Acta Scientiarum

http://periodicos.uem.br/ojs
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v45i1.61209

NONRUMINANT NUTRITION

Effects on meat quality of Yerba mate (*Ilex paraguariensis*) in the diet of chickens

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ABSTRACT. The objective is to evaluate the effects of the inclusion of yerba mate in the diet on the yield and quality of chicken meat stored frozen for 120 days after slaughter. The birds were distributed in a completely randomized design, with four treatments, and eight replications with 25 birds each. The treatments consisted of providing a basal diet with 1, 2, 4, and 6 g kg^{-1} of ground dehydrated Yerba mate. At slaughter, temperature, pH, and carcass yield were measured. 120 days after meat freezing, measurements of pH, colorimetry, cooking weight loss (CWL), shear force, and water retention capacity were estimated. The parameters evaluated after slaughter showed regression effects on breast and drumstick temperature. Breast temperature showed a decreasing linear effect (R^2=0.61). For the variable thigh temperature, there was a negative quadratic effect (R^2=0.66). The quality characteristics of breast and drumstick evaluated 120 days after freezing showed an increasing linear effect of drumstick CWL (R^2=0.38). Yerba mate can be included in up to 6 g kg^{-1} in chicken feed without changing pH, color, and meat tenderness after 120 days of freezing, maintaining carcass and cut yields.

Keywords: additive; antioxidant; storage; phytogenic; pH.

Received on October 14, 2021.
Accepted on April 18, 2022.

Introduction

Phytogenic additives are often researched as for their beneficial properties in animal feed because they improve performance, immunity, and quality of the final product (Benamirouche et al., 2020). In addition, compared to the use of performance-enhancing antibiotics, they promote an improvement in meat quality (Hazrati, Rezaeipour, & Asadzadeh, 2020).

The antioxidant activities of some phytogenics decrease the oxidative degradation of food by free radicals, favoring a longer shelf life (Koiyama et al., 2014). Chicken meat, compared to beef and pork, is more susceptible to lipid oxidation, as it has a higher proportion of polyunsaturated fatty acids in its composition, which originates free radicals and forms cholesterol oxides, changing the fatty acid composition and the production of volatile compounds (Kim, Chung, Chung, & Choi, 2015). For this reason, there is a growing interest in studies on phytogenic additives as potential natural antioxidants (Moraleco et al., 2019).

Yerba mate (*Ilex paraguariensis*) is a plant native to South America. Its dried leaves are rich in phenolic acids with pharmacological properties and antioxidant effects (Dourado et al., 2020). The ingestion of herb infusion may be an important source of essential minerals (Ca, K, Mg, S, and P) and vitamins (vitamin A and B vitamins) (Garcia et al., 2019). There is evidence that the substances contained in Yerba mate, such as xanthines, caffeine, flavonoids, and vitamins, exert actions on the cardiovascular, respiratory, muscular, and gastrointestinal systems (Reges & Eurípedes, 2001). This improves the antioxidant defense against the attack of free radicals (Lobo et al., 2021).

Yerba mate may be an alternative to modulate the fatty acid profile of meat, mainly monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), in broiler thighs (Garcia et al., 2019). Yerba mate extract has antimicrobial activity against some pathogenic microorganisms in broiler breast meat (*E. coli* and *P. mirabilis*), favoring the microbiological quality of the product (Costa, Racanicci, & Santana, 2017).

Brazil is the world market leader in chicken meat exports (Associação Brasileira de proteína Animal [ABPA], 2021), and the meat is sold frozen. During freezing, a series of physical and biochemical changes occur in the meat, such as water loss, color change, lipid and protein oxidation, which may affect meat quality (Wei et al., 2017). Due to these variations, industries look for products that contribute to minimize losses during the freezing process and promote a longer shelf life of meat products.

Thus, the objective of this study is to evaluate the effects of including in the chicken diet Yerba mate (*Ilex paraguariensis*) on the yield and quality of chicken meat stored frozen for 120 days after slaughter.

Material and methods

The experiment was carried out in the experimental aviary of the Federal University of Grande Dourados (UFGD), Dourados, Mato Grosso do Sul, Brazil. The research project was approved by the Ethics Committee on the Use of Animals (CEUA) of the UFGD under protocol no. 007/2012.

800 Cobb® 500 chicks with 1 day of age and average initial weight of 45 g were used. The birds were distributed in a completely randomized design, with four treatments, and eight replications with 25 birds per replication. The treatments consisted of providing a basal diet with 1, 2, 4, and 6 g kg^{-1} of ground dehydrated Yerba mate (*Ilex paraguariensis*). The experimental period was 42 days, divided into four phases: pre-initial (1 to 7 days), initial (8 to 21 days), growth (22 to 35 days), and termination (36 to 42 days).

The experimental diets were isonutritive based on corn, soybean meal, amino acids, and vitamin and mineral nuclei. Diets were formulated according to the nutritional requirements of the lineage as proposed by Rostagno et al. (2011). Table 1 shows the percentage and nutritional composition of the diets.

Table 1. Composition and calculation of nutritional values of diets for birds during the distinct phases.

Ingredient	Diet (%)			
	1-7 days	8-21 days	22-35 days	36-42 days
Corn	54.480	58.460	61.280	65.980
Soybean meal	38.310	34.790	31.580	27.370
Soy oil	2.200	2.140	3.130	2.960
Limestone	0.922	0.912	0.824	0.769
Dicalcium phosphate	1.892	1.525	1.334	1.069
Sodium chloride	0.350	0.350	0.350	0.350
DL-Methionine	0.354	0.283	0.252	0.236
L-Lysine	0.282	0.260	0.190	0.230
L-Threonine	0.103	0.057	0.038	0.474
Choline chloride	0.072	0.063	0.057	0.043
Inert	0.600	0.600	0.600	0.600
Vitamin premix	0.100	0.100	0.100	0.100
Mineral premix	0.100	0.100	0.100	0.100
Calculated composition				
Metabolizable energy (kcal kg^{1})	2.950	3.000	3.100	3.150
Crude Protein%	22.200	20.800	19.500	18.000
Met+Cys[1] %	0.940	0.840	0.780	0.730
Lysine[1] %	1.310	1.170	1.070	1.010
Threonine[1] %	0.850	0.760	0.700	0.650
Calcium%	0.920	0.810	0.730	0.630
Available phosphorus%	0.390	0.340	0.310	0.270

composition of vitamin premix: retinylacetate 7,000 IU, cholecalciferol 2,200 IU, α-tocopheroacetate 11 IU, menadione 1.6 mg, thiamine 2.0 mg, riboflavin 5.0 mg, pyridoxine B6 3.0 mg, cyanocobalamin 12 mcg, niacin 35 mg, pantothenic acid 13 mg, and follicacid 800 mg^{1}. **composition of mineral premix: * 8 mg, Fe 50 mg, I 1.2 mg, Mg 70 mg, Se 0.2 mg, and Zn 50 mg[1] Digestible values.

The birds were housed in 2.90 x 1.40 m boxes equipped with pendulum drinkers, tube feeders, rice husk bedding, curtains and over-curtains, an evaporative plate, and nebulizers to control the internal temperature. For heating during the initial phase, 250W infrared lamps were used. The light program for the Cobb® lineage was adopted using 40W lamps, obtaining 22 lumens m^{-2}.

Yerba mate was of the ground sieved type from the manufacturer Barão Comércio e Indústria de Erva Mate Ltda (Erechim, Brazil). Its composition is 100% yerba mate with 8% moisture, 20% crude fiber, and 7% mineral matter.

At the end of the experimental period (42 days of age), 16 birds were selected per treatment, two birds per replication, with a body weight between -10 and +10% of the average weight of the respective plot. The selected birds were submitted to a six-hour fasting period, euthanized by cervical dislocation, exsanguinated by bleeding from the jugular, scalded at 58°C, plucked, and eviscerated in order to evaluate the hot and cold carcass yield (disregarding head, neck, and feet). To evaluate the hot carcass and cold carcass yield (%), the hot carcass weight (HCW) and the cold carcass weight (CCW) were obtained after cooling, both based on live weight (Valentim et al., 2020).

After cooling eight carcasses per treatment, temperature and pH were evaluated in breast meat (*Pectoralis major*) and drumsticks (*Sartorius*). The temperature and pH were measured using a digital pH meter Texto 205 calibrated with two standards (pH 4.0 and pH 7.0), with an incision in the upper part of the sample for the introduction of the electrode, according to Assunção et al. (2020).

Carcasses were frozen for 120 days at -20°C. Subsequently, the samples were thawed at 5°C for 48 hours and then analyzed as for meat quality. For the analysis of meat quality, the breast (*Pectoralis major*) and drumsticks (*Sartorius*) were used. Color, water retention capacity, cooking weight loss, and shear force were evaluated.

The color analyses were performed using the Minolta Chroma Meter portable colorimeter (Model CR-400) and adopting the CIELab system, which evaluates the parameters luminosity (L*), red intensity (a*), and yellow intensity (b*), according to the methodology of Van Laack, Liu, Smith, and Loveday (2000).

The water retention capacity was determined using approximately 2 g of sample, which were placed between two filter papers and glass plates. They received a pressure exerted by a weight of 10 kg for five minutes. Afterwards, the samples were weighed again and the percentage of water retained in the meat was verified, assuming that the initial weight of the meat corresponded to 100% (Hamm, 1960).

For the analysis of cooking losses (CWL), meat samples were roasted in an electric oven at 170°C until they reached 70°C at the geometric center. This process was monitored with a digital thermometer. Cut weights before and after cooking were used to calculate cooking losses. These same samples were used to determine shear force (Garcia et al., 2002).

After reaching room temperature, the samples were cut in parallelepipeds with dimensions of 1x1x2 cm in quintuplicate. They were placed with the fibers oriented perpendicular to the Warner-Blatzler blades of the device, coupled to a TA.XT plus texture analyzer (Stable Micro Systems), which measures the shear force of the sample in kgf cm^{-2} (Garcia et al., 2002).

Data were verified as for normality of residues using the Shapiro-Wilk test and as for homogeneity of variances using Levene's test. Thereafter, samples were subjected to analysis of variance (ANOVA) and polynomial regression analysis using the GLM procedure of the SAS 9.3 statistical program (2011). An α=0.05 was adopted.

Results and discussion

Yerba mate levels included in the diet did not affect ($p > 0.05$) hot and cold carcass yields. For the parameters evaluated after the slaughter of broilers at 42 days of age, there were effects ($p < 0.05$) for breast and drumstick temperature according to the levels of Yerba mate (Table 2). Breast temperature showed a decreasing linear effect ($y=-8.20x+16.08$; $R^2=0.6119$) and thigh temperature showed a negative quadratic effect ($y=-40.33x^2+20.253x+18.16$; $R^2=0.66$).

Table 2. Carcass yield, temperature, and pH of breast and drumstick evaluated post-slaughter of broilers at 42 days of age fed on distinct levels of Yerba mate.

Yerba mate level (g kg^{-1})	Warm carcass yield	Cold carcass yield	Temperature (°C)	pH	Temperature (°C)	pH
			Breast		Drumstick	
1	76.27	77.74	15.64	5.94	18.96	6.33
2	77.52	78.83	14.98	5.95	22.14	6.52
4	77.61	79.22	11.10	5.99	18.78	6.37
6	77.40	78.74	11.94	5.99	16.10	6.35
MSE	0.242	0.274	0.461	0.020	0.528	0.030
P value	0.156	0.242	<0.0001*	0.870	<0.0001**	0.190

MSE: Mean standard error; * $y=-8.20x+16.08$; $R^2=0.6119$; ** $y=-40.33x^2+20.253x+18.16$; $R^2=0.6637$

Koiyama et al. (2014) studied a mixture of phytogenic additives in the diet of chickens and found no effects on the yield of cuts and carcasses of these alternative foods, thus corroborating the results of this study. Muscle deposition from breast and thigh cuts is intrinsically related to nutritional management and the interference of muscle protein-energy metabolism, which favors muscle growth. The inclusion of 1 to 6 g kg^{-1} of Yerba mate in the diet did not change muscle deposition in broilers. It does not interfere negatively with the main chicken cuts since the diets were isonutritive.

Differently from the results obtained in the present study, Monteiro, Lima, Parente, Pereira, and Lima (2018) did not observe effects on internal breast temperature after cooling broilers fed on diets containing homeopathic products. The authors found mean temperatures of 17.32 and 17.88°C for the homeopathic and control treatments, respectively. According to Fletcher (2002), the main quality attributes of poultry meat are appearance, texture, juiciness, flavor, and functional properties (pH, color, water retention capacity, tenderness, among others), which may be used as parameters for the consumer of poultry products.

For the quality characteristics of breast and drumstick meat evaluated after 120 days of freezing, there was an increasing linear effect ($p < 0.05$) of weight loss by drumstick cooking ($y=-11.596x+37.264$; $R^2=0.38$) (Table 3). As there was an increase in the levels of Yerba mate in the diet, there was a greater weight loss by cooking.

Table 3. Shear force (SC), cooking weight loss (CWL), and water retention capacity (WRC) of breast and drumstick of broilers at 42 days of age fed on diets containing distinct levels of Yerba mate after 120 days of freezing.

Yerba mate level (g kg^{-1})	SF (kgf)		CWL (%)		WRC (%)	
	Breast	Drumstick	Breast	Drumstick	Breast	Drumstick
1	1.75	1.31	28.39	36.15	28.15	15.34
2	1.99	1.23	30.56	35.82	24.20	12.44
4	1.62	1.28	30.18	30.76	26.99	14.44
6	1.64	1.11	30.87	31.25	25.78	14.62
MSE	0.068	0.059	0.617	0.819	0.883	0.632
P value	0.223	0.692	0.521	0.011*	0.461	0.435

MSE: Mean standard error; * $y=-11,596x+37,264$; $R^2=0.3884$

The functional properties of meat quality are directly related to its water retention capacity, as it affects palatability and shelf life (Genova Gaya & Ferraz, 2006). The ability of meat to retain water helps to maintain its physicochemical properties. Therefore, by acting directly as a modulator of the lipid profile Yerba mate can change the oxidative capacity of meat and its shelf life. Lipid oxidation can modify the structure of proteins, interfering with the water retention capacity, since the greatest loss of water occurs between the myofibrils and the cell membranes (Rajput, Ali, Naeem, Khan, & Wang, 2014). Thus, the lower water retention capacity is related to a higher protein oxidation, as authors found in studies on natural antioxidants in chicken meat (Rajput et al., 2014). Phytogenic additives such as Yerba mate contain flavonoids in their composition, which have favorable characteristics for improving the quality of chicken meat due to an antioxidant action.

Regarding shear force, studies comparing the efficiency of bamboo extract as a performance enhancer and the quality of chicken breast meat have shown that the addition of 3 g of bamboo extract to basal diets promoted better meat tenderness (18.67 N) (Shen et al., 2019). This difference was not observed in this study with the addition of Yerba mate. The authors attribute this to the fact that water retention was greater in the breasts of chicken fed on diets with the inclusion of bamboo extract, which in turn favored organoleptic and sensory attributes of the meat.

There was no effect ($p > 0.05$) between the levels of Yerba mate and the colorimetry parameters of breast and drumstick after 120 days of freezing (Table 4).

Table 4. Red content (a*), yellow content (b*), and luminosity (L*) of breast and drumstick of broilers at 42 days of age fed on diets containing distinct levels of Yerba mate after 120 days of freezing.

Yerba mate level (g kg^{-1})	a*	b*	L*	a*	b*	L*
	Breast			Drumstick		
1	1.08	12.24	52.33	5.26	10.84	47.31
2	1.40	13.62	50.12	6.01	11.71	45.38
4	1.76	11.32	49.75	3.84	10.77	46.16
6	1.09	14.01	50.16	4.38	13.38	49.09
MSE	0.429	0.551	0.854	0.443	0.630	0.856
P value	0.141	0.297	0.733	0.339	0.457	0.478

MSE: Mean standard error.

Color is the main factor in product selection by the consumer. Mirshekar, Dastar, and Shabanpour (2009), evaluating the effects of supplementation of 1,000 *ppm* extracts of rosemary, *echinacea*, green tea, and ascorbic acid on meat quality, also did not detect differences as for the color spectra a* and b*. When observing the color of meat of chickens fed on distinct levels of ethanolic extract of mango seed, there was no interference of this natural antioxidant with meat color (Farias et al., 2020).

The increase or decrease in color in meat products happens primarily due to biochemical reactions initiated in the pectoral muscles after slaughter, especially in products stored for prolonged periods. Scatolini et al. (2006) report that the increase in the storage time of chicken meat cuts represents higher values of luminosity and lower values of red content, which translates as an increase in the pallor of the product and as a possible decrease in consumer acceptance.

According to Monteiro et al. (2018), luminosity has a high correlation with the pallor of meat, which may be a negative point in the commercialization of this product, as luminosity is one of the parameters evaluated for the characterization of the meat as *Pale, Soft and Exudative* (PSE), thus shortening the shelf life and decreasing consumer acceptance. With the increase in market demands and the trend in consumption of processed meat products, the functionality of meat in terms of technological properties has also increased, prioritizing its sensory determination. Therefore, phytogenic alternatives that seek to improve the functionality of this product are justified and encouraged (Paiva, Trindade, Romero, and Silva-Barretto, 2021)

Likewise, Racanicci, Menten, Alencar, Buissa, and Skibsted (2011) concluded that Yerba mate may be an interesting natural alternative to be used in the diet of chickens in order to improve the lipid oxidative stability of meat, corroborating the findings of the present research, which reinforce the possibility of using herbal additives in poultry diets without compromising carcass yield and meat quality after storage.

Conclusion

Yerba mate can be included in up to 6 g kg^{-1} in chicken feed from 1 to 42 days without changing pH, color, and meat tenderness after 120 days of freezing, maintaining carcass and cut yields.

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