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Original Article

Replacement of Animal Fat by Canola Oil in Chicken Meatball

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ABSTRACT

This work aimed to develop chicken meatballs with five levels of animal fat replacement by canola oil and to evaluate the product's behavior during 120 days of storage. For that, analyzes were performed in the centesimal composition, fatty acid profile, shelf life and sensory parameters. The centesimal composition of the product did not present significant difference (p>0.05) between the treatments. However, canola oil addition improved the lipid profile, atherogenic and thrombogenic indexes, and the ratios of PUFAs/SFAs (0.91 to 1.61) and n6/n3 (12.63 to 3.74) in the products. Animal fat replacement and storage time also reduced meatballs Aw and pH. No differences in texture between treatments were detected after 30 days of storage. The lipid oxidation presented by mean values of TBARs ranged from 0.71 and 1.35 mg MDA/kg, indicating the onset and the regression of lipid oxidation. The color parameters exhibited a spectrum towards the luminous yellow color, predominant in both chicken meat and canola oil. The results of this study indicate that the substitution of animal fat by canola oil is promising in the production of meat products with good acceptability (70%) during the sensory analysis.

INTRODUCTION

In recent years, there has been a greater demand for low-fat meat products because of concerns about the development of syndromes such as obesity and heart disease associated with high fat intake, especially saturated fat (Afshari *et al.*, 2016). Therefore, the food industry has been looking to develop foods, among them meat products, with low fat contents. However, developing low-fat meat products has been a huge challenge as lipids have an important role in the texture, juiciness, and taste of the food. Besides, lipids have important physiological functions in the organism as a source of energy and essential fatty acids (EFAs), and as carriers of liposoluble vitamins (Özvural & Vural, 2008; Monteiro *et al.*, 2017).

Several studies have been proposed to develop meat products with lower levels of saturated fatty acids (SFAs) by replacing animal fat with vegetable oils. In general, SFAs has been considered a risk factor for cardiovascular disease (CVD) and, on the other hand, studies have shown that polyunsaturated fatty acids (PUFAs) intake was inversely associated with CVD risk (Monteiro *et al.* 2017, Barbut & Marangoni, 2018). For this reason, different studies suggest that PUFAs improve the lipid profile of foods (Yunes *et al.*, 2013; Afshari *et al.*, 2016; Monteiro *et al.*, 2017).

Therefore, the substitution of animal fat by vegetal oil contributes to the elaboration of products with better PUFAs/SFAs profiles, better ratio n6/n3 and reduction of atherogenic index (AI) and thrombogenic

index (TI) when compared to traditional products. Among the VOs, canola oil is the one with the lowest concentration of SFAs (6%), in addition to a high concentration of MUFAs (58%) and PUFAs (36%). The PUFAs in CO are represented mostly by linoleic acid (21%), alpha-linolenic acid (10%) and oleic acid (60%). Studies have found that these EFAs should be regularly ingested in the diet, with a lower n6/n3 ratio, as a means to prevent and control inflammatory diseases such as bowel disease (Monteiro *et al.* 2017; Visentainer *et al.*, 2015).

The objective of this work was to evaluate the effects of the substitution of animal fat at different levels by canola oil in chicken meatballs, considering the sensorial, physicochemical characteristics, lipid profile and storage stability.

MATERIAL AND METHODS

All the experimental procedures described here were previously approved by the Research Committee of Ethics of the Federal Institute of the State of Mato Grosso (protocol # 2483360). Also, before the sensory panel was performed, a microbiological assay was developed to ensure that the meatballs met the microbiological standards recommended by the International Commission on Microbiological Specifications for Foods (1986) and the National Sanitary Surveillance Agency (ANVISA), through Resolution No. 12 (BRAZIL, 2001).

Chicken meatballs preparation

For the processing of chicken meatballs, a basal mass without addition of animal fat and canola oil, which are the variable components of the experiment (Table 1), was prepared. The plant oil used was the commercially available canola oils Liza, from the industry Cargil SA, having citric acid as the antioxidant.

Grinded chicken breast was put in a mixer with soy protein previously hydrated with water for 30 minutes. After 2 minutes of mixing, the other ingredients were incorporated and the dough was homogenized for further 5 minutes in the mixer.

After that, the basal mass was divided into five homogenous portions and subdivided into three replicates for the replacement of the chicken fat by canola oil in the proportions of 0%, 25, 50, 75 and 100% (Table 1). Then, 30 g meatballs were manually cast, frozen at a temperature of -25°C in ultra-freezer, packed in polyethylene bags, identified by treatment and stored in a vertical freezer at -18°C for future analysis.

Table 1 – Ingredient composition of chicken meatballs with different levels of animal fat replacement by canola oil.

Fixed ingredients	Canola oil				
	0%	25%	50%	75%	100%
chickenbreast	68.90	68.90	68.90	68.90	68.90
Water	16.75	16.75	16.75	16.75	16.75
breadcrumbs	4.75	4.75	4.75	4.75	4.75
texturedsoy proteín	3.00	3.00	3.00	3.00	3.00
Salt	1.23	1.23	1.23	1.23	1.23
isolatedsoy proteín	1.00	1.00	1.00	1.00	1.00
driedonion	0.97	0.97	0.97	0.97	0.97
dehydrated parsley	0.19	0.19	0.19	0.19	0.19
tripoli phosphaeo	0.15	0.15	0.15	0.15	0.15
Sugar	0.08	0.08	0.08	0.08	0.08
monossodium glutamate	0.07	0.07	0.07	0.07	0.07
garlic aroma	0.07	0.07	0.07	0.07	0.07
sodium erythorbate	0.04	0.04	0.04	0.04	0.04
Variableingredients					
chickenfat	2.80	2.10	1.40	0.70	0.00
canola oil	0.00	0.70	1.40	2.10	2.80
Total	100	100	100	100	100

Immediately after the preparation, 80 meatballs of each replicate were randomly selected for sensory, centesimal, microbiological, physicochemical and fatty acid profile analyses. The other meatballs remained frozen for repetition of the same physicochemical analyzes after 30, 60, 90 and 120 days.

For that, meatballs were previously thawed at 4°C in BOD incubators. When roasted products were assessed, samples were baked at 150°C until reaching the central temperature of 71°C, according to the methodology adapted from AMSA (2016).

Analysis of the centesimal composition

For the analysis of centesimal composition, performed only at time 0, raw and roasted meatballs were used. Samples were previously homogenized in a multiprocessor and analyzed in duplicate for moisture, ashes, protein, lipids and carbohydrates according to procedures established by AOAC (2012). Final results were expressed as percentage of the sample's weight.

Analysis of fatty acid profile

The fatty acid profile of meatballs was exclusively assessed at time 0, using raw and roasted samples. Each sample was subjected to lipid cold extraction according to the methodology originally described by Folch, Lees and Stanley (1957). Then, aliquots were destined to gas chromagraph determination as established by Hartman and Lago (1973).

Based on the fatty acid profile, meatballs' atherogenic (AI) and thrombogenic (TI) indices were calculated following Ulbricht & Southgate (1991) equations, where:

$$AI = ((C12:0) + 4(C14:0) + (C16:0))/((n6) + (n3) + (\sum MUFAs))$$

$$TI = ((C14:0) + (C16:0) + (C18:0))/([0.5(\sum MUFAs) + 0.5(n6) + 3(n3) + (n3/n6))$$

All analyzes were performed in duplicate and expressed as percentage of the sample's weight.

Shelf life analysis

Shelf life analyzes were performed during the storage time of 0, 30, 60, 90 and 120 days. For this, raw meatballs were submitted to water activity (Aw), pH and Tbars analysis. Also, roasted samples were analyzed for texture and color. Aw determination was performed by the dew point technique using the AQUALAB 4TE equipment. Samples' pH was determined using an insertion electrode coupled to a portable digital potentiometer (Meat pH meter HI 99163). The Tbars was obtained according to the method described by Raharjo, Sofos & Schmidt (1992) and the values obtained were expressed in milligrams of malonaldehyde per kilogram of samples (mg maloaldehyde / kg sample).

For the texture analysis, samples of roasted meatballs were accommodated in the TA.XT.PLUS texturometer, with a Warner Bratzler probe coupled, calibrated for a cutting speed of 2 mm/s, a return speed of 5 mm/s, a sensitivity of 0.250 N and unit in kg/cm2. The objective color was analyzed using the Minolta CM-700D with the D65 illuminator and 10° viewing angle by the CIE L*a*b* color system. Three readings were taken at the center of the samples of roasted meatballs (AMSA, 2016).

Sensory analysis

A sensory panel was performed at time 0 using roasted meatballs. A total of 80 untrained judges evaluated the sensory characteristics of smell, color, overall appearance, texture and taste in a hedonic scale (1 - I highly disliked 9 - I liked it very much), and the preference index as recommended in the official methodology of the Adolfo Lutz Institute (Zenebon, Pascuet, Tiglea, 2008).

Statistical analysis

Data of centesimal composition were analyzed in a completely randomized design (CRD), with 5 treatments (canola oil %) and 3 replications of one meatball each. Data of fatty acid profile were analyzed in a factorial design with 10 treatments and 3 replications of one meatball each. Factors were presentation mode (raw and roasted) and canola oil % (0, 25, 50, 75 and 100%). Data of sensory analyses were analyzed in a CRD, with 5 treatments (canola oil%) and 80 replications of one judge each. Finally, data of shelf life analyses were analyzed in a factorial design with 25 treatments and 3 replications of one meatball each. Factors were storage time (0, 30, 60, 90 and 120 days) and canola oil % (0, 25, 50, 75 and 100%).

All data were initially tested for homogeneity of variances and normality of the studentized residues. After these assumptions were met, they were submitted to analysis of variance and, in case of significant differences, treatment means were separated by the Tukey test. The variables of the sensory test and pH were considered non-parametric, thus being submitted to a non-parametric analysis of variance (Wilcoxon test) and, in the case of significant differences, treatment means were separated by the Dunn test. In all stages, significance was set at 5% ($p \leq 0.05$).

RESULTS AND DISCUSSION

Centesimal composition

There was no significant difference between raw and roasted meatballs at different replacement levels (Table 2). This study corroborates with other studies

Table 2 – Centesimal composition of raw and roasted chicken meatballs with different levels of animal fat replacement by canola oil.

Item (% of original matter)	Canola oil					SEM	*p* values
	0%	25%	50%	75%	100%		
Raw meatballs							
carbohydrate	8.65	8.70	7.71	8.11	8.70	0.54	0.98
Ashes	2.51	2.46	2.49	2.52	2.52	0.01	0.07
Lipids	3.15	3.20	3.32	3.62	3.57	0.07	0.14
protein	17.08	17.00	18.40	17.90	16.70	0.53	0.88
moisture	68.60	68.63	68.08	67.85	68.51	0.16	0.46
Roasted meatballs							
carbohydrate	7.52	8.57	8.66	9.53	11.34	0.54	0.23
ashes	3.43	3.43	3.44	3.49	3.58	0.02	0.20
lipids	3.57	3.08	2.69	2.88	3.28	0.12	0.11
protein	25.69	24.36	25.06	24.82	23.75	0.34	0.51
moisture	59.79	60.55	60.15	59.27	58.04	0.32	0.08

that show the adequacy of substitution of animal fat by canola oil, regardless of presentation, raw or roasted.

The same was observed by Monteiro *et al.* (2017) and Backes *et al.* (2013) where they demonstrated that canola oil is an excellent substitute for animal fat, maintaining the product's centesimal characteristics unchanged.

Fatty acid profile

The fatty acid profile of treatments is shown in table 3. From the 11 fatty acids detected, the 16:0, 18:1 and 18:2 acids showed the highest concentrations. The same acids were detected by Monteiro *et al.* (2017) in the partial replacement of animal fat by canola oil.

The addition of canola oil in meatballs reduced total SFAs concentration and their individual porcentages. Afshari, R (2016); Yunes *et al.* (2013) and Monteiro *et al.* (2017) also found a reduction in the SFAs by replacing animal fat by vegetable oils in meat products. These findings can be explained by the fact that canola oil contains low levels of SFAs (6%), high levels of MUFAs (58%) and moderate levels of PUFAs (36%) when compared to other edible vegetables oils (Lin *et al.* 2013) and animal fat, supporting the CVD associated with SFAs (Monteiro *et al.*, 2017).

There were significant differences on MUFAs (16:1 and 18:1) concentrations between the treatments, as the replacement of animal fat by canola oil gradually reduced 16:1 concentration and increased 18:1 concentration. Visentainer *et al.* (2015), describes that fatty acid 18:1 (oleic acid) reduces levels of cholesterol and low-density lipoproteins (LDL) in the blood.

An increase in ∑ MUFAs values was detected as the concentration of canola oil in the product increased. Monteiro *et al.* (2017), Lee *et al.* (2015) and Yunes *et al.* (2013) detected the same behavior when replacing animal fat by vegetable oils, concluding that this approach resulted in a healthier product.

For PUFAs, no significant difference between treatments was detected only for the fatty acid 22:6. For the 18:2 there was a significant difference both by the canola oil % and the preparation method, where the values decreased as canola oil increased and also increased after coocking (roasted product). For 18:3,

Table 3 – Fatty acids profile of raw and roasted chicken meatballs with different levels of animal fat replacement by canola oil.

Essential fatty acid (%)	Canola oil					Preparation		SEM	*p* Values		
	0%	25%	50%	75%	100%	raw	roasted		Canolaoil	Preparation	Interaction
C14:0	1.08	1.33	1.37	1.15	0.93	1.31	1.03	0.07	0.26	0.06	0.46
C16:0	23.06A	19.85B	16.89C	14.59D	12.23E	17.13	17.51	0.73	< 0.01	0.33	0.79
C18:0	6.24A	5.71B	5.29C	4.86D	4.25E	5.25	5.30	0.13	< 0.01	0.56	0.11
∑ SFAs	30.38A	26.88B	23.55C	20.60D	17.41E	23.69	23.84	0.86	< 0.01	0.72	0.45
C14:1	0.38	0.14	0.08	0.11	0.00	0.14	0.15	0.04	0.07	0.94	0.94
C16:1	5.18A	4.15B	3.20C	2.64CD	2.08D	3.41	3.49	0.21	< 0.01	0.53	0.55
C17:1	0.09	0.09	0.08	0.09	0.09	0.09	0.09	0.00	0.44	0.28	0.20
C18:1	35.80E	39.56D	43.19C	47.64B	50.55A	43.79	42.90	1.02	< 0.01	0.08	0.46
∑ MUFAs	41.45E	43.94D	46.56C	50.48B	52.72A	47.43	46.63	0.79	< 0.01	0.06	0.37
C18:2	24.60A	23.42B	22.63B	21.47C	21.01C	22.37B	22.89A	0.26	< 0.01	0.02	0.45
C18:3	2.04E	3.16D	4.32C	5.09B	5.93A	4.13	4.08	0.27	< 0.01	0.78	0.61
C20:2	0.09B	0.14B	0.16B	0.11B	0.32A	0.15	0.18	0.02	< 0.01	0.09	0.51
C22:6	0.00	0.03	0.02	0.02	0.03	0.01	0.02	0.00	0.07	0.25	0.66
∑ PUFAs	26.73	26.75	27.13	26.69	27.28	26.66B	27.17A	0.10	0.15	0.01	0.28
Total fatty acid	98.55A	97.57AB	97.24B	97.77AB	97.42B	97.78	97.65	0.13	0.01	0.56	0.32
PUFAs/MUFAs	0.88D	0.99D	1.15C	1.30B	1.58A	1.18	1.19	0.05	< 0.01	0.78	0.33
n6	24.60A	23.42B	22.63B	21.47C	21.00C	22.36B	22.89A	0.26	< 0.01	0.02	0.45
n3	2.04E	3.18D	4.34C	5.10B	5.96A	4.14	4.11	0.27	< 0.01	0.82	0.60
n6/n3	12.20A	7.41B	5.24C	4.26CD	3.57D	6.48	6.59	0.59	< 0.01	0.70	0.83
Atherogenic index (AI)	0.40A	0.36B	0.30C	0.25D	0.20E	0.31	0.30	0.01	< 0.01	0.36	0.33
Thrombogenic index (TI)	0.59A	0.53B	0.45C	0.37D	0.30E	0.45	0.45	0.02	< 0.01	0.76	0.49

SFAs = saturated fatty acids; MUFAs = monounsaturated fatty acids; PUFAs = polyunsaturated fatty acids.

AI = ((C12:0) + 4(C14:0) + (C16:0)) / ((n6) + (n3) + (∑ MUFAs))

TI = ((C14:0) + (C16:0) + (C18:0) / (0.5(∑ MUFAs) + 0.5(n6) + 3(n3) + (n3/n6))

Means followed by the same letter, within each factor, are not different by Tukey test ($p<0.05$).

there was a significant increase in the values as the replacement of animal fat by canola oil occurred. The explanation for the correlation between a decrease in fat animal 18:2 and the increase in 18:3 is due to the fact that it has a low percentage of 18:3 (1.3%), whereas the canola oil contains higher concentrations (9.3%) (Martin *et al.;* Chiu *et al.*, 2008).

For the ∑ PUFAs there was only the significant difference between the preparation methods, where the values increased after the roasting. The difference between the treatments in the ∑ PUFAs in the present work was not verified due to the low percentage of lipid added to the meatballs (2.8% of the total mass of the product), which was insufficient so that the difference between the animal fat and the substituent, canola oil expressed significant difference. Monteiro *et al.* (2017) and Yunes *et al.* (2013) found an increase in the values of ∑ PUFAs in their respective studies when they replaced animal fat with canola oil in meat products. The different result presented by these authors is related to a greater proportion of the substituted lipid component in relation to the present study.

The sum of the total fatty acid and the PUFAs/SFAs ratio presented a significant difference (p<0.05). The increase in the PUFAs/ SFAs ratio occurred from the substitution of 50% canola oil since this oil is rich in PUFAs (Eskin & McDonald, 1991; Lin *et al.*, 2013). Muguerza, Ansorena and Astiasarán (2003) and Özvural & Vural (2008), also found this relationship in their studies where they replaced vegetable oils by animal fat in meat products, obtaining an increase in nutritional benefit, since SFAs are associated with CVD.

A significant increase (p<0.05) in the amount of fatty acid n3 and a reduction of n6 was observed. The n6 also showed a significant difference (p<0.05) in the preparation method, where the values increased in the roasted meatballs. These values are associated with the values found for 18: 2 and 18: 3, since the calculation of n3 and n6 is the sum of the fatty acid found.

The n6/n3 ratio significantly decreased from 12.20 to 3.57. This reason is important for reducing the risk of CVD, diabetes and cancer. Romero *et al.* (2013) Manhezi, Bachion, and Pereira (2008) have cited that high values of this ratio promoted the pathogenesis of many diseases, including cancer, cardiovascular disease, autoimmune and inflammatory diseases. Visentainer *et al.* (2015) cited that the ideal ratio of n6/n3 for good health is 1:1 to 4:1.

In relation to AI and TI, there was a significant difference in both, where the values obtained decreased accordingly to animal fat substitution. Monteiro *et al.* (2017) also reported this decrease in IA and TI in his work. IA and TI are good indicators of the dietary potential to induce atherosclerosis and thrombosis, signs associated with the establishment of CVD (Santos *et al.*, 2013).

In view of the obtained data, it is identified that the substitution of animal fat by canola oil improved the fatty acid profile of the elaborated product by significantly reducing the levels of SFAs, AI, TI and significantly increasing MUFAs levels and PUFAs/SFAs ratio. Regarding n6/n3 ratio, it was observed that the best substitution levels were 75% and 100%, maintaining a balance of the EFAs in the diet.

Shelf life

The results are presented in Table 4. There was no significant interaction between canola oil % and time for the Aw variable and a* and b* color parameters. Interaction between the factors was observed in the variables textures, Tbars and L* color parameters.

The pH variable was considered non-parametric, therefore the interaction between canola oil % and time was not evaluated. There was a significant effect (p<0.05) on the time factor. Verma *et al.* (2016) and Yunes *et al.* (2013) reported that pH increases significantly as the storage time grows. This increase, according to Jay (1996), is associated with the presence of basic compounds resulting from the decarboxylation reaction and deamination of some amino acids by the enzymes present in the meat. Thus, the increase of pH may be correlated with the production of these compounds and subsequent exhaustion of them, causing the values to fall.

The variable Aw presented a significant difference (p<0.05) between the meatballs with 100% substitution of canola for the other substitutions. Despite this difference, the levels found were not important for the sensory or conservation characteristics of the food.

This variable also showed a significant difference (p<0.05) in the time factor. There is a reduction between the time 90 and 120 days for the others. Backes *et al.* (2013) attributed the decrease in the pH found with the water retention capacity of the proteins, which is affected when the pH of the product approaches the isoelectric point (5.3), leading to dehydration of the product, pH near the isoelectric point is directly correlated with the Aw reduction of the product.

Backes *et al.* (2013) described that the amount of water in the product is one of the main factors responsible for the texture. However, this correlation

Table 4 – Shelf life parameters of chicken meatballs with different levels of animal fat replacement by canola oil and frozen stored for 120 days.

Factors	Aw	pH	Tbars (mg)	Texture (kgf/mm)	Color L*	Color a*	ColorB*
canola oil(%)							
0	0.98A	5.93	1.11	2.30	67.92	3.19	21.81
25	0.98AB	5.97	1.02	2.27	66.03	3.28	21.77
50	0.98AB	6.00	1.06	2.29	66.50	3.28	22.42
75	0.98AB	5.99	1.08	2.23	66.86	3.07	21.85
100	0.97B	5.95	0.93	2.06	66.93	3.27	22.25
time (days)							
0	0.98A	5.97BC	0.95	2.03	69.17	2.57B	21.24D
30	0.98B	6.20A	0.80	2.91	70.15	2.78B	22.12BC
60	0.98AB	6.05AB	1.24	2.18	69.95	2.57B	21.28CD
90	0.97C	5.86CD	1.05	2.11	57.05	4.19A	23.25A
120	0.97C	5.77D	1.17	1.91	67.92	3.99A	22.21B
SEM	<0.01	0.02	0.02	0.05	0.62	0.10	0.01
p values							
canolaoil	0.03	0.77	<0.01	0.04	0.05	0.71	0.15
time	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
interaction	0.08	-[1]	<0.01	<0.01	0.04	0.86	0.47

Aw = water activity.

Aw, pH and Tbars were analyzed in raw products; texture and color in roasted products.

[1] pH was analyzed in a non-parametric manner thus interaction between factors did not enter the statistical model.

Significant interactions are presented in Tables 5, 6 and 7.

Means followed by the same letter, within each factor, are not different by Tukey test ($p<0.05$).

was not found in the interaction found in the study (Table 5), where the best observed value of this interaction was at 30 days for all different concentrations of canola oil.

Hsu & Chung (1998) described that texture can be influenced by lipid, in addition to the preparation methodology of the product which is also an important factor, since the temperature and the methodology employed can affect the stability of lipids and their solubility. Animal fat and canola oil can influence the lipid oxidation of a product, which can cause food rancification during storage. Thus, lipid oxidation is a very important factor for the quality of the food, especially in products with a high PUFAs content such as poultry meat and canola oil (Nurkhoeriyati *et al.,* 2012; Karpińska-tymoszczyk, 2013; McDonald, 1991). In this sense, the Tbars test is a widely used test for the evaluation of lipid oxidation of products. During lipid peroxidation, aldehyde, ketone and other fatty acid degradation compounds are generated. The concentration of these compounds is usually expressed as amount of free malonaldehyde (MDA) (Karpińska-tymoszczyk, 2013).

Table 5 – Interaction between canola oil and storage time on the texture of raw chicken meatballs.

	Time (days)				
Canola oil	0	30	60	90	120
0%	2.23Ba	2.76Aa	2.26Bab	2.53ABa	1.7Cb
25%	1.95Bab	3.06Aa	2.04Bb	2.22Ba	2.1Ba
50%	2.00 Bab	3.09Aa	2.11Bb	2.24Ba	1.98Bab
75%	2.18BCab	2.78Aa	2.50 ABa	1.76Db	1.95CDab
100%	1.81Bb	2.86Aa	2.00 Bb	1.79Bb	1.82Bab

Means followed by the same uppercase letter (row), or same lowercase letter (column)are not different by Tukey test ($p<0.05$).

An interaction between time and canola oil % was observed for MDA (Table 6). During the storage time, the rate of lipid oxidation in meatballs at days 0, and 120 had a significant difference ($p<0.05$). The highest MDA index was detected at day 60 and later there was a downward trend, indicating the onset and regression of lipid oxidation in chicken meatballs. Karpińska-Tymoszczyk (2013) also identified this variation in storage time of frozen cooked turkey meatballs. Gokalp *et al.* (1983) and Kuo *et al.* (1987) explain that, during storage, malonaldehyde, which is an intermediate by-product formed in the lipid

Table 6 – Interaction between canola oil and storage time on the Tbars of raw chicken meatballs.

Canola oil	Time (days)				
	0	30	60	90	120
0%	0.96Cb	0.89Ca	1.31Aa	1.12Ba	1.35Aa
25%	0.92Cb	0.73Db	1.16ABb	1.08Ba	1.23Ab
50%	0.99Cb	0.78Db	1.33Aa	1.08BCa	1.14Bc
75%	1.1Ba	0.87Ca	1.27Aa	1.07Ba	1.09Bc
100%	0.73Cc	0.71Cb	1.15Ab	0.9Bb	1.09Ac

Means followed by the same uppercase letter (row), or same lowercase letter (column) are not different by Tukey test ($p<0.05$).

oxidation termination phase, may be oxidized to other organic acids and alcohols which cannot react with the TBA indicator agent. Ahamed *et al.* (2007) attributed the reduction of Tbars in long-term storage products to the MDA reaction in proteins, aminoacids and phospholipids. Also, Racanicci *et al.* (2004) described that the MDA content decreases when the rate of carbonylation with proteins becomes higher than the rate of Tbars formation. Nurkhoeriyati, Huda & Ahmad (2012) cite that some authors describe that MDA and other short chain carbon compounds are unstable and probably decompose into alcohols and organic acids, which are not detected by the TBA test. In relation to the concentrations of canola oil, the highest MDA index was observed in the concentrations with higher amounts of animal fat, probably because the citric acid contained in the commercial canola oil used here acted as antioxidants, helping to delay the lipid oxidation process. Because it is a natural compound, citric acid has been widely used as stabilizers in various products, including vegetable oils (Kubicek, Rohr, Rehm, 1985).

In the present study, the parameters of color a* (red-green) and b* (yellow-blue) showed an increase in their values with time after 90 days of storage (Table 7). Fernández-López *et al.* (2005) described that the oxidative process in meat and meat products lead to the degradation of lipids and proteins, which in turn contribute to the alteration of texture and color of exposed meat products. AMSA (2016) mentioned that oscillations in color parameter values may occur because the denaturation of myoglobin is not constant.

For the parameter L* (brightness) there was interaction between the time and the different

Table 7 – Interaction between canola oil and storage time on the color L* parameter of raw chicken meatballs.

Canola	Time (days)				
	0	30	60	90	120
0%	69.8Aa	70.89Aa	70.68Aa	59.17Ba	69.06Aa
25%	69.5ABa	70.51Aa	70.14ABa	52.57Cc	67.45Ba
50%	68.99Aa	69.20 Aa	70.00 Aa	56.27Bb	68.06Aa
75%	68.79ABa	70.80 Aa	69.84ABa	57.72Cab	67.16Ba
100%	68.77Aa	69.00 Aa	69.10 Aa	59.53Ba	67.00 Aa

Means followed by the same uppercase letter (row), or same lowercase letter (column) are not different by Tukey test ($p<0.05$).

canola oil % (Table 8). The levels of 0, 50 and 100% replacement presented the same behavior during the 120 days, demonstrating that there was no difference between the substitution levels and the storage time.

The averages found in the color parameters showed a product with yellow coloration, with low values of red and high luminosity. These findings may have been influenced by the raw material used, chicken meat and fat, which contains low amounts of myoglobin (Yilmaz,

Table 8 – Sensory analysis of chicken meatballs with different levels of animal fat replacement by canola oil.

Item	Canolaoil					SEM	P values
	0%	25%	50%	75%	100%		
odor	6.88	7.12	6.93	7.22	7.01	0.07	0.74
color	6.71	6.62	6.87	6.76	6.64	0.07	0.76
appearance	6.90	7.02	6.80	6.87	6.66	0.07	0.64
texture	6.96	7.36	7.25	7.18	6.92	0.07	0.38
flavor	7.24	7.62	6.94	7.36	7.41	0.07	0.10
acceptability index (%)	77.00	79.44	78.88	78.66	76.00	-	-

With the exception of the acceptability index, the other variables express the average concept obtained from 80 evaluators, in a scale from 1 (highly disliked) to 9 (liked it very much).

Isikl, Simsek, 2002) and canola oil itself, which are products of yellowish coloration and high luminosity.

Sensory analysis

Animal fat substitution did not influence metabolic smell, color, appearance, texture and taste in the time zero (Table 8). As there was substitution of only one type of lipid for another, contributing to the fact that there was no difference in the characteristics of the original product without the canola oil. In addition, the acceptability values showed that all products met the general assumptions for marketing (higher than 70%) (Zenebon, Pascuet, Tiglea, 2008). Therefore, there is no reason to suspect that the replacement of animal fat by canola oil alters the sensory characteristics of the product when we consider time zero of storage.

CONCLUSIONS

The replacement of animal fat by canola oil in chicken meatballs proved to be a viable alternative to produce a healthier product, since it achieved the objectives of improving the fatty acid profile of the product by reducing SFAs, IA and TI increasing unsaturated fatty acids and PUFAs/SFAs ratio and improving n6/n3 ratio, without significantly altering the characteristics of centesimal and shelf life traits and, especially, without changing the sensory characteristics of the product.

The replacement of animal fat by canola oil in chicken meatballs proved to be a viable alternative to improve the nutritional characteristics of the product, since the technology employed reached the objectives of improving the fatty acid profile of the product through the reduction of saturated fatty acids, atherogenic and thrombogenic indexes, increase of the unsaturated fatty acids, PUFA/MUFA ratio and improvement in the n6/n3 ratio, without significantly altering the composition and shelf life characteristics and without altering the sensorial characteristics of the product . Animal fat can be completely replaced by canola oil in the chicken meatballs, since not even the total replacement of animal fat by canola oil in the product, caused changes in texture, color parameters and oxidation that could be related to addition of the canola oil and the sensorial analysis confirmed the acceptance, proving the results of this research, the feasibility and importance of the substitution of animal fat by canola oil in chicken meatballs.

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