Nutritive Value of Protein in Hominy Feed Fractions[1]

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ABSTRACT

To ascertain if hominy feed is processed for optimal use as a feed ingredient, compositional analyses and nutritional evaluations were conducted on it and on components produced under different conditions. Hominy feed constitutes 27 to 35% of total dry-milled corn products and consists mainly of bran and bran meal, oil cake, and fine feed composed of degerminator fines and tailing meal. The level of protein in hominy feed (12%) exceeds that of corn (9%). Amino acid analyses conducted on hominy-feed fractions indicate that they contain higher levels of lysine, tryptophan, and other essential amino acids than whole corn or corn grits. However, processing conditions influence the actual nutritional value of protein in hominy-feed fractions. The nutritionally available lysine determined by reaction with 2,4-dinitrofluorobenzene is less than the total lysine of hominy feeds. Rat feeding studies showed differences in protein quality between corn germ processed by expeller to remove oil and germ extracted by solvent. Properly processed hominy feed can serve as a good protein source in nonruminant diets.

Although the corn dry-miller has directed his process toward optimum yields of prime goods (grits, meal, flour, and oil), from 27 to 35% of the corn after dry milling goes into hominy feed. Hominy feed is derived mostly from degerminator fines and tailing meal (fine feed), deoiled germ cake, bran and bran meal, broken grain, and other materials removed during cleaning (screenings). The variation in yield and product depends on grain quality and the nature of the milling operation. Almost all the 1.2 million tons of hominy feed produced annually is marketed as animal rations. Some processed germ is used in pet foods and as a protein-and-oil supplement for blended foods prepared for overseas donation programs. To find increased outlets for hominy feed and its components, additional information is needed on their composition and preparation.

A large portion of hominy-feed production is incorporated into mixed feeds for dairy cows or beef cattle. While the fiber content of the feed may be more beneficially utilized by these animals, the quality of hominy-feed protein is not critical in their diets. In contrast, such nonruminants as swine and poultry require higher levels of protein and a good balance of essential amino acids in their rations. Protein sources are important cost factors in feeding nonruminants. Therefore, the quality of protein in hominy-feed constituents was investigated as one means of expanding its use. Accurate amino acid analyses of hominy-feed constituents were obtained as a basis for least-cost feed formulations and development of new products from separate hominy-feed components.

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The processing of hominy-feed components may influence their nutritional value. Heating milling fractions to reduce their moisture level to acceptable values may impair protein quality. Expeller processing to remove oil subjects germ, and in some operations fine feed also, to extremely elevated temperatures. The intense heat may reduce digestibility and nutritional availability of certain amino acids in proteins of the processed materials. A newer alternative procedure of oil recovery by solvent extraction presents an economical means of attaining better oil yields with less-rigorous treatment of the germ. The protein quality of products prepared by both methods of oil removal was compared by evaluating their amino acid composition, available lysine, and growth promotion when incorporated into rat diets.

MATERIALS AND METHODS

Corn grains used in these studies were hybrid dent varieties from commercial sources. Hominy-feed ingredients were taken directly from mill and processing streams from Illinois Cereal Mills, Paris, Ill., and Lauhoff Grain Co., Danville, Ill. Materials used for comparing hominy-feed products produced by expeller and solvent extraction oil removal methods came from the Lauhoff Grain Co., Crete, Mo., and Danville, Ill., plants, respectively. In these hominy feeds, fine feed was subject to expeller processing or solvent extraction. Grits were also obtained from the Illinois Cereal Mills plant.

Samples of bran, fine feed, and germ were air-dried at room temperature and also dried under commercial conditions. The commercial dryers used air temperatures at approximately 160°F. Before solvent extraction in the laboratory, the dried germ was flaked by a single pass through a roller mill equipped with smooth rolls. The flaked germ was then covered with commercial hexane in a batch extractor for 3 hr. for oil extraction with the solvent. This process was repeated several times until the oil level was reduced to about 1%.

All proximate analyses were done by standard AOAC (1) procedures.

Amino acid analyses were carried out on hydrolysates obtained by refluxing 50-mg. samples in constantly boiling hydrochloric acid for 24 hr. under a nitrogen atmosphere. The amino acid contents of aliquots of these hydrolysates were quantitatively determined with a Phoenix automatic amino acid analyzer, Model K-8000, by the Benson and Patterson (2) accelerated procedure. Amino acid concentrations were calculated according to a computer technique described by Cavins and Friedman (3). Results are averages of at least duplicate analyses.

Tryptophan was determined by the method of Mertz[2] in which protein in corn and corn dry-milling fractions was first digested by a protease. Finely ground, defatted sample (50 to 200 mg.) was mixed with 10 ml., pH 7.4, 0.03M phosphate buffer containing 2 mg. Pronase and a few drops of chloroform. After being shaken at 37°C. for 24 hr., the mixture was centrifuged. A 1-ml. sample of the supernatant was then analyzed for tryptophan by the colorimetric method of Opieńska-Blauth et al. (4). Corrections of absorbance were made for sample and enzyme blanks.

Available lysine was determined by reacting the meal with 1-fluoro,2,4-dinitrobenzene by the method of Rao et al. (5). After extraction to

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[2] Mertz, E. T. Personal communication, Purdue University (1969).

remove excess reagent, the sample was hydrolyzed in 6N HCl and the ε-2,4-dinitrobenzyl lysine was separated by chromatography and determined colorimetrically as described by Rao et al. (5).

Protein efficiency ratios (PER) were determined at the Wisconsin Alumni Research Foundation, Madison, Wis., according to the standard AOAC (1) method. Samples were ground to −20 mesh. For each material tested, ten weanling rats were fed for 28 days a diet reduced to 10% protein and adjusted to similar proximate analyses by additions of cottonseed oil, cellulose, salt mixtures, starch, and 1% of a standard vitamin mixture. The reference protein standard against which rat growth was compared was Animal Nutrition Research Council (ANRC) casein. To permit comparison with whole-fat germ, PERs were determined on casein and expeller-germ cake diets with comparable fat levels.

RESULTS

Proximate Analyses

The proximate analyses of various components that contribute to hominy feed are compared in Table I with the composition of corn. Since mill streams contributing to various components of hominy feed are combined differently by different manufacturers, analyses were conducted on products from three processing plants. These products were found to vary, as seen from Table I.

TABLE I. YIELDS AND PROXIMATE ANALYSES OF CORN AND HOMINY-FEED COMPONENTS

Fraction	Estimated Average Annual Yield % of Grain	Moisture %	Dry Basis				
			Protein (N X 6.25) %	Fat (Ether extract) %	Fiber %	Ash %	N-Free extract %
Yellow dent corn	100	11.3	9.7	5.1	2.4	1.2	81.2
Germ, air-dried[a]	11.8	6.6	13.9	20.5	4.5	8.9	52.2
Germ, air-dried[b]		12.2	17.1	25.5	4.5	6.7	47.2
Germ, air-dried, solvent-extracted		8.2	23.0	0.6	4.6	9.2	62.6
Germ, heat-dried, solvent-extracted	9.8	4.2	23.0	1.3	4.4	9.1	62.2
Germ, heat-dried, expeller-processed	10.2	6.8	21.4	6.7	5.8	9.0	57.1
Bran and bran meal[a]	9.0	6.7	8.5	5.1	7.5	1.4	77.5
Bran[b] (coarse)		7.6	7.1	1.9	11.3	1.0	78.7
Bran meal[b] (fine)		8.0	8.9	3.1	6.3	1.0	80.7
Degerminator fines[b]		7.2	10.8	4.1	1.3	3.0	80.8
Tailing meal[b]		7.8	14.2	8.6	2.1	3.0	27.9
Fine feed[a,c]	10.7	8.1	11.9	7.3	2.8	2.1	76.0
Screenings[b]	4.7	8.0	10.5	4.0	7.6	2.4	72.3
Hominy feed[a], solvent-extracted	32.1	10.1	12.9	2.3	5.9	3.0	75.9
Hominy feed[d], expeller-processed	33.2	9.5	12.7	6.6	6.0	3.0	71.7

[a] Milling plant A.

[b] Milling plant B.

[c] Tailing meal and degerminator fines.

[d] Milling plant C.

Products prepared by solvent extraction both in the laboratory and commercially were also compared with materials produced by commercial expellers.

The most significant difference is the lower fat content of the germ cake after solvent extraction in contrast to expeller processing. The initial germ contains from 20.5 to 25.5% fat; the fat content is reduced to 5.0 to 6.5% by the expeller process, but is decreased to 1% or less by solvent extraction. The efficiency of solvent extraction has encouraged removal of oil by this process from fine feed, which consists primarily of determinator fines. In plants using the expeller process, oil is generally not removed from the fine feed, although in a hominy-feed sample studied in this investigation, the oil was expelled from the fine feed. The difference in oil content of the resultant hominy feed is important to cattle feeders and other feed consumers because of the somewhat-reduced net available energy of the solvent-extracted product.

The hominy feeds tested were significantly higher in protein than corn grain. Of several samples analyzed, all exceeded 11% protein and most were above 12% protein (dry basis) in contrast to corn, which generally runs 9.0% protein (Table I). This high level of protein in hominy feed is an asset that has not been previously stressed. While the bran and fine-feed fractions have higher levels of protein than whole grain, the germ is a major factor in elevating protein content. The germ reduced in oil ranged from 16 to 23% protein on the products tested. The guaranteed analysis of commercial hominy feed is only 10% protein on an as-is basis because of its variability.

Hominy feed also contains a higher level of other nutrients than does whole corn. The mineral content is especially high in germ and bran fractions as evidenced by their ash analyses (Table I).

The major drawback associated with hominy feed is its higher fiber content over corn (Table I). Of course, bran is the major source of fiber, having about 8%. Fiber content of deoiled germ ranges from 4.5 to 6.2% for materials from the two sources tested. When the miller produces a purer germ fraction, its levels of oil and protein are higher and its fiber content is less, but the germ fraction then becomes a smaller portion of the total product. The higher fiber content of hominy feed over that in corn results in a slightly lower value for total digestible energy.

Amino Acid Composition

In initial studies, samples of all mill streams contributing to hominy feed were subjected to amino acid analyses to establish which fractions were contributing the best levels of essential amino acids to the hominy feed mixture. Table II compares the amino acid analyses of whole-corn grain, corn grits, and hominy-feed ingredients. Amino acid analyses are presented as percentages of protein so that proteins in the different materials may be directly compared. The most limiting amino acids in corn grain based on requirements for poultry (6), swine (7), and humans (8) (summarized in Table III) are lysine, tryptophan, and threonine. Whole-corn grain contains appreciably more of these amino acids than do grits, which are representative of endosperm fractions. Further examination of Table II makes it evident that hominy-feed constituents are responsible for the higher content of these limiting amino acids in the whole kernel than in the endosperm. The highest concentrations of lysine and tryptophan are contained in the germ.

TABLE II. AMINO ACID ANALYSIS OF CORN MILLING FRACTIONS[a]

	Sample							
	Corn	Grits	Hominy feed	Bran meal	Bran	Tailing meal	Degerminator fines	Germ cake
% Protein	9.0	10.7	11.6	8.7	7.1	14.0	10.9	21.4
Amino Acid	% of Protein (g./16 g. N)							
Lysine	3.0	1.6	4.4	4.7	4.6	4.4	4.1	5.3
Histidine	2.9	2.8	3.5	2.8	2.8	2.7	2.8	2.9
Ammonia	2.3	2.7	2.3	2.0	2.0	1.7	1.8	1.5
Arginine	5.4	3.3	5.7	5.5	5.5	5.8	5.5	7.2
Aspartic	8.1	5.8	8.7	8.7	8.7	8.1	7.7	9.6
Threonine	4.3	3.6	4.6	4.6	4.6	3.9	3.9	4.5
Serine	5.1	5.1	5.3	4.7	4.7	4.5	4.5	4.7
Glutamic	22.4	22.1	20.3	17.5	17.5	18.0	18.8	16.7
Proline	14.9	11.1	12.6	11.1	11.1	10.5	11.1	8.9
Glycine	4.6	2.9	5.7	5.4	5.4	5.0	4.6	7.0
Alanine	7.9	8.1	7.7	7.0	7.0	6.9	7.0	7.2
1/2 Cystine	1.2	1.0	0.9	0.7	0.7	1.3	1.3	1.0
Valine	5.6	4.5	5.6	5.7	5.7	5.2	5.0	6.1
Methionine	2.6	2.5	2.0	1.9	1.8	2.0	1.9	2.1
Isoleucine	3.6	3.5	3.6	3.5	3.5	3.3	3.3	3.5
Leucine	13.3	15.2	11.5	10.6	10.6	10.2	11.1	8.3
Tyrosine	3.9	4.7	3.2	3.5	3.5	3.4	3.7	3.2
Phenylalanine	4.1	5.4	3.8	4.2	4.2	4.0	4.0	4.0
Tryptophan	0.7	0.4	1.6	1.5	1.5	0.9	1.6	2.0

[a] All products from milling plant A.

These levels exceed the minimum requirements for these amino acids in nonruminant rations. The amounts of lysine, tryptophan, and threonine in other hominy-feed ingredients exceed or approach the requirements for nonruminants. Corn contains more cystine, methionine, and phenylalanine than does hominy feed. The concentration of cystine and methionine is higher in hominy-feed protein than in that of soybean meal, the major protein source in the Corn Belt (9). In view of the amino acid analysis of hominy feed, it can, to a limited extent, undoubtedly replace protein supplements, such as soybean meal, which serve to elevate protein levels and to provide essential amino acid concentrations suitable for nonruminant diets.

Certain amino acids such as lysine, when heated in the presence of sugars, undergo chemical modification and degradation. Therefore, a comparison was made between amino acid analyses of germ heated or air-dried and extracted by either solvent or expeller process and hominy-feed preparations subjected to different treatments during processing to remove oil (Table IV). Only a small decrease (7%) in lysine resulted from heating germ; no significant changes in other amino acids were detected. Expeller processing of germ further decreased 16% its lysine content. Arginine also exhibited significant reductions in expeller-processed germ in contrast to its content in the initial air-dried solvent-extracted sample. As shown in Table IV, total lysine in hominy feed processed by expeller is slightly less than in a product prepared by solvent extraction. But this difference may not be significant since other amino acids in the two samples also vary, probably because these hominy-feed products were prepared in different plants. Changes in color and odor indicate that browning reactions occur in germ and other hominy-feed products

TABLE III. ESSENTIAL AMINO ACID REQUIREMENTS
(% of Protein, g./16 g. N)

Amino Acid	Poultry (Broilers and Starters) (6)	Swine 20–35 kg. (7)	Humans (8)
Lysine	5.0	4.3	4.2
Tryptophan	1.0	0.8	1.4
Methionine	3.7	3.8	2.4
Phenylalanine	6.5	3.1	2.8
Threonine	3.5	2.8	2.8
Valine	4.0	3.1	4.2
Isoleucine	3.0	3.1	4.2
Leucine	7.0	3.7	4.8
Arginine	6.0	1.2	...
Histidine	1.5	1.1	...
Glycine	5.0	...	...

when they are subjected to extensive heating during drying or expeller processing.

Nutritional Evaluation of Hominy-Feed Protein

Since amino acid analysis revealed that drastic heating during drying and oil removal might reduce the quality of the protein by diminishing some of the amino acids, other studies were undertaken to evaluate nutritional changes caused by elevated temperatures.

The results of the available lysine analyses are compared with total lysine analyses of germ and hominy feed subjected to either solvent extraction or expeller processing (Table V). In general, available lysine estimated by the chemical procedure was lower than total lysine values obtained by direct chromatographic

TABLE IV. EFFECT OF OIL-REMOVAL PROCESS ON AMINO ACID COMPOSITION OF HOMINY-FEED INGREDIENTS
(% of Protein, g./16 g. N)

	Oil Removal Process				
	Solvent			Expeller	
	Fraction				
	Germ		Hominy		Hominy
Amino Acid	Air-dried	Heat-dried	feed	Germ	feed
Lysine	6.3	5.9	4.5	5.2	4.2
Histidine	3.3	3.0	3.2	3.6	3.3
Ammonia	1.8	2.0	3.0	2.3	3.3
Arginine	9.2	9.0	6.7	7.8	6.2
Aspartic	8.8	8.5	7.2	8.2	6.6
Threonine	4.0	3.8	3.5	3.8	3.4
Serine	4.7	4.7	4.3	4.6	4.2
Glutamic	14.0	14.3	20.6	15.0	21.9
Proline	5.9	5.8	5.6	6.0	6.0
Glycine	6.0	5.9	4.7	6.0	4.5
Alanine	6.5	6.6	6.2	6.9	6.3
1/2 Cystine	1.6	1.6	1.1	1.6	1.0
Valine	5.3	5.2	4.8	5.2	5.0
Methionine	2.1	2.0	2.0	2.0	2.0
Isoleucine	3.2	3.2	3.2	3.3	3.3
Leucine	7.1	7.2	8.3	7.8	8.2
Tyrosine	3.7	3.3	3.4	3.5	3.0
Phenylalanine	4.0	3.9	3.7	4.0	3.5
Tryptophan	2.0	2.0	1.5	2.0	1.6

TABLE V. EFFECT OF PROCESSING CORN DRY-MILL PRODUCTS ON AVAILABLE LYSINE

Product	Oil Removal Process	% of Protein: Total Lysine	% of Protein: Available Lysine
Corn germ			
Air-dried[a]	Solvent	6.3	5.4
Heated[a]	Solvent	5.9	4.9
Corn germ press cake[a]	Expeller	5.3	3.5
Hominy feed[b]	Expeller	4.4	3.3
Hominy feed[c]	Solvent	4.4	3.8
Fine feed[b]	None	4.2	3.5
Bran and bran meal[b]	None	4.7	3.4
Corn	None	3.0	2.7

[a] Products from milling plant A.

[b] Products from milling plant B.

[c] Products from milling plant C.

analysis of acid hydrolysates. Expeller-processed germ exhibited considerably less available lysine than solvent-extracted germ. The value of available lysine in the commercially solvent-extracted hominy feed was only slightly greater than that in the expeller-processed product.

When fine feed and combined bran and bran meal fractions were analyzed for available lysine, these gave low values relative to their total lysine content (Table V). Protein in bran and fine-feed fractions may not be effectively dispersed to permit reaction with 2,4-dinitrofluorobenzene. Such tissues as pericarp and aleurone, which have heavy cell-walls, contribute appreciably to these fractions and may be the reason for poor protein extractability. Since bran and fine feed contribute about half the protein of hominy feed, their low level of available lysine may be an important factor in the low available-lysine analysis of hominy feeds.

To further establish whether processing method affects the quality of protein in hominy feeds, rat feeding studies were conducted. The diets used are given in Table VI. PERs were determined for materials processed either by solvent extraction or expeller operation. The corrected PER is the relative gain of rats in g. per g. protein fed compared with casein with a standard PER of 2.5. The results of the experiments are summarized in Table VII. The nutritional quality of heat-dried, but not extracted, corn-germ protein was high, with a PER equal to 2.19. However, the PER was reduced to 1.54 after expeller removal of oil from the germ. Solvent-extracted hominy feed had a PER of 1.74 compared to 1.42 for expeller-processed material. During oil removal, heating components of hominy feed by the expeller reduces the PER of hominy-feed components appreciably more than does solvent extraction.

Heating of germ during drying also reduces the protein quality, as shown by the PER data for air-dried and heat-dried solvent-extracted germ in Table VII. Solvent-extracted heat-dried germ had a slightly lower PER value than unextracted germ.

The PERs obtained for air-dried bran and fine feed and for solvent-extracted germ, when compared with the PER for solvent-extracted hominy feed, indicate that commercial conditions of processing may diminish protein nutritional value in

TABLE VI. DIET COMPOSITION OF PER STUDIES

Protein Source	Sample %	Cottonseed Oil %	U.S.P. Salts XIV %	Nonnutritive Cellulose[a] %	Water %	Vitamins[b] %	Corn Starch %
			Experiment 1				
Corn-germ meal	64.51	0	0.88	0	1.13	1.00	32.48
Expeller germ meal	49.75	12.93	0.83	0	1.62	1.00	33.87
ANRC[c] casein	10.89	16.01	4.87	2.70	4.47	1.00	60.06
Solvent-extracted hominy feed	86.20	6.19	2.68	0.21	0	1.00	3.72
Expeller hominy feed	86.95	3.22	2.66	0	0.44	1.00	5.73
ANRC casein	10.89	7.95	4.87	2.21	4.91	1.00	68.17
			Experiment 2				
Corn germ, air-dried	35.08	4.38	0.67	5.09	6.29	1.00	47.49
Corn germ, oven-dried	33.64	4.47	0.69	5.15	7.43	1.00	47.62
Bran	93.78	0.05	2.39		2.78	1.00	
Fine feed	67.89		2.33	4.80	3.66	1.00	20.32
Corn	86.11	0.68	2.66	4.76		1.00	4.79
ANRC casein	7.95	4.46	3.49	6.56	8.91	1.00	67.63

[a] Alphacel, Nutritional Biochemical Co., Cleveland, Ohio.

[b] AOAC vitamin mix, General Biochemical Co., Chagrin Falls, Ohio.

[c] ANRC, Animal Nutrition Research Council.

hominy feed. All PERs of the hominy-feed constituents exceed that of whole corn, determined as 1.26.

DISCUSSION

Although the quality and quantity of the protein in hominy-feed components have been recognized for many years, little emphasis has been placed on this protein as an important asset of hominy feed in nonruminant diets. In 1944, Mitchell and Beadles (10) showed that corn germ extracted at low temperature to remove oil exhibited high digestibility and biological value when fed to rats. They suggested that corn germ be reserved for food uses. Block and Bolling (11), using colorimetric assay methods, obtained evidence for the excellent balance of essential amino acids in corn germ. Until our studies were conducted, however, precise information on amino acid composition of representative germ and other hominy-feed components was not available for feed-composition calculations.

Kohler et al. (12) attribute reduced utilization of bran protein to the thick cell-walls of the tissue.. Low values for available lysine and PER in bran protein may be due to the poor accessibility of the protein to chemical reagents and digestive enzymes. Fine grinding and pelleting may be required to attain better utilization of bran protein.

The studies reported here establish that protein quality is markedly reduced in hominy feed when the germ and degerminator fines are subjected to expeller processing to remove oil. Protein quality is better retained by solvent extraction. Earlier, Schultz and Thomas (13) found that expeller processing greatly reduces the

TABLE VII. EFFECT OF PROCESSING OF GERM AND HOMINY FEED ON PER

Protein Source	Average of 10 Rats for 4 Weeks: Weight gain g.	Food consumption g.	Observed PER	Corrected PER
	Experiment 1			
ANRC casein[a]	92	307	2.99	2.50
Corn germ, heat-dried[b]	86	327	2.62	2.19
Expeller germ meal cake[b]	49	265	1.84	1.54
ANRC casein[c]	104	337	3.08	2.50
Expeller-processed hominy feed[d]	65	341	1.75	1.42
Solvent-extracted hominy feed[e]	89	413	2.15	1.74
	Experiment 2			
ANRC casein[c]	87	272	3.20	2.50
Germ, heat-dried, solvent-extracted[b]	83	318	2.61	2.04
Germ, air-dried, solvent-extracted[b]	92	314	2.93	2.29
Bran and bran meal, air-dried[e]	59	292	2.02	1.58
Fine feed, air-dried[e]	64	260	2.46	1.92
Corn	31	196	1.58	1.26

[a] High oil diet.

[b] Product from milling plant A.

[c] Low oil diet.

[d] Product from milling plant B.

[e] Product from milling plant C.

nutritional value of corn-germ protein obtained by wet-milling as compared with similar germ subjected to solvent extraction. Where corn germ is considered for human foods, certainly solvent extraction produces a better product in terms of flavor, appearance, and stability as well as nutritional quality, than expeller-processed germ. Antinutritional factors have been reported in cereal-grain germs, such as wheat (14), that require inactivation by mild heat treatment. However, Olsen (15) states that no improvement in feed quality results from heating wheat germ. In our study, no evidence for heat-labile antinutritional factors in the corn-germ samples used was acquired by comparing heat-dried samples with those dried at air temperature.

Components of hominy feed including bran, degerminator fines, and germ are a good source of nutritious protein, as evidenced by proximate analysis and amino acid composition. Rat feeding experiments demonstrate that low nutritional value of protein in some hominy-feed products may result from excessive heating and expeller processing to remove oil. When drying temperatures were kept minimal and solvent extraction replaced expeller processing, excellent nutritional responses were attained with individual hominy-feed constituents. The germ especially served as a good protein source. Further studies will be reported on the economic value of hominy feed relative to whole corn and soya meal as a feed material for nonruminants (16). Such studies will determine the economic benefit of improved processing methods and separate use of hominy-feed components, such as germ and fine-feed fractions, for nonruminant rations.

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