Ciência Rural, Santa Maria, v.52:10, e20210547, 2022 http://doi.org/10.1590/0103-8478cr20210547

ISSNe 1678-4596
ANIMAL PRODUCTION

Performance, meat quality, and lipidemia of meat-type quails fed with diets containing essential oils

Renata Gomes da Silveira Deminicis[1] **Camila Meneghetti**[1]
Antônio Amândio Pinto Garcia Júnior[2] **Cristiane Leal dos Santos Cruz**[2]
Bruno Borges Deminicis[3] **Bianca Mendes Maciel**[1]

[1]Universidade Estadual de Santa Cruz (UESC), 45662-900, Ilhéus, BA, Brasil, E-mail: renatademinicis@gmail.com. *Corresponding author.
[2]Universidade Estadual do Sudoeste da Bahia (UESB), Itapetinga, BA, Brasil.
[3]Universidade Federal de Mato Grosso (UFMT), Sinop, MT, Brasil.

ABSTRACT: *This study evaluated the effect of essential oil (ESOL) of Mentha piperita and Melaleuca alternifolia on meat-type quails. To examine performance, a completely randomized design was used, with four treatments and eight repetitions each, using seven birds per repetition. To assess lipidemia, a completely randomized design in a 4 × 2 factorial scheme was used, with four treatments and two collection conditions using eight repetitions and one bird per repetition. Weight gain, feed intake, feed conversion, carcass yield, cholesterol, high-density lipoporteins, triglycerides, pH, and brightness of quail breast meat were assessed. The data were analyzed for homoscedasticity and normality, and the means were subjected to analysis of variance. Adding M. piperita and M. alternifolia ESOL to the diets of meat-type quails can improve performance, carcass yield, and meat quality characteristics, comparable to the use of performance-enhancing antibiotics. The use of zinc bacitracin, M. piperita, and M. alternifolia under different collection conditions did not increase the serum levels of low-density and very low-density lipoproteins. The variation coefficients measured after 12 hours of fasting were 86% lower than without fasting.*
Key words: *feed consumption, weight gain, cholesterol.*

Desempenho, qualidade da carne e lipidemia de codornas de corte alimentadas com rações contendo óleos essenciais

RESUMO: *Objetivou-se com este estudo avaliar o efeito do uso dos óleos essenciais (OLES) de Mentha piperita e Melaleuca alternifolia em codornas de corte. Para o estudo do desempenho foi utilizado o delineamento inteiramente ao acaso, com quatrotratamentos e oito repetições, sendo sete aves por repetição. Para o estudo da lipidemia utilizou-se o delineamento inteiramente casualizado em esquema fatorial: 4x2, consistindo em quatro tratamentos e duas condições de coleta, com oito repetições, sendo uma ave por repetição. As variáveis analisadas foram: ganho de peso, consumo ração, conversão alimentar, rendimento de carcaça, colesterol, HDL, triglicerídeos, pH, capacidade de retenção de água, perda de peso por cozimento, luminosidade na carne do peito de codornas. Os dados obtidos foram analisados quanto à homocedasticidade e normalidade, as médias foram submetidas à análise de variância. O uso de OLES de M. piperita e M. alternifolia na dieta de codornas de corte pode proporcionar desempenhos zootécnicos, rendimentos de carcaça e características de qualidade da carne comparáveis ao uso de antibióticos melhoradores de desempenho. A redução no nível de colesterol HDL foi notada nas aves tratadas com Bacitracina de zinco e com os OLES de M. piperita e M. alternifolia, em 8,12; 16,52 e 3,36% respectivamente. O uso da Bacitracina de zinco, da M. piperita e da M. alternifolia associado às diferentes condições de coleta não aumentaram os valores séricos de LDL, VLDL. Os coeficientes de variação aferidos na condição "após 12 horas de jejum" apresentaram-se 86% inferiores à condição "sem jejum".*
Palavras-chave: *consumo de ração, ganho de peso, colesterol.*

INTRODUCTION

In Brazil, for decades, laying quails at the end of their egg production period were used for quail meat production. The introduction of specific lineages, such as the European quail (*Coturnix coturnix coturnix*), facilitated the production of larger carcasses and softer meat retaining its distinctive flavor (REZENDE et al., 2004; MERSEGUEL et al., 2019). Regarding the cost of quail production, feeding represents more than 70% of the total cost. Thus, diets with adequate nutritional levels to

Received 07.20.21 Approved 11.03.21 Returned by the author 02.03.22
CR-2021-0547.R1
Editors: Rudi Weiblen Wagner Araújo

optimize performance and facilitate greater economic return are of high interest (TEIXEIRA et al., 2013).

Antibiotics play an important role in the development of poultry farming, enabling significant increases in productivity due to the effects on intestinal microbiota of birds (LEE et al., 2004); however, continuous use of antibiotics is of great concern regarding the development of resistant bacteria and their transmission along the food chain. In response to this, several countries have abolished the use of antibiotics as performance enhancers in animal feed (BRENES & ROURA, 2010; KOIYAMA et al., 2014; PINHEIRO et al., 2015). The search for alternative feed additives has intensified, and plant products with potential use for this purpose have represented an important alternative source. Numerous plant-derived compounds showed considerable medicinal potential regarding animal production and human medicine, and respective research can effectively contribute to the search for new bioactive products (PERIĆ et al., 2009).

In addition to the possibility of partial and/or complete replacement of antibiotics by plant products to maintain or improve productive performance, phytogenic products may also promote beneficial changes regarding the lipid profile of animals. This has led to the search for natural products that can reduce cholesterol and plasma lipids (HARGIS, 1988; PIZZIOLO et al., 2011; KLASSA et al., 2013). In addition, consumers have been increasingly concerned with their diet, paying attention to the quality and nutritional composition of food and its effects on health (CRUZ & FARIA, 2019). Lipids are essential nutrients in the human diet and are crucial for specific functions of metabolism (FRENCH et al., 2000). However, the effects of lipids on human health can be beneficial or harmful, thus it is important to study lipidemia in birds such as chickens and quails, as such meat is consumed increasingly because it is considered better quality than red meat (NASCIF et al., 2004). TThis study evaluated the effect of essential oils (ESOL) of *M. piperita* and *M. alternifolia* on the performance, relative organ weight, carcass yield, meat quality, and lipidemia of meat-type quails under normal feeding conditions.

MATERIALS AND METHODS

A total of 224 one-day-old meat-type quails were purchased from a commercial hatchery. To assess performance variables, the quails were randomly assigned to four dietary treatments (i.e., control, zinc bacitracin, *M. piperita*, and *M. alternifolia* treatments) with eight repetitions and seven birds, each. To examine lipidemia, a completely randomized design in a 4 × 2 factorial scheme was used with four treatments, eight repetitions, and one bird per repetition. Experimental diets and water were provided *ad libitum*. The lighting program was 23 h light and 1 h darkness. The average temperature and relative humidity (RH; minimum and maximum) inside the barn were recorded throughout the experimental period. The minimum and maximum average temperature was 23.8 and 31.5 °C respectively, and RH was 42.3% and 75.62%.

The quails were raised in a stonewall barn with an area of 250 m^2, and they were kept in boxes with seven individuals per box (56 □ 81 □ 81 cm in height, width, and length, respectively), resulting in 0. 9372 m² surface area per individual. The boxes were constructed from wood and canvas (black hexagonal plastic 5 cm, with 2 inch). The floor was covered with wood shavings, and in the initial phase, the birds were kept within protective circles and were provided with water *ad libitum* through baby feeders and drinkers for broilers. At 21 days of age, the fences were opened, and the quails were allowed to occupy the entire area of the box; nipple drinkers were used, and the diet was supplied in a galvanized sheet trough.

The treatments comprised two phases, the first (initial phase) from 1 to 21 days of age, and the second (growth phase) from 22 to 42 days of age. The experimental diets were formulated to meet or exceed the nutritional needs of meat-type quails, according to SILVA & COSTA (2009). The ingredients, chemical composition, and energy of the diets are shown in table 1.

ESOL was added homogeneously to the diet adapted according to DAIRIKI et al. (2013); the control group received standard quail feed. For each kilogram of experimental feed, a mixture of soy oil and ESOL was added. According to DEMINICIS et al. (2021), no standardized ESOL dosage for supplementing production bird diets is known. Thus, the dosages corresponding to the minimum in vitro bactericidal concentration (MBC) used of ESOL of *M. piperita* (12.5 mg/kg of ration) and *M. alternifolia* (50 mg/kg ration) were determined in a preliminary experiment using a microdilution test (unpublished data). The action of essential oils on bacterial strains (*E. coli, S. enteritidis and S. aureus*) were tested according to the methodology standardized by the National Committee for Clinical Laboratory Standards (NCCLS, 2003). The test culture medium was prepared with Mueller Hinton broth and solution according to the methodology described by LINHARES NETO et al. (2018).

Table 1 - Centesimal composition of experimental diets*.

Ingredients (%)	---------------Initial (1 to 21 days)-----------------				---------------Growth (22 to 42 days)---------------			
	T1	T2	T3	T4	T1	T2	T3	T4
Corn	52.85	52.82	52.85	52.85	59.99	59.97	59.97	59.97
Soybean meal	42	42	42	42	35.4	35.39	35.39	35.39
MHL – Methionine (84%)	0.5	0.5	0.5	0.5	0.45	0.45	0.45	0.45
Lysine Sulfate (55%)	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
L- Threonine (98%)	0.25	0.25	0.25	0.25	0	0	0	0
Calcitic limestone	1.02	1.02	1.02	1.02	0.96	0.96	0.96	0.96
Dicalcium phosphate	1.32	1.32	1.32	1.32	0.87	0.87	0.87	0.87
Common Salt	0.4	0.4	0.4	0.4	0.33	0.33	0.33	0.33
Premix**	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Soy oil	1.16	1.16	1.06	1.05	1.5	1.5	1.38	1.36
Oil of *M. piperita*	-	-	0.096	-	-	-	0.125	-
Oil of *M. alternifolia*	-	-	-	0.113	-	-	-	0.147
Zinc Bacitracin	-	0.03	-	-	-	0.03	-	-
Calculated composition	--Nutritional levels--							
Metabolizable energy. kcal/kg	2900	2900	2900	2900	3025	3025	3025	3025
Crude protein. %	23.72	23.72	23.72	23.72	21.34	21.34	21.34	21.34
Crude fiber. %	2.82	2.82	2.82	2.82	2.61	2.61	2.61	2.61
Calcium. %	0.92	0.92	0.92	0.92	0.76	0.76	0.76	0.76
Available Phosphor %	0.42	0.42	0.42	0.42	0.33	0.33	0.33	0.33
Lysine dig. %	1.51	1.51	1.51	1.51	1.34	1.34	1.34	1.34
Dig methionine. %	0.77	0.77	0.77	0.77	0.7	0.7	0.7	0.7
Methionine + cystine dig. %	0.73	0.73	0.73	0.73	0.68	0.68	0.68	0.68
Threonine dig. %	1.17	1.17	1.17	1.17	0.84	0.83	0.83	0.83
Valina dig. %	1.15	1.15	1.15	1.15	1.03	1.03	1.03	1.03
Sodium %	0.17	0.17	0.17	0.17	0.14	0.14	0.14	0.14
Linoleic acid. %	1.22	1.22	1.22	1.22	1.3	1.3	1.3	1.3

*T1: Basal diet (negative control group); T2: Basal diet and 15% Zinc Bacitracin; T3: Basal diet and essential oil of *Mentha piperita* and T4: Basal diet and essential oil of *Melaleuca alternifolia*. **Guarantee levels per kg of feed for the initial phase: Vitamin A 9996 I.U; Vitamin D3 1248 I.U; Vitamin E 20.16 I.U; Vitamin K3 3 mg; Vitamin B1 3 mg; Vitamin B2 6 mg; Vitamin B6 4 mg; Vitamin B12 0.01008 mg; Niacin 40000mg; Pantothenic Acid 30 mg; Choline 260 g; Folic Acid 0.48 mg; Methionine 1580 mg; Copper 7.99 mg; Iron 499 mg; Manganese 0.07 mg; Zinc 49.99 mg; Iodine 1.20 mg; Selenium 0.19 mg; Salinomycin 550 mg. Guarantee levels per kg of feed for the final phase: Vitamin A 12000 I.U. Vitamin D3 3600 I.U. Vitamin E 180 U.I/kg; Vitamin K3 3.00 mg; Vitamin B1 3.60 mg; Vitamin B2 9.00 mg; Vitamin B6 6.00 mg; Vitamin B12 0.021 mg; Niacin 600 mg; Pantothenic Acid 22.50 mg; Folic Acid 0.150 mg; Choline 510 mg; Iron 7500 mg; Manganese 105 mg; Zinc 75 mg; Copper 15 mg; Iodine 1.80 mg; Selenium 0.30 mg.

Weight gain (WG), feed intake (FI), and feed conversion ratio (FCR) were analyzed in three phases: initial (1–21 days of age), growth–termination (22–42 days of age), and total (1–42 days of age), and quails were weighed at 1, 7, 14, 21, 28, 35, 42, and 42 days of age. The production efficiency index (PEI) was calculated using data from the time period of 1–42 days and was calculated according to KOIYAMA et al. (2014) using the formula PEI = average daily WG x (100 - mortality) / 10 × feed conversion ratio (FCR). The provided ration and leftovers were weighed to calculate the consumption and the FCR according to CORREA et al. (2007).

The hot carcass yield was evaluated at 42 days of age using two birds per repetition, and cooled carcass yield was assessed after 24 h at 2 °C, according to PINHEIRO et al. (2015). Two birds were used per repetition (eight repetitions), and the average of the two birds was considered the experimental unit, totaling 64 birds. The quails were fasted for 12 h and were then weighed, identified, and slaughtered, according to the following steps: stunning, bleeding, scalding, plucking, evisceration, and carcass cooling. Hot eviscerated carcasses without heads and feet were weighed. Based on the live weight of each bird, hot and cold gutted carcass yield (after cooling to 2 °C for 24 h) and relative weight of edible viscera (heart, liver, and gizzard) were evaluated. Hot and cooled carcass yields were calculated as carcass weight multiplied by 100 and divided by bird live weight. The relative weights of the spleen, heart, and liver were calculated based on the weight of the hot carcass.

The following quality variables were analyzed: pH, water holding capacity (WHC), weight loss by cooking (WLC), color, and luminosity parameters (L^*, a^*, b^*). To determine the pH (as an average of three measurements), a penetration electrode (HI 996163, Hanna Instruments®, Woonsocket, Rhode Island, USA) was used directly on the *pectoralis major* muscle, according to the methodology applied by PINHEIRO et al (2015).

WHC was measured using the method described by RAMOS & GOMIDE (2007), based on measuring the amount of water released when pressure was applied to the muscular tissue. For this, meat cubes (0.5 g) were placed between two filter papers (12.5 cm diameter) and between two glass plates (12 × 12 × 1 cm) on which a weight of 10 kg 5 min^{-1} (10 cm diameter) was applied. The breast meat samples were weighed after pressing, and water loss was calculated. The result was expressed as the percentage of exuded water in relation to the initial weight (RAMOS & GOMIDE, 2007).

To assess WLC, healthy filet samples were wrapped in metallized paper and were cooked using a double-sided metal plate by applying heat on both sides; samples were preheated and cooked at 150 ºC. Each side of the filet was heated for 4 min with a total of 8 min of cooking time or until reaching an internal temperature of 82–85 °C. After cooking, the filets were removed from the metallized paper and were cooled on absorbent paper at room temperature. Subsequently, the samples were weighed to assess WLC which was the difference between initial weight and cooked weight.

Breast meat color was determined using a colorimeter (Chroma Meter CR-410, Konica Minolta®, Osaka, Japan) in the CIELAB system by evaluating the parameters L^* (brightness), a^* (red content), and b^* (yellow content). The L^*, a^*, and b^* values were measured at three different points on the ventral surface and in the middle of the cranial section of the *pectoralis major* muscle.

To evaluate the effects of ESOL of *M. piperita* and *M. alternifolia* on lipid metabolism on the 42nd day of the experiment, 32 birds (8 per treatment) were fasted for 12 h, whereas the other 32 birds (8 per treatment) were not subjected to 12 h of fasting; blood samples were then collected according to SILVA et al. (2012). The material was collected in labelled tubes containing heparin as an anticoagulant at 0.05 mL/mL blood. The samples were centrifuged at 4000 × g for 15 min to obtain serum. Aliquots were used to measure plasma concentrations of triglycerides (TG), total cholesterol (TC), HDL cholesterol, VLDL cholesterol, and LDL cholesterol. Absorbance values were analyzed in triplicates by enzymatic colorimetric end-point reactions (Bioclin SA commercial kits, Belo Horizonte, MG, Brazil) using a visible ultraviolet light spectrophotometer.

Homoscedasticity and normality of the data were tested. The means were the subjected to analysis of variance using SAS software (SAS Institute, Cary, NC, USA), and treatments were compared using Tukey's test at $P < 0.05$.

RESULTS AND DISCUSSION

From 1–42 days, no effect of any treatment (control, zinc bacitracin, *M. piperita*, and *M. alternifolia*) on WG was observed (Table 2). The performance-enhancing antibiotic (bacitracin) and ESOL of *M. piperita* and *M. alternifolia* produced similar results in terms of WG. This is a promising result due to the countless beneficial effects of such natural compounds on animals, such as improved digestibility and absorption of nutrients, increased digestive secretions, modification of the intestinal microbiota, stimulation of the immune system, and antibacterial activities (COSTA, et. al., 2011).

Previous studies demonstrated that broilers fed ESOL of oregano, sage, rosemary, pepper, cinnamon, and fennel achieved final weights and WG similar to those of birds receiving performance-enhancing antibiotics (TRAESEL, et al., 2011). In the current study, the control group fed with a basal diet showed no difference in WG, possibly due to the consumption of larger amounts of feed, compared to the other treatments. WG was thus stable in the controls; however, from an economic point of view, this treatment is not profitable because of the higher cost of feed.

Total FI between 1 and 42 days was lower in birds fed diets containing bacitracin, *M. piperita*, and *M. alternifolia* ESOL because of the response of lower feed consumption in the growing-finishing period (22 to 42 days) (Table 2). The FI values of the control treatment were equivalent from 1 to 21 days

Table 2 - Average daily weight gain (DWG), total feed intake (FI), feed conversion ratio (FCR) in the stages of creation and productive e containing bacitracin and ESOL of *M. piperita* and *M. alternifolia*.

Variable	Control	Bacitracin	*M. piperita*	*M. alternifolia*	CV%
	---Treatments---				
DWG 1 a 21 days	6.38a	6.39a	6.39a	6.42a	3.77
DWG 22 a 42 days	5.57a	5.57a	5.51a	5.59a	10.33
DWG 1 a 42 days	5.97a	5.98a	5.95a	6.01a	5.09
FI 1 a 21 days	226.29a	230.22a	227.72a	226.06a	2.88
FI 22 a 42 days	544.86a	416.43b	426.25b	435.70b	9.85
FI 1 a 42 days	771.15a	646.65b	653.97b	661.76b	6.92
FCR 1 a 21 days	1.69a	1.72a	1.70a	1.68a	3.29
FCR 22 a 42 days	4.72a	3.57b	3.68b	3.74b	11.73
FCR 1 a 42 days	3.08a	2.58b	2.61b	3.63b	5.83
PEI%	19.38b	23.25a	22.75a	22.75a	7.59

*Averages followed by the same lowercase letter on the line do not differ by Tukey's test at 5% probability.

of age; however, during the periods from 22 to 42 days and from 1 to 42 days of age, these birds had consumed more feed than those in the other treatments.

In the growth phase (1–21 days), there was no effect of the treatments on FCR (Table 2). In the growth-termination phase (22–42 days), the effect of the treatments on FCR was verified, and the control treatment presented higher values than the other treatments. Considering the entire growth period (1–42 days), the effect of treatments on FRC was also verified to be similar among treatments with bacitracin and ESOLs. However, inferior to the control.

JANG et al. (2007) examined chickens fed a basal diet or a diet supplemented with either a commercial mixture of ESOLs (Crina Poultry, active ingredient thymol) or with antibiotics for 35 days, and no difference in FI, total WG, and FCR were observed. The lack of health challenges may have been the cause for the absence of differences in their study.

No significant effect of the treatments on hot carcass yield, cooled carcass yield, and relative organ weight was observed (Table 3). It is possible that the addition of ESOLs and bacitracin may not have shown a difference in the analyzed variables because the rearing environment did not constitute a sanitary challenge that would elicit substantial effects of antimicrobials. The quail litter was changed weekly, or daily, if it moisture was observed, thus the birds did not have direct contact with feces, and they were raised at an optimal density (ALBINO & BARRETO, 2003).

The lacking difference in carcass yield revealed that all treatments were similar and that the control group due to its higher FI showed similar responses regarding WG, facilitating performance similar to those of the other groups. This factor possibly contributed to the carcass yield response.

A study conducted by RIZZO et al. (2010) on supplementing the diets of broilers with mixtures of plant extracts reported that diets containing mixtures of plant extracts promoted a similar performance (hot and cold carcass reduction and productive performance) to that obtained with diets containing antibiotics. This was also observed in the current study, where the use of *M. piperita* and *M. alternifolia* ESOLs produced the same results as treatment with the antibiotic bacitracin. Moreover, diet significantly influenced the meat quality parameters at 42 days of age, including luminosity (L^*), color range from breast to yellow (b^*), WLC, and WHC, but did not significantly affect pH and red color (a^*) (Table 4). However, normal color dissipation and L^* values were < 45. In studies on quail meat quality, SANFELICE et al. (2010), reported an average L^* of 52.2, and they proposed that meat with such values is not desired by consumers as it shows a stronger tendency to pale. In a study on the characterization of pale meat in broilers, KOMIYAMA (2010) reported that filets of normal color produce mean L^* values of approximately 47.25.

The pH of meat in all treatments in the current study was suitable for consumption. The

Table 3 - Hot carcass yield (HCY), cooled carcass yield (CCY) and relative organ weight of meat-type quails fed with diets containing bacitracin and ESOL of *M. piperita* and *M. alternifolia*.

Variable	--------------------	--------------------Treatments	--------------------	--------------------	CV%
	Control	Bacitracin	*M. piperita*	*M. alternifolia*	
HCY	74.05a	73.75a	74.11a	74.34a	6.39
CCY	66.58a	69.54a	68.34a	65.89a	7.23
Heart	2.12a	2.12a	2.24a	2.27a	13.26
Liver	4.31a	4.03a	3.94a	5.04a	18.97
Gizzard	4.61a	4.70a	4.87a	5.02a	13.05
Intestine and pancreas	6.39a	5.85a	6.08a	7.17a	15.55

*Averages followed by the same lowercase letter on the line do not differ by Tukey's test at 5% probability.

meat reached the isoelectric point of the myofibrillar proteins (5.6–5.8) at the moment of the biochemical transformation, allowing the consumption of meat with an average pH of 6.29–6.43, suggesting a lower risk of microorganism proliferation and longer shelf life. According to ABREU et al. (2014), for quail meat to be within the normal range, it should have a pH of approximately 5.7.

The average final pH of quail breast meat was within the range of the pH stipulated for normal chicken breast meat and corroborated the results obtained by PINHEIRO et al. (2015). These authors reported medium values of 14.45 for red color tendency (a^*) in a study assessing different levels of crude protein and supplementation with essential amino acids on carcass yield and quail breast meat quality from 28 to 42 days of age, and concluded that breast meat is darker at higher proportions of protein in the feed.

Muscle fibers can be categorized as oxidative and glycolytic fibers, both of which are directly related to meat quality, especially with regard to sensory characteristics such as color, flavor, juiciness, and tenderness (BRACCINI, et al., 2021). As quail breast has glycolytic fibers, the L value should be higher than those observed here; however, the tonality of "b" is inversely proportional to the determined values, which may indicate intermediate oxidative-glycolytic fibers in the meat.

Comparing the parameters described for ostrich meat with those obtained in the present study,

Table 4 - The pH averages, luminosity (L^*), color range for red (a^*), color range for yellow (b^*), water holding capacity (WHC), weight loss by cooking (WLC) in breast of meat-type quails quail breast fed with rations containing bacitracin and ESOL of *M. piperita* and *M. alternifolia*.

Variable	--------------------	--------------------Treatments	--------------------	--------------------	CV%
	Control	Bacitracin	*M. piperita*	*M. alternifolia*	
pH	6.29a	6.43a	6.32a	6.34a	2
L^*	34.66c	37.58bc	41.33ab	44.11a	10.48
a^*	7.14a	6.31a	6.81a	6.95a	15.01
b^*	11.54ab	10.17b	11.01b	12.84a	11.51
WLC (%)	24.25a	22.50a	13.47b	13.94a	26.37
WHC (%)	43a	35a	37b	35b	9.16

*Averages followed by the same lowercase letter on the line do not differ by Tukey's test at 5% probability.

quail meat tended to shower lower L* values in the control treatment. However, quails receiving the diets containing bacitracin or *M. piperite* ESOL produced meat with the lowest b* values.

A study by LIMA et al. (2016) demonstrated the effect of *Stryphnodendron adstringens* and pacari (*Lafoensia pacari*) extracts on the stability and oxidative quality of broiler meat at 42 days of age. They reported that diet supplementation with these extracts did not affect the pH and color but reduced the shear strength of breast meat. In addition, supplementation with *L. pacari* increased L* and b* in thigh meat.

WHC is negatively correlated with luminosity values, which is a characteristic of meat with glycolytic and intermediate fibers. It is important to note that WHC is a physical-chemical parameter intrinsic to meat and can only be modified by genetic or nutritional factors due to the process of nutrient partitioning.

WHC is related to the nutritional value of the meat, and higher exudation may result in drier and less tender meat, whereas WLC is related to increased permeability of membranes where heat facilitates interactions between oxidizing agents, resulting in weight loss during the preparation of meat for consumption (LUIGGI et al., 2020; SAÑUDO et al., 1993). In the current study, quails in the control and bacitracin groups showed higher WHC than those in the ESOL treatments, whereas regarding WLC, the ESOL treatments showed less exudation.

Reduced exudation in the ESOL treatments may also be associated with antioxidant effects of some ESOLs, which may lead to reduced effects of compounds responsible for oxidation of membranes, thus changing membrane permeability. ELMALI et al. (2014), examined the effects of plant extracts and oil mixtures on the quality of quail breast meat through supplementation of drinking water with peppermint, thyme, and fennel ESOL and found that the treatments significantly increased antioxidant characteristics of meat.

Regarding lipidemia, no significant difference was observed between the experimental treatments and between pre-collection conditions (with or without 12 h of fasting) regarding TC and body weight (Table 5). The lacking effect on TC was in line with the results of SILVA et al. (2012), who examined the effects of different sources of essential

Table 5 - Average values obtained for total cholesterol (TC), triglycerides (TG), HDL, LDL and VLDL in the blood of quails submitted to different diets containing ESOL.

---After 12 hours of fasting---					
Variables	---Treatments---				
	Control	Bacitracin	*M. piperita*	*M. alternifolia*	CV%
TC (mg/dL)	205.37 Aa	210.87 Aa	202.87 Aa	197.0 Aa	9.78
TG (mg/dL)	90.12 Ba	89.87 Ba	88.0 Ba	97.87 Ba	13.6
HDL (mg/dL)	89.25 Ba	82.0 Ab	74.50 Ac	86.25 Aab	5.57
LDL (mg/dL)	98.12 Aa	110.75 Aa	110.87 Aa	92.12 Aa	19.26
VLDL (mg/dL)	18.0 Ba	18.0 Ba	17.5 Ba	18.5 Ba	13.69
Animal weight**(g)	256.05 Aa	250.0 Aa	257.50 Aa	265.0 Aa	6.48
---No Fasting---					
Variables	---Treatments---				
	Control	Bacitracin	*M. piperita*	*M. alternifolia*	CV%
TC (mg/dL)	205.50 Aa	214.0 Aa	199.50 Aa	196.25 Aa	9.02
TG (mg/dL)	156.62 Aa	163.37 Aa	155.25 Aa	137.12 Aa	18.42
HDL (mg/dL)	106.87 Aa	97.75 Aa	85.25 Aa	103.37 Aa	29.4
LDL (mg/dL)	67.25 Ba	83.50 Aa	83.25 Ba	65.37 Ba	45.78
VLDL (mg/dL)	31.25 Aa	32.75 Aa	31.25 Aa	27.37 Aa	18.58
Animal weight**(g)	262.50 Aa	255.62 Aa	261.87 Aa	268.12 Aa	6.31

*Averages followed by the same lowercase letter in the row and uppercase in the column (within each treatment) do not differ by Tukey's test at 5% probability. **additional information.

omega-3 and omega-6 fatty acids on the lipid profile of Japanese quails and reported no significant difference in TC between treatments (control diet; fish oil 2%; fish oil 4%; soy oil 2% and soy oil 4%).

HDL and total TG content were influenced by the experimental diets. KHALIFA & NOSEER (2019) supplemented the diets of quails with *Lactobacillus*, *Saccharomyces*, and ginger (*Zingiber officinale*) and observed that birds receiving ginger had the lowest levels of TC, LDL, and HDL, thus concluding that prebiotics may constitute an alternative to antibiotics in the production of quail meat.

In the present study, no effect of the treatments on TGs, LDL, and VLDL were observed when the effect of collection condition was accounted for. However, HDL was significantly affected by the treatments after 12 hours of fasting, whereas no effect was observed when the quails were not fasted (Table 5).

There was no effect of the interaction between treatments (zinc bacitracin, *M. piperita*, and *M. alternifolia*) and collection conditions (after 12 h with or without fasting) on HDL, and no interaction effect (treatment × collection condition) on LDL was observed when using zinc bacitracin. A significant interaction effect between treatments on TG and VLDL was observed. A significant effect of the interaction between the control treatment and collection conditions on HDL was found, and there was a significant effect of the interaction between treatment (control, *M. piperita*, and *M. alternifolia*) and collection condition on LDL. According to FALUDI et al. (2017), fasting is not necessary to precisely determine TC and HDL because the postprandial state does not interfere with the concentrations of these compounds. For this reason, the European Society for Atherosclerosis and the European Federation of Clinical Chemistry and Laboratory Medicine (2016), recommend that fasting is not necessary (NORDESTGAARD, 2016; DRIVER et al., 2016). In the present study, the coefficients of variation measured after 12 hours of fasting were 86% lower than those observed when birds were not fasted. Thus, the lipid profile may show higher variation in non-fasted birds.

CONCLUSION

Phytogenic additives based on *M. piperita* and *M. alternifolia* ESOLs in the diet of meat-type quails which can improve performance, hot and cooled carcass yield, relative organ weight, and meat quality characteristics comparable to those achieved using performance-enhancing antibiotics. Reduced serum levels of HDL cholesterol were observed in quails treated with zinc bacitracin and with ESOLs of *M. piperita* and *M. alternifolia*. The coefficients of variation measured after 12 hours of fasting were 86% lower than those without previous fasting.

ACKNOWLEDGEMENTS

This study was funded in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) in Brazil (Funding Code 001).

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

All procedures in this study were approved by the Ethics Committee on the Use of Animals of the Universidade Estadual de Santa Cruz (UESC, Ilhéus, BA, Brazil), approval number 016/18.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and writing of this manuscript. All authors critically revised the manuscript and approved the final version.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study, in data collection, analyses, or interpretation, in the writing of the manuscript, and in the decision to publish the results.

REFERENCES

ABREU, L. R. A.; et al. Influence of sex and age at slaughter on carcass yield and meat quality of meat quails. **Brazilian Journal of Animal Health and Production**, v.15, n.1, p.131–140, 2014. Available from: <https://www.scielo.br/j/rbspa/a/94LzkdHfRSYpW3Gtsqr9jtn/?lang=pt>. Accessed: Apr. 26, 2020. doi: 10.1590/S1519-99402014000100020.

ALBINO, L. F. T.; BARRETO, S. L. T. **Quails: quail breeding for egg and meat production**. Viçosa, MG: Aprenda Fácil, 2003. 268p.

BRACCINI, V. P. et al. Types of muscle fibers, identification, characteristics and quality of meat. **Brazilian Journal of Development**, v.7, n.3, p.21180–21190, 2021. Available from: <https://www.brazilianjournals.com/index.php/BRJD/article/view/25526>. Accessed: Jan. 18, 2020. doi: 10.34117/bjdv7n3-025.

BRENES, A.; ROURA, E. Essential oils in poultry nutrition: main effects and modes of action. **Animal Feed Science and Technology**, v.158, p.14, 2010. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0377840110000775>. Accessed: Jan. 15, 2020. doi: 10.1016/j.anifeedsci.2010.03.007.

CRUZ, F. L.; FARIA, P. B. Lipid profile of broiler meat from different crosses raised in alternative system. **Brazilian Archive of Veterinary Medicine and Zootechnology**, v.71, n.2, p.677-

686, 2019. Available from: <https://www.scielo.br/j/abmvz/a/x3gjLjHZXSY7nCj7YnDyNNF/abstract/?lang=pt>. Accessed: Feb. 02, 2020. doi: 10.1590/1678-4162-10168.

DAIRIKI, J. K. et al. **Procedure for including essential oils in fish feed**. Manaus: Embrapa Amazônia Ocidental, 2013. 8p. (Circular Técnica, 42). Available from: <https://www.infoteca.cnptia.embrapa.br/bitstream/doc/973005/1/CircTec42.pdf>. Accessed: Oct. 13, 2020.

DEMINICIS, R. G. S. et al. Systematic review of the use of phytobiotics in the nutrition of broilers. **Journal of Agroveterinary Sciences**, v. 20, no. 1, p. 098 - 106, 2021. Available from: <https://revistas.udesc.br/index.php/agroveterinaria/article/view/18816>. Accessed: Feb. 3, 2022. doi: 10.5965/223811712012021098.

DRIVER, S. L. et al. Fasting or nonfasting lipid measurements. It depends on the question. J. **American College of Cardiology**, v.67, n.10, p.1227-1234, 2016. Available from: <https://www.jacc.org/doi/abs/10.1016/j.jacc.2015.12.047>. Accessed: Mar. 11, 2021. doi: 10.1016/j.jacc.2015.12.047.

ELMALI, D. A. et al. Effects of plant extracts and (essential) oil mixture on breast meat quality of Japanese quails (*Coturnix coturnix japonica*). **Revue de Médecine Vétérinaire**, v.165, n.3, p.104-110, 2014. Available from: <https://www.revmedvet.com/2014/RMV165_104_110.pdf>. Accessed: May. 18, 2021.

FALUDI, A. A. et al. Update of the Brazilian guideline on dyslipidemia and prevention of atherosclerosis – 2017. **Brazilian Archives of Cardiology**, v.109, n.2, supl.1, 2017. Available from: <https://www.scielo.br/j/abc/a/whBsCyzTDzGYJcsBY7YVkWn/?lang=pt>. Accessed: May, 27, 2020. doi: 10.5935/abc.20170121.

FRENCH, P.; et al., Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass, grass silage, or concentrate based diets. **Journal of Animal Science**, v.78, p.2849-2855, 2000. Available from: <https://academic.oup.com/jas/article-abstract/78/11/2849/4625638?redirectedFrom=fulltext>. Accessed: Jun. 29, 2021. doi: 10.2527/2000.78112849x.

HARGIS, P. S. Modifying egg yolk cholesterol in the domestic fowl – a review. **World's Poultry Science Journal**, v.44, n.1, p.17-29, 1988. Available from: <https://www.tandfonline.com/doi/abs/10.1079/WPS19880002>. Accessed: Apr. 05, 2021. doi: 10.1079/WPS19880002.

JANG, I. S. et al. Effect of a commercial essential oil on growth performance, digestive enzyme activity and intestinal microflora population in broiler chickens. **Animal Feed Science and Technology**, v.134, p.304315, 2007. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0377840106002562>. Accessed: Jul. 15, 2021. doi: 10.1016/j.anifeedsci.2006.06.009.

KHALIFA, M. I.; NOSEER, E. A. Cholesterol quality of edible eggs produced by quail fed diets containing probiotic and/or ginger (*Zingiber officinale*). **Livestock Research for Rural Development**, v.31, n.10, 2019. Available from: <http://www.lrrd.org/lrrd31/10/mrwa31165.html>. Accessed: May, 03, 2021.

KLASSA, B. et al. Evaluation of the effect of garlic (*Allium sativum* L.) on plasma cholesterol in rabbits with induced hypercholesterolemia. **Brazilian Journal of Medicinal Plants**, v.15, n.4, p.557-565, 2013. Available from: <https://www.scielo.br/j/rbpm/a/QtDNFqMBX6DkjjqnGkdxmyk/abstract/?lang=pt>. Accessed: May, 13, 2021. doi: 10.1590/S1516-05722013000400012.

KOIYAMA, N. T. G. et al. Performance and carcass yield of broilers fed with a mixture of phytogenic additives in the diet. **Brazilian Agricultural Research**, v.49, n.3, p.225-231, 2014. Available from: <https://www.scielo.br/j/pab/a/JhtF56BnWtNhCcgyN4KghWB/?format=html&lang=pt>. Accessed: Sep. 09, 2020. doi: 10.1590/S0100-204X2014000300009.

KOMIYAMA, C. M.; et al. Physical, chemical and sensorial breast meat quality of spent breeder hens. **Ciência Rural**, v.40, n.7, p.1623-1629, 2010. Available from: <https://www.redalyc.org/pdf/331/33117728006.pdf>. Accessed: May, 18, 2021.

LEE, K. W. et al. Growth performance of broiler chickens fed a carboxymethyl cellulose containing diet with supplemental carvacrol and/or cinnamaldehyde. **International Journal of Poultry Science**, v.3, n.9, p.619-622, 2004. Available from: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.319.8690&rep=rep1&type=pdf>. Accessed: Feb. 01, 2021. doi: 10.3923/ijps.2004.619.622.

LIMA, C. B. et al. Dietary Supplementation of Barbatimão (*Stryphnodendron Adstringens*) and Pacari (*Lafoensia Pacari*) Extracts on the Oxidative Stability and Quality of Chicken Meat. **Brazilian Journal of Poultry Science**, v.18, p.669-676, 2016. Available from: <https://www.scielo.br/j/rbca/a/7v9vDWssn8fscHkD8qMHvjh/abstract/?lang=en>. Accessed: Apr. 10, 2021. doi: 10.1590/1806-9061-2015-0212.

LINHARES NETO, M. V.; et al. Avaliation anti-Candida of essential oils from three medicinal plants species (Astereaceae). **South African Journal of Botany**. v.115 p.132–137. 2018. Available from: <https://www.sciencedirect.com/science/article/pii/S025462991731298X>. Accessed: Feb. 21, 2021. doi: 10.1016/j.sajb.2018.01.017.

LUIGGI, F. G. G. et al. Use of bixin in the broiler diet and its effects on zootechnical performance and meat quality. **Brazilian Archive of Veterinary Medicine and Zootechnology**, v.25, n.1, p.95-108, 2020. Available from: <https://revistas.ufpr.br/veterinary/article/view/67904>. Accessed: Apr. 11, 2021. doi: 10.5380/avs.v25i1.67904.

MERSEGUEL, C. E. B. et al. Crude protein requirement for European quails. **Journal of Agroveterinary Science**, v.18, n.3, p.323-330, 2019. Available from: <https://www.revistas.udesc.br/index.php/agroveterinaria/article/view/12120>. Accessed: May, 18, 2021. doi: 10.5965/223811711832019323.

NASCIF, C. C. C.; et al., Determination of energy values of some oils and fats for broilers chickens males and females in the 21 day old **Brazilian Journal of Animal Science**, v.33, p.375-385, 2004. Available from: <https://www.scielo.br/j/rbz/a/ChcyQHzWQDwmNP8x37CcGpN/?lang=pt>. Accessed: Aug. 25, 2020. doi: 10.1590/S1516-35982004000200014.

NCCLS. **Performance Standards for Antimicrobial Disk Susceptibility Tests; Approved Standard Eighth Edition**. NCCLS document M2-A8 [ISBN 1-56238-485-6]. NCCLS, 940 West Valley Road, Suite 1400, Wayne, Pennsylvania 19087-1898 USA, 2003. Available from: <https://clsi.org/media/1631/m02a12_sample.pdf >. Accessed: May, 29, 2021.

NORDESTGAARD, B. G. et al. Fasting is not routinely required for determination of a lipid profile: clinical and laboratory implications including flagging at desirable concentration cut-points—a joint consensus statement from the European Atherosclerosis Society and European Federation of Clinical

Chemistry and Laboratory Medicine. **European Heart Journal**, v.37, n.25, p.1944-1958, 2016. Available from: <https://academic.oup.com/eurheartj/article/37/25/1944/1749006>. Accessed: Jul. 21, 2019. doi: 10.1093/eurheartj/ehw152.

PERIĆ, L. et al. Application of alternative of growth promoters in broiler production. Journal **Biotechnology in Animal Husbandry**, v.25, n.5-6, p.387397, 2009. Available from: <http://scindeks.ceon.rs/article.aspx?artid=1450-91560906387P>. Accessed: Jul. 19, 2021.

PINHEIRO, S. R. F. et al. Carcass yield and meat quality of beef quails fed diets with different levels of protein and supplemented with essential amino acids. **Ciência Rural**, v.45, n.2, p.292-297, 2015. Available from: <https://www.scielo.br/j/cr/a/jLF58jC64s9xqYvzcNN5DhK/abstract/?lang=pt&format=html>. Accessed: Jul. 04, 2018. doi: 10.1590/0103-8478cr20120327.

PIZZIOLO, V. R. et al. Plants with possible hypolipidemic activity: a bibliographic review of books published in Brazil between 1998 and 2008. **Brazilian Journal of Medicinal Plants**, v.13, n.1, p.98-109, 2011. Available from: <https://www.scielo.br/j/rbpm/a/bpM79KskCdkfNgjzmzFWthB/?lang=pt>. Accessed: Nov. 16, 2020. doi: 10.1590/S1516-05722011000100015.

RAMOS, E. M., GOMIDE, L. A. M. **Meat quality assessment - Fundamentals and methodologies**. In: Evaluation of abnormal meat: PSE and DFD conditions. Viçosa: UFV. Cap.10, p.531-575.

REZENDE, M. J. M. et al. Productive performance and biometrics of French quail viscera fed different levels of metabolizable energy and crude protein. **Acta Scientiarum. Animal Sciences**, v.26, n.3, p.353-358. 2004. Available from: <https://periodicos.uem.br/ojs/index.php/ActaSciAnimSci/article/view/1810>. Accessed: Nov. 25, 2020. doi: 10.4025/actascianimsci.v26i3.1810.

RIZZO, P. V. et al. Vegetable extracts in diets for broilers. **Brazilian Journal of Animal Science**, v.39, n.4, p.801-807, 2010. Available from: <https://www.scielo.br/j/rbz/a/XPdqqvQJwkX6hkhmPtdRKsQ/abstract/?lang=pt&format=html>. Accessed: Jan. 25, 2021. doi: 10.1590/S1516-35982010000400015.

ROSTAGNO, H. S. et al. 2017. **Brazilian Poultry and Swine Tables: Food Composition and Nutritional Requirements**. Departament of Animal Science-UFV, Viçosa, 2017. (488 p.).

SANFELICE, C.; et al. Evaluation and characterization of breast quality of broiler breeder hen in the end of productive cycle. **Food Science and Technology**, v.30(Supl.1), p.166-170, 2010. Available from: <https://www.scielo.br/j/cta/a/TrCnygWKGGRqY8kHSPbDz6S/?lang=pt&format=html>. Accessed: Jan. 25, 2021. doi: 10.1590/S0101-20612010000500025.

SAÑUDO, C. A. The organoleptic quality of the meat (IV): special reference to sheep. **Livestock World**. v.2, p.67-69, 1993. Available from: <https://www.mapa.gob.es/ministerio/pags/biblioteca/revistas/pdf_MG/MG_1993_2_93_67_69.pdf >. Accessed: Jul. 19, 2021.

SILVA, J. E. S. et al. Effect of essential fatty acids on lipidemia and vascularization of the yolk membrane of Japanese quails. **Brazilian Archive of Veterinary Medicine and Zootechnology**, v.64, n.6, p.1603-1612, 2012. Available from: <https://www.scielo.br/j/abmvz/a/VLQTJYd44JRw99pFWGY5KXP/?lang=pt>. Accessed: Jul. 01, 2021. doi: 10.1590/S0102-09352012000600029.

SILVA, J. H. V.; COSTA, F. G. P. **Table for Japanese and European quails**. 2.ed. Jaboticabal: FUNEP, 2009. 110p.

TEIXEIRA, B. B. et al. Performance of beef quails subjected to different levels of crude protein and metabolizable energy. **Rural Science**, v.43, n.3, p.524-529, 2013. Available from: <https://www.scielo.br/j/cr/a/PRnw67Jfg6yKnK9LYZvfhzd/?lang=pt>. Accessed: Feb. 17, 2021. doi: 10.1590/S0103-84782013005000014.