http://dx.doi.org/10.1590/1678-4162-12350

Arq. Bras. Med. Vet. Zootec., v.74, n.2, p.359-366, 2022

Intestinal morphometry and performance of broiler chickens subjected to diets with buriti oil

[*Morfometria intestinal e desempenho de frangos de corte submetidos a dietas com óleo de buriti*]

R. *Santis*[1], F.C.F. *Albuquerque*[2], R.L.S. *Silva*[1], L.R. *Mesquita*[1], I.D. *Ferreira*[2], L.R.B. *Dourado*[3], G.J.B.C. *Ferreira*[3]

[1]Graduate, Universidade Federal do Piauí, UFPI, *Campus* Cinobelina Elvas, Bom Jesus, Piauí, Brasil
[2]Undergraduate, Universidade Federal do Piauí, UFPI, *Campus* Cinobelina Elvas, Bom Jesus, Piauí, Brasil
[3]Universidade Federal do Piauí, UFPI, *Campus* Cinobelina Elvas, Bom Jesus, Piauí, Brasil

ABSTRACT

This study aimed to evaluate the productive performance, carcass yield, and intestinal morphometry of broiler chickens subjected to diets with the inclusion of buriti oil. Buriti oil is an energy food that can be used in chicken feed to replace soybean oil, which has a high cost in production, also has its anti-inflammatory, antioxidant, and antimicrobial properties, which can provide benefits in chicken feed. 180 male broilers of the Ross lineage were used, distributed in a completely randomized design with 3 treatments and 6 replicates of 10 birds per experimental unit. The experimental phase took place from 14 to 28 days and levels 0; 0.75 and 1.50% of buriti oil were added to the corn and soybean-based feed. It can be inferred that the buriti oil-based diets in the diet with insertion of levels of 0%, 0.75% and 1.50% did not differ significantly for the productive performance variables, but in relation to the productive yield there was a significant difference for carcass yield accompanied by greater disposition of abdominal fat, thigh and heart fat, a common effect in the use of oils. Although no statistical differences were observed for most of the variables in the assessment of intestinal morphometry, there was an increase in the crypt depth of the duodenum and ileum and an increase in the muscle layer of the duodenum and jejunum, which may have been caused by some injury to the intestine and not by direct effect of buriti oil. In the other variables there was no difference between treatments and it is concluded that buriti oil did not harm the performance, yield and intestinal morphometry of broiler chickens from 14 to 28 days of age.

Keywords: metabolizable energy, poultry feeding, intestinal villi

RESUMO

Objetivou-se, com essa pesquisa, avaliar o desempenho produtivo, o rendimento de carcaça e a morfometria intestinal de frangos de corte com dietas submetidas à inclusão do óleo de buriti. Trata-se de um alimento energético que pode ser utilizado na alimentação de frangos visando substituir o óleo de soja, o qual apresenta alto custo na produção. O óleo de buriti ainda possui suas propriedades anti-inflamatórias, antioxidantes, antimicrobianas, podendo conferir benefícios na alimentação de frangos. Foram utilizados 180 frangos de corte machos, da linhagem Ross, distribuídos em um delineamento inteiramente ao acaso, com três tratamentos e seis repetições de 10 aves por unidade experimental. A fase experimental ocorreu de 14 a 28 dias, e os níveis 0%, 0,75% e 1,50% de óleo de buriti foram inseridos na ração à base de milho e soja. Pode-se inferir que as dietas à base de óleo de buriti na dieta com inserção dos níveis de 0%, 0,75% e 1,50% não diferiram significativamente para as variáveis de desempenho produtivo, mas, em relação ao rendimento produtivo, houve uma diferença significativa para o rendimento de carcaça, acompanhado de maior disposição de gordura abdominal, gordura de sobrecoxa e coração, efeito comum na utilização de óleos. Apesar de não serem observadas diferenças estatísticas para a maioria das variáveis na avaliação da morfometria intestinal, houve aumento na

Corresponding author: ranuscesantis@gmail.com
Submitted: February 25, 2021. Accepted: February 18, 2022.

profundidade de cripta do duodeno e do íleo, bem como aumento da camada muscular do duodeno e do jejuno, que podem ter sido provocados por alguma injúria no intestino e não por efeito direto do óleo de buriti. Nas demais variáveis, não houve diferença entre os tratamentos, e conclui-se que o óleo de buriti não causou prejuízo ao desempenho, ao rendimento e à morfometria intestinal de frangos de corte no período de 14 a 28 dias de idade.

*Palavras-chave***:** *energia metabolizável, alimentação de aves, vilosidades intestinais*

INTRODUCTION

Poultry is the industrial sector of meat production that has grown the most in recent decades in different countries (Dalvandi *et al.*, 2020). This dynamism in the production of Brazilian poultry farming is primarily related to nutritional parameters that allow the complete expression of the genetic potential of the animal (Rostagno *et al.*, 2011). The nutritional factor is extremely important associated with the use of strategies that can affect the quality of meat products and their nutritional value, seeking the best nutritional performance and acceptability by the consumer (Gomez *et al*., 2020).

Consumers minimally processed meat products without preservatives and with a longer shelf-life sparking interest in the use of natural additives (Gomez *et al*., 2020). Thus, plant extracts and essential oils have aroused interest for their ability to benefit animal performance in addition to meeting this consumer demand (Zanatta *et al.*, 2010).

In this context, buriti oil (*Mauritia flexuosa* L.) appears as a food with great energy capacity, due to its high content of fatty acids (Manhães and Sabaa-Srur, 2011) and is still rich in its bioactive compounds, as it has considerable amounts of carotenoids , polyphenols and ascorbic acid, providing an antioxidant, anti-inflammatory and healing profile (Manhães and Sabaa-Srur, 2011). In addition, its production is abundant in certain regions of Brazil, which may favor several producers (Manhães and Sabaa-Srur, 2011). These characteristics, besides bringing benefits to the performance of broilers, might also influence the purchase profile by the consumers.

Therefore, this work aimed to evaluate the influence of diets containing different levels of buriti oil as an energetic feed on the morphometric characteristics of the intestinal tract (duodenum, jejunum and ileum), productive performance, and carcass yield of broiler chickens with 28 days of age.

MATERIAL AND METHODS

The experiment was performed in the Federal University of Piauí (UFPI), *campus* Professora Cinobelina Elvas – CPCE, located in the municipality of Bom Jesus – PI. The proceedings performed in the experiment were approved by the Ethics Committee in Animal Experimentation– CEEA/UFPI, with a favorable opinion approved under the number 007/13.

To carry out the experimental work, 180 male broilers of the Ross lineage were used. The animals were placed in 18 boxes, containing 10 birds each, distributed in a completely randomized design with 3 treatments and 6 replicates of 10 birds per experimental unit. The animals were distributed according to their average weight, containing tubular feeders and pendular drinkers, located in a masonry shed covered with ceramic tiles and cemented floor. The accommodation shed is partially open in which the partitions between the boxes were made of smooth wire mesh, and curtains were used to control temperature and air currents. The diets were formulated based on corn and soybean, with energetic values and chemical composition of the feed according to Rostagno *et al.* (2011) until the period of 14 days. The inclusion levels of 0% (T1), 0.75% (T2), and 1.50% (T3) of buriti oil were inserted in the feed for the experimental stage of the broilers, starting at 14 days, and the slaughter occurred at 28 days (Table 1). The supply of water and ration was provided *ad libitum*. The buriti oil that made up the diet obtained with local producers, being manually extracted through the pressing of the buriti pulp and added directly to the feed.

Table 1. Centesimal composition of the experimental diets for broiler chickens in the stage from 14 to 28 days of age

	Treatments		
Ingredient (%)	0%	0.75%	1.50%
Corn	64.024	64.024	64.024
Soybean meal 48%	28.963	28.963	28.963
Dicalcium phosphate	1.561	1.561	1.561
Limestone	0.922	0.922	0.922
Soybean oil	1.600	0.980	0.400
Common salt	0.496	0.496	0.496
Vit. Supl. min.[1]	1.000	1.000	1.000
DL-methionine	0.145	0.145	0.145
L-arginine	0.161	0.161	0.161
L-lysine HCL	0.564	0.564	0.564
L-valine	0.126	0.126	0.126
Inert[2]	0.300	0.170	0.000
Buriti oil	0.000	0.750	1.500
Total	100.00	100.00	100.00
Nutritional composition			
EMA (Mcal/kg)[3]	3,0002	2,9971	2,9975
Linoleic acid (%)	2.3217	2.4008	2.5009
Proteína bruta (%)	19,2553	19,2553	19,2553
Lisina dig. (%)	1,1739	1,1739	1,1739
Met+cist. dig. (%)	0,8465	0,8465	0,8465
Metionina dig. (%)	0,5889	0,5889	0,5889
Arginina dig. (%)	1,2676	1,2676	1,2676
Treonina dig.	0,7628	0,7628	0,7628
Triptofano dig.	0,2000	0,2000	0,2000
Valina dig.	0,9034	0,9034	0,9034
Cálcio (%)	0,8188	0,8188	0,8188
Cloro (%)	0,5703	0,5703	0,5703
Fósforo disp. (%)	0,3909	0,3909	0,3909
Potássio (%)	0,9059	0,9059	0,9059
Sódio (%)	0,2100	0,2100	0,2100

[1]Warranty levels per kg of the product: folic acid – 200.00mg; biotin - 10.000mg; chlorohydroxyquinoline – 7500.00mg; vitamin A – 1680000.00 UI; vitamin B1 – 436.50mg; vitamin B12 – 2400.00mcg; vitamin B2 – 1200.00mg; vitamin B6 – 624.00mg; vitamin D3 – 400000.00 UI; vitamin E – 3500.00mg ; vitamin K 3 – 360.00mg; niacin – 8400.00mg; sodium monensin – 25000.00mg; pantothenic acid – 3119.00mg; choline chloride – 80.710mg; selenium -75.00mg; iron sulphate 11.250 mg; manganese monoxide – 18740.00mg; iodine – 187.47mg; zinc – 17500.00mg; [2]Inert – sand; [3]AME of the buriti oil – 6854kcal/kg.

The evaluations for productive performance and carcass yield occurred at 28 days, when three broilers were randomly selected from each box, totalizing 54 samples. The broilers were weighed after a feed fasting of 8 hours straight and were afterward slaughtered to cervical dislocation, followed by blood drainage. For the performance evaluation, the weight gain (WG), Body weight (BW), feed intake (FI), and feed conversion (FC) were evaluated.

The carcass, breast, drumstick, and thigh yields, as well as the percentage (%) of abdominal fat, were measured to evaluate the carcass characteristics. The carcass yield was determined in relation to the fasting live weight of the broilers, and the yield of the remaining cuts was calculated in relation to the weight of the eviscerated carcass. For the definition of the weight of the eviscerated carcass, the weight of the broilers subjected to pre-slaughter fasting, without feathers, viscera, head, neck, and feet was considered. The abdominal fat was considered as the adipose tissue adhered around the cloaca, gizzard, and adjacent abdominal muscles, removed from the carcass. The percentage of abdominal fat was estimated by the ratio between the fat adhered to the above-mentioned organs and the carcass weight.

The means of these studied variables were evaluated using the GLM procedure of the Statistical Analysis System – SAS (1999). After analysis of variance, means were compared using the SNK test with a significance level of 0.05.

For the morphometric evaluation, one animal was randomly selected from each box. After the slaughter of the broilers, the collection of the intestinal fragments was performed. The cleavage process of the collected fragments comprised approximately 2 cm of each of the intestinal segments (duodenum, jejunum, and ileum) of each animal. The washing of the intestinal lumen was performed with distilled water, and the fragments were immersed in formalin fixers. The material was processed following standard histology techniques by passing the tissues through dehydration processes in growing alcohol solutions (50%, 70%, 80%, 90%, and 100%), absolute alcohol I, absolute alcohol II, absolute alcohol III, clarified in xylol I and xylol II, impregnated and included in paraffin I and II during one hour in each solution. The material included in paraffin blocks was processed in a microtome into 4 µm histological cuts, subjected to water bath at 60°C, deparaffinized in an oven at 60°C for one hour, and stained with hematoxylin and eosin (HE), with the analyses being performed by light microscopy, according to Junqueira and Junqueira (1983). The counts of the microscopic fields of view were performed using a light microscope (Nova Optical systems). The histological cuts that were viable for measurement were selected and, from each cut, 10 villi, 10 crypts, and 10 spots of the muscle layer were measured (Figure 1). The images were obtained with TOUPCAM™ digital camera coupled to the microscope. After selecting the villi and crypts suitable for measurement and obtaining their images, the measurements were made with the aid of the ToupView® 3.7 software. The analyzed variables were the height and width of the villi, height and width of the crypts, and thickness of the muscle wall of the intestine (Figure 1).

The analysis of variance test (Kruskal-Wallis) was applied to compare the three groups in relation to the mean of treatments test at 1% probability. The means of the studied variables were evaluated using the System for Analysis and Comparison of Means – SASM.

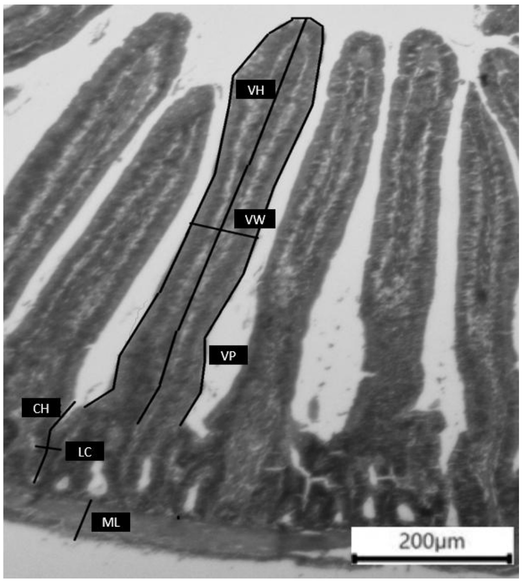

Figure 1. Photomicrograph depicting the measured areas. VP: villus perimeter; VH: villus height; VW: villus width; CH: crypt height; LC: crypt width; ML: muscle layer. HE staining. Visualization through a 4X objective lens.

RESULTS AND DISCUSSION

The mean body weight (BW), weight gain (WG), feed intake (FI), and feed conversion (FC) data are presented in Table 2. There was no significant effect between treatments with different inclusion levels of buriti oil in the diet of broiler chickens in the stage from 14 to 28 days of age.

There was no defined difference between treatments for the different levels of inclusion of buriti oil on the parameters mean weight, weight gain, feed intake and feed conversion. Comparing these variables, the use of 0.4% mastic oil in broiler diets resulted in greater weight gain and final weight of birds when compared to the control group (Toghyani *et al*., 2011). Still, for the same variables, when comparing with the results of Murakami *et al*. (2013), which evaluated cashew nut oil on the performance of broiler chickens, in birds challenged with coccidia, concluded an improvement in the performance of the birds.

Toghyani *et al*. (2011) comments that buriti oil has superiority in relation to its bioactive compounds when compared to other oils of vegetable origin. These compounds have an anti-inflammatory and antioxidant effect, improve the immune response, regulating the metabolism and use of nutrients, which may reflect on the productive performance (Perini *et al*., 2010). The result for aroeira oil and a cashew nut, which are oils rich in energy and their bioactive compounds, propagate a positive response when we compare the same results with our work. Considering the benefits found in buriti oil, for these variables, by increasing the levels of buriti oil in the diet, it can be observed that even without a significant effect between treatments, it is noteworthy that it did not bring harm, as the birds maintained their performance.

Table 2**.** Means and standard deviation of the mean body weight (BW), weight gain (WG), feed intake (FI) and feed conversion (FC) of broiler chickens subjected to diets with different levels of buriti oil in the diet in the stage from 14 to 28 days of age

Variable	Levels of buriti oil			CV (%)	p
	0%	0.75%	1.50%		
BW (kg)	1.351±0.05	1.358±0.07	1.342±0.05	4.28	0.89^{ns}
WG (kg)	0.955±0.04	0.950±0.06	0.947±0.03	4.79	0.95^{ns}
FI (kg)	1.501±0.06	1.455±0.07	1.502±0.04	3.88	0.30^{ns}
FC (kg/kg)	1.572±0.03	1.534±0.08	1.588±0.05	3.62	0.27^{ns}

CV (%) = coefficient of variation
*p < 0.01 ** p<0.10

The result of carcass yield (CY), chest yield (CHY), drumstick yield (DY), thigh yield (TY), wing yield (WY), heart yield (HY), fat yield (AFY), and liver yield (LY) are presented in Table 3. There was no significant effect between the carcass yield and the yield of the remaining cuts for the different inclusion levels of buriti oil.

Table 3. Means and standard deviation of the carcass yield (CY), chest yield (CHY), drumstick yield (DY), thigh yield (TY), wing yield (WY), heart yield (HY), abdominal fat yield (AFY), and liver yield (LY) of broiler chickens subjected to diets with different levels of buriti oil in the stage from 14 to 28 days of age.SA

Variable	Levels of buriti oil			CV (%)	p
	0%	0.75%	1.50%		
CY (%)	70.820 ± 1.84^{b}	69.238 ± 0.76^{a}	68.494 ± 0.69^{a}	1.74	0.01*
CHY (%)	35.742±1.07	36.814±1.10	35.920±1.14	3.05	0.22^{ns}
DY (%)	13.400±0.58	13.700±0.45	14.124±0.57	3.90	0.10**
TY (%)	15.149±0.89	15.570±1.09	15.592±0.91	6.25	0.68^{ns}
WY (%)	11.116±0.61	11.112±0.46	10.879±0.48	4.72	0.67^{ns}
HY (%)	0.775±0.03	0.752±0.05	0.695±0.07	7.26	0.06**
AFY (%)	1.893±0.05	2.261±0.42	2.126±0.18	12.57	0.08**
LY (%)	3.132±0.019	3.148±0.17	3.111±0.32	7.52	0.97^{ns}

CV (%) = coefficient of variation
*p < 0.01 ** p<0.10

Birds fed diets with the inclusion of buriti oil had lower carcass yield when compared to those fed diets without the inclusion of buriti oil. The other performance variables did not show significant differences (p>0.01). On the other hand, there was an increase in the means for abdominal fat yield, thigh yield and heart yield, which can be explained by the caloric increase in the diet. A challenge of commercial lines of poultry is the improvement of the carcass quality of chickens without especially causing an increase in abdominal fat, resulting in an excellent carcass

(Ferreira *et al*., 2015). A greater amount of energy present in oils can be a factor for fat predisposition (Pinchasov and Nir, 1992). This information can be confirmed in our work, in which as the levels of buriti oil in the diet increased, we can see an increase in abdominal fat, although this was not statistically observed.

Morais *et al*. (2017) mentions that buriti oil has a good metabolizable energy with a small difference between soybean oil. When comparing these values and considering that the proportion between n-6 and n-3 polyunsaturated fatty acids in soybean oil is low, it shows that the inclusion of buriti oil in the feed can improve the quality of carcass fat, which may have an effect positive in the nutritional quality of chicken meat, and promote a reduction in the levels of total lipids and cholesterol, an aspect increasingly demanded by consumers (Ferreira *et al*., 2015), since the role of oleic acid and fatty acids Polyunsaturated agents are directly related to their immunological, anti-inflammatory and antioxidant potential (Perini *et al.*, 2010).

Table 4 presents the results for the mean values of height, (VH), width (VW) and perimeter (VP) of the intestinal villi, width (LC) and depth of the intestine crypts (CD), and width of the muscle layer (ML) of the duodenum, jejunum and ileum in broiler chickens from 14 to 28 days of age subjected to diets containing different inclusion levels of buriti oil.

Table 4. Descriptive for the histomorphometric parameters: height (VH), width (VW), and perimeter of the villus (VP), height (CH) and depth of the crypt (CD) and muscle layer (ML) of the duodenum, jejunum and ileum in broiler chickens fed with different inclusion of buriti oil

Variable (µm)		Treatment		CV(%)	p
		Duodenum			
	0%	**0,75%**	**1,50%**		
VH	1616.02375	1640.20425	1674.344	10.90	0,42^{ns}
VW	167.13875	154.08025	166,536	18.89	0,40^{ns}
VP	3268.40425	3178.68275	3341.7235	10.48	0,88^{ns}
CD	80.21975^{b}	110.351^{a}	118.82315^{a}	15.14	0.01*
LC	45.76775	49.61625	50.435	15.12	0,32^{ns}
ML	187.29475	272.80	259.08	27.52	0.01*
		Jejunum			
VH	1385.476	1478.9405	1461.7335	10.96	0,42^{ns}
VW	94.8695^{b}	125.97425^{a}	129.87725^{a}	15.31	0,03*
VP	2791.30575	2959.26825	3069.76375	12.20	0,31^{ns}
CD	98.47525	125.499	122.4625	22.87	0,24^{ns}
LC	50.57075	51.07275	53.22	18.07	0,43^{ns}
ML	169.212^{b}	320.6055^{a}	285.03025^{a}	26.11	0,01*
		Ileum			
VH	762.07717	859.338	804.1175	15.48	0.32^{ns}
VW	125.9935	144.63983	156.7675	16.02	0,05**
VP	1562.00517	1727.6587	1672.2745	15.93	0,46^{ns}
CD	88.2285^{b}	137.3463^{a}	110.455^{a}	22.64	0,02*
LC	52.6105	51.683	54.853	10.76	0,64^{ns}
ML	227.15217	306.00117	291.39183	27.73	0,27^{ns}

CV(%) = coefficient of variation
*p < 0.01 ** p<0.10
µm = micrômetro

In the duodenal portion, we see a significant difference for CD when the levels of 0.75 and 1.5% of buriti oil in the diet were inserted, when higher values were compared to the group that did not receive the treatment. Structures such as villi, crypts and mucosal thickness can be altered by diet composition (Mirzaie *et al.*, 2020). The cells that make up the intestinal crypts accumulate and increase the size of the villi, thus increasing the absorption area. However, if as this proliferation of cells occurs, they are lost in the intestinal lumen, due to the non-maintenance of their integrity, there is a decrease in these villi (Óriá; Brito, 2016). According to Pluske *et al.* (1997) a higher value for crypt depth indicates an increase in mitosis rates, that is, an increase in proliferative activity to compensate for the loss in villi height (extrusion). Increased cell proliferation, with decreased villus height indicates a smaller absorption area.

Combined with mucosal immunity and other protective effects in chicken, stimulation of intestinal proliferation aims to partially ameliorate damage to the epithelium (Xie *et al.*, 2020). However, as no variations in the intestinal villi were observed, we can say that there was no damage to the absorption area.

It is possible that when there is an injury to the intestinal tissue, buriti oil has acted in tissue repair. Several authors mention that the bioactive properties of buriti oil can promote benefits due to the high concentration of fatty acids, provide prerequisites for the healing process, release of free radicals, have anti-inflammatory potential and act in the immunological process (Silva; Pighinelli, 2017; Perini *et al.*, 2010; Speranza *et al.*, 2018).

We can observe that the ML when added to the treatments present a higher average in relation to the group that was not inserted buriti oil for both the duodenum and the jejunum. According to Shiraishi *et al.* (2009) the muscle layer may undergo hyperplasia of its cells due to an attempt to increase its muscle strength to resist pressure with a defense function against a threat. This factor may reflect on the animal's productive performance (Rena *et al.*, 2007). An increase in muscle wall thickness causing hypertrophy contributes to altering productive performance (Aleixo *et al.*, 2011).

As buriti oil has antimicrobial and healing characteristics (Batista *et al.*, 2012), it is possible that it helped in tissue healing and regeneration. Both vitamin E and carotenoids act in the process of tissue repair and regeneration, binding to the wound's free radicals, thus providing protection to the injured tissue (Pianovski *et al.*, 2008).

Noleto *et al.* (2018) did not observe a beneficial effect on the jejunum segment of broiler chickens when fed with rations containing copaiba and sucupira oil. However, the results of Silva *et al.* (2011) who verified a greater height of the jejunum villi of the brooded birds when using 0.4% the red mastic oil (*Schinus terebinthifolius*) compared to birds treated without growth promoter at 21 days of age. The authors associate this fact with the presence of anti-inflammatory and antimicrobial properties present in *Schinus terebinthifolius.*

Considering that soy oil is a common product in chicken feed as an energy source, the inclusion of another oil, reducing the percentage of soy oil in the feed, could both cause damage and improve the villi absorption area. However, the addition of buriti oil did not harm the studied variables.

CONCLUSIONS

It can be inferred that diets based on buriti oil in the diet with insertion of levels of 0%, 0.75% and 1.50% did not differ for the productive performance variables, but there was a difference in relation to the yield. The was reduced for carcass yield accompanied by greater disposition of abdominal fat, thigh and heart fat, a common effect in the use of oils. Although no statistical differences were observed for most of the variables in the assessment of intestinal morphometry, there was an increase in the depth of the duodenum and ileum crypts and an increase in the muscle layer of the duodenum and jejunum, which may have been eliminated by some intestinal lesion not related to the effect of adding buriti oil. Thus, it can be concluded that buriti oil did not affect the studied variables.

REFERENCES

ALEIXO, V.M.; PRESSINOTI, L.N.; CAMPOS, D.V.S. *et al.* Histologia, histoquímica e histometria do intestino do intestino de jacaré-do-pantanal criado em cativeiro. *Pesqui. Vet. Bras*. v.31, p.1120-1128, 2011.

BATISTA, J.S.; OLINDA, R.G.; MEDEIROS, V.B. *et al.* Atividade antibacteriana e cicatrizante do óleo de buriti *Mauritia flexuosa* L. *Ciênc. Rural*, v.42, p.136-141, 2012.

DALVANDI, F.; ALMASI, H.; GHANBARZADEH, B. *et al.* Effect of vacuum packaging and edible coating containing black pepper seeds and turmeric extracts on shelf life extension of chicken breast fillets. *J. Food Bioprocess Eng*., v.3, p.69-78, 2020.

FERREIRA, G.S.; PINTO, M.F.; GARCIA NETO, M. *et al.* Ajuste preciso do nível de energia na dieta de frangos de corte para controle do desempenho e da composição lipídica da carne. *Ciênc. Rural*, v.45, p.104-110, 2015.

GOMEZ, I.; JANARDHANAN, R.; IBAÑEZ, F.C.; BERIAIN, M. J. The effects of processing and preservation technologies on meat quality: sensory and nutritional aspects. *Foods*, v.9, p.1416, 2020.

JUNQUEIRA, L.C.U.; JUNQUEIRA, L.M.M.S. *Técnicas básicas de citologia e histologia*. São Paulo: Santos, 1983. 123p.

MANHÃES, L.R.T.; SABAA-SRUR, A.U.O. Centesimal composition and bioactive compounds in fruits of buriti collected in Pará. *Ciênc. Tecnol. Aliment.*, v.31, p.856-863, 2011.

MIRZAIE, S.; SHARIFI.; S.D.; ZIRAK-KHATTAB, F. The effect of a *Chlorella* by-product dietary supplement on immune response, antioxidant status, and intestinal mucosal morphology of broiler chickens. *J. Appl. Phycol.*, v.32, p.1771-1777, 2020.

MORAIS, J.S.; BEZERRA, L.R.; SILVA, A.M.A. *et al.* Production, composition, fatty acid profile and sensory analysis of goat milk in goats fed buriti oil. *J. Anim. Sci.*, v.95, p.395-406, 2017.

MURAKAMI, A.N.N.; AMBONI, R.D.M.C.; PRUDÊNCIO, E.S. *et al.* Concentration of biologically active compounds extracted from Ilex paraguariensis St. Hil. by nanofiltration. *Food Chem.*, v.141, p.60-65, 2013.

NOLETO, R.A.; LEANDRO, N.S.M.; MELLO, H.H.C. *et al.* Supplementation of copaiba or sucupira oils in broiler diets. *Rev. Bras. Saúde Prod. Anim.*, v.19, p.83-92, 2018.

ORIÁ, R.B.; BRITO, G.A.C. *Sistema digestório: integração básico* – clínica. São Paulo: Edgard Blucher, 2016. Cap.12, p.275-314.

PERINI, J.A.L.; STEVANATO, F.B.; SARGI, S.C. *et al.* Ácidos graxos poliinsaturados n-3 e n-6: metabolismo em mamíferos e resposta imune. *Rev. Nutr.*, v.23, p.1075-1086, 2010.

PIANOVSKI, A.R.; VILELA, A.F.G.; SILVA, A.A.S. *et al.* Uso do óleo de pequi (*Caryocar brasiliensis*) em emulsões cosméticas: desenvolvimento e avaliação da estabilidade física. *Braz. J. Pharm. Sci*, v.44, p.249-259, 2008.

PINCHASOV, Y.; NIR, I. Effect of dietary polyunsaturated acid concentration on performance, fat deposition and carcass fatty acid composition in broiler chickens. *J.Poult. Sci.*, v.71, p.1504-1512, 1992.

PLUSKE, J.R.; HAMPSON, D.J.; WILLIANS, I.H. Factors influencing the structure and function of the small intestine in the weaned pig: a review. *Livest. Prod. Sci.*, v.51, p.215-236, 1997.

RENA, C.L.; SILVA, A.L.; BARRA, A.A. *et al.* Alterações morfométricas da musculatura dos músculos longitudinal e circular de ratos submetidos à criação de piloros no intestino delgado. *Rev. Colégio Bras. Cir.*, v.34, p.41-47, 2007.

ROSTAGNO, H.S.; ALBINO, L.F.T.; DONZELE, J.L. *et al. Tabelas brasileiras para aves e suínos*: composição de alimentos e exigências nutricionais. 3.ed. Viçosa: UFV, 2011. 252p.

SHIRAISHI, C.S.; AZEVEDO, J.F.; SILVA, A.V. *et al.* Análise morfométrica da parede intestinal e dinâmica de mucinas secretadas no íleo de frangos infectados por Toxoplasma gondii. *Rev. Ciênc. Rural*, v.39, p.2146-2153, 2009.

SILVA, R.F.J.; PIGHINELLI, L. Application of chitosan and buriti oil (*Mauritia flexuosa* L.) in skin wound healing. *J. Appl. Biotechnol. Bioeng.*, v.3, p.272-279, 2017.

SILVA, S.M.; SAMPAIO, K.A.; TAHAM, T. *et al.* Characterization of oil extracted from buriti fruit (*Mauritia flexuosa*) grown in the Brazilian Amazon region. *J. Am. Oil Chem. Soc.*, v.10, p.611-616, 2011.

SPERANZA, P.; LEÃO, K.M.M.; NARCISO, T.S.G. *et al.* Improving the chemical properties of Buriti oil (Mauritia flexuosa L.) by enzymatic interesterification. *Grasas Aceites*, v.69, p.282, 2018.

SAS. Statistical analysis system. Version 5. Cary: SAS Institute, 1999.

TOGHYANI, M.; TOGHYANI, M.; GHEISARI, A. *et al.* Evaluation of cinnamon and garlic as antibiotic growth promoter substitutions on performance, immune responses, serum biochemical and haematological parameters in broiler chicks. *Livest. Prod. Sci*., v.138, p.167-173, 2011.

XIE, S.; LI, Y.; ZHAO, S.; LV, Y.; YU, Q. *Salmonella* infection induced intestinal crypt hyperplasia through Wnt/β-catenin pathway in chicken. *Res. Vet. Sci*., v.130, p.179-183, 2020.

ZANATTA, C.F.; MITJANS, M.; URGATONDO, V. *et al.* Photoprotective potential of emulsions formulated with Buriti oil (*Mauritia flexuosa*) against UV irradiation on keratinocytes and fibroblasts cell lines. *Food Chem. Toxicol*., v.48, p.70-75, 2010.