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Metabolizable energy and standardized ileal digestibility of amino acids of corn co-products in broiler diets

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ABSTRACT - The objective of this study was to determine the energy values and standardized ileal digestibility (SID) of amino acids of corn, corn protein meal (CPM), corn germ (CG), and dried distillers' grains with solubles (DDGS) in broiler diets. In the first experiment, the apparent metabolizable energy (AME) and nitrogen-corrected apparent metabolizable energy (AMEn) values were determined using the total excreta collection method. A total of 240 14-day-old broiler chicks were randomly distributed in a completely randomized design with five treatments, including four different feed ingredients and a reference diet, each with eight replicates of six birds. In the second experiment, to determine the coefficient values of amino acids, 240 birds aged 14 to 28 days were randomly assigned to five treatments, including four different feed ingredients and a nitrogen-free diet, each with eight replicates of six birds. At 28 days of age, birds were slaughtered, and the digesta were collected to determine the standardized ileal digestibility coefficients and, subsequently, the digestibility of amino acids. The AMEn for corn, CPM, CG, and DDGS is 3178, 2171, 2473, and 3398 kcal/kg, respectively. The metabolizability coefficient of the AMEn percentages are 68.03% for corn, 46.62% for CPM, 44.15% for CG, and 73.39% for DDGS. The average digestibility of essential amino acids in corn, CPM, CG, and DDGS is 92.55, 52.63, 73.07, and 81.51%, respectively. For non-essential amino acids, the average digestibility in corn, CPM, CG, and DDGS is 90.59, 54.36, 70.20, and 79.47%, respectively, with an overall average of 85.21%.

Keywords: alternative feed ingredients, digestibility coefficients, metabolizability, poultry farming

1. Introduction

Corn is the largest agricultural crop in the world and is renowned for its versatility, with a wide range of uses, including human and animal nutrition. According to data from the National Supply Company (CONAB, 2020), the production of corn in the 2019/2020 harvest was estimated at 98.7 million tons in Brazil, of which 49 million tons were destined for animal feed. In addition to its use in animal nutrition, many byproducts can be used in animal feed, such as corn gluten meal and flour, corn germ, and distillery residues from ethanol production.

The production of ethanol from corn is a reality in Brazil, and according to the National Supply Company (CONAB, 2019), of the 35.5 billion L of ethanol produced in the 2019/2020 harvest, 1.69 billion were produced from corn, representing 3.35% of total production. The ethanol production process from corn results in the production of dried distillers' grains with solubles (DDGS) as the primary residue.

According to Bittencourt et al. (2019), corn DDGS contains digestible protein, fat, and phosphorus in its composition and can be used in the feed for broiler chickens. Dias et al. (2023) showed that corn ethanol co-products are rich in essential and non-essential amino acids and have satisfactory energy values for use in broiler chicken diets. Valentim et al. (2022) also concluded that the inclusion of 4, 8, and 12% DDGS in diets for the starter, grower, and finisher phases, respectively, did not adversely affect the performance and carcass yield of the broilers.

Corn germ (CG) is a result of the industrial processing of corn to extract germ oil (Espinosa-Pardo et al., 2020) and can provide metabolizable energy for poultry. Lopes et al. (2019) observed that up to 20% CG can be provided to broiler chickens without compromising productive performance. Corn protein meal (CPM) is derived from corn DDGS residues combined with residues from corn germ and gluten production, resulting in a higher protein content compared with DDGS (Hussain et al., 2019).

Currently, few studies on the use of corn protein flour for broiler chickens are found in the literature; therefore, it is important to determine the standardized ileal digestibility (SID) of amino acids and the metabolizable energy of this ingredient in these animals. Based on the proposed research, considering the extensive availability of corn co-products for animal nutrition, the objective of this experiment was to determine the energy values and SID of amino acids of corn, corn DDGS, CG, and CPM in broiler chicken diets.

2. Material and Methods

2.1. Animals and treatments

The experiment was carried out in Viçosa, Minas Gerais, Brazil (20.7523° S, 42.8826° W). A metabolism trial was conducted to determine the metabolizable energy values, and a digestibility trial was performed to determine the standardized ileal digestibility coefficient (SIDC) of amino acids of feed ingredients derived from corn co-products. All procedures involving animal research were previously approved by the Animal Production Ethics Committee, under protocol number 051/2018.

The birds were distributed in a completely randomized design with five treatments (four corn co-products: corn is not a corn co-product [40% inclusion], CPM [40% inclusion], CG [40% inclusion], DDGS [40% inclusion] + basal diet [control]), eight replicates per treatment, and six birds per experimental unit. The control diet was formulated based on corn and soybean meal, following the nutritional recommendations provided by Rostagno et al. (2017) for the period from 14 to 24 days of age (Table 1).

2.2. Energy metabolism trial

For the first experimental trial, 240 male Cobb 500 chicks, 14 days old, with an average weight of 442.0±10.0 g, were used. The birds were raised until 13 days of age in protected circles lined with wood shavings and fed balanced diets to meet the nutritional requirements for the initial growth phase, following the recommendations of Rostagno et al. (2017). These diets contained 2950 kcal/kg of metabolizable energy and 21% crude protein (CP).

At 14 days of age, the birds were transferred to metal batteries equipped with feeders, nipple drinkers, and covered trays for total excreta collection. The test diets were obtained by replacing 40% of the basal diet with the test feed, this level being chosen as proposed by Sakomura and Rostagno (2016), considering the total excreta collection for this type of metabolism test.

The experimental period lasted 10 days, consisting of five days for bird adaptation to the diets and facilities and five days for total excreta collection. All excreta from the birds were collected daily.

Table 1 - Composition of experimental diets used to determine the values of metabolizable energy and digestible amino acid content of feeds

Baseline reference diet[1]		Protein-free basal diet[2]	
Ingredient (%)		Ingredient (%)	
Corn	72.88	Corn starch	80.31
Soybean meal	22.46	Sugar	5.00
Soybean oil	1.00	Soybean oil	5.00
Dicalcium phosphate	1.60	Dicalcium phosphate	2.10
Limestone	0.92	Limestone	0.70
Salt	0.48	Salt	0.45
DL-methionine (99%)	0.14	Potassium carbonate	1.00
L-Lisine HCl (78%)	0.16	Corn cob	4.00
L-threonine (98%)	0.001	Vitamin premix[3]	0.15
Vitamin premix[3]	0.10	Mineral premix[4]	0.08
Mineral premix[4]	0.10	Choline chloride (60%)	0.20
Choline chloride (60%)	0.10	BHT[6]	0.01
Salinomycin (12%)[5]	0.05	Acid insoluble ash (Celite™)	1.00
BHT[6]	0.01		
Total	100.0	Total	100.0
Calculated composition			
Metabolizable energy (kcal/kg DM)	3050	-	-
Crude protein (%)	16.14	-	-
Digestible lysine (%)	0.84	-	-
Digestible methionine (%)	0.39	-	-
Methionine + digestible cystine (%)	0.61	-	-
Digestible threonine (%)	0.55	-	-
Digestible tryptophan (%)	0.66	-	-
Calcium (%)	0.81	-	-
Available phosphorus (%)	0.39	-	-
Sodium (%)	0.21	-	-

[1] Reference diet used to evaluate the metabolizable energy values of feeds.
[2] Reference diet used to evaluate the standardized ileal digestibility coefficients and digestible amino acid content of feeds.
[3] Composition per kg of product: vit. A, 12,000,000 IU; vit. D3, 22,000.00 IU; vit. E, 30,000 IU; vit. B1, 2200 mg; vit B2, 6000 mg; vit. B6, 3300 mg; pantothenic acid, 13,000 mg; biotin, 110 mg; vit. K3, 2500 mg; folic acid, 1000 mg; nicotinic acid, 530,000 mg; niacin, 250,00 mg; vit. B12, 16,000 µg; selenium, 0.25 g; antioxidant 120,000 mg, and QSP, 1000 g.
[4] Composition per kg of product: manganese, 75,000 mg; iron, 20,000 mg; zinc, 50,000 mg; copper, 4000 mg; cobalt, 200 mg; iodine 1500 mg; and QSP, 1000 g.
[5] Anticoccidial.
[6] Butyl hydroxy toluene.

After each collection, excreta samples were immediately frozen at −20 °C to prevent bacterial fermentation. At the end of the collection period, excreta were weighed and homogenized, and samples were taken and pre-dried in a forced-air oven at 55 °C for 72 h to determine the air-dry sample weight.

After pre-drying, samples of excreta and experimental diets were sent to the laboratory to determine the total nitrogen (N), dry matter (DM), and gross energy (GE) content (Silva and Queiroz, 2002). Apparent metabolizable energy (AME), apparent metabolizable energy corrected for nitrogen (AMEn), and the respective metabolizability coefficients (CMEm and CMEn) were calculated from the N and GE. The GE of diets, ingredients, and excreta was obtained using a calorimetric bomb (IKA® model PARR 6200). The ME and AMEn values were calculated using the equations proposed by Matterson et al. (1965):

$$\text{ME of DT or BF (kcal/kg)} = \frac{(\text{GE ingested} - \text{GE excreted})}{\text{Feed intake}} \quad (1)$$

$$\text{ME of ingredients (kcal/kg)} = \text{ME BF} + \frac{(\text{ME DT} - \text{ME BF})}{\text{\% of replacement}} \quad (2)$$

$$\text{AMEn of DT or BF (kcal/kg)} = \frac{(\text{GE ingested} - (\text{GE excreted} + 8.22 \times \text{NB}))}{\text{Feed intake}} \quad (3)$$

$$\text{AMEn of ingredients (kcal/kg)} = \text{MEN BF} + \frac{(\text{MEn DT} - \text{MEn BF})}{\text{\% of replacement}} \quad (4)$$

in which TD = test diet, BF = basal feed, and NB = nitrogen balance (N ingested − N excreted).

2.3. Amino acid digestibility determination

In the second experimental trial, 240 male Cobb 500 chicks, 24 days old and an initial weight of 880.0±15.0 g, were distributed in a completely randomized design with five treatments (the same co-products used in the first trial plus a nitrogen-free diet [control] based on starch; Table 1), eight replicates per treatment, and six birds per experimental unit. Acid-insoluble ash (Celite™) was added to all diets at a concentration of 1%. Celite™ is a brand of diatomaceous earth filter aids produced by Celite Corporation; it is a soft, natural siliceous sedimentary rock that easily disintegrates into a fine, white to off-white powder. The chickens were housed in metal batteries from 24 to 28 days of age and received the experimental diets. After a four-day adaptation period, all chickens were euthanized by electronarcosis to collect ileal digesta content. Electronarcosis consists of the application of a low voltage, high amperage electrical current to the animal through electrodes placed on the head and body. This induces a rapid loss of consciousness and temporary incapacitation, allowing the animal to be slaughtered in a more humane manner. To perform this procedure, the abdominal cavity was sectioned, and all the digesta content within the final 40 cm of the ileum was collected, using the ileocecal junction as a reference point. The ileal digesta samples were frozen at −40 °C for 72 h, lyophilized to remove water, and then sent to the laboratory for the determination of total amino acids by high-performance liquid chromatography (HPLC), following the methodology described by AOAC (2006).

The digesta DM and CP contents were also determined, according to Silva and Queiroz (2002). Insoluble acid ash and indigestibility factor were performed according to Joslyn (1970). Calculations of true ileal digestibility of amino acids were performed using the methodology proposed by Sakomura and Rostagno (2016).

Ileal indigestibility factor (IF):

$$\text{IF1} = \text{[CAI] in the diet / [CAI] sample} \quad (5)$$

$$\text{IF2} = \text{[CAI] in the DIP / [CAI] sample} \quad (6)$$

Ileal digestibility coefficient (IDC):

$$\text{AIDC \%} = (\text{\% AA diet} - (\text{\% AA dig} \times \text{IF1})) \times 100 / \text{\% AA diet} \quad (7)$$

$$\text{SIDC \%} = (\text{\% AA diet} - (\text{\% AA dig} \times \text{IF1}) - (\text{AA end PFD} \times \text{IF2})) \times 100 / \text{\% AA diet} \quad (8)$$

in which CAI = concentration of acid-insoluble ash, PFD = protein-free diet, AIDC = apparent ileal digestibility coefficient of amino acids, SIDC = standardized ileal digestibility coefficient of amino acids, % AA diet = percentage of amino acids in the diet, % AA dig = percentage of amino acids in the ileal digesta, and AA end = endogenous amino acids.

2.4. Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) at a 5% probability level, and means were compared using Tukey's test at a 5% probability level. To check the statistical assumptions of residual normality, the Shapiro-Wilk test was used, and the homogeneity of variances was evaluated using Levene's Test. All analyses were conducted using the statistical package of the Statistical Analysis System (SAS, 2010). The statistical model used is represented below:

$$Y_{ij} = m + t_i + e_i, \quad (9)$$

in which Y_{ij} = response variable of the different corn co-products, m = overall mean effect, t_i = fixed effect of treatments (corn co-products), and e_i = residual error.

3. Results

3.1. Energy metabolism assay

All corn co-products exhibited higher GE and CP values than corn. Among the feed ingredients, DDGS had the highest values of AME and AMEn, while CPM had the lowest value ($P<0.0001$). Corn was superior in providing metabolizable energy (AME and AMEn) compared with CPM and CG, even though the latter two had higher GE. When evaluating CMEn, the response pattern was similar to the AME and AMEn results, except that there was no significant difference ($P\geq0.05$) between CPM and CG (Table 2).

Table 2 - Dry matter (DM), crude protein (CP), gross energy (GE), apparent metabolizable energy (AME), nitrogen-corrected apparent metabolizable energy (AMEn), and metabolizability coefficient of the AMEn (CMEn) of feeds

Feed	Corn	CPM	CG	DDGS	CV (%)	P-value
DM (%)	87.17	88.54	91.86	89.08	-	-
CP (%)	8.00	44.26	12.97	25.30	-	-
GE (kcal/kg)	3870	4657	5603	4630	-	-
AME (kcal/kg)[1]	3275±51.20b	2191±26.04d	2487±19.25c	3644±26.37a	2.79	<0.0001
AMEn (kcal/kg)[1]	3178±48.49b	2171±25.86d	2473±19.12c	3398±25.76a	2.77	<0.0001
CMEn (%)	68.03±1.03b	46.62±0.55c	44.15±0.34c	73.39±0.55a	2.84	<0.0001

CPM - corn protein meal; CG - corn germ; DDGS - dried distillers' grains with solubles; CV - coefficient of variation.
[1] Values expressed in natural matter.
a-d - Different letters in the same row differ by Tukey's test ($P<0.05$).

3.2. Amino acid digestibility determination

Both CPM and DDGS have a higher absolute number of amino acids, which was expected since they have the highest CP content, 44.26 and 25.30%, respectively (Table 3). For all amino acids, corn has higher ($P\leq0.05$) SIDC compared with the evaluated co-products, except for the methionine and tyrosine, in which the digestibility coefficient of DDGS does not significantly differ ($P\geq0.05$) from corn (Table 4).

Despite having the highest CP content, the amino acid digestibility coefficients of CPM were lower among the evaluated feed ingredients. For essential amino acids, the highest coefficient found was for leucine (63.70%), while the least digestible was lysine (38.79%). As for non-essential amino acids, the highest and lowest digestibility coefficients were found for alanine (65.61%) and cystine (44.70%), respectively. Corn protein meal has high values of digestible amino acids, but due to their lower digestibility, the difference between CPM and DDGS decreases and, in some cases, is even lower, as in the case of methionine (Table 5).

4. Discussion

The chemical composition of corn can vary due to numerous factors, such as agronomic conditions, grain storage methods and duration, and even corn processing (Cromwell et al., 1993), which directly influences the chemical composition of co-products. Additionally, the method used to extract oil and starch from corn adds further variability to the chemical composition of co-products (Kim et al., 2010).

Table 3 - Total amino acid composition of corn co-products (% natural matter)

Amino acid	Corn	CPM	CG	DDGS
Essential amino acids				
Methionine	0.13	0.85	0.23	0.44
Lysine	0.27	1.61	0.53	0.59
Threonine	0.27	1.68	0.42	0.96
Valine	0.42	2.37	0.64	1.16
Isoleucine	0.23	1.84	0.41	0.85
Leucine	0.93	5.20	1.01	3.36
Arginine	0.35	1.92	0.70	1.31
Histidine	0.19	1.16	0.38	0.69
Phenylalanine	0.38	2.32	0.52	1.24
Non-essential amino acids				
Glycine	0.27	1.71	0.63	1.22
Serine	0.37	2.28	0.60	1.46
Tyrosine	0.33	1.91	0.37	1.01
Alanine	0.54	3.20	0.78	2.00
Glutamic acid	1.47	7.16	1.68	4.75
Cystine	0.10	0.89	0.23	0.29
Aspartic acid	0.45	3.13	0.84	2.08

CPM - corn protein meal; CG - corn germ; DDGS - dried distillers' grains with solubles.

Table 4 - Mean values and standard error of the mean of the standardized ileal digestibility coefficients of amino acids of corn co-products (% natural matter)

Amino acid	Corn	CPM	CG	DDGS	CV (%)	P-value
Essential amino acids						
Methionine	94.29±0.47a	44.28±2.26c	62.25±2.56b	90.20±1.60a	6.40	<0.001
Lysine	89.98±1.13a	38.79±1.90c	66.02±2.26b	70.36±1.18b	6.24	<0.001
Threonine	95.34±1.43a	45.38±1.36d	63.99±1.34c	72.83±1.07b	4.62	<0.001
Valine	93.39±0.78a	53.93±1.06c	80.50±1.70b	82.90±1.24b	3.92	<0.001
Isoleucine	93.81±0.77a	51.49±1.85c	74.12±2.43b	80.12±0.87b	5.35	<0.001
Leucine	91.97±0.62a	63.70±1.27d	78.73±1.21c	85.99±0.44b	2.92	<0.001
Arginine	95.27±0.56a	61.25±1.94d	75.15±2.55c	83.86±0.67b	5.17	<0.001
Histidine	85.59±1.17ab	54.32±1.83c	78.77±1.52b	80.69±0.99b	4.63	<0.001
Phenylalanine	93.35±0.71a	60.52±2.59d	78.07±1.62c	86.65±0.79b	4.98	<0.001
Non-essential amino acids						
Glycine	82.77±1.37a	47.69±1.36	61.28±1.27b	55.87±1.87b	5.89	<0.001
Serine	83.81±5.03ab	56.75±1.16c	71.49±1.53b	82.23±0.67b	9.07	<0.001
Tyrosine	90.04±1.44a	57.53±2.64c	72.79±0.85b	84.97±0.67a	5.14	<0.001
Alanine	90.38±0.71a	65.61±1.27d	75.70±0.61c	85.18±0.44b	2.53	<0.001
Glutamic acid	95.07±0.61a	61.86±1.55d	77.40±1.55c	88.15±0.81b	3.67	<0.001
Cystine	94.19±2.11a	44.70±1.96d	62.26±2.43c	83.56±0.89b	6.66	<0.001
Aspartic acid	97.84±0.67a	46.40±1.50d	70.45±0.97c	76.32±1.36b	3.95	<0.001

CPM - corn protein meal; CG - corn germ; DDGS - dried distillers' grains with solubles; CV - coefficient of variation.
a-d - Different letters in the same row differ by Tukey's test (P<0.05).

Consequently, the energy values of these feed ingredients can vary significantly. In the Brazilian Tables for Poultry and Swine (Rostagno et al., 2017), the AMEn values for corn and CG for broiler chickens are 3364 and 3144 kcal/kg, respectively, on a DM basis, whereas Rochell et al. (2011) found 3120 and 3495 kcal/kg of AMEn in two types of CG. Therefore, the level of residual constituents in the product will influence the available AMEn for broiler chickens. In the present study, the GE of CG was high, at 5603 kcal/kg, but the CMEn was low, at only 44.15%. As a result, the AMEn value was lower (2473 kcal/kg) than that found in the literature, possibly due to the high content of fibrous residues.

Table 5 - Mean values of digestible amino acids of corn co-products (% natural matter)

Amino acid	Corn	CPM	CG	DDGS
Essential amino acids				
Methionine	0.12	0.37	0.14	0.39
Lysine	0.24	0.62	0.35	0.41
Threonine	0.25	0.76	0.27	0.69
Tryptophan	-	0.18	0.11	-
Valine	0.39	1.27	0.51	0.96
Isoleucine	0.21	0.94	0.30	0.68
Leucine	0.85	3.31	0.79	2.88
Arginine	0.33	1.17	0.52	1.09
Histidine	0.16	0.63	0.29	0.55
Phenylalanine	0.35	1.40	0.40	1.07
Non-essential amino acids				
Glycine	0.22	0.55	0.38	0.68
Serine	0.31	1.29	0.42	1.20
Tyrosine	0.29	1.09	0.26	0.85
Alanine	0.48	2.09	0.59	1.70
Glutamic acid	1.39	4.43	1.30	4.18
Cystine	0.09	0.39	0.14	0.24
Aspartic acid	0.44	1.45	0.59	1.58

CPM - corn protein meal; CG - corn germ; DDGS - dried distillers' grains with solubles.

Corn protein meal is a co-product primarily formed from DDGS combined with other co-products such as CG and corn gluten meal. Despite its high GE (4657 kcal/kg), its CMEn was also below 50%, providing only 2171 kcal/kg of AMEn for broilers. Applegate et al. (2009) stated that DDGS has a high content of insoluble fibers, and as it is the main component of CPM, justifying the low metabolizability of energy in this feed. Dalólio et al. (2019) evaluated a sorghum protein meal, a co-product formed in a similar way to CPM, and found low CMEn values (57.35%), resulting in low available AMEn for the animals, at only 2819 kcal/kg.

Rochell et al. (2011) evaluated six different types of DDGS and observed AME values ranging from 2685 to 2903 kcal/kg for broiler chickens. In the present study, the CMEn of DDGS was 73.39%, resulting in a high AMEn of 3398 kcal/kg. The variation in values between studies can be explained by the fiber content of the feed ingredients.

The variation in the composition of corn co-products is high because the grain processing method to produce the product can vary between ethanol production plants. Ethanol extraction from corn can be done in two basic ways: wet milling or dry milling, each with its unique characteristics and equipment, which impacts the final composition of products and co-products (Rausch and Belyea, 2006). Therefore, differences between DDGS from different batches are common, and as a result, there should be constant updates to the energy values to ensure balanced diets that meet the requirements of the animals.

Corn gluten is a corn co-product with a high protein content, which can be 21 or 60% CP (Rostagno et al., 2017). According to Rostagno et al. (2017), there was higher amino acids digestibility for 60% corn gluten for birds, reaching 97.6% digestibility for leucine and the lowest value for lysine, around 90.2%.

As for 21% corn gluten, there was 90 and 72% digestibility for leucine and lysine, respectively. Even with lower digestibility for 21% corn gluten compared with 60%, both are superior to the CPM evaluated in the present study because gluten is formed after separating the starch in the corn processing, forming a protein aggregate with fewer residues, which is not the case for CPM.

Dalólio et al. (2019) also observed low digestible values for amino acids in sorghum protein meal, with about 38.48% digestibility for leucine and 33.70% for lysine. The amount of fiber in the formation of protein meals, such as CPM, comes from residues of other processing steps, such as DDGS, and this factor reduces the digestibility of protein and amino acids for broiler chickens.

The SIDC of most amino acids in corn is higher than in DDGS. However, DDGS exhibits high values, and when evaluating the main essential amino acids, we observed that the digestibility of methionine is 90.20% and that of lysine is 70.36%. When assessing non-essential amino acids, DDGS can reach 88.15% digestibility for glutamic acid and 85.18% for alanine. Adedokun et al. (2015) evaluated the SIDC of amino acids in five different types of DDGS in broiler chickens and found differences among them.

However, the SIDC results of amino acids were lower than in the present study, such as lysine, ranging from 49.9 to 63.3%, and methionine, ranging from 77.7 to 85.0% among the different corn co-products. The same pattern held for non-essential amino acids, with values ranging from 81.4 to 85.7% digestibility for glutamic acid and 78.6 to 83.3% for alanine. The difference in the SIDC of amino acids between DDGS in the two studies likely occurred due to the fiber content in the feed ingredients, as the corn co-products contained an average of 39.39% neutral detergent fiber, which can hinder nutrient digestibility.

Compared with the other evaluated feed ingredients, CG has intermediate SIDC values for amino acids, being lower ($P \leq 0.05$) than corn and higher ($P \leq 0.05$) than CPM. However, some amino acids show similar digestibility ($P \geq 0.05$) to DDGS, as in the case of lysine and valine. Despite this digestibility, in the present study, CG showed lower SIDC for amino acids than the same feed ingredient presented by Rostagno et al. (2017), in which the digestibility of all amino acids was above 80%, reaching values of 96.2% for arginine and 93.9% for tyrosine. Kim et al. (2008) also found high SIDC values for amino acids in CG in their study, all above 90%, except for histidine, which had 86.1% digestibility. In comparison with these studies, CG in the present study showed lower amino acid digestibility values, following the pattern of energy values, supporting the idea that the levels of residues in the feed influence its utilization by birds.

Dried distillers' grain with solubles, on the other hand, has a good profile of digestible amino acids for broilers due to its high CP concentration and digestibility coefficients of amino acids above 70%, except for glycine. Regarding their high energy values and substantial amounts of digestible amino acids, corn co-products such as DDGS, CG, and CPM can be included in broiler diets.

5. Conclusions

The AMEn for corn, CPM, CG and DDGS is 3178, 2171, 2473, and 3398 kcal/kg, respectively. The CMEn percentages are 68.03% for corn, 46.62% for CPM, 44.15% for CG, and 73.39% for DDGS. The average digestibility for essential amino acids in corn, CPM, CG, and DDGS is 92.55, 52.63, 73.07, and 81.51%, respectively. For non-essential amino acids, the average digestibility in corn, CPM, CG, and DDGS is 90.59, 54.36, 70.20, and 79.47%, with an overall average of 85.21%.

Conflict of Interest

The authors declare no conflict of interest.

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