Enzyme Supplementation of Baby Pig Diets

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Studies of the qualitative and quantitative protein and carbohydrate requirements of early weaned pigs indicated an insufficiency of proteolytic and amylolytic digestive enzymes. Supplementation of soybean protein and casein basal diets for baby pigs with certain proteolytic enzymes increased gains and feed efficiency as much as 29 and 23%, respectively. The results of these researches look promising from both fundamental and applied aspects.

IN STUDIES OF the qualitative and quantitative protein and carbohydrate-requirements of early weaned baby pigs at this station, it was discovered that baby pigs may not have fully developed proteolytic and amylolytic enzyme systems.

Speer, Ashton, Diaz, and Catron (*10*), developed a practical dry ration, I.S.C. Pre-Starter 75, on which baby pigs could be successfully weaned as early as 7 days of age or at a minimum of 5 pounds of body weight. This ration contained 40% dried skim milk.

Research by Hudman and others (*3*), who weaned pigs at 3-day intervals from 3 to 21 days of age and placed them on a diet containing starch as the only carbohydrate ingredient, indicated that 3-day-old pigs grew very poorly on the all-starch diet but pigs from 6 days of age or older grew somewhat better, but more poorly than on a high-milk diet. Further research by Hudman and others (*4*) showed that the addition of dried skim milk at three levels from 0 to 20 to 40% resulted in a significant linear increase in both gains and feed efficiency. Fractionation of the 40% level dried skim milk ration, which gave satisfactory performance, revealed that both the protein fraction and the carbohydrate fraction of the skim milk contributed to its superior performance over purified soybean protein–cornstarch diets.

Lewis and others (*8*), found that 1- to 5-week-old baby pigs failed to grow satisfactorily on the latter diet, even when supplemented completely with all known needed nutrients and sources of unidentified growth factors with known activity. However, Barnhart (*1*) and many other workers have reported satisfactory performance on this same type of basal diet when fed to pigs over 5 weeks of age. This difference in response due to age apparently could not be explained on an amino acid basis, nor on the basis of other known or unidentified growth factors. Therefore, enzyme insufficiency in the baby pig was indicated.

Kvasnitskiĭ and Bakeeva (*6*) reported that pepsin is present from the first day of life in the baby pig, but that it is not activated until hydrochloric acid appears at 20 to 30 days of age and not fully activated until 59 days of age. Although stomach contents were acid in early life, the authors believed that the nature of the food and the microflora of the gut were responsible. Recent work of Liu and others (*9*) recorded pH values of 4.2, 3.5, 3.9, 3.6, 4.0, and 4.2 on 6-hour fasted baby pig stomachs at 1, 7, 14, 21, 28, and 35 days of age. These nursing pigs had access only to their mother's milk.

Heck and Pelikahn (*2*) have reported that the enzyme content of the gastric juice of children increases with age. Vazquez (*11*) reported that trypsin and lipase increase with the age of children, but that amylase did not occur in many cases until 15 to 20 days after birth. Probably not coincidental, therefore, is the finding of Katsu (*5*) that human colostrum is high in diastase.

Larsen (*7*) found that young ruminating dairy calves could not digest cornstarch when it was fed directly into the omaso-abomasal cavity.

In their research, the authors have made four general approaches to the role of enzymes involved in food digestion by the baby pig: the feeding of various enzymes; in vivo and in vitro digestibility studies; analysis of enzyme secretory tissue; and the feeding of hydrolyzates. Only the results of the first approach, feeding of enzymes, are reported herein.

Experimental

Three experiments involving 184 pigs were conducted to study the effects of supplementing soybean and milk protein diets with various proteolytic enzymes for early weaned baby pigs and for older growing pigs.

Pigs in Experiment 668 were individually fed, whereas those in Experiments 675 and 677 were group fed. Cross-bred pigs were used and randomly allotted in all experiments. The baby pigs were weaned from the sows at 6 to 10 days of age, depending on body weight–age relationship, and started directly on the dry experimental diets. Baby pig management as described by Speer and others (*10*) was followed. Pigs were self-fed dry rations and watered automatically. All pigs were weighed and feed consumption recorded weekly.

The compositions of the experimental rations are shown in Table I. The rations were mixed weekly to minimize the possibility of enzyme inactivation by other feed ingredients.

The different experimental ingredients may be characterized as follows: The Drackett C-1 assay protein is a purified soybean protein containing 83.1% crude protein. The Drackett XG-2 protein is a purified soybean protein containing 95.2% crude protein with a low molecular weight of about 50,000. The Glidden high nutritive soybean protein is a purified protein containing 90% crude protein. The dried skim milk was low-heat spray-dried.

The potency and characteristics of the various enzymes used were as follows: pancreatin (U.S.P.), pepsin (1 : 3000 N.F.), Star-Zyme P (fungal protease), papain (3000 units gelatin liquification), and Mycozyme (a diastatic-proteolytic enzyme concentrate derived from cultures of a selected strain of *Aspergillus oryzae*).

Table I. Basal Diets

Ingredient	Experiment 668	Experiment 675 I, II, III	Experiment 677
Drackett C-1 assay protein[a]	29.70	29.70	23.70
DL-Methionine	0.10	0.10	0.10
Cornstarch	10.00	10.00	0.00
Sucrose	12.10	7.10	10.00
Dextrose	36.46	21.36	34.46
Lactose[b]	0.00	20.00	20.00
Dicalcium phosphate	3.95	3.95	3.76
Calcium carbonate	0.66	0.66	0.89
Trace minerals (CCC 35 D-10)[c]	1.63	1.63	1.63
Salt (I_2)	0.50	0.50	0.50
Vitamins and antibiotics[d]	0.40	0.50	0.50
Lard (stabilized)	2.50	2.50	2.50
Gr. dried beet pulp	2.00	2.00	2.00
	100.00	100.00	100.00
Crude protein, %	25	25	20

[a] When dried skim milk, casein, or other proteins were included, relative quantities of Drackett protein and sugars were altered to maintain constant protein level.
[b] When dried skim milk was added, lactose was not included.
[c] Tecmangam 2.453%; $FeSO_4 \cdot 7H_2O$ 11.068%; copper carbonate 0.085%; cobalt sulfate 0.059%; zinc sulfate 0.553%; magnesium sulfate 30.437%; magnesium carbonate 0.922%; potassium sulfate 54.418%; KI (Ca stearate) 0.004%.
[d] Calculated analysis per pound of diet: vitamin A 5000 I.U.; vitamin D_2 1000 I.U.; riboflavin 5 mg.; pantothenic acid 10 mg.; niacin 30 mg.; choline chloride 450 mg; Added per pound of diet: vitamin B_{12} 20 γ; folic acid 9 γ; thiamine 5 mg.; pyridoxine 2 mg.; p-aminobenzoic acid 8 mg.; biotin 20 γ; inositol 250 mg.; α-tocopherol 10 mg. menadione (vitamin K) 3 mg.; ascorbic acid 300 mg.; chlortetracycline 50 mg.

Table II. Design and Results of Experiment 668

Ration Treatment[a]	Initial Wt.[b], Lb.	5-Week Wt., Lb.	Gain, Lb.	Relative Gain, %	Lb. Feed/Lb. Gain	Feed Saving, %
1. Basal ration (Drackett C-1 assay protein)	6.3	19.2	12.9	100	2.24	0
2. Basal with 20% lactose	6.3	21.4	15.1	117	2.06	+ 8
3. Basal + 1% pancreatin	6.4	21.4	15.0	116	2.01	+ 10
4. Drackett XG-2 protein (low mol. wt.)	6.2	10.0[c]	3.8	29	4.96	−121
5. Glidden high nutritive soybean protein	6.2	16.3	10.1	78	2.47	− 10
6. Basal with 1.0% pancreatin (predigested) Drackett C-1 assay protein	6.2	16.6	10.4	81	2.88	− 29
7. Positive control basal with 40% dried skim milk	6.3	26.4[d]	20.1	156	1.64	+ 27

[a] Five individually fed pigs per treatment, except that No. 6 used 4 pigs. Total 34 pigs.
[b] Average initial age, 8.0 days.
[c] Significant decrease from basal (P = 0.05 or less).
[d] Significant increase over basal (P = 0.05 or less).

Table III. Design and Results of Experiment 675, Part I

Ration Treatment[a]	Initial Wt.[b], Lb.	5-Week Wt., Lb.	Gain, Lb.	Relative Gain, %	Lb. Feed/Lb. Gain	Feed Saving, %
1. Basal ration[c]	6.2	14.9	8.7	100	2.57	0
2. Basal + 1% pancreatin	6.4	15.6	9.2	106	2.53	+ 2
3. Basal + 1% pepsin	6.6	16.5	9.9	114	2.46	+ 4
4. Basal + 1% pepsin + 1% pancreatin	6.4	16.5	10.1	116	2.43	+ 5
5. Basal + 1% Star-Zyme P[d]	6.4	12.4	6.0	70	2.98	−16
6. Positive control basal with 40% dried skim milk	6.3	19.4	13.1	150	1.74	+32

[a] Single pens of 5 pigs each. Total 30 pigs.
[b] Initial age, 7.3 days.
[c] Drackett C-1 assay protein with 20% lactose.
[d] One pig removed during experiment.

Results and Discussion

The design and results of Experiment 668 are shown in Table II. Six litter mate pigs from each of five litters were randomly allotted across six ration treatments, providing five individually fed pigs for each ration treatment. Because of unexpected processing difficulties of the pancreatin predigested Drackett assay protein for treatment 6, corresponding litter mates could not be obtained for this treatment and only four pigs were placed on this ration.

None of the purified soybean proteins, regardless of supplementation or alteration by processing, produced growth responses comparable to that obtained from the dried skim milk positive-control basal diet. The differences in growth rate and feed efficiency among the basal ration, the 1% pancreatin ration, and the 20% lactose ration (equivalent as found in the 40% dried skim milk basal diet) were not statistically significant. The highly purified Drackett XG-2 soybean protein of low molecular weight significantly ($P = 0.05$) depressed growth with significantly ($P = 0.05$) poorer feed efficiency, despite the fact that this diet was supplemented with 0.03% DL-tryptophan and 0.20% DL-methionine. It is possible that supplementation with other amino acids was needed or that this highly purified protein was altered in some manner by processing, thereby making it less available. The basal ration containing the Drackett C-1 assay protein which had been previously predigested with 1% pancreatin (U.S.P.) failed to improve growth rate or feed efficiency. This is believed to be due to the unexpected processing difficulties which were encountered in producing the hydrolyzate. The positive-control basal, which included 40% dried skim milk, significantly improved gains and feed efficiency as compared to the basal ration containing the Drackett C-1 assay protein.

Inasmuch as both the gains and feed efficiency of the basal Drackett C-1 assay protein ration were improved (*3*) by the addition of 20% lactose, this amount of lactose was added to all subsequent basal Drackett protein rations used in these studies.

Table III shows the design and results of Experiment 675, Part I, in which six ration treatments, with single lots of five 1-week-old pigs per treatment, were compared.

Although the addition of 1% pancreatin resulted in a 6% improvement in growth, the response was not so great as that obtained in the previous experiment. The addition of 1% pepsin produced a 14% increase in gains and a 4% saving in feed. The combination of 1% pancreatin and 1% pepsin added simultaneously did not improve performance over either alone. The addition of 1% Star-Zyme P had a growth-depressing effect. Here again none of the enzyme supplementations to the Drackett protein basal ration were so effective in stimulating growth and in improving feed efficiency as was the substitution of 40% skim milk for the purified soybean protein.

Two ration treatments with replicated lots of four pigs per treatment were compared in Experiment 675, Part II. The design and results of this experiment are shown in Table IV. Here, again, the addition of a combination of 1% each of pepsin and pancreatin was effective in stimulating growth and improving feed efficiency. Low milk production, because of high environmental temperatures while these pigs were yet nursing the sows, is believed to be the principal cause of the low initial weight-age relationship.

In Experiment 675, Part III was similar in design to Part II, except that 28-pound weanling pigs were employed rather than early weaned pigs. The results shown in Table V support the hypothesis that older pigs have a more adequate digestibe enzyme system, inasmuch as the addition of a combination of pepsin and pancreatin failed to improve materially either gains or feed efficiency.

Table VI shows the design and results of Experiment 677, in which eleven ration treatments were compared with replicated lots of four pigs per treatment. In previous experiments some variation was observed in the length of time required for the baby pigs to start eating the dry diets. Nearly always the pigs fed the diets containing higher levels of dried skim milk began to eat earlier than pigs on other diets. In an attempt to reduce the variation in rate of gain among pigs, all pens of pigs in this experiment were initially started on a proved more palatable diet of 0.5 pound of I.S.C. Pre-Starter 75 per pig (*10*). All pigs were eating within 24 hours after being placed on experiment, and, by 48 hours, nearly all of the I.S.C. Pre-Starter 75 had been consumed.

The results are in agreement with the results obtained in Part I of Experiment 675, in that pancreatin, pepsin, and a combination of pepsin and pancreatin again indicated improvement in gains and feed efficiency. The addition of 1% papain or 1% Mycozyme was as effective as the combination of 1% each pepsin plus pancreatin, whereas, again, 1% Star-Zyme P was not effective in improving gains or feed efficiency. Supplementation of the Drackett protein basal diet with either 40% dried

Table IV. Design and Results of Experiment 675, Part II

Ration Treatment[a]	Initial Wt.,[b] Lb.	5-Week Wt., Lb.	Gain, Lb.	Lb. Feed/Lb. Gain
1. Basal ration[c]	7.0	19.3	12.3	2.13
2. Basal + 1% pepsin + 1% pancreatin[d]	7.1	22.9	15.8	1.74

[a] Replicated pens of 4 pigs each. Total 16 pigs.
[b] Initial age, 13.2 days.
[c] Drackett C-1 assay protein with 20% lactose.
[d] Two pigs died.

Table V. Design and Results of Experiment 675, Part III

Ration Treatment[a]	Initial Wt.,[b] Lb.	Final Wt., Lb.	Gain, Lb.	Lb. Feed/Lb. Gain
1. Basal ration[c]	28.0	47.0	19.0	1.94
2. Basal + 1% pepsin + 1% pancreatin	28.1	47.7	19.6	1.84

[a] Replicated pens of 4 pigs each. Total 16 pigs.
[b] Initial age, 53.4 days. 14 days on test.
[c] Drackett C-1 assay protein with 20% lactose.

Table VI. Design and Results of Experiment 677

Ration Treatment[a]	5-Week Wt.[b], Lb.	Gain, Lb.	Relative Gain, %	Lb. Feed/Lb. Gain	Feed Saving, %
1. Basal ration[c]	14.2	8.4	100	2.82	0
2. Basal + 1% pancreatin[d]	16.3	10.0	119	2.41	+15
3. Basal + 1% pepsin	16.2	10.4	124	2.20	+22
4. Basal + 1% pepsin + 1% pancreatin	16.8	10.8	129	2.18	+23
5. Basal + 0.5% Star-Zyme P	14.6	8.4	100	2.90	− 3
6. Basal + 1% papain	16.6	10.4	124	2.36	+16
7. Basal + 1% Mycozyme	16.8	10.8	129	2.31	+18
8. Casein-Drackett basal[e] protein	19.9	13.9	165	1.76	+38
9. No. 8 + 1% pepsin + 1% pancreatin	21.4	15.6	186	1.60	+43
10. 40% dried skim milk—Drackett basal	19.9	14.0	167	2.06	+27
11. No. 10 + 1% pepsin + 1% pancreatin	17.8	12.0	143	2.01	+29

[a] Two replicated pens of 4 pigs each per treatment. Total 88 pigs.
[b] Average initial weight and age = 6.0 lb. and 8.6 days.
[c] Drackett C-1 assay protein with 20% lactose.
[d] Two pigs became unthrifty during experiment and were removed.
[e] Casein added at the level contributed by 40% dried skim milk.

Statistical analysis.

1. Casein diets produced significantly ($P = 0.05$) heavier pigs at 5 weeks of age on significantly ($P = 0.05$) less feed than Drackett protein diets.
2. Dried skim milk diets produced significantly ($P = 0.05$) heavier pigs at 5 weeks of age on significantly ($P = 0.05$) less feed than Drackett protein diets.
3. Average effect of all enzyme additions to Drackett protein basal diets significantly improved feed efficiency ($P = 0.05$).

Table VII. Combined Results of Experiments 675 Part I, 675 Part II, and 677

Experiment	Basal		Basal + Pepsin + Pancreatin	
	Gain	Feed/lb. gain	Gain	Feed/lb. gain
675 I	8.7	2.57	10.0	2.43
675 II				
Rep. 1	13.8	2.05	17.0	1.73
Rep. 2	10.9	2.21	14.5	1.76
677				
Rep. 1	8.7	2.71	12.9	2.01
Rep. 2	8.0	2.93	8.8	2.35
Average	10.0	2.49	12.7[a]	2.06[b]

[a] Significant increase ($P = 0.05$ or less).
[b] Significant improvement ($P = 0.05$ or less).

Table VIII. Combined Results of Experiments 675 Part I and 677

Experiment	Basal Ration	Basal + Pancreatin	Basal + Pepsin	Basal + Pepsin + Pancreatin	Basal + Fungal Protease	Basal with 40% D.S.M.[a]
			Gain, Pounds			
675 I	8.7	9.2	9.9	10.1	6.0	13.1
675						
Rep. 1	8.7	12.1	10.3	12.9	11.2	14.4
Rep. 2	8.0	7.8	10.6	8.8	5.7	13.6
Average	8.5	9.7	10.3	10.6	7.6	13.7[b]
			Feed per Pound of Gain			
675 I	2.57	2.53	2.46	2.43	2.98	1.74
677						
Rep. 1	2.71	2.26	2.32	2.01	2.42	2.12
Rep. 2	2.93	2.56	2.07	2.35	2.37	2.00
Average	2.74	2.45	2.28[c]	2.26[c]	2.59	1.96[c]

[a] Dried skim milk.
[b] Significant increase over basal ($P = 0.05$ or less).
[c] Significant decrease under basal ($P = 0.05$ or less).

skim milk or its equivalent amount of casein, equally and significantly improved growth and feed efficiency. The addition of 1% each of pepsin and pancreatin to the casein diet further improved performance. However, enzyme supplementation to the dried skim milk diet failed to improve growth. This latter result is believed to be a physical rather than a nutritional effect in this case, as the enzyme-supplemented dried skim milk diet was observed to "paste-up" considerably in the self-feeder troughs and failed to feed down properly. In this experiment, the average effect of all enzyme additions to the Drackett protein basal diet improved feed efficiency significantly ($P = 0.05$).

Although consistent responses have been obtained from enzyme supplementation from experiment to experiment, variation in response within ration treatments has been too great to demonstrate statistical significance within every single experiment. However, when replications from all experiments are combined as shown in Table VII, a statistically significant ($P = 0.05$) improvement in both gains and feed efficiency was obtained from the addition of combination of 1% each pepsin and pancreatin to the Drackett protein basal diets. When the results of three replications each of six different ration treatments from two experiments are combined, as shown in Table VIII, the addition of pepsin alone or in combination with pancreatin improved feed efficiency significantly ($P = 0.05$). However, the substitution of 40% dried skim milk for Drackett C-1 assay protein significantly improved gains and feed efficiency ($P = 0.05$ or less).

Although much has been learned about the management of early weaned baby pigs, more information is needed on early weaning on semipurified dry diets, in order that variation between replications can be minimized. In these experiments a preliminary standardization period, which might have reduced the variation but increased the initial starting age and weight, was purposely sacrificed in order that the enzyme treatment effects could be studied at as early an age as possible.

The possibility exists that part of the response to enzyme supplementation may be due to unidentified growth factors in the crude preparations or even to an improvement in amino acid balance. Detailed digestibility trials and studies with inactivated enzyme preparations are in progress, in an effort to establish whether improved pig performance was due to enzyme activity or other stimulatory factors.

The reason for the marked improvement in growth and feed efficiency when dried skim milk or casein replaces part of the purified soybean protein is not completely clear. Improved palatability has been recognized, and an improved amino acid balance exists; both may be contributing factors.

The results of these researches look promising from both fundamental and applied aspects. However, much research remains to be done, both in determining optimum levels of effective enzymes for ration supplementation and in producing satisfactory predigested protein and carbohydrate ingredients for baby pig rations.

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