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Moringa leaf meal in diets of slow-growing chickens on metabolizability, performance, carcass, organ biometry and meat colorimetry

Farinha de folhas de moringa em dietas de frangos de crescimento lento sobre metabolizabilidade, rendimento, carcaça, biometria de órgãos e colorimetria da carne

VÁSQUEZ[1], José Virgilio Aguilar
ORCID 0000-0002-0266-3831

RODRIGUES[2], Kênia Ferreira
ORCID 0000-0002-2750-8870

VAZ[2], Roberta Gomes Marçal Vieira
ORCID 0000-0002-5490-5492

ARAÚJO[2], Caroliny Costa
ORCID 0000-0001-6252-5687

MACHADO[2], Shayanne Batista
ORCID 0000-0002-3564-1719

PINEDO[1], William Celis
ORCID 0000-0001-6396-6177

[1]Universidad Nacional Autónoma de Alto Amazonas (UNAAA), Facultad de Ingeniería – Programa de Estudios de Zootecnia – Departamento Académico de Ciencias Agropecuarias, Calle Prolongación Libertad nº 1220 -1228, Yurimaguas, Loreto, Alto Amazonas Loreto, Peru
[2]Universidade Federal do Norte do Tocantins (UFNT), Escola de Medicina Veterinária e Zootecnia, Departamento de Zootecnia, Campus de Araguaína, BR-153, Km 112, s/nº, Caixa Postal 132, CEP 77804-970 Araguaína, TO, Brasil
*Mail for correspondence: jaguilar@unaaa.edu.pe

ABSTRACT

Two investigations were developed. The first experiment was to determine the metabolizability of Moringa (*Moringa oleifera*) leaf meal. 120 slow-growing, 21-day-old chickens were used. The experimental period was seven days, four for adaptation to diets and three for collection of excreta. The Moringa leaf presented values for apparent metabolizability coefficients of dry matter, crude protein, crude energy and neutral detergent fiber, as well as apparent metabolizable energy and corrected metabolizable energy for a nitrogen balance, of 49.77%, 44.48%, 46.26% and 53.02%, and 2,334 kcal/kg, 2,159 kcal/kg respectively. The second experiment was to evaluate the inclusion of Moringa leaf meal in the diets of two hundred and forty slow-growing chickens from one to 80 days of age on performance, carcass characteristics, biometrics of digestive organs and meat color. The experimental design was completely randomized with four treatments (0.75%; 1.50%; 2.25% and 3.00% inclusion of the Moringa leaf), six repetitions and ten chickens per experimental unit; the inclusion levels of the Moringa leaf did not influence ($p > 0.05$) feed intake, weight gain, feed conversion, final weight at 30, 60 and 80 days, carcass, noble cut yields and meat color. The inclusion of Moringa leaf meal can be used up to the 3% level in slow-growing chicken diets, without affecting the productive performance of these animals.
Keywords: alternative food; meat quality; ration.

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RESUMO

Duas investigações foram desenvolvidas. O primeiro experimento foi para determinar a metabolizabilidade da farinha de folhas da moringa (*Moringa oleifera*), foram utilizadas 120 frangos de crescimento lento com 21 dias de idade, o período experimental foi de sete dias, quatro para adaptação às dietas e três para coleta de excretas; a folha de moringa apresentou valores para coeficientes de metabolizabilidade aparente de matéria seca, proteína bruta, energia bruta e fibra em detergente neutro, e energia metabolizável aparente, e energia metabolizável corrigida para balanço de nitrogênio de 49.77%, 44.48%, 46.26% e 53.02% e 2,334 kcal/kg, 2,159 kcal/kg, respectivamente. O segundo experimento teve como objetivo avaliar a inclusão de farinha de folha de moringa em dietas de duzentos e quarenta frangos de crescimento lento de um a 80 dias de idade sobre o desempenho, características de carcaça, biometria dos órgãos digestivos e cor da carne; o delineamento experimental foi inteiramente casualizado com quatro tratamentos (0.75%; 1.50%; 2.25% e 3.00% de inclusão de folha de moringa), seis repetições e dez frangos por unidade experimental; os níveis de inclusão da folha de moringa não influenciaram (p>0,05) o consumo de ração, ganho de peso, conversão alimentar, peso final aos 30, 60 e 80 dias, carcaça, rendimento de cortes nobres e cor da carne. A inclusão de farelo de folhas de moringa pode ser utilizada até o nível de 3% em rações para frangos de crescimento lento, sem afetar o desempenho produtivo desses animais.
Palavras-chave: alimentação alternativa; qualidade da carne; ração

INTRODUCTION

Advances in genetic improvement combined with nutrition, health and management techniques resulted in the high efficiency and organization of current aviculture to produce animal protein of high biological value for human consumption at low cost (Fernandes et al., 2012; Gobezle 2021). Food is one of the factors that most affects costs and is related to the variation in the availability of ingredients used in feed (Hauschild et al., 2010). The use of alternative foods in animal species is increasingly promising due to their nutritional quality, digestibility, bioactive compounds, the potential for cultivation in the tropics and affordable costs that promote the sustainable development of animal production. Replacing ingredients such as cereals, grains and oilseeds without changing performance at a lower cost has a beneficial result. Likewise, it is essential to know the energy value of foods so that formulations can aim at optimal animal performance (Sakomura and Rostagno, 2016). Legume leaves are necessary food resources for providing additional nutrients and bioactive compounds with beneficial effects on health and productivity (Sebola et al., 2015) and their inclusion in bird diets functions as a growth promoter (Movahhedkhah et al 2019). As a source of vegetable protein, it is the cheapest and most naturally abundant in these tree species, while also standing out for their high nutrient content. Therefore, its use in the feeding of non-ruminant animals is an alternative to replace conventional ingredients used in these species' diet (Iheukwumere et al., 2008; Gadzirayi et al., 2012). Moringa oleifera is a plant with a nutritional potential and applicability in animal feed; it is widely spread around the world and has characteristics that favor it as an alternative in poultry feed. Furthermore, in its nutritional profile, the leaves present high levels of essential compounds such as proteins, minerals and vitamins, in addition to the presence of bioactive compounds (Macambira et al., 2018). Some authors have demonstrated its ability to improve growth, weight gain and carcass performance in broiler chickens (Zanu et al., 2012; Nkukwana et al., 2014, Macambira et al. 2022). The aim of this study was to determine the nutritional value of Moringa leaf meal and its inclusion for increasing performance levels, yield in carcass and main cuts, the biometry of edible viscera and the colorimetry of the skin and meat of slow-growing chickens.

MATERIAL AND METHODS

Two experiments were conducted in the Poultry Sector at the School of Veterinary Medicine and Animal Science of the Federal University of Tocantins (FUT), located in Araguaína – TO/Brazil. The research project was approved and registered with the FUT Animal Use Ethics Committee, under nº 23.101.003.440/2019-02.

The first bioassay was carried out from November 10th to December 7th, 2019. One hundred and twenty slow-growing 21-day-old chicks (bare redneck) were used in a mixed batch, with an average weight of 559.09 ± 68.49 g. The birds were distributed in metallic batteries (1.00 x 1.00 x 0.40m) equipped with trough-type feeders and drinking troughs, which were cleaned and supplied twice daily to guarantee free access to water and feed throughout the trial period. From the 1st to the 20th day of age, the broilers received starter feed based on corn and soybean meal (Table 1); and from the 21st day on, the birds started to consume the experimental feed.

Table 1. Composition of basal diet provided to slow-growing broilers from 1 to 28 days of age.

Ingredients (g/100g)	Percent of composition of diet
Corn	56.490
Soybean meal	36.900
Inert	2.297
Dicalcium phosphate	1.910
Calcitic limestone	1.210
Common salt	0.568
L-Lysine HCl 78%	0.055
DL-Methionine 99%	0.266
Premix[(1)]	0.240
L-Threonine 98.5%	0.064
TOTAL	100.000
Nutrients (%)	Chemical composition of diet g/kg
Metabolizable energy (Mcal/kg of diet)	2.75
Crude protein	21.48

Calcium	1.061
Available phosphorus	0.450
Sodium	0.240
Chlorine	0.400
Potassium	0.860
Electrolytic balance (mEq/kg)[2]	211.430

[(1)]Composition/tonne: Folic Acid 150 mg, Cobalt 178 mg, Copper 2,675 mg, Choline 120 g, Iron 11 g, Iodine 535 mg, Manganese 31 g, Mineral matter 350 g, Niacin 7,200 mg, Calcium Pantothenate 2,400 mg, Selenium 60 mg, Vitamin A 1,920,000 IU, Vitamin B_1 300 mg, Vitamin B_{12} 3,600 mg, Vitamin B_2 1,200mg, Vitamin B_6 450mg, Vitamin D_3 360,000 IU, Vitamin E 3,600 IU, Vitamin K 480 mg, Zinc 22 g.
[2]Calculated according to Mongin (1981): Electrolytic scale = (mg/kg of Na + /22,990 feed) + (mg/kg of K + /39,102 feed) - (mg/kg of feed Cl - /35,453).

The experimental design was completely randomized, with two treatments, six replications and ten birds per experimental unit. The treatments were 1) reference diet in order to meet the nutritional requirements for this phase, according to Pinheiro et al. (2014); and 2) 80% reference diet + 20% Moringa leaf meal.
Moringa leaves were collected from a previously established planting plot close to the poultry breeding area. Then they were dried in a circulation oven at 55 °C for 48 hours to preserve their nature and nutritional value and processed in a Willey type mill with a 2 mm sieve.
The experimental period consisted of seven days: four days of feed adaptation and three days of total excreta collection (Rodrigues et al., 2005). Trays covered with plastic canvas were placed on the floor under each cage for the total collection of excreta (Sibbald, 1976; Sibbald and Slinger, 1963) and carried out twice a day (at 8 am and 4 pm) to avoid fermentation, according to Sakomura and Rostagno (2016). After each collection, the excreta were placed in plastic bags, correctly identified and stored in a freezer.
At the end of the experimental period, the amounts of feed consumed and the total excreta produced were estimated. Afterwards, the samples were thawed, homogenized, dried in a circulation oven at 55 ºC for 72 hours, processed in a Willey-type mill with a 1 mm sieve, and analyzed in the laboratory. Samples of experimental feed, excreta and ingredients were analyzed at the Animal Nutrition Laboratory of the School of Veterinary Medicine and Animal Science of the Federal University of Tocantins. For the determination of dry matter (DM), mineral matter (MM), crude protein (CP), and gross energy (GE), according to the methodologies described by Silva and Queiroz (2006) and to determine the neutral detergent fiber (NDF), the methodology of EMBRAPA (1999) was used. After analyzing the collected materials (excreta and rations), the apparent metabolizable energy (AME), the corrected apparent metabolizable energy for the nitrogen balance (AMEn) according to Sakomura and Rostagno (2016), and the apparent metabolizability coefficients of the dry matter (MCDM), crude protein (MCCP), crude energy (MCCE) and neutral detergent fiber (MCFDN) from basal, experimental and Moringa leaf diets, according to Matterson et al. (1965), were determined.

The second bioassay was carried out from September 27 to December 16, 2020. Two hundred and fifty slow-growing chicks (bare redneck) from one to 80 days of age, with an initial average weight of 40.00 ± 0.33 g, were used. During the first 30 days, the birds were distributed in metallic batteries (1.00 x 1.00 x 0.40m) equipped with trough-type feeders and drinkers, which were cleaned and supplied twice daily to guarantee free access to water and rations throughout the trial period. On the 30th day, the birds were distributed in experimental paddocks (5.00m x 7.00m), surrounded with screens and equipped with small wooden shelters (2.00m x 1.50m) and a clay tile roof containing a tubular feeder and an automatic gutter-type handcrafted drinker. Each experimental paddock was 35 m², an area that was larger than the recommendation of 0.5 m²/bird (ABNT, 2015). Moringa leaves were obtained from a plantation located in the FUT poultry sector. The leaves were dehydrated under shade at room temperature, then dried in a forced ventilation oven for 48 hours at 55 degrees, and finally crushed in an electric mill with a 2 mm sieve, and mixed in order to achieve a uniform mixture.

Four dietary treatments were designed with the increasing inclusion of the Moringa leaf: treatment 1) 0.75% inclusion; treatment 2) 1.50% inclusion; treatment 3) 2.25% inclusion; and treatment 4) 3.00% inclusion. The experimental diets were calculated considering the nutritional requirements recommended by Pinheiro et al. (2014) for slow-growing chicken in the phases from 1 to 30, 31 to 60 and 61 to 80 days (Table 2).

The bromatological values of the ingredients and experimental diets, determined in the Animal Nutrition Laboratory at the School of Veterinary Medicine and Animal Science at FUT, are shown in tables 3, 4 and 5. At 30, 60 and 80 days, chickens and feed were weighed to determine their performance. The variables evaluated were feed intake (FI), weight gain (WG), feed conversion (FC), final weight (FW), carcass yield (CY), prime cut yield (breast, thigh, drumstick and wing), biometrics of edible viscera (heart, liver, gizzard), lymphoid organs (spleen and bursa), abdominal fat, weight and length of the small intestine, luminosity (L*), red (a*), yellow (b*) and pH of the skin and breast meat.

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Table 2. Composition of experimental diets in the initial, growth and finishing phases (1 to 30, 31 to 60 and 61 to 80 days) with increasing levels of inclusion of Moringa leaf for slow-growing chickens

Ingredients	Inclusion levels of Moringa leaf (%)											
	1 to 30 days				31 to 60 days				61 to 80 days			
	0.75	1.50	2.25	3.00	0.75	1.50	2.25	3.00	0.75	1.50	2.25	3.00
Corn	56.060	55.722	55.384	55.046	63.285	62.949	62.613	62.277	74.523	73.832	73.140	74.449
Soybean meal	3	4	6	7	9	8	6	4	5	2	9	5
Inert	35.807	35.545	35.284	35.023	29.284	29.012	28.741	28.469	21.412	21.210	21.007	20.805
Dicalcium phosphate	1	9	6	4	6	9	3	7	4	2	9	6
Limestone	3.2454	3.0763	2.9072	2.7382	2.8413	2.6747	2.5080	2.3414	0.9261	0.9251	0.9240	0.9230
Moringa leaf	1.8223	1.8264	1.8305	1.8347	1.4580	1.4622	1.4665	1.4707	0.9173	0.9224	0.9274	0.9325
Common salt	1.2413	1.2411	1.2409	1.2406	1.2154	1.2152	1.2150	1.2148	0.7500	1.5000	2.2500	3.0000
DL-Methionine	0.7500	1.5000	2.2500	3.0000	0.7500	1.5000	2.2500	3.0000	0.5433	0.6634	0.7835	0.9036
Supplement Vitam. and	0.5004	0.5012	0.5019	0.5026	0.4160	0.4167	0.4174	0.4182	0.4242	0.4250	0.4259	0.4268
Min.[(1)(2)]	0.2824	0.2865	0.2906	0.2947	0.2881	0.2923	0.2965	0.3008	0.1704	0.1750	0.1796	0.1842
L-Lysine HCl	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
L-Threonine	0.0908	0.1002	0.1096	0.1191	0.1946	0.2044	0.2141	0.2239	0.1266	0.1350	0.1434	0.1519
	0.0000	0.0000	0.0000	0.0000	0.0660	0.0718	0.0775	0.0832	0.0062	0.0118	0.0174	0.0230
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nutrients (%)	Chemical composition of diet g/kg dried matter											
Metab. energy (Mcal/kg of diet)	2.75	2.75	2.75	2.75	2.85	2.85	2.85	2.85	3.10	3.10	3.10	3.10
Crude protein	21.50	21.50	21.50	21.50	19.30	19.30	19.30	19.30	16.50	16.50	16.50	16.50
Calcium	1.06	1.06	1.06	1.06	0.94	0.94	0.94	0.94	0.67	0.67	0.67	0.67
Available phosphorus	0.45	0.45	0.45	0.45	0.38	0.38	0.38	0.38	0.27	0.27	0.27	0.27
Sodium	0.24	0.24	0.24	0.24	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.21
Lysine digestible birds	1.09	1.09	1.09	1.09	1.02	1.02	1.02	1.02	0.79	0.79	0.79	0.79
Threonine digestible birds	0.72	0.71	0.71	0.70	0.69	0.69	0.69	0.69	0.55	0.55	0.55	0.55

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Methio. + Cistyn. digestible	0.86	0.86	0.86	0.86	0.82	0.82	0.82	0.82	0.65	0.65	0.65	0.65

(1) Chemical composition starting phase. Warranty levels: Calcium (min) 150.00 g / kg; calcium (max) 230.00 g / kg; phosphorus (min) 44.00 g / kg; sodium (min) 30.00 g / kg; iron (min) 600.00 mg / kg; copper (min) 2.405.00 mg / kg; zinc (min) 1,000.00 mg / kg; manganese (min) 1,400.00 mg / kg; iodine (min) 20.00 mg / kg; selenium (min) 7.00 mg / kg; cobalt (min) 4.00 mg / kg; vitamin A (min) 260,000.00 IU / kg; vitamin D3 (min) 65,000.00 IU / kg; vitamin E (min) 455.00 IU / kg; vitamin K3 (min) 52.00 mg / kg; vitamin B1 (min) 39.00 mg / kg; vitamin B2 (min) 195.00 mg / kg; niacin (min) 650.00 mg / kg; pantothenic acid (min) 390.00 mg / kg; vitamin B6 (min) 52.00 mg / kg; folic acid (min) 13.00 mg / kg; biotin (min) 1.50 mg / kg; vitamin B12 (min) 390.00 mcg / kg; choline (min) 10.00 g / kg; methionine (min) 28.00 g / kg; phytase (min) 10,000.00 IU / kg; nicarbazine 1,000.00 mg / kg; narasin 1,000.00 mg / kg; halquinol 600.00 mg / kg.

(1)Chemical composition growth and finishing phase. Warranty levels: Calcium (min) 165.00 g / kg; calcium (max) 200.00 g / kg; phosphorus (min) 35.00 g / kg; sodium (min) 30.00 g / kg; iron (min) 600.00 mg / kg; copper (min) 2,672.00 mg / kg; zinc (min) 1,000.00 mg / kg; manganese (min) 1,400.00 mg / kg; iodine (min) 20.00 mg / kg; selenium (min) 7.00 mg / kg; cobalt (min) 4.00 mg / kg; vitamin A (min) 250,000.00 IU / kg; vitamin D3 (min) 62,500.00 IU / kg; vitamin E (min) 625.00 IU / kg; vitamin K3 (min) 50.00 mg / kg; vitamin B1 (min) 37.00 mg / kg; vitamin B2 (min) 185.00 mg / kg; niacin (min) 625.00 mg / kg; pantothenic acid (min) 375.00 mg / kg; vitamin B6 (min) 50.00 mg / kg; folic acid (min) 12.50 mg / kg; biotin (min) 1.50 mg / kg; vitamin B12 (min) 370.00 mcg / kg; choline (min) 6,000.00 mg / kg; methionine (min) 18.30 g / kg; phytase (min) 10,000.00 IU / kg; halquinol 600.00 mg / kg; salinomycin 1,320.00 mg / kg.

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Table 3. Nutritional value of Moringa leaf, corn, soybean meal and experimental diets for the initial phase (1 to 30 days)

Ingredients and diets(1)	Dry matter(2) (%)	Mineral matter (%)	Crude protein (%)	Ether extract (%)	Crude fiber (%)	Neutral detergent fiber (%)	Gross energy (kcal/kg)
Moringa leaf	89.83	9.46	23.49	4.60	8.82	24.32	4,300.10
T1 (0.75% inclusion)	92.19	12.89	24.36	2.35	6.49	29.16	3,653.38
T2 (1.50% inclusion)	92.02	10.56	24.17	2.40	7.64	26.28	3,657.08
T3 (2.25% inclusion)	91.70	12.61	22.18	2.89	8.13	30.90	3,696.61
T4 (3.00% inclusion)	91.93	11.92	25.18	3.13	9.18	25.16	3,766.91

(1)Analyses carried out at the Animal Nutrition Laboratory at the FUT School of Veterinary Medicine and Animal Science; (2)Values expressed on the basis of dry matter

Table 4. Nutritional value of Moringa leaf, corn, soybean meal and experimental diets for the growth phase (31 to 60 days)

Ingredients and diets(1)	Dry matter(2) (%)	Mineral matter (%)	Crude protein (%)	Ether extract (%)	Crude fiber (%)	Neutral detergent fiber (%)	Gross energy (kcal/kg)
Moringa leaf	88.75	9.27	24.71	4.67	8.32	23.78	4,234.75
T1 (0.75% inclusion)	91.05	11.36	20.85	2.43	8.03	22.43	3,599.56
T2 (1.50% inclusion)	90.94	11.42	20.17	3.68	9.18	19.40	3,579.09
T3 (2.25% inclusion)	91.32	11.43	18.10	4.00	8.32	21.87	3,562.26
T4 (3.00% inclusion)	90.61	11.04	18.42	2.90	7.49	21.06	3,634.48

(1)Analyses carried out at the Animal Nutrition Laboratory at the FUT School of Veterinary Medicine and Animal Science; (2)Values expressed on the basis of dry matter

Table 5. Nutritional value of Moringa leaf, corn, soybean meal and experimental diets for the final phase (61 to 80 days)

Ingredients and diets(1)	Dry matter(2) (%)	Mineral matter (%)	Crude protein (%)	Ether extract (%)	Crude fiber (%)	Neutral detergent fiber (%)	Gross energy (kcal/kg)
Moringa leaf	90.08	8.87	25.37	4.97	9.03	24.12	4,201.75
	90.16	5.89	15.89	3.54	5.10	17.70	3,858.67

T1	(0.75%	90.93	5.98	18.16	3.18	5.24	15.44	3,901.04
inclusion)		90.69	5.88	15.56	3.42	4.50	17.47	3,935.56
T2	(1.50%	91.32	6.05	18.22	3.45	5.09	15.87	4,037.64
inclusion)								
T3	(2.25%							
inclusion)								
T4	(3.00%							
inclusion)								

(1)Analyses carried out at the Animal Nutrition Laboratory at the FUT School of Veterinary Medicine and Animal Science; (2)Values expressed on the basis of dry matter

At 80 days of age, two birds from each plot, with body weight close to the average of the plot (± 5%), were subjected to 12-hour fasting and slaughtered by cervical dislocation. They were then subjected to bleeding, scalding, plucking and evisceration procedures. After the previous procedure, the carcasses were submerged for 10 to 15 minutes in PVC buckets (60 liter -capacity) containing water at a temperature of 6 to 10 degrees, maintained by ice blocks, to evaluate the relative weights (%) of the whole carcasses (with feet, neck and head), of prime cuts (chest, thigh, drumstick and wing). The relative weight of the plucked and eviscerated carcass was calculated for the fasting weight.

Edible viscera (gizzard, heart and liver), lymphoid organs (spleen and bursa), small intestine, and abdominal fat from the peritoneal region were collected during evisceration; they were cleaned, dried on paper towels and weighed separately on a precision scale. In addition to weight, the length of the small intestine from the beginning of the duodenum to the ileocecal junction was measured. The relative weights of cuts, edible viscera, lymphoid organs, abdominal fat and small intestine were obtained for the plucked and eviscerated carcass.

In raw meat (without bone, skin, ligaments and fat) and breast skin, coloration was evaluated by the CIELAB system (L*= Luminosity, a*= red content and b*= yellow content) with an apparatus (Chroma meter®). This reading was carried out in three distinct points of the musculature while pH was determined utilizing a penetration electrode placed directly in the breast meat.

The experimental design was completely randomized, with four treatments (0.75, 1.50, 2.25 and 3.00% inclusion of the Moringa leaf), five replicates and ten birds per experimental unit. The data of the variables evaluated were submitted to normality and homoscedasticity tests.

RESULTS AND DISCUSSION

The metabolizable values of dry matter, crude protein, gross energy, neutral detergent fiber, apparent metabolizable energy, corrected for nitrogen balance, (Table 6) in the experimental diet were lower than the basal diet due to the inclusion level of 20%. Sakomura and Rostagno (2016) suggest that the level of food inclusion depends on the type of food with substitutions ranging from 20 to 40%. In this sense, the Moringa leaf has slightly lower metabolization coefficients, expressed by its high fiber content.

Table 6. Metabolizability coefficients of basal ration, experimental ration and Moringa leaf, and their respective standard deviations(1)

Food	MCDM(2) %	MCCP %	MCGE %	MCNDF %	AME (kcal/kg)	AMEn (kcal/kg)
Basal ration	69.17 ± 3.2	54.78 ± 6.9	72.59 ± 2.9	55.68 ± 4.4	3,019 ± 12	2,896 ± 10
Experimental ration	65.29 ± 2.9	52.72 ± 2.9	67.33 ± 2.2	55.15 ± 2.3	2,882 ± 93	2,748 ± 85
Moringa leaf	49.77 ± 14.6	44.48 ± 14.7	46.26 ± 10.9	53.02 ± 11.3	2,334 ± 47	2,159 ± 42

(1)Analyses performed at the Animal Nutrition Laboratory at the FUT School of Veterinary Medicine and Animal Science.
(2)Metabolizability coefficients of dry matter (MCDM), crude protein (MCCP), gross energy (MCGE), neutral detergent fiber (MCNDF), apparent metabolizable energy (AME) and corrected for nitrogen balance (AMEn)

According to Moyo et al. (2011), the chemical composition varies depending on the age of the plant, cultivar, soil type, fertilization, water availability and cutting interval. Soares et al. (2005), report that several factors may affect an ingredient's metabolizable energy and digestibility coefficients. These factors include the age of the birds, the chemical composition, the level of inclusion of the test ingredient, the consumption rate, the methodology used to determine the coefficients and possible antinutritional factors of foods. As a livestock feed, Moringa supplementation is beneficial and its leaves are highly nutritious; the components most commonly found are the complexes of vitamin B, vitamin C, beta-carotene, vitamin K, manganese and protein (Gobezle 2021).

The inclusion of Moringa leaf meal (Sebola et al. 2017) in Potchefstroom koekoek and Ovambo chicken strains does not affect digestibility, while in the Black Australop strain digestibility seems to be reduced. Hence, its use as a main component of diets of free-range chicken strains is recommended. Macambira et al. (2018), when working with Cobb-500 lineage chickens from 14 to 22 days of age fed with Moringa leaf bran, replacing 20% of the reference diet, found metabolizability values of dry matter (76.8), crude protein (71.7) and gross energy (85.4) that were very close to those found in this assay.

The inclusion of the Moringa leaf in rations for slow-growing chickens did not affect (P>0.05) feed intake, weight gain, and feed conversion of birds at 30, 60 and 80 days (Table 7).

Table 7. Average values of feed intake, weight gain, feed conversion and final weight of slow-growing chickens at 30, 60 and 80 days fed with inclusion of Moringa leaf

Variable	Inclusion of Moringa leaf (%)					P values			CV[4]
	0.75	1.50	2.25	3.00	General mean	LE[1]	QE[2]	LMF[3]	
1 at 30									
Feed intake (kg)	1.417	1.497	1.454	1.490	1.464	0.385	0.623	0.317	6.74
Weight gain (kg)	0.754	0.793	0.772	0.776	0.774	0.717	0.528	0.484	7.77
Feed conversion	1.880	1.888	1.887	1.925	1.895	0.274	0.588	0.683	3.11
Final weight at 30 days (kg)	0.794	0.833	0.811	0.816	0.814	0.716	0.533	0.482	7.39
1 at 60									
Feed intake (kg)	4.987	5.204	5.062	4.973	5.056	0.754	0.257	0.490	5.76
Weight gain (kg)	1.936	2.140	2.064	2.015	2.039	0.574	0.059	0.288	6.85
Feed conversion	2.579	2.431	2.464	2.469	2.486	0.267	0.203	0.435	5.20
Final weight at 60 days (kg)	1.976	2.180	2.104	2.055	2.079	0.573	0.060	0.288	6.71
1 at 80									
Feed intake (kg)	8.019	8.599	8.270	8.216	8.276	0.830	0.248	0.331	7.15
Weight gain (kg)	2.492	2.922	2.662	2.733	2.702	0.258	0.060	0.020	7.32
Feed conversion	3.220	2.944	3.121	3.007	3.073	0.214	0.324	0.054	5.80
Final weight at 80 days (kg)	2.532	2.962	2.701	2.773	2.742	0.258	0.060	0.020	7.22

(1)Linear effect; (2)Quadratic effect; (3)Lack of model fit; (4)Coefficient of variation

According to Oliveira et al (2020), *M. oleifera* can be an alternative for animal feed since, in addition to nourishment, it has bioactive compounds that can enable better performance and digestibility results. Macambira et al. (2018) showed that the inclusion of dry Moringa leaves with levels of 0, 1.5, 3.0, 4.5 and 6.0% in broilers from 10 to 40 days of age did not affect the zootechnical performance except for feed conversion in the period from 10 to 35 days, where a linear effect was observed. Similar effects were recorded by Gómez et al. (2016) when they worked with levels between 0 to 10% of inclusion in the finishing phase of broiler chickens. Different results were found by Sebola et al. (2015) where they verified the influence of the addition of the Moringa leaf with inclusion levels of 0, 25, 50 and 100 g/kg of DM in three slow-growing broiler lines

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(Potchefstroom Koekoek, Ovambo and Black Australorp), positively affecting performance. Similarly, Hassan et al. (2016) evaluated the productive performance of broilers using inclusion levels of 0.1%, 0.2% and 0.3%; results showed that the weight gain, feed intake and feed conversion increased as the level increased.

A result contrary to this study was obtained by Kavoi et al. (2016) who noted that amounts equal to or greater than 15% of Moringa leaf flour in broiler diets interfered with intestinal structure and weight gain. Along the same lines, Tesfaye et al. (2013) determined that the Moringa leaf can replace soybean meal in part - up to 5% - above which it affects performance. According to Ash and Petaia (1992), levels of leaf flour above 10% in broiler rations promote worsening feed conversion, a decrease in weight gain and an increase in animal consumption. The present research did not observe these effects, as the maximum inclusion level was 3%. Results allow us to state that the lack of effects on the performance of chickens may be related to the fact that the experimental diets meet the nutritional requirements of the birds in all evaluated treatments, regardless of the inclusion level. In addition, the Moringa is characterized by containing moderate amounts of protein and fiber, causing higher feed consumption, and consequently, a better response. According to research by Nkukwana et al. (2014), *Moringa oleifera* leaves act as a performance promoter, reflecting their effects on improving feed efficiency in the growth phase of birds.

The inclusion of the Moringa leaf in the feed of slow-growing chickens did not influence (P>0.05) carcass yield, nor the breast, thigh, drumstick and wing of chickens slaughtered at 80 days of age (Table 8).

According to Evaris et al. (2022) when working with slow-growing 107 Dominant Blue D male chickens raised with outdoor access in a tropical climate, fed with 3 and 6 g of Moringa leaf meal/kg of feed, from 72 days for 7 weeks, carcass yields (64.5 and 65.7%) lower than those reported in this trial were obtained (84.87%). This explains that the differences between studies in carcass yield are due to the different biological materials and diets used in each experiment, as well as the climate and environment where the tests are carried out, which can affect both animal performance and the composition of the Moringa. Similar results were found by Hassan et al. (2016), Gómez et al. (2016) and Macambira et al. (2018) when they evaluated carcass yield and prime cuts in broilers fed with increasing levels of Moringa leaf, where differences in the tested levels were not observed.

Table 8. Mean carcass yield and noble cuts of chickens slaughtered at 80 days of age, fed with the inclusion of Moringa leaf

Variable (%)	Inclusion of Moringa leaf (%)				General mean	P values			CV$^{(4)}$
	0.75	1.50	2.25	3.00		LE$^{(1)}$	QE$^{(2)}$	LMF$^{(3)}$	
Carcass	84.35	85.64	84.55	84.94	84.873	0.873	0.627	0.358	241
Breast	4	7	2	0	27.031	0.623	0.597	0.498	6.77
Thigh	27.40	27.28	26.34	27.10	13.588	0.373	0.969	0.851	4.43
Drumstick	1	4	8	5	14.480	0.478	0.275	0.048	3.04

Wing	13.429	13.504	13.683	13.737	10.448	0.017	0.062	0.007	2.95
	14.589	14.053	14.684	14.593					
	10.433	9.946	10.673	10.739					

(1)Linear effect; (2)Quadratic effect; (3)Lack of model fit; (4)Coefficient of variation

Breast muscle has more protein than fat; therefore, an excess of amino acids from Moringa leaf meal can increase protein synthesis in this type of muscle and promote its development (Evaris et al. 2022) - these author's results are similar to ours. Kumar and Pareek (2021) state that higher breast muscle weight could be attributed to higher protein deposition in birds fed Moringa-supplemented diets. The inclusion of Moringa in the diet did not have a significant effect on leg performance (thigh and drumstick) or on wing performance. However, they are lower than those reported by Evaris et al. (2022) because this author raised the chickens up to 114 days of age, which allowed a higher yield for these cuts.

The inclusion levels of the Moringa leaf did not affect ($p>0.05$) the mean values of the heart, liver, gizzard, abdominal fat, weight and length of the small intestine, spleen and bursa (Table 9).

Table 9. Relative weight of organs of chickens slaughtered at 80 days of age, fed with the inclusion of Moringa leaf

Variable (%)	Inclusion of Moringa leaf (%)				General mean	P values			CV(4)
	0.75	1.50	2.25	3.00		LE(1)	QE(2)	LMF(3)	
Heart	0.477	0.513	0.497	0.479	0.492	0.894	0.203	0.593	9.30
Liver	1.967	1.846	1.874	1.887	1.894	0.472	0.311	0.579	7.58
Gizzard	1.547	1.405	1.561	1.539	1.513	0.706	0.449	0.188	11.43
Abdominal fat	2.415	2.994	2.570	2.311	2.573	0.726	0.377	0.579	40.18
Small intestine	3.941	3.657	3.465	3.935	3.750	0.833	0.102	0.566	12.95
Small intestine length	181.3	184.2	170.4	178.8	178.7	0.533	0.717	0.261	9.34
Spleen	0.149	0.138	0.133	0.142	0.140	0.496	0.273	0.847	13.94
Bursa	0.115	0.088	0.092	0.090	0.096	0.387	0.518	0.656	42.42

(1)Linear effect; (2)Quadratic effect; (3)Lack of model fit; (4)Coefficient of variation

The development and functionality of the gastrointestinal tract in chickens are of paramount importance, as they can affect feed efficiency. There are

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differences in the results found by various authors on the use of Moringa on the weight and performance of the gizzard, liver or heart of broiler chickens. According to González-Alvarado et al. (2010), the normal development of the gizzard is significant for the bird, since it works as one of the factors that regulate the motility of the gastrointestinal tract. Thus, its inadequate development can affect the digestibility of nutrients and, as a consequence, bird performance; in the present study, no differences were found in the relative weight of the gizzard. Nkukwana et al. (2014) found no significant difference in the relative weight of the heart, gizzard, liver, pancreas and spleen of 35-day-old broilers fed diets containing increasing levels of Moringa bran (1, 3, and 5%) except for the bursa, which tended to increase at a 5% level. Zanu et al. (2012) found no difference in the yield of digestive organs for chickens fed with rations containing Moringa. However, these authors observed a linear increase in the yield of abdominal fat with the increase of Moringa in diets, a fact that was not observed in this study.

The inclusion levels of Moringa leaf bran in the rations for slow-growing chickens did not affect (p>0.05) the luminosity values (L*), red (a*), yellow (b*) and the pH values of the skin and breast meat (Table 10).

Table 10. Mean values of luminosity (L*), red (a*), yellow (b*), pH, skin and breast meat of slow-growing chickens slaughtered at 80 days of age, fed with the inclusion of Moringa leaf

Variable	Inclusion of moringa leaf (%)					P values			
	0.75	1.50	2.25	3.00	General mean	LE$^{(1)}$	QE$^{(2)}$	LMF$^{(3)}$	CV$^{(4)}$
	Skin								
L* (Luminosity)	70.26	69.88	70.25	69.56	69.99	0.56	0.82	0.54	2.08
a* (Red)	7.62	7.43	7.01	7.47	7.38	0.57	0.36	0.49	10.46
b* (Yellow)	10.15	14.01	12.77	11.77	12.18	0.41	0.02	0.23	17.52
	Meat								
L* (Luminosity)	59.59	59.54	60.15	57.71	59.25	0.12	0.10	0.24	2.58
a* (Red)	9.32	9.15	9.12	9.38	9.24	0.93	0.57	0.93	9.05
b* (Yellow)	9.47	12.40	12.87	13.95	12.17	0.17	0.67	0.75	39.27
pH	6.13	5.95	5.93	6.15	6.04	0.94	0.05	0.84	3.44

(1)Linear effect; (2)Quadratic effect; (3)Lack of model fit; (4)Coefficient of variation

A pH of 6.23 corresponds to a darker color; pH 5.96 to a standard color; and pH 5.81 to a light color (Qiao et al., 2001). According to this classification, the average pH found in this work was 6.04, corresponding to the standard color. The content of (L*) above 53 is classified as lighter than standard meat, which should be between 48 and 53. Hence, the meat classification found in this work can be characterized as "lighter", evidenced by the highest values of (L*) (Qiao et al., 2001). Meat gloss or luminosity can be induced by several conditions, resulting from the selective absorption of light by myoglobin and other components such as muscle fibers, proteins, and pH values, in addition to the fluids that are part of the meat tissue (Gaya and Ferraz, 2006). In the present study, no effects were found on the parameter's luminosity, a*, b* and pH in the meat. According to Ahmad et al. (2018), Moringa leaves are rich in carotenoids (15.25 mg of β-carotene in 100 grams of dry leaves), essential precursors of vitamin A when present in the feed. They can be deposited in meat, thus making the carcasses more yellowish.

Moringa leaf metabolizability coefficients were determined and expressed in dry matter. The inclusion of Moringa leaves could be used up to a 3% level in slow-growing chicken diets from one to 80 days of age without affecting performance characteristics.

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