EFFECTS OF DIET ON PERFORMANCE OF PIGS WEANED AT THREE WEEKS

by

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INTRODUCTION

The swine industry has become very efficient in maximizing production. Confinement rearing has proven to be an effective tool in increasing survival rate postweaning due to the availability of a highly controllable environment for the young pig. However, the nutrition of the early weaned pig to provide maximum growth is a problem facing many producers.

Weaning at three to four weeks of age has several advantages. Milk production of the sow often fails to meet the pig's increasing nutritional requirements between the third and fourth week of lactation. In addition, at three weeks postpartum, envolution of the reproductive tract of the sow has occurred, thereby rendering her capable of supporting another pregnancy. By weaning early, it is possible to increase the number of litters per sow per year.

However, there are some disadvantages from early weaning. The passive immunity obtained from the colostrum of the sow has begun to disappear and baby pigs are only beginning to develop their own immune system. This makes the pig very susceptible to disease. For this reason, it is necessary to provide adequate facilities to keep the newly weaned pig warm, dry, and draft-free. Also, the enzymatic system of pigs three to four weeks old is not capable of digesting many common feedstuffs. In addition, a newly weaned pig must learn to consume dry feed from a feeder, drink from the waterer, and develop a new social order. Lack of weight gain is possibly due to lack of feed intake in many pigs. Therefore, a highly nutritious diet is essential to maximize performance during this critical period.

Four trials were conducted to study dietary factors which would maximize the weight gains and feed efficiency of three week old weaned pigs. The effects of dried whey, partially delactosed whey, soy flour, casein and fat additions to the basal diet were studied. The effect of weaning age on the utilization of whey and the duration of feeding whey were also investigated.

REVIEW OF LITERATURE

Development of Enzymatic Systems in the Young Pig

Newborn pigs are not physiologically capable of digesting many diets. In order to formulate diets to maximize performance, a good understanding of the enzymes of the digestive system in the young pig is necessary.

Lactase

Sow milk contains high amounts of lactose; therefore, it is essential that the baby pig produce adequate amounts of lactase. Ekstrom *et al*. (1975) reported that lactase activity is high at birth, but declines to four weeks of age, at which time it reaches adult levels. However, Walker (1959) found that the actual amount of lactase remains constant, so that as the weight of the pig's digestive system increases, the quantity of lactase is actually seeming to decrease when expressed per kilogram body weight or per gram dry tissue. This is apparent in further research by Ekstrom in which he states that a high or continuous exposure to lactose is not necessary to prevent lactose intolerance. Therefore, lactase must be present at some level during all ages. It is possible that the rate of enzyme production can be influenced and perhaps increased by diet. Graham *et al*. (1981) found that total lactase activity increased more than two-fold when diets containing lactose vs. a basal diet containing no lactose was fed.

Sucrase

Hartman *et al*. (1961) and Walker (1959) found that sucrase activity is low at birth and increases to high levels at approximately six weeks.

Amylase

Pancreatic amylase, as well as amylase from the small intestine, increases from birth to high levels at six weeks of age (Walker, 1959). Hartman *et al*. (1961) found that the maximum amount of amylase produced by the pig has not yet been reached by eight weeks of age. Pond *et al*. (1971) reported that amylase activity per gram pancreas increased six-fold from birth to 23 days of age, while total activity increased thirty-fold. Pond and associates also found during the same time period that the weight of the pancreas increased six-fold. Graham *et al*. (1981) attributed part of this increase in enzyme activity to the heavier pancreas weights. Pigs fed a dried whey diet consumed more feed; therefore, had larger pancreas weights and increased enzyme activity. It is further suggested that higher feed intake can influence enzyme synthesis, secretion, or inactivation within the small intestine. Walker reported that the pig is able to break down adequate amounts of starch to maltose and dextrins but when fed starch the pigs did not grow. Therefore, he postulated that maltase activity is too low to sufficiently digest the maltose from degraded starch. This is contrary to work by Cunningham and Brisson (1957) who found that after the first week of life, the newborn is capable of digesting maltose and concluded that the digestion of starch was not limited by a deficiency of maltase. Maltase activity acts similar to amylase activity (Hartman et al., 1961; Walker, 1959) by increasing from birth to high levels at six to seven weeks of age.

Proteinase

Hartman et al. (1961) found little or no proteinase enzymes present in the pig during the first two weeks of life. At three weeks a sharp increase occurred in both weaned and unweaned pigs. However, pigs that were weaned had higher secretory power due to greater stomach tissue than those pigs allowed to remain on the sow, although this difference was small. Pond et al. (1971) found chymotrypsin per gram pancreas to decrease from birth to 23 days, although the total activity increased three-fold. Similarly, trypsinogen per gram pancreas increased three-fold while total activity increased twenty-fold.

Lipase

Lipase per gram pancreas decreased from birth to 23 days, according to Pond et al. (1971) even though total activity increased three-fold. Hartman et al. (1961) reported high levels of tributyrinase, a lipolytic enzyme, at birth and a gradual increase with age. A marked drop in tributyrinase levels was observed at weaning (one week of age). Recovery began at four weeks of age and by seven weeks of age pigs weaned at one week of age were approaching pigs remaining with the sow in tributyrinase levels. This may be a possible explanation for a decrease in fat digestion after weaning with a subsequent increase with advancing age.

Effect of Age and Weight on Post-weaning Performance

Age or weight at weaning has a direct effect on the degree of growth check or retardation that is experienced by the pig. Leibbrandt et al. (1975) weaned pigs at two, three, or four weeks of age and found that subsequent feed intake and rate of gain increased more rapidly as weaning age increased from two to four weeks. By three weeks after weaning, energy intake per unit metabolic size was maximized; at six weeks of age, those weaned at two or three weeks were equal to those weaned at four weeks.

According to Smith and Lucas (1957), weaning at 6.4 kilograms of weight is more advantageous ($P<.10$) than weaning at 3.6 or 9.1 kilograms by 56 days of age. Final weights for the 3.6, 6.4, and 9.1 kilogram initial weaning weights at 56 days were, respectively: 21.1, 22.8, and 21.7 kilograms. Although this data tends to favor the 6.4 kilogram weaning weight, the authors realize that any of the weights at eight weeks were acceptable for pigs of this age. Leibbrandt et al. (1975) postulated that weaning weight increases as weaning age increases, and the heavier or older pig will have a higher feed consumption during the first period of readjustment post-weaning. Therefore, energy intake is higher in those pigs with a higher feed consumption, so that post-weaning growth favors the older or heavier pigs. Armstrong and Clawson (1980) report four week weaned pigs gained faster with higher feed consumption than three week weaned pigs ($P<.05$).

Effect of Age on Diet Utilization

A marked difference between digestibility of a vegetable protein source and a milk protein source immediately post-weaning has been reported (Armstrong and Clawson, 1980; Combs et al., 1963; Graham et al., 1981; Kornegay et al., 1974; Maner et al., 1961; and Pekas et al., 1964). As age of the pig increases, the difference in digestibility between diets decreases. Armstrong and Clawson reported no difference between nonfat dried milk and corn soybean meal diets 14 to 28 days post-weaning. Combs found that differences in digestibility of dry matter, protein and energy of dried skim milk, fishmeal and soybean meal occurring from three to six weeks were not evident at seven to eight weeks of age. Similarly, Maner found casein and soybean meal to be of equal value to the pig at ten weeks of age, but not at three weeks. Kornegay found compensatory growth to occur by market weight between a basal diet and a 17.5 percent dried skim milk diet. However, Sewell and West (1965) reported no significant age differences when pigs were fed isolated soybean protein, dried skim milk, or lactose added to the isolated soybean protein or whey diets. The authors emphasized that these results obtained were from purified or semi-purified diets. Previous results in other studies in which differences were seen were obtained from diets containing crude feedstuffs. According to the authors, this difference in the diet composition could be one explanation for lack of differences being apparent in this trial.

Effect of Dietary Milk Products on Pig Performance

Due to the baby pig's enzymatic system, milk is a highly digestible food. For this reason, the use of milk products added to diets of newly weaned pigs is an opportunity for the producer. Many researchers have reported positive effects from adding milk products to the diet.

Armstrong and Clawson (1980) added 30 percent nonfat dried milk to a basal corn soybean meal diet fed to three to four week old pigs. This addition increased performance ($P<.05$). By adding a commercial milk product composing 30 percent of the diet, the same researchers improved efficiency ($P<.08$). Likewise, Crane (1953) found that adding 40 percent dried skim milk produced the most rapid and efficient gains when compared to additions of 0, 13, and 20 percent. Becker et al. (1957) observed no detrimental effect from feeding a 60 percent whey diet. However, gains and feed efficiency were not improved to a statistically significant extent over the control or 30 percent whey addition.

The amount of milk protein needed to produce a response has been variable, judging from the literature available. Noland et al. (1969) reported that a minimum of 15 percent dried skim milk was needed for a positive response. Miller et al. (1971) added 7.5 percent dried whey to a negative 16 percent protein control diet and produced results equal to a positive 19 percent protein control diet. Kornegay et al. (1974) fed a 17.5 percent dried whey diet and showed a significant increase in body weight gain, feed intake and an improvement in feed efficiency. However, feeding a ten percent dried skim milk diet produced no significant improvement; at market time, all pigs were equal in weight due to compensatory growth. Wahlstrom *et al*. (1974) tested five different diets:

(1) basal,

(2) ten percent whey,

(3) ten percent whey with five percent sugar,

(4) ten percent dried skim milk,

and (5) ten percent dried skim milk with five percent sugar.

The addition of sugar had no effect and no differences were reported in average daily gain or feed efficiency of the whey or dried skim milk vs. the basal.

Danielson *et al*. (1960) also compared dried skim milk and whey. Six different diets of varying quantities of dried skim milk and whey to equal 40 percent of the diet as milk product were fed:

(1) 40 percent dried skim milk,

(2) 30 percent dried skim milk, ten percent whey,

(3) 20 percent dried skim milk, 20 percent whey,

(4) ten percent dried skim milk, 30 percent whey,

(5) 40 percent whey,

and (6) basal diet.

During the first fourteen days of the experiment, the gains favored the 30 percent dried skim milk and ten percent whey, although not significantly different from the 40 percent dried skim milk diet. As additions of whey increased, gains were decreased. In order to maintain a constant protein level, soybean meal was added to the diets. The authors suggest that as the whey was increased the amount of soybean meal needed also increased. Since soybean meal is not as digestible as milk products, the increasing percentage of soybean meal caused digestibility to decrease resulting in decreased gains. In the work done by Graham et al. (1981), the authors compared a corn basal vs. a 25 percent whey or a 15 percent dried skim milk diet. The whey diet produced the greatest gains. Amylase, protease and lactase activities were highest in the whey diet. This was possibly the result of an increase in feed consumption. When pigs were switched to a cereal diet after two weeks, no detrimental effect was observed. In this trial, the dried skim milk diet produced the lowest gains. When analyzing the diets, the authors found a 1:1 corn soybean meal ratio in the 25 percent whey diet, and a 2:1 corn soybean meal ratio in the 15 percent dried skim milk diet. Again, the problem of digestibility of the soybean meal was evident.

Okai et al. (1976) compared simple, semi-complex, and complex diets for nursery pigs. The simple diet contained wheat, barley, soybean meal, and fishmeal. The semi-complex diet contained wheat, barley, oat groats, soybean meal, fishmeal, and dried skim milk, whereas the complex diet contained sucrose, dextrose, corn starch, tallow, soybean meal, fishmeal, dried skim milk and whey. Okai and co-workers observed an increase in growth rate in pigs fed the complex diet when weaned at three or five weeks of age. The three week weaned pigs had a higher rate of gain with the complex than with the semi-complex or simple diets, although the semi-complex seemed to be an improvement over the simple formulation. Bayley and Carlson (1970) reached the same conclusions using a simple corn soybean meal diet vs. a complex diet consisting of corn, wheat oat groats, dried skim milk, soybean meal and fishmeal.

If milk products are more advantageous than cereal products to the young pig, the question becomes: where does the advantage originate -- from the milk protein or from the lactose portion of the diet? Sewell and West (1965) found that pigs fed diets containing lactose gained significantly faster, with an improved feed efficiency, over those fed diets without lactose. They reported that by adding lactose, the utilization of isolated soy protein can be improved. Contrary results were obtained by Pekas et al. (1964) who added lactose to soybean meal to equalize lactose in all experimental diets and corn starch to a dried skim milk diet to equalize plant starches. The pigs on the milk diet grew significantly faster and required less feed than those on the soybean meal diet even though each contained the same amount of lactose.

Casein is a milk protein containing no lactose. For this reason, studies have been conducted using casein to determine the effect of lactose. Jenson et al. (1957) found an 86.8 percent corn casein diet equal to a 50 percent dried skim milk diet whereas Miller et al. (1971) added two percent to a 16 percent protein (negative control) diet. The improvement in gain and feed efficiency equalled the 19 percent protein (positive control) diet. Miller also observed a difference between a casein diet and a soybean meal diet. The pigs on the casein diet gained 30 percent more ($P<.05$), on 26 percent less feed. Casein, also, had a higher digestibility ($P<.01$) in their studies.

Maner et al. (1962) studied casein to discover the reason for its increase in digestibility. The authors fistulated ten day old pigs and compared isolated soy protein and casein diets. A pH of 2.0 is optimum for pepsin activity. After feeding, the pH rose to 5.6. Two hours later, the pH of those pigs fed casein had returned to 1.7. The pH of the pigs fed isolated soy protein returned to 1.3 in four hours. The isolated soy protein has a buffering action on the stomach and thus delays the activation of pepsinogen, thereby delaying and reducing the digestion of the protein. The aggregation of the curd is also reduced. They also found in studying rate of passage that at four weeks of age, the casein diet had a mean rate of passage of 42 hours and the isolated soy protein had a mean rate of passage of 19 hours. By eight weeks of age, there was no difference in rate of passage, both mean rates were 45 hours. The rate of passage is related to a difference in gastric pH.

Effect of Soy Flour on Pig Performance

Soy flour is more inexpensive than milk protein. For this reason, it has been researched as a possible use in nursery diets to replace milk products. Lennon _et al_. (1971) weaned pigs at 17 days of age and fed them an acid-treated or alkali-treated soy flour diet. The soy flour was treated before inclusion into the diet. The pH of the acid-treated soy flour diet was 6.4, while the alkali-treated diet pH was 10.6. The researchers studied the buffering effect of soy flour mentioned in the work by Maner _et al_. (1962) on rate of passage and stomach pH. In Lennon's work, the alkali-treatment produced higher gains and improved feed efficiency ($P<.01$) over the acid-treated diet. The alkali-treatment, also, increased gain ($P<.05$) and improved feed efficiency ($P<.10$) over the untreated soy flour. The untreated soy flour was supplemented with methionine, threonine, and lysine with no effect. The authors believed that alkali-treatment enhanced the utilization of nutrients. The average daily gains reported were the same as those reported for milk product diets. Jones et al. (1977) also utilized acid-treated soy flour in their experiments. They found no difference between feeding soy flour and casein. Also acid-treating the soy flour made no difference. The researchers also studied the amount of soy flour needed in the diet by feeding 15, 11, or 7 percent of the total calories in the diet as soy flour. The 15 percent and 11 percent diets were equal in performance, the seven percent diet having a decreased performance. Therefore, according to this experiment, it appears that 11 percent of the total calories (13 percent of dry matter) is needed in the diet to produce a positive response.

Effect of Fat in the Diet on Pig Performance

Crane (1953) added fat to the diet of nursery pigs at a rate of 7.5, 10, 12.5 and 15 percent. He found ten percent to provide the most rapid gains of these four levels. However, Armstrong and Clawson (1980) stated that increasing dietary energy had no beneficial effect on performance. The fat addition in their study did little to eliminate the post-weaning check and, also, did not affect intake. As reported earlier, Hartman et al. (1961) stated that the lipolytic enzyme, tributyrinase, has a marked decrease due to the stress of weaning and does not recover to normal levels for up to seven weeks. This could be a possible explanation for the post-weaning check observed by Armstrong and Clawson.

Peo et al. (1957) utilized 15 percent soybean meal and 15 percent dried skim milk as a protein source to obtain varying levels of protein. In addition to these diets, differing levels of fat (stabilized lard) at 0, 2.5, 5.0, and 10 percent were added. The authors found no difference in gain due to fat level. Feed efficiency was improved the first two weeks of the trial; however, overall feed efficiency for the four week trial period was similar. Lloyd et al. (1957) utilized 13 different fats or oils with the same basal diet to study the digestibility of fat at three weeks and seven weeks of age. The fats were grouped into short chain (coconut oil, butter 75 percent plus erucic acid at 25 percent), medium chain (lard, beef tallow, linseed oil, corn oil, and butter at 50 percent plus erucic acid at 50 percent), and long chain fats (fish oil, hydrogenated fish oil, rapeseed oil, erucic acid, and butter at 25 percent plus erucic acid at 75 percent). The researchers found an inverse relationship between the mean molecular weight (or length of chain) of the fatty acids of the various fats and oils and their apparent digestibility. The mean digestibilities at three weeks were: 86 percent (short chain), 70 percent (medium chain), and 37 percent (long chain). By seven weeks, the digestibilities had reached 96 percent (short chain), 90 percent (medium chain), and 78 percent (long chain). The authors suggest the increase in digestibility over time is due to an increase in bile secretion, thus resulting in increasing absorptive capacity of the pig.

MATERIALS AND METHODS

Introduction

Four trials were conducted to study the effects of dried whey, partially delactosed whey, soy flour, casein, and fat additions to the diets of newly weaned pigs. The effect of age at weaning and duration of feeding whey on the performance of the pigs was also studied. All pigs used were crossbreds obtained from the Kansas State University Swine Research Unit and housed in the research unit nursery. This facility is an environmentally controlled building equipped with woven wire floors over a V-type flush gutter.

The pigs in Trials I, III, and IV were weaned at 22±4 days; pigs in Trial II were weaned at two, three, four, or five weeks according to treatment. The pigs were placed in pens measuring 1.2 meters by 1.5 meters. Nipple waterers were blocked open to allow the pigs to become proficient at manipulating the waterer. Temperature was controlled throughout the trial according to pig comfort and condition. The number of pigs per pen varied between trials with six pigs per pen in Trial I, five pigs per pen in Trial III, and four pigs per pen in Trials II and IV. A random complete block design was utilized and pigs were allotted according to weight and litter (except in Trial II) with no regard to sex. Diets were fed ad libitum in all trials.

All pigs were weighed initially and weekly thereafter throughout the length of the trial. Feed consumption was also measured weekly throughout the trial. All trials ended when pigs were eight weeks of age.

Trial I

Trial I utilized five treatments (table 1) to observe the effect of varying amounts of lactose contained in whey on pig performance. A milo-soybean meal diet was used as the basal control diet. A 20 percent dried whole sweet whey diet (70 percent lactose) was compared to two 20 percent diets of delactosed whey sources (55 percent lactose). The fifth treatment consisted of feeding the 20 percent whole whey diet for two weeks, followed by a return to the basal diet for the duration of the trial. The two delactosed whey diets were obtained from two different sources: one considered a high quality source of whey obtained from Land O'Lakes Company, the other considered as product of unknown quality obtained from a local elevator.

Trial II

Trial II was designed to determine the effect of age of the young pig upon the utilization of whey. Pigs were weaned at two, three, four, or five weeks of age. Two diets were used: a 20 percent whole whey diet and a basal milo-soybean meal diet as shown in table 2.

TABLE 1. Composition of diets (Trial I).

Ingredients	Diets, %			
	A	B	C	D
Milo	56.82	43.22	43.22	43.22
Soybean meal	37.10	31.50	31.50	31.50
Corn oil	2.00	2.00	2.00	2.00
Whole whey		20.00		
Delactosed whey (source 1)			20.00	
Delactosed whey (source 2)				20.00
Limestone	1.30	1.00	1.00	1.00
Dicalcium phosphate	1.50	1.20	1.20	1.20
Trace mineral premix[a]	.10	.10	.10	.10
KSU vitamin premix[b]	.50	.50	.50	.50
Salt	.30	.10	.10	.10
ASP-250	.25	.25	.25	.25
L-lysine HCl[c]	.13	.13	.13	.13
	100.00	100.00	100.00	100.00
Calculated analysis				
Lysine	1.31	1.41	1.45	1.45
Crude protein	21.40	20.40	20.80	20.80
Calcium	.90	.90	1.10	1.10
Phosphorus	.72	.73	.77	.77

[a]Containing 10% Manganese, 10% Iron, 1% Copper, 10% Zinc, .3% Iodine, .1% Cobalt, 4% Calcium.

[b]Each kg of premix contained: Vit. A, 880,000 USP units; Vit. D_3, 66,000 USP units; Riboflavin, 990 mg; Choline chloride, 88 g; d-pantothenic acid, 2640 mg; Niacin, 5500 mg; Vit. E, 4400 IU; Vit. B_{12}, 4.84 mg; Menadione Dimethylpyrimidinal Bisulfate, 550 mg; Ethoxyquin, 6270 mg.

[c]L-lysine HCl 78% lysine activity.

TABLE 2. Composition of diets (Trials II and III).

Ingredients	Diets, % A	B
Milo	58.82	45.22
Soybean meal	37.10	31.50
Whole whey		20.00
Limestone	1.30	1.00
Dicalcium phosphate	1.50	1.20
Trace mineral premix[a]	.10	.10
KSU vitamin premix[b]	.50	.50
Salt	.30	.10
ASP-250	.25	.25
L-lysine HCl[c]	.13	.13
	100.00	100.00
Calculated analysis		
Lysine	1.31	1.41
Crude protein	21.60	20.60
Calcium	.90	.90
Phosphorus	.72	.74

[a]Containing 10% Manganese, 10% Iron, 1% Copper, 10% Zinc, .3% Iodine, .1% Cobalt, 4% Calcium.

[b]Each kg of premix contained: Vit. A, 880,000 USP units; Vit. D_3, 66,000 USP units; Riboflavin, 990 mg; Choline chloride, 88 g; d-pantothenic acid, 2640 mg; Niacin, 5500 mg; Vit. E, 4400 IU; Vit. B_{12}, 4.84 mg; Menadione Dimethylpyrimidinal Bisulfate, 550 mg; Ethoxyquin, 6270 mg.

[c]L-lysine HCl 78% lysine activity.

Trial III

The same diets as Trial II (table 2) were utilized in Trial III. The whey diet was fed for zero, one, two, three, four, or five weeks. Following this treatment, the pigs were switched to the basal diet. The objective of the trial was to determine the optimum length of time required that the whey diet should be fed to achieve maximum performance. By reducing the length of feeding time of the more expensive whey product, cost to the producer can be minimized.

Trial IV

Eight treatments were used in Trial IV (table 3). A corn soybean meal basal diet was utilized and the three treatments consisted of soy flour added at the rate of 25 percent of the protein source and casein at 25 and 50 percent of the protein source. To each of these diets five percent added fat from a dried product was added. This trial was designed to compare the value of adding a soy flour addition, casein addition at two levels and the fat addition to all treatments. Soy flour is more inexpensive than a milk protein source; therefore, substituting this ingredient might lower feed cost if performance is satisfactory. Casein contains no lactose, hence the value of lactose in the diet was evaluated. Fat was added to each diet to determine if the young pig could utilize fat and if it has a beneficial effect on pig performance.

TABLE 3. Composition of diets (Trial IV).

	Diets, %							
Ingredients	A	B	C	D	E	F	G	H
Corn	57.55	45.32	61.50	49.25	65.45	52.99	73.25	60.85
Soybean meal	38.50	38.50	12.60	12.60	24.30	24.30	10.30	10.30
Dried fat (40-60)		12.50		12.50		12.50		12.50
Modified soy flour			21.60	21.60				
Casein					6.10	6.10	12.20	12.20
Dicalcium phosphate	1.50	1.30	1.60	1.50	1.60	1.50	1.70	1.60
Limestone	1.10	1.10	1.30	1.20	1.30	1.40	1.40	1.40
Salt	.30	.30	.30	.30	.30	.30	.30	.30
Trace mineral premix[a]	.50	.50	.50	.50	.50	.50	.50	.50
KSU vitamin premix[b]	.10	.10	.10	.10	.10	.10	.10	.10
ASP-250	.25	.25	.25	.25	.25	.25	.25	.25
L-lysine HCl[c]	.20	.13	.25	.20	.10	.06		
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis								
Lysine	1.42	1.41	1.39	1.39	1.41	1.41	1.39	1.43
Crude protein	22.00	21.90	22.00	21.90	22.90	21.80	22.00	21.90
Calcium	.82	.83	.89	.88	.88	.95	.91	.94
Phosphorus	.73	.72	.73	.74	.72	.73	.71	.72

[a]Containing 10% Manganese, 10% Iron, 1% Copper, 10% Zinc, .3% Iodine, .1% Cobalt, 4% Calcium.

[b]Each kg of premix contained: Vit. A, 880,000 USP units; Vit. D_3, 66,000 USP units; Riboflavin, 990 mg; Choline chloride, 88 g; d-pantothenic acid, 2640 mg; Niacin, 5500 mg; Vit. E, 4400 IU; Vit. B_{12}, 4.84 mg; Menadione Dimethylpyrimidinal Bisulfate, 550 mg; Ethoxyquin, 6270 mg.

[c]L-lysine HCl 78% lysine activity.

RESULTS

Trial I

The results attained in Trial I are shown in table 4. Gain per pig for the first week on trial and feed efficiency were improved ($P<.05$) by adding whey or delactosed whey. Feed intake was not different between treatments. There were no statistically significant differences observed among pigs fed diets containing different sources of whey. During the second week of Trial I, pigs fed the whey diets consumed more feed and gained faster than pigs fed the basal diet. Again, no difference was seen among the pigs fed the whey diets in gain, feed intake or feed efficiency. When weeks one and two are combined, pigs fed the basal diet gained less ($P<.05$) and were less efficient ($P<.05$) than pigs fed whey. There were no differences between the two whey sources. When data for the entire 35 day trial are summarized, there was a significant improvement in pig gain by adding whey or delactosed whey over feeding the basal diet. No differences were observed in gain, feed intake or feed efficiency between the pigs fed the diets containing 20 percent whole whey or 20 percent delactosed whey from two different sources. Feeding 20 percent whole whey for two weeks and then switching to the basal diet for the remainder of the trial resulted in a slight decrease in feed intake with a slight improvement in feed efficiency over feeding 20 percent whey throughout the trial.

TABLE 4. Performance of 20±2 day old pigs fed diets containing whole whey, partially delactosed whey or whole whey for two weeks (Trial I).[ab]

	Treatments[c]					
	Basal	20% Whey	20%Del. Whey#1	20%Del. Whey#2	20%Whey for 2wks.	Standard Error
Initial wt., kg	4.82	4.82	4.82	4.77	4.73	.04
Week one:						
Gain/pig, kg	.35^{d}	.56^{e}	.71^{e}	.60^{e}	.78^{e}	.07
Feed intake/pig, kg	1.07	1.15	1.15	1.06	1.23	.08
Gain:feed	.33^{d}	.50^{e}	.60^{e}	.56^{e}	.64^{e}	.05
Week two:						
Gain/pig, kg	.79^{d}	1.14^{e}	1.00^{de}	1.01^{de}	.89de	.10
Feed intake/pig, kg	1.65^{d}	2.04^{e}	1.89^{de}	1.86^{de}	2.03^{de}	.13
Gain:feed	.47	.56	.53	.53	.44	.04
Weeks one and two:						
Gain/pig, kg	1.14^{d}	1.70^{e}	1.71^{e}	1.61^{e}	1.67^{e}	.14
Feed intake/pig, kg	2.72^{d}	3.19^{de}	3.04^{de}	2.92^{de}	3.26^{e}	.18
Gain:feed	.42^{d}	.53^{e}	.56^{e}	.52^{e}	.51^{e}	.03
Entire trial:						
Gain/pig, kg	10.05^{d}	11.24^{e}	11.25^{e}	11.22^{e}	10.74^{e}	.37
Feed intake/pig, kg	17.21^{d}	19.17^{e}	18.32^{de}	18.15^{de}	17.51^{d}	.55
Gain:feed	.60	.59	.62	.62	.62	.01

[a]Each value is the mean of 5 pens with 6 pigs per pen.

[b]Trial duration of 35 days.

[c]Row means with different superscripts differ significantly ($P<.05$).

Feed efficiency was not affected by diet in the entire trial. A treatment by week interaction was observed for feed intake and feed efficiency. Those pigs fed the whey diets ate more with an improved feed conversion the first two weeks of the trial; however, during weeks three, four, and five of the trial no differences occurred between the basal diet and any of the whey diets.

Trial II

The results obtained by Trial II are shown in tables 5 and 6. Pigs weaned at three, four, or five weeks had similar weights at eight weeks of age, as can be seen by figure 1, and weighed more ($P<.05$) than those weaned at two weeks (table 5). Feed efficiency improved ($P<.01$) as weaning age increased from two to five weeks; no significant difference was observed between those pigs weaned at three or four weeks of age. Across all weaning ages, pigs fed the 20 percent whey diet gained approximately one kilogram more than pigs fed the control diet (table 6). This was statistically significant ($P<.01$). Pigs fed the whey diet also consumed approximately two kilograms more feed ($P<.01$) than those receiving the control diet. However, pigs fed the control diet had an improved overall feed conversion ($P<.01$) over those fed the 20 percent whey diet. In table 7, the data have been further divided in order to visualize the differences seen by weaning age and the whey diet on pig final weights, feed intakes, and feed efficiencies.

TABLE 5. Performance of pigs weaned at two, three, four, or five weeks of age (Trial II).

	Weaning age, weeks[c]				Standard Error
	2	3	4	5	
Initial weight/pig, kg	3.82^{d}	5.50^{e}	7.45^{f}	9.62^{g}	.06
Final weight/pig, kg	14.29^{d}	16.97^{e}	18.79^{f}	17.70^{e}	.35
Feed intake/pig, kg	19.76^{d}	19.09^{d}	17.05^{e}	11.68^{f}	.59
Gain:feed	$.52^{d}$	$.60^{e}$	$.62^{e}$	$.70^{f}$	

[a]Each value is the mean of 4 pens with 4 pigs per pen.

[b]Trial endpoint at 8 weeks of age.

[c]Row means with different superscripts differ significantly ($P<.05$).

TABLE 6. Performance of pigs weaned at two, three, four, or five weeks of age fed a basal or 20% whey diet (Trial II).[ab]

	Treatments[c]		Standard Error
	Basal	20% Whey	
Initial wt./pig, kg	6.55	6.65	.04
Final wt./pig, kg	16.50[d]	17.36[e]	.25
Feed intake/pig, kg	15.97[d]	17.81[e]	.41
Gain:feed	.63[d]	.59[e]	.01

[a]Each value is the mean of 16 pens with 4 pigs per pen.

[b]Trial endpoint at 8 weeks of age.

[c]Row means with different superscripts differ significantly ($P<.05$).

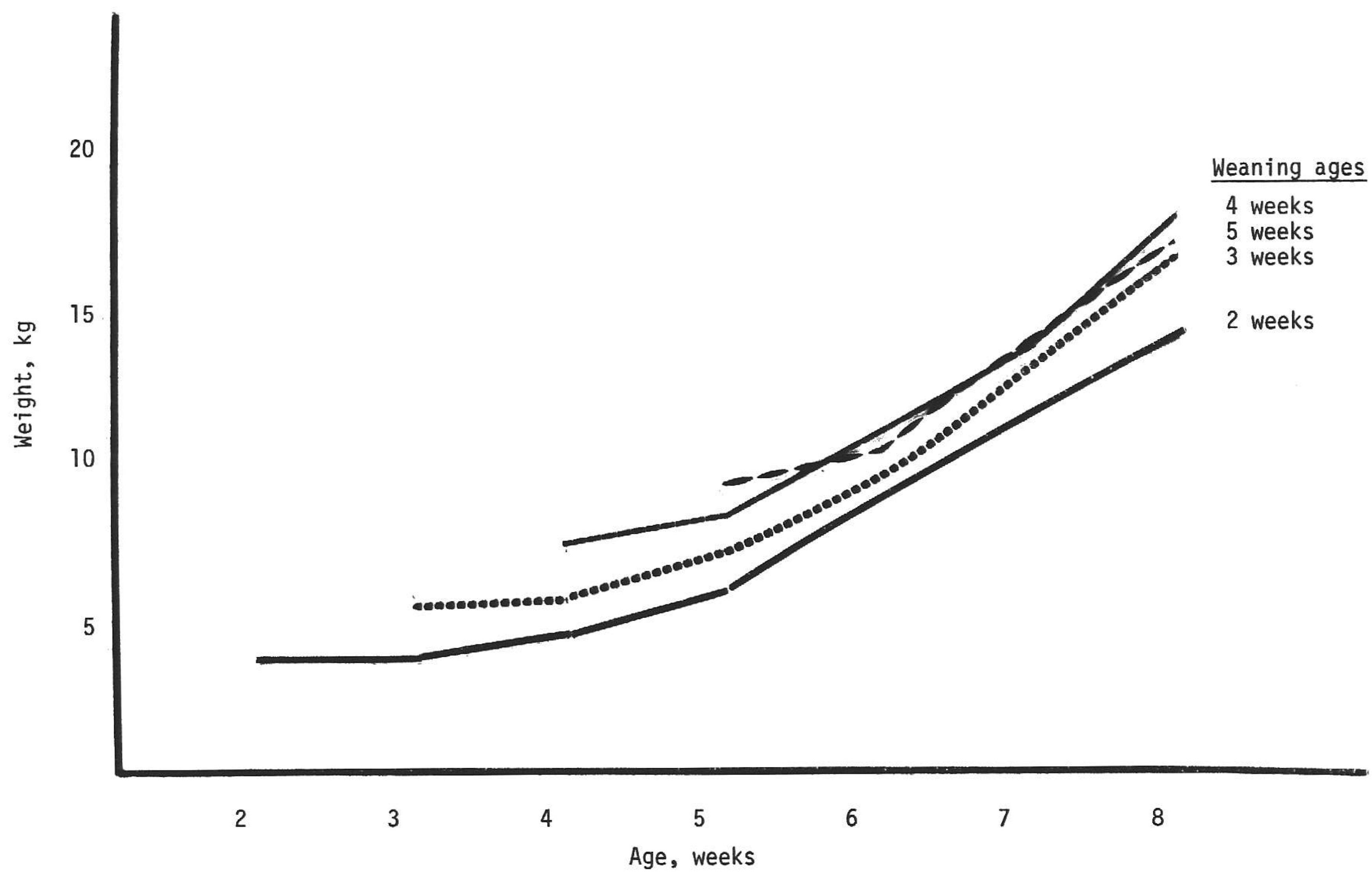

Figure 1. Gains of pigs weaned at two, three, four, or five weeks (Trial II).

TABLE 7. Pig performance according to weaning age and diet (Trial II).[a,b]

Weaning age, weeks	2		3		4		5	
Whey, %	0	20	0	20	0	20	0	20
Initial wt./pig, kg	3.82	3.83	5.48	5.52	7.38	7.51	9.50	9.74
Final wt./pig, kg	13.61	14.95	16.58	17.35	18.58	18.99	17.25	18.14
Feed intake/pig, kg	18.30	21.23	18.50	19.67	16.68	17.41	10.40	12.95
Gain:feed	.54	.50	.60	.60	.65	.59	.75	.65
Death loss[c]	0	4	0	0	0	0	0	0

[a]Each value is the mean of 4 pens with 4 pigs per pen.

[b]Trial endpoint at 8 weeks of age.

[c]Death loss is expressed as pigs per treatment group (16 pigs).

Trial III

Trial III was designed to determine the optimum length of time for feeding a 20 percent whole whey diet. The results are shown in table 8. No statistically significant differences were found in pig gain between diets for the first week of the trial, although a difference was observed in the second week. When the first and second weeks are combined, no significant differences are apparent, although a trend can be observed. Pigs fed no whey or whey for only one week tended to gain less than those fed whey for two weeks. However, by the completion of the 35 day trial, again no differences were seen in weight gain between any of the treatments. Feed intakes per pig across all treatments did not differ significantly for the first week, second week, first and second weeks combined, or the entire trial. Feed conversions differed in week one, weeks one and two combined and over the entire trial; however, these differences did not follow a consistent pattern.

Trial IV

The results of Trial IV appear in table 9. This trial was designed to compare a soybean meal to soy flour, and casein at 25 or 50 percent of the protein source and addition of fat to these diets. The additions of casein provided a linear response ($P<.05$) in gain and feed efficiency during weeks one and two, and overall feed efficiency. Addition of fat vs. no fat addition improved feed efficiency ($P<.05$) for the entire trial. No soy effect was significant over the basal diet. A fat by

TABLE 8. Performance of 22±4 day old pigs fed 20% whey for 0, 1, 2, 3, 4, or 5 weeks of a 35 day trial (Trial III).[ab]

	Treatments[c]						
	Basal	Whey for 1 week	Whey for 2 weeks	Whey for 3 weeks	Whey for 4 weeks	Whey for 5 weeks	Standard Error
Initial wt., kg	6.18	6.15	6.20	6.13	6.22	6.20	.04
Week one:							
Gain/pig, kg	.42	.43	.45	.56	.36	.62	.10
Feed intake/pig, kg	1.31	1.24	1.31	1.31	1.35	1.35	.09
Gain:feed	$.32^{ab}$	$.32^{ab}$	$.35^{ab}$	$.40^{ab}$	$.27^{a}$	$.44^{b}$	.06
Week two:							
Gain/pig, kg	1.62^{a}	1.66^{ab}	1.85^{ab}	1.89^{ab}	2.07^{b}	1.91^{ab}	.09
Feed intake/pig, kg	2.04	2.18	2.35	2.51	2.25	2.38	.16
Gain:feed	.80	.73	.81	.79	.91	.82	.05
Weeks one and two:							
Gain/pig, kg	2.04	2.09	2.30	2.45	2.43	2.53	.19
Feed intake/pig, kg	3.35	3.42	3.65	3.82	3.60	3.73	.24
Gain:feed	$.61^{ab}$	$.57^{a}$	$.64^{ab}$	$.64^{ab}$	$.67^{b}$	$.67^{b}$	.03
Entire trial:							
Gain/pig, kg	12.04	11.68	12.36	12.54	12.33	12.04	.40
Feed intake/pig, kg	18.62	19.15	20.11	20.69	19.09	19.60	.88
Gain:feed	$.65^{a}$	$.62^{ab}$	$.62^{ab}$	$.59^{b}$	$.62^{ab}$	$.62^{ab}$	.01

[a]Each value is the mean of 5 pens with 5 pigs per pen.

[b]Trial duration of 35 days.

[c]Row means with different superscripts differ significantly (P<.05).

TABLE 9. Performance of 18±3 day old pigs fed soybean meal, soy flour, 2 levels of casein and fat addition to these diets (Trial IV).[abc]

Treatments	Basal		Soy flour		6% casein		12% casein		Std. Err.
Fat level, %	0	5	0	5	0	5	0	5	
Initial wt., kg	5.58	5.49	5.36	5.35	5.41	5.36	5.35	5.30	.07
Week one:									
Gain/pig, kg	.39	.32	.34	.24	.35	.01	.75	.75	.20
Feed intake/pig, kg	.84	.89	.83	.86	.89	.72	.95	1.08	.11
Gain:feed	.45	.31	.30	.15	.35	-.05	.74	.62	.23
Week two:									
Gain/pig, kg	1.37	1.29	1.40	1.55	1.36	1.75	1.38	1.59	.22
Feed intake/pig, kg	2.15	2.00	2.20	2.11	2.20	1.98	2.32	1.88	.21
Gain:feed	.58	.72	.63	.73	.62	.83	.60	.89	.12
Weeks one and two:									
Gain/pig, kg[d]	1.64	1.60	1.75	1.77	1.72	1.75	2.11	2.32	.27
Feed intake/pig, kg	2.99	2.86	3.02	2.95	3.07	2.66	3.27	2.95	.30
Gain:feed[de]	.54	.56	.56	.60	.55	.64	.64	.80	.07
Entire trial:									
Gain/pig, kg	11.68	11.22	12.13	11.54	11.66	11.70	11.50	12.36	.49
Feed intake/pig, kg	18.43	17.70	19.52	17.34	17.91	16.92	16.81	16.50	.87
Gain:feed[de]	.64	.64	.62	.67	.65	.69	.69	.75	.02

[a]Each value is the mean of 4 pens with 4 pigs per pen.

[b]Trial duration of 35 days.

[c]Row means with different superscripts differ significantly ($P<.05$).

[d]Casein response is linear vs. the basal ($P<.05$).

[e]Fat addition improved performance ($P<.05$).

protein interaction was not seen; however, pigs fed the higher level of casein with the fat addition tended to outperform those pigs fed any of the other diets. When fat was added to each treatment, feed intake decreased; therefore, feed efficiency was improved.

DISCUSSION

Death loss for all trials combined was .85 percent.

Pigs fed 20 percent whole whey or 20 percent delactosed whey had an improved gain, increased feed intake and improved feed efficiency during the first two weeks postweaning. The advantage observed in gain for pigs fed whey in the diet over those fed the basal diet continued throughout the trial, although no significant differences were observed in feed intake or feed efficiency by the end of the trial. The improvement in gain of one to two kilograms in favor of the whey diets over the basal diet is in agreement with Clarkson (1982) as well as research conducted by Armstrong and Clawson (1980), Crane (1953), Noland et al. (1969), and Kornegay et al. (1974).

No differences were observed in gain, feed intake or feed efficiency between pigs fed whole whey and delactosed whey at 20 percent of the diet. Clarkson (1982) has shown similar results. This suggests that the advantage observed from the addition of whey to the diets of young pigs results from greater digestibility of the milk proteins rather than an increase in lactose contained in the diet. Delactosed whey purchased from a source of known quality resulted in no increase in pig gain over delactosed whey purchased from a source of unknown quality. Hence, the source of whey does not appear to be an important consideration.

Feeding diets containing 20 percent whole whey for the entire 35 day trial did not result in improved performance of pigs when compared to feeding the 20 percent whole whey diet for only the first two weeks of the trial before switching to the basal diet for the remainder of the trial. By using whey in the diet of the young pig for only two weeks, costs to the producer can be reduced.

Pigs were weaned at two, three, four, or five weeks in Trial II and fed either a basal milo soybean meal diet or 20 percent whole whey diet. Final weight and feed intake were increased when pigs were fed the whey diet, although no statistical difference was observed in feed efficiency. Initial weight increased with an advance in weaning age. Therefore, it appears that weaning at three weeks of age is as beneficial as weaning at five weeks.

A 20 percent whey diet was fed to pigs averaging 22 days for zero, one, two, three, four, or the entire five week trial. Gain the first two weeks of the trial favored pigs fed whey the first two weeks over those fed the basal diet or whey diet for only one week. By the end of the trial, this difference was no longer discernable. These data are contrary to Trial I and Clarkson (1982) who conducted other trials at Kansas State University. Leibbrandt et al. (1975) and Smith and Lucas (1957) reported that subsequent weight gain post-weaning favored the heavier or older pig at weaning. The pigs on this trial ranged from 18 to 26 days at weaning and averaged 6.18 kilograms. On the average, pigs in this trial were heavier and older than pigs in previous trials. This is a possible explanation for the lack of response to whey in Trial III.

Trial IV involved the addition of fat to the basal, soy flour, and casein added to the diets at 25 or 50 percent of the protein source. The diet containing 50 percent of the protein source as casein with five percent added fat tended to increase performance over the other diets. These pigs gained more with a lower feed intake which resulted in the best gain to feed ratio of all treatments. Casein is a milk protein containing no lactose. The gains and feed intakes observed in the casein diets are comparable to the whey and delactosed whey diets observed in Trial I, reinforcing the theory that the advantage to feeding milk products to newly weaned pigs is obtained from the milk proteins and not from the lactose content of the diet. Miller et al. (1971) and Maner et al. (1962) reported an increase in digestibility of casein which might pose another possible explanation for an increased response by feeding casein. Pigs fed the soy flour diet tended to have an improved overall gain and feed intake over the basal diet.

A decrease in feed intake in addition to an improvement in feed efficiency was observed with the addition of fat to each treatment. The decrease in intake is attributable to the increase in energy density of the diet with added fat. Problems were encountered in feeder management with the fat additions to the diets. Diets containing fat at the five percent level in this trial tended to bridge in the feeder and had to be manually fed down daily. After approximately six to seven weeks of age, the pigs could consume more than the trough would hold; therefore, the data obtained from the final two weeks of the trial may have been adversely affected.

SUMMARY

Four trials were conducted involving 586 pigs to study the effects of additions of whole whey, partially delactosed whey, soy flour, casein at two levels, and fat in the diet on growth, feed intake and feed efficiency. In addition, the optimum length of time for the inclusion of whey in the diet and the relationship of age at weaning to utilization of a whole whey diet were investigated.

The addition of milk products to the diets fed increased performance of newly weaned pigs over the basal diet. The magnitude of this difference ranged from one to two kilograms by eight weeks of age. Feeding 20 percent whole whey for the entire 35 day trial did not significantly improve performance over the same diet fed for only two weeks and then fed the basal diet for the duration of the trial. Feed costs were decreased by feeding the more expensive whey diet for only two weeks.

Two sources of delactosed whey were compared. One source was obtained from a commercial company (Land O'Lakes) and was considered to be of high quality; whereas, a second source was obtained from a local milling company and considered to be of unknown quality but similar to the product many swine producers would purchase on the market. No significant differences were observed between the pigs fed the two sources of delactosed whey in gain, feed intake or feed efficiency. Therefore, origin of the delactosed whey appears to have

little effect on performance in this study. In addition, no difference was observed between the different whey products. Pigs fed whole whey performed similarly to those fed partially delactosed whey.

When pigs were weaned at two, three, four, or five weeks of age and fed either a basal diet or a 20 percent whole whey diet, those fed the whey diet were superior in performance. As in the previous trial, a one to two kilogram advantage was observed from feeding a diet containing 20 percent whey. Pigs weaned at three or five weeks of age performed similarly and better than those weaned at two weeks, indicating that pigs can be weaned as efficiently at three weeks as those weaned at five weeks. Weaning at three weeks might increase sow productivity.

The addition of fat to the diets of newly weaned pigs resulted in a decrease in intake but an improvement in feed efficiency. The addition of soy flour did not result in any improvements over soybean meal. Casein at the level of 25 percent of the protein source in the diet does not appear to make an improvement in performance; whereas, casein added at 50 percent of the protein source resulted in improvement in pig performance.

The data obtained in these trials should be of benefit to swine producers in selecting the optimum nursery diet in order to minimize or eliminate a postweaning growth check. Good management practices should not be ignored; however, as was apparent when some of the diets, especially those containing fat, exhibited problems of bridging over in the feeder. It may be possible to pellet high-fat diets to help prevent this problem.

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EFFECTS OF DIET ON PERFORMANCE OF PIGS WEANED AT THREE WEEKS

by

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AN ABSTRACT OF A MASTER'S THESIS

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Four trials were conducted involving 586 pigs, averaging 21 days of age at weaning, to study the effects of additions of whole whey, partially delactosed whey from two sources, soy flour, casein at two levels, and fat in the diet. The effect of diet on growth, feed intake and feed efficiency was investigated. In addition, the optimum duration to feed whole whey diets to young pigs and the relationship of age at weaning to the effectiveness of utilization of a whole whey diet were studied.

The addition of whey to the diets increased performance of the pigs by one to two kilograms at eight weeks of age. Pigs fed 20 percent whole whey diets for only two weeks performed as well as those fed 20 percent whole whey for five weeks. No differences were observed in pig performance between pigs fed whole whey and partially delactosed whey diets. Partially delactosed whey from two different sources produced similar response.

Pigs weaned at three and five weeks of age were similar in performance but outperformed those weaned at two weeks by the completion of the trial (eight weeks of age). Pigs fed a 20 percent whole whey diet (weaned at two, three, four, or five weeks) outperformed those fed the basal diet.

The addition of five percent fat to the diet decreased feed intake and improved feed efficiency. Additions of soy flour and casein at 25 percent of the protein source resulted in no improvement over the basal diet. Casein at 50 percent of the protein source improved pig performance over the basal, soy flour and casein at 25 percent of the protein source.