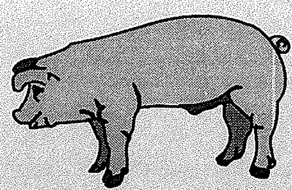
1998 UNIVERSITY OF ILLINOIS SWINE RESEARCH REPORTS



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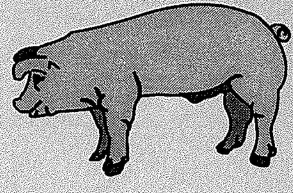

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The effect of feeding level and physiological state on total flow and amino acid composition of endogenous protein in swine

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Abstract

An experiment was conducted with the objective of investigating the effects of BW, feed intake, and the physiological condition of the animal on the loss and amino acid composition of endogenous protein in swine. The total endogenous protein loss at the distal ileum of 110 kg growing pigs, lactating sows, and gestating sows, given free access to feed, was 12.4 g, 9.4 g, and 11.2 g/kg DMI, respectively. These values were not different ($P > .10$). However, when gestating sows were fed only 2 kg/d, 17.8 g of endogenous protein were lost per kg DMI, which was higher ($P < .05$) than for any of the other groups. Likewise, restricted-fed gestating sows had an amino acid composition of endogenous protein that was significantly different from that of the other groups. The results from the experiment showed that age, BW, and the physiological condition of the animal have little or no effect on the amount of endogenous protein and amino acids lost at the distal ileum of pigs if calculated relative to DMI. However, daily feed intake had a significant effect on endogenous protein losses in sows as well as on amino acid composition of endogenous protein.

Introduction

Historically, endogenous protein has been defined as the protein recovered in fecal material from animals fed a protein-free diet (Mitchell, 1924). Because the amino acid composition of protein is altered by the microbes in the hindgut, it is now accepted that protein and amino acid losses should be determined at the distal ileum rather than in fecal output (Sauer and Ozimek, 1986; Sauer and de Lange, 1992).

Nutrient digestibilities and endogenous losses are usually determined in weanling or growing pigs. Subsequently, these numbers are applied to all categories of swine, and it has been proposed that the amount of endogenous losses as well as the amino acid composition of endogenous protein is constant regardless of the live weight of the animal (Boisen and Moughan, 1996). However, the hypothesis that values for endogenous losses obtained in growing pigs also can be applied to gestating and lactating sows has never been tested. Likewise, it is not documented that the amino acid composition of endogenous protein is constant, regardless of the physiological state or the feed intake of the animal. The objective of the present work was to test these hypotheses.

Materials and methods

Ten growing barrows (average BW: 110 ± 3.9 kg) arising from the matings of Camborough 15 sows to PIC line 326 boars (PIC, Franklin, KY) were used to measure endogenous losses for growing pigs. Five adult multiparous sows (Camborough 15, PIC, Franklin, KY) were used to determine endogenous losses for sows under different physiological conditions and subjected to different feeding regimes. All animals were prepared with a T-cannula surgically installed in the distal ileum. A protein-free diet containing .25% chromium oxide as an indigestible marker was formulated (Table 1).

The experiment consisted of four collection periods. The growing pigs were collected once, and the sows were collected in lactation and twice in the following gestation period. The growing pigs and the lactating sows were allowed ad libitum access to the experimental diet. Gestating sows were restricted to 2 kg feed/d in the first collection period, but the diet was fed to appetite during the second collection period. However, only four sows were used in this last period. All animals were fed the experimental diet for 7 d with digesta being collected over two 12 h periods on d 6 and 7.

Data for feed intake were summarized at the end of each collection period, and average daily feed intake was calculated for each pig and period on a total basis as well as in relation to the metabolic body weight ($kg^{0.75}$) of the animals. The endogenous flow of each amino acid was calculated for each animal and period as mg lost/kg DMI. The amino acid composition of endogenous protein was calculated for each animal group by expressing each amino acid as a percentage of total endogenous protein.

Results were subjected to analysis of variance using the Proc GLM procedure of SAS (SAS, 1995), and treatment means were separated using the least square difference test.

Results

Animals remained healthy throughout the experiment and readily consumed their diets (Table 2). Growing pigs consumed an average of 2.67 kg/d of feed, but lactating sows and gestating sows given free access to feed consumed more ($P < .05$), 5.05 kg and 4.35 kg/d, respectively. However, if feed intake was calculated in relation to metabolic BW of the animals, there were no differences in daily feed intake ($P > .05$) among these three groups. Restricted fed gestating sows were allowed to eat only 2 kg of feed/d, which was significantly less ($P < .05$) than what sows given free access to feed consumed on a daily basis as well as in relation to metabolic BW. All animals lost weight during the week they were fed the protein-free diet (Table 2). Lactating sows lost more weight ($P < .05$) than did any of the other groups during this week.

Endogenous losses of amino acids and protein for each animal group are presented in Table 3. The endogenous protein loss of lactating sows was numerically lower, but not significantly different ($P = .11$) from that of growing pigs or gestating sows given free access to feed. However, lactating sows had the numerically lowest loss of all amino acids except for tryptophan and glycine compared to the other groups, but not all of these differences were significant. The restricted-fed gestating sows had a greater ($P < .05$) loss of endogenous protein than any of the other groups. Likewise, the losses of all amino acids were numerically higher in restricted-fed sows compared to the other groups, significantly so for the loss of arginine, histidine, phenylalanine, glycine, proline, and serine ($P < .05$).

The amino acid composition of endogenous protein in lactating sows and gestating sows allowed ad libitum access to the diet was not different ($P > .05$) from the composition of endogenous protein in growing pigs, except for glycine in lactating sows (Table 4). The amino acid composition of endogenous protein in gestating sows fed only 2 kg/d was significantly different from that in growing pigs for all amino acids except arginine, histidine, glycine, and serine. Furthermore, these sows had a lower ($P < .05$) amount of indispensable amino acids and a higher ($P < 0.5$) amount of dispensable amino acids in endogenous protein than the other groups. In particular, the loss of proline in sows restricted in their feed intake was higher ($P < .05$) than in any of the other groups.

Discussion

The values for endogenous losses of protein and amino acids for growing pigs are in agreement with those previously reported in studies in which a protein-free diet had been fed (e.g., de Lange et al., 1989a, 1989b; Wang and Fuller, 1989; Leterme et al., 1996). Furthermore, the amino acid composition of endogenous protein from growing pigs in this study parallels previous estimates (Wünsche et al., 1987).

The values for endogenous losses obtained in growing pigs were close to those obtained in sows given free access to feed, although the levels were somewhat lower in lactating sows. However, lactating sows had a significantly higher feed intake than did the growing pigs. Comparing the values obtained in lactating sows with those obtained in gestating sows given free access to feed, it appears that, except for isoleucine, there were no significant differences in the amount of endogenous amino acids recovered at the distal ileum. This observation indicates that the difference between growing pigs and lactating sows is caused by the significant difference in daily feed intake between the two groups of animals rather than by the difference in the physiological condition of the animal.

Furuya and Kaji (1992) compared endogenous losses in 45-kg growing pigs and in 92-kg pigs, and they found no significant differences in endogenous amino acid losses between these two groups of pigs. Our results in growing pigs and sows allowed ad libitum access to feed are in agreement with these observations.

When gestating sows were restricted to 2 kg/d, the endogenous loss of protein was higher ($P < .05$) than that for any of the other groups. The values for arginine, histidine, glycine, serine, and proline were significantly higher ($P < .05$) than those obtained with the other groups, and for all other amino acids the numerically highest values were obtained in gestating sows fed 2 kg/d. This finding indicates that feed intake *per se* has a significant effect on endogenous losses of protein and amino acids if calculated in relation to feed intake. A similar finding has previously been reported (Fuller and Cadenhead, 1991; Furuya and Kaji, 1992; Butts et al., 1993). Therefore, it is important to consider daily feed intake when values for endogenous losses are compared among different experiments.

The composition of endogenous protein was not significantly different ($P > .05$) among the three groups of animals that were fed to appetite (Table 4), but the restricted-fed gestating sows had a significantly different amino acid composition of endogenous protein. This indicates that neither the BW nor the physiological state of the animal affects the amino acid composition of endogenous protein if calculated proportionally to DMI. However, as was the case for the total flow of endogenous protein, the amino acid composition was influenced by the feeding level of the animals.

Implications

The growing pig above 100 kg BW is a good model for estimating the endogenous losses of protein and amino acids at the distal ileum in gestating and lactating sows. Furthermore, the amino acid composition of endogenous protein in sows is not different from that in growing pigs. However, daily feed intake affects the amount of endogenous protein and amino acids lost at the distal ileum as well as the amino acid composition of endogenous protein. Because lactating sows usually have a higher feed intake and gestating sows usually have a lower feed intake than growing pigs, they also have different losses of endogenous protein and amino acids.

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Table 1. Composition (as is) of the experimental diet [a]

Ingredient	g /100 g
Corn starch	81.6
Soybean oil	4.0
Sucrose	5.0
Solka floc[b]	5.0
Dicalcium phosphate	3.2
Limestone	.4
Trace mineral salt [c]	.35
Vitamin premix [d]	.2
Chromium Oxide	.25

[a] .7 g Ca and .6 g P per 100 g diet.
[b] James River, Berlin, NH.
[c] The trace mineral salt provided the following quantities of minerals per 100 g diet: Se, .030 mg; I, .035 mg; Cu, .8 mg; Mn, 2 mg; Fe, 9 mg; Zn, 10 mg; NaCl, 273 mg.
[d] The vitamin premix provided the following quantities of vitamins per kg diet: Vitamin A, 5,250 IU; vitamin D_3, 525 IU; vitamin E, 40 IU; menadione K, 2 mg; vitamin B_{12}, .016 mg; riboflavin, 4 mg; D-pantothenic acid, 11 mg; niacin, 15 mg; choline chloride, 110 mg.

Table 2. Feed intake and average daily gain of animals fed the experimental diet

Item	Pigs	Lactating sows	Gestating Sows		SEM [a]
			Restricted-fed	Ad libitum-fed	
n	10	5	5	4	
BW, kg	111.67 [b]	215.30 [c]	213.00 [c]	234.63 [c]	8.74
BW, $kg^{0.75}$	34.31 [b]	56.11 [c]	55.72 [c]	59.90 [c]	1.76
ADG, g	-132 [b]	-2,800 [c]	-687 [b]	-422 [b]	369
ADFI, kg	2.67 [b]	5.04 [c]	2.0 [b]	4.35 [c]	.28
ADFI, $g/kg^{0.75}$	79 [b]	90 [b]	36 [c]	73 [b]	5.68

[a] Pooled standard error of the mean
[b, c] Means within a row lacking a common superscript are different ($P < .05$)

Table 3. Endogenous losses (mg/kg DMI) of protein and amino acids in growing pigs and sows fed a protein-free diet [a]

Group	Pigs	Lactating sows	Gestating sows		SEM[b]
			Restricted-fed	Ad libitum-fed	
n	10	5	5	4	-
Crude protein	12,437 [c]	9,396 [c]	17,780 [d]	11,218 [c]	1,311
Indispensable amino acids					
Arginine	361 [c]	266 [d]	528 [e]	303 [cd]	32
Histidine	156 [c]	136 [c]	222 [d]	153 [c]	16
Isoleucine	392 [c]	252 [d]	376 [c]	317 [c]	42
Leucine	591 [cd]	446 [c]	644 [d]	498 [cd]	46
Lysine	428 [c]	292 [d]	522 [c]	413 [cd]	46
Methionine	123 [c]	80 [d]	128 [c]	105 [cd]	12
Phenylalanine	341 [cd]	268 [c]	372 [d]	293 [cd]	32
Threonine	527 [cd]	454 [c]	606 [d]	508 [cd]	45
Tryptophan	151	130	162	125	13
Valine	491 [c]	340 [d]	532 [c]	430 [cd]	51
Mean	3,561 [cd]	2,664 [d]	4,092 [c]	3,143 [cd]	332
Dispensable amino acid					
Alanine	591 [c]	406 [d]	650 [c]	510 [cd]	57
Aspartate	878 [c]	604 [d]	1,010 [c]	800 [cd]	85
Cysteine	236 [de]	174 [c]	268 [e]	188 [cd]	16
Glutamate	1,139 [c]	752 [d]	1270 [c]	958 [cd]	111
Glycine	857 [c]	1,020 [c]	1,446 [d]	778 [c]	107
Proline	1,977 [c]	782 [c]	5,044 [d]	1,090 [c]	562
Serine	450 [c]	376 [c]	622 [d]	455 [c]	43
Tyrosine	299 [c]	214 [d]	328 [c]	235 [cd]	28
Mean	6,427 [c]	4,328 [c]	10,638 [d]	5,013 [c]	860
All amino acids	9,988 [c]	6,992 [c]	14,730 [d]	8,155 [c]	1,067

[a] The endogenous loss of protein and each amino acid was calculated as the amino acid or protein concentration in digesta DM multiplied by the ratio between chromium in digesta DM and chromium in feed DM.

[b] Pooled standard error of the mean.

[c, d, e] Means within a row lacking a common superscript are different ($P < .05$).

Table 4. Amino acid composition of endogenous protein in growing pigs and sows [a]

Group	Pigs	Lactating sows	Gestating sows		SEM[b]
			Restricted-fed	Ad libitum-fed	
n	10	5	5	4	
Crude protein	100	100	100	100	
Indispensable amino acids					
Arginine	2.93	2.87	3.00	2.74	.13
Histidine	1.29	1.45	1.25	1.39	.08
Isoleucine	3.19 [c]	2.69 [cd]	2.11 [d]	2.84 [c]	.20
Leucine	4.88 [c]	4.81 [c]	3.64 [d]	4.49 [cd]	.29
Lysine	3.48 [c]	3.12 [cd]	2.96 [d]	3.67 [c]	.18
Methionine	1.01 [c]	.85 [cd]	.72 [d]	.93 [cd]	.06
Phenylalanine	2.82 [c]	2.87 [c]	2.10 [d]	2.62 [cd]	.16
Threonine	4.35 [c]	4.96 [c]	3.42 [d]	4.70 [c]	.27
Tryptophan	1.27 [c]	1.41 [c]	.92 [d]	1.16 [cd]	.08
Valine	3.99 [c]	3.62 [cd]	3.00 [d]	3.93 [c]	.24
Mean	29.21 [c]	28.64 [c]	23.12 [d]	28.46 [c]	1.51
Dispensable amino acids					
Alanine	4.81 [c]	4.34 [c]	3.66 [d]	4.59 [c]	.19
Aspartate	7.20 [c]	6.50 [cd]	5.69 [d]	7.18 [c]	.42
Cysteine	1.94 [c]	1.87 [cd]	1.52 [d]	1.75 [cd]	.10
Glutamate	9.26 [c]	8.06 [cd]	7.12 [d]	8.64 [c]	.42
Glycine	6.85 [c]	11.55 [d]	8.19 [c]	7.13 [c]	.86
Proline	14.38 [c]	7.80 [c]	28.30 [d]	8.88 [c]	3.23
Serine	3.70	4.09	3.49	4.15	.20
Tyrosine	2.46 [c]	2.30 [cd]	1.85 [d]	2.07 [cd]	.14
Mean	50.61 [c]	46.52 [c]	59.83 [d]	44.39 [c]	2.66
All amino acids	79.82 [cd]	75.17 [c]	82.95 [d]	72.85 [c]	2.35

[a] The endogenous loss of each amino acid was calculated as the percentage of total endogenous protein loss.

[b] Pooled standard error of the mean.

[c, d, e] Means within a row lacking a common superscript are different (P < .05).