Revista Ciência Agronômica, v. 53, e20207545, 2022
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Meat quality in European quail supplemented with sources of polyunsaturated fatty acids[1]

Qualidade de carne de codornas europeias suplementada com fontes de ácidos graxos poli-insaturados

Cecylyana Leite Cavalcante[2]*, José Jordão Filho[3], Sthelio Braga da Fonseca[4], José Humberto Vilar da Silva[3], Bruno Raniere Lins de Albuquerque Meireles[4], Diógenes Gomes de Sousa[2], Janiele Ferreira da Silva[2], Laryssa Querino da Silva Duarte[5]

ABSTRACT - The aim of this study was to carry out a comparative evaluation of the effect of adding different sources of PUFAS to the diet on performance, carcass yield, chemical composition, and the physical characteristics of breast meat from European quail. A total of 280 European quail with a mean weight of 90.97 ± 0.5 g, during the growth period and ranging from 14 to 42 days of age, were distributed in a completely randomised design with seven treatments, and five replications of eight birds each. The quail were fed on diets containing 2% of the following lipid sources and mixtures: 1. Soybean oil (SBO); 2. Linseed oil (LSO); 3. Brazil Nut Oil (BNO); 4. Fish oil (FSO); 5. LSO+SBO; 6. BNO+SBO; and 7. FSO+SBO. Performance measures, such as carcass yield and meat quality (chemical composition, pH, centrifugation loss, weight loss by cooking, shear strength and colour) were evaluated. The performance measures (weight gain, feed intake and feed conversion) were influenced by the source of lipids. The FSO diet showed better performance. Quails fed on the BNO (18.27 g/bird/day) and LSO (17.58 g/bird/day) diets had a higher feed intake. Carcass yield and the chemical composition of the meat showed no significant differences (P > 0.05), while the chemical and physical characteristics showed differences between the lipid sources added to the diet. The addition of sources of polyunsaturated fatty acids caused no harmful effects to the birds or undesirable changes in meat quality.

Key words: *Cortunix cortunix cortunix*. Oils. PUFAS.

RESUMO - Objetivou-se com esse estudo avaliar de forma comparativa a influência de diferentes fontes de PUFAS na dieta sobre o desempenho, rendimento de carcaça, composição química e características físicas da carne do peito de codornas europeias. Foram utilizadas 280 codornas europeias, peso médio 90,97 ± 0,5 g, durante período de crescimento, compreendido de 14 a 42 dias de idade, distribuídas em delineamento inteiramente ao acaso com sete tratamentos, e cinco repetições com 8 aves cada. As codornas foram alimentadas com rações contendo 2% das seguintes fontes e misturas lipídicas: 1. Óleo de soja (SBO); 2. Óleo de linhaça (LSO); 3. Óleo de castanha- do-Pará (BNO); 4. Óleo de peixe (FSO); 5. LSO+SBO; 6. BNO+SBO; e 7. FSO+SBO. Foram avaliadas as medidas de desempenho, rendimento de carcaça e características de qualidade de carne (composição química, pH, perda por centrifugação, perda de peso por cocção, força de cisalhamento e cor). As medidas de desempenho (ganho de peso, consumo de ração e conversão alimentar) foram influenciadas pelas fontes lipídicas. A dieta FSO apresentou melhor desempenho. As codornas alimentadas com as dietas BNO (18,27 g/ave/dia), LSO (17,58 g/ave/dia) apresentaram maior consumo de ração. O rendimento de carcaça e a composição química da carne não apresentaram diferença significativa (P > 0,05), enquanto que as características químicas e físicas apresentaram diferença entre as fontes lipídicas suplementadas na dieta. A adição de fontes de ácidos graxos poli-insaturados não causaram efeitos prejudiciais às aves e alterações indesejáveis à qualidade de carne.

Palavras-chave: *Cortunix cortunix cortunix*. Óleos. PUFAS.

DOI: 10.5935/1806-6690.20220015
Editor-in-Article: Prof. Alek Sandro Dutra - alekdutra@ufc.br
*Author for correspondence
Received for publication on 13/08/2020; approved on 22/09/2021

[1]Parte da dissertação da primeira autora, apresentada ao Programa de Pós-Graduação em Tecnologia Agroalimentar - PPGTA do Centro de Ciências Humanas, Sociais e Agrárias (CCHSA) da Universidade Federal da Paraíba (UFPB)

[2]Programa de Pós-Graduação em Tecnologia Agroalimentar do CCHSA (UFPB), Bananeiras-PB, Brasil, cecyleite@hotmail.com (ORCID ID 0000-0002-7961-9628), didi19_gomes@hotmail.com (ORCID ID 0000-0003-2799-4263), janieledellety@hotmail.com (ORCID ID 0000-0002-5140-8175)
[3]Departamento de Ciência Animal, Centro de Ciências Humanas Sociais e Agrárias, Universidade Federal da Paraíba (UFPB), Bananeiras-PB, Brasil, jjordaofilho@yahoo.com.br (ORCID ID 0000-0003-3964-9301), vilardasiva@yahoo.com.br (ORCID ID 0000-0001-8605-2829)
[4]Unidade Acadêmica de Tecnologia de Alimentos, Universidade Federal de Campina Grande (UFCG), Campus Pombal, Pombal-PB, Brasil, sthelio@yahoo.com.br (ORCID ID 0000-0002-3005-5438), bruno_meireles7@hotmail.com (ORCID ID 0000-0002-3604-9768)
[5]Licenciatura em Ciências Agrárias, Programa Institucional de Bolsa de Iniciação Científica (PIBIC/CNPq/UFPB), CCHSA, Bananeiras-PB, Brasil, laryssaquerino@gmail.com (ORCID ID 0000-0002-9909-1058)

INTRODUCTION

Quail farming is important to the poultry industry in Brazil, as it is a low-cost activity, a result of the small area required for implementation, little expenditure on feed, and especially the rapid financial return (TON *et al*., 2011) from the production of eggs and meat, products that are readily accepted by the consumer.

The European quail (*Coturnix Cortunix Cortunix*) stands out for meat production due to its rapid growth, with a live weight of approximately 200 g at 35 days, which allows for early slaughter, in addition to producing a carcass yielding more meat than Japanese quail (SILVA *et al*., 2012). Quail meat contains essential amino and fatty acids, is easily digested and has a taste similar to that of wild birds, which makes it a superior delicacy among sources of animal protein (RAJI *et al*., 2015).

The addition of certain food ingredients to poultry diets has a direct influence on meat quality, such as the physical characteristics, and the chemical and nutritional composition of the meat, affecting its acceptance by consumers (MAZIZI; ERLWANGER; CHIVANDI, 2020). Lipid sources are added to poultry diets for various reasons which include an increase in the energy concentration, aiding the absorption of fat-soluble vitamins, improving bird acceptance of the diets, reducing the caloric increase in situations of thermal discomfort, and enhancing the nutritional functionality of poultry meat and eggs by increasing the levels of essential fatty acids (BAIÃO; LARA, 2005), in addition to improving the performance of pelletising and extrusion machines.

Oils, both vegetable and of animal origin, contain polyunsaturated fatty acids (PUFAS), which, added to animal feed in suitable proportions, can increase the accumulation of PUFAS and enrich the meat (SOBOL; RAJ; SKIBA, 2016), as well as affect the sensory characteristics of the meat, and meet consumer demand for quality food with a nutritional composition that brings benefits to consumer health. The aim of this study, therefore, was to carry out a comparative evaluation of the effect of different sources of PUFAS in the diet on performance, carcass yield, chemical composition, and the physical characteristics of breast meat from European quail.

MATERIAL AND METHODS

The experiment was conducted from Octuber to December 2019 in the Poultry Laboratory of the Centre for Human, Social and Agrarian Sciences (CCHSA), on Campus III of the Federal University of Paraíba (UFPB), in the city of Bananeiras, Paraíba. The project was submitted to and approved by the Animal Ethics Committee (CEUA) of UFPB, under protocol no 3382060519.

A total of 280 European quail (*Cortunix Cortunix Cortunix*) with a mean initial weight of 90.97 ± 0.5 g, during the growth period and ranging from14 to 42 days of age, were used. The birds were distributed in a completely randomised design with seven diets and five replications of eight quail per plot, and were housed in a crate with a floor size of 1.0 x 0.8 m covered in wood shavings. The crate was screened and equipped with a hanging feeder and water dispenser, and 60 w lamps.

The experimental diets were based on corn and soybean meal, and were supplemented to meet the nutritional requirements of European quail, as per the recommendations of Silva and Costa (2009) (Table 1); the diets and water were offered at will throughout the experimental period.

The lipid sources and mixtures were added to the feed based on the following diets: 2% soybean oil (SBO), 2% linseed oil (LSO), 2% Brazil nut oil (BNO) and 2% fish oil (FSO), with three further mixtures comprising 1% LSO with 1% SBO, 1% BNO with 1% SBO and 1% FSO with 1% SBO.

At the end of the experimental period, the leftovers and quail were weighed to assess feed intake, weight gain and feed conversion. Feed intake was calculated from the difference between the feed offered and the leftovers, weight gain was determined from the difference between the weight of the birds at the start and end of the experiment, while feed conversion was obtained from the ratio between feed intake and weight gain.

At 42 days of age, a total of 175 quail, five per plot and 25 per treatment, were selected based on mean weight and subjected to an eight-hour water fast. After fasting, the birds were individually weighed and anesthetised with pentobarbital at a dose of 60 to 100 mg/kg, euthanised, and exsanguinated. The birds were then plucked and gutted to obtain the carcass weight and the weight of the prime cuts, represented by the breast, thigh and drumstick. The breasts, chosen for the analysis, were packed in hermetically sealed, Ziploc plastic bags, identified and stored in a refrigerator at -4 ºC for 24 hrs; they were then maintained at -18 ºC for further analysis.

To determine carcass yield, the weight of the cleaned, eviscerated carcass with no head, feet or legs was considered relative to the live weight after fasting, while the yield of each cut (breast, thigh and drumstick) was calculated by dividing the weight of the cut by the weight of the carcass.

To analyse meat quality, the following were evaluated 24 hours after slaughter: pH and centrifugation loss as per the methodology of Herrero *et al*. (2005),

Table 1 - Food and nutritional composition of the experimental diets[1]

Ingredients (%)	Soybean oil (SBO)	Linseed oil (LSO)	Brazil nut oil (BNO)	Fish oil (FSO)	LSO+SBO	BNO+SBO	FSO+SBO
Corn	56.471	56.465	56.530	56.326	56.468	56.501	56.399
Soybean meal	38.301	38.302	38.290	38.327	38.301	38.295	38.314
Soybean oil	2.000	-	-	-	1.000	1.000	1.000
Linseed oil	-	2.000	-	-	1.000	-	-
Brazil nut oil	-	-	2.000	-	-	1.000	-
Fish oil	-	-	-	2.000	-	-	1.000
Limestone	1.062	1.062	1.062	1.062	1.062	1.062	1.062
Dicalcium Phosphate	0.929	0.929	0.929	0.929	0.929	0.929	0.929
Common salt	0.351	0.351	0.351	0.351	0.351	0.351	0.351
Inert	0.350	0.356	0.302	0.469	0.353	0.326	0.409
DL-Methionine	0.299	0.299	0.299	0.299	0.299	0.299	0.299
Vitamin premix	0.100	0.100	0.100	0.100	0.100	0.100	0.100
L-Lysine	0.061	0.061	0.062	0.061	0.061	0.061	0.061
Mineral premix	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Antioxidant	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Zinc Bac	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition of the experimental diets							
Crude protein (%)	22.000	22.000	22.000	22.000	22.000	22.000	22.000
Metabolizable energy (kcal/kg)	2.950	2.950	2.950	2.950	2.950	2.950	2.950
Calcium (%)	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Potassium (%)	0.865	0.865	0.865	0.865	0.865	0.865	0.865
Chlorine (%)	0.254	0.254	0.254	0.254	0.254	0.254	0.254
Phosphorus (%)	0.290	0.290	0.290	0.290	0.290	0.290	0.290
Sodium (%)	0.160	0.160	0.160	0.160	0.160	0.160	0.160
Arginine (%)	1.406	1.406	1.406	1.406	1.406	1.406	1.406
Lysine (%)	1.140	1.140	1.140	1.140	1.140	1.140	1.140
Met+Cis (%)	0.890	0.890	0.890	0.890	0.890	0.890	0.890
Methionine (%)	0.589	0.589	0.589	0.589	0.589	0.589	0.589
Threonine (%)	0.754	0.754	0.754	0.754	0.754	0.754	0.754
Tryptophan (%)	0.250	0.250	0.250	0.250	0.250	0.250	0.250
Valine (%)	0.941	0.941	0.941	0.941	0.941	0.941	0.941

[1]As recommended by Silva e Costa (2009); Digestible amino acids

and weight loss by cooking as per Honikel (1987). The colour was determined using a Konica Minolta model CR-400 Colorimeter, with a D65 standard lighting system and a viewing angle of 10°. The parameters L* (Luminosity), a* (-a = green; + a = red) and b* (-b = blue; + b = yellow) were expressed based on the CIELAB system (International Commission on Illumination). Shear strength was measured using a TA-XT Express texture analyser from Stable Micro Systems.

Protein composition, moisture and mineral matter was analysed using the meat frozen at -18 ºC, following methodologies described in the Association of Official Analytical Chemists (2000), while the lipid analysis was carried out as per the methodology described by Folch, Lees and Sloane-Stanley (1957).

The data were subjected to analysis of variance and interpreted by Tukey's test at a maximum level of 5% probability. The SAS Statistical Analysis Software v 9 (2012) was used.

RESULTS AND DISCUSSION

The quail that ingested diets containing sources of PUFAS showed a difference (p < 0.05) in terms of feed intake, weight gain and feed conversion (Table 2).

Despite the supply of 2% balanced oils, calculated so that energy levels remained the same for all diets, the different sources of PUFAS affected intake (P < 0.05). The quail that received diets with LSO and BNO consumed the greatest amount of feed. The added oils may have increased the palatability of the feed and favoured increased consumption of these diets, as each bird received the same amount of feed, water and space to move around.

Quails fed on diets containing SBO and BNO showed greater weight gain compared to those receiving the SBO+FSO diet (P < 0.05), which was similar to the other diets (P > 0.05).

Feed conversion, calculated as the ratio of feed intake to weight gain, showed a significant difference between diets (P < 0.05). The FSO diet had the lowest feed conversion rate; this is due to the lower feed intake and greater weight gain of the quail fed on this diet showing good performance with a feed conversion rate of 2.49 g/g. As such, the composition of this diet appeared to favour greater nutrient digestibility, contribute to the satiety of the birds, and result in greater weight gain.

The carcass characteristics, represented by carcass yield, and the yield of the breasts, thighs and wings, were not influenced by the sources of lipids added to the diet (Table 3) (P > 0.05), which always maintained the same energy level of the feed.

The live weight of the quail after fasting and prior to slaughter ranged from 227.38 to 247.33 g at 42 days of age, which is within the expected range according to Silva *et al*. (2012), who reported that European quail reach approximately 200 g by 35 days of age.

Table 2 - Performance of quail fed on diets supplemented with different sources of PUFAS

Source of Lipids	Feed Intake (g/bird/day)	Weight gain (g/bird/day)	Feed Conversion (g/g)
SBO	15.65 ± 0.77 c	6.19 ± 0.55 a	2.54 ± 0.17 ab
LSO	17.58 ± 0.88 ab	6.02 ± 0.26 ab	2.92 ± 0.17 a
BNO	18.27 ± 0.60 a	6.33 ± 0.41 a	2.90 ± 0.20 ab
FSO	14.95 ± 1.14 c	6.03 ± 0.25 ab	2.49 ± 0.27 b
LSO+SBO	15.53 ± 1.33 c	5.63 ± 0.41 ab	2.77 ± 0.25 ab
BNO+SBO	15. 71 ± 0.76 c	6.05 ± 0.46 ab	2.61 ± 0.30 ab
FSO+SBO	15.83 ± 0.64 bc	5.41 ± 0.25 b	2.93 ± 0.04 a
SEM	0.91	0.39	0.22
P-value	0.0001	0.0111	0.0067

a,b mean values in a column followed by lowercase letters differ by Tukey's test (P > 0.05); SEM = standard error of the mean SBO: soybean oil; LSO: linseed oil; BNO: Brazil nut oil; FSO: fish oil

Table 3 - Carcass characteristics of quail at 42 days of age fed on different sources of PUFAS

Source of Lipids	Live weight after fasting (g)	Yield (%)			
		Carcass	Breast	Thigh	Wing
SBO	234. 61 ± 10.48	88.96 ± 1.16	31. 76 ± 1.37	18.14 ± 0.81	6.83 ± 0.68
LSO	227. 38 ± 16.26	90.42 ± 2.18	28.92 ± 3.37	16.56 ± 1.82	5.60 ± 0.70
BNO	243. 73 ± 20.08	90.70 ±0.86	30.69 ±3.54	17.14 ± 1.60	6.08 ± 0.89
FSO	242. 08 ± 14.49	88.66 ± 1.42	31.94 ± 1.53	16. 09 ± 1.33	6.11 ± 0.48
LSO+SBO	247.33 ± 8.83	86.49 ± 4.32	32.99 ± 1.28	17.59 ± 0.46	6.48 ± 0.71
BNO+SBO	234. 61 ± 9.45	89.21 ± 1.07	31.61 ± 2.97	16.89 ± 1.92	5.83 ± 0.67
FSO+SBO	236.33 ± 9.72	89.59 ± 1.44	32.11 ± 1.65	16.84 ± 0.46	6.26 ± 0.10
SEM	13.36	2.09	2.47	1.33	0.65
P-value	0.2210	0.0783	0.2356	0.3025	0.1037

SEM = standard error of the mean SBO: soybean oil; LSO: linseed oil; BNO: Brazil nut oil; FSO: fish oil

Carcass yield ranged from 86.49% to 90.70%, breast yield from 28.92% to 32.99%, thigh yield from 16.09% to 18.14%, and the wings from 5.60% to 6.83% (Table 3). Abreu *et al*. (2014), evaluating meat yield in European quail at 42 days of age, found a yield of 78.39%, 27.88 and 18.95% for the carcass, breast and legs, respectively, with only leg yield one percent higher than in the present study.

Veras *et al*. (2019) studied the addition of two levels of coconut and canola oil in the diet of European quail, and found no difference between the oils in terms of cut yield, reporting that this was due to the relationship of the cuts with the genetic factors of the birds, and because similar amounts of oil were used in the different treatments. This may have happened in the present study since the same amount of oil was added to each diet.

The sources of PUFAS added to the diet did not change the chemical composition of the breast meat ($P > 0.05$) (Table 4). The results agree with those of Guven, Kiliç and Ozer (2015) who studied the effect of different oils on the quality of Japanese quail meat, and found no significant difference in terms of chemical composition. Japanese quail also showed no difference in the chemical composition of the breast meat when fed on diets supplemented with linseed oil or fish oil (EBEID *et al*., 2011).

The amount of protein in the breast meat of quail as determined in this study ranged from 20.0% to 21.43%, which qualifies it as an important source of animal protein. Guven, Kiliç and Ozer (2015), analysing the protein content in the breast of Japanese quail fed on different sources of lipids, found a total 18.1% lower than in this study. This can be explained by the different species, where European quail have been bred for meat production, and by the use of different lipid sources.

The breast meat of the quail had a lipid content between 3.22% and 4.52%. The fact there is no significant difference in the amount of total lipids in the meat can be explained by the addition of the same level of oil (2%) to each diet, thereby not changing the composition of the diets. Breast meat from poultry does not show a large variation in total lipids, since the amount of fat is relatively low, and the highest lipid concentration is deposited in the skin and in the tissue of the thigh and drumstick (BAEZZA *et al*., 2010).

Diets supplemented with sources of PUFAS influenced the pH, centrifugation loss, weight loss by cooking, shear strength and colour (L, a* and b*) ($p < 0.05$) (Table 5). Fatty acids modify several technological aspects of meat, and differences can be explained by the total number of groups of fatty acids, and variations in the melting point that can change the colour, pH and texture (SEMWOGERERE *et al*., 2019).

The BNO+SBO diet afforded a higher final pH (5.97) in the breast meat compared to the diets with either SBO or FSO. This difference in pH between diets may be related to pre-slaughter factors: during the conversion of muscle to meat, the muscle glycogen content directly influences the final pH; pre-slaughter stress may cause a depletion of glycogen reserves, producing less lactic acid and resulting in an increase in the final pH (MAZIZI; ERLWANGER; CHIVANDI, 2020; MIR *et al*., 2017).

The LSO diet showed greater loss by centrifugation (18.14%). Evaluating the water retention capacity (WRC) of the meat, the results showed a lower WRC during the centrifugation process for diets that contain higher levels of unsaturated lipids.

This may be related to the different sources of PUFAS added to the diet of the birds, causing a lower

Table 4 - Chemical composition (%) of the breast meat of quail fed on diets containing sources of PUFAS

Source of Lipids	Moisture	Protein	Lipids	Mineral Matter
SBO	71.74 ± 1.27	20.48 ± 1.01	4.44 ± 0.41	1.65 ± 0.15
LSO	73.96 ± 0.52	20.00 ± 1.09	3.22 ± 0.22	1.49 ± 0.10
BNO	71.61 ±1.33	21.43 ± 0.87	4.52 ± 0.87	1.37 ± 0.27
FSO	72.19 ± 1.36	20.38 ± 0.34	4.25 ± 1.37	1.58 ± 0.23
LSO+SBO	73.10± 0.48	20.94 ± 0.55	4.12 ± 0.50	1.41 ± 0.34
BNO+SBO	72.52 ± 1.02	21.32 ± 0.68	4.04 ± 0.56	1.61 ± 0.18
FSO+SBO	72.26 ± 0.28	21.20 ± 0.70	4.19 ± 0.90	1.53 ± 0.1
SEM	0.99	0.79	0.78	0.19
P-value	0.06	0.13	0.52	0.49

SEM = standard error of the mean SBO: soybean oil; LSO: linseed oil; BNO: Brazil nut oil; FSO: fish oil

Table 5 - Chemical and physical characteristics of the meat from quail fed on diets containing sources of PUFAS

Source of Lipids	pH	CL (%)	LBC (%)	SF (kgf)	Colour		
					L*	a*	b*
SBO	5.83 ± 0.1 bc	14.15 ± 2.15 b	14.69 ± 3.15 a	1.38 ± 0.03 a	54.05 ± 3.63 abc	5.70 ± 1.51 b	11.74 ± 1.51 ab
LSO	5.95 ± 0.1 ab	18.14 ± 2.0 a	14.24 ± 0.66 ab	1.07 ± 0.03 bc	58.07 ± 5.30 a	6.97 ± 1.66 ab	14.63 ± 2.12 a
BNO	5.88 ± 0.1 abc	15.93 ± 1.27 ab	9.64 ± 1.01 b	0.85 ± 0.03 c	50.58 ± 3.40 bc	6.24 ± 1.44 ab	12.61 ± 2.63 ab
FSO	5.78 ± 0.1 c	15.35 ± 1.52 ab	11.01 ± 1.39 ab	1.10 ± 0.02 b	57.02 ± 5.04 a	5.72 ± 0.78 b	14.45 ± 2.30 a
LSO+SBO	5.95 ± 0.9 ab	12.98 ± 1.30 b	11.02 ± 1.25 ab	1.28 ± 0.14 ab	56.47 ± 4.59 ab	5.67 ± 1.12 b	14.30 ± 2.60 ab
BNO+SBO	5.97 ± 0.1 a	12.36 ± 1.54 b	12.76 ± 1.15 ab	1.14 ± 0.1 ab	52.11 ± 4.85 abc	7.36 ± 1.41 ab	11.43 ± 2.50 b
FSO+SBO	5.85 ± 0.1 abc	13.98 ± 1.79 b	14.52 ± 2.31 ab	1.16 ± 0.04 ab	49.45 ± 6.55 c	8.22 ± 3.71 a	13.20 ± 2.53 ab
SEM	0.07	1.70	1.76	0.07	4.87	1.91	2.35
P-value	0.002	0.0012	0.0156	0.0006	0.0001	0.0092	0.0044

a,b mean values in a column followed by lowercase letters differ by Tukey's test ($P > 0.05$); SEM = standard error of the mean CL: centrifugation loss; LBC: loss by cooking; SF: shear force. SBO: soybean oil; LSO: linseed oil; BNO: Brazil nut oil; FSO: fish oil

WRC in the meat due to increased oxidation of the cell membranes (HANG; MOLEE; KHEMPAKA, 2018), since the oxidant defence system of the muscle directly affects water retention capacity via such factors as the melting point of the lipids, or lower integrity of the muscle cell membranes due to oxidative stress (BIANCHI *et al.*, 2009). Hang, Molee and Khempaka (2018), when supplementing the diet of chickens with linseed and fish oil, found a reduction in the water retention capacity of the meat.

When analysing LBC, the SBO diet had the highest value (14.69%), showing similar behaviour to centrifugation loss, where diets with higher amounts of PUFAS suffered greater weight loss by cooking. These results are similar to those of Bianchi *et al*. (2009), who found a higher LBC in the breast meat of chickens that received vegetable oils in their diet.

The amount of water loss was not enough to affect the tenderness characteristics of the meat, evaluated by the shear strength parameter, which ranged from 0.85 to 1.38 kgf, classifying the meat as tender; this is an important characteristic in terms of product acceptance by the consumer. Similar values were found by Vargas-Sanchéz *et al*. (2018), who, when evaluating the shear strength of breast meat from Japanese quail, found values from 0.88 to 1.30 kgf. Abreu *et al*. (2014), studying the influence of sex and age at slaughter in European quail, observed similar values, ranging from 1.20 to 1.39 kgf, and considered quail meat softer than chicken meat.

Regarding the colour, the quail that received the FSO+SBO diet had a mean value for the L* parameter (lightness) of less than 50.0. This result suggests that the addition of 2% of the mixture of soybean oil and fish oil to the diet resulted in darker meat compared to the other diets, which returned L* values of between 52.11 and 58.07, disagreeing with the studies by Genchev *et al*. (2008), who commented that meat from quail breasts is dark, with values of L* less than 50.0, a* greater than 4.5 and b* less than 10.0.

The LSO and FSO diets had higher levels of luminosity (L*) and yellow (b*); this can be explained by the predominant pigments in these lipid sources causing changes in the colour of the meat, giving it a lighter appearance. FSO+SBO had the highest value for red (a*). In all treatments, the a* parameter of the quail breast was greater than 4.5, while the mean values for b* (yellow) differed from those described by Genchev *et al*. (2008), with values above 10.0.

Colour is an important parameter, which is directly related to the initial choice of consumers and final product satisfaction. Oxidative muscle fibres predominate in the breast meat of quail, that is, red fibres rich in myoglobin, unlike the breast meat of chicken; this entails higher values for the colour parameters L*, a* and b* (GENCHEV *et al*., 2010) in the breast meat of quail, with similar results to those of wild birds. However, in this study, the different lipid sources affected the colour (L*, a* and b*), showing significant differences ($p < 0.05$), where the composition of the diet and addition of sources or supplements to the bird feed can influence pigment deposition in the meat. Research shows that the main factors affecting the colour of poultry meat are the levels of haem pigment in the meat, slaughter and pre-slaughter factors (NARINC *et al*., 2013), together with other aspects, such as nutrition, strain, age and sex, that also influence meat quality.

CONCLUSION

Added sources of polyunsaturated fatty acids caused changes in the performance measures. Carcass yield and the chemical composition of the meat were not influenced by the different lipid sources. There was a significant difference in physical characteristics between diets. In general, these sources can be added to quail diets without harmful effects to the birds.

REFERENCES

ABREU, L. R. A. *et al*. Influência do sexo e idade de abate sobre rendimento de carcaça e qualidade da carne de codornas de corte. **Revista Brasileira de Saúde e Produção Animal**, v. 15, p. 131-140, 2014.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. **Official methods of analysis**. 17. ed. Washington: AOAC International, 2000. 1018 p.

BAEZZA, E. *et al*. Effect of sex and genotype on carcase composition and nutritional characteristics of chicken meat. **British Poultry Science**, v. 51, p. 344-353, 2010.

BAIÃO, N. C.; LARA, L. J. C. Oil and fat in broiler nutrition. **Brazilian Journal of Poultry Science**, v. 7, n. 3, p. 129-141, 2005.

BIANCHI, M. F. *et al*. The influence of dietary lipid source on quality characteristics of raw and processed chicken meat. **European Food Research and Technology**, v. 229, n. 2, p. 339-48, 2009.

EBEID, T. A. *et al*. The effect of omega-3 enriched meat production on lipid peroxidation, antioxidative status, immune response and tibia bone characteristics in japanese quail. **Czech Journal of Animal Science**, v. 56, n. 7, p. 314-24, 2011.

FOLCH, J.; LEES, M.; SLOANE-STANLEY, G. H. A simple method for the isolation and putification of total lipids from animal tissue. **Journal Biological Chemical**, v. 226, n. 1, p. 497-509, 1957.

GENCHEV, A. *et al*. Meat quality and composition in Japanese quais. **Trakia Journal of Sciences**, v. 6, p. 72-82, 2008.

GENCHEV, A. *et al*. Physicochemical and technological properties of Japanese quail meat. **Trakia Journal of Sciences**, v. 8, p. 86-94, 2010.

GUVEN, R.; KILIÇ, B.; OZER, C. O. Influence of using different oil sources in quail nutrition on meat composition and quality parameters. **Animal Science**, v. 58, 2015.

HANG, T. T. T.; MOLEE, W.; KHEMPAKA, S. Linseed oil or tuna oil supplementation in slow-growing chicken diets: can their meat reach the threshold of a “high in n-3 polyunsaturated fatty acids” product?. **Journal of Applied Poultry Research**, v. 27, n. 3, p. 389-400, 2018.

HERRERO, A. M. *et al*. Ultrastructural Changes and Structure and Mobility of Myowater in Frozen-Stored Hake (Merluccius merluccius L.) Muscle: Relationship with Functionality and Texture. **Journal of agricultural and food chemistry**, v. 53, n. 7, p. 2558- 2566, 2005.

HONIKEL, K. O. The water binding of meat. **Fleischwirtsch**, v. 67, p. 1098-1102, 1987.

MAZIZI, B. E.; ERLWANGER, K. H.; CHIVANDI, E. The effect of dietary Marula nut meal on the physical properties, proximate and fatty acid content of Japanese quail meat. **Veterinary and Animal Science**, v. 9, 2020.

MIR, N. A. *et al*. Determinants of broiler chicken meat quality and factors affecting them: a review. **Journal of Food Science and Technology**, v. 54, n. 10, p. 2997-3009, 2017.

NARINC, D. *et al*. Quality of Japanese quail meat: characteristics, heritabilities and genetic correlations with some slaughter characteristics. **Poultry Science**, v. 92, n. 7, p. 1735-1744, 2013.

RAJI, A. *et al*. Characteristics and approximate composition of the carcass of Japanese quail (Coturnix japonica) in a semi-arid area of Nigeria. **Trakia Journal of Sciences**, v. 13, n. 2, p. 159-165, 2015.

SAS INSTITUTE. SAS/STAT. **User’s guide**: Statistics. Version 9, 2012.

SEMWOGERERE, F. *et al*. Meat quality, fatty acid profile, and sensory attributes of spent laying hens fed expeller press canola meal or a conventional diet. **Poultry Science**, v. 98, n. 9, p. 3557-3570, 2019.

SILVA, J. H. V. *et al*. Exigências nutricionais de codornas. **Revista Brasileira de Saúde e Produção Animal**, v. 3, n. 3, p. 775-790, 2012.

SILVA, J. H. V.; COSTA, F. G. P. **Tabela para codorna japonesas e europeias**. 2. ed. Jaboticabal: FUNEP, 2009. 110 p.

SOBOL, M.; RAJ, S.; SKIBA, G. Effect of fat content in primal cuts of pigs fed diet enriched in n-3 polyunsaturated fatty acids on health- promoting properties of pork. **Journal of Animal and Feed Sciences**, v. 25, p. 20-28, 2016.

TON, A. N. S. *et al*. Exigências de lisina digestível e de energia metabolizável para codornas de corte em crescimento. **Revista Brasileira de Zootecnia**, v. 40, n. 3, p. 593-601, 2011.

VARGAS-SÁNCHEZ, R. D. *et al*. Effect of dietary supplementation with Pleurotus ostreatus on growth performance and meat quality of Japanese quail. **Livestock Science**, v. 207, p. 117-125, 2018.

VERAS, A. G. *et al*. Canola and coconut oils in the feed of European quail (Coturnix coturnix). **Revista Brasileira de Zootecnia**, v. 48, 2019.