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Stability of pre-fried chicken, quail and chicken nuggets with mechanically separated meat (MSM) from quail

Estabilidade de nuggets pré-fritos de frango, codorna e frango com carne mecanicamente separada (CMS) de codorna

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The creation of quails has increased in Brazil and in the world, for the production of meat and eggs. However, industries have not invested in the use of slaughter by-products. The objective was to investigate the stability of pre-fried chicken nuggets, quail and chicken with mechanically separated meat of quail nuggets. Initially, the color of the quails and dough were analyzed, and the yield of mechanically separated meat was calculated. The nuggets were developed and the centesimal composition was determined. Soon after, analyses of pH, water activity, lipid oxidation (TBARS, substances reactive to thiobarbituric acid), internal and external color, quantification of enterobacteria and psychrotrophs, were carried out at times 0, 15, 30 and 45 days of storage at - 18ºC. It was observed that the external color of the quails is light and the internal dark, and the yield of mechanically separated meat was 50%. The color of quail and chicken dough with mechanically separated meats is darker than chicken. In the centesimal analyses, chicken nuggets had higher protein contents (14.76%); and chicken nuggets with mechanically separated meat lower moisture contents (47.91%) and higher carbohydrate values (30.05%). During storage of the nuggets, there was a drop in pH, an increase in lipid oxidation; the outer color was preserved and the inner one darker. The microbiological quality was satisfactory. In this way, this evidence contributes to reducing environmental impacts, with the reuse of by-products from quail, in addition to being a protein and exotic source used in gastronomy.
Keywords: poultry meat, restructured, coturniculture.

A criação de codornas tem aumentado no Brasil e no mundo, para produção de carne e ovos. Entretanto, as indústrias não têm investido no aproveitamento de subprodutos do abate. Objetivou-se investigar a estabilidade de nuggets pré-fritos de frango, codorna e frango com carne mecanicamente separada (CMS) de codorna. Inicialmente, foi analisada a cor das codornas e massas, e calculado o rendimento da CMS. Os nuggets foram desenvolvidos e determinou-se a composição centesimal. Logo após, análises de pH, atividade de água, oxidação lipídica (TBARS, substâncias reativas ao ácido tiobarbitúrico), cor interna e externa, quantificação de enterobactérias e psicrotróficos, foram conduzidas nos tempos 0, 15, 30 e 45 dias de armazenamento a -18ºC. Observou-se, que a cor externa das codornas é clara e a interna escura, e o rendimento da CMS foi de 50%. A cor das massas de codorna e frango com CMS são mais escuras que as de frango. Nas análises centesimais, os nuggets de frango tiveram maiores teores de proteínas (14,76%); e os de frango com CMS menores teores de umidade (47,91%) e maiores valores de carboidratos (30,05%). Durante a estocagem dos nuggets houve queda do pH, aumento da oxidação lipídica; a cor externa ficou preservada e a interna mais escura. A qualidade microbiológica foi satisfatória. Dessa forma, estas evidências, contribui para diminuir os impactos ambientais, com a linha de reaproveitamento de subprodutos provenientes da codorna, além de ser uma fonte proteica e exótica usada na gastronomia.
Palavras-chave: carne de aves, reestruturados, coturnicultura.

1. INTRODUCTION

In the last years, the poultry production has achieved significant growth, in order to supply the nutrition needs of populations, offering animal protein sources [1, 2]. It stands out in this field, the creation of quails, called coturniculture, used mostly for egg production and meat in some regions [3, 4]. However, the consumption of its meat and other by-products is still low, and becomes essential in food, because it is an exotic, viable, sustainable bird and of excellent nutritional value.

The Japanese quail (*Coturnix coturnix japonica*) has a small size, consumes less feed and is used in Brazil for eggs production [5, 6]. However, the consumption of derivatives such as egg, is due to the lack of a correct destination of the carcasses in the end of Japanese cycle, because there are no specific slaughterhouses for these birds in the country. The quail is European strain (*Coturnix coturnix*), has a large size and is used for meat production [7, 8]. These birds have meat rich in amino acids and essential fatty acids, vitamins E and C and elements such as iron, phosphorus, calcium, sodium and selenium [6-11]. In this way, both of them, quail and Japanese quail can offer health benefits, however, Brazilian poultry industries have not invested in waste recovery and the population is unware of the meat nutrients, due to high prices in some markets and the impact on the purchase when they see a darker meat.

It is known that the slaughter and commercialization of quail in Brazil are already adopted by some slaughterhouses and the use of meat adhered to the bones of few units that exist in the country, such as mechanically separated meat (MSM), still needs to be investigated because it can generate profitability and contribute to sustainability. Many times, industries by-products without treatment and correct destination, can be deposited in rivers, springs, lakes and soils, and can increase environmental pollution [12-14]. That said, there must to be more scientific investigations, in order to take advantage in meat raw materials in several food products.

It is observer that, in literature, there is a lack of works using Japanese quail meat in the elaboration of protein products. However, it is already known that the insertion of quail meat in restructured such as nuggets is proven [6, 11, 15-17], obtaining highlights, with results for new research in meat technology area. In this line, meat and the MSM can be introduced into gastronomy, capable of generating aromas and flavors.

The Normative Instruction n.° 4, of March 31, 2000 of the Ministry of Agriculture, Cattle and Supplying (MAPA) does not regulate the percentage of inclusion of MSM in restructured such as nuggets, stipulates only for sausages and the percentage that can be used from poultry, cattle and swine [18]. However, even so, the MSM can be applied in formulations, including fried restructured, which are easier to be prepared and provide practicality during purchase.

The use of MSM in nuggets can serve people with a lower income and contribute to food security. The MSM has a high nutrient content and increases environmental visibility [2, 13, 19]. Therefore, in view of these reports, the objective was to produce, characterize the centesimal composition and investigate the stability of pre-fried nuggets made with chicken, quail meat and mechanically separated meat (MSM) of quail during storage at -18°C for 45 days.

2. MATERIALS AND METHODS

2.1 Raw material and production of mechanically separated meat (MSM) of quail

The chicken breast (2 kg) (Sadia, São Paulo, SP, Brazil) and the quail cuts (1.615 kg) (Villa Germania, Indaial, SC, Brazil), sold in trays, were purchased at a local market in the city of Lavras, Minas Gerais, Brazil, and conducted to the Meat Technology Laboratory (Labcarnes) of the Department of Food Science from Federal University of Lavras – MG.

Using a knife, the quail was deboned. The fresh waste was placed inside an electric pulper (Caf Máquinas, Rio Claro, SP, Brazil) to obtain the MSM. After, the MSM was weighed on an analytical balanced (C&F Balanças LTDA, Belo Horizonte, MG, Brazil) to calculate the yield of extraction percentage (%), stored in sterilized polyethylene plastic bags and, both meat, quail and chicken, were milled, using 3 mm diameter discs, in a meet grinder (Beccarro, PB-22, Rio Claro, SP, Brazil) refrigerated at -18°C in a conventional freezer (model GTPC – 575, Gelopar, Chapada Araucária, PR, Brazil). The Figure 1, just below, demonstrates the steps of obtaining the MSM and the equation 1, demonstrates the yield calculation.

Figure 1: quail (A), boning (B), meat raw material separation (C) and obtaining mechanically separated meat (MSM) (D).

$$RD = (PF/PI) \times 100 \quad (1)$$

Which: RD (%) = Yield; PF (g) = Final weight of MSM of quail; PI (g) = Initial weight of boneless quails.

For the investigation of the initial color, a CM-700 spectrophotometric colorimeter Kônica Minolta Sensing Inc, Osaka, Japan), as suggested by Ramos and Gomide (2007) [20] was applied on the outer surface of the quails, using a plastic film (Boreda, Contagem, MG, Brazil). During boning, the internal color of the quail and, subsequently, the external color of the masses, were analyzed. Were used the CieLab color indices, being them: luminosity (L*) ranging from dark (0) to light (100), red index (a*) from green (−) to red (+) and yellow index (b*) with intensity form blue (−) to yellow (+).

2.2 Preparation, frying and evaluation of the centesimal composition

The meat was homogenized inside a basin in the following order: 1) meat, 2) half of the cold water (-0.04°C), 3) refined iodized salt (CISNE, São Paulo, SP, Brazil) and 4) swine lard (Sadia, São Paulo, SP, Brazil). Then, seasonings such as cream of onion, garlic, pepper, purchased at an establishment were incorporated into the dough. After, the cassava starch was introduced (Amafil Indústria e Comércio de Alimentos LTDA – Cianorte, PR, Brazil), the phosphate (New Max Industrial, Americana, SP, Brazil), the isolated soy protein (ISP) (New Max industrial, Americana, SP, Brazil) and finally the other half of cold water. In this way, after mixing, the dough was covered with a plastic film, left under refrigeration in a freezer (-18°C) for 15 minutes, until reaching the temperature of 0°C. The nuggets formulations are shown in Table 1 and were changed according to Farag et al. (2021) [6] and Barros et al. (2019) [21].

Soon after the rest period of the masses, they were opened using a domestic roller, pressed in sizes of 2 cm, refrigerated again at -18°C in a conventional freezer for another 15 minutes. In the second part of the development of the Nuggets, the masses were cut, modeled using mold and introduced into liquid and types of breading flours.

The nuggets were passed in wheat flour (Vilma, Contagem, Minas Gerais, Brazil) with maize starch (KIMIMO, Grupo 3corações, Guarulhos, São Paulo, Brazil). After, were immersed in the breading liquid and the excess drained. For the production of the breading liquid were used wheat flour (250 g), maize starch (150 g), whole milk (Embaré Indústrias Alimentícias S.A., Belo Horizonte, MG, Brazil) (100 g) and salt (20 g). Finally, the product was introduced into a covering flour composed of breadcrumbs (Pachá Alimentos, Contagem, MG, Brazil). Then, after the preparation of the nuggets (Figure 2), a pre-frying in soybean oil (LIZA, CARGILL ALIMENTOS, Minnesota, United States of America) in electric fryer, in the temperature of 190° per 30 second was conducted. After frying, the nuggets were placed inside polystyrene plastic bags, stored in plastic trays with the bottom coated with aluminum foil and frozen at -18°C in a conventional freezer.

Table 1: Formulations used to prepare the nuggets of chicken, quail and chicken with mechanically separated meat (MSM) of quail.

Formulations (%)				**Weight (g)**		
Ingredients	**Chicken**	**Quail**	**Chicken/MSM**	**Chicken**	**Quail**	**Chicken/MSM**
Chicken	100.00	0	70.00	1000.00	-	700.00
Quail	0	77.50	-	-	775.00	-
MSM	0	0	30.00	-	-	300.00
Swine lard	13.00	10.08	13.00	130.00	100.75	130.00
Water	10.00	7.75	10.00	100.00	77.50	100.00
ISP	1.30	0.39	1.30	13.00	3.88	13.00
Phosphate	0.50	0.39	0.50	5.00	3.88	5.00
Sodium erythorbate	0.35	0.27	0.35	3.50	2.71	3.50
Cassava starch	1.00	0.78	1.00	1.00	10.85	1.00
Salt	1.40	1.09	1.40	14.00	10.85	14.00
Onion cream	0.35	0.27	0.35	3.50	2.71	3.50
Garlic powder	0.20	0.16	0.20	2.00	1.55	2.00
White pepper	0.05	0.04	0.05	0.50	0.39	0.50

Formulations: chicken (100% of chicken breast); quail (100% of quail meat) and Chicken/MSM (70% of chicken + 30% of mechanically separated meat (MSM) of quail).

Figure 2: Grinding of meats (A), dough preparation (B), molding (C) and the pre-fried nuggets (D).

Elapsed manufacturing time, centesimal analyses of moisture, crude protein, ethereal extract, ash and carbohydrates were carried out according to the methodologies determined by the Official Methods of Analysis of Aoac International [22], with some modifications.

2.3 Stability study of pre-fried nuggets

The stability of the nuggets was evaluated by physicochemical analyses during the time 0, 15, 30 and 45 days of storage at -18°C.

2.3.1 pH, water activity, lipid oxidation and color

The pH was determined by inserting a penetration electrode coupled to a pH metrodigital (model HI 99163, Hanna Instruments, Barueri, SP, Brazil) directly over the pieces of nuggets in 3 random spots. The water activity analyse was conducted in a Aqualb® device (model 4 TE, Barueri, SP, Brazil) using 10 g of crushed nuggets, with a temperature of 25°C±1°C.

Lipid oxidation occurred according to Tarladgis et al. (1960) [23], with some adaptations. Analytical units of 5 g of the nuggets were weighed inside plastic pots and after pipetted 15 mL of perchloric acid 3.86% and 1 mL of synthetic antioxidant BHT (butylhydroxytoluene) (0.15%). The grinding was conducted on a Turratec TE 102 (TECNAL, Piracicaba, SP, Brazil). Than, 5 mL of the filtrate was homogenized with 5 mL of thiobarbiturate acid (TBA) 0.02 M, inside test tubes in a water bath (ESTANHOF, Lavras, Minas Gerais, Brazil), at 100°C for about 30 minutes. The absorbance was read at 532 mm in a spectrophotometer (SP 2000 UV, BEL Engineering, Piracicaba, SP, Brazil). The concentration of malondialdehyde (MAD) was determined from an analytical curve with 1,1,3,3- tetraethoxypropane (TEP) and the results expressed in mg of MDA/kg.

To study the internal and external color, was used a spectrophotometric colorimeter, with 5 reading values, described by Ramos e Gomide (2007). The luminosity index (L*), red index (a*) and yellow index (b*) were obtained. Then, the saturation (c*) was calculated through the equation: $c^* = [(a^{*2} + b^{*2}) 1/2]$ and the tonality angle (h*) °h = tangent arc (b*/a*). The calculation of global color difference (ΔE*) was conducted according the equation $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

2.4 Count of psychotrophs and enterobacteria

25 g of nuggets were mixed with 225 mL of peptone water 0,1% (v-v) in a Stomacher homogenizer (Metroterm®, 1204M, Porto Alegre, Rio Grande do Sul, Brazil) for 490 strokes/minute for 3 minutes. The methodology used was according to Da silva et al. (2017) [24]. Briefly, for the count of mesophiles and enterobacteria, aliquots 1 mL of the dilutions were removed from the tubes and placed on petri dishes. The culture medium poured for mesophilic count was Tryptone Soy Agar (TSA) (Himedia, Índia), while for enterobacteria was used Bile Lactose Violet Agar (VRBG) (Himedia, Índia) with an overlayer. Both petri dishes were incubated at 37°C for 24 hours. The experiment was applied in triplicate and with three repetitions.

2.5 Statistic analyse of pre-fried nuggets

To evaluate the centesimal composition, Completely Randomized Design (DIC) with 6 repetitions and 3 treatments, followed by Turkey test ($p \leq 0.05$). The stability study (0, 15, 30 e 45 days) was conducted in a DIC, with 6 repetitions, performed na analysis of variance (ANOVA) and applied the Turkey test ($p \leq 0.05$), followed by regression for the days with the use of the *Software* Sisvar version 5.4 *Build 80* [25].

3. RESULTD AND DISCUSSION

3.1 Yield of MSM, color of quail and dough

The yield of extraction is important for meat industries [12, 26]. During the obtaining of the MSM, was verified a yield of 50%, as shown in the calculation of Equation 2:

$$RD = (355/710) \times 100 = 50\ \% \qquad (2)$$

The results shown that the yield may have been influenced by the tip of pulping machine, but in general, there is the applicability of reuse of by-products. Within the meat industry, it must have a control of the sharpening of machines, knives and other equipments [26]. It was observed, during analysis, that the residues adhered to the bones were small, which made it difficult for them to pass through the machine. It is emphasized that a quality boning must be maintained to have a better MSM yield.

The external color of quails is light with an average L* value of 60.41 and the internal color is darker with a value of 45.56. Added to this, the external index value a* was low (7.10) and higher internally (14.99) demonstrating a reddish color concentrated inside the chest (Figure 3). The external b* values were lower (6.67) and internally higher, demonstrating a yellowish color (9.08).

The quail dough had an average value of L* of 63.35 and the chicken/MSM of 61.3 being darker than chicken (68.32). In addiction, quail and chicken/MSM were reddish than chicken a*

(9.6), with average values of a* respectively of: 14.52 and 13.11. The quail and chicken dough had similar value of b* of 18.43 and 18.44, being a little less yellowish than chicken/MSM (19.88). Right bellow, Figure 3 shows the colors of the doughs.

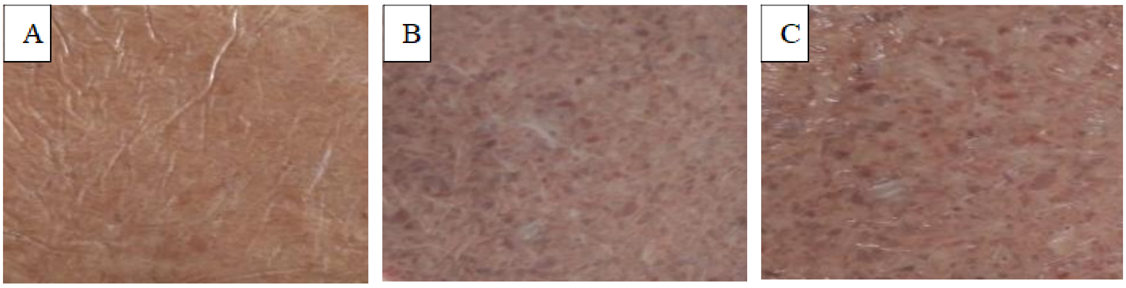

Figure 3: Color of chicken dough (A), quail (B) and chicken/MSM of quail (C). The photos were taken from a cell phone at a resolution of 3060 x 4080 pixels.

3.2 Centesimal composition

It is known that quail products can be accepted by the population and are rich in nutrients [16]. In this way, analyse a nutrient from a food is valid because many of them are essential to health. Quail meat is easily digested and low in fat [11, 15]. It is estimated that it has a moisture, protein and fat content around 75%, 21% and 2% respectively [27, 28]. However, when used in restructured products, the composition of nutrients can be modified [16]. The results found on centesimal composition of the nuggets are shown in Table 2.

Table 2: Centesimal composition of chicken, quail and chicken/MSM of quail nuggets.

Centesimal composition	Treatments		
Chemical parameters	Chicken	Quail	Chicken/MSM
Moisture	56.07 ± 0.35 a	53.44± 0.40 b	47.91 ± 0.55 c
Crude protein	14.76 ± 0.97 a	8.80 ± 1.02 b	9.04 ± 0.52 b
Ashes	2.02 ± 0.06 a	2.00 ± 0.04 a	1.99 ± 0.03 a
Fat	12.08 ± 0.25 a	10.61 ± 0.43 a	10.99 ± 0.35 a
Carbohydrates	15.04 ± 1.12 b	22.89 ± 0.75 c	30.05 ± 0.75 a

Treatments: chicken, quail and chicken with mechanically separated meat (MSM) of quail (Chicken/MSM). Equal letters in the same column do not differ from each other, by the Turkey test at the 5% significance level.

It was observed that there were significant differences ($P<0.05$) in the treatments, except in the ash and fat content (Table 2). The results of ashes are similar to those found by Choudhary et al. (2019) [11] and Shinde et al. (2019) [15] who reported values for quail nuggets around 2.5%.

Frying in oil at a temperature around 150-200°C, cooks the nuggets [29, 30]. As seen, there were no significant differences for nuggets in fat content. Barros et al. (2019) [21], found for chicken nuggets a value close to 13% fat and Choudhary et al. (2019) [10] a content of 12%, when prepared with quail meat. Farag et al (2021) [6] reported that quail sausage products had the highest fat content of 12.22; 18.05% respectively. Quail meta was ground in a grinder before introduction into the dough, which may have released an amount of fat. It is known that during the deboning and grinding process, fatty acids are released [26]. The high fat content, may be due to the nuggets going through pre-frying, in which there is a large amount of oil in the final product.

When the nuggets do not go through the frying and breading process, the fat content tends to be lower [16]. Chicken nuggets showed the highest moisture content ($P<0.05$) with a value of 56.07% followed by the quail 53.44% and finally the chicken/MSM of 47.91%. Choudhary et al. (2019) [11] when adding 10% Bengal flour to quail nuggets found a moisture content of 58.6%, similar to the moisture content of chicken nuggets. Possibly, the moisture variations may be due to evaporation of water in the meats used or the formation of water droplet in the nuggets, as seen by Shinde et al. (2019) [15]. Higher protein contents (P<0,05) of 14.76% were found for chicken nuggets, when compared to the others. Farag et al. (2021) [6] found that sausage and quail Kofta produced had the higher protein contents between 15.52 and 22.10. Shinde et al. (2019) [15] reported values close to 20% protein in quail nuggets.

It is known that the fast freezing is more effective than slow freezing in the conservation of the meat, the last one form ice crystals, responsible for the denaturation of proteins [11]. The cooking process at high temperatures, water content, damage during preparation and after processing and ingredients possibly affect the protein content [16]. It is also noticed, that chicken/MSM nuggets obtained higher amounts of carbohydrates (30.05%). The flours and breading liquids of the nuggets may have left the carbohydrates values higher and the protein levels lower.

3.3 Storage study of pre-fried nuggets for 45 days at -18°C

3.3.1 pH, water activity and lipid oxidations (Thiobarbituric Acid Reactive Substance Index)

The type of meat, water, salt, chemical and natural ingredients, can modify the values of pH and water activity of nuggets [15, 16, 31]. Other factors can affect this variables, like superficial freezing and the metabolites produced by microorganisms, which can increase acidity values [11, 15]. Table 3, shows the medium values over the storage days of the different variable, such as pH, water activity and lipid oxidation (Tbars).

Table 3: pH, water activity (Aw) and Tbars of chicken, quail and chicken with mechanically separated quail meat (MSM) nuggets stored at -18°C for 45 days.

Analysis	Days	Treatments			
		Chicken	**Quail**	**Chicken/MSM**	**Mean**
	0	5.92± 0.086 a	6.12± 0.093 b	6.16±0.088 b	6.06
	15	6.06±0.064 a	6.36±0.042 b	6.19± 0.011ab	6.20
pH	30	5.96±0.064 a	6.18±0.115 b	6.02±0,095 ab	6.05
	45	5.48±0.051 a	5.56±0.212 a	5.41±0.153 a	5.48
	Mean	5.85	6.05	5.94	
	0	0.950±0.003 a	0.946± 0.004 a	0.948± 0.004a	0.94
	15	0.942±0.003 a	0.953±0.006 b	0.954±0.003 b	0.94
Aw	30	0.958±0.007 a	0.959±0.002 a	0.954±0.004 a	0.95
	45	0.955±0.002 ab	0.960±0.002 b	0.949±0.003 a	0.95
	Mean	0.95	0.95	0.95	
	0	1.52± 0.19 a	2.08±0.24 b	1.64±0.15 a	1.74
	15	1.18±0.18 a	1.45±0.14 a	1.31±0.16 a	1.31
Tbars	30	1.36±0.11 a	1.86±0.11 b	1.66 ±0.16 ab	1.62
	45	1.72±0.25 a	1.48±0.05 a	1.53±0.15 a	1.57
	Mean	1.44	1.71	1.53	

Treatments: chicken, quail and chicken with mechanically separated meat (MSM) of quail (Chicken/MSM). Equal letters in the same column do not differ from each other, by the Turkey test at the 5% significance level.

It was noticed that pH values were close to neutrality in 0 time, having significant difference P<0.05 in the treatments, and the chicken had an average value of 5.92, considered low, when compared to quail (6.12) and chicken/MSM (6.16). It is noticed that there were significant differences (P<0.05) in pH values over the evaluation days, except on the 45th day, when the values were very similar. It was observed that there was a quadratic effect that caused an increase in pH from day 0 to 15th day and a pH reduction for all treatments in the following days, as shown by Figure 4.

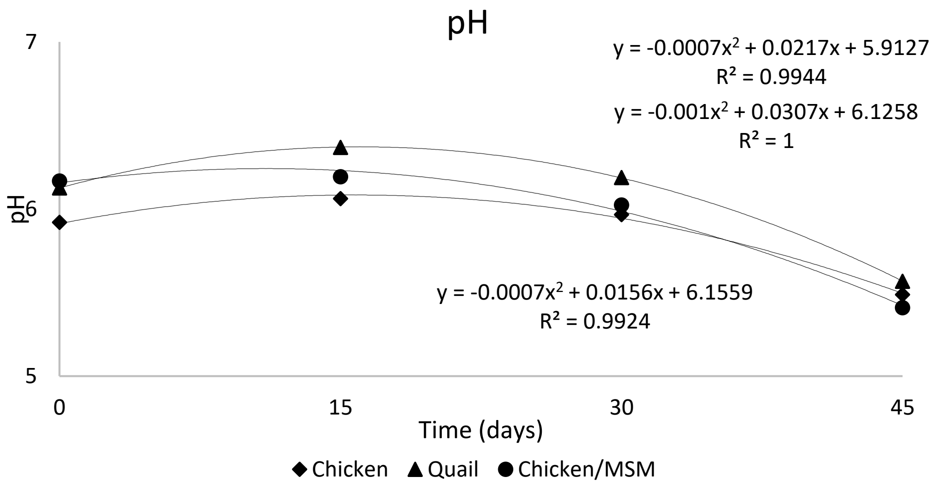

Figure 4: Graph and regression coefficient of pH of nuggets over 45 days stored at -18°C.

Shinde et al. (2019) [15], found that the pH dropped significantly for the control quail nuggets and with the addition of corn flour during storage. Choudhary et al. (2019) [11], found that the pH increased for control quail nuggets and with Bengal flour, which can be due to bacterial metabolites and protein deamination.

Water activity is essential for the multiplication of microorganisms [31]. From Table 3, it is possible to observe that there was no significant difference in water activity values of the nuggets in 0 time. It was observed que the values remained above 0.94. Figure 5, shows that at 15 time, the water activity of chicken nuggets was lower, but it increased in the following days for all treatments, being on the 45th day, higher for quail.

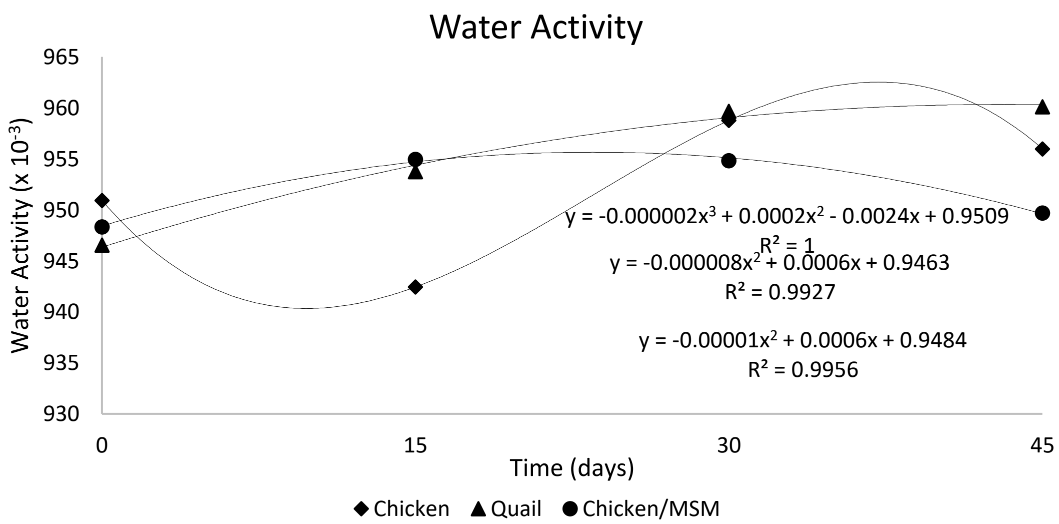

Figure 5: Graph and regression coefficient of water activity of nuggets over 45 days stored at -18°C.

The lipid oxidation that occurs in meat products promotes the rancid taste [15]. Table 3, shows that there was significant difference ($P<0.05$) between treatments, the quail had a higher value of 2.08 mg/kg of malondialdehyde. The highest value for both treatments may be due to the amount of oil and volatile metabolites production, as reported by Shinde el at. (2019) [14]. During evaluation of the lipid oxidation of nuggets, Choudhary et al. (2019) [11], pointed out that the increase of TBA can be attributed to aerobic packaging or packaging material with oxygen permeability that leads to faster lipid oxidation.

Oxygen is introduced into poultry meat during boning process. Allied to this, there is a self-oxidation of polyunsaturated fatty acids, located mainly in the phospholipids derivatives from the bone marrow [19, 26]. Due to the oxidation process, aldehydes, ketones, hydrocarbons, esters, furans and lactones are generated during storage, which are responsible for sensorial modifications [32, 33]. The cubic effect throughout the storage, caused a decrease in Tbars from 0 to 15 days and an increase until reaching 30 days, but at 45th day, the values dropped in both treatments, as observed in Figure 6.

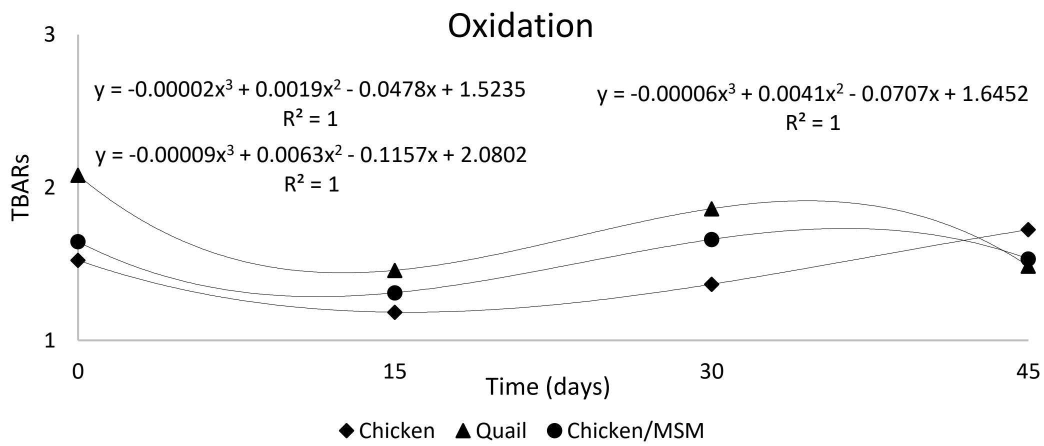

Figure 6: Graph and regression coefficient of lipid oxidation of nuggets over 45 days stored at -18°C.

3.4 Color and microbiological quantification

Color is a fundamental attribute in the purchase of nuggets Bashir et al. (2022) [34]; Cao et al. (2020) [32]. The external color is attributed to frying, temperature, type of oil, flours and breading liquids [29, 35]. Regarding the interior color, besides being affected bay frying, it depends on the ingredients. Clearly in Table 4, it was observed that the storage at -18°C affected the internal and external color of the nuggets. Table 5, shows the average values calculated by the global difference of color from the first day (0) to the last day of storage (45).

Regarding the internal color (Table 3), it was observed that quail nuggets are darker than the others ($p<0.05$). Chicken/MSM nuggets are similar to the chicken ones, being lighter. Throughout the storage there was a decrease in L *, which left both treatments darker. In the values of the index (a*) it is noted that the red color prevailed in the quail nuggets ($P<0.05$) and over the days there was a decrease in values for all the treatments, with a discoloration. The internal b* values showed that the quail nuggets ($P<0.05$) are a little less yellowish when compared to other treatments. In c* no significant difference was found in time 0, confirming a slightly red color in the nuggets, but, over the days there was a decay of the values, confirming the loss of color in the index a*. From the results of tonality h* it is possible to observe that chicken and chicken/MSM nuggets internally are similar, predominating a yellowish color, when compared to the quail one. Throughout the storage, the treatments had high values of h*, preserving the yellowish color.

During frying, the reaction of amines with reducing sugars occurs in the nuggets, forming the Maillard reaction, with a darker color [35]. Observed that the external L* was preserved, indicating to the nuggets a light color. Externally, the a* values of chicken nuggets were higher ($P<0.05$), predominating a red color, followed by chicken/MSM and finally the quail one. Throughout the storage, there was a loss of red color. The external b* values indicated that quail nuggets are less yellowish than the others. The yellowish color practically remained throughout the storage. The c* variable confirms that externally the chicken and chicken/MSM nuggets are very similar and the h values, demonstrate the external color yellowish.

Table 4: Internal and external color of chicken quail and chicken with mechanically separated quail meat (MSM) stored at -18°C for 45 days.

		Treatments			
Internal color	**Days**	**Chicken**	**Quail**	**Chicken/MSM**	**Mean**
L*	0	69.50±2.12 b	63.52±1.58 a	68.34±0.46 b	67.12
	15	70.47±1.22 b	65.68±1.44 a	67.57±1.34 a	67.90
	30	68.07±1.92 a	62.80±1.22 b	67.99 ±0.53a	66.28
	45	64.60±1.32 ab	59.54 ±1.98b	65.47±1.65 a	63.20
	Mean	68.16	62.88	67.34	
a*	0	6.65±0.54 a	8.49±0.83b	6.97±0.36a	7.37
	15	6.19±0.11 a	8.13±0.27 b	6.91±0.25 c	7.07
	30	5.62±0.15 a	7.62±0.39 b	6.60±0.31 c	6.61
	45	1.94±0.16 a	3.03±0.11b	2.91±0.07b	2.62
	Mean	4.61	6.81	5.84	
b	0	15.19±0.21 a	13.82±0.92 b	15.97±1.06 a	14.99
	15	14.97±0.55 ab	14.07±0.70 a	15.55±0.39 b	14.86
	30	13.66±0.64 a	12.63±0.32 a	15.40±0.51 b	13.89
	45	13.50±0.57 a	14.21±0.76 a	15.78±1.01 b	14.49
	Mean	14.33	13.68	15.67	
c	0	16.60±0.28 a	16.26±0.75 a	17.44 ±0.87a	16.76
	15	16.20±0.50 a	16.25±0.63 a	17.02±0.37 a	16.49
	30	14.77±0.65 a	14.76±0.37 a	16.76±0.58 b	15.43
	45	13.64±0.59 a	14.53±0.77 a	16.05±0.98 b	14,74
	Mean	15.30	15.45	16.81	
h	0	66.37±1.63 a	55.80±2.26 b	66.31±2.15 a	62.82
	15	67.48±0.81 a	59.93±1.07 b	66.02±1.00 a	64.47
	30	67.60±0.49 a	58.90±1.21 b	66.81±0.63 a	64.43
	45	81.83±0.43 b	77.91±0.54 a	79.46±0.37 a	79.73
	Mean	70.82	63.13	69. 65	
External color	**Days**				
L*	0	61.84±0.54 a	62.24±1.94 a	60.28±0.58 a	61.45
	15	63.05±1.43 a	63.30±1.23 a	66.44±0.73 b	64.26
	30	65.57±0.72 b	63.13±1.65 ab	62.09 ±2.14a	63.59
	45	61.85±0.88 a	61.37 ±1.60a	61.85±1.08 a	61.69
	Mean	63.07	62.51	62.66	
a*	0	10.35±0.38 b	8.52± 0.98a	9.47±1.33 ab	9.44
	15	9.57±0.52 a	9.76±0.62 a	9.26±0.36 a	9.53
	30	8.52±0.37 a	8.66±0.26 a	9.47±0.90 a	8.88
	45	5.95±0.47 a	5.78±0,25a	6.65±0.45a	6.12
	Mean	8.59	8.18	8.71	
b*	0	23.27±1.21 b	17.93±1.90 a	21.70±2.40 b	20.96
	15	21.18±0.65 a	21.91±1.54 a	21.40±1.14 a	21.49
	30	18.98±1.04 a	18.65±0.98 a	20.48±1.29 a	19.37
	45	19.91±0.98 a	18.89±0.87 a	21.06±1.05 a	19.95
	Mean	20.83	19.34	21.16	
c*	0	25.47±1.24 b	19.85±2.02 a	23.68 ±2.73b	23.00
	15	23.25±0.54 a	23.99±1.59 a	23.32±1.17 a	23.52
	30	20.81±1.10 a	20.57±0.98 a	22.57±1.54 a	21.31
	45	20.78±1.08 a	19.76±0.84 a	22.09±0.56 a	20.87
	Mean	22.57	21.04	22.91	
h*	0	65.99±0.46 ab	64.61±1.17 a	66.44±0.74 b	65.68
	15	65.66±1.52 a	65.95±0.67 a	66.58±0.61 a	66.06
	30	65.80±0.50 a	65.09±0.55 a	65.20±1.13 a	65.36
	45	73.37±0.61 a	72.93±0.87 a	72.46±1.08 a	72.92
	Mean	67.70	67.14	67.67	

Treatments: chicken, quail and chicken with mechanically separated meat (MSM) of quail (Chicken/MSM). Equal letters in the same column do not differ from each other, by the Turkey test at the 5% significance level.

To determine if there is a visually difference in food color, the calculation of global difference (ΔE*) is used. The average values of ΔE* (± standard deviation) in relation to times 1 and 45 days are in Table 5, demonstrating that the internal and external color of the chicken nuggets were more noticeable to be observed in the human eye.

Table 5: Mean and standard deviation of the global color difference (ΔE) found for nuggets in relation to control of each storage time as -18°C for 45 days.*

	Treatments		
	Chicken	**Quail**	**Chicken/CMS**
Internal global color difference (ΔE*)	6.01±1.49	5.57±1.76	4.52±0.76
External global difference (ΔE*)	6.16±0.77	3.34±0.18	3.153±0.22

Treatments: chicken, quail and chicken with mechanically separated meat (MSM) of quail (Chicken/MSM).

It is known that the values of global color difference between 0.5 and 1.5 are not noticeable. Above, can be detected by the human eye [36]. The values in Table 5 indicate that internal and external color can be visually observed. Table 6, shows the regression equations, representing the mean values and adjusted models with their given regression coefficient (R^2), to predict the internal and external color of the nuggets during the evaluation days.

Table 6: Regression equation to predict the internal and externa color of the nuggets during the 45 days of storage ate -18°C.

Internal indices	**Regression equations**	**R^2**
L	$y = -4303.09x^2 + 104449.98x + 67171194.15$	1.00
a	$y = -4103.70x^2 + 86718.55x + 7206610.80$	0.96
b	$y = 117.81x^3 – 7135.80x^2 + 71530.81x + 14999444.00$	1.00
c	$y = -459.58x^2 – 26857.87x + 16828328.40$	0.98
h	$y = 15168.60x^2 – 344794.76x + 63685599.10$	0.92
External indices	**Regression equations**	**R^2**
L	$y = -5149.38x^2 + 233685.17x + 61571111.10$	0.95
a	$y = -3154.32x^2 + 712999.9x + 9380889.35$	0.99
b	$y = 265.10x^3 – 17840.75x^2 + 243481.59x + 20968889.00$	1.00
c	$y = -1065.46x^2 – 9267.72x + 23230407.15$	0.79
h	$y = 7989.21x^2 – 219476.24x + 66155333.90$	0.89

During the storage days, it was observed that psychrotrophic and enterobacteria plaques were absent from colonies. The frying process and freezing, may have preserved longer the nuggets [5]. These investigations showed that the microbiological quality was satisfying.

4. CONCLUSION

This study demonstrated the viability of quail MSM. It also shows that the color of the nuggets, internally became darker during storage and externally more yellowish. The chicken/MSM nuggets were very similar to the chicken ones. The protein contents of the nuggets were low and the microbiological quality adequate. Frying in oil caused an increase in lipid oxidation and the pH decayed throughout the storage. The consumer is expected to have acceptance of nuggets because the colors define the purchase option. Sensory studies and formulations adjustments are suggested, with the increasing use of MSM of quail and Japanese quail in the elaboration of protein products.

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