Chemical Composition and Metabolizable Energy Values of Corn Germ Meal Obtained by Wet Milling for Layers

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ABSTRACT

An experiment was carried out to determine the chemical composition, metabolizable energy values, and coefficients of nutrient digestibility of corn germ meal for layers. The chemical composition of corn germ meal was determined, and then a metabolism assay was performed to determine its apparent metabolizable energy (AME) and apparent metabolizable energy corrected for nitrogen (AMEn) values and its dry matter and gross energy apparent metabolizability coefficients (CAMDM and CAMGE, respectively). In the 8-day assay (four days of adaptation and four days of total excreta collection), 60 29-week-old white Lohman LSL layers were used. A completely randomized experimental design, with three treatments with five replicates of four birds each, was applied. Treatments consisted of a reference diet and two test diets, containing 20 or 30% corn germ meal. Results were submitted to analysis of variance and means were compared by the Tukey tests at 5% probability level. The chemical composition of corn germ meal was: 96.39% dry matter, 49.48% ether extract, 1.87% ashes, 7243 kcal gross energy/kg, 11.48% protein, 0.19% methionine, 0.21% cystine, 0.48% lysine, 0.40% threonine, 0.72% arginine, 0.35% isoleucine, 0.83% leucine, 0.57% valine, and 0.37% histidine, on as-fed basis. There were no statistical differences in AME, AMEn, CAMDM, and CAMGE values with the inclusion of 20 and 30% corn germ meal in the diets. On dry matter basis, AME, AMEn, CAMDM, and CAMGE values of corn germ meal were: 4,578 and 4,548 kcal/kg, 4,723 and 4,372 kcal/kg, 64.95 and 61.86%, respectively.

INTRODUCTION

Compared with other animal industry, poultry production presents higher productivity, shorter production cycles, and cheaper protein offer. Research on new technologies has significantly promoted the development of productivity of the poultry industry. In particular, studies on alternative feedstuffs have allowed considerable reduction in production costs. Although most poultry feeds are based on corn and soybeans, regions that do not produce these ingredients have higher production costs, and need to seek alternatives.

Corn germ meal (CGM) is a co-product of corn wet milling and may be used as an alternative feedstuff for poultry. Corn can generate several co-products, and the corn processing industry may add value to corn through wet or dry milling.

In Brazil, it is estimated that there are 10,000 tons of CGM available annually for oil extraction or to be used directly in animal feeds (Abimilho, 2010). Up to 20% defatted corn germ can be added to broiler diets without any damage to performance (Brunelli *et al.*,

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2006). It was observed that the inclusion of up to 50% CGM derived from dry milling did not affect layer performance (Brito *et al.*, 2005).

When obtained by wet milling with no oil extraction, CGM has high ether extract level (EE). Studies carried out by Lima (2007) and Lima *et al.* (2012) show that EE content in CGM ranges between 46 and 60%, providing it with a huge energy potential, with apparent metabolizable energy (AME) values of 2232-4800 kcal/kg. It should be mentioned, however, that not only EE content affects the potential of energy utilization, but also animal class and bird age. Therefore, CGM may potentially replace oil in feeds, increasing their energy density. In addition, the use of feedstuffs rich in fatty acids has the beneficial effect of reducing feed passage rate through the gastrointestinal tract (Andreotti *et al.*, 2004), which increases the digestibility of feedstuffs, increasing their metabolizability coefficients. Another important advantage of the use of oil-rich ingredients in the diet is the improvement of pellet quality, particularly due to mass aggregation (Penz Jr. & Vieira, 1992).

Considering that there are few studies on corn germ meal obtained by wet milling, and that most of studies were carried out with defatted CGM, the objective of the present study was to determine the chemical composition and metabolizable energy values of full-fat corn germ meal obtained by wet milling for layers.

MATERIALS AND METHODS

Location and chemical analyses

The experiment was carried out in the experiment layer house of the Laboratory of Poultry Research (Laboratório de Pesquisa com Aves, LAPAVE) of the Department of Animal Science of Universidade Federal Rural de Pernambuco, Brazil.

The evaluated CGM was obtained from the company Corn Products do Brasil, located in Cabo de Santo Agostinho, state of Pernambuco, Brazil. A representative sample was collected and submitted to the laboratory of nutrition of the Department of Animal Science for analyses. The following analyses were performed: dry matter, crude protein, EE, and ashes, using the methods described by Silva & Queiroz (2006). Amino acid profile was determined by the company Evonik and gross energy content was analyzed in a calorimetric bomb by Universidade Federal de Viçosa.

Birds and Experimental procedure

A metabolism assay was carried out with commercial layers according to the methodology described by Hill & Anderson (1958). Sixty 26-week-old Lohman LSL layers were distributed according to a completely randomized experimental design, with three treatments with five replicates of four birds each. Treatments consisted of a reference diet, a mixture of 80% of the reference diet + 20% CGM (CGM20%), and a mixture of 70% of the reference diet + 30% CGM. The reference diet was formulated according to the recommendations of the Brazilian Tables for Poultry and Swine of Rostagno *et al.* (2005), as shown in Table 1.

Table 1 – Ingredients and nutritional and energy compositions of the reference diet.

Ingredients	%
Corn	60.047
Soybean meal	26.414
Calcitic limestone	9.837
Dicalcium phosphate	1.375
Salt	0.334
Soybean oil	1.573
Mineral, vitamin, and amino acid supplement[1]	0.400
DL-Methionine 99	0.020
Total	100.000
Nutritional and energy composition[2]	
Apparent metab. energy, kcal/kg	2.700
Crude protein, %	17.00
Calcium, %	4.200
Available phosphorus %	0.350
Digestible methionine + cystine, %	0.610
Digestible methionine %	0.368
Digestible lysine %	0.800
Potassium, %	0.665
Sodium, %	0.150

[1]Mineral, vitamin, and amino acid supplement for layers (composition/kg product): Vit. A: 2,000,000 IU, Vit. D3: 575,000 IU, Vit. E:3,750 mg, folic acid: 125 mg, calcium pantothenate: 1,750 mg, biotin: 3.75 mg, niacin: 5.000 mg, pyridoxine: 425mg, riboflavin: 750 mg, thiamine: 50mg, Vit. K3: 250 mg, Vit.B12: 2.500 mcg, choline: 52.19g, selenium: 62.5 mg, iron: 7,500mg, copper: 19,750 mg, manganese: 15,000 mg, zinc: 15,000mg, iodine: 250 mg, methionine: 247.5g, colistin: 2,000 mg. [2]Values calculated according to the Tables of Rostagno *et al.* (2005).

Birds were housed in galvanized iron-mesh cages (50 x 50 x 45 cm), with capacity of four birds per cage. Trays lined with black plastic canvas were placed under the cages for excreta collection. The eight-day experimental period was divided in four days of adaptation to the diets and four days of excreta collection.

Powdered ferric oxide at 1% was added to the diets as fecal marker to determine the beginning and end of

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the collection period. Water and feed were offered *ad libitum*. A lighting program of 17 hours of natural and artificial light was adopted.

Excreta were collected twice daily, at 08:00 and 16:00. Excreta were placed in plastic bags, duly identified, weighed, and stored in a freezer at -20°C until the end of the experiment to prevent fermentation. At the end of the experiment, excreta were thawed and homogenized per experimental unit. Aliquots of approximately 400g were removed per unit, pre-dried, ground in a knife mill, and submitted to the Laboratory for analyses.

Analytical procedures and evaluated parameters

Feed and excreta were submitted to the Animal Nutrition Laboratory of the Department of Animal Science of Universidade Federal Rural de Pernambuco to determine dry matter, crude protein, and ether extract contents, according to the previously mentioned methods.

Apparent metabolizable energy (AME) and apparent metabolizable energy corrected for nitrogen balance (AMEn) of the experimental diets and CGM were determined according to the equations proposed by Matterson *et al.* (1965). The coefficients of apparent metabolizability of dry matter (CAMDM), gross energy (CAMGE), and ether extract (CAMEE) were determined according to the following equations: CAMGE = (AMEn/GE) x 100, CAMDM = feed intake – [(excreta)/feed intake)] x 100, on dry matter basis.

Statistical Analysis

Results were submitted to analysis of variance and means were compared by the test of Tukey at 5% probability level, using SAS package (SAS, 2004).

RESULTS

Humidity value of CGM was low (3.61%). Crude protein, ether extract, and ash average values of CGM were 11.48, 49.48, and 1.87%, respectively (Table 2).

Mean amino acid values of CGM were 0.19% methionine, 0.21% cystine, 0.40% methionine+cystine, 0.48% lysine, 0.40% threonine, 0.72% arginine, 0.35% isoleucine, 0.83% leucine, 0.57% valine, 0.37% histidine, 0.45% phenylalanine.

The results showed that the dietary inclusion of CGM changed the chemical composition of the reference diet, increasing dry matter, ether extract, and gross energy contents, and reducing crude protein and ash contents (Table 3).

Table 2 – Dry matter, crude protein, ether extract, gross energy, ash, and amino acid values of full-fat corn germ meal.

Chemical composition		Amino acid composition, %	
Humidity	3.61	Methionine	0.19
Dry matter, %	96.39	Cystine	0.21
Crude protein, %	11.48	Methionine + cystine	0.40
Ether extract	49.48	Lysine	0.48
Ashes, %	1.87	Threonine	0.40
Gross energy, kcal/kg	7243	Arginine	0.72
		Isoleucine	0.35
		Leucine	0.83
		Valine	0.57
		Histidine	0.37
		Phenylalanine	0.45

[1] Values analyzed by the company Evonik.

Table 3 – Dry matter, crude protein, ether extract, gross energy, ash, and amino acid values of the reference and experimental diets.

Components,%	Experimental diet		
	Reference	20%CGM	30%CGM
Dry matter	90.45	91.74	92.32
Crude protein	16.67	15.40	14.82
Ether extract	4.40	13.55	17.72
Ashes	11.85	10.07	9.01
Gross energy (kcal/kg)	4119	4757	5065

Dry matter intake was statistically higher when layers were fed the reference diet compared with those fed the 20%CGM and 30%CGM, which in turn, were not different (90.2 and 95.0 g/bird/day), as shown in Table 4.

Excreta dry matter was not influenced by the treatments. Layers fed the 30%CGM diet presented higher EE intake (16.84 g/bird/day) compared with the other treatments, followed by those fed the 20%CGM diet (12.22 g/bird/day), and the reference diet (4.92 g/bird/day). Fecal EE content was statistically different among treatments, with the highest level obtained in the excreta of layers fed 30%CGM (51.49 g/bird/day), followed by the 20%CGM and the reference diet, with 35.22 and 8.42 g/bird/day, respectively.

Table 4 – Mean dry matter (DM) and ether extract (EE) intake and excretion of the layers submitted to the different treatments.

Parameters	Experimental diet			CV	F
	Reference	20%CGM	30%CGM		
DM intake, g/bird/day	112.00 a	90.20 b	95.00 b	9.28	**
DM excretion, g/bird/day	21.04 a	19.70 a	21.17 a	8.16	ns
EE intake, g/bird/day	4.92 c	12.22 b	16.84 a	8.55	**
EE excretion, g/bird/day	0.84 c	3.25b	5.15 a	17.02	**

Means followed by different letters in the same row are statistically different by the test of Tukey at 5% probability level.

** p<0.01

The reference diet presented statistically higher coefficients of metabolizability of all evaluated parameters compared with the other diets (Table 5).

Table 5 – Mean coefficient of apparent metabolizability of the dry matter, ether extract, gross energy, and apparent metabolizable energy (AME) and apparent metabolizable energy corrected for nitrogen balance (AMEn) values of the experimental diets, on dry matter basis.

Coefficient of metabolizability, %	Treatments			CV (%)	F
	Reference	20%CGM	30%CGM		
Dry matter	69.59 a	64.93 b	64.37 b	3.84	0.126
Ether extract	82.85 a	71.18 b	69.44 b	4.84	20.42
Gross energy	78.34 a	73.39 b	71.21 b	3.80	8.33
AME (kcal/kg)	3,226 a	3,491 b	3,607 b	3.73	11.55
AMEn (kcal/kg)	3,155 a	3,437 b	3,536 b	3.44	14.57

Means followed by different letters in the same row are statistically different by the t test at 5% probability level.

** p<0.01

The CAMDM results obtained for the reference, CGM20%, and CGM30% diets were 69.59, 64.93, and 64.37%, respectively. There was no influence of the CGM20% and CGM30% diets on CAMDM, CAMEE, CAMGE, AME, or AMEn.

The study showed that increasing the dietary inclusion of corn germ meal from 20 to 30% did not affect CAMGE, CAMEE, AME, or AMEn values. Values of 64.93 and 62.53% were obtained for CAMGE and CAMEE, respectively (Table 6).

Table 6 – Mean coefficients of apparent metabolizability of dry matter (CAMDM) and of gross energy (CAMGE) and apparent metabolizable energy (AME) and apparent metabolizable energy corrected for nitrogen balance (AMEn) values of corn gluten meal, on dry matter basis.

Parameters	Replacement levels		Means	CV	F
	20%	30%			
CAMDM, %	64.93	64.37	64.65	3.8	NS
CAMGE, %	62.53	60.88	61.86	12.86	NS
AMEn (kcal/kg)	4,715	4,441	4,578	11.43	NS
AMEn (kcal/kg)	4,723	4,372	4,548	10.56	NS

NS= non-significant

The obtained AMEn value of the evaluated CGM was 4,723 kcal/kg, which is very close to the AME value of 4,715 kcal/kg, demonstrating that birds were at zero nitrogen balance.

DISCUSSION

The CGM evaluated in this study derived from corn wet milling, aiming at extracting and processing starch for the food industry. Dry milling of corn, which objective is processing by-products for human consumption, is less efficient in separating corn fractions, and the resulting CGM contains less fat and consequently higher moisture. The low humidity value obtained in the evaluated CGM was low (3.61%) due to its high EE content (49.48%). Comparing with literature reports, this result is different than those obtained by Brum *et al.* (2000), Brito *et al.* (2005), and Brunelli *et al.* (2006) in defatted corn germ meal, of 11.17, 10.00, and 9.81%, respectively, as well as by Rostagno *et al.* (2011), of 10.29%.

The differences in crude protein levels and amino acid profiles are mainly related to CGM ether extract content. This shows processing does not have a strong influence on CGM composition, which in turn, depends on the corn from which it derived. Corn composition provides important information on the composition of its processed products and co-products.

The obtained crude protein value is consistent with those reported in literature of 10.88, 9.81, and 10.38% (Brito *et al.*, 2005; Brunelli *et al.*, 2006; Rostagno *et al.*, 2011, respectively).

Average amino acid ratios in the evaluated CGM agree with the findings of Rostagno *et al.* (2011), but not with those of Brum *et al.* (2000) for CGM derived from dry milling, which were 0.19 and 0.25% methionine, 0.41 and 0.55% methionine+cystine, 0.45 and 0.42% lysine, 0.39 and 0.32% threonine, 0.65

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and 0.56% arginine, 0.33 and 0.24% isoleucine, 0.90 and 0.71% leucine, 0.50 and 0.38% valine, 0.31 and 0.26% histidine, and 0.43 and 0.36% phenylalanine, respectively. Tryptophan was not analyzed in the present study, but the authors above obtained a value of 0.09%. In general, amino acid values presented in literature are consistent with the findings of this study and similar to those found in corn because CGM crude protein content is close or higher than that found in Brazilian corn.

The following values were reported for EE content of CGM derived from dry milling for starch extraction: 9.6 and 11.41% (Brito *et al.*, 2005; Rostagno *et al.*, 2011), whereas Brunelli *et al.* (2006) presented a much lower fat value (0.60%) for defatted corn germ meal. This variation in fat content, both in defatted and full-fat CGM, depends on processing and corn variety. This also apply to corn itself, as shown by Rodrigues *et al.* (2001) and Albino *et al.* (1982), who analyzed corn composition and obtained 1.88 and 5.65% fat content, respectively. This represents a 66.54% variation, which may subsequently be reflected in CGM nutritional composition.

The observed gross energy value is 1.59 higher than that reported by Rostagno *et al.* (2011), of 4250 kcal/kg. This difference results from the EE level of CGM, in which each gram of lipids supplies and average of 8.5 cal, and therefore, presents higher energy density.

Coefficients of digestibility and AME and AMEn contents of the diets may explain the energy utilization of specific feedstuffs. In the present study, EE content was the main determining factor. The experimental feeds presented 13.55 and 17.72% EE with the dietary inclusion of 20 and 30% CGM, respectively.

The layers fed the reference diet presented higher dry matter intake because that diet was balanced and contained less fat, differently from the other diets, which contained large amounts of CGM and high EE content. Feed intake was lower when CGM was fed. According to Mateos & Sell (1981), fat-rich diets promote slower feed passage rate. Increased fatty acid ingestion activates hormones that slow down peristaltic movements, increasing the time the digesta remains in the digestive system and promoting the perception of satiety (Macari *et al.*, 2002), thereby reducing feed intake.

The lower CAMDM of the feeds with CGM inclusion may be attributed to the higher fat content of this ingredient, which may have significantly influenced feed digestion and absorption. The higher coefficient of metabolizability of the reference diet is related to its lower fat content compared with the CGM diets.

Fat content also significantly influenced CAMDM, CAMEE, and CAMGE, with the feeds containing CGM presenting lower digestibility values and higher AME and AMEn content. Fatty acids have very diverse chemical structures that directly affect their digestibility, such as degree of saturation and chain size. Fat digestibility is also affected by the concentration of free fatty acids in the digesta, and animal factors, including maturity of the gastrointestinal tract and intestinal villus status. Wiseman & Salvador (1991) reported that the combination of a high concentration of saturated fatty acids and free fatty acids (FFA) reduced ether extract digestibility and metabolizable energy content. High FFA concentrations reduce the formation of micelles in the small intestine, consequently impairing fat absorption. The saturation of lipid-absorbing proteins in the small intestine may have affected digestibility, as the CGM diets had high EE content.

Despite the lack of significant differences in EMA levels and in the coefficients of dry matter and ether extract digestibility, further research should be carried out using lower CGM inclusion levels to verify if the levels of 20 and 30% are indeed the most adequate. However, despite of the lack of statistical difference between 20 and 30% CGM inclusion levels, CMAEE and CMAEB tended to decrease as CGM level increased.

CONCLUSIONS

The evaluated CGM presented the following chemical composition: 96.39% dry matter, 49.48% ether extract, 1.87% ashes, 7.243 kcal/kg gross energy, 11.48% protein, 0.19% methionine, 0.21% cystine, 0.48% lysine, 0.40% threonine, 0.72% arginine, 0.35% isoleucine, 0.83% leucine, 0.57% valine, and 0.37% histidine, on as-fed basis. Mean AME, AMEn, CAMDM, and CAMGE of the evaluated CGM were 4,578 and 4,548 kcal/kg, 4,723 and 4,372 kcal/kg, 64.95 and 61.86%, respectively.

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