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Hydrolyzed feather meal as a source of amino acids for finisher pigs

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Abstract

21 gilts and 21 castrated males were used to evaluate the value of hydrolyzed feather meal (FM) as a source of amino acids for finisher pigs, and to determine the possibility of replacing soybean meal (SBM) completely with FM by lysine supplementation. Dietary treatments consisted of five iso-lysinic (planned, 7.3 g kg^{-1}; actual, 8.0–8.8 g kg^{-1}) SBM diets containing 0 to 120 g FM kg^{-1}. Two additional diets containing 90 g FM kg^{-1} were formulated to be iso-nitrogenous to the SBM diet containing 0 g FM kg^{-1}. For these FM diets, SBM was replaced completely by FM, and one of the two diets was supplemented with L-lysine · HCl to achieve a target level of 7.3 g lysine kg^{-1}. At an average weight of 67.5 ± 3.4 kg, pigs were assigned randomly within sex to seven dietary treatments. Pigs were housed individually, and allowed ad libitum access to feed and water. All pigs were slaughtered at an average weight of 100.4 ± 3.2 kg to assess carcass traits. The rate (linear, $P < 0.05$; cubic, $P = 0.09$) and efficiency of weight gain (linear, $P = 0.07$) decreased as dietary FM increased. However, the response of pigs to the initial increment of FM (30 g kg^{-1}) in weight gain and greater feed intake of pigs fed the diet containing 120 g FM kg^{-1} seemed to be responsible for overall decreases in these criteria. The rate and efficiency of weight gain in pigs fed other SBM diets containing FM were similar. Although there were no statistically significant trends among pigs fed the SBM diets, the inclusion of 120 g FM kg^{-1} seemed to result in the inferior carcass quality as indicated by consistently lower values for carcass specific gravity (1.040 vs. 1.045), proportion of carcass lean (48.7 vs. 51.6%) and the rate of lean accretion (236.4 vs. 301.4 g d^{-1}). Pigs fed the two FM diets (with and without lysine supplementation) grew slower than those fed the SBM diet containing 0 ($P < 0.01$) or 90 g FM kg^{-1} ($P = 0.06$). Similar results were obtained for the efficiency of weight gain ($P < 0.05$) and rate and efficiency of lean

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accretion ($P < 0.05$). There was no effect of lysine supplementation on the rate and efficiency of weight gain. Pigs fed the FM diet supplemented with lysine, however, had less 10th rib backfat ($P = 0.10$), larger longissimus muscle area ($P = 0.08$), greater proportion of carcass lean ($P < 0.05$), and higher rate ($P = 0.08$) and efficiency of lean accretion ($P < 0.05$) than those fed the FM diet without lysine supplementation. The results indicate that FM up to 90 g kg^{-1} may be incorporated in the diet without adversely affecting carcass traits of finisher pigs. In addition, although weight gain may be reduced, FM can be used as the only source of protein supplement without decreasing the carcass quality, provided that the diet is supplemented with crystalline lysine to alleviate its deficiency.

Keywords: Feather meal; Pig; Growth performance; Carcass traits

1. Introduction

The competition between humans and animals for quality sources of protein is likely to increase continuously because of ever-increasing world population. It is, therefore, important to explore fully the potential of all protein sources as feed ingredients for animals (Aherne and Kennelly, 1985). Feather meal has been of interest in nutrition research because of its high protein content (Han and Parsons, 1991), and it has been used to replace a portion of protein sources in practical poultry diets (Cupo and Cartwright, 1991).

With a possible exception of lysine, the indispensable amino acid availability of hydrolyzed feather meal (FM) seems to be similar to that of soybean meal (SBM) in nonruminant species (Bielorai et al., 1983; Knabe et al., 1989; Han and Parsons, 1991). But based on the NRC (1988) requirement for amino acids, feather meal is deficient in lysine, the first limiting amino acid in typical swine diets. For this reason, it has not been used extensively for swine, and it is commonly recommended that the amount of feather meal should be limited to about 5% of the diet for optimum performance (Seerley, 1991).

Previous research (Chiba et al., 1995) demonstrated that FM was an effective source of extra dietary nitrogen to enhance leanness of finisher pigs. Furthermore, the performance of pigs fed a diet containing 15% FM was similar to those fed a SBM diet containing the same level of lysine, indicating that finisher pigs can utilize higher levels of FM than those commonly recommended. In that research, however, corn and SBM provided a fixed amount of dietary lysine or protein, and FM supplied additional lysine and protein.

The research described herein was conducted to evaluate the value of FM as a source of dietary amino acids for finisher pigs, and to determine the possibility of replacing SBM completely with FM by lysine supplementation.

2. Experimental procedures

2.1. Animals and facilities

21 gilts and 21 castrated males (28 Landrace × Hampshire × Duroc and 14 Landrace × Yorkshire × Duroc) were selected based on the breed combination and weight, and

housed in individual pens with solid concrete floors in an open-front building. At an average weight of 67.5 ± 3.4 kg, backfat thickness (BF) was measured with an ultrasound instrument as described previously (Chiba, 1995). Pigs were assigned randomly within breed combination and sex to seven dietary treatments with three gilts and three castrated males per diet. All pigs were slaughtered at an average weight of 100.4 ± 3.2 kg. Pigs were allowed ad libitum access to feed and water. Pig weight and feed consumption data were recorded once every two weeks. Near the end of the experiment, data were collected more frequently according to the slaughter schedule.

2.2. *Experimental diets*

Previous research (Chiba, 1992) established that this population of pigs require 7.3 g lysine kg^{-1} for optimum performance during the finisher phase, which is 20.8% greater than the current lysine recommendation (NRC, 1988). To determine the optimum level

Table 1
Composition of diets based on soybean meal or feather meal for finisher pigs (air-dry basis) [a]

Item	SBM diets containing FM ($g\ kg^{-1}$)					FM diets	
	0	30	60	90	120	Iso-N	Iso-N + Lys
Ingredients ($g\ kg^{-1}$):							
Corn	803.3	781.6	761.9	741.3	719.6	850.8	846.3
SBM (48% crude protein)	168.0	152.9	137.8	122.6	107.5	–	–
FM	–	30.0	60.0	90.0	120.0	90.0	90.0
L-lysine · HCl	–	–	–	–	–	–	4.5
Dried fat [b]	–	7.0	12.0	18.0	25.0	29.0	29.0
Dicalcium phosphate	14.5	14.3	14.1	13.9	13.7	16.7	16.7
Limestone	8.2	8.2	8.2	8.2	8.2	7.5	7.5
Salt	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Trace mineral-vitamin premix [c]	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Calculated analysis:							
DE ($MJ\ kg^{-1}$)	14.4	14.4	14.4	14.4	14.4	14.5	14.4
Crude protein ($g\ kg^{-1}$)	150	166	183	200	216	150	150
Lysine ($g\ kg^{-1}$)	7.3	7.3	7.3	7.3	7.3	3.7	7.3
Chemical analysis ($g\ kg^{-1}$) [d]:							
Crude protein	130	145	161	168	186	133	138
Lysine	8.3	8.0	8.8	8.4	8.3	5.2	8.1
Threonine	7.9	8.8	10.5	11.1	11.5	8.9	8.2
Isoleucine	6.9	7.8	9.8	10.5	10.8	8.1	7.2
Valine	8.5	10.0	12.6	13.9	15.0	11.3	10.0
Histidine	4.8	4.4	5.0	4.8	4.0	3.0	2.7

[a] SBM = soybean meal; FM = hydrolyzed feather meal; Iso-N = iso-nitrogenous to the SBM diet containing 0 g FM kg^{-1}; Iso-N + Lys = Iso-N plus L-lysine · HCl; DE = digestible energy; all diets were formulated to contain 7.00 g Ca and 6.00 g P kg^{-1}. [b] Contained 99% crude fat (Fat Pak® 100. Milk Specialties Co., Dundee, IL). [c] Provided the followings per kilogram of diet: Mg, 269 mg; Zn, 80 mg; Fe, 80 mg; Mn, 40 mg; Cu, 10 mg; I, 1 mg, Co, 0.4 mg; Se, 0.3 mg; vitamin A, 5,500 IU; vitamin D_3, 1,760 IU; vitamin E, 16.5 IU; menadione dimethylpyrimidinol bisulfite, 2.2 mg; riboflavin, 4.4 mg; d-pantothenic acid, 17.6 mg; niacin, 35.2 mg; vitamin B_{12}, 27.5 μg; choline, 95 mg. [d] Diets were not analyzed for sulfur amino acids or tryptophan.

Table 2
Analyzed crude protein and amino acid contents of hydrolyzed feather meal (air-dry basis)

Item	$g\ kg^{-1}$
Crude protein	719.4
Amino acid [a]:	
Lysine	21.7
Threonine	48.6
Isoleucine	46.3
Valine	67.3
Histidine	4.8
Leucine	79.8
Phenylalanine + tyrosine	74.8
Arginine	82.8
Alanine	44.6
Aspartic acid	68.2
Glutamic acid	110.7
Glycine	79.2
Proline	102.7
Serine	119.7

[a] Hydrolyzed feather meal sample was not analyzed for sulfur amino acids or tryptophan.

of dietary FM, five iso-lysinic (7.3 g kg^{-1}) SBM diets were formulated to contain 0, 30, 60, 90 or 120 g FM kg^{-1} (Table 1). The FM contributed 0, 6.9, 13.8, 20.7 and 27.6% of total lysine, respectively, to these five diets. Two additional diets containing 90 g FM kg^{-1} were used to investigate the possibility of replacing SBM completely with FM. The FM diets were formulated to be iso-nitrogenous (**Iso-N**) to the SBM diet containing 0 g FM kg^{-1}, and L-lysine · HCl was added to one of the two diets to achieve 7.3 g lysine kg^{-1} (**Iso-N + Lys**). All indispensable amino acid contents of this diet were at least 20.8% greater than the current recommendations (NRC, 1988). Diets were formulated based on the amino acid content of feed ingredients reported by the NRC (1988).

To avoid possible confounding effects of dietary energy density, dried fat product (Milk Specialties Co., Dundee, IL) was used to achieve similar digestible energy (DE) contents of diets (14.4 to 14.5 MJ kg^{-1}). All diets were formulated to meet or exceed the nutrient requirements for finisher pigs (NRC, 1988), except the lysine content of the FM diet without lysine supplementation (Iso-N). Feed and FM samples were analyzed for crude protein (AOAC, 1984) and amino acids (Chiba, 1994; Tables 1 and 2).

2.3. Slaughter procedures

Pigs were slaughtered at the university's meat laboratory using conventional procedures. Carcass traits were assessed, and the weight of internal organs was determined as described previously (Chiba, 1994). The rate of lean accretion and proportion of carcass lean were estimated using equations reported by the National Pork Producers Council (1991).

2.4. Statistical analysis

Data were analyzed as a generalized randomized block design (Addelman, 1969) using the GLM procedure of SAS (1988). Sex was used as a blocking criterion, and the initial weight was used as a covariate for the growth data. Because of the differences in the final weight among pigs (92–106 kg), it was also included in the model as a covariate. The final weight was used as a covariate for carcass and organ data. Preplanned, nonorthogonal contrasts were used to evaluate the treatment effects: the linear, quadratic and cubic effects of five SBM diets containing 0 to 120 g FM kg^{-1}, the SBM diet containing 0 g FM kg^{-1} vs. FM diets (Iso-N and Iso-N + Lys), the SBM diet containing 90 g FM kg^{-1} vs. FM diets, and the Iso-N vs. Iso-N + Lys diets.

3. Results

The results of amino acid analysis indicated that lysine contents of all diets were greater than intended values. The lysine content of FM was greater than the value reported by the NRC (1988) (Table 2), which may partly explain those differences. Similarly, the lower crude protein (CP) content of FM (Table 2) may have been responsible for the lower CP content of the FM diets, but it does not account for a lower CP content of the SBM diet containing 0 g FM kg^{-1}. Because corn and SBM samples were not obtained in this research, no clear explanation for the differences can be offered. The CP contents of FM diets (Iso-N and Iso-N + Lys) were, however, relatively similar to the SBM diet containing 0 g FM kg^{-1}.

3.1. Growth performance

Although feed and DE intakes varied, there was no clear effect of dietary treatments on these criteria (Table 3). Weight gain of pigs fed the SBM diets decreased (linear, $P < 0.05$; cubic, $P = 0.09$) as the FM content increased from 0 to 120 g kg^{-1}. Similarly, gain to feed, gain to DE intake and gain to lysine intake ratios tended to decrease (linear, $P = 0.07$) as the dietary FM content increased.

Pigs fed the two FM diets grew more slowly than those fed the SBM diet containing 0 ($P < 0.01$) or 90 g FM kg^{-1} ($P = 0.06$). Similarly, gain to feed and gain to DE intake ratios were lower in pigs fed the FM diets than those fed the SBM diet containing 0 ($P < 0.05$) or 90 g FM kg^{-1} ($P < 0.05$). There was no effect of lysine supplementation on weight gain or efficiency of feed or DE utilization. Pigs fed the FM diet without lysine supplementation (Iso-N) consumed less lysine, which resulted in differences in lysine intake between the FM diets and the SBM diet containing 0 ($P < 0.01$) or 90 g FM kg^{-1} ($P < 0.05$), and between the Iso-N and Iso-N + Lys diets ($P < 0.001$). As would be expected, these differences were reflected in gain to lysine intake ratio in the opposite direction, i.e., greater the lysine intake, lower the gain to lysine intake ratio.

3.2. Carcass traits and organ weights

There were no differences in ultrasound BF at the beginning of the experiment (overall average, 14.1 mm), indicating that the initial body composition was similar

Table 3
Effects of replacing soybean meal with hydrolyzed feather meal as a supplemental source of dietary amino acids on growth performance of pigs growing between 68 and 100 kg live weight [a]

Item [b]	SBM diets containing FM (g kg^{-1})					FM diets		
	0	30	60	90	120 [c]	Iso-N	Iso-N + Lys	CV (%)
Feed intake (g d^{-1})	3339	3374	3228	3122	3519	3211	3161	11.3
Weight gain (g d^{-1}) [defg]	929	994	868	856	864	759	762	10.7
Gain to feed (g kg^{-1}) [hij]	278	295	270	277	245	236	246	12.3
DE intake (MJ d^{-1})	48.2	48.7	46.6	45.1	50.8	46.5	45.6	11.3
Lysine intake (g d^{-1}) [fkl]	24.2	24.5	23.5	22.6	25.5	12.4	22.9	11.6
Gain:DE intake (g MJ^{-1}) [hij]	19.3	20.4	18.7	19.1	16.9	16.3	17.0	12.3
Gain:lysine intake (g g^{-1}) [fhkl]	38.4	40.7	36.6	38.1	33.5	62.4	34.2	11.8

[a] SBM = soybean meal; FM = hydrolyzed feather meal; Iso-N = iso-nitrogenous to the SBM diet containing 0 g FM kg^{-1}; Iso-N + Lys = Iso-N plus L-lysine·HCl; DE = digestible energy. [b] Least squares means were based on six individually fed pigs per diet; both the initial (67.5 ± 3.4 kg) and final weights (100.4 ± 3.2 kg) were included in the model as covariates. [c] Removed one pig from the experiment. [d] The SBM diets containing 0 to 120 g FM kg^{-1}: linear, $P < 0.05$. [e] The SBM diets containing 0 to 120 g FM kg^{-1}: cubic, $P = 0.09$. [f] The SBM diet containing 0 g FM kg^{-1} vs. Iso-N and Iso-N + Lys diets, $P < 0.01$. [g] The SBM diet containing 90 g FM kg^{-1} vs. Iso-N and Iso-N + Lys diets, $P = 0.06$. [h] The SBM diets containing 0–120 g FM kg^{-1}: linear, $P = 0.07$. [i] The SBM diet containing 0 g FM kg^{-1} vs. Iso-N and Iso-N + Lys diets, $P < 0.05$. [j] The SBM diet containing 90 g FM kg^{-1} vs. Iso-N and Iso-N + Lys diets, $P < 0.05$. [k] The SBM diet containing 90 g FM kg^{-1} vs. Iso-N and Iso-N + Lys diets, $P < 0.001$. [l] The Iso-N vs. Iso-N + Lys diets, $P < 0.001$.

among pigs assigned to various diets. The inclusion of 0 to 120 g FM per kg of the SBM diets resulted in no significant trends ($P > 0.10$) in any of the carcass traits or estimated lean, but pigs fed the diet containing 120 g FM kg^{-1} had lower numerical values for carcass specific gravity, proportion of carcass lean and the rate of lean accretion compared to those fed the other SBM diets Table 4. Although pigs fed the diet containing 120 g FM kg^{-1} tended to have heavier kidneys (quadratic, $P = 0.09$), there was no clear effect of dietary treatments on the weight of internal organs among pigs fed the SBM diets.

The rate and efficiency of lean accretion were lower in pigs fed the FM diets than those fed the SBM diet containing 0 ($P < 0.05$) or 90 g FM kg^{-1} ($P < 0.05$). Similar results ($P < 0.05$) were obtained for the weight of kidneys. Pigs fed the FM diets supplemented with lysine (Iso-N + Lys) had less 10th rib BF ($P = 0.10$), larger longissimus muscle area ($P = 0.08$), greater proportion of carcass lean ($P < 0.05$), and higher rate ($P = 0.08$) and efficiency of lean accretion ($P < 0.05$) than those fed the FM diet without lysine supplementation (Iso-N).

4. Discussion

Because of the competition between animals and humans for quality sources of nutrients, the effort to find viable alternative sources of amino acids and energy for pigs may be important for successful swine production in the future. Feed costs for finisher

Table 4
Effects of replacing soybean meal with hydrolyzed feather meal as a supplemental source of dietary amino acids on carcass traits, carcass lean and organ weights of pigs at 100 kg [a]

Item [b]	SBM diets containing FM (g kg^{-1})					FM diets		
	0	30	60	90	120 [c]	Iso-N	Iso-N + Lys	CV, %
Carcass trait:								
Average BF (mm)	29.2	28.8	28.8	28.1	29.9	32.6	29.9	19.1
10th rib BF (mm) [d]	27.5	26.0	23.6	23.0	27.8	32.0	24.8	28.1
LMA (cm^2) [e]	35.6	39.1	37.3	36.5	35.5	30.6	36.0	14.6
Specific gravity	1.043	1.043	1.045	1.047	1.040	1.038	1.045	0.9
Estimated lean:								
Proportion (%) [f]	51.2	50.9	53.1	51.2	48.7	45.2	50.7	8.3
Accretion (g d^{-1}) [egh]	303.5	300.1	320.0	282.1	236.4	131.7	224.1	34.9
Efficiency (g MJ DE^{-1}) [fgh]	6.5	6.4	7.1	6.3	4.5	2.8	5.3	35.9
Internal organs (g):								
Liver	1490	1607	1600	1593	1659	1591	1501	9.8
Kidneys [ghi]	339	328	337	323	359	295	288	7.8

[a] SBM = soybean meal; FM = hydrolyzed feather meal; Iso-N = iso-nitrogenous to the SBM diet containing 0 g FM kg^{-1}; Iso-N + Lys = Iso-N plus L-lysine · HCl; BF = backfat thickness; LMA = longissimus muscle area; estimated lean = carcass lean containing 5% fat; efficiency = efficiency of estimated lean accretion. [b] Least squares means were based on six individually fed pigs per diet; the final weight (100.4 ± 3.2kg) was included in the model as a covariate. [c] Removed one pig from the experiment. [d] The Iso-N vs. Iso-N + Lys diets, $P = 0.10$. [e] The Iso-N vs. Iso-N + Lys diets, $P = 0.08$. [f] The Iso-N vs. Iso-N + Lys diets, $P < 0.05$. [g] The SBM diet containing 0 g FM kg^{-1} vs. Iso-N and Iso-N + Lys diets, $P < 0.05$. [h] The SBM diet containing 90 g FM kg^{-1} vs. Iso-N and Iso-N + Lys diets, $P < 0.05$. [i] The SBM diets containing 0 to 120 g FM kg^{-1}: quadratic, $P = 0.09$.

pigs account for the largest economic input in most swine enterprises, and it is possible that finisher pigs can utilize unique feed ingredients better than younger pigs. There is, therefore, an opportunity to use alternative feed ingredients during this phase of swine production.

Feather meal has been of interest in nutrition research because of its high protein content (Han and Parsons, 1991). But feather meal is deficient in lysine and possibly other amino acids such as tryptophan, methionine and histidine for finisher pigs (NRC, 1988) depending on their availability. The low lysine content of feather meal may account for its infrequent use because the adequacy of lysine is the primary concern for most swine diets. As indicated before, it is generally recommended that the use of feather meal should be limited to about 5% of the diet for optimum performance (Seerley, 1991).

The overall rate and efficiency of weight gain in pigs fed the SBM diets decreased as the FM content increased from 0 to 120 g kg^{-1}. However, the response of pigs to the initial increment of FM (30 g kg^{-1}) in weight gain and greater feed intake of pigs fed the diet containing 120 g FM kg^{-1} seemed to be responsible for overall decreases in these criteria. The rate and efficiency of weight gain in pigs fed other SBM diets were relatively similar.

The beneficial effect of feeding FM on the carcass quality has been observed in swine (Chiba et al., 1995) and poultry (Cabel et al., 1988; Cupo and Cartwright, 1991). In the present research, however, the dietary FM content had no clear effect on carcass traits or carcass lean. Furthermore, feeding the SBM diet containing 120 g FM kg^{-1} tended to decrease carcass quality of finisher pigs as indicated by consistently lower values for carcass specific gravity (1.040 vs. 1.045), proportion of carcass lean (48.7 vs. 51.6%) and the rate of lean accretion (236.4 vs. 301.4 g d^{-1}) compared with those fed other SBM diets containing FM, even though the statistical evidence was very weak to support this contention (quadratic, $P = 0.22$).

The effort to determine the optimum level of dietary FM by using the broken-line model (Robbins, 1986) or to describe the response surface by using the regression analysis (SAS, 1988) was not successful. But the results may indicate that FM up to 90 g kg^{-1} can be incorporated in the diet without adversely affecting carcass quality of finisher pigs.

It is generally recommended that FM should be incorporated in swine diets based on the lysine content (Seerley, 1991). This method is, however, likely to increase the CP content of diets. Because of similarities in the availability of many amino acids between FM and SBM for nonruminant species (Bielorai et al., 1983; Knabe et al., 1989; Han and Parsons, 1991), it might be possible to replace SBM completely with FM in swine diets by lysine supplementation. Lysine supplementation would decrease the amount of dietary FM required, and also the CP content of swine diets. These lower protein diets may alleviate the possible environmental concern resulting from the increase in urinary nitrogen excretion of pigs fed diets high in protein content (Lenis, 1989).

As expected, pigs fed the FM diet without lysine supplementation had lower weight gain and rate and efficiency of lean accretion than those fed the SBM diets. The addition of L-lysine · HCl to achieve a target level of 7.3 g lysine kg^{-1} did not alleviate the growth depression caused by a complete replacement of SBM with 90 g FM kg^{-1}. Carcass BF, longissimus muscle area and proportion of carcass lean were, however, improved by lysine supplementation (Table 4). Although the rate of lean accretion in pigs fed the Iso-N + Lys diet was lower than those fed the SBM diets containing 0 or 90 g FM kg^{-1}, it was caused by the extension in the feeding period (6.9 days).

Even though, the weight of metabolically active organs associated with the dietary N content (Chiba, 1992; Chiba, 1994; Chiba et al., 1995) may have contributed to the depression of weight gain as indicated by the kidney data, the lack of growth response to lysine supplementation is rather difficult to explain. The indispensable amino acid content of the Iso-N + Lys diet was at least 20.8% greater than the NRC (1988) recommendations (e.g., the second limiting amino acid, tryptophan, was 25.3% greater than the NRC requirement). The total content of all indispensable amino acids, therefore, should have been adequate. This indicates that the availability of not only lysine but other amino acids in FM may be lower than those in SBM for pigs. This contention, however, does not explain the carcass data. Although direct statistical comparisons were not made, carcass traits between pigs fed the FM diet supplemented with crystalline lysine and the SBM diet containing 0 or 90 g FM kg^{-1} were similar.

In summary, even though there were some variations, the rate and efficiency of weight gain in pigs fed the SBM diets containing 0 to 120 g FM kg^{-1} were relatively similar. Likewise, the addition of FM to partially replace SBM had no clear effect on carcass traits or carcass lean of finisher pigs. Including 120 g of FM per kg of the diet, however, resulted in inferior carcass quality as indicated by clear numerical differences in some carcass response criteria. A complete replacement of SBM with FM resulted in depressed rate and efficiency of weight gain in pigs, but carcass quality was maintained by lysine supplementation. Although a definite conclusion cannot be made, the results indicate that FM up to 90 g kg^{-1} may be incorporated in the diet without adversely affecting carcass traits of finisher pigs. In addition, although weight gain may be reduced, FM can be used as the only source of protein supplement without decreasing the carcass quality, provided that the diet is supplemented with crystalline lysine to alleviate its deficiency.

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