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Development of a Functional Healthy Chicken and Beef Mortadella Fortified with Polyunsaturated Fatty Acids and the Evaluation of Their Chemical, Microbiological, and Sensory Properties

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ABSTRACT

This study aimed to evaluate the chemical, physical, and microbiological properties of beef and chicken mortadella (BM and CM, respectively) to determine the effect of flaxseed and oregano oils on mortadella samples as compared to the control. Twelve mortadella samples (6 rolls and 6 slices) were analyzed each forming six treatments: T1 (BM control), T2 (CM control), T3 (CM fortified with flaxseed oil), T4 (CM fortified with oregano oil), T5 (BM fortified with flaxseed oil) and T6 (BM fortified with oregano oil). Results obtained during six months of storage were significantly different except for those of the fatty acid profile. Results of chemical analysis showed a moisture content was around 65%, fat content ranged from 11.19-13.90% in BM and 9.77-10.43% in CM, protein content was around 14%, cholesterol content ranged from 21.5-52 mg/100 g in BM, and 16-55 mg/100g in CM, ash content was around 3%, collagen content was around 1.68%, salt content was around 2%, and the negative [H^+] (ph) content was around 6.5. Oregano oil was found to increase the L* value in both BM and CM. Both oils reduced a* and b* values and were found to be differently affected by the addition of oils. The antimicrobial properties of both oils were observed (an approximate 1 log CFU/g reduction). The resulting sensory scores indicated that both BM and CM were acceptable with no significant differences in texture, sliceability, appearance, and color.

Keywords: Fatty acid profile, fat, cholesterol, antimicrobial properties.

INTRODUCTION

Meat is the most known source of protein worldwide, as it provides our bodies with minerals (such as zinc and iron), vitamins, and fat which are very important for the metabolism and function of the human body (Wood *et al*., 2007). Due to the importance of this food to our diet, ready-to-eat meat products are developed at a lower price and a shorter preparation time, which can be very useful for full-time working women (Creed, 2010). Mortadella, i.e., the most accepted processed meat product, is considered one of them because of its amazing taste, texture, and ease of incorporation into sandwiches (Berasategi *et al*., 2014; Abdullah, 2004).

Mortadella (also called bologna sausages) is an emulsified processed meat product (Badar *et al.*, 2021), that originated in Italy when pork and pork fat were essential components of this ready-to-eat food. However, due to religious beliefs, mortadella in Islamic countries

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can be prepared from beef, sheep, or poultry meat (Mohammed *et al*., 2015). These polyethylene or vacuum-packaged products can be purchased either in supermarkets or in butcher stores, either in rolls or sliced (Romero *et al*., 2012).

Meat and meat products are rich in saturated fatty acids (SFA) and contain low amounts of unsaturated fatty acids (Wood *et al*., 2007). Many sources, including the World Health Organization and Food and Agriculture Organization, declared that saturated fat intake is strongly related to coronary heart disease, high low-density lipoprotein (LDL), obesity, and cancer (Park *et al.*, 1989). This has consequently made consumers nowadays concerned about consuming meat and meat products (Hygreeva *et al*., 2014), where64% of them tend to read the labels of food products before buying them and this number, according to the International Food Information Council Foundation, is increasing every year. Some consumers check the saturated fat content in food whereas others look for "no saturated fat" (Hodgkins *et al*., 2019). Nowadays, it is a great interest of food scientists and technologists to develop healthier meat and meat products using natural antioxidant and antimicrobial substances, and this also includes planning to reduce SFA content in these products and to increase both mono and polyunsaturated fatty acids (MUFA and PUFA, respectively) (Ospina *et al*., 2012). Meat and meat products took a major interest in this research because they are considered an important source of dietary fat especially when people showed no interest in reducing their intake. Therefore, it is recommended to impart some modification in the fatty acid profile of these products in order to obtain a healthier$\omega 6/\omega 3$ and PUFA/SAT ratios in parallel with reduced cholesterol content if possible (Jimenez-Colmenero *et al*., 2015).

The incorporation of vegetable oils into meat and meat products, either in emulsion or in emulsion gels, is one of the recent techniques that aim to improve the fatty acid profile of these products. It is even more challenging to find the appropriate oil that could do the job without affecting the acceptability and organoleptic properties of the product (Domínguez *et al.*, 2021).

The aim of this study was to develop new meat products including beef and chicken mortadella (BM and CM, respectively) that are healthier with high nutritional quality by the addition of flaxseed and oregano oils which are considered rich sources of PUFAs. This could contribute to lowering the risk of coronary disease and other numerous serious illnesses.

Materials and Methods:

Mortadella Manufacture:

Raw Batter Preparation:

Six mortadella samples were prepared at a local meat factory with different formulations as shown in Table 1. For beef and chicken mortadella, 25 kg was used for each treatment.

Table 1: The formulations of the prepared mortadella samples incorporated with flaxseed and oregano oils

	Treatments					
Ingredients	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Beef (kg)	25	-	-	-	25	25
Chicken (kg)	-	25	25	25	-	-
Flaxseed oil (ml)	-	-	7.4	-	7.4	-
Oregano oil (ml)	-	-	-	18.5	-	18.5
Starch (kg)	0.88					
Sodium tripolyphosphate (g)	127					
Spices (g)	238					
Ice-water (kg)	4.8					

Sodium nitrite (ppm)	99.2
NaCl (g)	571.42
Garlic (g)	39.7

Cooking and Storage:

Mortadella batches were thermally processed in a steam oven and then, after restoring the temperature of the product, the cooked mortadella was retained in its original casing and held at 4°C throughout the duration of the experiment (Abdullah, 2004).

Chemical Analysis:

Proximate Analysis:

Beef and chicken mortadella samples were analyzed for moisture, protein, fat, ash, collagen, and salt using NDC Infralab™ e-Series NIR Meat Analyzer approved by AUS-MEAT Ltd (Watkins *et al*., 2021).

pH:

The pH of the mortadella samples was measured in a homogenate prepared with 10 g of sample and distilled water (90 ml) using a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland). All determinations were performed in triplicate (Korkeala *et al*., 1986).

Thiobarbituric Acid Reactive Substances Values (TBARS):

The extent of lipid oxidation of the six samples was determined using the TBARS method described by Faustman *et al*. (1992). After measuring the absorbance of each sample at 530nm using a spectrophotometer, the TBA number was then expressed using a conversion factor of 7.8 (Cheah & Hasim, 2000).

Cholesterol Content Determination:

The cholesterol content was enzymatically analyzed using the colorimetric method Boehringer Mannheim / R-Biopharm AG, Cat. No.10 139 050 035, Darmstadt, Germany. The absorbance of each sample was measured using a spectrophotometer (Spectro, Model NO. 2000RS, USA) at 405 nm (Domínguez, 2017). Finally, the cholesterol content was calculated using the following formula:

$C_{cholesterol} = 0.711\times \Delta A$ [g cholesterol/l sample solution]

ΔA: the subtract absorbance of the blank from the absorbance of the sample.

The cholesterol content was then converted to g/100g using the following formula (Röschlauet al., 1974):

$Content_{cholesterol} = (C_{cholesterol}$ [g/l sample solution]/ weight of the sample in g/l solution) * 100 [g/100 g]

Fatty Acid Profile and Instrumental Analysis:

The fat was extracted using the Soxhlet method. The fatty acid methyl esters (FAMEs) of the mortadella samples were prepared according to Hewavitharana *et al.* (2020). The FAMEs were identified using a chromatogram of fatty acids standard.

Physical Analysis:

Color Determination (L*, a*, b* values):

The color of the twelve mortadella samples (6 rolls and 6 slices) was determined using Chroma Meter model CR-400 (Konica Minolta Sensing, Japan). The instrument was calibrated using a standard reference white ceramic plate (instrument catalog no. 12733097) and the L^* (lightness), a^* (redness), and b^* (yellowness) values were measured in three replicates from each sample (Dutra *et al*., 2017).

Microbiological Analysis:

All of the twelve mortadella samples (6 slices and 6 rolls) were analyzed for coliforms, *Escherichia coli*, *Staphylococcus aureus*, lactic acid bacteria, and aerobic plate count. The initial suspension and decimal dilution were prepared according to AOAC (1995). Lactic acid bacteria were detected using MRS culture media in the regular Petri dishes and incubated at 30°C for 48h according to ISO 15214:1998. The specialized 3M Petri films were used for the detection and enumeration of each of the other microorganisms according to ISO 9001. Coliforms were then incubated at 44°C for 24h and 48h for E. coli whereas the *Staphylococcus aureus* was incubated at 35°C for 24h and the aerobic plate count at 30°C for 72h.

Sensory Evaluation:

The sensory analysis of the six mortadella samples (T1, T2, T3, T4, T5, and T6) was carried out by 20 panelists using a 9-point hedonic scale, in which test subjects were asked to differentiate numerically between the samples in terms of the relative degree of liking for each one. Scores assigned ranged from 1 to 9 as follows; (1) dislike extremely, (2) dislike very much, (3) dislike moderately, (4) dislike slightly, (5) neutral/ neither like nor dislike, (6) like slightly, (7) like moderately, (8) like very much and (9) Like extremely (Schutz & Cardello, 2001).

Statistical Analysis:

All measurements were performed in triplicates and the mean values were declared. Analysis of variance (ANOVA) using JMP (release 10, SAS institute, Cary, NC) was carried out to determine any significant differences among the treatment parameters associated with the developed mortadella properties. The least significant difference (LSD) at a 5% level of probability was determined to separate differences in the properties among treatments.

Results and Discussion:

Chemical Analysis:

Proximate Analysis:

The results of proximate analysis, salt, and collagen obtained are shown in Table 2. The moisture content among the six mortadella samples was not significantly different, however, some values were slightly above the Jordanian standards (1996) which states that the maximum moisture level in mortadella should be 65%. Similar data were also reported by Lee *et al*. (2015), Guerra *et al.* (2011), and Prestes *et al*. (2014) who declared that the moisture content should increase when the fat content is reduced and vice-versa.

Table 2 - Proximate analysis, collagen, salt, and pH values* of the six formulated beef and chicken mortadella samples incorporated with flaxseed and oregano essential oils

	Proximate analysis						
Treatment	**Moisture(%)**	**Fat(%)**	**Protein(%)**	**Ash(%)**	**Collagen(%)**	**Salt(%)**	**pH**
T1	$65.03^{a}\pm0.50$	$11.19^{bc}\pm0.45$	$14.52^{c}\pm0.71$	$3.40^{a}\pm0.08$	$1.64^{b}\pm 0.02$	$2.14^{a}\pm 0.03$	$6.65^{a}\pm0.21$
T2	$65.09^{a}\pm0.27$	$9.77^{d}\pm 0.71$	$15.01^{a}\pm0.14$	$3.36^{a}\pm 0.02$	$1.66^{b}\pm 0.02$	$2.02^{b}\pm 0.05$	$6.57^{c}\pm0.22$
T3	$65.64^{a}\pm0.62$	$10.43^{cd}\pm0.15$	$14.92^{ab}\pm0.05$	$3.11^{c}\pm 0.03$	$1.56^{c}\pm 0.03$	$1.93^{c}\pm 0.03$	$6.57^{d}\pm0.20$
T4	$64.78^{a}\pm0.61$	$10.14^{cd}\pm0.24$	$14.17^{d}\pm0.05$	$3.25^{b}\pm 0.03$	$1.68^{ab}\pm 0.03$	$1.92^{c}\pm 0.04$	$6.19^{b}\pm0.20$
T5	$64.66^{a}\pm0.50$	$12.50^{b}\pm0.31$	$14.11^{d}\pm0.06$	$3.41^{a}\pm 0.03$	$1.74^{a}\pm 0.02$	$2.04^{b}\pm 0.02$	$6.57^{c}\pm0.20$
T6	$65.68^{a}\pm0.55$	$13.90^{a}\pm0.47$	$14.84^{b}\pm0.06$	$3.26^{b}\pm 0.03$	$1.67^{b}\pm 0.02$	$2.05^{b}\pm 0.02$	$6.53^{b}\pm0.20$

*Each value is a mean of 3 readings ± SD.
Levels not connected by the same letter are significantly different ($p<0.05$).
T1: Control of beef mortadella**; T2:** Control of chicken mortadella**; T3:** Chicken mortadella + flaxseed oil**; T4:** Chicken mortadella + oregano oil; **T5:** Beef mortadella + flaxseed oil**; T6:** Beef mortadella + oregano oil.

The fat content in BM was increased from 11.19 % in the control T1, to 12.50 % in T5, to 13.90 % in T6. It is noticeable that oregano oil has increased the fat content more than flaxseed oil. In CM, the fat content also increased from 9.77 % in T2 to 10.43% in T3, to 10.14 % in T4 showing statistically similar data. However, it did not exceed the fat level (25%) claimed by the Jordanian standard (1996). Guerra *et al.* (2011) claimed that the increase in the fat content has a positive impact on the stability of the emulsion-based meat product and may increase the thermal stability and the loss of liquid from the product; this is due to the availability of free radicals and molecules to connect with moisture and protein.

The protein content was significantly different among samples and was compatible with the Jordanian standards which state that the protein level in mortadella should be at a minimum of 12% (Jordanian Standard, 1996). The decrease in protein content was also found by Lee *et al.* (2015) and Lee & Kim (1986) who reported that the protein and moisture content in emulsion-type processed meat should be higher than those in processed meat with mixed vegetable oils.

The ash content did not largely differ between samples and was compatible with the Jordanian standards (1998). As for the collagen content, values increased after the addition of the oils which is desirable; because it increases the juiciness and improves the textural properties of low-fat meat products (Prestes *et al.*, 2014; Araújo *et al.*, 2019).

The salt content among all samples decreased and did not exceed the recommended value (3%) set by the Jordanian laws (2008).

pH:

The results obtained from measuring the pH over weeks are shown in Figures 1 and 2. It is clear that the addition of the oils has caused a decrease in the pH and this was also observed by Banerjee *et al.* (2012) and De Souto *et al.* (2021).

As shown in Figures 1 and 2, the pH behavior was not stable over the weeks. According to Lima *et al.* (2021), the decrease in pH could be due to an acidic formation and phenolic acids. Furthermore, Rason *et al.* (2007) interpreted the pH decrease due to the activity of lactic acid bacteria.

The increase in pH, as reported by Sindelar *et al.* (2007), may accelerate the curing-related reaction and could happen due to the high buffer ability of the products and the differences between the samples.

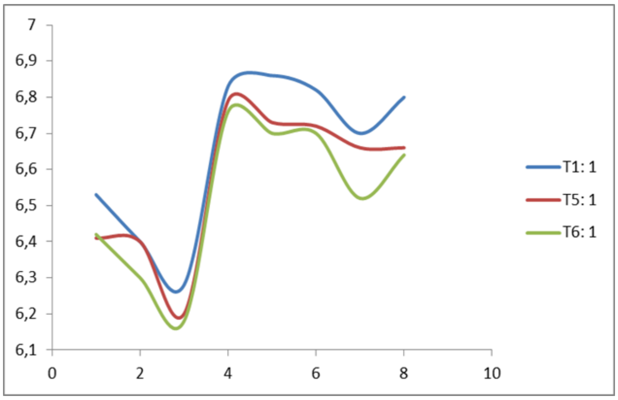

Figure 1: The pH changes in the three rolls of beef mortadella during>8 weeks of storage, T1 (control beef mortadella), T5 (beef mortadella containing flaxseed oil), and T6 (beef mortadella containing oregano oil).

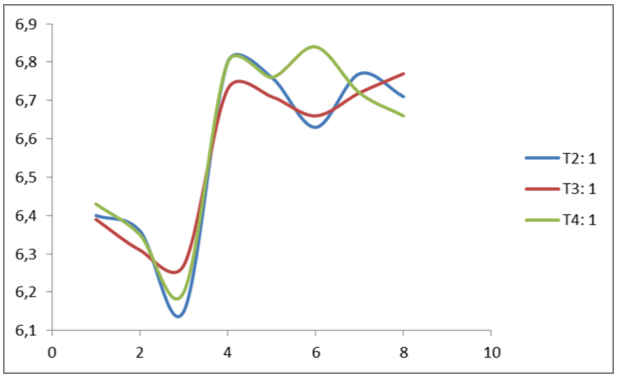

Figure 2: The pH changes in three rolls of chicken mortadella samples over 8 weeks of storage, T2 (chicken mortadella control), T3 (chicken mortadella containing flaxseed oil), and T4 (chicken mortadella containing oregano oil)

Thiobarbituric Acid Reactive Substances Values (TBARS):

The TBARS values measured from the twelve mortadella samples (6 rolls and 6 slices) are shown in Table 3. The significance was tested between the treatments themselves (letters on the left) and between the treatments and the weeks (letters on the right).

Table 3: Thiobarbituric acid reactive substances (TBARS) values* of the twelve mortadella samples over 7 weeks of Storage

	Storage week						
Treatment	**Week 1**	**Week 2**	**Week 3**	**Week4**	**Week 5**	**Week 6**	**Week 7**
T1 : 1	${}_{a}3.92^{b} \pm 0.47$	${}_{c}3.45^{d} \pm 0.09$	${}_{a}4.14^{b} \pm 0.11$	${}_{a}3.01^{c} \pm 0.42$	${}_{a}4.76^{d} \pm 0.09$	${}_{bc}6.84^{a} \pm 0.11$	${}_{b}7.06^{a} \pm 0.06$
T1 : 2	${}_{b}2.57^{d} \pm 0.05$	${}_{a}4.68^{c} \pm 0.19$	${}_{ab}6.16^{b} \pm 0.28$	${}_{a}2.01^{d} \pm 0.05$	${}_{c}6.79^{b} \pm 0.20$	${}_{bc}6.50^{b} \pm 0.24$	${}_{b}9.25^{a} \pm 0.13$
T2 : 1	${}_{d}2.27^{d} \pm 0.44$	${}_{c}2.60^{d} \pm 0.18$	${}_{a}4.11^{c} \pm 0.41$	${}_{bc}2.17^{d} \pm 0.17$	${}_{a}3.64^{d} \pm 0.68$	${}_{b}7.07^{a} \pm 0.14$	${}_{b}8.02^{b} \pm 0.53$
T2 : 2	${}_{a}2.81^{d} \pm 0.12$	${}_{b}4.31^{c} \pm 0.20$	${}_{b}4.62^{c} \pm 0.16$	${}_{c}1.45^{e} \pm 0.14$	${}_{b}8.52^{a} \pm 0.36$	${}_{a}7.34^{b} \pm 0.34$	${}_{b}9.25^{a} \pm 0.03$
T3 : 1	${}_{cd}2.79^{c} \pm 0.24$	${}_{b}3.14^{c} \pm 0.05$	${}_{c}4.02^{d} \pm 0.05$	${}_{bc}2.18^{d} \pm 0.01$	${}_{a}2.87^{d} \pm 0.04$	${}_{a}8.15^{a} \pm 0.81$	${}_{a}10.19^{b} \pm 0.16$
T3 : 2	${}_{a}2.81^{f} \pm 0.11$	${}_{d}3.33^{e} \pm 0.08$	${}_{ab}6.12^{d} \pm 0.14$	${}_{a}2.04^{g} \pm 0.01$	${}_{b}8.29^{b} \pm 0.08$	${}_{abc}6.7^{c} \pm 0.43$	${}_{a}11.13^{a} \pm 0.52$
T4 : 1	${}_{bc}3.07^{cd} \pm 0.73$	${}_{b}3.16^{cd} \pm 0.52$	${}_{b}3.35^{c} \pm 0.07$	${}_{b}2.41^{d} \pm 0.03$	${}_{b}2.82^{e} \pm 0.02$	${}_{bc}7.06^{b} \pm 0.19$	${}_{a}8.22^{a} \pm 0.05$
T4 : 2	${}_{c}2.15^{e} \pm 0.06$	${}_{c}3.93^{d} \pm 0.12$	${}_{a}5.97^{bc} \pm 0.08$	${}_{b}1.71^{e} \pm 0.14$	${}_{b}8.43^{b} \pm 0.37$	${}_{c}6.20^{c} \pm 0.56$	${}_{ab}10.90^{a} \pm 0.44$
T5 : 1	${}_{ab}3.60^{b} \pm 0.23$	${}_{a}4.17^{b} \pm 0.22$	${}_{a}4.14^{b} \pm 0.27$	${}_{c}2.94^{c} \pm 0.08$	${}_{b}5.02^{c} \pm 0.08$	${}_{c}6.57^{a} \pm 0.67$	${}_{ab}7.26^{a} \pm 0.58$
T5 : 2	${}_{b}2.54^{f} \pm 0.09$	${}_{c}3.95^{e} \pm 0.23$	${}_{b}4.83^{d} \pm 0.05$	${}_{d}1.27^{g} \pm 0.05$	${}_{a}11.50^{b} \pm 0.25$	${}_{abc}6.72^{c} \pm 0.27$	${}_{a}12.41^{a} \pm 0.30$
T6 : 1	${}_{cd}2.53^{d} \pm 0.18$	${}_{a}3.98^{c} \pm 0.15$	${}_{c}4.34^{d} \pm 0.17$	${}_{b}2.32^{d} \pm 0.06$	${}_{a}4.70^{e} \pm 0.03$	${}_{c}6.45^{b} \pm 0.74$	${}_{b}7.01^{a} \pm 0.28$
T6 : 2	${}_{c}2.26^{e} \pm 0.02$	${}_{e}3.65^{e} \pm 0.11$	${}_{ab}5.29^{d} \pm 0.05$	${}_{a}2.13^{e} \pm 0.01$	${}_{b}9.23^{b} \pm 0.78$	${}_{ab}7.04^{c} \pm 0.25$	${}_{a}11.3^{a} \pm 0.29$

*Each value is a mean of 3 readings ± SD.
Levels not connected by the same letter are significantly different ($p<0.05$).
T1: Control of beef mortadella; T2: Control of chicken mortadella; T3: Chicken mortadella + flaxseed oil; T4: Chicken mortadella + oregano oil; T5: Beef mortadella + flaxseed oil; T6: Beef mortadella + oregano oil.

The TBARS levels ranged from 2.15 to 3.92mg malonaldehyde/kg of the sample in the first week of analysis, which is the fourth week after production. These findings are in agreement with Kalaitsidis *et al*. (2021) and De Oliveira *et al*. (2012) who revealed that the decreased value of TBA in samples fortified with oregano oil was because it contains carvacrol, whereas TBA values in samples fortified with flaxseed oil increased, and this could be because flaxseed oil does not contain a natural antioxidant (Lima *et al*., 2021). Furthermore, the decrease in TBA values during long storage was also explained by the decomposition of malonaldehyde according to Lima *et al.* (2021) and Maqsood *et al*. (2012).

The TBARS values were higher than the recommended value (1–2 mg/kg) by Gadekar *et al*. (2014). This could be because the oxidation started during the processing and manufacturing of mortadella. The slices showed greater values than rolls, and this may explain why they expire faster.

Cholesterol Content Determination:

The results of cholesterol content obtained from the six mortadella samples are shown in Table 4. According to the USDA, the cholesterol content in BM and CM should not exceed 56 and 53.57 mg/100g, respectively. Our results are still within the recommended values except for the CM fortified with flaxseed oil (i.e., T3), in this regard, Teolis (2019) and Dinh *et al.* (2011) claimed that the recommended value of the cholesterol content in CM could achieve 70mg/100g, because the cholesterol content in chicken cannot be the same depending on many factors.

Table 4: Cholesterol content in the six mortadella samples

Treatments	T1	T2	T3	T4	T5	T6
Cholesterol (mg/100g)	21.5^{d} ±0.01	16^{e} ±0.01	55^{a} ±0.01	17.5^{d} ±0.01	52^{b} ±0.02	41.5^{c}±0.01

*Each value is a mean of 3 readings ± SD.
Levels not connected by same letter are significantly different (p<0.05). T1: Control of beef mortadella; T2: Control of chicken mortadella; T3: Chicken mortadella + flaxseed oil; T4: Chicken mortadella + oregano oil; T5: Beef mortadella + flaxseed oil; T6: Beef mortadella + oregano oil.

In this study, the cholesterol content was found to be increased in the experimental samples. Lim (2021), Unhapipatpong *et al.* (2021) and Saldaña *et al*. (2015) explained this by the richness of some vegetable oils in saturated fats.

Fatty Acid Profile:

The fatty acid profile of the six mortadella samples, in addition to oregano and flaxseed oils, are shown in Table 5. The fatty acid composition was not significantly different among the samples. Myristic acid (C14:0) content was found to be decreased after the addition of the oils. This cannot be preferable since Carneiro *et al.* (2021) revealed that this fatty acid is attributed to the increased LDL in blood serum that is responsible for hypercholesterolemia; which causes cardiovascular disease, sequelae, and arteriosclerosis.

Palmitic acid was decreased and was found to be the most abundant SFA among all mortadella samples. This finding was confirmed by Parunović *et al*. (2013) and Romero *et al*. (2013). The sums of SFAs were found to be decreased to be closer to the recommended value by the USDA (30.6%) as reported by De Almeida *et al*. (2015). These results, which are in agreement with Carneiro *et al.* (2021), Osuna *et al.* (2018), De Souto *et al*. (2021) and Singh *et al*. (2011), should be convenient since developing products with low SFAs content is one of the aims of the food industry technologists.

Palmitoleic fatty acid (C16:1) content was found to be decreased and this goes in agreement with Carneiro *et al*. (2021) who claimed that this fatty acid plays a major role in lipid metabolism, balances the HDL (good cholesterol) and LDL (bad cholesterol; reduce sugar levels in the blood and prevent the accumulation of fatty tissue that surrounds liver and heart).

Oleic fatty acid (C18:1) content was decreased, although it was the predominant MUFA as similarly reported by Romero *et al*. (2013), Singh *et al*. (2011), and Carneiro *et al.* (2021) who also revealed that this fatty acid could reduce the cholesterol level in blood.

The sums of MUFAs decreased to a small extent and these findings were also in agreement with Carneiro *et al.* (2021), Osuna *et al.* (2018), Parunović *et al.* (2013), and Singh *et al*. (2011). According to Lucas-González *et al.* (2020), the decrease in MUFAs content might be related to the decrease in oleic fatty acid. However, the sums of PUFAs were found to be increased after the addition of the oils and this was also confirmed by Carneiroet *et al*. (2021) and Osuna *et al*. (2018).

The $\Sigma\omega6/\Sigma\omega3$ ratio should not be lower than 4 as mentioned by Carneiro *et al.* (2021). The obtained unbalanced $\Sigma\omega6/\Sigma\omega3$ ratios could be, as explained by Simopoulos (2010), due to the high levels of omega-6 in mortadella products as compared to the omega-3 fatty acid content. The index of atherogenicity (IA) and the index of thrombogenicity (IT) were found to be decreased after the addition of the oils and this was in accordance with the findings of Saldaña *et al.* (2018),

The PUFA/Sat. ratio, which could be used for the evaluation of the lipid fraction in food samples as claimed by Saldaña *et al*. (2015), was expectedly found to be increased. This was in agreement with Osuna *et al.* (2018), Lucas-González *et al.* (2020), and Saldaña *et al*. (2018).

Table 5: Fatty acid profile* of the six mortadella treatments (chicken and beef) incorporated with flaxseed and oregano essential oils, both in rolls and slices, during a twenty-four-week storage period, in addition to the fatty acid composition of flaxseed and oregano essential oils.

	Treatments						**Essential oil**	
Fatty acid	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**Flaxseed**	**Oregano**
C14:0 (Myristic)	0.75^a ±0.02	0.76^a ± 0.02	0.71^a ± 0.02	0.70^a ±0.02	0.66^a ±0.02	0.65^a ±0.02	4.85^a ±0.12	0.03^a
C16:0 (Palmetic)	24.91^a ±0.62	25.20^a ±0.63	23.82^a ±0.60	24.14^a	22.64^a ±0.57	23.44^a ±0.59	0^a ±0	8.95^a ±0.22
C17:0	0.33^a ±0.008	0.11^a ±0.003	0.24^a ±0.006	0.10^a	0.10^a ±0.003	0.10^a ±0.002	0^a ±0	0^a ±0
C18:0 (Stearic)	6.99^a ± 0.17	7.03^a ± 0.18	7.31^a ± 0.18	6.81^a ± 0.17	6.72^a ± 0.17	6.52^a ± 0.16	4.09^a ± 0.1	5.76^a ± 0.14
C20:0 (Arachidic)	0.25^a±0.006	0.26^a ±0.007	0.22^a ±0.006	0.26^a	0.23^a ±0.006	0.24^a ±0.006	0.15^a ±0.004	0^a ±0
C22:0 (Behenic)	0.10^a ±0.003	0.18^a ±0.004	0.05^a ±0.001	0.24^a	0.14^a ±0.004	0.17^a ±0.004	0.02^a ±0.001	0^a ±0
C24:0 (Lignoceric)	0.17^a ±0.004	0.15^a ±0.004	0.32^a ±0.008	0.28^a	0.18^a ±0.004	0.23^a ±0.006	0.19^a ±0.005	0^a ±0
Σ SFA	33.51^a ±0.84	33.69^a ±0.84	32.68^a ±0.82	32.55^a ±	30.66^a ± 0.77	31.35^a ± 0.78	9.23^a ± 0.23	14.74^a ± 0.37
C16 :1	4.21^a ± 0.11	4.20^a ± 0.10	4.05^a ± 0.10	4.08^a ±0.10	4.17^a ±0.10	4.05^a ±0.10	0^a ±0	0.52^a ±0.01
C17 :1	0.11^a ±0.003	0.29^a ±0.007	0.28^a ±0.007	0.39^a ±0.01	0.32^a ±0.008	0.33^a ±0.008	0^a ±0	0^a ±0
C18 :1 (Oleic)	39.89^a ±1	40.05^a	39.91^a ±1	39.53^a	40.11^a ±1.003	38.77^a ±0.97	19.85^a ±0.50	43.5^a ±1.09
C20 :1	0.14^a ±0.004	0.14^a ±0.004	0.06^a ±0.001	0.16^a	0.16^a ±0.004	0.15^a ±0.004	0^a ±0	0^a ±0
ΣMUFA	44.36^a ±1.11	44.68^a ± 1.12	44.29^a ± 1.11	44.15^a ±	44.75^a ± 1.12	43.30^a ± 1.08	19.85^a ±	44.02^a ± 1.10
C18 :2 (Linoleic)	18.30^a ± 0.46	17.71^a ±0.44	18.45^a ±0.46	19.30^a	20.32^a ±0.51	21.13^a ±0.53	15.13^a ±0.38	39.9^a ±1
C18 :3 (Linolenic)	1.02^a ±0.03	1.07^a ±0.03	1.28^a ±0.03	1.15^a ±0.03	1.23^a ±0.03	1.40^a ±0.04	53.71^a ±1.34	1.27^a ±0.03
ΣPUFA	19.33^a ±0.48	18.78^a ±0.47	19.73^a ±0.49	20.45^a	21.55^a ±0.54	22.53^a ±0.56	68.84^a ±1.72	41.17^a ±1.03
ΣTrans	0.49^a ± 0.01	0.81^a ± 0.02	0.92^a ± 0.02	0.54^a ± 0.01	0.60^a ± 0.01	0.60^a ± 0.02	1.89^a ± 0.05	0^a ± 0
ΣOther	2.32^a ±0.06	2.04^a ±0.05	2.37^a ±0.06	2.30^a ±0.06	2.45^a ±0.06	2.22^a ±0.06	0.12^a ±0.003	0.07^a ±0.002
ω_6	18.30	17.71	18.45	19.30	20.32	21.13	15.13	39.9
Σ ω_6	18.30^a ±0.46	17.71^a ±0.44	18.45^a ±0.46	19.30^a	20.32^a ±0.51	21.13^a ±0.53	15.13^a ±0.38	39.9^a ±1
ω_3	1.02	1.07	1.28	1.15	1.23	1.40	53.71	1.27
Σ ω_3	1.02^a ±0.03	1.07^a ±0.03	1.28^a ±0.03	1.15^a ±0.03	1.23^a ±0.03	1.40^a ±0.04	53.71^a ±1.34	1.27^a ±0.03
$\Sigma\omega_6/\Sigma\omega_3$	17.89^a ±0.45	16.59^a ±0.41	14.42^a ±0.36	16.75^a	16.56^a ±0.41	15.08^a ±0.38	0.28^a ±0.007	31.41^a ±0.79
I.A	0.55^a ±0.01	0.56^a ±0.01	0.53^a ±0.01	0.52^a ±0.01	0.48^a ±0.01	0.49^a ±0.01	0.26^a ±0.007	0.17^a ±0.004
I.T	1.04^a ±0.03	1.05^a ±0.03	1.01^a ± 0.03	0.99^a ± 0.03	0.92^a ± 0.03	0.94^a ± 0.03	0.32^a ± 0.01	0.35^a ± 0.01
PUFA/Sat.	0.58^a± 0.05	0.56^a± 0.05	0.60$^{a\,\pm}$0.05	0.63$^{a\,\pm}$0.05	0.70^a ± 0.05	0.72^a± 0	7.46^a ± 0.08	2.79^a ± 0.04

*Each value is a mean of 3 readings ± SD. Levels not connected by same letter(s) are significantly different. **T1**: Control of beef mortadella; **T2**: Control of chicken mortadella; **T3**: Chicken mortadella + flaxseed oil; **T4**: Chicken mortadella + oregano oil; **T5**: Beef mortadella + flaxseed oil; **T6**: Beef mortadella + oregano oil.

Physical Analysis:

Color Determination (L*, a*, b* values):

The results obtained from the color measurements of the six rolls of mortadella samples in which the L*, a*, and b* values were noted are presented in Table 6, where the significance was studied between treatments.

Table 6: Mean values for color parameters L*, a*, and b* of the six rolls of chicken and beef mortadella samples, prepared with the inclusion of flaxseed and oregano essential oils.

Treatments	Color component		
	L*	a*	b*
T1 : 1	48.85^{bc}±	17.75^{a}± 0.34	14.05^{a}± 0.87
T2 : 1	49.02^{bc}±	13.32^{c}± 0.17	13.83^{a}± 0.03
T3 : 1	50.80^{ab}±	13.42^{c}± 0.08	13.64^{a}± 0.08
T4 : 1	52.60^{a}± 0.08	13.58^{c}± 0.05	13.97^{a}± 0.01
T5 : 1	47.11^{c}± 0.09	16.67^{b}± 0.09	13.49^{a}± 0.03
T6 : 1	53.06^{a}± 1.87	16.87^{b}± 0.72	13.90^{a}± 0.63

*Values are means of triplicate determinations ±SD.
* Levels not connected by the same letter(s) are significantly different.
T1: Control of beef mortadella, **T2**: Control of chicken mortadella, **T3**: Chicken mortadella + flaxseed oil, **T4**: Chicken mortadella + oregano oil, **T5**: Beef mortadella + flaxseed oil, **T6**: Beef mortadella + oregano oil

The addition of oils has affected the color parameters in different ways, where oregano oil has increased the lightness L^* of both BM and CM, and flaxseed oil has decreased the L^* of BM and increased the L^* of CM. The addition of both oils decreased the redness a* in BM but not in CM and did not affect the yellowness b* of both BM and CM. This is in agreement with De Oliveira et al. (2012) and Lim et al. (2021) who reported that the fading of the cured color could be because of the interaction between nitrate and some compounds found in these oils, as it could also be related to the TBARS values.

Microbiological Analysis:

Determination of coliforms in rolls and slices of beef and chicken mortadella:

The results of the total coliforms obtained from the three rolls of BM over the weeks are shown in Figure 3, and those obtained from the three rolls of CM in Figure 4. The addition of the oils has decreased the microbial load in both BM and CM, however, it was noticeable that the load in mortadella fortified with oregano oil was reduced to a higher degree than those fortified with flaxseed oil. This means that oregano oil has shown higher antimicrobial activity than flaxseed oil and this might be, as Lacroix explained because oregano oil is rich in phenolic compounds (Gutiérrez-Grijalva *et al*., 2017), whereas flaxseed oil is rich of terpenoids (Styrczewska *et al*., 2012).

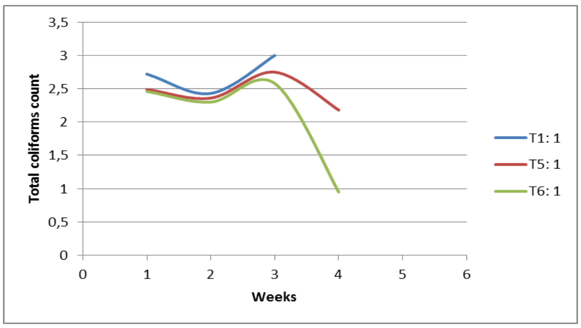

Figure 3: Total coliforms count in the developed beef mortadella samples; T1:1 (beef control mortadella), T5:1 (beef mortadella containing flaxseed oil), and T6:1 (beef mortadella containing oregano oil).

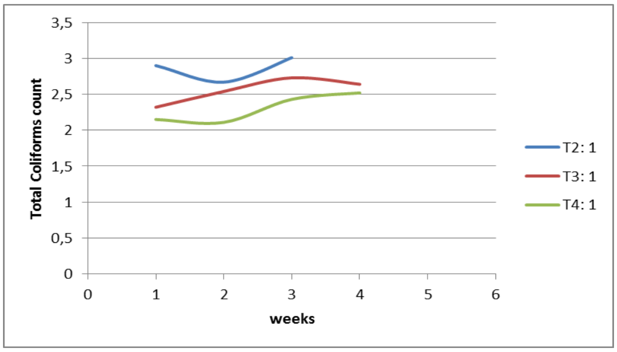

Figure 4: Total coliforms in the developed chicken mortadella samples; T2:1 (chicken control mortadella), T3:1 (chicken mortadella containing flaxseed oil), and T4:1 (chicken mortadella fortified with oregano oil).

Friedrich *et al*. (2008) and Burt (2004) claimed that the decrease in coliform count could be associated with the decrease in pH. Ockerman & Basu (2010) also reported that the ingredients added to the sausages (such as garlic, spices, sodium lactate, potassium sorbate, and the combination of lactate and NaCl) could affect microbial growth.

Aerobic plate count (APC):

The results of the enumeration of the aerobic bacteria obtained from the three rolls of BM over 24 weeks of storage are shown in Figure 5, and those obtained from the three rolls of CM in Figure 6. The bacterial load was low at the first weeks, and then it was increased to range from 0.95 to 3.5 log CFU/g for BM, and from 0 to 3.26 log CFU/g for CM. Similar results were found by Ahmad and Srivastava (2006) and Friedrich *et al*. (2008) who reported that the critical limit of APC was 5 log CFU/g.

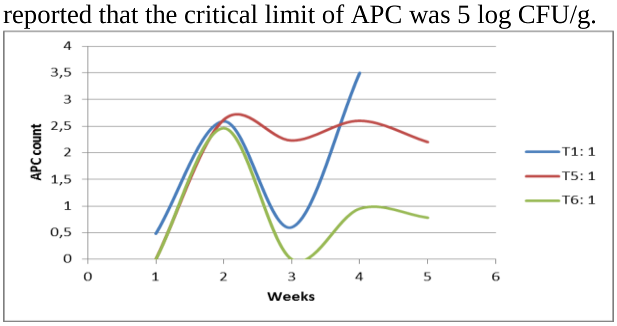

Figure 5: Aerobic plate count in the three beef mortadella samples; T1:1 (beef control mortadella), T5:1 (beef mortadella containing flaxseed oil), and T6:1 (beef mortadella containing oregano oil).

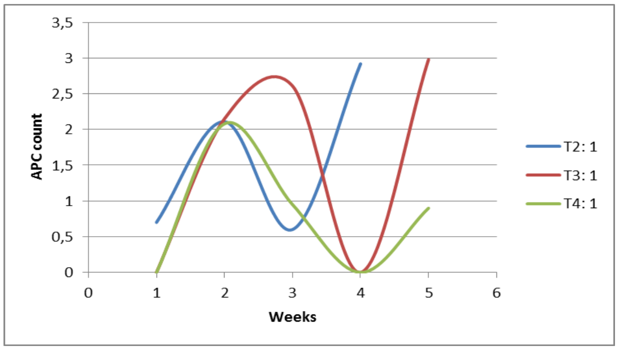

Figure 6: Aerobic plate count in the three chicken mortadella samples; T2:1 (chicken control mortadella), T3:1 (chicken mortadella containing flaxseed oil), and T4:1 (chicken mortadella containing oregano oil).

Lactic Acid Bacteria:

The results of the enumeration of lactic acid bacteria obtained from the three rolls of BM over six months of storage are shown in Figure 7, and those obtained from the three rolls of CM in Figure 8. The flaxseed oil showed an increased load of lactic acid bacteria when compared to the two other samples, this growth enhancement of bacteria can be explained by the low dose of flaxseed oil as was found by Zhou *et al*. (2019).

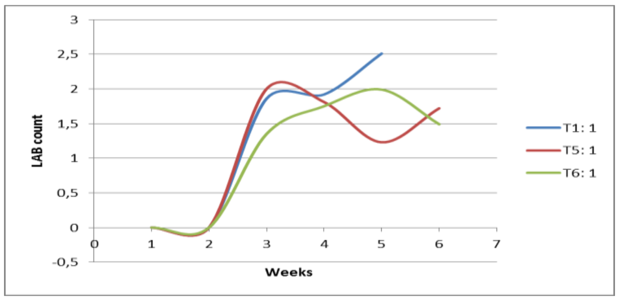

Figure 7: Lactic acid bacteria in three beef mortadella samples; T1:1 (beef control mortadella), T5:1 (beef mortadella containing flaxseed oil), T6:1 (beef mortadella containing oregano oil).

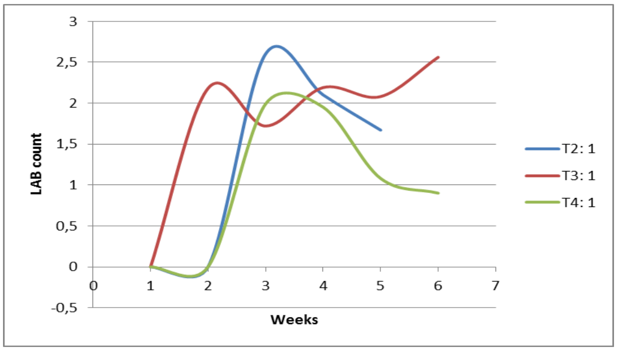

Figure 8: Lactic acid bacteria in three chicken mortadella samples; T2:1 (chicken control mortadella), T3:1 (chicken mortadella containing flaxseed oil), T4:1 in (chicken mortadella containing oregano oil).

In our study, lactic acid bacteria were absent during the first weeks. This could be because of the added ingredients into mortadella (such as spices, garlic, and potassium sorbate) that might have increased the lag phase of this bacteria (Ockerman & Basu, 2010).

Sensory Evaluation:

The results of the sensory evaluation are shown in Figure 9. Data showed that the preferences among samples differed from one parameter to another. Although there were no significant differences in texture, sliceability, appearance and color.

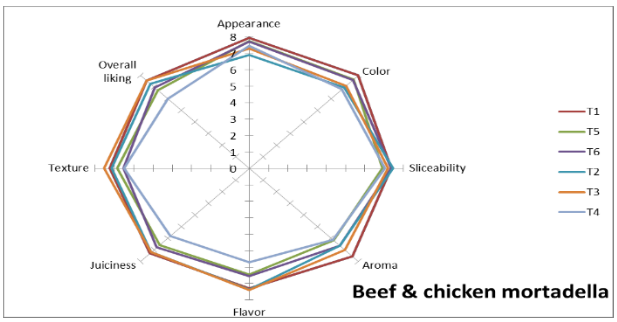

Figure 9: The sensory evaluation scores of the six mortadella samples; T1 (beef control mortadella), T2 (chicken control mortadella), T3 (chicken mortadella containing flaxseed oil), T4 (chicken mortadella containing oregano oil) T5 (beef mortadella containing flaxseed oil), T6 (beef mortadella containing oregano oil).

Most scores of the sensory parameters have ranged from 5.7 to 8.0, i.e., from “like slightly” to “like very much”. This means that the addition of the oils did not affect the acceptability of both BM and CM. The panelists liked the developed products and did not give any negative comments on them. A similar finding was reported by Manuel *et al*. (2011), Carneiro *et al*. (2021), Osuna *et al*. (2018), and Kavuşan *et al*. (2020).

Results also showed that the sensory parameters of the samples in both beef and chicken were affected by the addition of the oils in which oregano oil improved the color, appearance, and sliceability of mortadella, and flaxseed oil mostly improved the flavor, texture, juiciness and overall liking of mortadella samples. Our findings are in agreement with Choi *et al*. (2010), Lee *et al.* (2015), Alejandre *et al*. (2016), and Berasategi *et al*. (2013).

Conclusion:

The incorporation of both flaxseed and oregano oils has slightly increased the cholesterol levels in the formulated samples but did not exceed the recommended value. In this regard, further research should be conducted using a mixture of oils that could decrease the LDL level, such as corn oil. The oxidation value tends to be high even before oils were added, therefore it is suggested that an antioxidant should be further added. The developed samples showed a healthier lipid status which includes an increase in PUFAs, and a decrease in SFAs, IA, and IT and $\Sigma\omega6/\Sigma\omega3$ ratio. This indicates that the developed products are healthier than the control. In addition to that, both CM and BM were microbiologically safe and organoleptically acceptable.

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تطوير مرتديلا دجاج ولحم بقري صحية وظيفية مدعمة بالأحماض الدهنية المتعددة غير المشبعة وتقييم خصائصها الكيميائية والميكروبيولوجية والحسية

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ملخص

هدفت الدراسة إلى تقييم الخواص الكيميائية، الفيزيائية والميكروبية لمرتديلا اللحم (م.ل) و الدجاج (م.د) وذلك من أجل تحديد أثر زيت بذور الكتان و زيت الزعتر على عينات المرتديلا بعد مقارنتها مع المرتديلا العادية. اثنتا عشرة عينة من المرتديلا (6 لفات و6 شرائح) ناتجين عن ستة معالجات خضعوا الى التحليل: ت1 (م.ل عينة ضابطة)، ت2 (م.د عينة ضابطة)، ت3 (م.د تحتوي زيت بذور الكتان)، ت4 (م.د تحتوي زيت الزعتر)، ت5 (م.ل تحتوي زيت بذور الكتان)، ت6 (م.ل تحتوي زيت الزعتر). النتائج المأخوذة خلال ستة أشهر من التخزين كانت مختلفة احصائياً ما عدا نتائج الأحماض الدهنية. نتائج التحليل الكيميائي: الرطوبة كانت حوالي65 ٪، الدهن تراوح ما بين 12.19 إلى 13.90٪ في م.ل و من 9.77 إلى 10.43٪ في م.د، البروتين كان حوالي 14٪، الكوليسترول تراوح ما بين 21.5 إلى 52 ملغ/100غ في م.ل و من 16 إلى 55 ملغ/100 غ في م.د، الرماد كان حوالي 3٪، الكولاجين كان حوالي 1.68٪، الملح كان حوالي 2٪ و الرقم الهدروجيني السالب (ph) كان حوالي 6.50. زيت الزعتر زاد من قيمة ل* في كل من م.ل و م.د، انخفضت قيم كل من أ* و ب* عند اضافة الزيوت. تمت ملاحظة الخصائص المضادة للميكروبات لكل من الزيوت (تقريبا بنسبة reduction 1 log CFU/g). أشارت نتائج التقييم الحسي إلى أن كلاً من م.ل و م.د كانا مقبولين مع عدم وجود فروق معنوية إحصائية في القوام وقابلية التقطيع والمظهر واللون.

الكلمات الدالة: قيم الأحماض الدهنية، الدهون، الكوليسترول، الخواص المضادة للميكروبات