PROTEOLYTIC ENZYMES IN BABY PIG NUTRITION

by

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INTRODUCTION

Since 1950 a considerable amount of emphasis and research has been directed toward the development of techniques and rations for early weaning of baby pigs. Dry rations have been developed which have proved successful in the early weaning of pigs one to two weeks of age, weighing between 5 and 10 pounds in body weight, Lewis *et al.* (1952), Crampton (1953), Crane (1953), and Speer *et al.* (1954).

In early work the rations contained essentially dried skimmilk as the source of protein and simple sugars as the primary source of carbohydrates. Since dried skimmilk is a very expensive ingredient and needed in human foods, other sources of protein have been sought.

Early weaned baby pigs which received soybean protein as the only source of protein grew very slowly, Catron *et al.* (1955). The difference in growth could not be explained on the basis of palatability of the two diets since the average daily feed consumption of baby pigs fed diets containing soybean protein was 1.68 pounds as compared to 1.75 pounds for those receiving dried skimmilk diets. This difference in growth could not be corrected by adding unidentified growth factors and twice the known vitamin requirements.

The feeding of partial fractions of dried skimmilk to baby pigs by Hudman (1956) has shown that both casein and

(5) the feeding of pepsin (1:3000) at different levels to baby pigs under various conditions.

lactose are important in obtaining superior growth and feed efficiency from dried skimmilk. It was also shown that levels of 0, 20, and 40 percent dried skimmilk in baby pig rations gave a linear increase in growth and feed efficiency.

A diet containing soybean protein as the sole source of protein has been shown to give excellent growth when fed to pigs weighing 25 pounds or more, Barnhart (1954).

Lewis (1956) has presented evidence that the difference in growth of the baby pig (under 5 weeks of age) fed soybean protein as compared to milk protein is due, in part, to the deficiency of proteolytic digestive enzymes in the baby pig.

Since research shows the baby pig to be deficient in certain proteolytic enzymes, it was the purpose of this research to determine the degree of proteolytic enzyme insufficiency of the baby pig and to improve the utilization of soybean protein through the use of proteolytic enzymes.

This problem was approached in five ways: (1) the feeding of various proteolytic enzymes at various levels; (2) the feeding of soybean protein hydrolyzates produced with different proteolytic enzymes; (3) determination of the digestibility of soya protein fed either in combination with or without the addition of proteolytic enzymes; (4) assay of the proteolytic activity of the ingesta and the proteolytic secretory glands of baby pigs sacrificed at different ages;

REVIEW OF LITERATURE

In the review of literature, only limited amounts of information could be found which dealt with this subject on swine. Therefore, this review of the literature has been broadened to include the young of other species of animals. It is recognized that there may be a difference between species but it is also true that many similarities do exist.

Digestive Enzyme Secretion in the Young

Gastric secretion

Beaumont (1834) showed that the gastric juice has protein-splitting properties. Two years later Schwann (1836) named the active principle pepsin. Heidenhain (1883) was the first to conclude that pepsin is produced in the chief cells of the stomach. He also observed that changes took place in the chief cells during different stages of digestion with varying pepsin content of the gastric mucosa.

Hammarsten (1874) found no pepsin in a human fetus of seven months but observed that the gastric mucosa of full-term infants was richer in pepsin than that of any newborn animal (dog, cat, rabbit) examined by him. Schmidt (1914) examined the pepsin contents of the stomachs of four newborn infants who had died before or shortly after birth. Of these, three were full-term infants and one a premature infant. He found pepsin values in two of the full-term cases corresponding, according to his calculations, to 20 percent of the values in an adult. The premature infant had a pepsin content corresponding to 50 percent of the full-term cases. The third full-term infant showed considerably lower values than the premature infant. Keene and Hewer (1929) reported pepsin to be present in the fetal stomach as early as the 6th fetal month and hydrochloric acid was found to be present in 11 of 15 full-term fetuses.

Werner (1948) studied the gastric mucous membrane of 70 newborn infants (47 premature) and examined them histologically for the occurrence and amount of pepsinogen granules. He reported that premature infants showed little or no pepsinogen granules in their chief cells. In the full-term infant, however, the granules were always present and in much greater quantities than in any of the premature cases. The peptic activity of these full-term infants per unit surface area corresponds to only about 10 percent of that of a human adult or of a full-grown pig.

Needham (1931) who has given an excellent review of the role and development of enzymes in prenatal life thinks that the bulk of the literature on this subject is not very accurate since most of the work has been conducted by medical investigators using questionable methods of analysis on infants that had been dead for some hours. Smith (1951) in a review of the enzyme development in the fetus and newborn infant believes that the normal infant has the enzymes available to digest all foods with the exception of complex carbohydrates. In agreement with this Hirschowitz (1957) states that once the fetus has fully matured, there seems to be no reason to believe that the peptic cell should secrete pepsin at a lower concentration in the child than in the adult.

In contrast to man, animals have been examined in detail immediately after being sacrificed. Hammarsten (1874) observed that the gastric mucosa of dogs contains no pepsin until two weeks after birth. These findings were supported by Wolffhügel (1876), Langendorff (1879), and Gmelin (1904). Gmelin also made histological studies of the gastric mucosa and found no granules in the chief cells until two weeks after birth.

Sewall (1878) investigated the fetus of sheep and reported that the chief cells are first differentiated when the fetus is about 5.5 inches in length (mature fetus about 20 inches). He also showed that the fetus 7.5 inches in length showed peptic activity of the gastric mucosa. Sewall further stated that the parietal cells appeared comparatively early and increased in number up to the time of birth, when they were relatively as numerous as in the adult stomach.

Hill (1956) reported that it was possible to distinguish the future peptic cells in the 75-day-old fetus of sheep and by 85 days many of the peptic cells contained poorly defined pepsinogen granules. In contrast to Sewall, Hill (1956) found that the parietal cells were very sparse until birth and increased rapidly during the first 48 hours of life. These findings were supported by the fact that the abomasal contents during fetal life and at time of birth were close to pH 7.0. Thus, even though pepsinogen is present in the newborn lamb, the pH conditions are not suitable for the activation of pepsin until 24 to 36 hours after birth, when the increasing number of parietal cells bring about an increase in the acidity of the abomasal contents by the secretion of hydrochloric acid.

Early work by Hammarsten (1874) has shown that the cat is low in pepsin activity during the first week after birth but rich in pepsin after ten days. Sewall (1878) could demonstrate no digestive action on protein with extracts from the fetal stomach of kittens prior to birth. Toldt (1880) observed that the differentiation of cells in the gastric glands of kittens was not complete until about one week after birth. These findings are in good agreement with those of Hammarsten (1874).

No pepsin was found in the rabbit immediately after birth according to Wolffhügel (1876). Werner (1948) in a histological study found no growth of the chief cells in the newborn, whereas Hammarsten (1874) reported a considerable amount of pepsin in two-week-old rabbits.

In the rat, Langendorff (1879) found pepsin to be present immediately before birth. Likewise, Werner (1948) found pepsinogen granules in the rat at birth with the quantity increasing during the first day of life. Some preliminary studies were made on rats by Hill (1956). Five rats varying in age from 20 hours to 25 days were examined. Histologically the gastric mucosa of the newborn animal was poorly developed and no specific cell differentiation could be made. At six days of age only occasional parietal and peptic cells could be defined. At 12 to 18 days the glands were well defined and numerous parietal cells and a few peptic cells were observed. At 25 days the mucosa of the young resembled that of the adult rat.

Grützner (1875) demonstrated that the gastric mucosa of the bovine contained peptic activity as early as the third embryonic month. Langendorff (1879) has substantiated these findings. Kastelic *et al.*(1950) working with synthetic milk for calves postulated a pepsin and hydrochloric acid insufficiency. However, Huber (1958) has sacrificed calves from 1 to 42 days of age and reported that the pepsin activity of the stomach mucosa was relatively high at birth and decreased slightly with age.

Sewall (1878) found no pepsin activity in the gastric mucosa of fetal pigs five to seven inches in length. Langendorff (1879) and Mendel (1906) reported similar results on fetal pigs just prior to their birth. A gastric fistula was employed by Kvasnitskiĭ and Bakeeva (1940) to study the development of the baby pig's ability to secrete pepsin and hydrochloric acid. The gastric secretion was found to contain rennin and pepsin from the first day after birth but the hydrochloric acid was not present until 20 to 30 days of age. The stomach contents were acid prior to the 20th day but the authors attributed this to the contents of the feed and to the microflora rather than to the secretion of hydrochloric acid. After the onset of hydrochloric acid secretion, the authors found that its increase was not linear as the secretion dropped off prior to weaning.

Liu et al. (1955) recorded average pH values of 4.2, 3.5, 3.9, 3.6, and 4.0 on six hour fasted baby pig stomachs at 1, 7, 14, 21, and 28 days of age respectively (each group represents six pigs). These pigs had access only to their mother's milk. A lower pH value has been reported in baby pigs by Cunningham and Brisson (1957). They found that the pH values of the stomach contents of nine nursing pigs, 12 hours to 7 days old, ranged from 1.85 to 3.20 and the pH values of the stomach contents of six other two- to three-week-old nursing pigs were in all cases above 3.5.

Lewis et al. (1957) have reported the pepsin activity in the stomachs of pigs ranging from 1 to 42 days of age. The results of their trials are presented, in part, in Table 1. The authors state that at the time of birth there is negligible pepsin activity present in the stomach of the pig. The pepsin activity remains low until the pig is about three weeks of age, after which there is a linear increase in the quantity of pepsin activity present.

These authors suggest that these low levels of pepsin activity may be one cause for the poor utilization of vegetable protein by early weaned pigs up to three or four weeks of age.

Pancreatic secretion

Langendorff (1879) from an experimental investigation of six human fetuses of four to six months found that only half of the fetuses contained trypsin. In 17 human fetuses, Keene and Hewer (1929) made a qualitative test for trypsin activity of the pancreas. They found trypsin to be present from the fourth fetal month on. In histological studies of the pancreas they found granular formation in cells as early as the third fetal month. Klumpp and Neale (1930) investigated the duodenal enzyme activity of 74 children ranging from 1 month to 12 years of age. The children were fed a test meal of 30 to 60 cubic centimeters of 40 percent cream and after a period of time a sample of ingesta was removed by a tube inserted into the duodenum via the throat and stomach. In contrast,

Table 1. Pepsin activity of stomach tissue extracts from baby pigs[a]

Litter No.	1	7	14	Age, days 21	28	35	42
	Units of pepsin activity/G. of dry weight of tissue						
1	0.08	0.22	0.21	0.47	0.78	1.4	--[b]
2	0.08	0.21	0.20	--	--	--	--
3	0.04	0.22	0.21	0.31	0.88	2.1	1.7
4	0.08	0.22	0.21	0.63	1.00	1.0	1.7
5	0.10	0.18	0.19	0.55	0.38	0.9	--
6	0.07	0.14	0.17	0.73	1.45	1.5	--
Av.	0.07	0.20	0.20	0.55	0.90	1.4	1.7

[a]Condensed from Lewis et al. (1957).

[b]Blanks indicate pigs were not available.

amylase activity was found to be very low in children under one year of age. However, in children from 1 to 12 years the amylolytic activity was higher than the average for adults. Studies on the lipolytic activity of these same children showed a consistently low trend throughout childhood. Extremely low values were observed in children under one year of age. These findings have been verified by Andersen and Dueholm (1949).

Werner (1948) studied the proteolytic activity of the pancreas in 24 infants that had died. Sixteen of these infants were premature. The author has stated that the proteolytic activity of the pancreas of full-term infants in some cases corresponds to 85 percent of that of a full-grown pig. However, the premature infant weighing less than 2000 grams at birth showed a very low proteolytic activity of the pancreas. From these observations it was pointed out that the premature infant is poorly equipped to digest protein. Berkman (1951) reported that the amylase, lipase and trypsin in duodenal juice was much lower in healthy children from 5 to 18 months of age than in adults. There was a greater difference in the trypsin activity between the young and adult than there was in the amylase and lipase activity between the young and old. Carnevale et al. (1954) in a study of 7 premature, 8 newborn, and 18 infants from 2 to 12 months of age found that the amylase activity was very small in the premature infants, and, in some cases, no activity was detected in the first week of life. The amount of amylase activity did increase with age. The full-term infant in most instances possessed a higher amylase activity than did the premature infant. The lipase activity was found to be lowest in the premature infants, higher in the newborn infants born at term and highest in the older babies. The proteolytic activity was always present and the difference between groups was small. However, the activity increased somewhat with age.

Guilbert and Barbero (1954) in a review of the literature have stated that in their estimation the proteolytic function of the digestive tract in premature and newborn infants is essentially qualitative. Madey and Dancis (1949) in a study of 16 premature infants reported normal trypsin values.

Recent work by Huber (1958) has shown that the protease activity of the pancreas of calves was low at the first day of age but increased sharply in the first week where it remained fairly constant to the sixth week of age.

In a study of induction of pancreatic enzymes in rats, Grossman _et al_. (1942) found that a diet high in carbohydrates caused an increase in amylase activity and a decrease in trypsin and lipase activities while a high fat, low protein diet decreased all of the pancreatic enzymes.

In work with rats Magee and Anderson (1955) have reported that rats receiving casein have a higher trypsin and lipase activity than rats receiving gelatine or zein as a source of protein. Magee and White (1958) in later work have found that rats fed diets alternating between high (18 percent) and low (6 percent) protein have a higher proteolytic enzyme activity of the pancreas than rats fed the low (6 percent) protein ration. Rats fed the 18 percent protein diet showed a higher amylase and protease activity than the rats fed the 6 percent protein diet. The pancreatic amylase and protease activity of rats fed the 15 percent protein diet was about the same as those fed the alternating high, low protein diets.

Daly and Mirsky (1952) found that the pancreatic glands of adult white mice contained about 20 percent secretory enzymes on a dry weight basis.

In studies with the suckling pig, Kitts _et al_. (1956) reported that the amylolytic activity of pancreatic glands was very low at one day of age and increased markedly with advancing age. On the other hand, they found that the lipolytic activity of the digestive system of the young pig is of a high order at birth and remained high with increasing age. Hudman _et al_. (1957) have also found that the amylase activity of the baby pig is very low at birth and increases significantly with age. The authors also reported that the maltase activity of the dry pancreatic tissue of the baby pig was so low that the role of pancreatic maltase is probably of little significance.

Experimental investigations by Lewis _et al_. (1957) have shown that the baby pig is much like the human infant in its trypsin secretion. The results of these trials are presented, in part, in Table 2. There was no definite increase in trypsin activity per gram of dry tissue with increasing age. There was an increase in trypsin activity per animal but this was due largely to the increased size of the pancreas and not to a larger amount of enzyme produced per unit of tissue. These results have led the authors to conclude that the young pig, at birth, is capable of producing relatively large amounts of trypsin. However, the pig to pig variation was high.

In contrast to the results reported by Lewis _et al_. (1957), Catron _et al_. (1958) have determined the protease activity of the pancreas and the small intestinal contents of baby pigs ranging in age from birth to 56 days of age. They found: (1) that the protease activity per gram of wet pancreatic tissue of the pigs which nursed their mothers increased approximately four-fold from birth to 56 days of age; (2) that the protease activity per gram of wet pancreatic tissue of pigs which were weaned at one week of age showed an increase of approximately three-fold from birth to 56 days of age; (3) that the protease activity per gram of intestinal content (wet) of these same pigs increases approximately eight-fold from birth to 56 days of age.

Although the investigations reported above are not always

Table 2. Trypsin activity of pancreatic tissue extracts from baby pigs[a]

Litter No.	Age, days 1	2	3	4	5	6	7
	Units of trypsin activity/G. of dry weight tissue						
1	1.00	0.66	4.20	1.70	0.78	1.40	--[b]
2	0.39	0.78	0.72	--	--	--	--
3	2.60	0.52	0.54	0.22	0.38	1.70	0.28
4	0.36	0.15	2.20	0.38	0.84	0.11	4.20
5	1.10	0.34	0.52	0.25	0.36	0.42	--
6	0.35	0.80	0.30	0.28	0.34	1.10	--
Av.	0.97	0.64	1.41	0.57	0.54	0.95	2.24

[a]Condensed from Lewis et al. (1957).

[b]Blanks indicate pigs were not available.

consistent, it appears that the digestive enzymes are low early in life and increase as the individual grows older.

Feeding of Enzymes

Wyzan et al. (1951) fed unheated soybean oil meal as a source of protein to adult dogs and added to the ration papain at the rate of one percent of the protein. The addition of papain to the ration improved protein digestibility from 54.7 percent in the ration containing inactivated papain to 63.1 percent in the ration containing active papain. The biological value was not affected by the addition of papain.

Schmidt et al. (1937) have administered oral pancreatin to dogs which have been deprived of their pancreatic juice. Five dogs were placed on a submaintenance diet of 200 grams of lean beef for three consecutive seven-day periods. Twenty-five grams of pancreatin (2 x U.S.P.) per day were fed during the second seven-day period. Four dogs fed a maintenance diet of 600 grams of beef heart were treated in a similar manner. Fecal analysis showed that pancreatin decreased the elimination of nitrogen and fat approximately 60 and 59 percent, respectively, regardless of the quantity of feed eaten. It was concluded that pancreatin when given in adequate amounts will effectively reduce nitrogen and fat loss in the feces of dogs having achylia pancreatica.

Williams and Knodt (1951) conducted an experiment in which pancreatin and papain powder was added to a milk replacement diet of young calves. Calves receiving 200 grams of pancreatin per day gained 14.7 pounds during the 49-day trial, whereas calves receiving papain at the rate of either 200 or 50 grams per day gained 28.9 and 32.8 pounds respectively. Even though the research workers had no control ration, they concluded that the addition of papain and pancreatin to the milk replacement diet was deleterious in that growth was poor and feed consumption was low.

Noller and Huffman (1955) found that calves fed a milk replacement diet containing plant protein gained 9 pounds during the first 30 days as compared to 22 pounds for calves receiving milk during the same period of time. After the first 30-day period, which the authors designated as the critical period, the weight gains of the calves fed the two types of diets are about the same. Ratcliff and Jacobson (1957) added animal diastase and pepsin to diets of young calves. The inclusion of the enzymes in the ration decreased gains slightly. However, the feed consumption of the calves receiving the supplemented enzymes was slightly less than the nonsupplemented.

In a recent report, Fries _et al_. (1958) have added pepsin (1:3000) to a milk replacement diet at the rate of 0.5 percent of the ration. Three types of milk replacers were tested; soybean flour-corn, soybean flour-cerelose, and skimmilk-cerelose. The addition of pepsin increased daily gains but the increase was not statistically significant. The calves receiving the soybean flour-cerelose gained the slowest of the three groups and also showed the greatest response to pepsin supplementation.

Davison (1942) fed amylase and trypsin to 23 infants suffering from digestive disturbance. Sixteen of the 23 infants were apparently benefited by the consumption of the enzymes. Their daily weight gains varied from 15 to 112 grams, the appetites usually improved, and their stools generally became formed and smaller in amount.

Clickner and Follwell (1926) fed levels of 0, 1, 2, 3, and 5 percent of "protozyme" to Leghorn pullets raised to 20 weeks of age. The weights of the pullets at the end of the 20 weeks were 2.65, 2.80, 2.89, 3.03, and 3.24 respectively. It is tempting to speculate that the improvement in gains might have been due to B-vitamins or unidentified growth factors since little was known at that time about the vitamin requirements.

Hastings (1946) reported an improvement in chick growth and feed efficiency when an enzyme preparation, which had been produced by a fungus growth on wheat bran, was added to a high fiber mash. The results showed an increased gain of six ounces and a feed saving of 0.5 pounds per pound of gain. No advantage was found by using the enzyme preparation in a low-fiber mash. Patrick (1955) was not able to show an improvement in gains of chicks from the addition of several proteolytic enzyme preparations. Balloun and Baker (1957) have conducted two experiments in an effort to determine if the addition of a proteolytic enzyme to the diets of chicks will improve weight gains and feed efficiency. In the first experiment, pepsin (1:3000) was fed at 0.25, 0.50, 0.75, and 1.0 percent of the diet; pancreatin, Rhozyme B-6, Lederle enzyme X-108, and Rhozyme P-11 were fed at 1.0 percent; ficin was fed at the rate of 0.1 percent. No improvement in growth or feed efficiency was obtained from the addition of any of the enzymes. The supplementation of ficin reduced gains and feed efficiency severely. In the second experiment, a 3 x 3 factoral experiment was conducted using three levels of protein (21.0, 18.5 and 16.0 percent) and three levels of pepsin (none, 0.5, and 1.0 percent). No improvement in weight gain or feed efficiency was obtained from the addition of pepsin to the three levels of protein. The authors concluded that the baby chick has a well-developed proteolytic enzyme system at birth.

Jensen _et al._ (1957) have reported that the addition of a mixture of Takadiastase and Clarase when added to a ration containing pearled barley increased growth and feed efficiency of chicks fed from birth to four weeks of age. The levels of the enzymes fed was none, 0.5, 1.0, and 2.0 grams per pound of feed. The following year Fry et al. (1958) reported that the supplementation of Clarase 300 at the rate of one gram per pound of feed containing barley improved weight gains and feed efficiency of poults. However, the supplementation of the enzyme to rations containing wheat or corn had little effect on poults fed from birth to 27 days of age. Miner and Denton (1957) reported from their feeding trials with poults that little or no benefit was obtained by the supplementation of a practical type corn-soybean oil meal diet with pepsin, lipase, or amylase.

Culbertson et al. (1926) in an early experiment have reported that "protozyme" fed at the rate of 4 pounds per 100 pounds of supplement increased average daily gains of finishing hogs from 1.61 pounds for the non-supplemented to 1.71 pounds for the supplemented hogs. The addition of the enzyme improved feed efficiency only slightly. Lewis et al. (1955) have shown that the supplementation of proteolytic enzymes to semi-purified diets containing Drackett C-1 assay protein and casein improves weight gains and feed efficiency of early weaned baby pigs fed from 1 to 5 weeks of age. The average of three experiments showed that the combination of pepsin and pancreatin improved gains from 10.0 pounds for the nonsupplemented, to 12.7 pounds for the supplemented pigs, or a relative improvement of 12.7 percent. Likewise, the feed per pound of gain was improved (20.9 percent) from 2.49 for the nonsupplemented, to 2.06 for the supplemented. Pancreatin and pepsin supplemented separately also improved weight gain and feed efficiency consistently. Dietary supplementation of pepsin and pancreatin in combination to pigs which were 53 days of age did not improve weight gain or feed efficiency significantly. In further studies Lewis (1956) has reported that baby pigs reared individually in a relatively disease-free building failed to show a consistent improvement in gains and feed efficiency. A digestibility study gave variable results which did not allow for definite conclusions. Lewis (1956) also conducted an experiment in which a laxative, cascara, was added to the diet in order to determine if the rate of food passage through the pig influenced the response to enzyme supplementation. Baby pigs receiving the laxative grew somewhat faster during the first two weeks on experiment when supplemented with one percent pepsin (1:3000). However, after four weeks on experiment, five weeks of age, the advantage was lost. This loss was believed to be due to an acquired resistance to the action of cascara by the baby pig.

Alsmeyer *et al*. (1957) have reported an improvement in feed efficiency but no improvement in growth of baby pigs when pepsin (1:3000) plus pancreatin (N.F.) were supplemented at the rate of one percent of the ration. Hudman and Peo

(1956) showed that the supplementation of pig starter creep-fed with 0.25 percent pepsin improved the growth rate of pigs which had been sow-raised but the supplementation did not improve the performance of early weaned pigs.

Cunningham and Brisson (1957) and Meade (1957) could not show a consistent improvement in the performances of baby pigs when pepsin was supplemented to the ration.

Feeding of Protein Hydrolyzates

Magnusson (1945) conducted experiments involving 150 premature infants. He reported that the supplementation of the mother's milk with a pancreatic digest of casein increased the growth of infants over those which had received whole casein as a supplement.

Werner (1948) judging from his own studies of the digestive enzyme system of infants advised the use of predigested protein in supplementation of infant diets. However, Madey and Dancis (1949) have stated that the gain in weight of infants whose diet was supplemented with casein which had been digested with trypsin was no greater than those of infants supplemented with whole casein. They concluded that it is unnecessary to supplement the diet of the premature infant with casein which has been predigested. Heck and Pelikahn (1953), from their experimental findings, have suggested the use of protein hydrolyzates to premature infants in need of protein in addition to that found in the mother's milk. They also advise the use of a commercial enzyme preparation to older infants with chronic gastric disorders.

An experiment in which casein digested with Rhozyme P-11 and protease 15 was fed to dogs and rats has been reported by Chow (1948). The nitrogen balance and protein efficiency were found to be essentially the same for the digested casein and nondigested casein. The authors concluded that neither the degree of hydrolysis nor the mode of attack affected the nutritional value of the hydrolyzates as long as the essential amino acids were not destroyed.

The work of Mueller et al. (1940) showed that rats fed casein digested with fresh pancreas extract was nutritionally equal or superior to casein itself. Food intake showed that per gram of nitrogen ingested casein gave 9.75 grams gain in weight, whereas the casein digest gave 11.9 grams gain in weight. Cox and Mueller (1944) have used fresh pork pancreas to digest casein, lactalbumin, and beef serum protein. Rats were fed the digested and nondigested forms of the three sources of protein. Growth of the rats receiving the digested lactalbumin and beef serum protein was greater than for the nondigested proteins. However, the weights of the casein hydrolyzate fed rats were much lower than the weights of rats fed nondigested casein.

Wissler et al. (1947) have stated that a protein hydrolyzate should be derived from a high quality protein and should be prepared with a minimum of damage to any of its essential amino acids. These authors conducted an experiment in which young adult male rats were protein-depleted and fed different sources of protein which had been predigested with either acid or an enzyme. In general, they found that the hydrolyzates prepared from high quality animal proteins by enzymatic hydrolysis offer the greatest promise.

Patrick (1955) has reported that enzymatic digest of casein supplemented to a peanut meal ration did not always give as good growth supplementary value as regular casein when fed to chicks. The longer the digestion time of casein the lower the growth promoting value. The author suggests that this lower value may be due to a destruction of amino acids or some essential peptide.

The feeding of soybean hydrolyzates digested with pancreatin has been reported by Lewis (1956). Drackett C-1 assay protein and soybean oil meal (50 percent protein) were digested with pancreatin (1.4 x U.S.P.) for approximately 0, 2, 4, 8 and 16 hours. Pancreatin was added to the solution at the rate of two percent of the solids. The predigestion of soybean proteins for 2, 4, or 8 hours improved weight gain and feed efficiency over pigs receiving the zero-hour digests. In both cases the 16-hour digests failed to equal the zero digests. These results verify those of Patrick (1955), mentioned earlier, where he reported that the longer the digestion time of casein the lower the growth promoting value.

Cunningham and Brisson (1957) have reported that soybean protein predigested with pepsin for 24 hours resulted in severe diarrhea and death of two-day-old pigs, whereas pigs receiving regular soybean protein survived to the end of the four-week test. It should be pointed out that in order to digest protein with pepsin the pH value of the solution must be near one to obtain maximum digestion. Therefore, a large quantity of acid must be added to the solution for digestion. It is probable that the acid or the salt of the acid could have been the cause for the diarrhea and death of the pigs.

Mareček and Herbrychová (1954) reported the digestion of animal and plant proteins by pepsin, trypsin and pancreatin. The hydrolysis of animal proteins after a definite period of time gave rise to all amino acids approximately in the same ratio as found in the original protein, whereas hydrolysis of plant proteins proceeded in such a way that the amino acids glutamic and aspartic acids, cystine, serine, glycine, and theonine were less represented. In general, animal proteins were more easily digested by pepsin, trypsin, and pancreatin than were the plant proteins.

Protein Digestion by the Young

There has been a considerable amount of work done on the digestibility of various nutrients in man and animals. It is the intentions of this author to present only a portion of the work as it relates to the proteolytic enzyme systems and to the supplementation of enzymes.

Hartmann and Wells (1948) presented data showing that the fetal rat, with the placenta still functioning, has the ability to digest in part such induced foods as milk and starch, but the ability to digest meat is less well developed.

Arnold et al. (1951) have starved young adult rats for 24 hours and then given them a diet containing casein and glucose with and without papain. The rats were sacrificed 2.5 hours later and the extent of protein digestion was determined. Papain increased the digestion of the casein 1.5 to 2.1 times. Similar results have been reported by Hinkel and Arnold (1951). Hwang and Ivy (1951) reported that papain has been used extensively as an anthelmintic and also as an aid in digestive disturbances.

Gordon et al. (1937) have reported that premature infants fed cows milk utilized 70.9 percent of the protein, whereas infants fed cows milk utilized 70.4 percent of the protein. Levine (1948) has stated that the digestibility of protein is high, 90 percent, in healthy infants and children.

As mentioned earlier, Wyzan _et al_. (1951) found that the addition of papain to the diets of dogs receiving unheated soybean meal increased protein digestion from 54.7 percent in the ration containing inactivated papain to 63.1 percent in the ration containing active papain.

Noller _et al_. (1956) studied the apparent digestibility of protein in calves fed whole milk, evaporated milk, and milk replacement rations containing plant proteins. When calves were 12 days of age the average apparent digestibility of protein for whole milk, evaporated milk, and plant protein milk replacers was 81.2, 58.3, and 2.5 percent respectively. When the calves were 36 days of age the corresponding apparent protein digestibilities were 93.0, 90.0, and 40.4 percent.

Lewis (1956) has reported that the apparent digestibility of soybean protein is higher in pigs five weeks of age as compared to pigs two weeks of age. The addition of one percent pepsin (1:3000) did not appear to influence the digestibility in his experiments. Neagle _et al_. (1958) have found similar results in studies with proteolytic enzymes of fungal origin. The apparent digestibility coefficients for two- and five-week old pigs were approximately 82 and 86 percent respectively.

Cunningham and Brisson (1957) were unable to show an improvement in the apparent protein digestibility of a soybean protein ration containing pepsin and pancreatin when fed to early weaned pigs. Contrary to the findings of other researchers, these workers found that the apparent digestibility of protein in the one-week-old pig was higher than that of the four-week-old pig.

Lloyd <u>et al</u>. (1957) have compared the apparent digestibilities of crude protein in three and seven-week-old pigs and found them to be 85.3 percent and 88.5 percent respectively. Hays (1957) has compared the apparent nitrogen digestibility between soybean oil meal and dried skimmilk diets fed to early weaned baby pigs. The apparent nitrogen digestibility coefficients for soya protein were 77 and 82 percent for the two and five week age periods, respectively, whereas the digestibility of the milk protein changed very little with age (95 percent as compared to 96 percent for the two and five week age periods, respectively).

Pellett (1957) has reported on an experiment in which a pig was fed a diet containing 4.5 percent protein for six months. The pig was then placed on a 7.5 percent protein diet for two weeks during which time the apparent digestibility of the protein rose from 56 to 84 percent. Five weeks after the pig was returned to the 4.5 percent protein ration, the apparent digestibility of the protein was down to its original level.

Skipitaris <u>et al</u>. (1957) found that the addition of 16 percent sucrose to a barley ration lowered the apparent digestibility of crude protein by five percent in pigs.

EXPERIMENTAL

The 15 experiments reported are on file in the Swine Nutrition Section of the Animal Husbandry Department, Iowa State College, Ames, Iowa. These are numbered as Experiments 683, 705, 727, 735, 762, 780, 795, 800, 843, 864, 884, 891, 910, 914, and 929.

Since much of the management and procedure practices were common to most of the experiments, the following information is presented to avoid repetition.

The pigs used in all of these experiments, with the exception of Experiments 795, 843, and 910, were from crossbred sows (Farmers Hybrid, Poland China, Landrace, Duroc) mated to Farmers Hybrid boars. Experiment 795 was a field test in which extensive cross breeding had been practiced and the exact breeding of the pigs was unknown. The pigs in Experiment 843 were from crossbred sows (Landrace, Farmers Hybrid, Poland China) mated to Duroc boars. Experiment 910 was conducted with purebred Landrace.

The pigs were castrated at four days to two weeks of age, given an iron pill, iron paste or injected with iron dextran at birth and at one week of age, and vaccinated with a mixture of hog cholera and erysipelas serum at five days of age.

All of the experiments were conducted on concrete floors with the exception of Experiments 910 and 929 which were digestibility studies and in these two experiments the pigs were maintained on wire floors. Self-feeders and self-waterers were accessible at all times in all of the experiments.

Experiments 780, 864, 884, 910, and 929 were conducted in Unit E. This building has 36 individual pens with self-feeders and constant-flow type waterers. The floors of these pens were raised approximately one foot and thermostatically heated by a controlled radiant heat system. At the beginning of each experiment the floor temperature was held at 80 degrees Fahrenheit and was reduced five degrees each week to 65 degrees Fahrenheit. The temperature was maintained at this level for the remainder of the experiment. The room temperature was thermostatically controlled by an air conditioning unit and a forced-air gas furnace. The room temperature at the start was maintained at 75 degrees Fahrenheit the first week and was decreased five degrees each week until the temperature reached 65 degrees Fahrenheit. The temperature was maintained at this level for the remainder of the experiment.

The building has germicidal lamps which are located around the interior walls of the building. A disinfectant pad is located at the only entrance to the building and germicidal lamps are located about one foot above the disinfectant pad. The air entering the building must pass through a series of germicidal lamps. The design of this building provides for a very good environmental control and the disease level is undoubtedly lower in this building than in the other experimental units.

In Unit C, in which Experiments 683, 727, 735, and 800 were conducted, the temperature was thermostatically controlled, and was maintained between 65 and 70 degrees Fahrenheit (or at environmental temperature when the outside temperature was greater than the inside temperature). This building did not have radiant floor heating available. Heat lamps were provided for the first two weeks of the experiments conducted in this building so as to provide for adequate floor temperature. However, the length of time that the heat lamps were used varied with the conditions of the experiment.

Unit D, in which Experiments 705, 735, 762, 843, 891, and 914 were conducted, has radiant floor heating. Heat lamps were provided for the first week of the experiments. The temperature was thermostatically controlled and was maintained in the same manner as in Unit C described above.

The pigs were individually weighed at the time that they were placed on experiment and at weekly intervals thereafter. Feed consumption was also obtained at weekly intervals. When a pig died, the remaining pigs and feed in the pen were weighed so that feed consumption could be determined. Pigs that died while on experiment were sent to the Veterinary Diagnostic Laboratory for examination.

Below is a description of the enzymes used in these experiments. The description is based on information provided by the manufacturers and information from the literature.

The crude pepsin was National Formulary 1:3000 pepsin in powder form. This means that one pound of this pepsin will digest not less than 3000 or more than 3500 pounds of freshly coagulated and disintegrated egg albumen in 2.5 hours at 52 degrees centigrade in water acidulated with hydrochloric acid. The optimum pH for the action of pepsin is between 1.5 and 2.0. The action of pepsin is to hydrolyze the peptide linkages, the products being mainly proteoses and peptones.

The crude pancreatin was powdered U.S.P. (United States Pharmacopeia) grade. This material will convert not less than 25 times its weight of casein into proteoses in one hour at 40 degrees centigrade. Variable non-standardized amounts of amylase and lipase are also present in addition to the standardized proteolytic activity. The optimum pH for the proteolytic action of pancreatin is between 7.5 and 8.5. When proteins are subjected to the action of pancreatin under optimum conditions, the protein molecules are first solubilized and broken down into polypeptides. The peptidases then breaks the polypeptide chains down to form smaller peptides and amino acids. Both the pepsin (1:3000) and the pancreatin (U.S.P.) were supplied by Cudahy Laboratories, Incorporated, Omaha, Nebraska.

The papain used was the purified No. 1 white powder. It is a mixture of enzymes produced from the latex, preferably of the unripe fruit, of the papaya tree, *Carica papaya*. The potency of the papain used was not given, except that it exceeded the National Formulary requirements. The optimum pH range is between five and seven. Peptones, proteoses, and peptides can be obtained from casein by papain digestion. Its principal use is for its proteolytic activity although lipase activity is present. The papain was furnished by Paul Lewis Laboratories, Incorporated, Milwaukee, Wisconsin.

Ficin is a proteolytic enzyme obtained from the latex of the fig tree, genus *Ficus*. Exposure of ficin to the skin should be prevented and the eyes should be protected due to its tissue-dissolving properties. Ficin dusted into a rabbit's eye has been found to cause damage within 80 seconds. The optimum pH range is between four and eight and it has a proteolytic activity 4 to 20 times that of papain. The ficin was supplied by Merck and Company, Incorporated, Rahway, New Jersey.

Mycozyme is a combination of many enzymes derived from a selected strain of *Aspergillus oryzae*. It contains amylase, maltase, peptidase, lipase, invertase, phosphatase, sulfatase, and others in lesser concentration. Mycozyme is used mostly for its amylase activity and is standardized on its ability to liquify potato starch. The Mycozyme was supplied by Paul

Lewis Laboratories, Incorporated, Milwaukee, Wisconsin.

Rhozyme P-11 is characterized by its ability to hydrolyze protein. It also has some diastase and lipase activity. The organisms used to produce Rhozyme P-11 are undisclosed other than it is of fungal origin. The optimum pH is near 7.5.

Rhozyme B-6 is a bacterial enzyme used primarily for its proteolytic activity; however, it does contain a small amount of diastase activity. The organism used to produce Rhozyme B-6 is also undisclosed. The optimum pH is about 7.0. Rhozyme P-11 and Rhozyme B-6 were furnished by Rohm and Haas Company, Philadelphia, Pennsylvania.

With two exceptions, (Experiments 795 and 914) the pigs were weaned from the sows at one to two weeks of age. The experiments were conducted for a period of four weeks unless otherwise stated. The statistical analyses made by analysis of variance or test of all comparisons among means were done as outlined by Snedecor (1956) and Cochron and Cox (1957). In each of the experiments, the pen was considered the experimental unit and the data were analyzed on that basis. When a pig was removed from an experiment in which individual feeding was employed, the missing data were calculated by methods described by Snedecor (1956). The observations were treated as calculated values in the analysis of variance and the corresponding degrees of freedom removed from the error term.

All of the pigs were given a ration containing 40 percent dried skimmilk for the first two days after they were placed on experiment. This practice was followed to insure that all pigs were eating well before they were placed on the less palatable corn-soybean oil meal basal ration. The composition and calculated analysis of this ration are shown in Table 9. This ration was also used as the positive control ration in Experiments 705 and 727. The positive control ration was used in some of the experiments in order to determine the relative performance of pigs fed a corn-soybean oil meal ration with those fed a ration high in dried skimmilk. Table 10 shows the composition and calculated analysis of the positive control ration fed in Experiment 843.

The contents of the trace mineral mix used are shown in Table 14.

Tables 15, 16 and 17 show the amounts of vitamins and antibiotics added per pound of complete ration for each of the experiments.

The calculated analysis for each of the basal rations are shown in Tables 18, 19, and 20.

Table 21 shows the amount and kind of antibiotics added to the rations.

Enzyme Supplementation of Baby Pig Rations

Experiment 683

Objectives The purpose of this experiment was to determine the effects various crude proteolytic enzymes have on baby pig gains and feed efficiency, to determine whether the addition of the enzymes gives the same response in both soybean protein and milk protein diets, and to determine if the response from the feeding of enzymes is due to an unidentified growth factor(s).

Procedure Ten ration treatments were compared with three replicated pens of four pigs for each treatment. All enzymes were added at the rate of one percent of the ration. The enzymes added were papain, Rhozyme B-6, Mycozyme, Rhozyme P-11, pepsin (1:3000), pancreatin (U.S.P.) and inactivated pepsin. The inactivated pepsin was prepared by making up a suspension of the crude pepsin (1:3000) and adjusting to pH 8.0 with one normal sodium hydroxide. The suspension was allowed to stand for two hours with constant stirring before mixing it with the feed. Tests proved after the experiment was conducted that the pepsin had not been completely inactivated but had been reduced from an activity of 1:3000 to an activity of 1:20.

The diets are presented in Table 3. Drackett C-1 assay protein is a purified soybean protein containing about 83 percent protein on an air dry basis. The dried skimmilk diet was used as a positive control diet since the overall objective of this experimental work was to improve the utilization of soybean protein by baby pigs to equal that of dried skimmilk. Each pen receiving the diet containing dried skimmilk was given 20 pounds of the ration containing 40 percent dried skimmilk. After this feed had been consumed, the ration which contained 10 percent dried skimmilk was fed for the remainder of the experiment.

The average initial age and weight of the baby pigs were 9.0 days and 5.9 pounds, respectively.

Results and discussion The results of this experiment are shown in Figure 1. The analysis of variance and test of all comparisons among means of gain and feed required per pound of gain are shown in Table 23 in the appendix. Table 24, in the appendix, shows the average pen gains and feed per pound of gain.

With one exception, the pigs receiving Drackett assay protein diets containing one percent enzymes were superior in growth and feed efficiency as compared to pigs receiving the Drackett assay protein diet containing no supplementary enzymes. The exception to this was the growth of the pigs receiving the plant enzyme, papain. The addition of one percent pepsin to the dried skimmilk diet decreased both growth and feed efficiency. The best response by the supplementation

Table 3. Composition of basal ration used in Experiments 683, 705 and 891, and dried skimmilk rations used in Experiment 683

Ingredients	Basal	40% DSM	10% DSM
Glucose	34.49	16.00	
Lactose	20.00		
Sucrose	10.00	5.00	15.00
Toasted corn flakes (8.1% protein)		8.55	
Rolled oats (15.5% protein)			40.00
Ground yellow corn (9.5% protein)			9.10
Drackett C-1 assay protein (83% protein)	23.70		
Solvent soybean oil meal (50% protein)		12.10	15.00
Fish meal (60% protein)		2.50	2.50
Dried skimmilk (34% protein)		40.00	10.00
Dried whey (sweet) (12% protein)		2.50	2.50
dl-methionine	0.10		
Dried brewers yeast (45% protein)		1.00	
Corn steep water (24% protein)		1.00	
Calcium carbonate (38% calcium)	0.86	0.50	0.50
Dicalcium phosphate (26% calcium) (18% phosphorus)	3.72	1.20	2.75
Trace mineral mix (C.C.C.)[a]		0.15	0.15
Trace mineral mix (35D-10)[a]	1.63		

[a]See Table 14.

Table 3. (Continued)

Ingredients	Basal	40% DSM	10% DSM
Stabilized lard	2.50	5.00	
Dried beet pulp	2.00	2.00	
Vitamin-antibiotic premix	0.50	2.00	2.00
Iodized salt	0.50	0.50	0.50
Total (lb.)	100.00	100.00	100.00

of enzymes to the soybean protein diet was obtained from the addition of the partially inactivated pepsin. This would suggest the possibility that the enzymes were exerting their effects by supplying an unidentified growth factor(s) as well as an enzymatic effect or that the 1.0 percent pepsin (1:3000) was too high. It should be remembered that the inactivated pepsin did contain some proteolytic activity as mentioned above.

The weight gain was somewhat less than might be expected when compared to results of other experiments with comparable diets fed and age of pigs. These poor gains can be attributed, in part, to the high temperature and to the scouring of the pigs. The experiment was conducted in Unit C in the summer of 1955. The inside temperature on several occasions approached 95 degrees Fahrenheit which is very unfavorable to

Figure 1. Experiment 683 - Gains and feed per pound of gain of pigs fed various sources of proteolytic enzymes[a]

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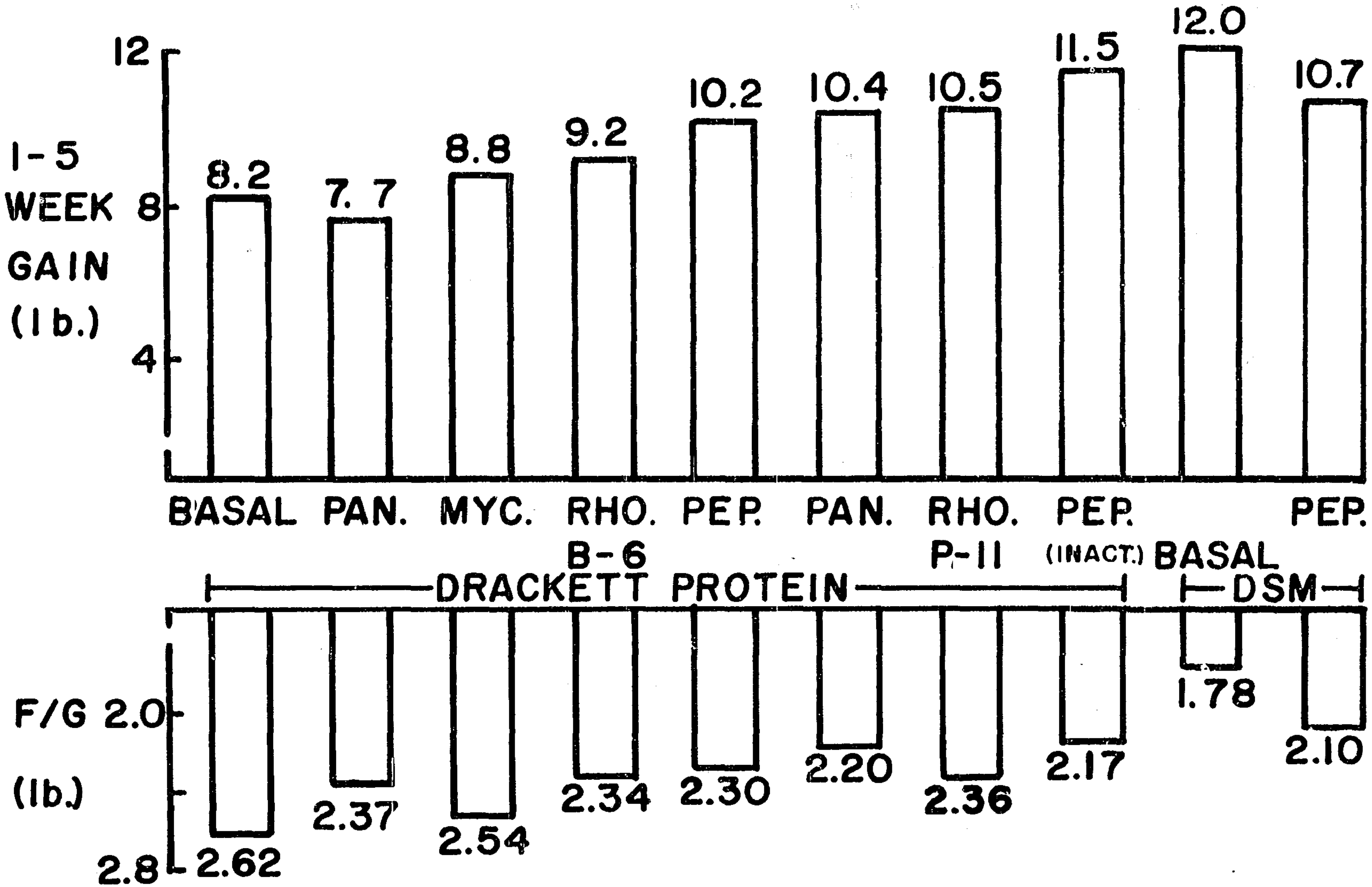
[a]Pan. = pancreatin, Myc. = Mycozyme, Rho. = Rhozyme, pep. = pepsin.


12
1-5
WEEK 8
GAIN
(lb.)
4
8.2
7.7
8.8
9.2
10.2
10.4
10.5
11.5
12.0
10.7
BASAL
PAN.
MYC.
RHO.
B-6
PEP.
PAN.
RHO.
P-11
PEP.
(INACT.)
BASAL
PEP.
DRACKETT PROTEIN
DSM
F/G 2.0
(lb.)
2.8
2.62
2.37
2.54
2.34
2.30
2.20
2.36
2.17
1.78
2.10

the growth and well being of baby pigs. The scouring was rather extensive throughout the experiment.

One pig died after being on experiment for three weeks and another died during the fourth week of the experimental period. Necropsy examination of the first pig showed a fibrinous exudate in the esophagus, catarrhal enteritis, and a follicular necrotic colitis. The second pig showed hyperemia of the stomach and an enteritis. In both cases, examination for pathological bacteria gave negative results.

The animal enzymes appeared to give a superior response in growth and feed conversion than did the enzymes produced from plants and microorganisms.

Experiment 705

Objective Because of the increased growth of the pigs receiving the partially inactivated pepsin in Experiment 683, the purpose of this experiment was to determine what level of pepsin would give the best response in growth and feed efficiency and to determine if a combination of pepsin and pancreatin at a low level is more effective than pepsin alone.

Procedure Seven ration treatments were compared with three replicated pens of four pigs each. The levels of pepsin (1:3000) added to the rations were 0.0625, 0.25 and 1.0 percent of the diet. Pepsin (1:3000) and pancreatin (U.S.P.) were added in combination to the rations at the rate of 0.05

percent each. A treatment with the addition of ficin (plant enzyme) was also included to determine if it was effective in improving growth. Because of its high activity, only 0.1 percent was added to the ration. The basal ration was the same as that used in Experiment 683 and is shown in Table 3. A 40 percent dried skimmilk ration was also fed as a positive control.

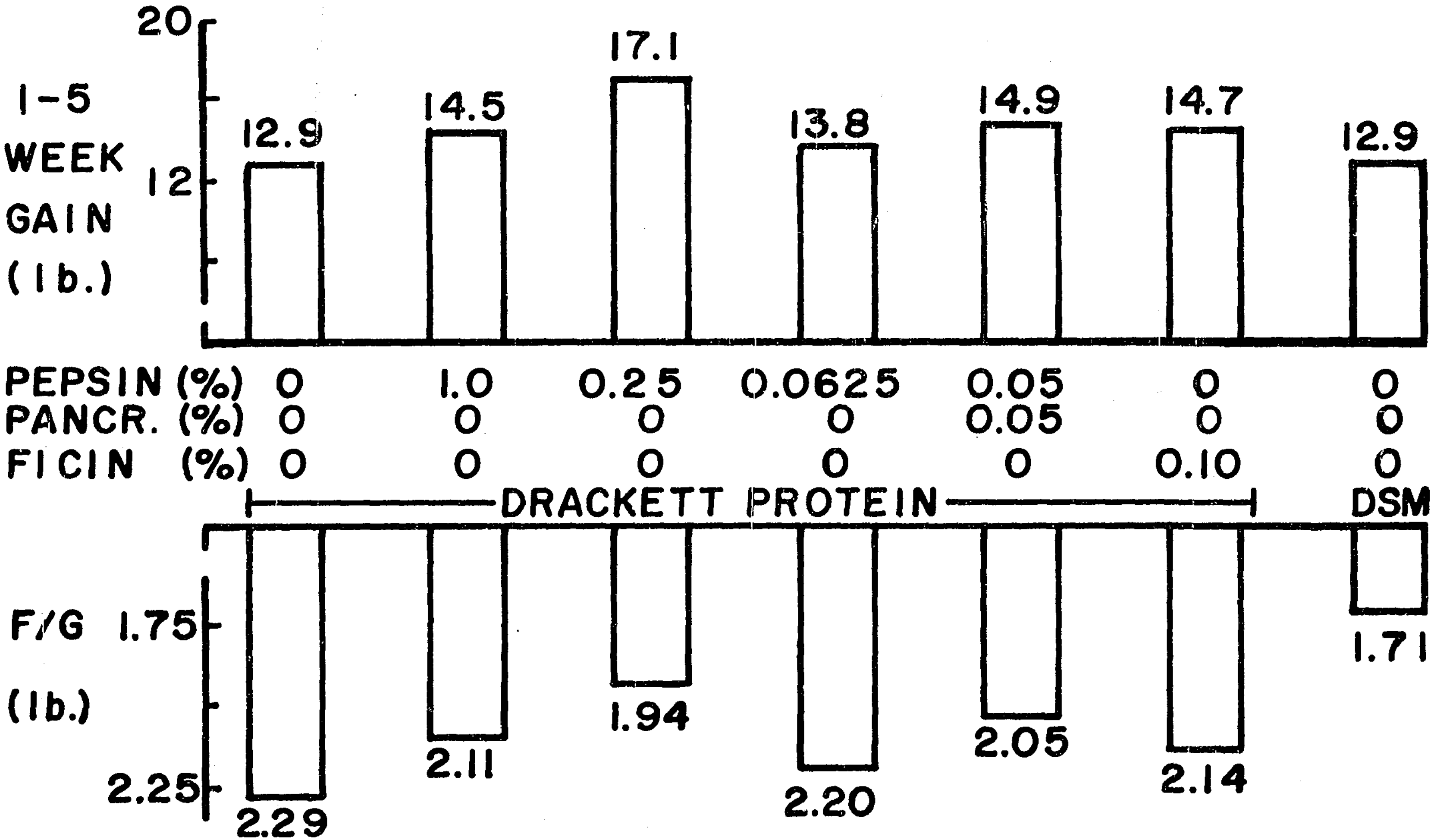
The ficin treatment was fed to only two pens of pigs due to inadequate space. The missing value was calculated by procedures outlined by Snedecor (1956) and the data were subjected to an analysis of variance with one degree of freedom subtracted from the error term.

This experiment was conducted in Unit D during the winter of 1955-1956. The average initial age and weight of the baby pigs were 10.3 days and 6.5 pounds, respectively.

Results and discussion The results of this experiment are shown in Figure 2.

The individual pen data and the analysis of variance are presented in the appendix in Tables 25 and 26, respectively. The pigs receiving the treatments containing the supplemental enzymes outperformed the pigs receiving the basal ration with no enzymes added. The quadratic regression of the levels of pepsin was significant ($P < 0.05$) for gains. The pigs receiving the ration treatment containing 0.25 percent pepsin grew more rapidly and required less feed per pound of gain than

Figure 2. Experiment 705 - Gains and feed required per pound of gain of pigs fed ficin, pancreatin and various levels of pepsin


1-5 WEEK GAIN (lb.)
20
12
12.9
14.5
17.1
13.8
14.9
14.7
12.9
PEPSIN (%) 0 1.0 0.25 0.0625 0.05 0 0
PANCR. (%) 0 0 0 0 0.05 0 0
FICIN (%) 0 0 0 0 0 0.10 0
DRACKETT PROTEIN
DSM
F/G (lb.)
1.75
2.25
2.29
2.11
1.94
2.20
2.05
2.14
1.71

the pigs fed the other ration treatments. From this experiment it appeared that the optimum level of pepsin in baby pig diets fed soybean protein is somewhere near 0.25 percent.

The growth and feed efficiency was somewhat improved in the ficin treatment as compared to the basal ration but was not as good as the treatment containing 0.25 percent pepsin. The poor performance of the pigs receiving the dried skimmilk diet can be attributed to an outbreak of scouring among the pigs on this treatment. During the last week of the experiment severe scouring occurred among the pigs fed the dried skimmilk ration and in many instances weight loss resulted. Although scouring was rather extensive in all of the treatments, it was not severe enough to cause an appreciable reduction in growth as the average weight gains ranged from 12.9 pounds for the basal treatment to 17.1 pounds for the treatment containing 0.25 percent pepsin.

Death occurred to one pig during the third week on experiment and a necropsy examination showed the presence of an enteritis. Bacteriological examination resulted in the isolation of an organism identified as Pseudomonas spp.

Experiment 735

Objective The purpose of this experiment was to determine whether the response to lower levels of pepsin could be repeated, whether lower levels of pepsin in a dried skimmilk ration would improve growth and feed efficiency, and whether air conditioning would have an effect on the response of the ration treatments.

Procedure Eight ration treatments were compared in a 2 x 2 x 4 factorial arranged experiment with two replicated pens of four pigs per treatment. Four levels of pepsin (1:3000) (0, 0.25, 0.5, and 1.0 percent) were compared in a diet containing soybean oil meal as the chief source of protein and also in a diet containing 40 percent dried skimmilk. The design of this experiment is presented in Table 27 in the appendix.

This experiment was conducted in the summer of 1956. The eight ration treatments with and without air conditioning were conducted in both Units C and D. Since poor gains had resulted the previous summer, it was felt that a more favorable growth might be obtained by controlling the temperature which in turn might influence the response to the supplementation of pepsin.

Pepsin was chosen as the enzyme to test further because of the greater weight gains that had been obtained in the two previous experiments as well as in experimental results reported by Lewis (1956).

The soya protein was changed from the Drackett C-1 assay protein, fed in the two previous experiments, to soybean oil meal (50 percent protein). Ground yellow corn was also substituted for glucose. This gave a more practical type ration which would be applicable to the field. The composition of the two basal rations are presented in Table 11 in the appendix.

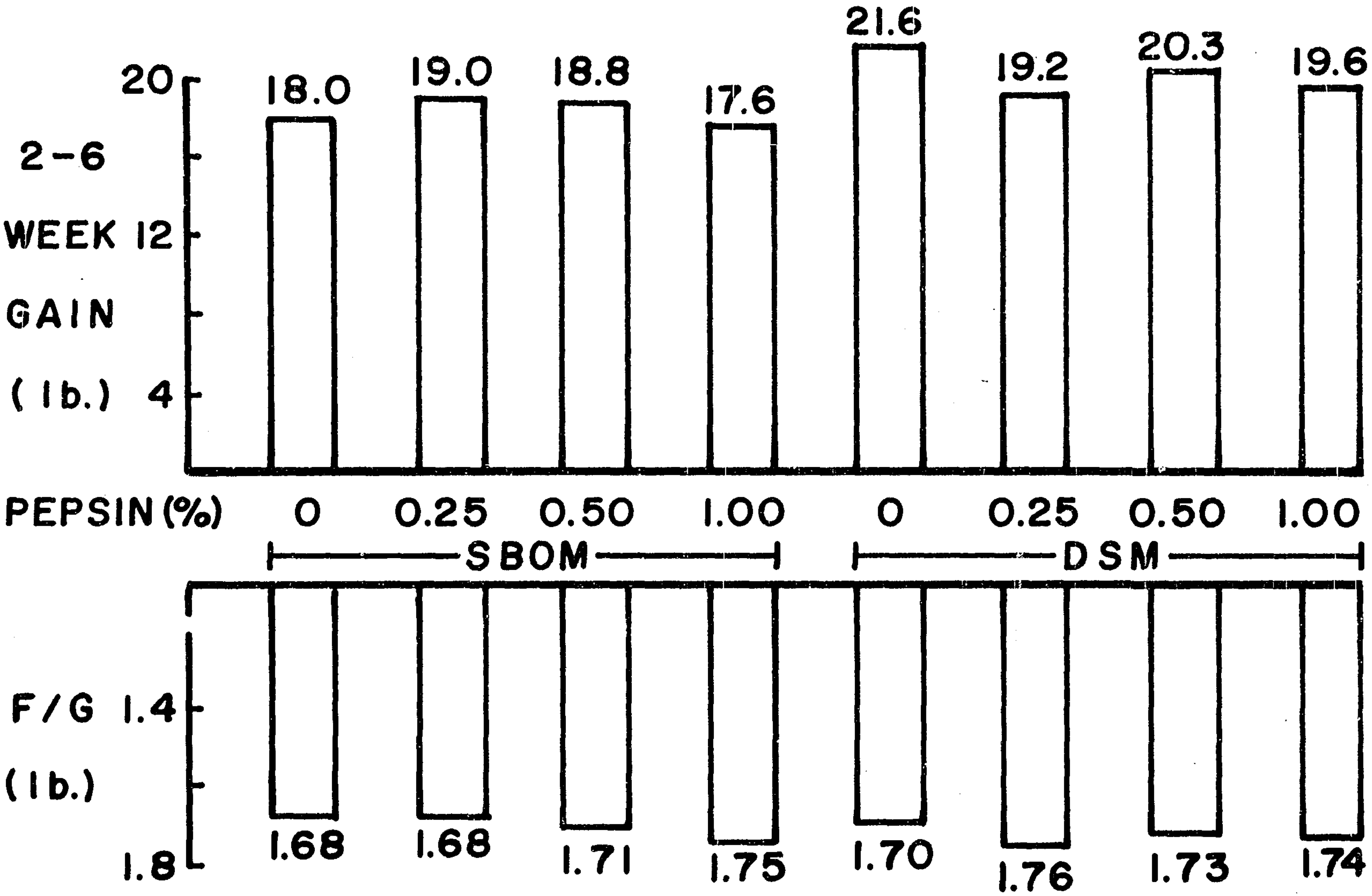
The average initial age and weight of the pigs were 15.6 days and 7.7 pounds. These pigs had been weaned at an average age of 8.6 days and placed on a pretreatment ration of 40 percent dried skimmilk for one week to obtain a more uniform group of pigs starting on feed. Twenty percent more pigs than were to be used were weaned and placed on the pretreatment. This allowed for 10 percent of the fastest growing pigs and 10 percent of the slowest growing pigs to be discarded when the pigs were allotted to their respective treatments.

Results and discussion The results of this experiment are presented in Figure 3. The individual pen data and the analysis of variance are shown in Tables 27 and 28 in the appendix.

Preliminary analysis of variance indicated that there was no significant difference in growth and feed efficiency due to air conditioning or buildings. Thus, the data were pooled and considered as four replications of each treatment as shown in the analysis of variance and in Figure 3. The lack of response to air conditioning could have been due to a very mild summer.

There was no significant difference in growth response

Figure 3. Experiment 735 - Effects of supplemental pepsin to soybean oil meal protein and 40 percent dried skimmilk diets for baby pigs



2-6
WEEK
GAIN
(lb.)
20
12
4
18.0
19.0
18.8
17.6
21.6
19.2
20.3
19.6
PEPSIN (%)
0
0.25
0.50
1.00
0
0.25
0.50
1.00
SBOM
DSM
F/G
(lb.)
1.4
1.8
1.68
1.68
1.71
1.75
1.70
1.76
1.73
1.74

due to the supplementation of pepsin. However, there was a slight trend for improvement in growth of the pigs which were fed the corn-soybean oil meal rations supplemented with either 0.25 or 0.5 percent pepsin. All of the dried skimmilk treatments containing pepsin produced slower growth than the dried skimmilk diet containing no pepsin. This supports the results obtained in Experiment 683. From these results it appears that baby pigs receiving a high level of dried skimmilk in their rations do not benefit from the supplementation of pepsin. The dried skimmilk rations produced a significant ($P < 0.05$) improvement in growth of pigs when compared to the rations containing soybean oil meal.

There was essentially no difference in feed efficiency among the eight treatments.

The lack of improvement in feed efficiency and growth by the addition of the enzyme might have resulted from three factors. First, the pigs were somewhat older when they were placed on the experimental treatments than were the pigs in Experiments 683 and 705; second, the pigs had received a dry diet containing 40 percent dried skimmilk for one week in a pre-experimental period; and third, there was very little scouring among the pigs. Lewis (1956) has advanced the theory, with some evidence to support it, that the rate of food passage may influence the growth response to the supplementation of pepsin. That is, the faster the rate of food passage through the gastro-intestinal tract, the greater the response to enzyme supplementation. The baby pig may have a sufficient supply of digestive enzymes to digest the food if the rate of food passage were normal but with the increase in rate of food passage due to scouring, the baby pig's enzyme system would be insufficient.

Experiment 795

Objective The purpose of this experiment was to determine the response of baby pigs fed diets containing pepsin in field tests and to determine whether there is a difference in response to pepsin by heavy versus light pigs.

Procedure Two ration treatments were compared in a 2 x 2 factorial arranged experiment. The pigs were weaned at three weeks of age and were kept on experiment for four weeks. They were weaned in groups of about 30 and each group was divided in half according to their weight. The larger pigs were designated as heavy and the smaller pigs were designated as light. These groups were then assigned to a ration treatment which contained either 0.25 percent pepsin (1:3000) or no pepsin. The number of pigs per pen ranged from 3 to 18 with an average of 13 pigs per pen. The average initial weight was 12.4 pounds for the heavy pigs and 8.8 pounds for the light pigs.

The pigs were housed in three different buildings. Two of the buildings were wooden structures while the third was a steel building. A total of 996 pigs was used in this trial. The experiment was conducted in cooperation with the city of Kansas City Municipal Farm, Kansas City, Missouri.

The pigs were weighed only at the beginning and end of the experiment. When a pig died the date was recorded and an estimate was made of the amount of feed eaten by the pig.

Results and discussion The results of this experiment are shown in Figure 4. The heavy pigs grew faster than the light pigs and required less feed per pound of gain. There was no improvement in the growth rate and feed efficiency of heavy pigs receiving the pepsin supplemented diet when compared to those receiving the non-supplemented ration. However, the weight gain and feed efficiency of the supplemented light pigs was 7.4 and 2.56 pounds respectively, as compared to 6.8 and 2.95 pounds respectively, for the non-supplemented light pigs. The average weight gains and feed required per pound of gain of the heavy and light pigs are shown in Table 4.

The slow growth and poor feed efficiency can be attributed, in part, to the scouring of the pigs which was rather severe. Many of the pigs died during the experiment. Although necropsy examinations were not made, it was believed that the cause for most of the deaths was a weakened condition of the pigs which resulted from scouring.

Figure 4. Experiment 795 - Effects of weaning weights and supplemental pepsin to soybean oil meal protein diets on pig gains and feed required per pound of gain

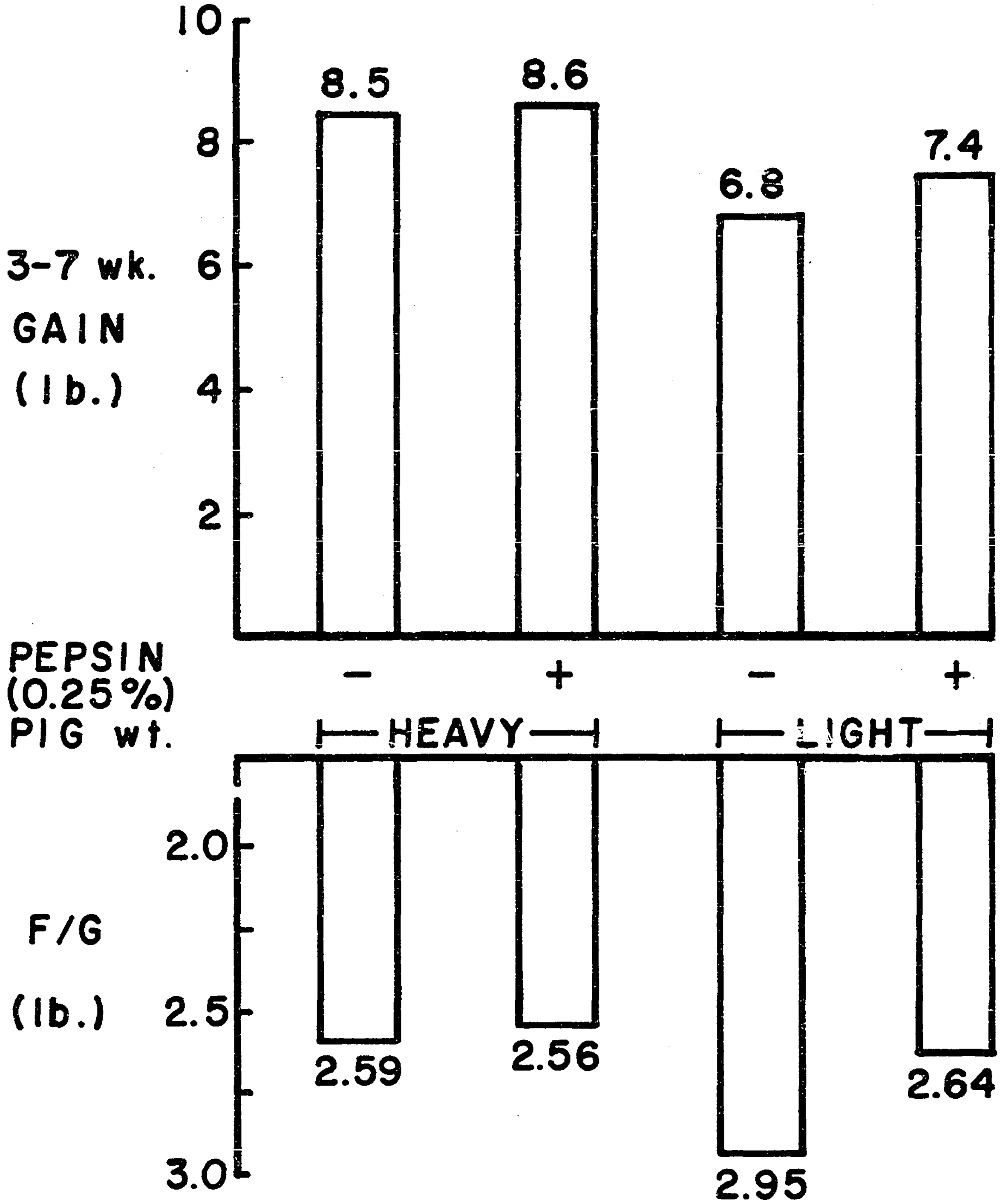

10
8
6
4
2
8.5
8.6
6.8
7.4
3-7 wk.
GAIN
(lb.)
PEPSIN
(0.25%)
PIG wt.
-
+
-
+
HEAVY
LIGHT
2.0
F/G
(lb.)
2.5
3.0
2.59
2.56
2.95
2.64

Table 4. Experiment 795 - Summary of total gains and feed required per pound of gain

Treatment	Quality of pigs	No. of pens	Total pigs	3-7 week gains(lb)	Feed/ gain
Basal (corn-soya)	Heavy	18	233	8.5	2.59
Basal (corn-soya)	Light	20	250	6.8	2.95
Basal + 0.25% pepsin	Heavy	18	261	8.6	2.56
Basal + 0.25% pepsin	Light	19	252	7.4	2.64
	Heavy and light pigs combined				
Basal		38	483	7.6	2.77
Basal + 0.25% pepsin		37	513	8.0	2.60

Experiment 843

Objective The purpose of this experiment was to determine if lower levels of pancreatin when supplemented to a diet containing soybean oil meal would increase growth of baby pigs when compared to the same ration containing pepsin, a combination of pepsin and pancreatin, or a ration containing no supplemented enzymes.

Procedure Seven ration treatments were compared using three replicated pens of four pigs each. The design of this experiment is shown in Table 29 in the appendix. The composition of the basal ration is shown in Table 11 in the appendix. The diet was a practical type diet made up largely of soybean oil meal, ground yellow corn, rolled oats, and dried whey. Saccharin (soluble) was used as a source of sweetening in the place of sucrose.

One ration treatment containing 20 percent dried skimmilk was used as a positive control. The composition of this ration is shown in Table 10 in the appendix. Only two pens of pigs were fed the 20 percent dried skimmilk ration. The missing value was calculated by procedures outlined by Snedecor (1956) and the data were subjected to an analysis of variance with one degree of freedom subtracted from the error term.

One level of pepsin (1:3000) (0.25 percent) and two levels of pancreatin (U.S.P.) (0.25 and 0.50 percent) were tested. A combination of 0.25 percent pepsin (1:3000) and 0.25 percent pancreatin (U.S.P.) was added to one treatment.

A treatment containing 0.15 percent pepsin, 0.15 percent pancreatin, 0.15 percent amylase, 0.025 percent lipase, and 0.025 percent bile salts was also included to determine if the combination of several enzymes and bile salt would be effective in improving baby pig performance.

This experiment was conducted in Unit D during the winter of 1957-1958. The average initial age and weight of the baby pigs were 14.0 days and 8.0 pounds, respectively.

Results and discussion The results of this experiment are shown in Table 29 in the appendix. No improvement in growth of baby pigs was obtained from the supplementation of enzymes to the ration. The greater weight gain of the pigs receiving the ration containing no supplemented enzymes can be attributed to the growth of the pigs in the third replication. The average weight gain of the pigs in this pen was more than two pounds greater than any of the other pens. No explanation of this improvement in growth can be given. It doesn't seem likely that the changes made in the basal ration would result in the lack of growth response to enzyme supplementation.

Poor growth was also obtained from the pigs receiving the dried skimmilk ration. Although the ration contained only 20 percent dried skimmilk as compared to 40 percent in the previous positive control rations, the weight gains were much less than would be expected.

There was essentially no difference in the feed required per pound of gain among the different treatments. However, the pigs receiving the treatment containing 0.50 percent pancreatin were somewhat less efficient.

Very little scouring by the pigs was observed in this experiment.

One pig receiving the dried skimmilk ration died shortly after the experiment was completed. Necropsy examination of the pig revealed ulceration of the cornea in one eye and subendocardial hemorrhages. Bacteriological examination did not reveal bacterial pathogens.

Factors Affecting the Growth Response of Baby Pigs Fed Rations Supplemented with Proteolytic Enzymes

Experiment 762

Objective Lewis (1956) observed that the rate of food passage influenced the response obtained from the supplementation of pepsin as mentioned previously. The purpose of this experiment was to determine if these observations could be repeated.

Procedure Six ration treatments were compared with replicated lots of four pigs per lot. Two different laxatives, cascara and aerosol OTB, were used to increase the rate of food passage. Powdered cascara was added at the rate of 20 milligrams per pound of diet and aerosol OTB was added at the rate of 200 milligrams per pound of diet. Each of the diets containing the laxatives were fed with and without 0.25 percent pepsin (1:3000). The basal ration is presented in Table 11, and the design of the experiment is shown in Table 30 in the appendix.

This experiment was conducted in Unit D during the winter of 1956-1957.

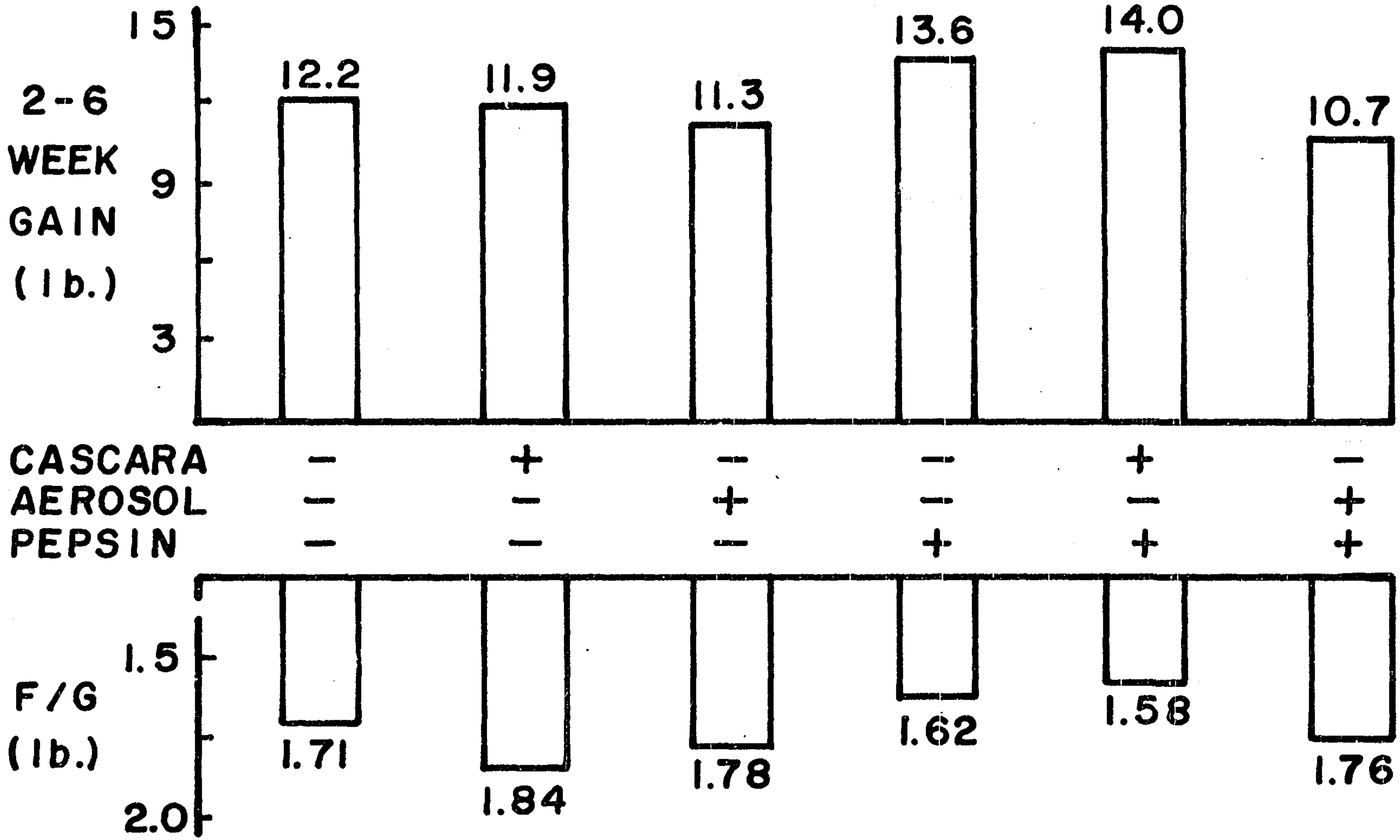
The average initial age and weight of the baby pigs were 13.1 days and 7.4 pounds, respectively.

Results and discussion   The results of this experiment are presented in Figure 5. The addition of the laxative to the ration containing no pepsin resulted in decreased weight gains and feed efficiency. The pigs receiving supplemental pepsin gained 13.6 pounds as compared to 12.2 pounds gained by the pigs receiving no supplemental pepsin. The pigs which received the ration containing both pepsin and cascara gained 14.0 pounds as compared to 11.9 pounds for the pigs which received the ration containing cascara. This would indicate that the pepsin offset the deleterious effect of the cascara which is believed to be caused by the increase in rate of food passage. The pigs which received the diet containing aerosol and pepsin did not perform as well as the pigs receiving aerosol or pepsin alone. The scouring index of the pigs in this experiment was rather high. However, the pigs receiving the laxative scoured slightly more than the pigs receiving no laxative.

The feed per pound of gain was somewhat improved in the treatments receiving pepsin. Logically, the pigs receiving the laxative were less efficient in feed conversion than those with no laxative in the ration. The analysis of variance is presented in Table 31 in the appendix.

One pig died during the third week on experiment. Necropsy examination showed the presence of a fibrinous pleuritis, a sero fibrinous pericarditis, and a catarrhal

Figure 5. Experiment 762 - Effects of supplemental pepsin without and with cascara or aerosol to soybean oil meal protein diets on pig gains and feed required per pound of gain



15
2-6
WEEK
GAIN
(lb.)
9
3
12.2
11.9
11.3
13.6
14.0
10.7
CASCARA − + − − + −
AEROSOL − − + − − +
PEPSIN − − − + + +
1.5
F/G
(lb.)
2.0
1.71
1.84
1.78
1.62
1.58
1.76

enteritis. Bacteriological examination did not reveal bacterial pathogens.

Experiment 780

Objective Lewis (1956) has also observed that the supplementation of a ration containing soybean protein with pepsin did not improve the growth of baby pigs when housed in Unit E. This was believed to be caused by a low disease level environment which resulted in less scouring by the baby pigs. The purpose of this experiment was to determine whether the rate of food passage would have an influence on the growth rate of baby pigs fed pepsin in a relatively low disease level building.

Procedure Four ration treatments were compared using nine individually fed pigs per ration treatment. The experimental design is shown in Table 32 in the appendix. The basal ration was the same as the one fed in Experiment 762. The cascara was added to the ration at the rate of 500 milligrams per pound. This level of cascara was chosen after observations were made from a preliminary experiment. The basal ration and the ration containing cascara were fed with and without 0.25 percent pepsin (1:3000).

Missing values were calculated by procedures outlined by Snedecor (1956) and the data were subjected to an analysis of variance with two degrees of freedom subtracted from the error term.

At the end of the experiment each pig was given a capsule of ferrous oxide as a marker to determine the rate of food passage. The rate of food passage was measured in hours from the time the pigs were given the capsule until the indicator first appeared in the feces. Although this method is not a true measure of the average time the food stays in the digestive tract, it was felt that it was a good relative measure of how fast the food passes through the digestive tract.

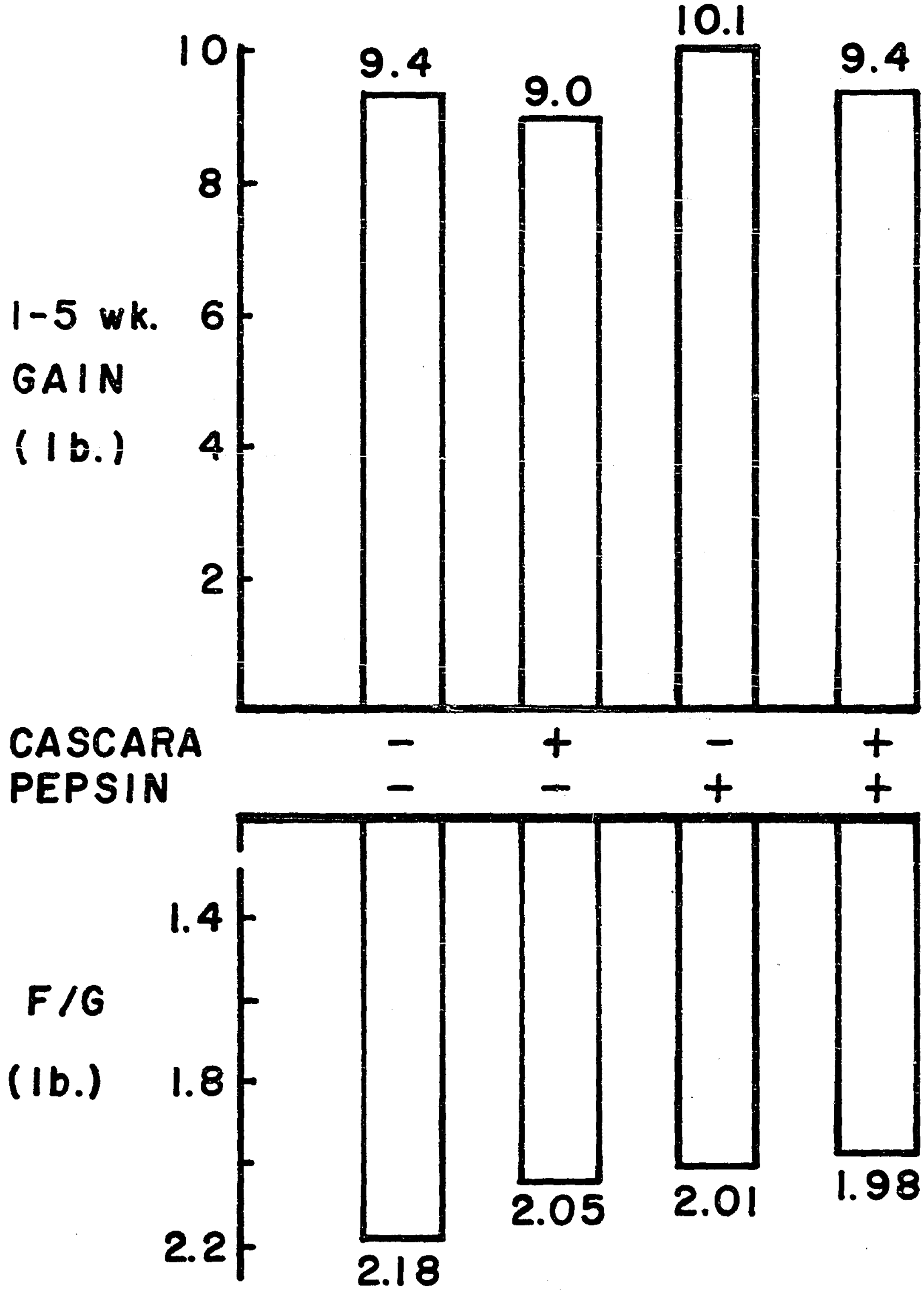
The pigs were housed in Unit E and the experiment was conducted during the spring of 1957.

The average initial age and weight of the baby pigs were 7.0 days and 6.25 pounds, respectively.

Results and discussion The results of this experiment are presented in Figure 6. The addition of cascara to the ration decreased the average weight gains of the baby pigs from 9.4 pounds for the non-supplemented to 9.0 pounds for the supplemented pigs. The addition of 0.25 percent pepsin (1:3000) to the ration containing cascara improved the gains by 0.4 pounds. Thus, the supplementation of the ration containing cascara with pepsin offset the deleterious effect of the cascara. The pigs receiving the ration supplemented with pepsin gained 10.1 pounds as compared to 9.4 pounds for the non-supplemented.

The feed required per pound of gain was less in the rations supplemented with pepsin and/or cascara. The differ-

Figure 6. Experiment 780 - Effects of supplemental pepsin without and with cascara to soybean oil meal protein diets on pig gains and feed required per pound of gain



10
8
6
4
2
1-5 wk.
GAIN
(lb.)
9.4
9.0
10.1
9.4
CASCARA
PEPSIN
− − + − − + + +
1.4
1.8
2.2
F/G
(lb.)
2.18
2.05
2.01
1.98

ences in both weight gain and feed required per pound of gain were not significant. The analysis of variance is shown in Table 33 in the appendix.

The rate of food passage through the gastro-intestinal tract of pigs which received the cascara was 13.9 hours as compared to 15.9 hours for the pigs receiving no cascara. These differences were significant ($P < 0.05$). Even though the rate of food passage was increased as measured by the first appearance of an indicator in the feces, the feces of the pigs receiving the cascara were not watery enough to be classed as scouring. The scouring in this experiment was very slight.

One pig had to be removed during the first week of the experiment due to a sore mouth. A second pig died during the first week of the experiment. Necropsy examination showed the presence of a gastric and catarrhal enteritis. In addition there was a beginning atrophy of the turbinates. Bacteriological examination gave negative results for pathogenic organisms.

Experiment 891

Objective The response in growth and feed efficiency of baby pigs fed a ration supplemented with pepsin has varied greatly. Since the composition of the basal rations fed had changed, this experiment was conducted to determine whether the type of ration has an influence on the growth and feed efficiency of baby pigs fed supplemental pepsin, and to determine whether inactivated pepsin would give a growth response.

Procedure Five ration treatments were compared with four replicated pens. The pens in two of the replications contained four pigs each, whereas the pens in the other two replications contained three pigs each. The design of the experiment is presented in Table 5. The composition of the ration containing soybean oil meal as the source of protein is shown in Table 13. This ration was a practical type ration and was similar to other practical type rations fed previously. The composition of the ration containing Drackett C-1 assay protein as the source of protein is shown in Table 3. This ration was the same as the basal rations fed in Experiments 683 and 705. Pepsin (1:3000) was added at the rate of 0.25 percent of the ration. The ration containing the soybean oil meal and the ration containing the Drackett C-1 assay protein were fed with and without the pepsin. The fifth treatment was composed of the ration containing Drackett C-1 assay protein supplemented with 0.25 percent inactivated pepsin.

The inactivated pepsin was prepared by making up a suspension of the crude pepsin (1:3000) and adjusting to pH 8.0 with two normal sodium hydroxide. The suspension was heated

Table 5. Experiment 891 - Summary of pig gains and feed required per pound of gain

Rep	Treatments (protein and 0.25% pepsin)				
	SBOM	SBOM + pepsin	Drackett	Drackett + pepsin	Drackett + pepsin (inact.)
		2-6 week gains (lb.)			
1	14.6	7.9	16.8	9.0	13.1
2	7.4	9.1	10.4	10.6	12.2
3	11.3	17.4	15.5	16.5	16.9
4	10.2	13.9	11.0	9.7	9.6
Av.	10.9	12.1	13.4	11.4	13.0
		Feed/gain (lb.)			
1	1.71	2.04	1.95	2.48	2.28
2	2.06	1.79	2.22	2.22	1.97
3	1.83	1.71	2.04	2.01	2.05
4	1.79	1.60	2.26	2.10	2.32
Av.	1.85	1.78	2.12	2.20	2.16

at 90 degrees centigrade for two hours with constant stirring before mixing it with the feed. Tests on the inactivated material showed that no pepsin activity was present even after standing in a solution at pH 1.0 for four hours.

This experiment was conducted in Unit D during the spring of 1958.

The average initial age and weight of the baby pigs were 14.0 days and 8.2 pounds, respectively.

Results and discussion The results of this experiment are presented in Table 5. The analysis of variance for this experiment is presented in Table 34 in the appendix. No significant difference was observed in growth among the pigs fed the five ration treatments. However, the average gain for the pigs receiving the soybean oil meal was improved from 10.9 pounds to 12.1 pounds by the addition of 0.25 percent pepsin. The Drackett C-1 assay protein ration supplemented with pepsin produced somewhat slower growth than the Drackett C-1 assay protein ration containing no supplemented pepsin. No improvement in growth was observed from the treatment containing the inactivated pepsin. The average weight gain of the pigs receiving the diet containing the Drackett C-1 assay protein was slightly larger than the pigs receiving the soybean oil meal protein.

The feed per pound of gain was not improved by the supplementation of 0.25 percent pepsin. There was, however, a significant ($P<0.05$) difference in the feed required to produce a pound of gain between the two types of protein fed. The pigs receiving the diet containing the soybean oil meal protein were more efficient in feed conversion than the pigs fed the diet containing the Drackett C-1 assay protein.

Relatively little scouring of the pigs was observed during the experiment. One pig died during the second week of the experimental period. Necropsy examination of the pig revealed no significant gross lesions other than an enteritis. Bacteriological examination did not reveal the presence of bacterial pathogens.

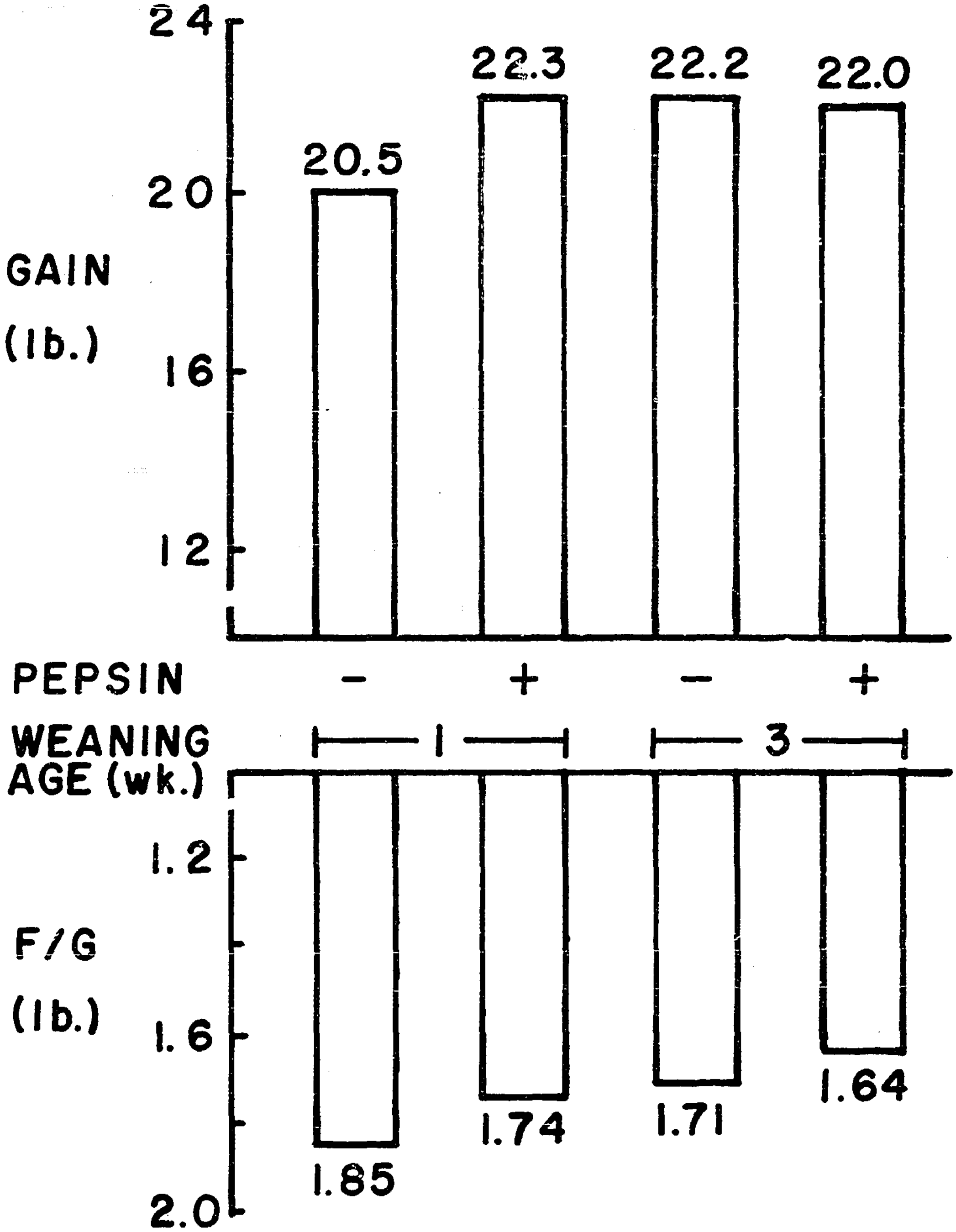
Experiment 914

Objective The purpose of this experiment was to determine whether the weaning age of the pig would have an effect on the growth rate of pigs fed a diet supplemented with pepsin.

Procedure Two ration treatments were compared using four replicated pens of four pigs per pen in a 2 x 2 factorial arranged experiment. The design of the experiment is shown in Table 35 in the appendix. At one week of age, one-half the pigs from each litter were weaned and placed on the ration treatments. At three weeks of age the pigs remaining on the sow were weaned and placed on the same ration treatments as the one-week weaned pigs. The basal ration was a practical type diet and the composition is shown in Table 13 in the appendix.

The early weaned pigs remained on experiment for six weeks, whereas the pigs weaned at three weeks of age remained on experiment for only four weeks. Thus, both groups of pigs were taken off the experiment at the same time. The one- and three-week-old weaned pigs were fed the basal ration with and without 0.25 percent supplemented pepsin (1:3000). The

Figure 7. Experiment 914 - Effects of weaning pigs at one and three weeks of age on their response to rations supplemented with pepsin



24
20
16
12
GAIN
(lb.)
20.5
22.3
22.2
22.0
PEPSIN
-
+
-
+
WEANING
AGE (wk.)
1
3
F/G
(lb.)
1.2
1.6
2.0
1.85
1.74
1.71
1.64

average initial weight of the one- and three-week weaned pigs was 5.7 and 10.5 pounds, respectively.

This experiment was conducted in Unit D in the summer of 1958.

Results and discussion The results of this experiment are presented in Figure 7. The growth rate of the early weaned pigs supplemented with 0.25 percent pepsin (1:3000) was significantly ($P < 0.05$) greater than the non-supplemented pigs. However, the feed required to produce a pound of gain was not significantly improved even though the feed required to produce a pound of gain was less for the pepsin supplemented pigs in each replication. The analysis of variance for the one-week-weaned pigs is presented in Table 36 in the appendix.

There was no improvement in growth of the three-week-weaned pigs receiving the pepsin when compared to the non-supplemented ones. A slight improvement in feed required per pound of gain was observed in the three-week-weaned pigs whose ration was supplemented with pepsin.

It should be pointed out that the average weight gains and feed required to produce a pound of gain for the one-week-weaned pigs represents the average for a six-week period, whereas the averages for the three-week-weaned pigs represents a four-week-period. Thus, as can be seen in Figure 7, the three-week-weaned pigs gained as much weight in the four-week period as the one-week weaned pigs gained in the six-week period. These results were expected since the ration fed is not a recommended diet for pigs weaned at one week of age. These results show that the age at which the baby pig is weaned does influence the response obtained from the supplementation of pepsin.

The analysis of variance of the pooled data of the one- and three-week weaned pigs is presented in Table 37 in the appendix. No significant difference was observed in the growth rate of the pigs due to the addition of pepsin to the ration. Even though there was no significant improvement observed in feed efficiency due to the supplementation of pepsin when the pigs weaned at different ages were analyzed separately, there was, however, a significant ($P < 0.05$) improvement in feed required per pound of gain by the pigs whose ration was supplemented with pepsin when the data of the two groups were pooled. There was also a significant ($P < 0.05$) age effect. The pigs weaned at three weeks of age required less feed to produce a pound of gain.

These results strongly support the theory that the earlier the pig is weaned the greater the response in weight gain due to the addition of pepsin to the ration. Scouring was severe for the first three weeks in the pigs weaned at one week of age. However, very little scouring was observed in the pigs weaned at three weeks of age.

Experiment 910

Objective The purpose of this experiment was to determine whether the level of protein fed would have an influence on the response of baby pigs whose diets were supplemented with 0.25 percent pepsin (1:3000), whether the level of protein fed has an influence on the apparent digestibility of the protein, and whether the supplementation of pepsin increases the apparent digestibility of protein.

Procedure Six ration treatments were compared in a 2 x 3 factorial arranged experiment using six individually fed pigs per ration treatments. The design of the experiment is presented in Table 38 in the appendix. Three levels of protein were fed with and without pepsin. The pepsin (1:3000) was added at the rate of 0.25 percent of the ration. The three levels of protein fed were calculated to be 15, 20 and 25 percent. Soybean oil meal (50% protein) and lactose were used as the major sources of protein and carbohydrates and the protein levels were adjusted by adjusting the lactose and soybean oil meal. The compositions of the basal rations are presented in Table 13 in the appendix.

This experiment was conducted in Unit E in the summer of 1958.

The pigs were weaned at one week of age and placed in groups on floor pens in Unit E. The pigs were fed a preliminary ration composed of 40 percent dried skimmilk for three days. This preliminary feeding period was conducted so that all of the pigs would become adjusted to eating a dry ration before being placed on the less palatable lactose-soybean oil meal experimental ration. Saccharin (soluble) was added to the experimental ration at the rate of 0.05 percent to increase the palatability. After the pigs were fed the 40 percent dried skimmilk ration for three days, litter-mate pigs were randomly allotted across the six treatments. If the pigs were not eating the dry ration at the end of the three day preliminary feeding period the whole litter was discarded.

After the pigs were allotted to their respective treatments, they were placed on wire screens. Three days after being placed on the experimental ration, total fecal collections were carried out for a period of seven days. Collections were made three times each day and the wet feces were placed in polyethylene bags and stored in a deep freeze. During the fourth week of the experiment, a second collection of the total feces was conducted in the same manner as the first collection.

At the end of each collection period the feces were placed in a drying oven for 72 hours at 100 degrees centigrade. A sample of feed was dried in the same manner so that the nitrogen in the feed could be determined on a dry weight basis.

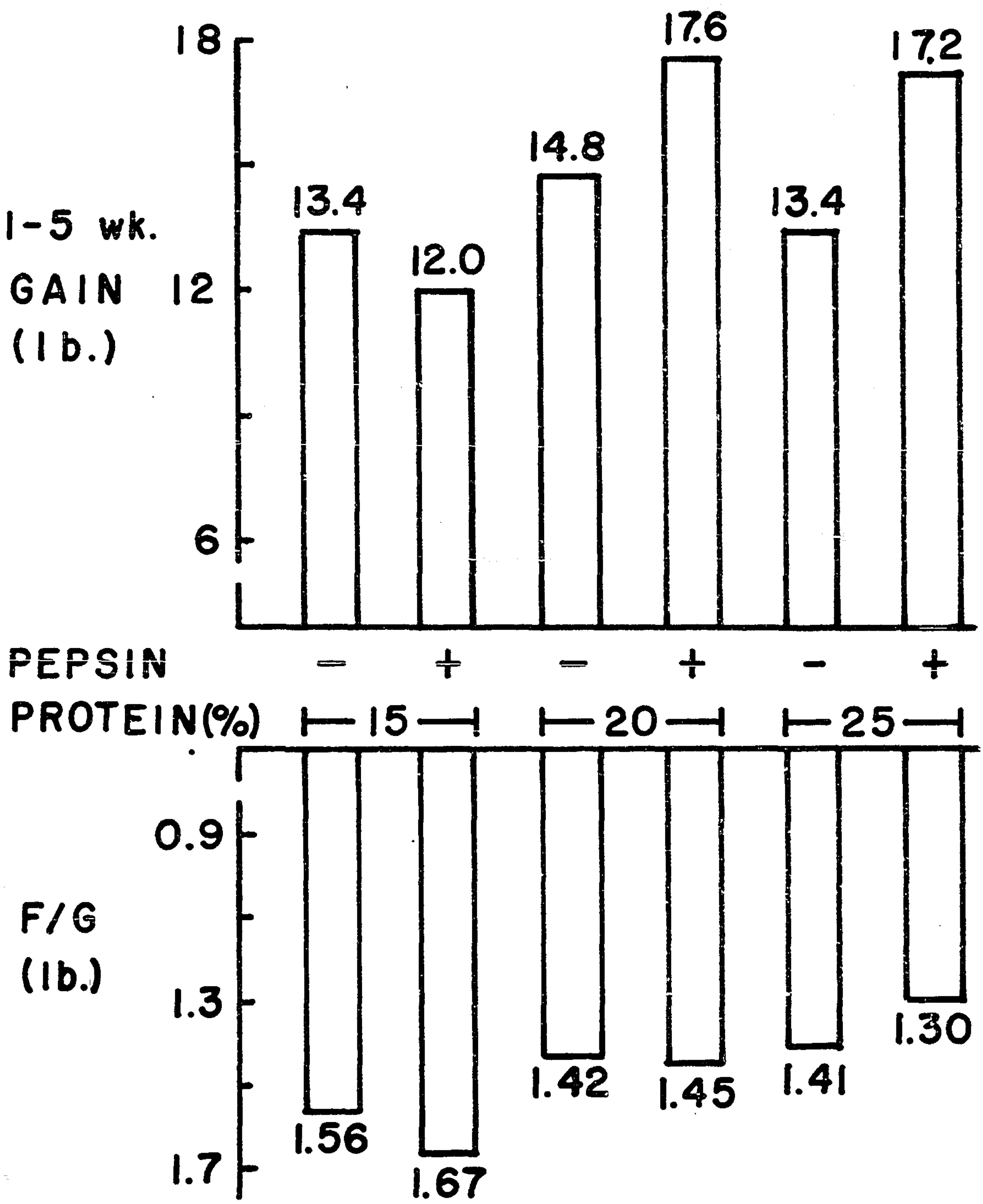
A standard macro-Kjeldahl procedure was used for the determination of the nitrogen in both the feed and the feces. Each of the determinations were run in duplicate. The apparent digestibility of the nitrogen was calculated by using the data from the nitrogen determinations and quantity of feed eaten as well as the quantity of feces excreted. The apparent digestibility of the nitrogen was expressed as apparent digestibility of protein by multiplying the nitrogen by 6.25.

Missing values were calculated by the procedures outlined by Snedecor (1956). The degrees of freedom subtracted from the error term corresponds to the number of missing values.

The average initial age and weight of the pigs were 10.0 days and 6.5 pounds, respectively.

Results and discussion The results of the growth and feed data are shown in Figure 8. Although there appeared to be a trend toward increased growth by the pigs receiving the higher levels of protein, the differences were not significant. The growth of the pigs receiving the 15 percent protein ration supplemented with 0.25 percent pepsin (1:3000) was somewhat less than the non-supplemented ration. However, the growth of the pigs receiving the 20 and 25 percent protein rations supplemented with pepsin were improved by about three pounds when compared to the 20 and 25 percent protein rations containing no added pepsin. Here again, the pepsin supplemented rations tended to improve growth but the differences were not significant.

Figure 8. Experiment 910 - Effects of protein levels without and with supplemental pepsin on pig gains and feed required per pound of gain

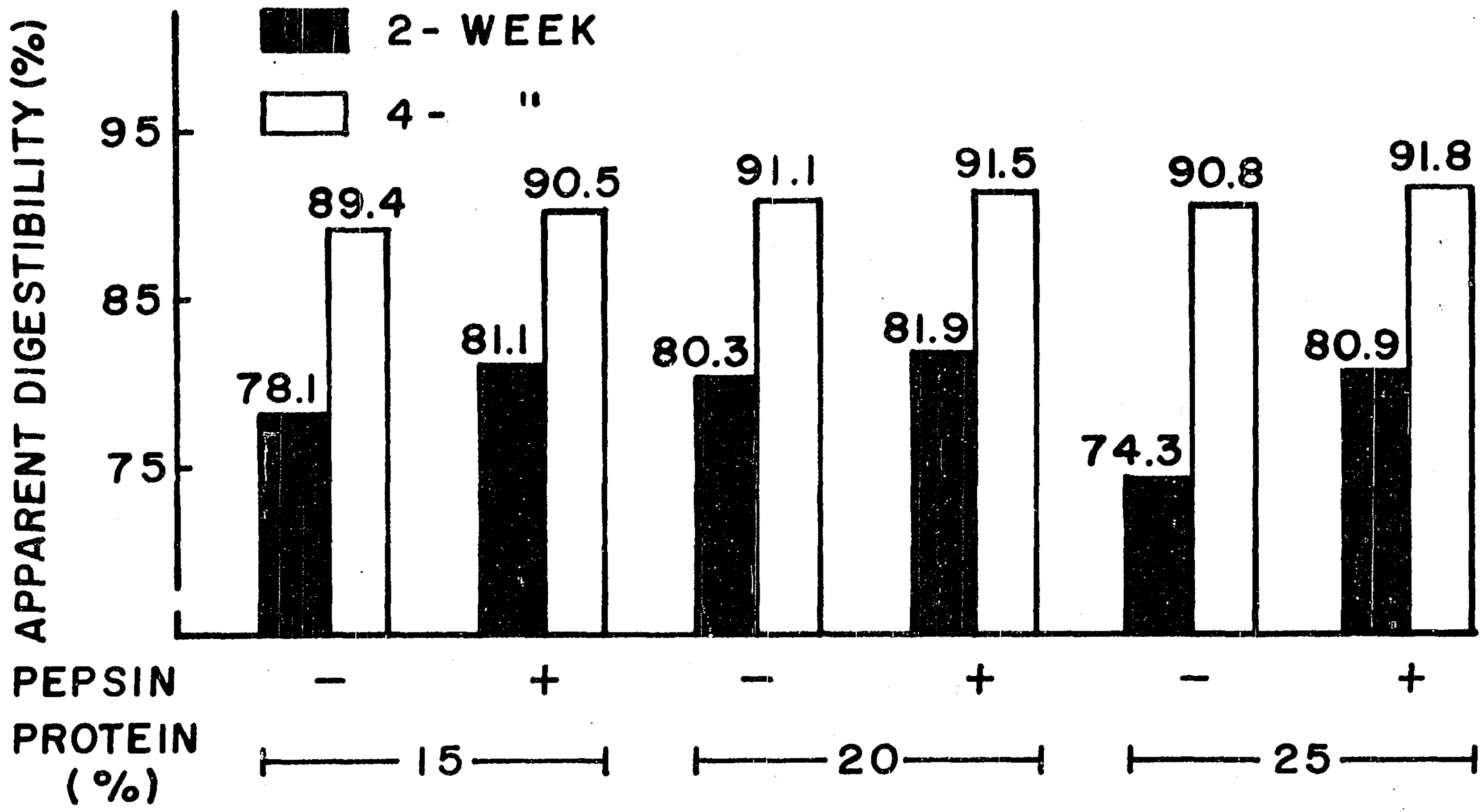

18
17.6
17.2
14.8
13.4
13.4
1-5 wk.
12.0
GAIN 12
(lb.)
6
PEPSIN
−
+
−
+
−
+
PROTEIN(%)
15
20
25
0.9
F/G
(lb.)
1.3
1.30
1.42
1.45
1.41
1.56
1.7
1.67

No improvement in feed efficiency was observed by the supplementation of pepsin to the rations. There was, however, a significant ($P < 0.05$) linear improvement in feed required to produce a pound of gain as the level of protein in the ration increased. It should be pointed out that the feed required to produce a pound of gain is less in the 20 and 25 percent protein rations than is usually encountered when soybean oil meal is used as a source of protein. The possible cause of this could be due to lactose being used as the only source of carbohydrate since the carbohydrate of choice for the baby pig has been shown to be lactose, Hudman (1956). The analysis of variance for the gain and feed required per pound of gain is presented in Table 39 in the appendix.

One pig died during the first week of the experiment. Necropsy examination of the pig revealed no gross lesions. Bacteriological examination did not reveal the presence of pathogenic bacteria. During the second week of the experimental period a second pig died. Necropsy examination showed evidence of a septicemia. Bacteriological examination revealed a Salmonella sp. A third pig was taken off experiment during the second week because of its failure to eat. Scouring was rather extensive during the first two weeks of the experiment.

The pigs were farrowed in pasture units which had previously contained growing-finishing hogs. Thus, the pigs

Figure 9. Experiment 910 - Comparison of apparent digestibility of soybean oil meal protein by pigs at two and four weeks of age


2- WEEK
4- "
APPARENT DIGESTIBILITY (%)
95
85
75
89.4
90.5
91.1
91.5
90.8
91.8
78.1
81.1
80.3
81.9
74.3
80.9
PEPSIN
−
+
−
+
−
+
PROTEIN (%)
15
20
25

were scouring when they were weaned and the Salmonella sp. organism was brought into the unit with the pigs.

The results of the digestibility studies are presented in Figure 9. The individual pig data are presented in Table 40 in the appendix. The apparent digestibility of protein by the two-week-old pigs was significantly ($P<0.05$) improved when pepsin (1:3000) was added at the rate of 0.25 percent of the ration. The average apparent digestibilities for the pepsin supplemented and non-supplemented pigs were 81.3 and 77.6 percent, respectively.

Although a slight improvement in apparent digestibility of protein was observed in the four-week-old pigs supplemented with pepsin, no significant difference was evident. The analysis of variance for the apparent digestibility of the protein is presented in Table 41 in the appendix. The difference in the response (apparent digestibility of protein) to pepsin supplementation to two- versus four-week-old pigs was probably due mainly to two factors. First, the pigs have a better developed enzyme system at four weeks of age than they have at two weeks of age and, second, the scouring of the pigs was much greater during the first collection period. Thus, the pepsin secreted by the baby pigs did not have as long a period of time to digest the protein because the food moved through the digestive tract at a faster than normal rate.

The apparent digestibility of the protein by the four-week-old pigs was about 10 percent greater than the two-week-old pigs. This is further evidence that the older pig is better equipped to utilize soybean oil meal protein.

There was a significant ($P < 0.05$) positive correlation between the apparent digestibility of protein during the first collection period and the growth of the pigs during the four weeks of the experiment.

Experiment 929

Objective The purpose of this experiment was to determine whether pepsin (1:3000) added at the rate of 0.25 percent of the ration would increase the apparent digestibility of protein and whether a laxative added to the ration during the fourth week of the experiment would influence the apparent digestibility of the protein.

Procedure The management of the pigs was the same as that described in Experiment 910. The basal ration was of the same composition as the 25 percent protein ration fed in Experiment 910. The basal ration was fed with and without 0.25 percent pepsin (1:3000) for the first three weeks of the experiment to 18 individually fed pigs on each ration treatment. During the fourth week of the experiment, nine of the pigs from each ration treatment were fed the same diet they had received for the first three weeks of the experiment and the other nine pigs from each ration treatment were fed the same diet with cascara added. The powdered cascara was added at the rate of two grams per pound of feed. The pigs were allotted to their respective treatments in the fourth week of the experiment on the basis of the apparent digestibility of protein in the first digestion trial.

The rate of food passage was determined as described in Experiment 780.

The fecal collections, nitrogen determinations, and apparent digestibility of protein were conducted in the same manner as described in Experiment 910.

This experiment was conducted in Unit E during the fall of 1958.

The average initial age and weight of the pigs were 10.0 days and 6.4 pounds, respectively.

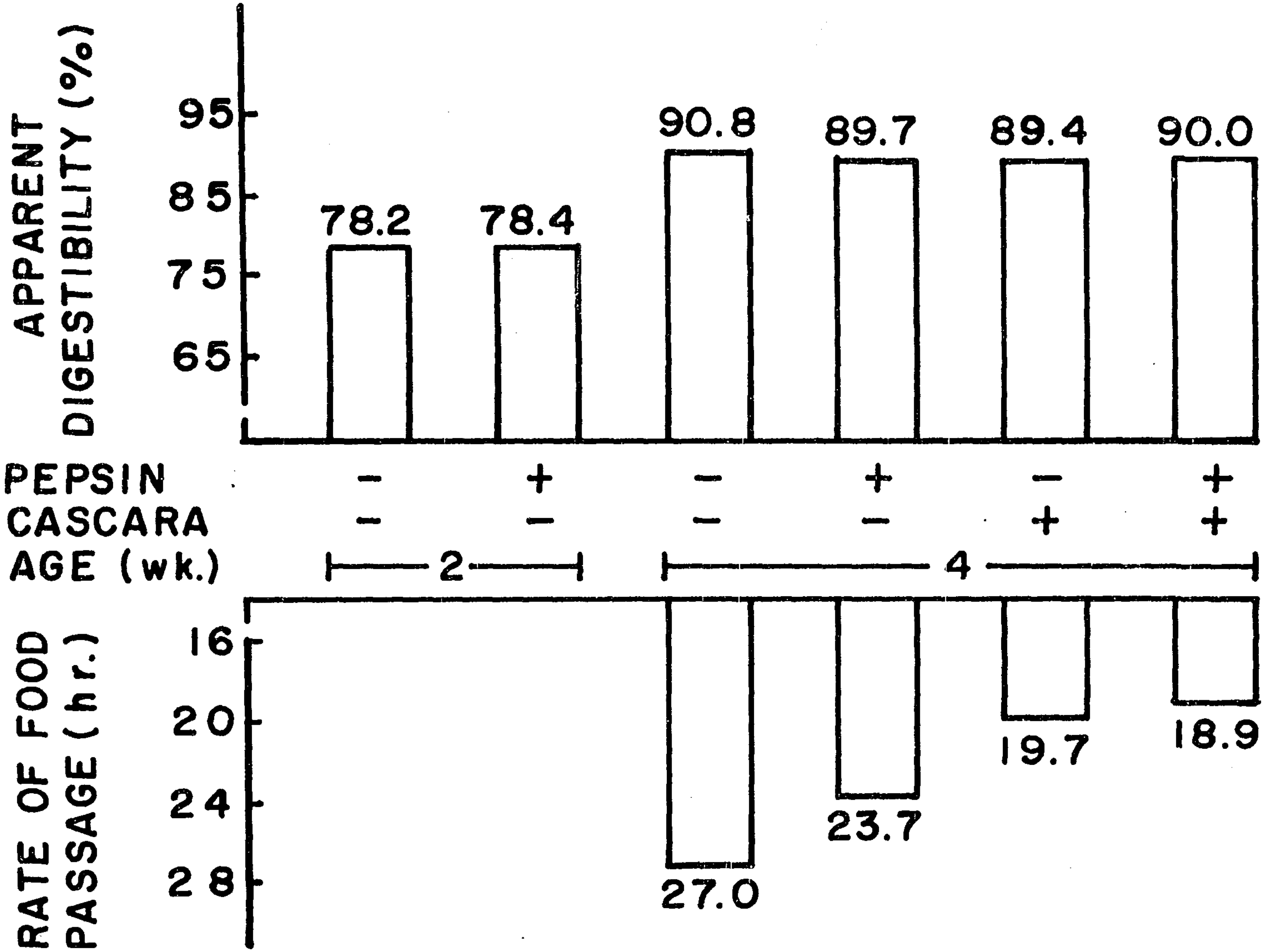
Results and discussion The weight gains and feed required per pound of gain are presented in Table 42 in the appendix. Since the pigs were fed the cascara only during the last week of the experiment, it cannot be assumed that the differences in the growth rate and feed efficiency of the pigs were a direct result of the rations fed. It was felt that the pigs might become resistant to the laxative effect of the cascara when fed over a long period of time. This was the reason that the cascara was fed only during the last week of the experiment. The addition of the pepsin to the ration did not improve the growth of the pigs during the four-week experimental period.

The addition of cascara to the ration for the last week did not appear to have an effect on the feed efficiency when averaged for the four-week experimental period. The pigs fed the diets supplemented with pepsin required 0.10 pounds less feed to produce a pound of gain than the non-supplemented pigs. However, these differences were not significant. The analysis of variance of gain, feed per pound of gain, and rate of food passage is presented in Table 43 in the appendix.

There was essentially no difference in the apparent digestibility of protein due to the ration treatments in either the two- or four-week-old pigs. The apparent digestibilities of protein for the pigs two and four weeks of age were about 78 and 90 percent, respectively. These are essentially the same values that were obtained for the same periods in Experiment 910. The summary for the digestibility trials is shown in Figure 10 and the individual pig data are presented in Table 44 in the appendix.

Powdered cascara added at the rate of two grams per pound of diet resulted in a significant ($P < 0.05$) increase in the rate of food passage. The results are shown in Figure 10. The individual pig data are presented in Table 45 in the appendix. There was very little scouring of the pigs during the experimental period. Even though the cascara signifi-

Figure 10. Experiment 929 - Effects of supplemented pepsin on the apparent digestibility of soybean oil meal protein by two-week-old pigs, and the effects of supplemented pepsin with and without cascara on the apparent digestibility of soybean oil meal protein and the rate of food passage


APPARENT DIGESTIBILITY (%)
95
85
75
65
78.2
78.4
90.8
89.7
89.4
90.0
PEPSIN - + - + - +
CASCARA - - - - + +
AGE (wk.) 2 4
RATE OF FOOD PASSAGE (hr.)
16
20
24
28
27.0
23.7
19.7
18.9

cantly increased the rate of food passage through the digestive tract, the pigs were not classed as scouring. Preliminary tests indicated that two grams of cascara per pound of ration was the maximum amount that could be added without causing a decrease in feed consumption. The powdered cascara has a very bitter taste and the feed is apparently distasteful to the pig if more than two grams of the cascara per pound of feed are added.

In Unit E where the disease level is relatively low, it would appear that a larger quantity of laxative would be needed to produce a scouring condition in pigs than in a conventional building where the disease level is higher and the feces of the pigs tend to be more watery. Thus, some other cathartic would need to be used to produce a scouring condition without reducing feed intake of the baby pigs where the disease level is relatively low.

The coefficient of correlation ($r = +0.57$) between the rate of food passage and apparent digestibility of protein during the fourth week of the experiment was significant ($P < 0.05$). Although the actual rate of food passage was not measured during the first digestion trial, the scouring days for the pigs receiving the pepsin was 1.9 compared to 0.9 days for the non-supplemented pigs. Assuming that the pepsin had no effect on the rate of food passage and the increased scouring of the pigs receiving the supplemented pepsin was by chance, then the supplemented pepsin may have increased the apparent digestibility of the protein since the digestibility coefficients of the two ration treatments were the same but the scouring indices of the pigs receiving the pepsin was greater. This is assuming that there is a significant correlation between the rate of food passage and the apparent digestibility as found in the second digestion trial.

One pig died during the second week of the experiment. Necropsy examination of the pig revealed a counterclockwise volvulus of the small intestine.

Feeding of Soybean Oil Meal Hydrolyzates

Experiment 727

Objective The purpose of this experiment was to determine whether the predigestion of soybean oil meal with proteolytic enzymes would improve pig growth.

Procedure A total of 112 baby pigs averaging 6.2 pounds and 8.5 days of age and confined on concrete in groups of four pigs to a pen were used in this trial. The pigs were allotted at random within each of two replications with the restriction that no pen contained littermate pigs.

This experiment was conducted in Unit C during the spring of 1956.

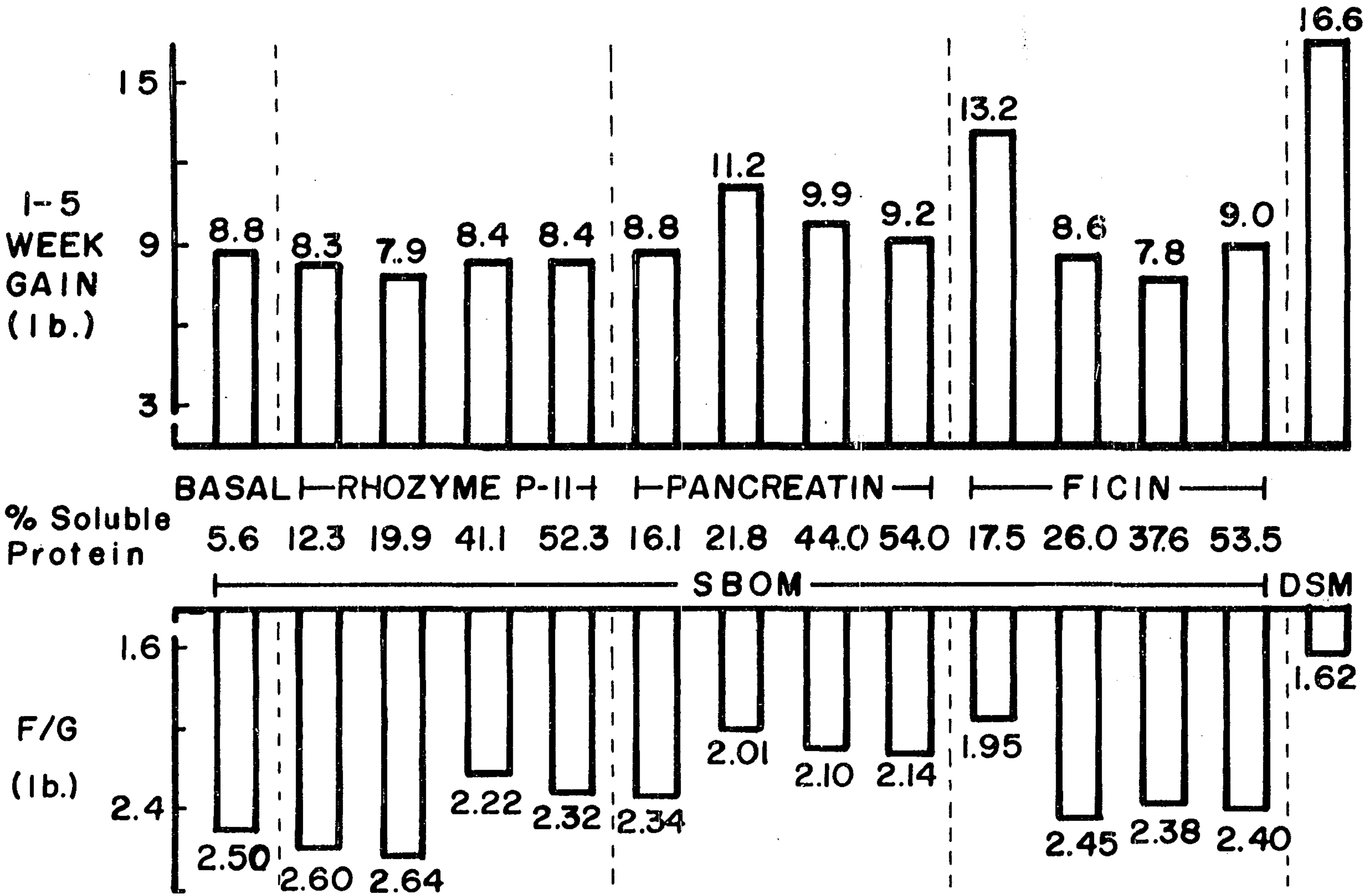
There were 14 ration treatments tested, twelve of the ration treatments consisted of hydrolyzates produced by either Rhozyme P-11, pancreatin (U.S.P.), or ficin. Soybean oil meal (50% protein) was hydrolyzed to four different degrees of soluble protein by each of the proteolytic enzymes. The degree of hydrolysis as determined by the trichloroacetic acid technique is presented in Figure 11. The percent soluble protein as expressed in these trials is the percent soluble nitrogen per total nitrogen. One ration treatment contained the soybean oil meal processed through the same procedure as the hydrolyzates but no enzyme was added to the substrate to produce hydrolysis. The composition of this ration is presented in Table 11. A 40 percent dried skimmilk ration treatment was also fed to compare the soybean oil meal protein treatments with milk protein.

The degree of hydrolysis was traced, using nitrogen analysis at the isoelectric point, which when compared to the total nitrogen available would yield the permanently soluble protein which is a measure of the extent of hydrolysis. The soybean protein hydrolyzates were all dried in a similar manner as milk is spray dried.

The predigested protein was produced by Archer-Daniels-Midland Company, Minneapolis 2, Minnesota, under the supervision of Miss Twile M. Paulsen.

<u>Results and discussion</u> The results are shown in Figure 11. The analysis of variance and individual pen data

Figure 11. Experiment 727 - Gains and feed efficiency of baby pigs as affected by rations containing soybean oil meal predigested to four levels of soluble protein by either Rhozyme P-11, pancreatin, or ficin


1-5 WEEK GAIN (lb.)
15
9
3
8.8
8.3
7.9
8.4
8.4
8.8
11.2
9.9
9.2
13.2
8.6
7.8
9.0
16.6
BASAL
RHOZYME P-11
PANCREATIN
FICIN
% Soluble Protein
5.6 12.3 19.9 41.1 52.3 16.1 21.8 44.0 54.0 17.5 26.0 37.6 53.5
SBOM
DSM
F/G (lb.)
1.6
2.4
2.50
2.60
2.64
2.22
2.32
2.34
2.01
2.10
2.14
1.95
2.45
2.38
2.40
1.62

of gain and feed per pound of gain are presented in the appendix in Tables 46 and 47, respectively.

The soybean oil meal predigested with Rhozyme P-11 did not improve the growth of the baby pigs during the experimental period. The pancreatin digests showed some promise in improving the growth of early weaned pigs. The pigs receiving the ration which contained the pancreatin hydrolyzed protein predigested to 21.8 percent soluble protein gained 11.2 pounds during the four-week experimental period, whereas the pigs receiving the basal ration gained 8.8 pounds for the same period.

The soybean oil meal predigested with ficin to 17.5 percent soluble protein showed the most promise of any of the hydrolyzates. The gain of the pigs fed the ration containing this material was 13.2 pounds, as compared to 8.8 pounds for the pigs fed the nondigested soybean oil meal. These gains were much less than the 16.6 pounds gain of the pigs receiving the 40 percent dried skimmilk ration. The composition of the 40 percent dried skimmilk ration is presented in Table 9 in the appendix.

The feed per pound of gain was improved in all of the treatments receiving the predigested protein with the exception of two rations containing material predigested with Rhozyme P-11 to 12.3 and 19.9 percent soluble protein.

Five pigs died during the experimental period. The first two pigs died during the second week of the experiment. Necropsy examination of one pig revealed an omphalitis, fibrinous peritonitis, petechiation of the kidneys, and peri-renal edema. The other pig which died during the first week revealed only an enteritis. The third and fourth pigs died during the third week of the experimental period. Necropsy examination of both pigs revealed only an enteritis. Necropsy examination of the fifth pig which died during the fourth week of the experimental period revealed hemorrhages on the bladder mucosa, hemorrhages on the epicardium, and enteritis. Bacteriological examination did not reveal the presence of bacterial pathogens in any of the pigs which died during the experiment.

It should be pointed out here that the predigested material fed was rather high in ash content, approximately 10 percent. Potassium hydroxide was used to adjust the solution to the desired pH value for the optimum action of the enzymes used in the actual predigestion of the soybean oil meal. Thus, the potassium content was much higher in the predigested material than is found in natural-feed-stuffs. It was thought that the high pH of the predigests might be objectionable to the pig since the high pH value and the potassium in the predigests might give the material a "soapy" taste. Thus, phosphoric acid was added before the material was dried to yield a pH value of approximately 7.0. The actual processing technique of the digestion cannot be disclosed due to policy of Archer-Daniels-Midland Company.

The high ash content of the material may have had an influence on the growth rate of the pigs. The ficin predigested material which gave the greatest improvement in growth and feed efficiency (17.5 percent soluble protein) contained about 9.2 percent ash, whereas the other samples contained approximately 10 percent ash. A second factor which may have had an influence on the improved growth and feed efficiency by this material was the pH value. The pH value for the ficin predigested soybean oil meal to 17.5 percent soluble protein was 5.6, whereas the pH values for the other samples were approximately 7.0.

Experiment 864

Objective The purpose of this experiment was to determine whether the growth of the baby pigs could be increased by the addition of various levels of the predigested soybean oil meal to the ration.

Procedure Four ration treatments were compared with six individually fed pigs per treatment. The treatments are presented in Table 48 in the appendix. The composition of the rations are presented in Table 12 in the appendix.

Solvent extracted soybean oil meal (50 percent protein) without previous treatment was used as the major source of protein in rations containing no hydrolyzates. The hydrolyzate used in this experiment was the soybean oil meal predigested with ficin to 17.5 percent soluble protein. This is the same material that gave the greatest growth response in Experiment 727.

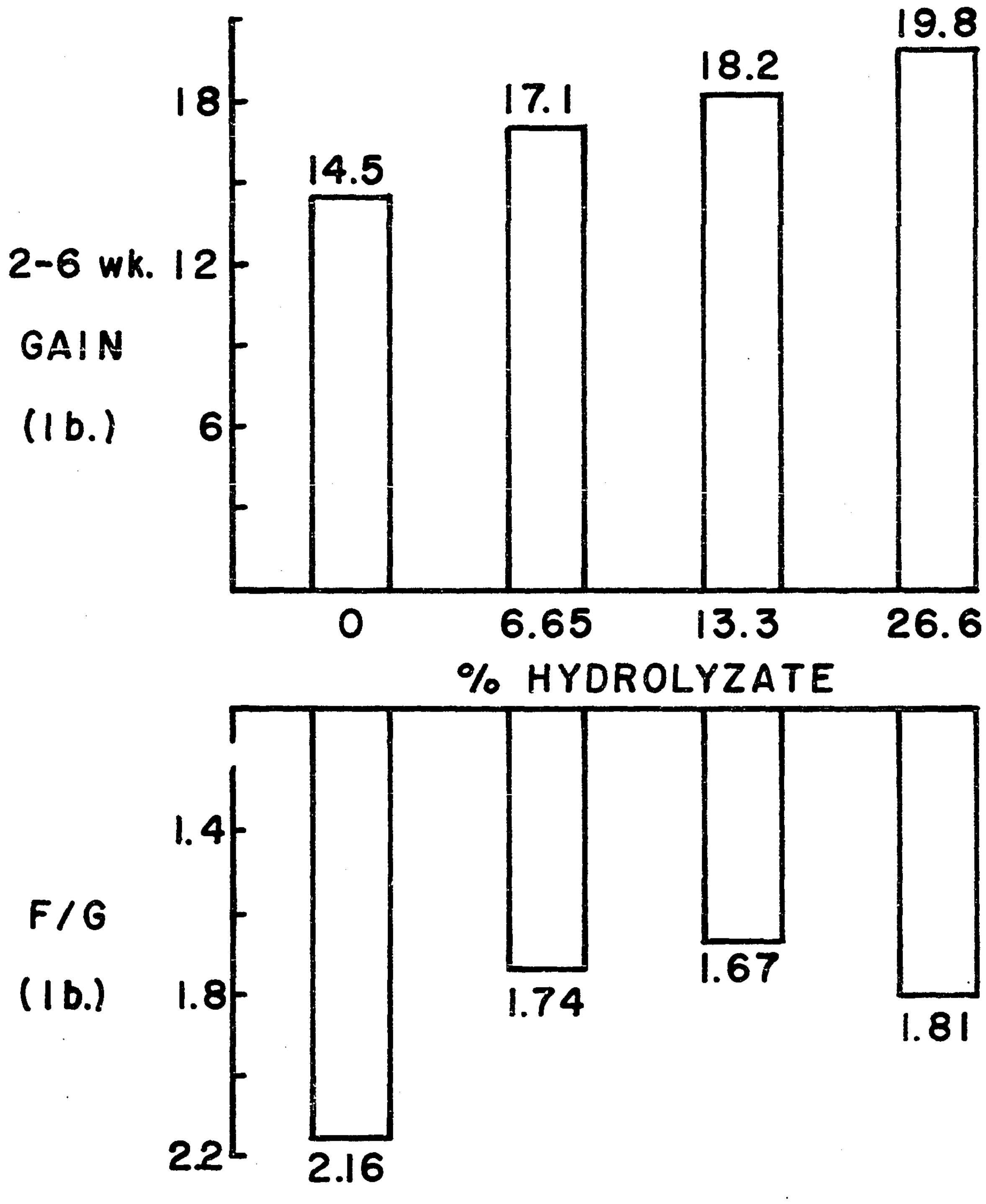
The hydrolyzate was fed at the rate of 0, 6.65, 13.30, and 26.60 percent of the rations.

The average initial age and weight of the pigs were 13.0 days and 8.4 pounds, respectively.

Results and discussion The results are presented in Figure 12. There was a significant ($P<0.05$) linear increase in the growth of the pigs as the level of hydrolyzates increased. These results support the findings in Experiment 727. The growth of the pigs in this trial was superior to those in the previous experiment. Three factors which may have influenced these differences are: first, the pigs were about four days older in this experiment; second, the hydrolyzate was fed at lower levels, thus the ash content of the feed was lower; and third, the pigs in this experiment were individually fed in Unit E, whereas the pigs in Experiment 727 were group fed in Unit C. As mentioned earlier, the pigs housed in Unit E have an advantage due to the well-controlled environmental conditions.

There was an improvement in feed efficiency where pigs were fed the rations containing the hydrolyzates. The great-

Figure 12. Experiment 864 - Effects of levels of soybean oil meal hydrolyzates, predigested with ficin to 17.5 percent soluble protein, on gains and feed efficiency of baby pigs



19.8
18.2
17.1
14.5
18
2-6 wk. 12
GAIN
(lb.)
6
0
6.65
13.3
26.6
% HYDROLYZATE
1.4
F/G
(lb.)
1.8
2.2
1.74
1.67
1.81
2.16

est improvement in feed efficiency was observed in the treatment receiving 13.30 percent predigested soybean oil meal. The feed required to produce a pound of gain was 1.67 for this treatment as compared to 2.16 for the treatment containing no predigested soybean oil meal.

The analysis of variance for gain and feed required per pound of gain is shown in Table 49 in the appendix.

Practically no scouring of the pigs was observed in this experiment.

Experiment 884

Objective   The purpose of this experiment was to compare the rate of growth of pigs fed three sources of protein, solvent extracted soybean oil meal (50 percent protein), solvent extracted soybean oil meal hydrolyzate (50 percent protain), and casein (88 percent protein).

Procedure   Three ration treatments were compared with eight individually fed pigs per treatment. The treatments are presented in Table 6. The composition of the rations are presented in Table 12 in the appendix. The soybean oil meal hydrolyzate was the same material as used in Experiment 864. The percent of the predigested soybean oil meal used in the ration was 32.5 percent. This was higher than any of the levels added to the rations in Experiment 864.

Missing values were calculated by procedures outlined by

Table 6. Experiment 884 - Summary of pig gains and feed required per pound of gain

Rep.	Treatments (protein)		
	SBOM	SBOM hydrolyzate (ficin digested)	Casein
	2-6 week gains (lb.)		
1	14.3[a]	9.5	23.0
2	10.4	12.9	16.8
3	23.3	13.1	23.3
4	14.9	17.8	17.7
5	17.8	13.3	22.9
6	12.2	16.8	22.2
7	10.2	12.0	20.8
8	19.6	15.2[a]	19.2
Av.	15.3	13.8	20.7
	Feed/gain (lb.)		
1	1.86[a]	2.13	1.35
2	1.86	1.85	1.55
3	1.87	2.05	1.54
4	1.71	1.83	1.49
5	2.04	2.08	1.61
6	1.97	1.80	1.64
7	1.84	1.91	1.63
8	1.63	1.77[a]	1.43
Av.	1.85	1.93	1.53

[a]Calculated values (Snedecor, 1956, p. 310).

Snedecor (1956). Two degrees of freedom were subtracted from the error term to correct for the two missing values.

The average initial age and weight of the pigs were 14.0 days and 9.3 pounds, respectively.

<u>Results and discussion</u> The results of this experiment

are presented in Table 6. The growth rate and feed efficiency of the pigs receiving the casein diet were significantly ($P < 0.05$) improved over the pigs receiving either the solvent extracted soybean oil meal or the soybean oil meal hydrolyzate. There was no significant difference in the growth rate or feed efficiency of the pigs receiving the two soybean oil meal rations. The analysis of variance is presented in Table 50 in the appendix.

The poor performance of the pigs receiving the predigested protein as compared to the pigs receiving the casein was rather surprising since the pigs receiving the predigested protein in Experiment 864 showed superior performance. The increased percentage of hydrolyzate in the ration of this experiment may have been a contributing factor to the slower growth of the pigs since the ash content of the predigested material was 9.2 percent as compared to approximately 6.0 percent for the regular soybean oil meal. This may have an effect on the growth of the pigs as discussed earlier.

Pepsin Activity of the Stomach Tissue and Stomach Contents

Experiment 800

Objective It has previously been suggested that the baby pig secretes insufficient amounts of pepsin to sufficiently digest soybean protein. This experiment was designed to determine the peptic activity of extracts from the stomach tissue and stomach contents of baby pigs at weekly intervals from birth to eight weeks of age.

Procedure The pigs sacrificed in this experiment were the progeny of crossbred sows (Poland China, Landrace, and Duroc) mated to Farmers Hybrid boars. Sixteen litters of pigs were selected for this study. The only stipulations in the selection of the litters were that the pigs appear healthy at birth and that the litters contain enough pigs for the weekly sacrifices.

Eight litters of pigs nursed the sows for the entire experiment and the other eight were early weaned at one week of age. The pigs which were not early weaned received only their mother's milk as a source of feed, and were housed with their dam outside Unit C in concrete pens. The early weaned pigs were self-fed in individual pens in Unit C. Self-waterers were also made available to the pigs at all times.

This experiment was conducted during the summer of 1957.

For the first week after weaning, the pigs were fed a 40 percent dried skimmilk ration similar to the one present in Table 9. From two to five weeks after weaning the pigs received an 18 percent protein starter ration which consisted of 21.1 percent ground yellow corn, 15 percent sucrose, 20 percent rolled oats, 15 percent solvent soybean oil meal (50 percent protein), 10 percent dried skimmilk, 10 percent whey

2.5 percent condensed fish solubles, 2 percent stabilized lard, plus vitamins and minerals. During the last three weeks of the experiment the pigs were fed an 18 percent grower ration composed of 69 percent ground yellow corn, 20 percent solvent soybean oil meal (50 percent protein), 2.5 percent condensed fish solubles, 2.5 percent dried distiller solubles, 2.5 percent dried whey, plus minerals and vitamins.

The sacrificing date of each pig was predetermined at birth by random selection from within the litter. Two pigs from four of the litters on each treatment were sacrificed at birth, 2, 4, 6 and 8 weeks of age. Thus, these litters consisted of 10 pigs each. In the other four litters on each treatment, two pigs from each litter were sacrificed at 1, 3, 5 and 7 weeks. There were only eight pigs in each of these litters. Sixteen pigs were sacrificed in each of the nine age groups which gave a total of 144 pigs sacrificed in the experiment.

On the day that the pigs were to be sacrificed, they were removed from their respective pens for a period of two hours. At the end of the two-hour period the pigs were returned to their respective pens and allowed to eat or nurse for 30 minutes. They were then placed in holding pens for one hour. At the end of this time the pigs were sacrificed.

The pigs were electrocuted and then bled. The body cavity was opened and the stomach was removed as rapidly as possible. Exterior fat and connective tissue were trimmed from the stomachs as they were removed from the carcasses. After the contents of each stomach had been thoroughly mixed, a sample was removed and placed in a waxed paper cup. After the ingesta sample had been taken, each stomach was washed of its contents in cold tap water and then weighed. The stomachs and the samples of stomach contents were stored in a deep freeze, at approximately minus 15 degrees centigrade, until they were assayed for their peptic activity.

In the preparation of the stomach tissues for peptic activity, the tissues were weighed and the weight recorded. Nine milliliters of 0.085 normal hydrochloric acid was added for each gram of tissue. The 1:10 dilution was homogenized for two minutes in a Waring Blender. The homogenate was poured into a flask and stoppered with a foil covered cork stopper and stored in a cold room at 4 degrees centigrade for approximately 18 hours.

The stomach contents were prepared by the same method as the tissue except only three milliliters of the acid water was added per gram of contents and the mixture was blended for one minute.

The peptic assays of the stomach tissue and the stomach contents were determined in replicates with approximately 20 samples per group.

A standard curve was determined for each group of assays.

Figure 13. Experiment 800 - Standard curve employed in the calculations of the dilution factors[a]

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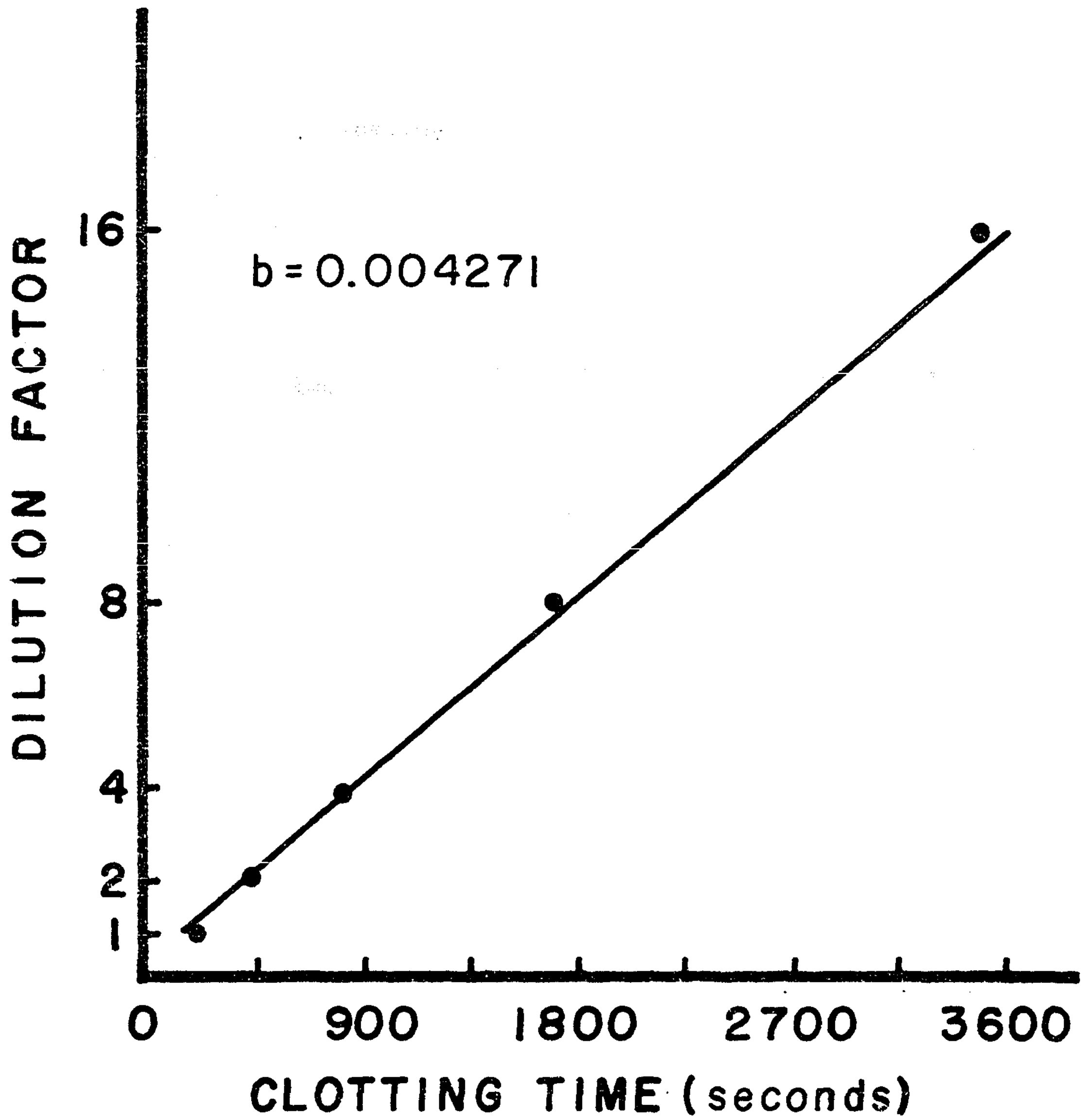
[a]Dilution factor units of 1, 2, 4, 8, and 16 represents 2.4, 1.2, 0.6, 0.3, and 0.15 units of N.F. activity, respectively.


DILUTION FACTOR
16
8
4
2
1
b = 0.004271
0
900
1800
2700
3600
CLOTTING TIME (seconds)

The standard curve presented in Figure 13 represents the pooled standard curves for all determinations. A Y intercept was calculated for each individual standard curve. A dilution factor for each assay was determined by using the b value of the pooled standards and the Y intercept value from the individual standard curve in which the assay was determined.

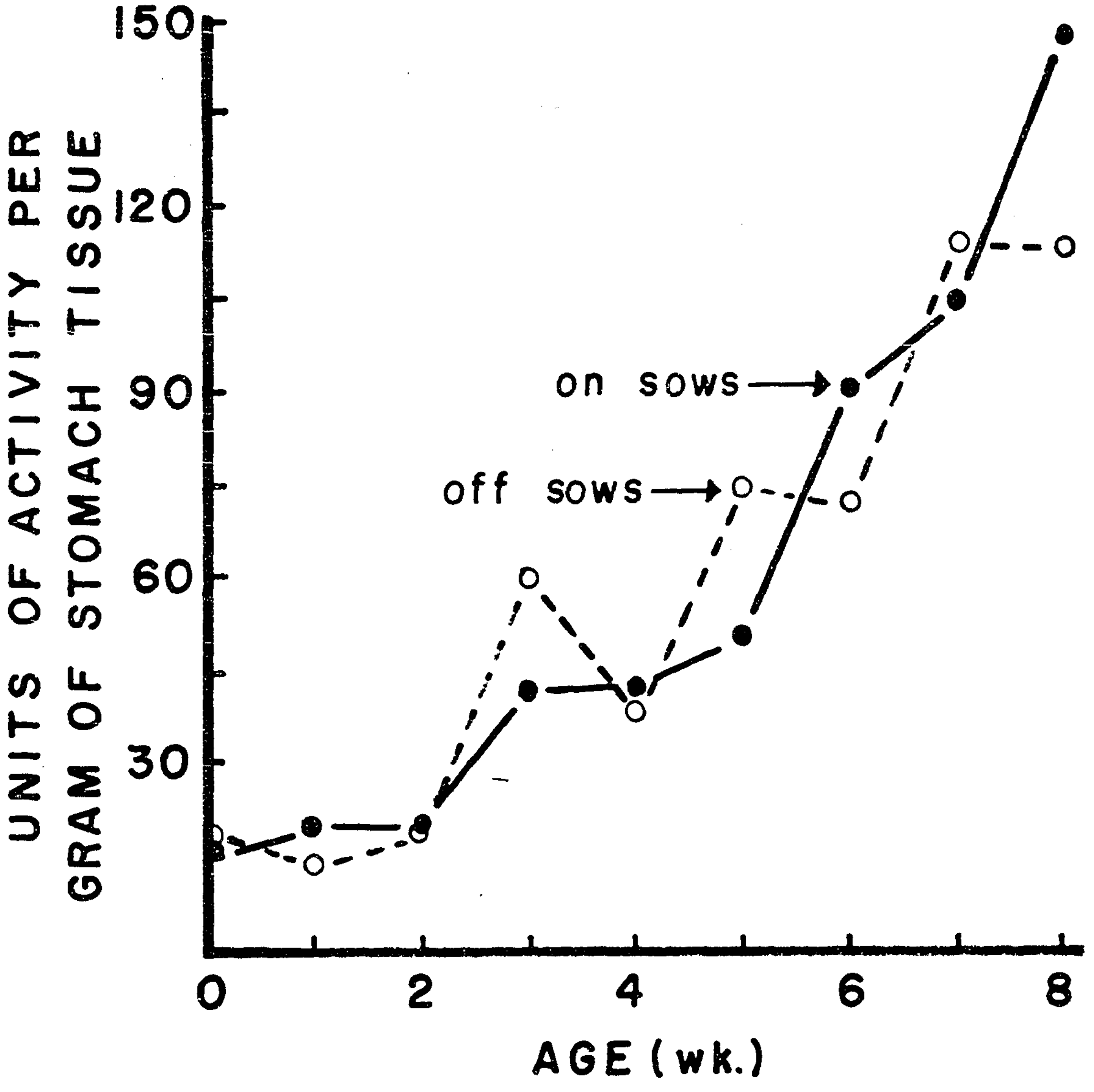
The protease activities at pH 5.5 were determined by the milk-clot method of Anderson et al. (1951) using a reconstituted dry skimmilk substrate. National Formulary Reference pepsin served as the standard. Results are reported in terms of National Formulary activity calculated on a wet weight basis.

The relationship between the dilution factor and the peptic activity is presented on the facing page of Figure 13.

When the peptic activity of a sample was too small to measure, a minimum value was assigned to that sample to allow for statistical analysis. When a missing value occurred due to an insufficient quantity of a sample or for any other reason, the missing value was obtained by calculating the average value for that age group and treatment.

Results and discussion The results of the pepsin activity from the extracts of the stomach tissue are presented in Figure 14. There was no significant difference in the pepsin activity due to the treatment (early weaned pigs versus

Figure 14. Experiment 800 - Pepsin activity of pig stomach tissue extracts plotted against age


UNITS OF ACTIVITY PER GRAM OF STOMACH TISSUE
150
120
90
60
30
on sows
off sows
0
2
4
6
8
AGE (wk.)

nursing pigs). There was, however, a significant ($P < 0.01$) increase in the pepsin activity as the age of the pig increased. The tendency for the values to rise and fall as the age increases is believed to be due largely to litter effect, especially among the early weaned pigs. As mentioned earlier, two pigs from the same litter were sacrificed every other week.

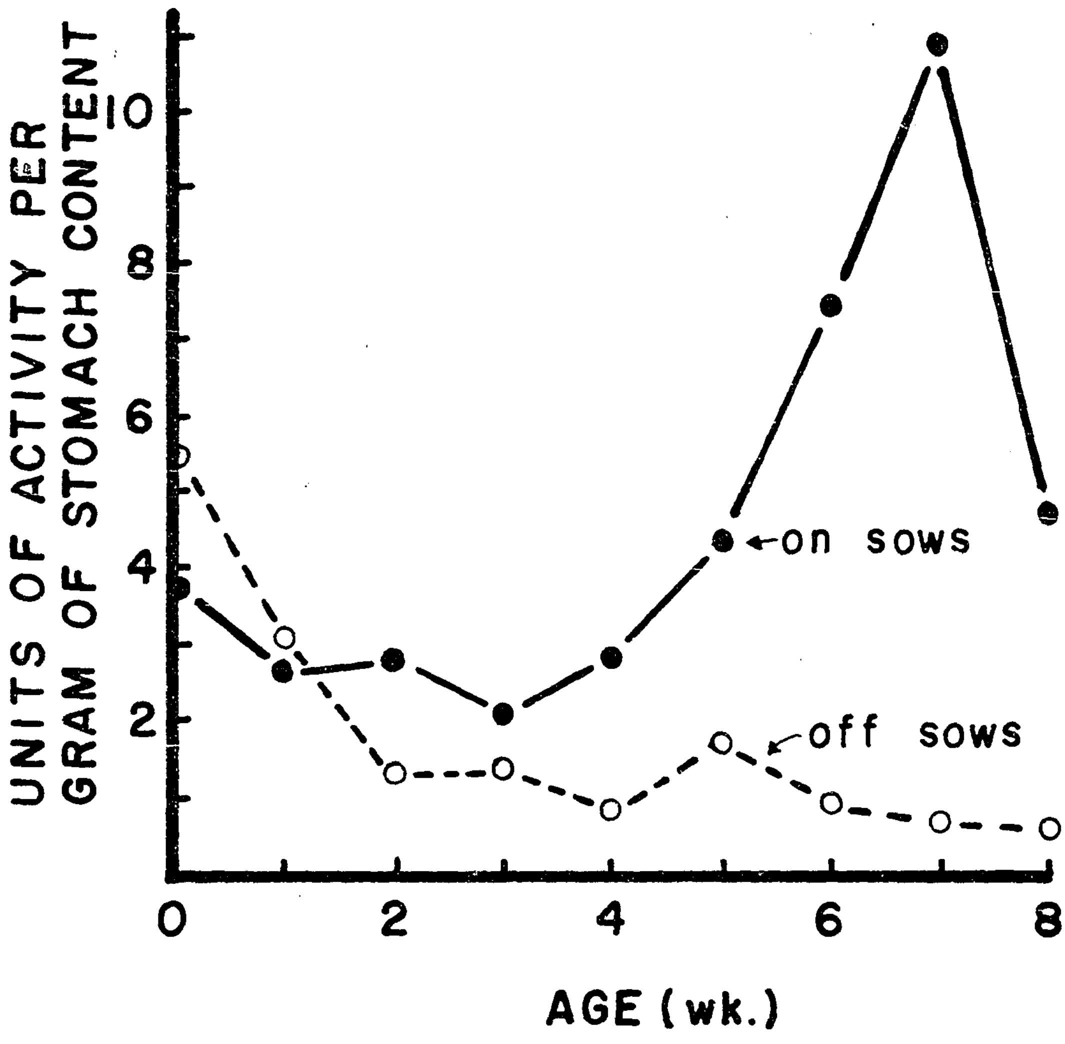
Even though it appears that some values are smaller than the previous week, the values for litter mate pigs actually increase in each successive two-week period.

The results of th^ pepsin activity from the extracts of the stomach contents are presented in Figure 15. The pepsin activity of the stomach contents of pigs nursing their mothers showed a slight decline for the first three weeks and then an increase in activity to seven weeks of age. There was a low level of activity observed at eight weeks of age.

The pigs that were early weaned showed a decline in the pepsin activity of the stomach contents from birth to eight weeks of age. The significance of these results will be discussed later.

The analysis of variance is presented in Table 51 in the appendix.

Figure 15. Experiment 800 - Pepsin activity of pig stomach contents plotted against age


UNITS OF ACTIVITY PER GRAM OF STOMACH CONTENT
0
2
4
6
8
10
AGE (wk.)
on sows
off sows

GENERAL DISCUSSION

Enzyme Supplementation of Baby Pig Rations

The results of Experiment 683 comparing six proteolytic enzymes supplemented to a soybean protein ration at the rate of one percent of the diet resulted in an improvement in both growth and feed efficiency of baby pigs weaned at approximately one week of age. These results are in agreement with the studies reported by Lewis et al. (1955) in which one percent pepsin and/or one percent pancreatin was supplemented to a similar ration. The improved performance in both growth and feed efficiency of the pigs receiving the partially inactive pepsin led the author to believe that pepsin added at the rate of less than 1.0 percent of the diet might result in a greater increase in growth of the pigs.

In Experiments 705 and 735, in which various levels (0.0625, 0.125, 0.25, 0.50 and 1.0 percent) of pepsin were supplemented to a soybean protein ration, the diet containing 0.25 percent pepsin resulted in improved gains and feed efficiency when compared to the other treatments. Thus, it would appear that even though the ration containing 1.0 percent pepsin improves growth and feed efficiency a still further improvement is obtained by supplementing the ration with only 0.25 percent pepsin. The reason for the superiority of the lower level of pepsin is not clear. However, it is possible that the higher levels may be injurious to the gastro-intestinal tract of the baby pigs. Cunningham and Brisson (1957) have reported that baby pigs weaned at two days and fed a ration containing pepsin equivalent to approximately 1.67 percent pepsin (1:3000) and 0.5 percent pancreatin lived for 19.6 days as compared to 27.8 days for the non-supplemented pigs. Autopsy of the animals that died disclosed a large gastric ulcer in one of the control pigs. Redness of the greater curvature of the stomach and yellow patches on the intestine were observed in two pigs on the enzyme supplemented ration.

Cunningham and Brisson (1957) and Meade (1957) have reported trials dealing with enzyme supplementation of baby pig diets in which a consistent improvement in the performance of baby pigs could not be shown when pepsin was supplemented to the rations. In one trial that Cunningham and Brisson (1957) conducted, eight pigs two days of age were fed a diet consisting of 35 percent ground fish meal, 44.6 percent glucose, 20 percent lard, plus mineral and vitamins. Four pigs received the basal diet and the other four pigs received the basal diet plus 5.0 grams each of pepsin (1:10,000) and pancreatin per kilogram of diet. All of the pigs died before the end of the five-week experiment. It is questionable whether these results can be compared to the present studies since the pepsin was supplemented at a higher level and the type of protein used was different. Furthermore, the 100 percent death loss encountered and the limited number of pigs involved in the experiment conducted by Cunningham and Brisson makes any interpretation of the results doubtful.

No improvement in growth or feed efficiency of early weaned pigs was observed when various levels (0.125, 0.25, 0.5 and 1.0 percent) of pepsin (1:3000) were added to a ration containing 40 percent dried skimmilk. These findings may be due to the fact that casein is more rapidly digested with animal proteases than are the plant proteins. Thus, the baby pig may secrete a sufficient quantity of enzymes to digest milk protein but may not secrete a sufficient quantity of enzymes to adequately digest the soybean protein. Mareček and Herbrychová (1954) have found <u>in vitro</u> that animal proteins were more easily digested with pepsin, trypsin, and pancreatin than were the plant proteins. These workers also observed that the hydrolysis of the animal proteins gave rise to all amino acids approximately in the same ratio as found in the original protein, whereas hydrolysis of plant proteins proceeded in such a way that the amino acids do not appear in the same ratio as found in the original protein.

The pigs which received a dried skimmilk or casein ration usually grew at a faster rate than pigs receiving a soybean protein ration. These findings are in accordance with the results of Lewis (1956), Hudman (1956), and Hays (1957).

A general summary of the growth and feed efficiency of early weaned pigs fed a soybean protein ration with and without pepsin is presented in Table 7. As mentioned earlier, pepsin (1:3000) was added to the ration in Experiment 683 at the rate of 1.0 percent of the total diet. In all of the other experiments listed in Table 7, pepsin (1:3000) was added at the rate of 0.25 percent of the diet. All other ration treatments containing supplemented ingredients other than the levels of pepsin mentioned were not considered.

These data show that the weight gains of pigs receiving the supplemented and non-supplemented pepsin were 13.9 and 12.9 pounds, respectively. This represents a 7.8 percent improvement in favor of the pigs receiving the pepsin. The feed per pound of gain was improved from 1.98 pounds for the non-supplemented pigs to 1.88 pounds for the supplemented pigs. On a percentage basis these data represent a feed saving of 5.1 percent.

Factors Affecting the Growth Response of Baby Pigs Fed Rations Supplemented with Proteolytic Enzymes

The pH in the stomach of the baby pig has been reported by Liu _et al_. (1955) and Cunningham and Brisson (1957) to have

Table 7. Summary of gains and feed per pound of gain for all experiments conducted

Experiment No.	Type of protein	Gains (lb.)		Feed/gain(lb.)	
		Basal	Pepsin	Basal	Pepsin
683[a]	Drackett	8.2	10.2	2.62	2.30
705	Drackett	12.9	17.1	2.29	1.94
735	SBOM	18.0	19.0	1.68	1.68
762	SBOM	12.2	13.6	1.71	1.62
780	SBOM	9.4	10.1	2.18	2.01
795	SBOM	7.6	8.0	2.77	2.60
843	SBOM	13.6	13.2	1.68	1.65
891	SBOM	10.9	12.1	1.85	1.78
691	Drackett	13.4	11.4	2.12	2.20
910	SBOM	14.8	17.6	1.42	1.45
914[b]	SBOM	20.5	22.3	7.85	1.74
929	SBOM	12.8	11.9	1.62	1.53
Av.		12.9	13.9	1.98	1.88

[a]Pepsin (1:3000) added at the rate of 1 percent of the diet. Pepsin (1:3000) was added at the rate of 0.25 percent in all other experiments.

[b]Pigs conducted on a six-week test. All others were for a four-week test.

a value of approximately 3.5. From these data the question has arisen as to whether the supplementation of pepsin to the diets of baby pigs would increase the digestion of the protein in the pig's stomach, since the optimum pH value for pepsin activity is between 1.0 and 2.0 depending on the source of protein. There is, however, some peptic activity, although small, at pH values of 3.5. For discussion, let us assume that the baby pig does secrete a sufficient quantity of pepsin to adequately digest plant protein at an optimum pH value. The desired amount of digestion will not occur because the actual pH value of the stomach is not optimum for pepsin activity. It would appear logical that an increase (by supplementation of the diet) in the pepsin concentration in the stomach would increase the digestion of the protein to a more desirable degree (whatever this may be).

The age of the pigs appears to have an influence on the response of pigs fed rations supplemented with pepsin. In Experiment 914 a significant ($P < 0.05$) improvement in growth was observed where pigs one week of age were fed a ration containing 0.25 percent pepsin. However, the growth of litter mate pigs weaned at three weeks of age was not improved by the supplementation of the enzyme. Lewis *et al.* (1955) reported that the supplementation of pepsin and pancreatin to pigs 53.4 days of age failed to improve either gains or feed efficiency materially. Thus, as these authors have suggested, it appears that the older pigs have a more adequate digestive enzyme system.

It is recognized that properly fortified corn-soybean oil meal diets will produce excellent growth when fed to weanling pigs weighing 25 pounds or more. Barnhart (1954) reported excellent growth of weanling pigs in which purified soybean protein was the sole source of protein.

The effort to improve the utilization of soybean protein by early weaned pigs is two-fold. First, the expense factor is important. Today the price of 34 percent protein dried skimmilk ranges from 12 to 16 cents per pound, compared to 2.5 to 3.5 cents per pound for soybean oil meal (44 or 50 percent protein). The overall savings of using soybean oil meal and dried whey in the place of dried skimmilk is approximately 75 dollars per ton according to Catron et al. (1957). The second factor involved in the search to replace milk protein with plant protein for baby pigs is the prediction that all milk products will be used for human consumption in the near future because of the increasing population. The adoption of early weaning pigs with all its advantages, Catron et al. (1957), will become limited in the future unless milk protein can be successfully replaced by vegetable protein.

The lower apparent digestibility of soybean protein by pigs two weeks of age as compared to pigs four to five weeks of age further supports the hypothesis that the baby pig is deficient in proteolytic enzymes. The average apparent digestibility of soybean protein by the same pigs at two and four weeks of age were observed to be approximately 79 and 90 percent, respectively. Lewis (1956), Lloyd et al. (1957), and Hays (1957) have reported improvement in digestibility of protein by the baby pig with increasing age. The 90 percent value for apparent digestibility of plant protein by the four-week-old pig is a somewhat higher value than reported by other workers. The variation could be due to the carbohydrates fed. Skipitaris et al. (1957) have reported that the addition of 16 percent sucrose to a barley ration fed to barrows decreased the apparent digestibility of the protein by five percent.

In the trials reported by this author, lactose was used as the sole source of carbohydrate, whereas Lewis (1956) and Hays (1958) fed diets containing 15 percent sucrose. Thus, if the addition of sucrose does decrease the apparent digestibility of protein, this would account for the higher apparent digestibility of protein observed by this author.

The three levels (15, 20 and 25 percent) of protein fed did not significantly influence the growth of the pigs or the apparent digestibility of the protein. These findings are in contrast with those reported by Lewis (1956) who reported a significant linear improvement in the growth of pigs which received 12, 16, or 20 percent protein. However, there was a significant linear improvement in feed efficiency as the protein level increased.

The supplementation of cascara to the diet, at the rate of two grams per pound, in an attempt to increase the rate of food passage was successful only to a limited extent. The time required for the marker to first appear in the feces of the pigs receiving the cascara was approximately six hours less than those which received no cascara. However, the ability to produce a condition similar to bacterial, fungal or viral scouring was not obtained because of the pigs' refusal to readily consume a diet containing more than two grams of cascara per pound of diet.

The time for the marker to first appear in the feces of nonscouring pigs weighing approximately 30 pounds was about 25 hours after feeding. The time required for the marker to appear in the feces of scouring pigs was 6 to 10 hours, depending on the severity of scouring. The 25-hour value is somewhat higher than that reported by Castle and Castle (1956). They found that in fattening (older) pigs the first appearance of the marker occurred in the feces 10 to 24 hours after feeding.

Lewis (1956) was unable to obtain an increase in the growth rate of pigs by the supplementation of proteolytic enzymes when the pigs were housed in Unit E. He suggested that this lack of growth response was due to a slower rate of food passage. It was also the opinion of Lewis that the pigs scoured less in this building than in the conventional buildings because of a lower disease level. However, in Experiment 910 there was a considerable amount of scouring among the individually fed pigs. The apparent explanation stems from the manner in which the pigs were handled prior to the experimental period. The pigs were farrowed in the months of July and August in dirt lots which had previously been used for growing-finishing hogs. After weaning at seven days of age, they were placed in a common holding pen for three days and fed a 40 percent dried skimmilk ration. These pretreatment steps were conducted to assure that all pigs were eating a dry ration before being placed on a less palatable soybean oil meal protein ration. Thus, it is obvious that any contamination that the pigs obtained in the dirt lots was brought into the building with them. Also, any one pig could have contaminated the rest since all of the pigs were placed in the same common holding pen prior to experimental treatment.

A preliminary test in Unit D indicated that cascara supplemented to the ration at the rate of 500 milligrams per pound of ration would cause a condition similar to scouring. However, when this level was added to the ration in Experiment 780 (conducted in Unit E), a scouring condition was not observed. Since the pigs housed in the conventional building have a greater tendency to scour, it seems logical that a smaller quantity of cascara would be required to produce a scouring condition.

A significant positive correlation was observed between the rate of food passage (in hours) and the apparent digestibility coefficient of protein (in percent).

A summary of several experiments on the influence of scouring in baby pigs on the response to pepsin supplementation is presented in Table 8. In the experiments where

Table 8. Influence of scouring in baby pigs and response to pepsin supplementation

Experiment No.	Type of protein	Gains (lb.)		Feed/gain(lb.)	
		Basal	Pepsin	Basal	Pepsin
		Scouring in pigs			
683[a]	Drackett	8.2	10.2	2.62	2.30
705	Drackett	12.9	17.1	2.29	1.94
762	SBOM	12.2	13.6	1.71	1.62
795	SBOM	7.6	8.0	2.77	2.60
910	SBOM	14.8	17.6	1.42	1.45
914[b]	SBOM	20.5	22.3	1.85	1.74
Av.		12.7	14.8	2.11	1.94
		Little or no scouring in pigs			
735	SBOM	18.0	19.0	1.68	1.68
780	SBOM	9.4	10.1	2.18	2.01
843	SBOM	13.6	13.2	1.68	1.65
891	SBOM	10.9	12.1	1.85	1.78
891	Drackett	13.4	11.4	2.12	2.20
929	SBOM	12.8	11.9	1.62	1.53
Av.		13.0	13.0	1.86	1.81

[a]Pepsin (1:3000) added at the rate of 1 percent of the diet. Pepsin (1:3000) was added at the rate of 0.25 percent in all other experiments.

[b]Pigs conducted on a six-week test. All others were for a four-week test.

scouring was evident, the pigs gained 14.8 pounds as compared to 12.7 pounds for the non-supplemented. This was an improvement in growth of 16.5 percent. No improvement in growth was observed from the supplementation of pepsin where there was little or no scouring. Likewise, there was a greater improvement in feed efficiency (8.1 percent) from the pepsin supplementation in the trials where the incidence of scouring was evident as compared to the trials where little or no scouring was observed (2.7 percent).

There is a possibility that the increase in growth of pigs receiving supplemental pepsin is due, in part, to an unidentified growth factor(s). However, the probability seems small since the quantity of pepsin (1:3000) fed was only 0.25 percent of the diet and, also, the pigs which received the completely inactivated pepsin did not show an improvement in growth or feed efficiency when compared to the pigs receiving the nonsupplemented ration. These findings are in agreement with the results reported by Lewis (1956).

Feeding of Hydrolyzates

The feeding of soybean oil meal predigested with either pancreatin or ficin showed some promise in improving the growth and feed efficiency of early weaned pigs. In the first experiment (727) the material predigested with ficin to 17.5

percent soluble protein gave the greatest improvement in pig performance. In the second experiment (864) various levels (6.65, 13.3, and 26.6 percent) of the soybean oil meal predigested to 17.5 percent soluble protein by ficin were added to a practical type ration, a significant linear improvement in growth of pigs was observed. However, the third experiment (884) failed to support the two previous experiments. No improvement in growth or feed efficiency was obtained from the feeding of the hydrolyzate in this experiment.

There have been many conflicting results reported in the literature as to whether or not predigested protein is superior to nondigested protein when fed to young animals and human infants. Mueller et al. (1940), Cox and Mueller (1944), Magnusson (1945), and Lewis (1956) have reported that the predigested protein is superior to the natural protein in promoting growth. However, Madey and Dancis (1949), Patrick (1955), and Cunningham and Brisson (1957) found no improvement in the growth of the young when fed predigested protein.

The method by which the hydrolyzates were produced was not given in most instances. However, when the protein is predigested with most proteolytic enzymes a pH adjustment of the solution must be made to allow for maximum activity of the enzyme. An acid or a base must be added to the solution depending on the enzyme used. Thus, in the final product the ash content is much higher than in the original material.

It is possible then that any beneficial effect obtained by the hydrolysis of the protein is offset by the increased ash content of the material.

The degree to which the protein is digested should not cause a deleterious effect insofar as growth is concerned unless destruction of essential amino acids by the enzyme or putrefaction has occurred.

The feeding of predigested proteins would probably improve growth only in animals which do not have a sufficient proteolytic enzyme system to properly digest the natural protein.

Pepsin Activity of the Stomach Tissue and Stomach Contents

The analysis of the pepsin activity of the stomach tissue revealed that the peptic activity per gram of wet tissue increased with increasing age of the pig. These findings are in excellent agreement with the results reported by Lewis et al. (1957).

The results of the study on the pepsin activity of the stomach contents revealed that the peptic activity per gram of contents decreased with increasing age of the early weaned pigs (birth to eight weeks of age). These findings conflict with the theory that the five-week-old pig can utilize soybean protein more efficiently than the two-week-old pig because they secrete a larger quantity of pepsin. However, as the pig increases in age, the peptic activity may become less important due to an increase in the secretion of proteolytic enzymes by the pancreas and small intestine as observed by Catron et al. (1958). Also, many experiments show that pigs five weeks of age or over can utilize soybean protein quite well.

The findings reported here do not imply that the total amount of pepsin found in the stomach contents of early weaned pigs decreases with age. The total ingesta of the stomachs of pigs eight weeks of age was much larger than the ingesta of the younger pigs. However, the total weight of the ingesta was not recorded and, therefore, the total pepsin activity could not be calculated.

The time selected to sacrifice the pigs after they had eaten may have been much too short to allow for maximum secretion of pepsin into the ingesta.

More work is needed to accurately determine the pepsin activity of the stomach contents. Preliminary trials should be conducted to determine at what time after feeding the pepsin activity of the ingesta is highest.

The results of this study, along with the findings of Bailey et al. (1956), Kitts et al. (1956), and Lewis (1956) indicate that certain qualitative and quantitative changes in the digestive secretions do occur in the early life of the pig.

SUMMARY

Fifteen experiments involving 2006 pigs were conducted to determine: (1) the ability of the baby pig to utilize soybean protein; (2) the adequacy of the pepsin secretion of the baby pig; (3) factors which cause variations in the response of the baby pigs supplemented with pepsin. Five general approaches to the problem were undertaken: (1) the feeding of proteolytic enzymes; (2) the determination of the apparent digestibility of soybean protein in the presence or absence of pepsin; (3) the feeding of predigested soybean protein; (4) the analysis of stomach ingesta and the stomach tissue for pepsin activity; and (5) the feeding of pepsin to baby pigs under various conditions.

The addition of one percent pepsin (1:3000), pancreatin (U.S.P.), Rhozyme P-11, Rhozyme B-6, and Mycozyme to a Drackett protein-lactose diet improved both growth and feed efficiency of baby pigs. However, the addition of one percent papain to the same diet resulted in no improvement in growth of the baby pigs.

In 12 observations the supplementation of pepsin to baby pig diets containing soybean protein as the major source of protein resulted in an average improvement in growth and feed efficiency of 7.8 and 5.1 percent, respectively. The optimum level of pepsin (1:3000) as determined by growth and feed

efficiency of baby pigs was 0.25 percent.

The addition of various levels (0.25, 0.50 and 1.0 percent) of pepsin (1:3000) to a 40 percent dried skimmilk diet did not improve the growth or feed efficiency of early weaned pigs.

Three experiments were conducted in which soybean oil meal hydrolyzates (50 percent protein) were fed as a source of protein. In the first trial the hydrolyzates fed were prepared by digesting the soybean oil meal with either pancreatin, Rhozyme P-11, or ficin to various degrees of soluble protein. The protein predigested with ficin to 17.5 percent soluble protein gave the greatest improvement in growth and feed efficiency of baby pigs. In the second trial the feeding of various levels (0, 6.65, 13.3, and 26.6 percent) of the ficin predigested soybean protein at the 17.5 percent soluble protein level resulted in a significant ($P < 0.05$) linear increase in growth of the baby pigs. However, in the third trial no improvement in growth or feed efficiency was observed from the use of this hydrolyzate in the pig diets.

Under these conditions, air conditioning of baby pig's units in the summer months appeared to have no influence on the growth or feed efficiency. Neither was there an effect of air conditioning on the response of baby pigs to pepsin supplementation.

The tendency for the baby pigs to scour affected their growth response to the supplementation of pepsin. A summary of the trials in which a great deal of "looseness" was observed resulted in a 16.5 percent improvement in growth and 8.1 percent improvement in feed efficiency of early weaned pigs which had received pepsin in the diets. However, there was no difference in the growth of pigs fed diets with or without pepsin in the trials where there was little or no scouring.

In comparison to one-week-old weaned pigs, the pigs weaned at three weeks or older showed little or no improvement in growth from the addition of the pepsin to the ration.

The apparent digestibility of soybean protein by early weaned pigs was determined in two experiments. In the first trial, the addition of 0.25 percent pepsin (1:3000) to the ration of pigs two weeks of age significantly improved the apparent protein digestion from approximately 77 percent for the non-supplemented to 81 percent for the supplemented pigs. There was, however, no improvement in the protein digestion by four-week-old pigs due to pepsin supplementation of the ration. The supplementation of pepsin to the diets in the second experiment resulted in no differences in apparent digestibility of protein by pigs either two or four weeks of age.

The analysis of the stomach tissues of baby pigs for pepsin revealed a significant increase in activity per gram of unit tissue from birth to eight weeks of age. There were no significant differences, however, in pepsin activity of stomach contents of baby pigs sacrificed from birth to eight weeks of age.

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APPENDIX

Table 9. Composition and calculated analysis of ration used for the preliminary feeding period and for positive control ration in Experiments 705 and 727

Ingredient		Amount
Ground yellow corn (9.5% protein)		30.00
Sucrose		15.00
Dried skimmilk (34% protein)		40.00
Solvent soybean oil meal (50% protein)		6.90
Stabilized lard		2.50
Dried beet pulp (8% protein)		2.00
Dicalcium phosphate (26% calcium)(18% phosphorus)		0.95
Iodized salt		0.50
Trace mineral premix (35-C-41)[a]		0.15
Vitamin-antibiotic premix[b]		2.00
Total		100.00
	Calculated analysis	
Protein	%	20.0
Fat	%	3.9
Fiber	%	1.4
Calcium	%	0.8
Phosphorus	%	0.7
Vitamin A	I.U./lb.	5000
Vitamin D_2	I.U./lb.	1000
Riboflavin	Mg./lb.	5.0
Pantothenic acid	Mg./lb.	10
Niacin	Mg./lb.	30
Choline	Mg./lb.	450
Vitamin B_{12}	Mcg./lb.	20
Chlortetracycline	Mg./lb.	50

[a]Composition given in Table 14.

[b]In addition to vitamins listed in calculated analysis the following were added at the indicated rates per pound of ration: folic acid, 0.5 mg.; thiamine, 3.0 mg.; pyridoxine, 1.5 mg.; PABA, 2.0 mg.; biotin, 3.0 mg.; inositol, 250 mg.; ascorbic acid, 100 mg.; alpha tocopherol acetate, 10 mg.; menadione, 0.5 mg.

Table 10. Composition and calculated analysis of dried skimmilk ration used in Experiment 843

Ingredient		Amount
Ground yellow corn (9.5% protein)		42.65
Ground oat groats (15.5% protein)		20.00
Solvent soybean oil meal (50% protein)		9.00
Dried skimmilk (34% protein)		20.00
Condensed fish solubles (32% protein)		2.50
Saccharin (soluble)		0.05
Stabilized lard		2.00
Calcium carbonate (38% calcium)		0.40
Dicalcium phosphate (26% calcium)(18% phosphorus)		0.70
Iodized salt		0.50
Trace mineral premix (35-C-41)[a]		0.20
Vitamin-antibiotic premix		2.00
Total		100.00
	Calculated analysis	
Protein	%	20.0
Fat	%	4.8
Fiber	%	1.9
Calcium	%	0.7
Phosphorus	%	0.6
Vitamin A	I.U./lb.	3000
Vitamin D_2	I.U./lb.	500
Riboflavin	Mg./lb.	5.0
Pantothenic acid	Mg./lb.	10
Niacin	Mg./lb.	30
Choline	Mg./lb.	500
Vitamin B_{12}	Mcg./lb.	20
Antibiotics[b]	Mg./lb.	50

[a]Composition given in Table 14.

[b]Contained the following: procaine penicillin, 10 mg.; streptomycin, 30 mg.; mycostatin, 10 mg.

Table 11. Composition of the basal rations

Ingredient	Experiment 727	735 SBOM	735 DSM	762 and 780	795	843
Ground yellow corn (9.5% protein)	20.00	20.57	31.61	31.50	43.30	35.85
Rolled oats (15.5% protein)					20.00	20.00
Lactose	21.95	20.00				
Sucrose	15.00	15.00	15.00	15.00		
Dried skimmilk (34% protein)			40.00		10.00	
Condensed fish solubles (32% protein)						2.50
Solvent soybean oil meal (50% protein)	33.80	36.10	6.80	29.00	12.50	20.45
Fish meal (60% protein)					2.50	
Dried whey (sweet)(12% protein)				15.00	5.00	15.00
dl-methionine	0.05	0.05				
Stabilized lard	2.50	2.50	2.50	2.50	2.50	2.00
Saccharin (soluble)					0.05	0.05
Dried beet pulp (8% protein)	2.00	2.00	2.00	2.00		
Dicalcium phosphate (26% calcium) (18% phosphorus)	1.50	2.40	1.04	1.90	0.70	0.95
Calcium carbonate (38% calcium)	0.80	0.38	0.05	0.45	0.50	0.50
Iodized salt	0.25	0.50	0.50	0.50	0.25	0.50
Trace mineral premix[a]	0.15	0.10	0.10	0.15	0.20	0.20
Vitamin-antibiotic premix	2.00	0.40	0.40	2.00	2.50	2.00
Total (lb.)	100.00	100.00	100.00	100.00	100.00	100.00

[a]Trace mineral mix (35-C-41) was used in Experiments 727, 762, 780, 795, and 843. Trace mineral mix (C.C.C.) was used in Experiment 735. The compositions of these are shown in Table 14.

Table 12. Composition of the basal rations

Ingredient	Experiment 864				Experiment 884		
	Hydrolyzate (%)						Hydrol
	0	6.65	13.3	26.6	SBOM	Casein	SBOM
Ground yellow corn (9.5% protein)	20.95	21.30	21.75	22.45	26.48	29.60	29.60
Ground oat groats (15.5% protein)	15.00	15.00	15.00	15.00			
Lactose					15.00	15.00	15.00
Sucrose	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Corn starch						12.22	
Dried whey (sweet)(12% protein)	15.00	15.00	15.00	15.00			
Hydrolyzed solvent soybean oil meal (52.7% protein)		6.65	13.30	26.60			32.50
Casein (88% protein)						19.40	
Solvent soybean oil meal (50% protein)	28.00	21.00	14.00		35.50		
Stabilized lard	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Monocalcium phosphate (17% calcium)(24% phosphorus)					1.30	2.20	1.10
Dicalcium phosphate (26% calcium) (18% phosphorus)	1.20	1.10	1.00	0.90			
Calcium carbonate (38% calcium)	0.40	0.50	0.50	0.60	0.47	0.33	0.55
Iodized salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[a]	0.20	0.20	0.20	0.20	2.00	2.00	2.00
Vitamin-antibiotic premix	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Total (lb.)	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a]Trace mineral mix (35-C-41) was used in Experiment 864 and trace mineral mix (35-D-10A) was used in Experiment 884. The composition of these are shown in Table 14.

Table 13. Composition of the basal rations

Ingredient	Experiment 891	910[a]	910[b]	910[c] and 929	914
Ground yellow corn (9.5% protein)	20.70				35.90
Ground oat groats (15.5% protein)	15.00				20.00
Sucrose	15.00				
Lactose		59.91	50.08	40.12	
Dried whey (sweet)(12% protein)	15.00				15.00
dl-methionine		0.04	0.05	0.06	
Solvent soybean oil meal (50% protein)	28.00	30.10	40.30	50.47	20.45
Condensed fish solubles (32% protein)					2.50
Stabilized lard	2.00	2.50	2.50	2.50	2.00
Saccharin (soluble)		0.05	0.05	0.05	
Calcium carbonate (38% calcium)	0.40			0.15	0.50
Dicalcium phosphate (26% calcium)(18% phosphorus)	1.20	2.70	2.32	1.95	0.95
Iodized salt	0.50	0.50	0.50	0.50	0.50
Dried beet pulp (8% protein)		2.00	2.00	2.00	
Trace mineral premix (35-C-41)[d]	0.20	0.20	0.20	0.20	0.20
Vitamin-antibiotic premix	2.00	2.00	2.00	2.00	2.00
Total (lb.)	100.00	100.00	100.00	100.00	100.00

[a]Ration contained 15 percent protein.

[b]Ration contained 20 percent protein.

[c]Ration contained 25 percent protein.

[d]The composition is shown in Table 14.

Table 14. Contents of trace mineral mix used

	Trace minerals (C.C.C.)		Trace minerals (35-D-10A)	Trace minerals (35-D-10)	Trace minerals (35-C-41)	
	Percent of total ration					
Element	0.10	0.15	2.00	1.63	0.15	0.20
	Parts per million contributed to the ration					
Iron	70.0	105.0	362.0	362.5	105.6	140.8
Copper	4.8	7.2	7.6	7.6	7.4	9.8
Cobalt	1.6	2.4	3.1	3.1	2.4	3.2
Manganese	56.8	85.2	101.5	101.5	85.2	113.6
Potassium	7.4	11.2	3980.0	3979.0	11.2	15.0
Iodine			0.4	0.4		
Magnesium			530.0	1000.0		
Zinc	17.6	26.4	50.0	32.4	122.4	163.2

Table 15. Amounts of vitamins and antibiotics added per pound of complete ration

Ingredients	Experiment				
	683 and 705	727	735		762 and 780
			SBOM	DSM	
Vitamin A, I.U.	5,000	5,000	3,000	3,000	3,000
Vitamin D_2, I.U.	1,000	1,000	1,000	1,000	1,000
Riboflavin, Mg.	4.9	4.4	4.4	1.2	2.3
Calcium pantothenate, Mg.	9.6	7.1	6.9	2.8	4.4
Niacin, Mg.	29.2	25	24	2.4	17.0
Choline chloride, Mg.	450			317	
Vitamin B_{12}, Mcg.	20	20	20	20	20
Alpha tocopherol acetate, Mg.	10	10	10	10	10
Ascorbic acid, Mg.	300	100	100	100	100
Menadione, Mg.	3.0	0.5	0.5	0.5	0.5
Thiamine, Mg.	5.0	3.0	3.0	3.0	3.0
Pyridoxine, Mg.	0.7	0.7	1.5	1.5	1.5
P A B A, Mg.	7.9	2.0	2.0	2.0	2.0
Inositol, Mg.	250		250	250	
Folic acid, Mcg.	9.0	500	500	500	500
Biotin, Mcg.	20	3.0	3.0	3.0	3.0
Antibiotic, Mg.[a]	50	67	50	50	50

[a]See Table 21.

Table 16. Amounts of vitamins and antibiotics added per pound of complete ration

Ingredients	Experiment 843	884	891 SBOM	891 Drackett
Vitamin A, I. U.	2641	3000	2790	5000
Vitamin D_2, I. U.	500	500	500	1000
Riboflavin, Mg.	2.5	4.5	2.7	4.9
Calcium pantothenate, Mg.	3.7	9.2	4.2	9.6
Niacin, Mg.	20.3	27.2	24.1	29.2
Choline chloride, Mg.	23	390		450
Vitamin B_{12}, Mcg.	20	20	20	20
Alpha tocopherol acetate, Mg.		10		10
Ascorbic acid, Mg.		100		300
Menadione, Mg.		0.5		3.0
Thiamine, Mg.		3.0		5.0
Pyridoxine, Mg.		1.5		1.2
P A B A, Mg.		2.0		8.0
Inositol, Mg.		250		250
Folic acid, Mcg.	250	500	250	9.0
Biotin, Mcg.		3.0		250
Antibiotic, Mg.[a]	50	50	50	50

[a]See Table 21.

Table 17. Amounts of vitamins and antibiotics added per pound of complete ration

Ingredients	Experiment 795	864	910	914	929
Vitamin A, I. U.	2750	2750	3000	2641	3000
Vitamin D_2, I. U.	600	500	500	500	500
Riboflavin, Mg.	2.2	2.7	4.5	2.5	4.4
Calcium pantothenate, Mg.	4.0	4.2	7.6	3.7	7.0
Niacin, Mg.	17.5	24.1	26.0	20.3	26.0
Vitamin B_{12}, Mg.	20	20	20	20	20
Folic acid, Mg.	300	250	250	250	250
Antibiotic, Mg.[a]	50	50	50	50	50

[a]See Table 21.

Table 18. Calculated analysis of basal rations

Item		Experiment					
		683 and 705	727	735 SBOM	735 DSM	762 and 780	795
Protein	%	20.00	20.00	20.00	20.00	20.00	18.8
Fat	%	2.60	3.33	3.50	3.90	3.90	5.3
Fiber	%	0.40	1.74	2.00	1.40	2.06	2.0
Calcium	%	1.25	0.80	0.85	0.85	0.85	0.7
Phosphorus	%	0.85	0.70	0.70	0.70	0.70	0.6
Vitamin A	I.U./lb.	5,000	5,200	3,000	3,000	3,000	3,032
Vitamin D_2	I.U./lb.	1,000	1,000	1,000	1,000	1,000	500
Riboflavin	Mg./lb.	5	5	5	5	5	4
Pantothenic acid	Mg./lb.	10	10	10	10	10	8
Niacin	Mg./lb.	30	30	30	30	30	25
Choline	Mg./lb.	450	480	705	705	510	586
Vitamin B_{12}	Mcg./lb.	20	20	20	20	20	20
Antibiotics[a]	Mg./lb.	50	67	50	50	50	50

[a]See Table 21.

Table 19. Calculated analysis of basal rations

Item		Experiment				
		843	864	884		
				SBOM	Casein	Hydrolyzate
Protein	%	20.0	20.0	20.0	20.0	20.0
Fat	%	4.5	3.6	3.2	3.4	3.2
Fiber	%	2.1	1.7	1.7	0.7	1.7
Calcium	%	0.7	0.7	0.7	0.7	0.7
Phosphorus	%	0.6	0.6	0.6	0.6	0.6
Vitamin A	I.U./lb.	3,000	3,000	3,266	3,296	3,296
Vitamin D_2	I.U./lb.	500	500	500	500	500
Riboflavin	Mg./lb.	5	5	5	5	5
Pantothenic acid	Mg./lb.	10	10	12	10	12
Niacin	Mg./lb.	30	30	33	30	33
Choline	Mg./lb.	601	593	900	450	870
Vitamin B_{12}	Mcg./lb.	20	20	20	20	20
Antibiotics[a]	Mg./lb.	50	50	50	50	50

[a]See Table 21.

Table 20. Calculated analysis of basal rations

Item		Experiment					
		891		910[a]	910[b]	910[c] and 929	914
		Drackett	SBOM				
Protein	%	20.00	20.0	15.00	20.00	25.00	20.0
Fat	%	2.60	3.7	2.70	2.70	2.80	4.5
Fiber	%	0.40	1.7	1.30	1.60	1.90	2.0
Calcium	%	1.25	0.7	0.70	0.70	0.70	0.7
Phosphorus	%	0.85	0.6	0.65	0.65	0.65	0.6
Vitamin A	I.U./lb.	5,000	3,000	3,000	3,000	3,000	3,000
Vitamin D_2	I.U./lb.	1,000	500	500	500	500	500
Riboflavin	Mg./lb.	5	5	5	5	5	5
Pantothenic acid	Mg./lb.	10	10	9	10	10	10
Niacin	Mg./lb.	30	30	30	30	30	30
Choline	Mg./lb.	450	593	400	524	656	601
Vitamin B_{12}	Mcg./lb.	20	20	20	20	20	20
Antibiotics[d]	Mg./lb.	50	50	50	50	50	50

[a]Ration contained 15 percent protein.

[b]Ration contained 20 percent protein.

[c]Ration contained 25 percent protein.

[d]See Table 21.

Table 21. Amount of antibiotics added to the rations

Experiment number	Oxytetra-cycline	Chlortetra-cycline	Procaine penicillin	Streptomycin	Mycostatin
		Mg. per pound of ration			
683	50				
705		50			
727		30	20	17	
735		30	20		
762		40			10
780		40			10
795			10	30	10
843			10	30	10
845			10	30	10
864			10	30	10
884			10	30	10
891			10	30	10
910			10	20	10
914			10	30	10
929			10	30	10

Table 23. Experiment 683 - Analysis of variance and test of all comparisons among means of pig gains and feed required per pound of gain

Source of variation	Degrees of freedom	Mean squares	
		Gain	Feed/gain
Replications	2	7.775[a]	0.1356[a]
Ration treatments	9	6.059[a]	0.1670[a]
Error	18	2.026	0.0370
Total	29	3.674	0.0841

Q-test of all comparisons among means[b]

	Basal	Pap.	Myc.	B-6	Pep	Pan	P-11	Pep (In.)	DSM	DSM + Pep
Av. gain	8.2	7.7	8.8	9.2	10.2	10.4	10.5	11.5	12.0	10.7
Av. feed/gain	2.62	2.37	2.54	2.34	2.30	2.20	2.36	2.17	1.78	2.10

[a]Significant at P = 0.05 or less.

[b]Q = 2.4 for significant differences (P = 0.05) among mean gains, Q = 0.33 for significant differences (P = 0.05) among mean feed/gain.

Table 25. Experiment 705 - Summary of pig gains and feed required per pound of gain

Rep.	Treatment (protein) Drackett C-1 assay protein % enzymes added: None	Pepsin 1.0%	Pepsin 0.25%	Pepsin .0625%	Mixture[a] 0.1%	Ficin 0.1%	40% DSM: None
			1-5 week gains (lb.)				
1	13.2	15.0	17.5	12.6	14.4	12.6	10.5
2	13.2	13.6	18.2	13.6	15.6	14.9[b]	13.2
3	12.2	15.0	15.6	15.1	14.7	16.6	14.9
Av.	12.9	14.5	17.1	13.8	14.9	14.7	12.9
			Feed/gain (lb.)				
1	2.17	2.08	1.90	2.19	2.13	2.35	1.96
2	2.25	2.23	1.97	2.23	2.05	2.15[b]	1.64
3	2.24	2.01	1.96	2.17	1.98	1.91	1.53
Av.	2.29	2.11	1.94	2.20	2.05	2.14	1.71

[a]Mixture: 0.05% pepsin and 0.05% pancreatin.

[b]Calculated values (Snedecor, 1956, p. 310).

Table 24. Experiment 683 - Summary of pig gains and feed required per pound of gain

Rep.	Enzymes (1% of ration)									
	None	Papain	Mycozyme	Rhozyme B-6	Pepsin	Pancreatin	Rhozyme P-11	Pepsin[a] (Inact)	None	Pepsin
	Drackett C-1 assay protein								Dried skimmilk	
	1-5 week gains (lb.)									
1	6.7	9.9	9.0	9.1	10.9	11.0	11.0	13.8	13.8	13.5
2	7.7	6.8	8.8	9.2	11.0	9.8	9.8	10.2	9.2	8.8
3	10.2	6.3	8.5	9.3	8.6	10.4	10.8	10.6	13.1	9.7
Av.	8.2	7.7	8.8	9.2	10.2	10.4	10.5	11.5	12.0	10.7
	Feed/gain (lb.)									
1	2.82	2.04	2.33	2.38	2.27	1.92	2.30	1.89	1.86	1.91
2	2.76	2.42	2.61	2.45	2.36	2.42	2.58	2.27	1.92	2.24
3	2.28	2.66	2.67	2.20	2.28	2.26	2.20	2.35	1.56	2.16
Av.	2.62	2.37	2.54	2.34	2.30	2.20	2.36	2.17	1.78	2.10

[a]Pepsin (1:3000) was partially inactivated with sodium hydroxide to pepsin (1:20).

Table 26. Experiment 705 - Analysis of variance of pig gains and feed per pound of gain

Source of variation	Degrees of freedom	Mean squares gain	Mean squares feed/gain
Replications	2	2.725	0.0225
Ration treatments	6	6.375[a]	0.1071[a]
Levels of pepsin vs. others	1	0.869	0.1429[a]
Levels of pepsin	3	9.950	0.0643
Linear	1	5.860	0.0614
Quadratic	1	16.530[a]	0.0949
Cubic	1	7.460	0.0367
DSM vs. ficin and combination	1	7.480	0.2964[a]
Ficin vs. combination	1	0.060	0.0104
Error	11[b]	2.000	0.0211
Total	19[b]	3.458	0.0484

[a]Significant at P = 0.05 or less.

[b]One degree of freedom subtracted for calculated missing value (Snedecor, 1956, p. 310).

Table 27. Experiment 735 - Summary of pig gains and feed required per pound of gain

	Treatment (protein)							
	SBOM				40% dried skimmilk			
	% pepsin (1:3000)							
Rep.	0	0.25	0.5	1.0	0	0.25	0.5	1.0
	2-6 week gains (lb.), air condition							
1	20.6	18.2	16.8	20.3	22.0	18.2	19.3	18.2
2	17.0	18.8	18.2	14.4	21.3	17.5	21.6	19.7
	2-6 week gains (lb.), non-air condition							
1	14.0	21.0	20.7	14.9	19.7	19.8	18.3	17.6
2	20.4	17.8	19.6	20.8	23.4	21.4	22.0	22.9
Av.	18.0	19.0	18.8	17.6	21.6	19.2	20.3	19.6
	Feed/gain (lb.) air condition							
1	1.55	1.79	1.87	1.61	1.54	1.74	1.59	1.69
2	1.74	1.71	1.72	1.91	1.75	1.89	1.79	1.80
	Feed/gain(lb.) non-air condition							
1	1.85	1.59	1.67	1.83	1.77	1.73	1.80	1.81
2	1.59	1.63	1.59	1.66	1.74	1.70	1.75	1.64
Av.	1.68	1.68	1.71	1.75	1.70	1.76	1.73	1.74

Table 28. Experiment 735 - Analysis of variance of pig gains and feed per pound of gain

Source of variation	Degrees of freedom	Mean squares Gain	Feed/gain
Replication	3	12.547[a]	0.0309[a]
Ration treatments	(7)	6.440	0.0040
SBOM vs DSM	1	26.650[a]	0.0055
Levels of pepsin(SBOM)	(3)		
Linear	1	0.904	0.0127
Quadratic	1	3.994	0.0004
Cubic	1	0.184	0.0006
Levels of pepsin (DSM)	(3)		
Linear	1	4.554	0.0007
Quadratic	1	2.419	0.0031
Cubic	1	6.384	0.0047
Error	21	4.013	0.0093
Total	31	5.387	0.0102

[a]Significant at P = 0.05 or less.

Table 29. Experiment 843 - Summary of pig gains and feed required per pound of gain

Rep.	SBOM: None	SBOM: Pepsin 0.25%	SBOM: Pancreatin 0.25%	SBOM: Pancreatin 0.5%	SBOM: Mixture[a] 0.5%	SBOM: Mixture[b] 0.5%	20% DSM: None
				1-5 week gains (lb.)			
1	12.8	12.3	12.7	8.4	12.4	11.9	11.3[c]
2	11.7	13.8	12.3	10.7	12.1	10.7	12.7
3	16.3	13.5	13.5	14.1	11.3	13.7	12.0
Av.	13.6	13.2	12.8	11.1	11.9	12.1	12.0
				Feed/gain (lb.)			
1	1.72	1.77	1.74	2.13	1.90	1.68	1.80[c]
2	1.66	1.57	1.66	1.72	1.62	1.62	1.71
3	1.66	1.60	1.72	1.65	1.73	1.67	1.56
Av.	1.68	1.65	1.71	1.83	1.75	1.66	1.69

Treatments (protein); Enzyme and % added.

[a]Mixture: 0.25% pepsin and 0.25% pancreatin.

[b]Mixture: 0.15% pepsin, 0.15% pancreatin, 0.15% amylase, 0.025% bile salt, and 0.025% lipase.

[c]Calculated values (Snedecor, 1956, p. 310.)

Table 30. Experiment 762 - Summary of pig gains and feed required per pound of gain

Rep.	Basal	Cascara (20 mg. /lb.)	Aerosol (200 mg. /lb.)	Pepsin (0.25%)	Cascara (20mg./lb) + pepsin (0.25%)	Aerosol (200 mg./lb.) + pepsin (0.25%)
			2-6 week gains			
1	11.2	10.6	14.0	13.7	13.2	12.8
2	13.2	13.2	8.6	13.4	14.7	8.6
Av.	12.2	11.9	11.3	13.6	14.0	10.7
			Feed/gain (lb.)			
1	1.70	1.88	1.63	1.60	1.74	1.81
2	1.72	1.79	1.93	1.63	1.43	1.72
Av.	1.71	1.84	1.78	1.62	1.58	1.76

Table 31. Experiment 762 - Analysis of variance of pig gains and feed per pound of gain

Source of variation	Degrees of freedom	Mean squares	
		Gain	Feed/gain
Replications	1	1.204	0.0016
Ration treatments	(5)	3.203	0.0192
Enzymes	1	2.614	0.0432
Laxitive	2	4.816	0.0122
Interaction	2	1.886	0.0144
Error	5	5.749	0.0200
Total	11	4.179	0.0180

Table 32. Experiment 780 - Summary of pig gains and feed required per pound of gain

Rep.	Treatment: Basal	Cascara (500 mg./lb.)	Pepsin (0.25%)	Cascara (500 mg/lb) + pepsin (0.25%)
		1-5 week gains (lb.)		
1	10.8	16.3	17.3	11.9
2	12.8	11.6[a]	8.1	15.9
3	5.6	4.2	3.9	10.0
4	16.4	10.8	13.8	12.2
5	12.7	7.4	8.5	9.2
6	7.4	11.8	12.3	6.1
7	7.6	8.8	12.0	6.8
8	5.4	4.4	6.6[a]	7.4
9	5.7	5.5	8.3	5.4
Av.	9.4	9.0	10.1	9.4
		Feed/gain (lb.)		
1	2.31	1.55	1.73	1.97
2	1.82	1.75[a]	1.95	1.51
3	2.20	2.33	2.85	1.71
4	2.00	1.74	1.44	1.60
5	1.60	1.89	1.85	1.90
6	2.11	2.05	1.59	2.00
7	2.24	2.02	2.18	2.56
8	2.91	2.61	2.44[a]	1.97
9	2.44	2.51	2.07	2.59
Av.	2.18	2.05	2.01	1.98

[a]Calculated values (Snedecor, 1956, p. 310).

Table 33. Experiment 780 - Analysis of variance of pig gains, feed per pound of gain, and rate of food passage

Source of variation	Degrees of freedom	Mean squares		
		Gain	Feed/gain	Rate of passage
Replications	8	39.367[a]	0.3540[a]	6.392
Treatments	(3)	1.905	0.0709	14.748
Pepsin	1	3.062	0.1308	6.334
Cascara	1	2.507	0.0600	37.007[a]
Interaction	1	0.147	0.0220	0.903
Error	22[b]	7.676	0.0929	5.549
Total	33[b]	14.834	0.1542	6.590

[a]Significant at P = 0.05 or less.

[b]Two degrees of freedom subtracted for calculated missing value (Snedecor, 1956, p. 310).

Table 34. Experiment 891 = Analysis of variance of pig gains and feed per pound of gain

Source of variation	Degrees of freedom	Mean squares	
		Gain	Feed/gain
Replications	3	29.785[a]	0.0245
Treatments	(4)	4.387	0.1460[a]
Inactivated pepsin vs. others	1	3.160	0.0891
Pepsin	1	0.601	0.0005
Protein	1	3.706	0.4727[a]
Protein x pepsin	1	10.080	0.0218
Error	12	7.386	0.0314
Total	19	10.296	0.0544

[a]Significant at $P = 0.05$ or less.

Table 35. Experiment 914 - Summary of pig gains and feed required per pound of gain

Rep.	Treatments			
	Basal	Pepsin (0.25%)	Basal	Pepsin (0.25%)
	1-7 week gains (lb.)		3-7 week gains (lb.)	
1	21.4	22.4	19.5	21.6
2	20.6	22.9	19.4	18.8
3	19.1	21.4	24.9	23.0
4	21.0	22.6	24.8	24.6
Av.	20.5	22.3	22.2	22.0
	Feed/gain (lb.)			
1	1.94	1.70	1.68	1.62
2	1.80	1.78	1.77	1.63
3	1.84	1.83	1.73	1.75
4	1.81	1.67	1.67	1.55
Av.	1.85	1.74	1.71	1.64

Table 37. Experiment 914 - Analysis of variance of gain and feed per pound of gain of one and three week weaned pigs

Source of variation	Degrees of freedom	Mean squares Gain	Mean squares Feed/gain
Replications	3	5.989	0.0086
Ration treatments	(3)	2.738	0.0304[a]
Age	1	1.690	0.0588[a]
Pepsin	1	2.724	0.0315[a]
Age x pepsin	1	3.801	0.0008
Error	9	3.779	0.0033
Total	15	3.989	0.0098

[a]Significant at $P = 0.05$ or less.

Table 36. Experiment 914 - Analysis of variance of pig gains and feed per pound of gain of one week weaned pigs

Source of variation	Degrees of freedom	Mean squares	
		Gain	Feed/gain
Replications	3	1.235	0.0035
Treatment	1	6.480[a]	0.0210
Error	3	0.197	0.0059
Total	7	1.539	0.0071

[a]Significant at P = 0.05 or less.

Table 39. Experiment 910 - Analysis of variance of pig gains and feed per pound of gain

Source of variation	Degrees of freedom	Mean squares	
		Gain	Feed/gain
Replications	5	23.385	0.0253
Ration treatments	(5)	29.634	0.0998
Protein	(2)	38.521	0.2116
Linear	1	38.760	0.4004[a]
Quadratic	1	38.281	0.0228
Pepsin	1	26.351	0.0015
Protein x pepsin	2	22.380	0.0371
Error	22[b]	17.502	0.0405
Total	32[b]	20.317	0.0474

[a]Significant at P = 0.05 or less

[b]Three degrees of freedom subtracted for calculated missing value (Snedecor, 1956, p. 310).

Table 38. Experiment 910 - Summary of pig gains and feed required per pound of gain

	Treatments					
	15% protein		20% protein		25% protein	
Rep.	Basal	Pepsin (0.25%)	Basal	Pepsin (0.25%)	Basal	Pepsin (0.25%)
			1-5 week gains (lb.)			
1	12.8	17.2	14.7	21.1	15.5[a]	19.4
2	14.5	12.8	15.8	18.0	13.3	21.1
3	10.7	9.6	13.9	22.9	17.4	13.1
4	12.5	12.9	15.2	5.7	11.0	14.3[a]
5	18.6	16.0	9.5	22.1	13.1	18.9
6	11.6[a]	3.8	19.7	15.9	10.3	16.1
Av.	13.4	12.0	14.8	17.6	13.4	17.2
			Feed/gain (lb.)			
1	1.67	1.42	1.52	1.34	1.40[a]	1.38
2	1.39	1.47	1.34	1.38	1.43	1.35
3	1.84	1.82	1.59	1.31	1.51	1.34
4	1.45	1.50	1.32	1.91	1.36	1.31[a]
5	1.40	1.58	1.41	1.44	1.39	1.23
6	1.60[a]	2.24	1.32	1.31	1.37	1.21
Av.	1.56	1.67	1.42	1.45	1.41	1.30

[a]Calculated values (Snedecor, 1956, p. 310).

Table 40. Experiment 910 - Summary of apparent digestibility of protein by pigs two and four weeks of age

Rep.	Treatments					
	15% protein		20% protein		25% protein	
	Basal	Pepsin (0.25%)	Basal	Pepsin (0.25%)	Basal	Pepsin (0.25%)
	Two week digestibilities (%)					
1	70.46	82.96	73.50	76.56	63.00	84.87
2	83.73	76.95	81.52	82.12	83.38	83.61
3	76.10	80.53	81.00	85.30	82.52	80.56
4	75.34	81.18	74.30	73.91	61.07	66.55
5	81.47	87.33	84.12	89.29	78.08	81.90
6	81.30[a]	77.55	87.22	84.25	77.97	87.64
Av.	78.07	81.08	80.28	81.90	74.34	80.86
	Four week digestibilities (%)					
1	90.40	89.21	89.66	90.19	89.99[a]	90.87
2	88.48	91.17	91.78	93.41	91.66	89.56
3	86.79	92.25	91.78	91.61	91.70	91.16
4	90.36	88.94	91.50	93.11	92.08	92.35[a]
5	91.16	91.87	90.52	92.66	87.70	92.05
6	89.30[a]	89.43	91.09	88.14	91.56	94.83
Av.	89.42	90.48	91.06	91.52	90.78	91.80

[a]Calculated value (Snedecor, 1956, p. 310).

Table 42. Experiment 929 - Summary of pig gains and feed required per pound of gain

Rep.	Basal	Cascara (2 gm./lb.)	Pepsin (0.25%)	Pepsin (0.25%) + Cascara (2 gm./lb.)
		1-5 week gains (lb.)		
1	20.1	18.8	17.5	21.5
2	11.0	14.3	7.7	8.8
3	11.4	11.6	18.7	14.1
4	16.7	12.1	12.2	12.5
5	15.1	9.5	14.8	14.2
6	12.4	14.3[a]	9.0	14.5
7	11.3	11.0	12.0	13.5
8	6.0	8.9	5.6	13.9
9	11.6	7.1	9.4	6.5
Av.	12.8	12.0	11.9	13.3
		Feed/gain (lb.)		
1	1.37	1.43	1.45	1.39
2	1.76	1.29	1.78	1.41
3	1.68	1.58	1.20	1.40
4	1.50	1.52	1.43	1.16
5	1.72	2.02	1.56	1.58
6	1.50	1.63[a]	1.58	1.62
7	1.48	1.58	1.44	1.39
8	2.07	1.67	1.88	1.46
9	1.49	1.66	1.43	1.75
Av.	1.62	1.60	1.53	1.46

[a]Calculated values (Snedecor, 1956, p. 310).

Table 41. Experiment 910 - Analysis of variance of protein digestibility of pigs two and four weeks of age

Source of variation	Two weeks		Four weeks	
	Degrees of freedom	Mean squares	Degrees of freedom	Mean squares
Replications	5	130.97[a]	5	1.186
Treatments	(5)	47.29	(5)	4.322
Protein	2	36.86	2	7.218
Linear	1	23.50	1	10.868
Quadratic	1	50.22	1	3.569
Pepsin	1	124.62[a]	1	6.503
Protein x pepsin	2	19.05	2	0.334
Error	24[b]	25.32	22[c]	3.242
Total	34[b]	44.09	32[c]	3.090

[a]Significant at P = 0.05 or less.

[b]One degree of freedom subtracted for calculated missing value (Snedecor, 1956, p. 310).

[c]Three degrees of freedom subtracted for calculated missing value (Snedecor, 1956, p. 310).

Table 43. Experiment 929 - Analysis of variance of pig gains, feed per pound of gain, and rate of food passage

Source of variation	Degrees of freedom	Mean squares		
		Gain	Feed/gain	Rate of food passage
Replications	8	43.700[a]	0.1725[a]	125.439[a]
Treatments	3	5.750	0.0456	127.233[a]
Pepsin	1	1.210	0.1156	38.441
Cascara	1	0.040	0.0169	328.819[a]
Pepsin vs. cascara	1	16.000	0.0044	14.440
Error	23[b]	7.278	0.0307	27.873
Total	34	15.713	0.0406	59.597

[a]Significant at P = 0.05 or less.

[b]One degree of freedom subtracted for calculated missing value (Snedecor, 1956, p. 310).

Table 44. Experiment 929 - Summary of apparent digestibility of protein by pigs two and four weeks of age

Rep.	Basal	Pepsin	Cascara (2 gm./lb.)	Cascara (2 gm./lb.) + pepsin (0.25%)
	Two week digestibilities (%)			
1	84.07	83.98		
2	84.20	84.09		
3	80.61	77.11		
4	81.27	75.13		
5	81.49	82.12		
6	78.66	76.56		
7	83.32	83.51		
8	75.16	75.46		
9	79.70	81.55		
10	80.00	87.12		
11	79.21[a]	79.36		
12	69.59	63.50		
13	69.90	71.47		
14	77.37	82.24		
15	72.02	75.09		
16	79.22	78.85		
17	81.81	82.19		
18	70.69	71.64		
Av.	78.24	78.39		
		Four week digestibilities (%)		
1	90.84	91.86	91.15	89.32
2	89.81	84.33	89.25	91.14
3	91.37	89.82	90.61	92.20
4	88.29	89.77	87.64	88.88
5	92.83	91.89	89.07	91.40
6	89.28	86.87	87.23[a]	87.73
7	93.69	93.96	91.47	88.56
8	89.84	87.71	87.31	88.41
9	90.82	91.13	91.00	92.05
Av.	90.76	89.70	89.41	89.97

[a]Calculated values (Snedecor, 1956, p. 310).

Table 45. Experiment 929 - Rate of food passage of pigs five weeks of age

Rep.	Basal	Cascara (2 gm./lb)	Pepsin (0.25%)	Pepsin (0.25% + cascara (2 gm./lb.)
		Rate of food passage (hours)		
1	21.2	20.1	26.7	12.7
2	26.1	12.3	11.0	21.3
3	21.7	23.6	20.0	13.6
4	24.9	22.1	29.2	24.6
5	34.6	13.8	15.0	17.8
6	15.1	10.9[a]	14.5	13.6
7	38.4	33.7	37.6	19.6
8	30.3	20.4	28.6	20.6
9	31.0	20.6	30.7	26.5
Av.	27.0	19.7	23.7	18.9

[a]Calculated value (Snedecor, 1956, p. 310).

Table 46. Experiment 727 - Analysis of variance of pig gains and feed per pound of gain

Source of variation	Degrees of freedom	Mean squares	
		Gain	Feed/gain
Replications	1	2.520	0.0069
Ration treatments	13	12.142[a]	0.1552[a]
SBOM and DSM basal vs. others	1	41.900[a]	0.1834
SBOM Basal vs. DSM Basal	1	61.622[a]	0.7833[a]
Type of Hydrolsate	2	5.822	0.1800[a]
Within P-11[b]	4	0.208	0.0807
Within Pancreatin[b]	4	2.070	0.0981
Within ficin[b]	4	9.192	0.1287
Linear regression	1	3.800	0.0062
Deviation from regression	3	10.990	0.1287
Remainder	13	3.929	0.0534
Total	27	7.831	0.1007

[a]Significant at P = 0.05 or less.

[b]The basal ration is computed with each of the within analysis.

Table 47. Experiment 727 - Summary of pig gains and feed required per pound of gain

Rep.	SBOM (Protein)													40% DSM
	Enzyme and % soluble protein													
	None	Rhozyme P-11				Pancreatin				Ficin				
	5.6	12.3	19.9	41.1	52.3	16.1	21.8	44.0	54.0	17.5	26.0	37.6	53.5	
	1-5 week gains (lb.)													
1	7.9	6.5	6.0	7.1	8.9	10.3	10.7	7.8	8.4	12.2	10.6	8.3	8.9	18.7
2	9.7	10.1	9.8	9.8	8.1	7.4	11.8	12.0	10.1	14.2	6.5	7.2	9.1	14.6
Av.	8.8	8.3	7.9	8.4	8.4	8.8	11.2	9.9	9.2	13.2	8.6	7.8	9.0	16.6
	Feed/gain (lb.)													
1	2.32	2.70	2.86	2.30	2.31	2.19	2.03	2.32	2.31	1.93	2.15	2.18	2.29	1.54
2	2.69	2.49	2.42	2.13	2.34	2.48	1.99	1.87	1.96	1.97	2.75	2.57	2.51	1.70
Av.	2.50	2.60	2.64	2.22	2.32	2.34	2.01	2.10	2.14	1.95	2.45	2.38	2.40	1.62

Table 48. Experiment 864 - Summary of pig gains and feed required per pound of gain

Rep.	% soybean oil meal hydrolyzate (ficin digested, 17.5 % soluble protein)			
	0	6.65	13.3	26.6
		2-6 week gains (lb.)		
1	15.1	19.0	23.3	18.2
2	6.4	19.1	19.7	19.1
3	11.4	20.3	15.2	19.7
4	18.1	15.9	17.0	17.6
5	20.1	16.4	18.3	24.4
6	15.7	11.9	15.7	19.6
Av.	14.5	17.1	18.2	19.8
		Feed/gain (lb.)		
1	1.53	1.57	1.65	2.05
2	3.94	1.62	1.67	1.80
3	2.33	1.65	1.63	1.80
4	1.77	1.80	1.65	1.81
5	1.73	1.84	1.73	1.69
6	1.69	1.93	1.68	1.69
Av.	2.16	1.74	1.67	1.81

Table 49. Experiment 864 - Analysis of variance of pig gains and feed per pound of gain

Source of Variation	Degrees of freedom	Mean squares Gain	Mean squares Feed/gain
Replications	5	10.556	0.1743
Ration treatment	(3)	29.869	0.2944
Linear	1	81.221[a]	0.2534
Quadratic	1	7.528	0.5931
Cubic	1	0.858	0.0365
Error	15	12.629	0.2316
Total	23	14.427	0.2273

[a]Significant at P = 0.05 or less.

Table 50. Experiment 884 - Analysis of variance of pig gains and feed per pound of gain

Source of variation	Degrees of freedom	Mean squares	
		Gain	Feed/gain
Replications	7	13.565	0.0250
Ration treatment	(2)	105.640[a]	0.3536[a]
Soya vs. casein	1	202.130[a]	0.6816[a]
Hydrolyzate vs. SBOM	1	9.151	0.0256
Error	12[b]	12.533	0.0128
Total	21[b]	21.744	0.0493

[a]Significant at P = 0.05 or less.

[b]Two degrees of freedom subtracted for calculated value (Snedecor, 1956, p. 310).

Table 51. Experiment 800 - Analysis of variance of pepsin activity of stomach tissue and stomach content

Source of variation	Degrees of freedom	Mean squares	
		Stomach tissues	Stomach contents
Litter group within treatment	6	2152.72	66.29
On versus off sow treatment	1	173.34	270.24[a]
Age	8	26202.82[a]	32.65
Linear	1	193292.01[a]	10.76
Quadratic	1	10792.40[a]	58.15
Remainder	6	5538.11	32.04
Age x treatment	8	1465.27	54.78[a]
Age x treatment x litter group	48	1004.12	24.47
Pigs within litter, age, treatment, and litter group	69	866.06	31.61
Total	140	2442.69	33.91

[a]Significant at P = 0.05 or less.