Amino Acid Digestibility and Energy Concentration of Fermented Soybean Meal and Camelina Meal for Swine[1]

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Summary
Two experiments were conducted to determine the amino acid and GE digestibility of fermented soybean meal and camelina meal. For Exp. 1, to determine standardized ileal amino acid digestibility, five growing gilts (BW= 60.4 lb) were surgically fitted with T-cannulas at the terminal ileum and randomly allotted to 1 of 3 dietary treatments in a crossover design with 3 periods. The basal diets were corn starch–based with adequate vitamins and minerals to meet the pigs' requirements. The experimental treatments consisted of the basal diet with 30% fermented soybean meal or 39.25% camelina meal as the sole protein sources. A third nitrogen-free diet was also fed to determine basal endogenous amino acid losses.

For Exp. 2, to determine energy concentrations, 6 growing barrows (BW = 64.8 lb) were randomly allotted to 1 of 3 dietary treatments in a crossover design with 3 periods. The corn-based treatment diets had 25% fermented soybean meal or 30% camelina meal. A third corn basal diet was also offered to allow for energy calculations by the difference method. All diets contained 0.25% titanium oxide as an indigestible marker. Digesta samples were collected and analyzed for amino acid concentrations, and fecal samples were collected and analyzed for energy concentrations. After chemical analysis, standardized and apparent ileal digestible (SID and AID, respectively) amino acids were determined, and DE, ME, and NE were calculated for each ingredient. On a DM basis, GE, DE, ME, and NE were 1,973, 1,377, 1,232, and 880 kcal/lb, respectively, for fermented soybean meal and 2,075, 1,150, 1,041, and 715 kcal/lb, respectively, for camelina meal. In fermented soybean meal, the AID for lysine, methionine, threonine, and tryptophan were 63.5 ± 7.5, 84.6 ± 1.0, 74.0 ± 3.5, and 81.8 ± 1.4%, respectively, and SID values were 71.1 ± 6.2, 89.2 ± 2.1, 88.0 ± 3.1, and 93.7 ± 2.0%, respectively. For camelina meal, the AID for lysine, methionine, threonine, and tryptophan were 47.3 ± 7.7, 74.6 ± 3.3, 39.7 ± 6.8, and 67.3 ± 8.3%, respectively, and SID values were 53.9 ± 6.4, 77.7 ± 3.5, 51.6 ± 6.7, and 79.7 ± 6.8%, respectively. The SID availability for amino acids in fermented soybean meal were relatively high and similar to published values for soybean meal, with the exception of lysine. Standardized ileal digestible amino acid availability values for camelina meal were low, indicating that it may have contained the high glucosinolate concentrations generally observed in camelina meal.

Key words: camelina meal, fermented soybean meal, digestibility, finishing pig

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Introduction

Soybean meal is traditionally included in most swine diets because it provides a good balance of indispensable amino acids; however, the presence of certain antinutritional factors, such as trypsin inhibitors, pectins, and lectins, has been shown to reduce the growth performance of weanling pigs because their gastrointestinal tracts are not fully developed. Thus, highly digestible animal proteins, such as spray-dried animal plasma, poultry by-product meal, and fish meal, are often included in diets for young pigs. Recent research also has concluded that fermented soybean meal may be used to replace conventional soybean meal in diets fed to young pigs without reducing growth performance because most antinutritional factors are eliminated or reduced during the fermentation process. Feeding fermented soybean meal in lieu of conventional soybean meal may decrease nursery diet costs because it may be possible to reduce levels of specialty animal products and increase levels of fermented soybean meal.

Similar to canola, camelina is traditionally produced for oil production because of its relatively high concentration of omega-3 fatty acids. It is distantly related to rapeseed and is classified in the mustard family. Its major limitation in animal diets is high glucosinolate concentration. Although camelina meal is not widely used in current swine diet formulations, its availability may increase because camelina is a potential source of oil for biofuel production. Camelina meal is left after the cold extraction of oil from the camelina seed; the meal retains a high level of oil (10 to 15%) as well as at least 30% protein. The Food and Drug Administration has granted approval for camelina meal to be fed in swine diets at up to 2% of the diet, but companies must obtain a commercial feed license before manufacturing feed with camelina meal as an ingredient. Only limited research has been done to determine the amino acid digestibility and energy content of camelina meal to determine its feeding value in swine diets; therefore, the objective of these experiments was to determine the amino acid digestibility and energy values of fermented soybean meal and camelina meal for swine.

Procedures

Experimental procedures and animal care were approved by the Kansas State Institutional Animal Care and Use Committee. This experiment was conducted at the Kansas State University Swine Teaching and Research Facility in Manhattan, KS.

Experiment 1

Five growing gilts (initially 60.4 lb; PIC, Hendersonville, TN) were surgically fitted with a T-cannula on their right flanks, approximately 6 in. anterior to their ileocecal valves. The pigs were allowed to recover from surgery then placed in individual stainless-steel metabolism cages in an environmentally controlled building. Each cage was equipped with a feeder and a nipple waterer to allow for ad libitum access to water. During the first 9 d after surgery (recovery period), the pigs were fed a common diet ad libitum. On d 10 after surgery, the pigs were randomly allotted to 1 of 3 dietary treatments in a single Latin square design. The basal diets were corn starch–based with adequate vitamins and minerals to meet the pigs' requirements. Experimental treatments consisted of the basal diet with 30% fermented soybean meal (Fermentation Experts, Denmark) or 39.25% camelina meal (Dakota Lakes Research Farm, Pierre, SD) as the sole protein sources. A third nitrogen-free diet was also fed to determine basal endogenous amino acid losses (Table 1). Titanium oxide was added in all diets at 0.35% as an indigestible marker. There were 3 periods in the experiment, and each period consisted of 7 d. The first 5 d of each period were used to allow pigs to adapt to the dietary treatment. On d 6 and 7, ileal digesta were collected over a 10-h period (between 7:00 a.m. and 5:00 p.m. each day). Pig BW was determined at the start of each period before new diets were fed to allow for determination of the daily feed allocation, which was calculated to be 3 times the estimated daily maintenance requirements for energy. The daily feed allocation was equally divided between two equal amounts and given twice daily at 0600 and 1800 h.

On collection days, the cannula of each pig was opened to allow the digesta to flow out of the ileum and into a latex balloon. Balloons were checked and removed every 30 min or as they became full. Contents of the balloons were then transferred into 500-mL plastic containers and stored in a freezer (-4°F) until further chemical analyses were conducted. After the collection phase of the experiment, digesta samples from each period from each animal were thawed and homogenized. A subsample from each homogenized ileal digesta collection was then transferred to a new 500-mL plastic container, freeze-dried, and ground for amino acid analysis.

Amino acid analysis for the diets, fermented soybean meal, camelina meal, and ileal digesta samples were conducted at the University of Missouri-Columbia Agricultural Experiment Station Chemical Laboratories. The test diets, fermented soybean meal, and camelina meal were analyzed for DM, CP, crude fat, crude fiber, ash, Ca, P, ADF, and NDF in a commercial laboratory (Ward Laboratories, Inc., Kearney, NE).

Titanium oxide was an indigestible marker used to calculate amino acid digestibility values. The apparent ileal digestibility for amino acids in the experimental protein sources were calculated using the following equation:

$$AID = \{100 - [(AAd/AAf) \times (Tif/Tid)]\} \times 100$$

where AID is the apparent ileal digestibility of an amino acid (%), AAd is the amino acid concentration in the ileal digesta DM, AAf is the amino acid concentration in the feed DM, Tif is the titanium concentration in the feed DM, and Tid is the titanium concentration in the ileal digesta DM.

The basal endogenous amino acid loss (EAAL) to the ileum of each amino acid was determined based on the digesta obtained after feeding the nitrogen-free diet using the following equation:

$$EAAL = [AAd \times (Tif/Tid)]$$

where EAAL is the basal endogenous amino acid loss (g/kg of DMI), AAd is the amino acid concentration in the ileal digesta DM, Tif is the titanium concentration in the feed DM, and Tid is the titanium concentration in the ileal digesta DM.

Standardized ileal digestibilities of each amino acid were then calculated by correcting the AID for the EAAL for each amino acid using the following equation:

$$SID = [AID + (EAAL/AAf) \times 100]$$

where SID is the standardized ileal digestibility of an amino acid (%).

Experiment 2

Six growing barrows (initially 64.8 lb; PIC, Hendersonville, TN) were housed in individual stainless-steel metabolism cages in an environmentally controlled building. Each cage was equipped with a feeder and a nipple waterer for ad libitum access to water. Pigs were randomly allotted to 1 of 3 dietary treatments in a single Latin square design in which pigs were fed all 3 diets in a random order. The corn-based treatments contained 25% fermented soybean meal or 30% camelina meal. A third corn basal diet was fed to allow for calculation of energy concentration by the difference method (Table 2). Titanium oxide was added in all diets at 0.35% as an indigestible marker. There were 3 periods in the experiment, and each period consisted of 8 d. The first 5 d of each period were used to allow pigs to adapt to the dietary treatment followed by 3 d of total fecal collection. On the morning of d 5, a marker (ferric oxide) was added to the first 100 g of the feed allocation, and after the 100 g was consumed, the remainder of the allocation was given. Fecal collection began when the marker first appeared in the feces. On the morning of day 9, a marker was added to the feed again when the pig began its next diet. Collection continued until the marker appeared again in the feces.

On collection days, feces were collected twice daily at the time of feeding. Feces were stored in a freezer (-4°F) until further chemical analyses were conducted. After the collection period for the experiment, feces were thawed and homogenized within each pig and diet. Homogenized collections were dried in a forced-air oven at 140°F and then were weighed, ground, and subsampled for chemical analysis.

Adiabatic bomb calorimetry (Parr Instruments, Moline, IL) was used to determine the GE energy content in the diets, fermented soybean meal, camelina meal, and fecal samples. The concentration of titanium oxide in the diets and fecal samples was determined and used to calculate digestibility.

The DE values of both the fermented soybean meal and camelina meal diets were calculated using the same equation for AID to determine the total tract digestibility (ATTD) of energy. This value was then multiplied by the analyzed concentration of GE in the diets to obtain the total amount of DE in the diet. The ME and NE were determined using the following equations:

$$ME = 1 \times DE - 0.68 \times CP$$ ($R^2 = 0.99$; Noblet and Perez, 1993[4])

$$NE = (0.87 \times ME) - 442$$ ($R^2 = 0.94$; Noblet et al., 1994[5])

Results and Discussion

Nutrient analysis

The nutrient compositions of experimental diets containing fermented soybean meal and camelina meal for Exp. 1 are reported in Table 3, and the analyzed nutrient composition of the fermented soybean meal and camelina meal is reported in Table 4. The CP content of fermented soybean meal was 47.5%, which was considerably lower than the

[4] Noblet, J., and J.M. Perez. 1993. Prediction of digestibility of nutrients and energy values of pig diets from chemical analysis. J. Anim. Sci. 71:3389–3398.

[5] Noblet, J., H. Fortune, X.S. Shi, and S. Dubois. 1994. Prediction of net energy value of feeds for growing pigs. J. Anim. Sci. 72:344–354

NRC (2012[6]) published value of 58.2% CP when converted on a DM basis. As a result, the amounts of most amino acids in fermented soybean meal were lower than those reported for other fermented soybean meal sources, especially for lysine. The crude fat content of fermented soybean meal was 1.8%, which is less than the value reported in NRC (2012) of 2.5% crude fat when converted to a DM basis. This result suggests variation in the fermentation process among plants manufacturing fermented soybean meal.

The CP content of camelina meal in the present study was 35.3% (DM basis), which is similar to the as-fed value of 35.15% reported by NRC (2012); unfortunately, no DM content was listed for camelina meal in this publication. The amino acid profile provided in the NRC (2012) for camelina meal was similar to the values in the current study.

Experiment 1
For fermented soybean meal, the AID for lysine, methionine, threonine, and tryptophan were 63.5, 84.6, 74.0, and 81.8%, respectively (Table 5). After AID values were corrected for basal ileal endogenous losses, SID values for lysine, methionine, threonine, and tryptophan were calculated to be 71.1, 89.2, 88.0, and 89.9%, respectively. The fermented soybean meal source used in this study had lower SID for lysine, similar SID for methionine, and higher SID for threonine and tryptophan than reported by the NRC (2012).

For camelina meal, the AID for lysine, methionine, threonine, and tryptophan were 47.3, 74.6, 39.7, and 67.3%, respectively (Table 5). To the best of our knowledge, no other published research determines the digestibility of amino acids in camelina meal for swine.

Experiment 2
The GE and calculated DE, ME, and NE for fermented soybean meal were 1,973, 1,377, 1,232, and 880 kcal/lb of DM, respectively (Table 6). The NRC (2012) values reported for fermented soybean meal are 2,214, 1,941, and 1,762 kcal/lb for GE, DE, and ME, respectively, when converted to a DM basis. The reason for the difference in energy content is not fully known but could be partially explained by the lower crude fat in the products we tested compared with those represented by the NRC.

The GE and calculated DE, ME, and NE for camelina meal were 2,075, 1,150, 1,041, and 715 kcal/lb of DM, respectively; GE reported in the NRC (2012) was 2,237 kcal/lb on an as-fed basis. Again, DM was not reported in the NRC (2012) for camelina meal; however, the GE observed in the current study converted to an as-fed basis was 1,895 kcal/lb, which is considerably lower than that reported by the NRC (2012). The oil content of the source listed in the NRC (2012) was 18.5%, however, whereas the source in the current study was only 11.9% (as-fed). This difference is likely responsible for the large difference in energy content between the two sources.

In conclusion, fermented soybean meal is a plant protein source with a nutrient profile and associated digestibility coefficients that allow it to be considered a meaningful

[6] NRC. 2012. Nutrient Requirements of Swine. 11th rev. ed. Natl. Acad. Press, Washington, DC.

ingredient for inclusion in nursery pigs diets. Camelina meal, however, had poorer SID amino acid availability and lower nutrient concentrations, making it a less attractive ingredient for swine diets. Comparing the results we obtained with those published in the NRC (2012) for similar products shows considerable variation that could originate from differences in processing conditions, specific variety of the source grain, weather, growing conditions, etc. The ultimate value of these plant-derived protein ingredients will depend on their impact on growth performance of pigs and the resulting impacts on economic indicators such as income over feed cost.

Table 1. Diet composition, Exp. 1 (as-fed basis)[1]

Ingredient, %	Fermented soybean meal	Camelina meal	N-free
Corn starch	53.77	44.79	68.89
Fermented soybean meal	30.00	-	-
Camelina meal	-	39.25	-
Soybean oil	3.00	3.00	3.00
Monocalcium phosphate, 21% P	1.20	1.00	1.50
Limestone	0.63	0.79	0.86
Salt	0.40	0.40	0.40
Vitamin premix	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
Sow add pack	0.25	0.25	0.25
Potassium chloride	-	-	0.50
Magnesium oxide	-	-	0.10
Titanium oxide	0.35	0.35	0.35
Powdered cellulose[2]	-	-	4.00
Sucrose	10.00	10.00	20.00

[1]A total of 5 pigs (PIC 327 × 1050; initially 60.4 lb BW) were used in a crossover design with 3 periods to provide 5 observations per treatment.

[2]Solka-Floc; International Fiber Corp. (North Tonawanda, NY).

Table 2. Diet composition, Exp. 2 (as-fed basis)[1]

Ingredient, %	Fermented soybean meal	Camelina meal	Corn
Corn	71.40	66.40	96.00
Fermented soybean meal	25.00	-	-
Camelina meal	-	30.00	-
Monocalcium phosphate, 21% P	1.60	1.60	1.80
Limestone	0.85	0.85	1.05
Salt	0.40	0.40	0.40
Vitamin premix	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
Titanium oxide	0.35	0.35	0.35

[1]A total of 6 pigs (PIC 327 × 1050; initially 64.8 lb BW) were used in a crossover design with 3 periods to provide 6 observations per treatment.

Table 3. Analyzed nutrient composition of experimental diets, Exp. 1 (% as-fed basis)

Item	Fermented soybean meal	Camelina meal	N-free
DM	90.29	90.75	91.70
CP	11.31	13.36	0.33
Indispensable amino acids			
Arginine	0.70	1.08	0.01
Histidine	0.26	0.28	0.00
Isoleucine	0.49	0.49	0.02
Leucine	0.82	0.83	0.03
Lysine	0.52	0.61	0.01
Methionine	0.14	0.22	0.00
Phenylalanine	0.55	0.55	0.02
Threonine	0.41	0.51	0.01
Tryptophan	0.13	0.12	<0.04
Valine	0.56	0.70	0.02
Dispensable amino acids			
Alanine	0.49	0.62	0.02
Aspartic acid	1.17	1.04	0.02
Cysteine	0.14	0.28	0.00
Glutamic acid	1.84	2.13	0.03
Serine	0.46	0.53	0.01
Tyrosine	0.36	0.36	0.00

Table 4. Analyzed DM content and nutrient composition of fermented soybean meal and camelina meal (%, DM basis)[1]

Item	Fermented soybean meal	Camelina meal
CP	47.5	35.3
Crude fat	1.8	13.0
ADF	6.5	26.6
NDF	13.6	48.8
Ca	0.50	0.57
P	0.93	0.95
Ash	7.13	6.33
Indispensable amino acid		
Arginine	2.89	2.78
Histidine	1.07	0.72
Isoleucine	1.98	1.16
Leucine	3.30	2.07
Lysine	2.20	1.55
Methionine	0.59	0.63
Phenylalanine	2.21	1.35
Threonine	1.63	1.31
Tryptophan	0.56	0.32
Valine	2.14	1.70
Dispensable amino acid		
Alanine	1.91	1.54
Aspartic acid	4.71	2.62
Cysteine	0.57	0.72
Glutamic acid	7.06	5.13
Serine	1.76	1.36
Tyrosine	1.56	0.92

[1] The as-received DM of the fermented soybean meal was 89.43%, and the camelina meal was 91.34%.

Table 5. Apparent (AID) and standardized ileal digestibility (SID) coefficients (%) of fermented soybean meal and camelina meal, Exp. 1[1]

	AID, %		SID, %[2]	
Amino acid, %	Fermented soybean meal	Camelina meal	Fermented soybean meal	Camelina meal
Indispensable				
Arginine	81.6(7.6)	77.4 (5.8)	93.4 (4.6)	84.5 (3.4)
Histidine	80.3(1.6)	67.2 (4.8)	88.2 (2.7)	74.7 (3.2)
Isoleucine	82.4(1.3)	60.8 (4.1)	89.1 (2.1)	67.5 (3.5)
Leucine	83.0(0.8)	65.6 (4.4)	89.9 (1.5)	72.7 (3.8)
Lysine	63.5(7.5)	47.3 (7.7)	71.1 (6.2)	53.9 (6.4)
Methionine	84.6(1.0)	74.6 (3.3)	89.2 (2.1)	77.7 (3.5)
Phenylalanine	84.3(0.3)	64.6 (4.2)	90.4 (2.0)	70.9 (3.5)
Threonine	74.0(3.5)	39.7 (6.8)	88.0 (3.1)	51.6 (6.7)
Tryptophan	81.8(1.4)	67.3 (8.3)	93.7 (2.0)	79.7 (6.8)
Valine	82.1(2.0)	63.3 (4.1)	89.9 (2.2)	69.6 (4.4)
Dispensable				
Alanine	73.8(4.7)	52.2 (6.4)	86.8 (4.0)	62.2 (3.7)
Aspartic acid	77.4(3.4)	56.9 (4.6)	84.4 (3.6)	64.9 (4.1)
Cysteine	67.7(3.9)	51.3 (5.3)	80.6 (3.4)	58.0 (4.8)
Glutamic acid	82.6(1.4)	73.3 (3.5)	87.8 (1.6)	77.8 (3.0)
Serine	77.4(3.2)	44.7 (7.0)	89.2 (2.8)	55.1 (6.1)
Tyrosine	79.7(2.5)	52.2 (4.6)	86.6 (1.1)	59.1 (3.7)

[1]Values are the mean of 5 observations per treatment. Standard deviation for each digestibility value is shown in parentheses.
[2]The SID represents the corrected AID for basal endogenous loss of an amino acid. Calculated basal endogenous losses after feeding the N-free diet were (g/kg of DMI) arginine, 0.08; histidine, 0.02; isoleucine, 0.04; leucine, 0.06; lysine, 0.04; methionine, 0.01; phenylalanine, 0.04; threonine, 0.07; tryptophan, 0.02; valine, 0.05; alanine, 0.07; aspartic acid, 0.09, cysteine, 0.02; glutamic acid, 0.11; serine, 0.06; tyrosine, 0.03.

Table 6. Energy values (DM basis) of fermented soybean meal and camelina meal[1]

Ingredient, kcal/lb	Fermented soybean meal	Camelina meal
GE	1,973	2,075
DE[2]	1,377 (90)	1,150 (181)
ME[3]	1,232 (90)	1,041 (181)
NE[4]	880 (78)	715 (158)

[1] A total of 6 pigs (PIC 327 × 1050; initially 27.4 kg BW) were used in a crossover design with 3 periods to provide 6 observations per treatment.
[2] The DE values were determined using the difference procedure (Adeola, 2001).
[3] ME was calculated using the equation: ME = 1 × DE – 0.68 × CP (R^2 = 0.99; Noblet and Perez, 1993).
[4] NE was calculated by using the equation: NE = (0.87 × ME) - 442 (R^2 = 0.94; Noblet et al., 1994).