

# Metabolizable Energy and Metabolizability Coefficients of Moringa and Bocaiuva for Slow-Growing Broilers at Different Ages

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## **Abstract**

This study aimed to determine nutrient metabolizability coefficients and apparent metabolizable energy (AME) and nitrogen-corrected AME (AMEn) values of moringa leaf meal and bocaiuva pulp for slow-growing broilers. Three hundred and fifty 1-day-old chicks of the Red Naked Neck line were allocated to five treatments in a completely randomized design with seven replicates of 10 birds. Treatments consisted of a control diet and four test diets. The proportion of ingredients evaluated in the test diets was 20% moringa leaf meal and bocaiuva pulp and 40% corn and soybean meal. The total excreta collection method was applied with 1% ferric oxide included in the diets as a marker of start and end of collection, in the starter, grower and finisher phases. The metabolizability coefficients of dry matter, crude protein and ether extract and the AME and AMEn values of moringa leaf meal, bocaiuva pulp, corn and soybean meal were determined. Data were subjected to analysis of variance and means were compared by Tukey's test at the 5% probability level. The protein from moringa leaf meal and the fat from bocaiuva pulp are highly metabolizable by birds at different ages. The AME and AMEn values of moringa leaf meal ranged from 2557 to 2868

Kcal/kg and 2205 to 2479 Kcal/kg, respectively. In bocaiuva pulp, AME and AMEn ranged between 2680 and 3119 Kcal/kg and 2483 and 2490 Kcal/kg, respectively. Therefore, the alternative ingredients can be used in the formulation of diets for slow-growing broilers to partially replace corn and soybean meal.

**Keywords:** alternative ingredient, bocaiuva pulp, moringa leaf meal

## 1. Introduction

The main raw materials used in the formulation of poultry diets (corn and soybean meal) directly influence rises in production costs. Thus, the use of alternative sources able to meet the requirements of birds in different rearing phases has been widely researched by nutritionists (Generoso et al. 2008), aiming at reducing such expenses.

However, to formulate nutritionally viable diets, it is essential to know the nutritional value of feedstuffs (Generoso et al. 2008) and the growth and energy metabolism of birds and investigate the factors that affect them as well as the availability and utilization of the other diet nutrients (Sakomura et al. 2004a).

The variable chemical composition of feedstuffs has been a major problem to nutritionists (Generoso et al. 2008), because the nutritional value of those ingredients is related to the soil-climatic conditions of the area where the plant was grown and its vegetative stage, harvest age and fraction used (leaves, stems or stem + leaves, pulp, whole fruit) (Brito et al. 2005; Arruda et al. 2010).

Therefore, considering the factors inherent to feedstuffs and the constant genetic evolution of poultry farming, it is necessary to determine the nutritional values of ingredients used in the formulation of diets for those animals (Rodrigues et al. 2001; Nunes 2003; Carvalho 2004; Sakomura et al. 2004b, Nery 2007; Brumano 2006).

The choice of which feedstuffs to use in the formulation of broiler diets depends on detailed knowledge of their chemical composition, viability of inclusion and intended inclusion levels (Mutayoba et al. 2011; Ebenebe et al. 2013; Gadziraya et al. 2012), as well as how the nutrients will be utilized through the different animal life stages (Santos et al. 2012).

Brazil has a great diversity of plant-based foods and derived products that can be used in animal feeding. Moringa and bocaiuva are noteworthy examples of such alternatives found in the country. The nutritional characteristics of moringa leaf meal make it a great option as an alternative to soybean meal in animal nutrition (Macambira et al. 2016), as it is high in protein, has a good essential amino acid composition and contains insignificant amounts of antinutritional compounds (Makkar et al. 1996; Ferreira et al. 2008).

Bocaiuva is considered an alternative for inclusion in poultry diets as a substitute for corn due to its high yield, which can exceed 30 t/ha (Moreira and Sousa 2009), as well as nutritional composition (Ramos et al. 2008).

The conflicting results found in the literature and the scarcity of research illustrating the utilization of energy and the metabolizability of nutrients from alternative ingredients used in

the diets of slow-growing broilers at different ages indicate the need for metabolism studies, considering that these birds have a different growth rate compared to industrial birds. As a consequence, diets are formulated with nutritional data from composition tables determined using fast-growing lines.

Few studies have examined the use of moringa leaf meal and bocaiuva pulp in the diets of slow-growing broilers. Thus, the present study proposes to determine the nutrient metabolizability coefficients and the apparent metabolizable energy and nitrogen-corrected apparent metabolizable energy values of moringa leaf meal and bocaiuva pulp for slow-growing broilers at different ages.

## 2. Material and Methods

### 2.1 Birds, Experimental Design and Husbandry

The experimental procedures described herein were approved by the Ethics Committee on Animal Use (CEUA) (approval no. 977/2018).

Three hundred and fifty 1-day-old male chicks of the Red Naked Neck line were allocated to five treatments in a completely randomized design with seven replicates and ten birds per experimental unit. Birds were housed in metabolic cages (60 × 80 × 42 cm) equipped with a trough-type feeder, a nipple-type drinker and a tray for excreta collection. The total excreta collection methodology was employed, following Sakomura and Rostagno (2016).

The composition of the main ingredients used in the diets is shown in Table 1. The treatments consisted of a corn- and soybean meal-based control diet formulated to meet the nutritional requirements of brown-egg replacement layers, according to Rostagno et al. (2017) (Table 2); a test diet composed of 80% of control diet + 20% moringa leaf meal (dried and ground leaves of moringa); a test diet composed of 80% of control diet + 20% bocaiuva meal (waste post oil extraction); a test diet composed of 60% of control diet + 40% corn; and a test diet composed of 60% of control diet + 40% soybean meal. Feed and water were available *ad libitum*.

### 2.2 Determination of Metabolizable Energy

The trials were conducted in the periods of 19 to 26 (starter phase), 47 to 54 (grower phase) and 69 to 76 (finisher phase) days of age. Each period consisted of three days of adaptation to the experimental diets and five days of excreta collection. In the periods when no metabolizability trial was undergoing, all birds were fed control diet. During the experiment, mortality, maximum and minimum temperatures and relative air humidity were recorded at 07h00 and 17h00.

Table 1. Chemical composition and gross energy values of the ingredients, on a dry matter

basis

Nutrient	Moringa leaf meal	Bocaiuva pulp	Corn	Soybean meal
DM (g/100 g)	89.63	92.47	90.04	91.64
CP (g/100 g)	15.02	3.97	7.06	43.48
CF (g/100 g)	10.17	7.93	0.81	0.70
NDF (g/100 g)	21.67	35.55	8.48	17.54
ADF (g/100 g)	16.47	28.33	3.22	5.76
EE (g/100 g)	3.21	12.64	3.00	1.78
MM (g/100 g)	12.50	5.08	1.08	6.28
GE (MJ/k g)	15.82	19.27	16.50	17.89

Ferric oxide (1%) was added to the diets as a marker to establish the start and end of the excreta collection period. Excreta were collected twice daily, at 08h00 and 16h00. In all trials, the amount of feed supplied and orts at the end of the collection period were weighed to determine total feed intake. At the end of each collection, excreta were packed in plastic bags, which were labeled per treatment and replicate, and immediately frozen for later analyses. Samples of feed and ingredients were stored for later analyses.

### 2.3 Analysis

At the end of the collections, all excreta samples corresponding to each experimental unit and rearing phase were thawed, weighed and homogenized. Samples were pre-dried in a forced-air oven (55 °C) for 72 h and then processed through a knife mill with 1-mm sieves to obtain a finely ground material, which was placed in plastic containers for analyses of dry matter (DM), ether extract (EE) and nitrogen (N), following Silva and Queiroz (2002).

The metabolizability coefficients of dry matter (MCDM), crude protein (MCCP) and ether extract (MCEE) and the apparent metabolizable energy (AME) and nitrogen-corrected AME (AMEn) values were determined using equations proposed by Matterson et al. (1965).

### 2.4 Statistical Analysis

Data were subjected to analysis of variance and means were compared by Tukey's test at the 5% probability level using SAS 9.0 statistical software.

Table 2. Centesimal composition and calculated values of control diet for slow-growing

broilers

Ingredient (g/100 g)	Rearing phase		
	Starter (19 to 26 days)	Grower (47 to 54 days)	Finisher (69 to 76 days)
Corn (7.88%)	59.44	63.23	72.63
Soybean meal (46%)	34.41	30.71	24.33
Soybean oil	0.05	0.05	-
Inert	2.28	1.93	-
Dicalcium phosphate	1.79	1.80	1.62
Limestone	1.00	0.98	0.91
Salt	0.42	0.38	0.35
DL-methionine	0.27	0.24	-
L-lysine HCl	0.13	0.07	-
L-threonine	0.05	0.02	-
Vitamin supplement <sup>1</sup>	0.10	0.10	0.10
Mineral supplement <sup>2</sup>	0.05	0.05	0.05
	Calculated values		
Metabolizable energy (Kcal/kg)	2,850	2,850	3,004
Crude protein (g/100 g)	20.98	19.50	17.05
Dig. methionine + cysteine (g/100 g)	0.84	0.77	0.48
Dig. lysine (g/100 g)	1.14	0.96	0.76
Dig. threonine (g/100 g)	0.76	0.68	0.58
Calcium (g/100 g)	0.95	0.93	0.84
Av. phosphorus (g/100 g)	0.44	0.43	0.39
Sodium (g/100 g)	0.18	0.17	0.16

<sup>1</sup>Mineral supplement (provides per kg of diet): 11.00 mg zinc; 3.04 mg pantothenic acid; 0.22 mg iodine; 0.06 mg selenium; 90.3 mg choline; 8.48 mg iron; 2.64 mg copper; 15.15 mg manganese. <sup>2</sup>Vitamin supplement (provides per kg of diet): 2,400 IU vitamin A; 480 IU vitamin D3; 0.32 mg vitamin K3; 0.51 mg vitamin B1; 1.38 mg vitamin B2; 0.64 mg vitamin B6; 2.88 mg vitamin B12; 3.00 mg vitamin E; 7.12 mg niacin.

### 3. Results

### 3.1 Environment

Mean values of maximum and minimum temperatures and relative humidity in the experimental period varied from 25.3 to 32.9 °C and 45.8 to 69.3% in the starter phase (19 to 26 days); 22.7 to 29.9 °C and 54.2 to 72.3% in the grower phase (47 to 54 days); and 22.2 to 27.3 °C and 62.4 to 75.1% in the finisher phase (69 to 76 days). The birds were found to be under moderate heat stress in the grower and finisher phases.

### 3.2 Metabolizability Coefficients

In the period of 19 to 26 days of age, the highest MCDM ( $P < 0.05$ ) was found with corn, whereas the lowest ( $P < 0.05$ ) was found with moringa leaf meal and intermediate values were obtained with bocaiuva pulp and soybean meal (Table 3). The MCCP of bocaiuva pulp was higher ( $P < 0.05$ ) than that of soybean meal and similar ( $P > 0.05$ ) to those found with corn and moringa leaf meal. Bocaiuva pulp showed the highest ( $P < 0.05$ ) MCEE, and the MCEE of corn and soybean meal were similar ( $P > 0.05$ ).

Table 3. Metabolizability coefficients of moringa leaf meal, bocaiuva pulp, corn and soybean meal for slow-growing broilers at different ages

19 to 26 days						
Variable (g/100 g)	Moringa leaf meal	Bocaiuva pulp	Corn	Soybean meal	CV (%)	P-value
Dry matter	65.59 <sup>b</sup>	65.85 <sup>ab</sup>	65.87 <sup>a</sup>	65.68 <sup>ab</sup>	0.30	0.0392
Crude protein	60.91 <sup>ab</sup>	61.28 <sup>a</sup>	61.11 <sup>ab</sup>	60.77 <sup>b</sup>	0.44	0.0096
Ether extract	84.65 <sup>c</sup>	85.59 <sup>a</sup>	84.99 <sup>b</sup>	85.15 <sup>b</sup>	0.22	<0.0001
47 to 54 days						
Variable (g/100 g)	Moringa leaf meal	Bocaiuva pulp	Corn	Soybean meal	CV (%)	P-value
Dry matter	60.10 <sup>c</sup>	60.67 <sup>b</sup>	61.05 <sup>a</sup>	60.49 <sup>b</sup>	0.42	<0.0001
Crude protein	54.58 <sup>a</sup>	54.84 <sup>a</sup>	54.69 <sup>a</sup>	54.20 <sup>b</sup>	0.40	<0.0001
Ether extract	72.05 <sup>bc</sup>	72.88 <sup>a</sup>	71.96 <sup>c</sup>	72.15 <sup>b</sup>	0.15	<0.0001
69 to 76 days						
Variable (g/100 g)	Moringa leaf meal	Bocaiuva pulp	Corn	Soybean meal	CV (%)	P-value
Dry matter	79.72 <sup>b</sup>	79.87 <sup>b</sup>	80.32 <sup>a</sup>	79.76 <sup>b</sup>	0.30	<0.0001
Crude protein	58.96	58.99	58.98	58.60	0.48	0.0507
Ether extract	73.40 <sup>ab</sup>	73.63 <sup>a</sup>	73.09 <sup>b</sup>	73.13 <sup>b</sup>	0.45	0.0192

Means followed by common letters in the same row do not differ according to Tukey's test.

From 47 to 54 days of age, a significant difference was detected ( $P < 0.05$ ) for MCDM, MCCP and MCEE. The highest and lowest ( $P < 0.05$ ) MCDM were found for corn and moringa leaf meal, respectively. The MCDM of bocaiuva pulp and soybean meal were similar ( $P > 0.05$ ). The MCCP of moringa leaf meal, bocaiuva pulp and corn were also similar ( $P > 0.05$ ), whereas that of soybean meal was the lowest. Bocaiuva pulp exhibited the highest ( $P < 0.05$ ) MCEE, while the MCEE of moringa leaf meal was similar ( $P > 0.05$ ) to those of corn and soybean meal.

In the period of 69 to 76 days, a significant difference was detected ( $P < 0.05$ ) for MCDM and

MCEE. The highest ( $P < 0.05$ ) MCDM was found for corn, whereas lower values were found for moringa leaf meal, bocaiuva pulp and soybean meal. There were no significant differences ( $P > 0.05$ ) for the metabolizability of CP between the different feedstuffs. Bocaiuva pulp showed a higher ( $P < 0.05$ ) MCEE. Corn and soybean meal exhibited a lower ( $P < 0.05$ ) MCEE; however, the MCEE of moringa leaf meal was similar ( $P > 0.05$ ) to those of bocaiuva, corn and soybean meal.

### 3.3 Metabolizable Energy

Significant differences were recorded ( $P < 0.05$ ) for the AME and AMEn values at the different ages (Table 4). The AME of corn and soybean meal were higher ( $P < 0.05$ ) and similar to each other ( $P > 0.05$ ) in the period of 19 to 26 days of age. The alternative feedstuffs showed the lowest ( $P < 0.05$ ) AME values, which were similar ( $P > 0.05$ ) to each other. The AMEn values of corn and soybean meal were similar ( $P > 0.05$ ). Moringa leaf meal showed a lower ( $P < 0.05$ ) AMEn value; however, the AMEn value of bocaiuva pulp was similar ( $P > 0.05$ ) to that of moringa leaf meal and soybean meal.

Table 4. Apparent metabolizable energy (AME) and nitrogen-corrected apparent metabolizable energy (AMEn) of moringa leaf meal, bocaiuva pulp, corn and soybean meal for slow-growing broilers at different ages

19 to 26 days						
Variable (Kcal/kg)	Moringa leaf meal	Bocaiuva pulp	Corn	Soybean meal	CV (%)	P-value
AME	2557 <sup>b</sup>	2680 <sup>b</sup>	3581 <sup>a</sup>	3603 <sup>a</sup>	15.97	<0.0001
AMEn	2205 <sup>c</sup>	2483 <sup>bc</sup>	3379 <sup>a</sup>	2864 <sup>ab</sup>	15.97	<0.0001
47 to 54 days						
Variable (Kcal/kg)	Moringa leaf meal	Bocaiuva pulp	Corn	Soybean meal	CV (%)	P-value
AME	1461 <sup>c</sup>	2714 <sup>b</sup>	3591 <sup>a</sup>	2590 <sup>b</sup>	10.56	<0.0001
AMEn	1322 <sup>c</sup>	1730 <sup>bc</sup>	3178 <sup>a</sup>	2228 <sup>b</sup>	10.56	<0.0001
69 to 76 days						
Variable (Kcal/kg)	Moringa leaf meal	Bocaiuva pulp	Corn	Soybean meal	CV (%)	P-value
AME	2868 <sup>b</sup>	3119 <sup>b</sup>	4044 <sup>a</sup>	3118 <sup>b</sup>	14.35	<0.0001
AMEn	2479 <sup>b</sup>	2490 <sup>b</sup>	3887 <sup>a</sup>	2427 <sup>b</sup>	14.35	<0.0001

Means followed by common letters in the same row do not differ according to Tukey's test ( $P < 0.05$ ).

In the period of 47 to 54 days of age, corn showed the highest ( $P < 0.05$ ) AME and AMEn values. The AME values of bocaiuva pulp and soybean meal were similar ( $P > 0.05$ ), whereas moringa leaf meal exhibited the lowest ( $P < 0.05$ ) AME value. The AMEn value of bocaiuva pulp was similar ( $P > 0.05$ ) to that of moringa leaf meal and soybean meal.

From 69 to 76 days of age, the highest ( $P < 0.05$ ) AME and AMEn values were found with

corn. The AME and AMEn values of moringa leaf meal, bocaiuva pulp and soybean meal were similar ( $P>0.05$ ).

#### 4. Discussion

Several factors influence the metabolizability of nutrients from broiler diets, e.g., feed particle size and processing, bird age and sex, rearing environment and chemical composition of the dietary ingredients.

The chemical composition of moringa leaf meal, bocaiuva pulp, corn and soybean meal is highly variable across studies. The nutritional value of those feedstuffs is related to their chemical composition, soil-climatic conditions of the area where the plant was grown, plant vegetative stage and harvest age, and the fraction used (leaves, stem or stem + leaves, pulp, whole fruit) in the making of the meal or flour (Brito et al. 2005; Arruda et al. 2010). These variations in chemical composition imply differences in the nutrient metabolizability coefficients and AME and AMEn values of the feedstuffs.

The chemical composition of the moringa leaf meal evaluated in the present study (89.63% DM, 15.02% CP, 3.21% EE, 12.50% MM and 3781 Kcal/kg GE) revealed lower values than that determined by Macambira (2016), who found 90.17% DM, 18.31% CP, 8.65% EE, 11.10% MM and 4526 Kcal/kg GE in the ingredient.

As regards the chemical and energy composition of bocaiuva pulp, a slight variation was observed for the CP, EE and MM levels in relation to literature descriptions. Similar DM and GE values were reported by Almeida (1998): 91.3% and 4632 Kcal/kg, respectively. However, that author observed values lower than those obtained in the current study for CP, EE and MM (2.65, 8.46 and 3.45%, respectively).

Variations were also observed in the chemical and energy composition of corn and soybean meal compared to literature descriptions. Nutrient and energy levels lower than those found in the current experiment were reported by Rostagno et al. (2017), i.e., 88.1% DM, 44.4% CP, 0.52% EE, 5.19% MM and 4,051 Kcal/kg GE in soybean meal; and 87.0% DM, 6.92% CP, 3.22% EE, 0.94% MM and 3,865 Kcal/kg GE in corn. However, those values were obtained with fast-growing broilers.

Values lower than those reported in the present study were observed by Santos et al. (2012), who found 89.62% DM, 8.41% CP, 4.64% EE, 1.20% MM and 3947 Kcal/kg GE in corn. Ramos (2012), on the other hand, observed 88.50% DM, 47.70% CP, 3.24% EE, 6.51% MM and 4267 Kcal/kg GE in soybean meal, which are similar to the present findings.

With respect to the minimum and maximum temperature and relative humidity means, the birds were found to be under moderate heat stress, especially in the grower phase. The thermal comfort zone varies according to age: in the first seven days of age, it is 32 °C; from the 8th to the 14th day, 29 °C; from the 15th to the 21st day, 26 °C; and from the 22nd to the 30th day of age, 23 °C (Globoaves 2015).

After the period of maturation of the thermoregulatory system, the chicken, like other homeothermic animals, maintains its body temperature constant over variations in the

environment. However, when the physiological and behavioral responses to high temperatures are inadequate, body temperature increases (Yahav et al. 1998) and, in an attempt to mitigate this increase in body temperature, broilers minimize endogenous heat production by reducing their intake, which then leads to a decrease in nutrient and energy metabolizability (Yahav et al. 2005; Welker et al. 2008).

The observed MCDM and MCCP of moringa leaf meal were lower than those reported by Macambira et al. (2018), who found the respective values of  $76.8 \pm 6.6$  and  $71.7 \pm 7.3$  in fast-growing broilers (Cobb 500) at 14 days of age. Slow-growing broilers may exhibit different nutrient utilization patterns due to a lower growth rate associated with the formation of digestive organs and enzyme production, which occur at a different rhythm when compared to fast-growing birds

The MCDM, MCCP and MCEE of corn obtained in the present experiment from 19 to 26 days of age were lower than the 88.99, 88.19 and 92.29%, respectively, reported by Santos (2012). Those authors also observed higher MCDM, MCCP and MCEE in soybean meal: 49.7, 71.45 and 46.74%, respectively, in slow and fast-growing broilers (Isa Label and Cobb lines) at different ages.

Of the metabolizability coefficients determined in this study (MCDM, MCCP and MCEE), MCCP was the lowest ( $P < 0.05$ ) in all evaluated feedstuffs. The presence of antinutritional factors such as dietary fiber components, phenolic compounds and enzyme inhibitors modify digestion and chemical reactions, thereby altering the release of amino acids and proteins through enzymatic processes (Hiane 2006). The presence of fiber, especially structural polysaccharides of cell walls and their interactions with protein, may reduce the accessibility of protein to proteolysis, reducing its metabolizability (Melito and Tovar 1995; Galland-Irmouli et al. 1999).

The AME and AMEn values of moringa leaf meal, bocaiuva pulp, corn and soybean meal were higher when determined in older birds. This assertion is corroborated by the findings of Batal and Parsons (2002), Sakomura et al. (2004), Mello et al. (2009) and Santos et al. (2012). A linear increase in pancreatic amylase, trypsin and lipase with the advance of age was observed by Sakomura et al. (2004). In their study, the greatest increase was observed in the second week of age, which coincides with the period of greatest digestive enzyme activity, demonstrating that the older the bird is, the better the utilization of dietary energy.

The AME values of moringa leaf meal were lower than the 2978 Kcal/kg and 2725 Kcal/kg described by Olugbemi et al. (2010) and Nkakwana et al. (2014), respectively.

The current AME and AMEn results for corn and soybean meal differ from those reported by Mello et al. (2009), who measured those variables in corn in broilers in the periods of 10 to 17 days (starter phase), 26 to 33 days (grower phase) and 40 to 47 days of age (finisher phase). The said authors found AME and AMEn values of 3167 and 3168 Kcal/kg in the starter phase, 3144 and 3135 Kcal/kg in the grower phase and 3390 and 3389 Kcal/kg in the finisher phase, respectively. These results are lower than those obtained in the present study, which may be explained by the fact that those authors used fast-growing lines, whose rearing

phases are different from those of slow-growing lines. Likewise, the above-mentioned authors found lower AME and AMEn values with soybean meal: 1759 and 1748 Kcal/kg in the starter phase, 2206 and 2192 Kcal/kg in the grower phase and 2247 and 2296 kcal/kg in the finisher phase, respectively.

Overall, in view of the existing differences in growth rate between lines and variations in the AME and AMEn coefficients between the feedstuffs evaluated at different ages, further studies are warranted to investigate the metabolizability of ingredients used in the formulation of diets for slow-growing broilers so that food composition tables can be improved with energy values determined according to the bird's age.

In this context, it is concluded that AME and AMEn values of moringa leaf meal range between 2557 and 2868 Kcal/kg and 2205 and 2479 Kcal/kg, respectively, while the AME and AMEn values of bocaiuva pulp vary from 2680 to 3119 Kcal/kg and 2483 to 2490 Kcal/kg, respectively.

The alternative ingredients can thus be used in the formulation of diets for slow-growing broilers to partially replace corn and soybean meal.

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