose. Feed efficiency in period 1 was similar in pigs fed the control diet and the corn-SBM diets with and without lactose (Treatments 1, 6, and 7; Table 3.18).

Efficiency of feed utilization during the subsequent 3 wk period (Period 2) was similar among pigs regardless of the previous experimental diet. Data for period 2 (Table 3.19) are presented within replicate since a significant treatment by replicate interaction was observed ($P<.02$).

Average daily feed intake during wk 1, wk 2, period 1, period 2, or the total 5 wk trial was not significantly affected by dietary treatment (Table 3.20). Treatment means across the three replicates are presented since no treatment by replicate interaction was observed.

The results of this study for ADG and G:F for the 14 d experimental period (Period 1) were presented within replicate since a significant treatment by replicate interaction ($P<.01$) was observed. However, treatment means for period 1 will be used to compare to other literature in the following discussion.

Several workers have reported higher ADG 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, 1981; Walker et al., 1986) or SBM (Combs et al., 1963; Sherry et al., 1978; Wilson and Leibholz, 1981).

The 183.2 g/d gain reported for pigs fed the diet in which 50% of the DSM and whey was replaced with ISP without lactose, as well as the .58 G:F ratio in this study, are lower than values reported by Decuypere et al. (1981) of 354 g/d gain and a .93 G:F ratio, and by Dietz et al. (1988) of 310 g/d and a 1.00 G:F ratio in pigs fed similar diets. The ADG of 157 g/d and the .52 G:F ratio reported in this study for 100% substitution of milk proteins by ISP without lactose were similar to those reported by Geurin et al. (1988) of 122 g/d gain and a .54 G:F ratio, but were lower than those reported by Dietz et al. (1988) of 330 g/d gain and a .84 G:F ratio.

The 181.3 g/d gain reported in this study for pigs consuming ISP diets with lactose was greater than the ADG reported by Mateo and Veum (1980) of 109.8 g/d, but was lower than the gain reported by Sewell and West (1965) of 294.8 g/d. The .59 G:F ratio for pigs fed the ISP diet with lactose in this study was similar to the .54 G:F ratio noted by Mateo and Veum (1980), and was higher than the .44 G:F observed by Sewell and West (1965). The ADG and G:F observed in this study for 50% substitution of DSM and whey by ISP with lactose were similar to those observed for 100%

substitution of ISP with lactose at the expense of milk proteins.

The 170.1 g/d gain noted in this study for the corn-SBM diet with lactose was lower than the gain for a similar diet reported by Dietz et al. (1988) of 260 g/d, but the .60 G:F ratio reported here was higher than the .48 G:F noted by Dietz et al. (1988). The ADG observed here for the corn-SBM diet without lactose of 151.2 g/d was lower than the gains reported by Combs et al. (1963) and Wilson and Leibholz (1981) of 249.5 and 178.2 g/d, respectively. However, the .51 G:F ratio reported here was higher than the .44 G:F observed by Combs et al. (1963).

The gains in this study for the milk protein diet of 177.3 g/d is somewhat less than those reported by other workers for this age pig (Combs et al., 1963; Leece et al., 1979; Partridge, 1981; Walker et al., 1986) which range from 330 to 420 g/d. However, their reported G:F ratios were similar (.54 to .67) to the .57 reported here.

Feed intake values reported here for the milk protein based diet was less than those reported by other workers which range from 340 to 710 g/d (Combs et al., 1963; Leece et al., 1979; Decuypere et al., 1981; Partridge, 1981; Walker et al., 1986), but are higher than those observed by Geurin et al. (1988) and Dietz et al. (1988) of 240 and 260 g/d, respectively, for this age pig. Reported ADFI levels of 580 and 540 g/d (Leece et al., 1979; Partridge, 1981) for pigs fed SBM protein based diets well exceed the 298.4 g/d reported in this study. ADFI for pigs of a similar age fed ISP based diets have ranged from 270 to 380 g/d with an ADFI of 297.5, 308.2, 315.2, and 309.6 g/d reported here for the 50% ISP diet with lactose, 100% ISP diet with lactose, 50% ISP diet without lactose, and 100% ISP diet without lactose, respectively.

This study suggests that performance in early weaned pigs was enhanced by maintaining constant lactose in the diet as ISP replaced milk protein. This effect was most evident in wk 1 of the experiment. There also appeared to be more variability in response to substitution of milk proteins for soy protein without lactose. This lactose effect is consistent with the observations of Sewell and West (1965) who reported that pigs receiving diets containing additions of lactose had higher weight gains and improved feed efficiency when compared to pigs consuming diets containing ISP without lactose. Giesting et al. (1985) noted that pigs consuming lactose supplemented diets had significantly greater daily gain and feed intake when compared to pigs fed cornstarch or hydrolyzed cornstarch supplemented diets. Similar results were reported by Dietz et al. (1988) who found that pigs fed diets containing ISP plus lactose had a higher performance than those fed diets containing DSM. In contrast, no difference in pig performance due to carbohydrate source was observed when pigs between 1 and 29 days of age were fed diets containing either lactose or wheat starch (Wilson and Leibholz, 1979) or diets containing either lactose or glucose (Mateo and Veum, 1980).

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 replace milk proteins without sacrificing performance. The results of this study indicate that the lactose component of milk products may explain part of the response to milk protein observed in early weaned pigs, and that partial or total replacement of milk proteins with ISP with lactose addition will produce performance equivalent to that observed with milk protein, and may be used to replace milk proteins when economic circumstances allow.

TABLE 3.1.

COMPOSITION OF DIETS FED DURING PERIOD 1 (2 WK).

	Treatment[a]						
Ingredient	1	2	3	4	5	6	7
Corn, U.S. No. 2	44.825	49.075	53.225	70.445	70.645	38.845	61.515
Soybean Meal, 50%	13.80	7.00	0.30	7.00	3.60	27.90	26.00
Casein	----	----	----	1.48	----	----	----
Nurish 2000[b]	----	15.00	30.00	----	----	----	----
Nurish 3000[b]	----	----	----	6.64	13.28	----	----
Dried Skim Milk	10.00	5.00	----	----	----	----	----
Whey Protein Isol.	----	----	----	1.89	----	----	----
Whey, Dried Isol.	20.00	10.00	----	----	----	----	----
Fishmeal, Menhaden	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Lactose, 97%	----	2.57	5.14	----	----	20.61	----
Soybean Oil	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Lysine, HCL	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Ethoxyquin	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Methionine	----	----	----	----	----	0.10	0.05
Apralan[c]	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Calcium Carbonate	0.40	0.37	0.30	0.75	0.86	0.61	0.75
Dicalcium Phosphate	0.51	0.52	0.55	1.32	1.15	1.47	1.22
Vit. TM Premix	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Tryptophan	----	----	0.02	----	----	----	----
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 3.1. (Continued)

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[a]As fed basis.
[b]Protein Technologies International, St. Louis, MO.
[c]Supplies 8,800 IU vitamin A, 880 IU vitamin D, 37 IU vitamin E, 44 mg pantothenic acid, 59 mg niacin, 8.8 mg riboflavin, 7.3 mg menadione sodium bisulfate, .04 mg vitamin B^{12}, 3 mg biotin, 6 mg pyridoxin, 2 mg folic acid, 10 mg thiamine, 880 mg choline choloride, .2 mg selenium, .06 g manganese, .2 g zinc, .2 g iron, .02 g copper, .2 g magnesium, 1 g potassium, and .4 mg iodine per kg of feed.

TABLE 3.2.

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

	Treatment[a]						
	1	2	3	4	5	6	7
ME, Kcal/kg.	3454.61	3456.81	3461.22	3452.40	3448.00	3452.40	3478.86
Lactose, %	19.99	19.99	19.99	0.00	0.00	19.99	0.00
Lysine, %	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Crude Protein, %	19.90	19.73	19.64	21.49	22.68	20.07	21.03
Threonine, %	0.89	0.83	0.77	0.89	0.89	0.80	0.84
Tryptophan, %	0.25	0.24	0.26	0.26	0.28	0.25	0.26
Met + Cys, %	0.72	0.74	0.77	0.83	0.89	0.76	0.78
Calcium, %	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Phosphorus, %	0.70	0.70	0.70	0.70	0.70	0.70	0.70

[a]As fed basis

TABLE 3.3.

COMPOSITION OF ISOLATED SOYBEAN PROTEIN (NURISH 3000).

ITEM	%
Protein	90.0 minimum
Moisture	6.0 maximum
Fat	1.0 maximum
Fiber	0.2 maximum
Ash	5.0 maximum

TABLE 3.4.

COMPOSITION OF ISOLATED SOYBEAN PROTEIN (NURISH 2000).

ITEM	%
Protein	35.1
Lactose	50.0
Moisture	4.0
Fat	2.0
Fiber	<0.2
Ash	8.5

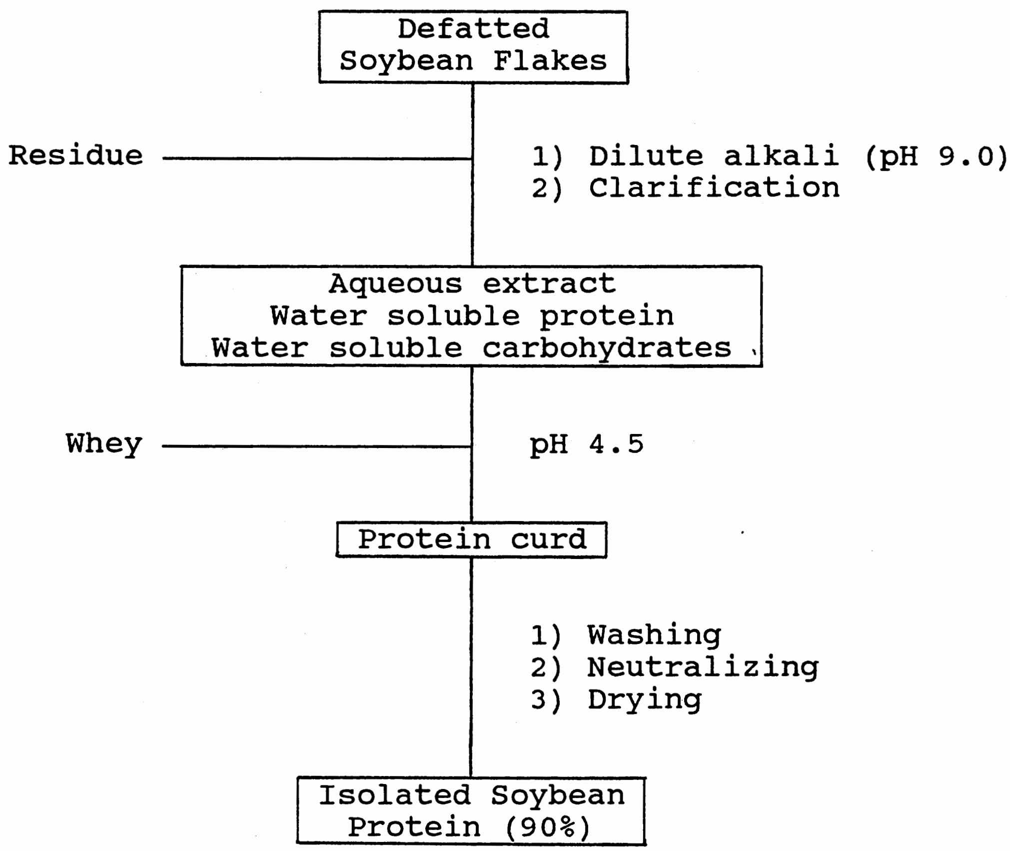

Figure 3.1. Outline of Process for the Production of Isolated Soybean Protein.

TABLE 3.5.

COMPOSITION OF DIET FED DURING PERIOD 2 (3 WK)

Ingredient	% of Diet[a]
Yellow Corn	67.55
Soybean Meal	28.50
Dicalcium Phosphate	1.95
Calcium Carbonate	.90
Vit. TM Premix[b]	.375
Lysine	.15
Salt	.40
Copper Sulfate	.075
Apralan[c]	.10
	100.00

[a]As fed basis
[b]Supplied 6,600 IU vitamin A, 660 IU vitamin D, 28 IU vitamin E, 6.6 mg riboflavin, 33 mg pantothenic acid, 44 mg niacin, .03 mg vitamin B^{12}, 5.5 mg menadione sodium bisulfite, 45 mg manganese, 150 mg iron, .15 mg selenium, .3 mg iodine, 15 mg copper, and 150 mg zinc per kg of feed.
[c]Contains 75 g Apramycin per lb.

Calculated Composition 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 3.6.

EFFECT OF PROTEIN SOURCE AND LEVEL OF LACTOSE ON ADG DURING WEEK 1, g/d.[a]

	Treatment[b,c]				
Replicate	1	2	3	4	5
1	126.9	147.1	75.3	133.6	133.3
2[d]	144.2	117.2	106.4	130.2	60.5
3[e]	198.1	245.7	194.4	205.7	223.0
Trt. mean	156.4	170.0	125.4	156.5	139.0

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.01).
[d]Linear decrease in ADG with increasing level of Nurish 3000 in treatments 1, 4, and 5 without lactose (P<.01).
[e]Quadratic response to increasing level of Nurish 2000 in treatments 1, 2, and 3 with constant lactose (P<.05).

TABLE 3.7.

EFFECT OF LEVEL OF LACTOSE IN CORN-SOYBEAN MEAL DIETS ON ADG DURING WEEK 1, g/d.[a]

	Treatment[b,c]		
Replicate	1	6	7
1	126.9	158.0	77.7
2	144.2[d]	55.1[e]	30.2[e]
3	198.1	211.1	212.8
Trt. mean	156.4	141.4	106.9

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.01).
[d,e]Means in same row with different superscripts differ (P<.05).

TABLE 3.8.

EFFECT OF PROTEIN SOURCE AND LEVEL OF LACTOSE ON ADG DURING WEEK 2, g/d.[a]

	Treatment[b,c]				
Replicate	1	2	3	4	5
1	150.2	133.7	132.3	209.3	139.1
2	319.7	314.3	393.7	377.5	293.8
3[d]	142.6	128.0	185.8	42.1	92.3
Trt. mean	204.2	192.0	237.3	209.6	175.1

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.001).
[d]Quadratic response to increasing level of Nurish 3000 in treatments 1, 4, and 5 without lactose (P<.04).

TABLE 3.9.

EFFECT OF LEVEL OF LACTOSE IN CORN-SOYBEAN MEAL DIETS ON ADG DURING WEEK 2, g/d.[a]

	Treatment[b,c]		
Replicate	1	6	7
1	150.2	237.6	198.4
2	319.7	260.3	321.8
3	142.6	98.3	67.0
Trt. mean	204.2	198.7	195.7

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.001).

TABLE 3.10.

EFFECT OF PROTEIN SOURCE AND LEVEL OF LACTOSE ON ADG DURING PERIOD 1 (2 WK), g/d.[a]

	Treatment[b,c]				
Replicate	1	2	3	4	5
1	130.3	140.4	103.3	171.5	135.7
2[d]	231.9	216.3	250.6	254.3	177.7
3	169.8	186.8	190.1	123.9	157.7
Trt. mean	177.3	181.2	181.3	183.2	157.0

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.001).
[d]Quadratic response to increasing level of Nurish 3000 in treatments 1, 4, and 5 without lactose (P<.05).

TABLE 3.11.

EFFECT OF LEVEL OF LACTOSE IN CORN-SOYBEAN MEAL DIETS ON ADG DURING PERIOD 1 (2 WK), g/d.[a]

	Treatment[b,c]		
Replicate	1	6	7
1	130.3	197.8	137.0
2	231.9	157.7	176.6
3	169.8	154.7	139.9
Trt. mean	177.3	170.1	151.2

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.001).

TABLE 3.12.

EFFECT OF PROTEIN SOURCE AND LEVEL OF LACTOSE ON ADG DURING PERIOD 2 (3 WK), g/d.[a]

	Previous Treatment[b]						
Item	1	2	3	4	5	6	7
Average daily gain	552.4	546.7	551.3	537.4	548.2	509.0	524.6

[a]Least squares means.
[b]Replicate effect (P<.001).

TABLE 3.13.

EFFECT OF PROTEIN SOURCE AND LEVEL OF LACTOSE ON FEED EFFICIENCY DURING WEEK 1, G:F.[a]

	Treatment[b]				
Item	1	2	3	4	5
G:F[c]	.80	.84	.63	.78	.62

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Linear decrease in G:F with increasing level of Nurish 3000 in treatments 1, 4, and 5 without lactose (P<.04).

TABLE 3.14.

EFFECT OF LEVEL OF LACTOSE IN CORN-SOYBEAN MEAL DIETS ON FEED EFFICIENCY DURING WEEK 1, G:F.[a]

	Treatment[b]		
Item	1	6	7
G:F	.80	.73	.48

[a]Least squares means.
[b]Replicate effect (P<.001).

TABLE 3.15.

EFFECT OF PROTEIN SOURCE AND LEVEL OF LACTOSE ON FEED EFFICIENCY DURING WEEK 2, G:F.[a]

	Treatment[b,c]				
Replicate	1	2	3	4	5
1	.33	.33	.32	.44	.29
2[d]	.64	.74	.87	.79	.72
3[e]	.38	.34	.46	.13	.27
Trt. mean	.45	.47	.55	.45	.43

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.03).
[d]Linear increase in G:F with increasing level of Nurish 2000 in treatments 1, 2, and 3 with lactose (P<.02).
[e]Quadratic response to increasing level of Nurish 3000 in treatments 1, 4, and 5 without lactose (P<.02).

TABLE 3.16.

EFFECT OF LEVEL OF LACTOSE IN CORN-SOYBEAN MEAL DIETS ON FEED EFFICIENCY DURING WEEK 2, G:F.[a]

	Treatment[b,c]		
Replicate	1	6	7
1	.33	.54	.44
2	.64	.72	.77
3	.38	.27	.17
Trt. mean	.45	.51	.46

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.03).

TABLE 3.17.

EFFECT OF PROTEIN SOURCE AND LEVEL OF LACTOSE ON FEED EFFICIENCY DURING PERIOD 1 (2 WK), G:F.[a]

	Treatment[b,c]				
Replicate	1	2	3	4	5
1	.44	.47	.35	.50	.37
2	.69	.75	.81	.79	.66
3	.58	.61	.59	.44	.52
Trt. mean	.57	.61	.59	.58	.52

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.01).

TABLE 3.18.

EFFECT OF LEVEL OF LACTOSE IN CORN-SOYBEAN MEAL DIETS ON FEED EFFICIENCY DURING PERIOD 1 (2 WK), G:F.[a]

	Treatment[b,c]		
Replicate	1	6	7
1	.44	.64	.45
2	.69	.66	.64
3	.58	.50	.42
Trt. mean	.57	.60	.51

[a]Least squares means.
[b]Replicate effect (P<.001).
[c]Treatment x replicate interaction (P<.01).

TABLE 3.19.

EFFECT OF PROTEIN SOURCE AND LEVEL OF LACTOSE ON FEED EFFICIENCY DURING PERIOD 2 (3 WK), G:F.[a]

	Previous Treatment[b,c]						
Replicate	1	2	3	4	5	6	7
1	.61	.64	.65	.62	.61	.65	.61
2	.62	.59	.61	.60	.63	.56	.54
3	.58	.63	.55	.65	.61	.55	.63
Trt. mean	.60	.62	.60	.62	.62	.59	.60

[a]Least squares means.
[b]Replicate effect (P<.02).
[c]Treatment x replicate interaction (P<.02).

TABLE 3.20.

EFFECT OF PROTEIN SOURCE AND LEVEL OF LACTOSE ON AVERAGE DAILY FEED INTAKE, g/d.[a]

	Treatment						
Period	1	2	3	4	5	6	7
Wk 1[b]	192.1	200.4	194.1	203.9	212.0	181.7	183.4
Wk 2[b]	437.6	394.6	422.3	426.5	407.1	385.9	413.4
Period 1	312.3	297.5	308.2	315.2	309.6	283.8	298.4
Period 2	928.2	884.3	917.2	864.7	888.7	860.2	879.1
Total (5 wk)	679.1	649.6	673.6	644.9	657.0	628.6	646.8

[a]Least squares means.
[b]Replicate effect (P<.01).

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