EFFECT OF SOURCE OF DIETARY PROTEIN ON ILEAL AMINO ACID AVAILABILITY IN EARLY WEANED PIGS

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Story in Brief

A 4 x 4 Latin square trial was conducted using four early weaned gilts fitted with simple ileal T-cannula to determine the effect of protein source on protein and amino acid availability. The availability of dry matter, ash, nitrogen and amino acid in 25-day-old pigs fed either dried skim milk, isolated soy protein, soy protein concentrate or soybean meal diets were determined at the ileum. The pigs were fed semi-purified diets formulated to contain 22% crude protein. The availability of dry matter, nitrogen and overall essential amino acids and nonessential amino acids at the terminal ileum of early weaned pigs was higher in pigs fed dried skim milk, isolated soy protein and soy protein concentrate diets than in those fed a soybean meal diet. The availability of nitrogen and all amino acids except glutamic acid increased with increasing piglet age. Ileal availabilities for lysine and valine were higher for pigs fed the dried skim milk diet than for those fed any of the soybean protein diets. Availabilities of all other amino acids were similar among dried skim milk, isolated soy protein and soy protein concentrate diets. This study suggests that low availability of lysine may limit performance of pigs fed soybean proteins.

(Key Words: Swine, Early Weaned Pig, Amino Acid Availability.)

Introduction

Weaning as early as 18 days often is desirable for swine producers to maximize efficiency. However, early weaning commonly results in low feed intake, poor feed conversion, intestinal malabsorption and weight losses in the early weeks post-weaning. Weaning causes changes in the morphology of the small intestine of pigs.

Protein is utilized more efficiently from casein than from soybean meal until the pig is about 5 weeks of age. This can be explained partially by lower digestibility of the nitrogen in the soybean proteins and incomplete hydrolysis of soybean protein in the small intestine.

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Soybean proteins can be improved by processing for early weaned pigs. Alkali or acid treatment of soybean protein has been shown to improve pig performance. Isolated soy protein and soy protein concentrate now available may be improved over those used previously. Knowledge of differences in amino acid availability, particularly for lysine, should allow formulation of early weaned pig diets on an available amino acid basis.

Several studies have shown that protein sources vary not only in amino acid content but also in amino acid availability as measured either at ileum or in fecal samples. However, studies in early weaned pigs, where the effects of protein source may be more critical, have not been tested adequately. This study was conducted to determine the biological availability of dry matter, ash, nitrogen and individual amino acids in milk and soybean proteins fed to ileally cannulated early weaned pigs.

Materials and Methods

Four Yorkshire gilts were surgically fitted with simple T-cannula located in the distal ileum approximately 2 inches from the ileocecal junction. Pigs were removed from their sows at 18 days of age at which time the cannulas were surgically installed. Immediately following surgery pigs were returned to the sow where they remained with the rest of the litter for a 5-day recovery period. Creep feed and water were available at all times during the convalescent period. After recovery, the pigs were removed to an environmentally controlled feeding room where they were housed in individual elevated metal pens measuring two by 3 feet. Temperature in the feeding room was maintained between 80 and 90°F for the duration of the trial. After a 2-day adjustment period, the pigs at 25 days of age were started on a 4 x 4 Latin square trial.

Dietary treatments consisted of one milk and three soybean protein sources in semi-purified cornstarch-cerelose based diets (Table 1). Protein sources included dried skim milk (DSM), isolated soy protein (ISP), soy protein concentrate (SPC) and soybean meal (SBM). Twenty-two percent crude protein diets were formulated to exceed the NRC (1988) requirement for crude protein for the 11- to 22-lb pig by 10% such that no single amino acid would be limiting. Diets were supplemented with vitamins and minerals to provide completely balanced diets for this age and weight of pigs. Chromic oxide was added as an indigestible marker to allow for availability determinations. Each pig was fed a measured quantity of feed twice daily at 8:00 a.m. and 8:00 p.m. and allowed continuous access to the feed for a 1-h period after which all uneaten feed was removed. Water was available all the time.

Each of the four 7-day experimental periods consisted of a 4-day adjustment period followed by a 3-day collection period. Ileal samples were collected continuously on each collection day, beginning 1 h after the morning

Table 1. Composition of experimental diets.

Ingredients	Diet[a]			
	DSM	ISP	SPC	SBM
Corn starch	13.60	14.47	9.33	4.13
Cerelose	13.60	14.47	9.33	4.13
Solka floc	5.00	5.00	5.00	5.00
Lactose		32.01	32.01	32.01
Soybean oil	5.00	5.00	5.00	5.00
Dried skim milk	60.88			
Isolated soy protein[b]		24.35		
Soy protein concentrate[c]			33.49	
Soybean meal, 50%				45.30
Calcium carbonate	.08	.65	.67	.73
Dicalcium phosphate	.24	2.45	2.36	2.10
Vitamin, TM premix[e]	.95	.95	.95	.95
Salt	.30	.30	.30	.30
Apralan[d]	.10	.10	.10	.10
Chromic oxide	.25	.25	.25	.25
Total	100.00	100.00	100.00	100.00

[a] DSM: dried skim milk protein; ISP: isolated soy protein; SPC: soy protein concentrate; SBM: soybean meal.

[b] Isolated soy protein, soluble, PP-620, Protein Technologies International.

[c] Soy protein concentrate, promocalf, Central Soya, Fort Wayne, IN.

[d] Contained 75 g Apramycin per lb.

[e] Supplied 8,800 IU vitamin A, 880 IU vitamin D, 37 IU vitamin E, 44 mg pantothenic acid, 59 mg niacin, 8.8 mg riboflavin, 7.3 menadione sodium bisulfate, .04 mg vitamin. B_{12}, 3 mg biotin, 6 mg pyridoxine, 2 mg folic acid, 10 mg thiamin, 880 mg choline chloride, .2 mg selenium, .06 g manganese, .2 g zinc, .2 g iron, .2 g copper, .2 g magnesium, 1.0 g potassium, and .4 mg iodine, per kg of feed.

feeding and continuing until either 50 g of wet samples was collected for each pig or until feeding time of the evening meal. Samples were collected in vinyl bags suspended from the cannula. Bags containing samples were changed at a maximum of 1-h intervals. After removal from the pig all digesta samples were immediately frozen and stored at -20°C. Ileal and fecal samples collected over the three collection days of each period were composited by treatment prior to lyophilyzation and grinding for laboratory analysis.

Dry matter (DM), ash, nitrogen (N) and amino acid content of feed, ileal and fecal samples were determined by AOAC (1980) methods. Amino acid concentration was determined by ion exchange chromatography using a Beckman model 6300 automatic AA analyzer. Acid hydrolysis was conducted under nitrogen reflex in 6 N HCl for 22 h.

Results and Discussion

Protein and amino acid composition of the complete diets are shown in Table 2. The three soybean protein diets were similar in essential amino acid content but higher in all essential amino acids except methionine, valine and isoleucine than the dried skim milk diet.

The availability of dry matter and ash from various protein sources at both the terminal ileum and over the total digestive tract is shown in Table 3. The apparent availability of DM and ash in protein sources at both sites was lower ($P<.01$) in pigs fed soybean meal diet than in pigs fed all other protein sources; DM availability among pigs fed the dried skim milk, isolated soy protein and soy protein concentrate diets was similar. Dry matter disappearance from the hind gut ranged from 10.5% for soybean meal diet to 5.5% for dried skim milk diet which may reflect the higher fiber content of soybean meal and the high digestibility of nutrients in dried skim milk. The ash availability at both sites was similar for all dietary treatments.

The ileal availability of nitrogen, essential amino acid and nonessential amino acid was lower ($P<.01$) in pigs fed soybean meal diet than in those fed all other protein sources (Table 4). The average ileal availability of essential amino acids by pigs fed the SBM was 79.2% compared to 89.3, 88.5 and 88.4% for those fed the DSM, ISP and SPC diets, respectively. The ileal availability of lysine and valine was higher ($P<.05$) in pigs fed the DSM than in those fed any of the soybean protein sources; availability of these essential amino acids was higher from ISP and SPC than from the SBM diet. For the other essential amino acid, there were no significant differences among DSM, ISP and SPC diets.

The availability of N and amino acid in pigs fed the SBM diet was lower than for those fed other dietary protein sources. This may reflect the presence of proteolytic enzyme inhibitors, indigestible carbohydrate complexes and antigenic constituents in soybean endosperm; these may account for the inferior

Table 2. Protein and amino acid composition of diets[a].

Ingredients	Diet[a]			
	DSM	ISP	SPC	SBM
Crude protein, %	23.30	23.75	23.87	24.04
Amino acids, %				
Essential				
Arginine	.71	1.56	1.64	1.68
Histidine	.51	.58	.61	.64
Isoleucine	1.32	1.06	1.10	1.13
Leucine	1.99	2.01	2.02	2.12
Lysine	1.33	1.49	1.56	1.60
Methionine	.54	.35	.37	.38
Phenylalanine	.97	1.19	1.23	1.22
Threonine	.97	1.03	1.09	1.15
Valine	1.39	1.18	1.14	1.17
Nonessential				
Alanine	.90	1.15	1.19	1.13
Aspartic acid	1.73	2.77	2.89	3.02
Cystine	.23	.29	.37	.33
Glutamic acid	5.01	4.55	4.52	4.76
Glycine	.69	.92	.97	1.02
Proline	2.76	1.27	1.27	1.32
Serine	1.21	1.26	1.29	1.36
Tyrosine	.84	.75	.76	.83

[a] Dry matter basis.
[b] See Table 1 for explanation of diet code name.

Table 3. Availability of dry matter and ash at the end of the small intestine and in the total digestive tract of early weaned pigs[a].

Ingredients	Diet[a]				
	DSM	ISP	SPC	SBM	SE
Dry matter, %					
Terminal ileum	84.72[c]	83.57[c]	82.74[c]	71.80[d]	2.2
Total tract	90.24[c]	89.29[c]	88.72[c]	82.27[d]	1.5
Difference[e]	5.52[f]	5.72[f]	5.98[f]	10.47[f]	.5
Ash, %					
Terminal ileum	60.92	59.17	58.40	59.00	2.6
Total tract	63.99	62.83	61.73	63.12	2.3
Difference[e]	3.07[f]	3.66[f]	3.33[f]	4.12[f]	1.1

[a] Values are least squares means of four observations.
[b] See Table 1 for explanation of diet code names.
[c,d] Means in the same row with different superscripts differ (P<.01).
[e] Differences were obtained by subtracting ileal availabilities from total tract availabilities. In DM availability SBM differs from others (P<.01).
[f] Availability of DM and ash between feces and ileum differs (P<.05).

growth and feed efficiency observed for early weaned pigs fed the SBM diet compared to those fed milk protein diets. Similar availabilities of amino acids among the DSM, ISP and SPC diets may reflect removal of antinutritional factor(S) and antigenic material(s) present in the soybean during production of isolated soy protein or soy protein concentrate.

A linear increase over time (P<.05) was observed in ileal availability of N, of essential amino acids and of nonessential amino acids with the exception of glutamic acid (Table 5). These changes in availability due to protein sources and time should be considered when formulating diets for young pigs, especially when SBM is used as a supplemental protein source to meet minimum requirements for lysine.

The apparent availability of amino acids to the ileum of pigs fed soybean protein source diets increased with increasing age. Pigs fed the SBM diet showed 10.7% increase in apparent essential amino acid availability from first to fourth week. However, the utilization of milk protein diet has been shown not to change with age of pigs (Table 6). More precise diet formulation may be achieved when availability of the amino acids in a feedstuff are considered. Formulation of diets based upon available amino acids should result in a more valid comparision of soybean protein vs milk based protein.

Table 4. Apparent ileal availability of nitrogen and amino acids in milk and soybean protein sources in early weaned pigs[a].

Item	Diet[b]				
	DSM	ISP	SPC	SBM	SE
Nitrogen[c], %	89.22	88.32	87.65	77.29	1.8
Amino acids, %					
Essential					
Arginine[c]	88.4	90.7	90.4	82.2	2.2
Histidine[c]	86.5	88.4	88.2	80.5	2.0
Isoleucine[c]	92.2	90.2	90.1	81.9	2.2
Leucine[c]	92.5	91.8	91.6	82.2	.9
Lysine[c]	91.7[d]	88.2[e]	88.3[e]	79.3	1.7
Phenylalanine[c]	88.6	87.8	87.9	77.4	1.2
Threonine[c]	85.3	84.9	85.3	74.9	1.7
Valine[c]	89.5[d]	85.7[e]	85.6[e]	75.3	1.6
Mean	89.3[f]	88.5[f]	88.4[f]	79.2[g]	1.6
Nonessential					
Alanine[c]	89.7	88.9	89.1	79.9	1.7
Aspartic acid[c]	88.6	90.2	89.3	81.2	1.6
Glutamic acid[c]	93.4	92.2	92.4	82.2	2.0
Glycine[c]	84.9[d]	81.7[e]	81.9[e]	73.5	1.9
Proline[c]	85.8	85.4	84.9	77.8	1.6
Serine[c]	94.4	93.7	93.2	84.5	1.4
Tyrosine[c]	89.9	87.5	86.9	77.8	3.1
Mean	89.5[f]	88.7[f]	88.2[f]	79.5[g]	1.7

[a] Values are means of four observations.
[b] See Table 1 for explanation of diet code name.
[c] The SBM diet differs from other diets(P<.01).
[d,e] Means in the same row with different superscripts differ (P<.05).
[f,g] Means in the same row with different superscripts differ (P<.01).

Table 5. Effect of age on apparent ileal amino acid availability in early weaned pigs[a].

Item	Week				
	1	2	3	4	SE
Dry matter, %	78.9	78.2	83.3	82.6	1.3
Nitrogen, %	82.8	83.2	87.7	88.4	.8
Amino cids, %					
Essential					
Arginine[c]	84.2	84.7	90.4	88.7	1.4
Histidine[c]	83.7	83.5	89.2	88.4	1.7
Isoleucine[c]	87.2	81.9	89.7	91.3	1.6
Leucine[b]	87.4	89.4	90.9	92.0	2.1
Lysine[c]	83.1	84.2	88.3	90.7	2.0
Phenylalanine[c]	84.2	85.1	86.9	88.4	1.6
Threonine[c]	78.5	78.7	84.7	85.7	1.9
Valine[c]	83.6	83.4	85.8	88.4	1.9
Nonessential					
Alanine[b]	85.3	85.9	88.3	91.3	1.8
Aspartic acid[c]	84.2	84.7	89.5	90.2	2.0
Glutamic acid	89.7	88.6	90.8	89.3	2.0
Glycine[b]	76.9	77.7	82.1	83.4	2.1
Proline[c]	80.2	80.4	83.3	84.9	1.8
Serine[c]	86.4	85.2	91.3	92.2	1.7
Tyrosine[c]	83.2	83.7	89.0	89.7	1.9

[a] Values are means of four observations.
[b] Linear effect P<.01.
[c] Linear effect P<.05.

Table 6. Effect of age on apparent ileal amino acid availability of milk and soybean protein sources in early weaned pigs[a].

Diet[b]	Week 1	2	3	4
	%	%	%	%
DSM				
EAA	88.1	87.6	89.5	90.7
NEAA	89.5	89.7	89.3	89.0
ISP				
EAA	86.0	86.1	90.1	91.2
NEAA	86.9	87.2	90.9	91.4
SPC				
EAA	87.1	86.9	90.1	91.5
NEAA	86.8	87.1	89.8	90.9
SBM				
EAA	74.9	75.3	83.5	85.6
NEAA	75.2	77.1	83.2	85.4

[a] Values are obtained by means of eight essential amino acids and seven nonessential amino acids, respectively.
[b] See Table 1 for explanation of diet code names.

Literature Cited

AOAC. 1980. Official Methods of Analysis (13th Ed.). Association of Official Analytical Chemists, Washington, DC.

NRC. 1988. Nutrient Requirements of Domestic Animals. Nutrient Requirements of Swine. (9th Rev. Ed.). National Academy Press, Washington, DC.