

Enhancement of Chemical, Nutritional, and Quality of Low-Fat Mortadella Made from Mechanically Deboned and Whole Chicken Muscle with the Addition of Flaxseed and Thyme Oils

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ABSTRACT

This study aims to compare low-fat chicken mortadella made with whole chicken muscle (WCM) and mechanically deboned chicken meat (MDCM) that were enriched with flaxseed oil and thyme oil. Four mortadella types were manufactured: 100% WCM (T1), 100% MDCM (T2), 100% WCM + 2% flaxseed oil + 0.15% thyme oil (T3), and 100% MDCM + 2% flaxseed oil + 0.15% thyme oil (T4). Mortadella samples were investigated for proximate composition, thiobarbituric acid (TBA) value, pH, fatty acid profile, color, sensory evaluation, and analysis of variance (ANOVA) using the least significant differences at the 5% level of probability. Proximate composition was affected by the type of chicken meat (WCM vs. MDCM). TBA values of the added oils samples were lower than the control samples. pH values of WCM mortadella were lower ($p \leq 0.05$) in comparison with those of MDCM, where the oils did not affect pH during the storage period. The incorporation of oils raised the total polyunsaturated fatty acids (PUFA) and lowered the total saturated fatty acids (SFA). MDCM samples had significantly higher redness intensity than WCM samples, additionally, storage and oils added did not affect the color. Sensory results showed that juiciness, texture, and overall liking scores were significantly different.

Keywords: Chicken mortadella, Flaxseed oil, Thyme oil, Chemical composition, Lipid oxidation, Fatty acids, Nutritional Status.

INTRODUCTION

Meat and meat products are considered primary food products in the human diet, supplying multiple essential nutrients such as amino acids, fat, vitamins, and minerals (Saldaña et al., 2018). Mortadella is an emulsified meat product that is popular, highly consumed, and has a

substantial market for the sector industries with a fat content of up to 30% (Trindade et al., 2011; Saldaña et al., 2018). Many factors could influence its consumption, namely the product's sensory and nutritional properties, safety, and convenience (Trindade et al., 2011). A meat emulsion from one or more animal species is used to make this product (Cenci et al., 2018).

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Poultry meat is the principal driver of overall meat production growth in response to increasing worldwide demand, as has the production of mechanically deboned chicken meat (MDCM), which is commonly utilized in meat products (Monsalve-Atencio et al., 2021). Mechanically deboned meat is defined as a product obtained by mechanically separating muscle from the bone where whole poultry carcasses, sections of carcasses, and in particular residual flesh left on the bones following hand deboning processes can all be deboned with this method (Abdullah & Al-Najdawi, 2005). The lipid composition of the resulting meat is affected by mechanical deboning, which typically has high lipid content in comparison with hand-deboned meat. These lipids primarily come from bone marrow and bone tissue (Trindade et al., 2004). Because of its high lipid content, MDCM is very suitable for oxidation (Reitznerová et al., 2017).

However, excessive fat consumption has adverse health effects, which include obesity and an increased risk of cardiovascular disease (Auriema et al., 2019). Consumer purchase decisions are influenced by convenience, health aspects, and a preference for low-fat, and reduced-calorie meat products (Auriema et al., 2019). Their focus is now shifting toward the development of functional foods, and one strategy for doing so is to incorporate functional ingredients during the processing of meat (Ahlawat et al., 2019). Saturated fatty acids (SFA) can be replaced with polyunsaturated fatty acids (PUFA), notably omega-3 (n-3) fatty acids, to improve the nutritional profile of meat products (Bolger et al., 2017). Plant oils, such as flaxseed oil, can be used as a source of n-3 fatty acids since they are less prone to lipid oxidation, including endogenous antioxidants, and contain less long-chain PUFA (Josquin et al., 2012). Nevertheless, despite the presence of these endogenous antioxidants, lipid oxidation still occurs (Bolger et al., 2017).

Exogenous antioxidants, both synthetic (e.g. BHA and BHT), and natural such as green tea catechins and vitamin E, have been utilized to prevent lipid oxidation in meat products with high levels of n-3 fatty acids (Ansorena & Astiasarán, 2004; Valencia et al., 2008; Bolger et al.,

2017). Thyme oil is an antioxidant natural ingredient that is effective in extending shelf life and improving the sensory quality of meat and meat products (Miura & Nakatani, 1989; Jayasena & Jo, 2014).

The objective of this study was to formulate low-fat mortadella using both whole chicken muscle (WCM) and MDCM to investigate the effect of flaxseed and thyme essential oils (EOs) on the quality of WCM and on the improvement capacity of some inferior properties of the MDCM without affecting the sensorial acceptability.

Material and Methods:

Chicken Mortadella Preparation:

Four treatments of chicken mortadella were prepared at a local meat factory as described by Abdullah (2004). Flaxseed oil and thyme oil were purchased from a local market. The composition of the prepared chicken mortadella is shown in Table 1. In this study, whole chicken muscle (WCM) and mechanically deboned chicken meat (MDCM) was used to produce four chicken mortadella treatments which are detailed in Table 2.

Table 1: Ingredients used for the batter preparation of chicken mortadella.

Ingredients	Quantity (kg)
Chicken Meat (WCM or MDCM)	20
Starch	0.6
Soy protein	0.4
Sodium chloride	0.3
Ice-water	2
Spices	0.2
Sodium tripolyphosphate	0.01
Ascorbate	0.01

WCM: whole chicken muscle, MDCM: mechanically deboned chicken meat

Table 2: Composition of the prepared chicken mortadella treatments.

Composition (%)	Treatments			
	T1	T2	T3	T4
WCM	100	-	100	-
MDCM	-	100	-	100
Flaxseed oil	-	-	2	2
Thyme oil	-	-	0.15	0.15

WCM: whole chicken muscle, MDCM: mechanically deboned chicken meat

T1: whole chicken muscle (WCM) mortadella (control 1); **T2:** mechanically deboned chicken meat (MDCM) mortadella (control 2); **T3:** WCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%); **T4:** MDCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%).

A total of 20 kg of chicken meat was used for all four treatments. The chicken meat was coarsely ground, chopped, and blended in two stages: first, ground meat was blended in a bowl chopper (Alpina, Geneva, Switzerland) at low speed for 2 minutes at a temperature of 0 °C. Sodium chloride (salt), ascorbate, sodium tripolyphosphate, and ice water were added and blended for 2 minutes at high speed (at this stage, the temperature of the mixture reached -2 °C). Afterward, starch, soya, and spices were added, and in the case of T3 and T4, 40 ml of flaxseed oil at 2g/100g according to Bolger et al. (2017), and 50 ml of thyme oil (0.15%) was added to the mixture which was blended for 3 minutes at low speed. After which, the temperature of the final meat blend was 8°C. The batter immediately after chopping was loaded onto a trolley, transferred to the filling machine, and loaded into the funnel of the machine where it was vacuum stuffed into the polythene casing. After stuffing, the casing was closed and sealed with a metal clip. Mortadella batches were thermally cooked in a steam oven at 60°C for 2h (internal product temperature 50°C), then the temperature increased to 85°C for 1h. The temperature of mortadella was decreased to 55°C by cold water spray for 30 minutes then left at room temperature for 2h before storing it at 4°C in the refrigerator.

Proximate Analysis:

Protein, fat, moisture, ash, and salt contents were determined using the InfraLab NIR meat analyzer (LIMAB UK Ltd). The InfraLab NIR Meat Analyzer works by pulsing light at a different known wavelength, the NIR Fat analyzer compares the absorption rate to an internal reference, thus, making it possible to determine exactly by how much each wavelength is being absorbed. Using high-speed signal processing, the algorithm converts the infrared signals into an output that is proportional to the chemical content using a calibration curve. The measurement is unaffected by changes in process conditions such as particle size, temperature, ambient lighting, and humidity changes.

Fatty Acid Profile:

Crude fat was obtained according to the AOAC (2000) Soxhlet method. Fatty acid methyl esters (FAMES) were produced by EC Regulation no. 2568/91. Fatty acid profiles were measured by capillary GLC column (Restek, Rtx-225, USA, cross bond 50%-cyanopropylmethyl 50%-phenylmethylpolysiloxane, 60m × 0.25mm/D × 0.25µm df) immediately after esterification by injection of 1.00 µl of the hexane layer through the injection port of the GLC (model GC-2010, Shimadzu. Inc., Koyoto, Japan). The FAMES were injected after adjusting the GLC conditions. The initial oven temperature was 165°C, held for 4 minutes, increased at a rate of 2°C/min to 180°C, increased at a rate of 5°C/min to 230°C, and then held for 6 minutes, for a total program time of 36 minutes. The injector temperature was 250°C, the FID temperature was 260°C, the flow rate was 1 ml/min Helium, and the split ratio used was 80. The FAMES were identified using a chromatogram of fatty acids standard. The results were expressed as a percentage of the total fatty acids. The data from the fatty acid composition analysis were used to determine the index of atherogenicity and thrombogenicity using the following calculations:

Ulbricht & Southgate (1991) proposed a new index called the index of atherogenicity (IA) indicating the

relationship between the sum of the major saturated fatty acids and the major unsaturated fatty acid classes (Ghaeni

$$IA = [(C16:0 + (4 \times C14:0) + C18:0)] / (\Sigma MUFA + \Sigma \omega 6 + \Sigma \omega 3)$$

et al., 2013). It follows as:

The index of thrombogenicity (IT) was developed with IA by Ulbricht & Southgate (1991) which demonstrates a proclivity to form clots in blood vessels. IT is defined as the relationship between pro-thrombogenic (SFA) and anti-thrombogenic (MUFAs and PUFA) fatty acids (Ghaeni et al., 2013). The following formula was used:

$$IT = (C14:0 + C16:0 + C18:0) / [(0.5 \times \Sigma MUFA) + (0.5 \times \omega 6 + (3 + (\Sigma \omega 3 / \Sigma \omega 6))]$$

Thiobarbituric Acid Reactive Substances Values (TBARS):

The extent of lipid oxidation was determined by using the TBARS method according to Faustman et al. (1992). Measurements of lipid oxidation were made during 20 weeks of refrigerated storage (4°C). Triplicates from each treatment were taken for analysis. Sample absorbance was measured at 532 nm using a Spectrophotometer (Spectro, 2000 spectrophotometer LaboMed, inc). The TBARS number was expressed as milligrams of malondialdehyde (MDA) per kilogram of the sample using a conversion factor of 7.8 (Cheah & Hasim, 2000) and was calculated using the following formula:

$$TBA_{value} = Abs(532) \times 7.8$$

Determination of pH:

The pH of mortadella samples was determined by blending 10 g of the sample with the distilled water (90 ml), and homogenized with a stomacher for 30 seconds. The homogenate pH was measured by using a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland). All determinations were performed in duplicate runs throughout storage time for up to 20 weeks.

Color Measurement:

The surface color of mortadella samples was measured using a colorimeter Hunter Lab ColourFlex (Chroma Meter, CR-400, Konica Minolta, Sensing, INC., Japan) for 11 weeks. The hunter values of L*, a*, and b* correspond to lightness, redness, and yellowness, respectively. Color measurements were made after the production of mortadella and then after three months of storage. The value for each of these parameters was calculated as the average of two measurements on each sample in different areas of the surface of the sample at room temperature (Maskan, 2001).

Sensory Evaluation:

Sensory evaluation was conducted by 30 non-trained panelists from the teaching staff, graduate students, Ph.D. students, and technicians of the Department of Nutrition and Food Technology at the University of Jordan. The panelists were from both sexes and of different ages. The samples of all treatments were sliced, placed on plastic plates, and served to panelists who evaluated desirability for appearance, flavor, juiciness, texture, and overall liking using a 9-point hedonic scale as described by Larmond (1991). Each sample was coded with a randomly selected three-digit number.

Statistical Analysis:

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 differences (LSD) at the 5% level of probability were determined to separate differences in the properties among treatments.

Results and Discussion:

Proximate Composition:

The proximate composition of prepared chicken mortadella samples is presented in Table 3. Values showed a significant difference ($p \leq 0.05$) in moisture, fat, protein, ash, and salt values for the analyzed treatments (i.e., T1, T2, T3, and T4) of chicken mortadella.

Table 3: Mean values for the proximate composition of chicken mortadella samples prepared with the addition of flaxseed oil and thyme oil.

Moisture(%)	Fat(%)	Protein(%)	Ash(%)
70.16 ^a ±0.01	1.05 ^d ±0.01	19.6 ^a ±0.01	3.34 ^b ±0.01
63.95 ^d ±0.01	10.85 ^a ±0.01	14.48 ^c ±0.01	3.46 ^a ±0.01
69.69 ^b ±0.01	1.09 ^c ±0.01	19.59 ^a ±0.01	3.15 ^c ±0.01
64.26 ^c ±0.01	10.61 ^b ±0.01	14.6 ^b ±0.01	3.47 ^a ±0.01

Data are expressed as means of triplicate determinations.

Levels not connected by the same letter are significantly different ($p \leq 0.05$) \pm SD.

T1: whole chicken muscle (WCM) mortadella (control 1); **T2:** mechanically deboned chicken meat (MDCM) mortadella (control 2); **T3:** WCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%); **T4:** MDCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%).

The moisture content of all treatments ranged from 63.95% to 70.16%, which was within the range allowed by the Jordanian standard of meat and meat products-sausage products (JS816:2008 3rd edition). The mean moisture values of WCM mortadella samples T1 and T3 were found to be 70.16% and 69.69%, respectively. These values were in disagreement with those reported by Sharma et al. (2020), who noted that the moisture content ranged between 61.92% and 63.44% in chicken mortadella made from manually deboned meat, most likely due to the higher fat content than in their samples. The moisture content of MDCM mortadella was 63.95% for T2 and 64.26% for T4. Similar data were found by Pereira et al. (2011).

Fat content found among all treatments ranged from 1.05% to 10.85%, which was lower than the Jordanian standard of meat and meat products – sausage products (JS816:2008 3rd edition). This was possible because, during mortadella manufacturing, no fat was added to the raw batter preparation. Fat values of WCM mortadella obtained were 1.05% for T1 and 1.09% for T3. These results were approximately near to those reported by Trindade et al. (2004). However, fat content among MDCM mortadella samples was 10.85% for T2 and 10.61% for T4; which resembles that found by Daros et al. (2005) who reported a fat content of 11.20% in the sample that contained 100% MDCM. The higher fat content of MDCM mortadella compared to that of WCM mortadella ($p \leq 0.05$) was attributed to the different

composition of lipids of MDCM; which has a high proportion of the released heme pigments of the bone marrow compared to the manually deboned chicken because of the mechanical separation process (Sözen & Hecer, 2013).

The protein content obtained among all treatments was compatible with the Jordanian standard of meat and meat products-sausage products (JS816:2008 3rd edition). Protein values of WCM mortadella were 19.60% for T1 and 19.59% for T2 which were not significantly different ($p \geq 0.05$). Bolger et al. (2017) found a relatively comparable protein content of 17.5% in chicken sausages made with the thigh. The protein content of T2 and T4 was 14.48% and 14.60%, respectively. This was in agreement with Pereira et al. (2011).

Comparing moisture, fat, and protein results for WCM samples (T1 and T3) with the other samples of MDCM (T2 and T4), the highest moisture and protein values were found in treatments with the lowest fat content; which coincided with that mentioned by Benedict (1987) who reported that a lot of skeletal tissues, moisture, and protein vary in direct proportion, while the fat content is inversely proportional to moisture and protein.

Ash values obtained in WCM mortadella were 3.34 and 3.15 for T1 and T3, respectively. The study results were in resemblance to those found by Souza et al. (2011). The obtained ash mean values found in MDCM mortadella were 3.46% and 3.47% for T3 and T4, respectively, which were not significantly different. Our

results were nearly similar to those obtained by Horita et al. (2014). However, there was a significant difference between the ash content of WCM samples and of MDCM samples, at which the latter exhibited higher values, due to the bone components mainly iron and calcium as a result of mechanical deboning (Sözen & Hecer, 2013).

Regarding salt content of all treatments, values ranged from 1.9% to 2.26% which were in line with the Jordanian standard of meat and meat products-sausage products (JS816:2008 3rd edition). There was a significant difference in salt content between the WCM and MDCM that was expected, probably because they were from two different batches.

Fatty Acid Profile:

The fatty acid profile for all mortadella treatments is shown in Table 4. The total saturated fatty acids (SFA) of WCM samples T1 and T3 were 35.14% and 32.54%, respectively, and the total monounsaturated fatty acids (MUFA) content was 45.82% for T1 and 45.59% for T3. The total polyunsaturated fatty acids (PUFA) content was 20.78% and 23.79% for T1 and T3, respectively. The results were in agreement with those of Bolger et al. (2017) who noted that the total SFA content of chicken thigh sausages was 33.8%, total MUFA was 44.7%, and

total PUFA was 20.9%. In the case of MDCM mortadella treatments, the total SFA of T2 and T4 found were 32.98% and 29.80%, respectively. The total MUFA was 49.23% for T2 and 49.62% for T4, and PUFA contents of T2 and T4 were 19.90% and 22.70%, respectively. Reitznerová et al. (2017) found nearly similar results in chicken frankfurters made with MDCM, where the authors reported that SFA content was 35.27%, MUFA was 47.89%, and PUFA was 16.82%. They stated that the low content of PUFA (16.82%) was probably due to the addition of pork back fat in frankfurters samples.

The total trans fatty acids of T1, T2, T3, and T4 were 0.74, 0.37, 0.56, and 0.36, respectively. The findings were in agreement with Aro et al. (1998) who noted that the total trans fatty acid content in chicken meat samples varied from 0.2 to 1.7%.

The predominant SFA present in all treatments (T1, T2, T3, and T4) was palmitic acid (C16:0) and stearic acid (C18:0), while the main MUFA was oleic acid (C18:1). The most abundant PUFA was linoleic acid (C18:2), followed by linolenic acid (C18:3). Baggio and Bragagnolo (2006) found similar findings regarding main fatty acids in chicken sausages made with chicken meat with similar values.

Table 4: fatty acid profile (% of total fatty acid) of chicken mortadella (made from whole chicken muscle and mechanically deboned chicken) prepared with the addition of flaxseed oil and thyme oil.

Fatty acids (% of total fatty acid)	T1	T2	T3	T4
C14:0	1.65 ^a ±0.04	0.48 ^c ±0.01	1.05 ^b ±0.02	0.41 ^d ±0.01
C16:0	25.93 ^a ±0.63	25.88 ^a ±0.63	24.52 ^b ±0.59	22.76 ^c ±0.55
C16:1	4.90 ^c ±0.11	5.16 ^b ±0.12	4.99 ^{bc} ±0.12	5.44 ^a ±0.13
C17:0	0.11 ^b ±0.00	0.05 ^d ±0.00	0.13 ^a ±0.00	0.06 ^c ±0.00
C17:1	0.68 ^a ±0.01	0.06 ^c ±0.00	0.43 ^b ±0.01	0.06 ^c ±0.00
C18:0	7.24 ^a ±0.17	6.51 ^{bc} ±0.15	6.68 ^b ±0.16	6.34 ^c ±0.15
C18:1tr	0.31 ^a ±0.01	0.15 ^b ±0.00	0.04 ^d ±0.00	0.14 ^c ±0.00
C18:1	40.23 ^b ±0.98	44.01 ^a ±1.07	40.16 ^b ±0.97	44.11 ^a ±1.07
C18:2tr	0.14 ^a ±0.00	0.05 ^c ±0.00	0.06 ^b ±0.00	0.04 ^d ±0.00
C18:2 ω6	19.58 ^b ±0.47	19.01 ^b ±0.46	19.35 ^b ±0.47	21.25 ^a ±0.51
C18:3tr	0.28 ^b ±0.01	0.16 ^c ±0.00	0.45 ^a ±0.01	0.17 ^c ±0.00
C18:3 ω3	1.20 ^c ±0.02	0.88 ^d ±0.02	4.43 ^a ±0.10	1.44 ^b ±0.03
C22:0	0.19 ^b ±0.00	0.02 ^d ±0.00	0.14 ^c ±0.00	0.21 ^a ±0.01

Σ SFA	35.14 ^a ± 0.85	32.98 ^b ± 0.80	32.54 ^b ± 0.79	29.80 ^c ± 0.72
Σ MUFA	45.82 ^b ± 1.11	49.23 ^a ± 1.20	45.59 ^b ± 1.11	49.62 ^a ± 1.21
Σ PUFA	20.78 ^c ± 0.50	19.90 ^c ± 0.48	23.79 ^a ± 0.58	22.70 ^b ± 0.55
Σ TRANS	0.74 ^a ± 0.01	0.37 ^c ± 0.01	0.56 ^b ± 0.01	0.36 ^c ± 0.01
n6/n3	16.26 ^b ± 0.00	21.46 ^a ± 0.00	4.36 ^d ± 0.00	14.67 ^c ± 0.00
PUFA/SFA	0.59 ^d ± 0.00	0.60 ^c ± 0.00	0.73 ^b ± 0.00	0.76 ^a ± 0.00
AI	0.59 ^a ± 0.00	0.49 ^c ± 0.00	0.51 ^b ± 0.00	0.42 ^d ± 0.00
TI	0.95 ^a ± 0.00	0.89 ^b ± 0.00	0.70 ^d ± 0.00	0.74 ^c ± 0.00

Data are expressed as means of triplicate determinations.

Levels not connected by the same letter are significantly different ($p \leq 0.05$) \pm SD.

T1: whole chicken muscle (WCM) mortadella (control 1); **T2:** mechanically deboned chicken meat (MDCM) mortadella (control 2); **T3:** WCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%); **T4:** MDCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%).

In the case of MDCM samples, Reitznerová et al. (2017) reported similar results in MDCM where the contents of C16:0, C18:0, C18:1, C18:2, and C18:3 were 23.56%, 6.68%, 37.35%, 16.47%, and 1.17%, respectively.

The total amount of SFA in the modified mortadella samples T3 and T4 decreased significantly by 7.40% and 9.63%, respectively, in comparison with their control samples. However, the PUFA content of T3 and T4 increased significantly by 14.47% and 14.09%, respectively, compared to T1 and T2. Similar results were found by Pelser et al. (2007), who noted that PUFA content increased with increased levels of flax oil (3% to 6%) in fermented sausages. According to Valencia et al. (2008), there was a significant decrease in total SFA in cooked pork sausages containing linseed oil, fish oil, and natural antioxidants.

Oil-incorporated samples showed a significant increase in linolenic acid by 268.44% for T3 and 63.58% for T4 when compared to control samples (T1 and T2). This was possibly due to the addition of flaxseed oil which had a high linolenic acid content (55.05%), in addition to the antioxidant effect of thyme oil that prevented the deterioration of linolenic acid. This agrees well with Valencia et al. (2008) who pointed out a significant increase in linolenic acid content in pork sausages containing linseed oil, fish oil, and natural antioxidants (Green tea catechins and green coffee antioxidants). The authors elucidated the protective effect of these antioxidants on linolenic acid. Nevertheless, the presence of pigments and lipid components resulting from

mechanical separation behaves as a catalyst in the auto-oxidation (Sözen & Hacer, 2013), which could have contributed to the oxidation of C18:3 during the cooking process; resulting in a slight increase of linolenic acid in T4 in comparison with T3.

Depending on the results obtained, there was a significant decrease in the total trans fatty acids of the modified sample (T3) when compared to the control sample (T1); indicating that thyme oil decreased the fatty acid oxidation, thus, the decomposition of primary compounds from lipid oxidation that can induce the formation of trans fatty acids (Aureima et al., 2021). A similar finding was found by Aureima et al. (2021). In the case of MDCM samples, there was no significant difference in trans content between T2 and T4; most likely because thyme oil was exhausted to prevent oxidation during the cooking process in the presence of pigment released during mechanical separation which behaves as a catalyst in the auto-oxidation (Sözen & Hacer, 2013).

The PUFA/SFA ratio significantly increased by 23.63% and 26.26% for T3 and T4, respectively, in comparison with the control treatments (T1 and T2). The increased ratio was considered beneficial from a health point of view since higher concentrations of PUFAs decrease the presence of serum lipids (Souto et al., 2021). A similar observation was noted by Valenzuela-Melendres et al. (2018) who reported an increase in PUFA/SFA ratio when the flaxseed increased in beef patties. Also, Pelser et al. (2007) reported an increase in

PUFA/SFA ratio in the modified sausages with flaxseed oil and canola oil.

There was a significant reduction in the then 6/n3 ratio (linoleic/linolenic acid) in the experimental samples compared to the control ones. In the case of WCM samples, the n6/n3 dropped from 16.23 to 4.36, whereas in MDCM samples, it was reduced from 21.46 to 14.67. The same trend was found by Valenzuela-Melendres et al. (2018) upon the addition of flaxseed in beef patties, at which the authors reported a decrease in the n6/n3 ratio from 8 to 0.3. The high decrease in the n6/n3 in the case of WCM samples was probably due to the higher increase in linolenic acid (Pelser et al., 2007) compared to MDCM samples. The slight decrease in the n6/n3 ratio in MDCM samples, which contain high amounts of pigments and iron, has proved to possess more intensive oxidative changes (Sözen & Hacer, 2013). Josquin et al. (2012) declared that the product is better in terms of health when the n6/n3 ratio is lower. A ratio of 5:1 was recommended for dietary n6/n3 fatty acids (Valencia et al., 2008).

The addition of flaxseed oil and thyme oil resulted in a significant decrease in AI from 0.59 (T1) to 0.50 (T3) in WCM samples, and from 0.49 (T2) to 0.42 (T4) in MDCM samples. Also, TI values decreased significantly from 0.95 to 0.70 and from 0.89 to 0.74 for T1-T3 and T2-T4, respectively. Similar results were reported by Bolger et al. (2017). However, all samples displayed TI and AI of less than 1.0, indicating a lower risk of participating in the development of cardiovascular diseases and of forming thrombi in blood vessels (Souto et al., 2021).

Lipid Oxidation:

Lipid oxidation values of chicken mortadella samples, measured by TBARS assay, are depicted in Figure 1. According to the results obtained, there was no significant difference ($p \leq 0.05$) between T1 and T3 (with the added oils); indicating that the addition of thyme oil as a natural antioxidant could be necessary with the addition of flaxseed oil which is rich in PUFA (Bolger et al., 2017).

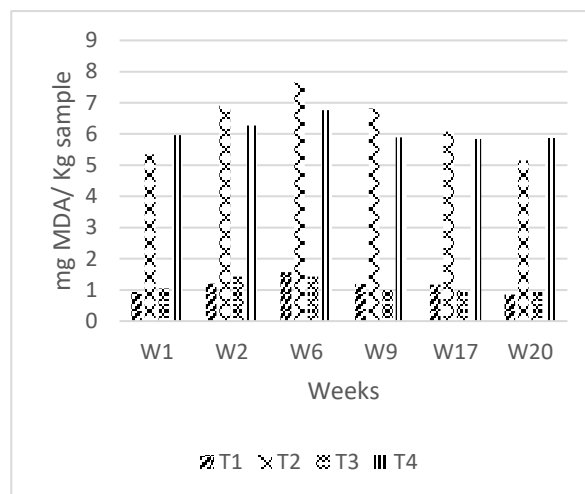


Figure 1: TBARS values (mg MAD/kg sample) of chicken mortadella formulated (made from whole chicken muscle, and mechanically deboned chicken), prepared with the addition of flaxseed oil and thyme oil during 20 weeks of storage.

Significantly lower levels of lipid oxidation were noted in T3 after 9 weeks of storage to reach 0.93 mg of MDA equivalents/kg at the end of the storage period. The same pattern was also observed in the case of the control treatment (T1). Ansorena & Astiasaran (2004) revealed that in omega-3 enriched fermented sausages, the TBARS value of 3 mg MDA equivalents /kg has been associated with rancidity. Therefore, 20 weeks of refrigerated storage for WCM mortadella is recommended and the whole-muscle chicken as raw material was a good choice for chicken sausages, similar to that found by Cavalcante Da Rocha et al. (2020).

For MDCM mortadella, the TBARS values of T2 were higher than those of T4 ($p \leq 0.05$) probably due to the antioxidant effect of the added thyme oil. That was also proved by Munekata et al. (2015) who reported that the phenolic compounds from the peanut skin might, in addition to their radical scavenging activity, exhibit metal chelating activity that results in the formation of stable complexes with heme and non-heme ions. The TBARS values for the T4 sample during the storage period ranged from 5.87 to 6.76mg of MDA equivalents/kg which were in disagreement with the results of Munekata et al. (2015) who found a TBARS value of mechanically deboned chicken patties enriched by peanut skin extract as an

antioxidant of 0.85 mg of MDA equivalents/kg. That was could be due to the mechanically deboned chicken meat that contains iron as a pro-oxidant, and the higher content of PUFA because of the added flaxseed oil (Srinivassane, 2011), and the cooking process (Munekata et al., 2015).

The stability of TBARS values of T3 and T4 after 9 weeks until the end of storage indicates the important effect of thyme oil as an antioxidant, especially with meat products enriched by flaxseed oil. Essential oils having polyphenols (such as thyme oil) can react with free radicals and hydroxyls which converts them into more stable forms (Sharma et al., 2020).

In a comparison of the TBARS values of WCM and MDCM mortadella, there was a massive gap between them. That possibly was because the mechanical separation process of deboning triples the number of pigments. Lipid components and pigments released by

mechanical separation behave as a catalyst in auto-oxidation (Sözen & Hecker, 2013).

pH Measurement:

Table 5 shows the mean pH values of the studied chicken mortadella. Data showed an increase after 4 weeks of storage, probably due to the synthesis of basic amines and the buffer capacity of the medium, in addition to the added sodium phosphate to raise the pH and improve the emulsion stability of meat (Cenci et al., 2018). Then, the mean values started to decrease until the end of the storage period. This may be explained by the action of lactic acid bacteria which was responsible for the fall in pH during the storage of meat products (Hastaoğlu et al., 2021).

Table 5: Measured pH values of chicken mortadella (made from whole chicken muscle, and mechanically deboned chicken), prepared with the addition of flaxseed oil and thyme oil.

Treatment	Storage time (in weeks)					
	W1	W4	W8	W10	W18	W20
T1	$_{F}6.19^c \pm 0.01$	$_{AB}6.55^c \pm 0.00$	$_{CD}6.47^d \pm 0.01$	$_{A}6.57^a \pm 0.12$	$_{BC}6.49^c \pm 0.01$	$_{BC}6.50^b \pm 0.01$
T2	$_{F}6.56^a \pm 0.01$	$_{A}6.77^a \pm 0.01$	$_{B}6.71^a \pm 0.00$	$_{C}6.69^a \pm 0.01$	$_{B}6.72^a \pm 0.01$	$_{C}6.68^a \pm 0.01$
T3	$_{F}6.26^b \pm 0.01$	$_{A}6.55^c \pm 0.01$	$_{B}6.51^c \pm 0.01$	$_{D}6.41^b \pm 0.03$	$_{B}6.51^b \pm 0.00$	$_{C}6.48^c \pm 0.01$
T4	$_{E}6.57^a \pm 0.01$	$_{A}6.76^b \pm 0.01$	$_{B}6.70^b \pm 0.01$	$_{C}6.63^a \pm 0.02$	$_{B}6.71^a \pm 0.01$	$_{B}6.69^a \pm 0.01$

Data are expressed as means of triplicate determinations.

Levels not connected by the same letter are significantly different ($p \leq 0.05$) \pm SD.

Capital letter within the same row with different superscript letters have significant differences between storage periods using LSD ($p \leq 0.05$) Small letter within the same column with different subscript letters have significant differences between treatments using LSD ($p \leq 0.05$).

T1: whole chicken muscle (WCM) mortadella (control 1); **T2:** mechanically deboned chicken meat (MDCM) mortadella (control 2); **T3:** WCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%); **T4:** MDCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%).

The pH values of WCM and MDCM mortadella over the storage period ranged from 6.19 to 6.57 and from 6.56 to 6.77, respectively. These obtained values were acceptable and within the mortadella quality criteria (Cenci et al., 2018).

Results found by Oliveira et al. (2019), who made mortadella formulations using poultry breasts, were similar to our findings. In the case of MDCM, similar

results were found by Cenci et al. (2018). The mean pH values of WCM mortadella were significantly lower in comparison with those of MDCM mortadella. The results are in agreement with Abdullah & Al-Najdawi (2005) results.

The pH results showed that there was no significant difference between the control samples (T1 and T2) and the modified ones (T3 and T4), therefore, it can be

concluded that there was no effect of flaxseed and thyme oils addition on the pH values of chicken mortadella. Similar to the findings of Hastaoğlu et al. (2021) and Pelser et al. (2007).

Color Measurement:

Values of L^* (lightness), a^* (redness), and b^* (yellowness) for all treatments at week 2 and week 11 of storage are presented in Table 6. No significant difference ($p>0.05$) was detected in L^* and b^* parameters, while there was a significant difference ($p\leq 0.05$) in the a^* parameter between WCM and MDCM samples.

The results of the L^* parameter of WCM samples during the 11 weeks of storage period ranged from 61.35 to 61.99 for T1 and from 58.38 to 58.89 for T3. The Values were in agreement with Comunian et al. (2014). The L^* values of MDCM samples during the storage ranged from 49.89 to 52.89 for T2, and from 49.41 to 50.23 for T4. The results were lower than those obtained by Auriema et al. (2019) who reported an L^* value of 69.48. This could be due to the mechanically deboned chicken and chicken breast mixture used in their mortadella manufacturing.

There was no significant difference ($p\geq 0.05$) between the control samples (T1, T2) and the experimental samples (T3, T4), indicating that the oils used (flaxseed and thyme oils) did not affect the L^* parameter. A similar result was observed by Bolger et al. (2017) who noted no significant difference in L^* value after the incorporation of flaxseed oil (2%) in chicken sausages. Jin et al. (2016) proved that thyme and rosemary added to pork sausages did not affect the lightness of modified samples in comparison with the control.

During the storage period, there was no significant difference in all treatments. This is in agreement with Munekata et al. (2015) who also reported no variation in L^* during the storage of chicken patties with added peanut skin extract. On the other hand, the absence of oxygen as a result of vacuum packaging contributed to the stability of L^* during storage (Vergara et al., 2020).

The redness (a^*) values obtained for WCM samples during the storage period ranged from 2.19 to 2.42 for T1,

and from 2.16 to 2.65 for T3. The values of redness found for MDCM samples during the storage period ranged from 13.87 to 14.39 for T2 and from 13.85 to 15.23 for T4. These results are in close agreement with those found by Miller et al. (2020) who measured the redness value for frankfurters made with chicken breast and MDCM; the authors reported a range from 3.22 to 4.81 in frankfurters made with chicken breast, and from 12.80 to 14.28 in frankfurters made with MDCM during 98 days of storage. The difference ($p\leq 0.05$) found in a^* values between WCM and MDCM samples was possible because of the higher bone marrow content (Miller et al., 2020) and increased myoglobin and hemoglobin content in mechanically deboned meats (Mielnik et al., 2002).

Additionally, in terms of redness, there was no significant difference ($p\geq 0.05$) determined between the control samples (T1, T2) and the oil-incorporated modified samples (T3, T4). This indicates that the oils used had no effect on the redness parameter during the storage period. Similar findings were observed by Pelser et al. (2007) who reported that fermented beef sausages – in which 10-20% of pork back fat was substituted by flax oil and encapsulated fish oil– did not affect the product redness.

The yellowness (b^*) results of WCM control samples during the storage period ranged from 17.36 to 18.26 for T1 and from 17.92 to 18.40 for T3, and those of MDCM ranged from 14.75 to 15.25 for T2 and from 15.94 to 16.18 for T4 during the storage period. The results are nearly similar to those found by Miller et al. (2020), who reported that the b^* values in frankfurters made with chicken breast ranged from 14.12 to 16.19, and for frankfurters made with MDCM, values ranged from 15.04 to 15.64. There was no significant difference ($p\geq 0.05$) regarding product yellowness among all samples (WCM vs. MDCM), which is in agreement with Miller et al. (2020). Also, yellowness values for all samples were stable during storage ($p\geq 0.05\%$) due to the absence of oxygen in vacuum packaging (Vergara et al., 2020).

Table 6: Effect of flaxseed oil and thyme oil on color parameters (L*: lightness, a*: redness, and b*: yellowness) of chicken mortadella at week 2 and week 11 of refrigerated storage.

Treatment	L* (Lightness)		a* (Redness)		b* (Yellowness)	
	Week 2	Week 11	Week 2	Week 11	Week 2	Week 11
T1	$_{A}61.99^{a} \pm 2.10$	$_{A}61.35^{ab} \pm 0.21$	$_{A}2.19^{b} \pm 0.48$	$_{A}2.42^{b} \pm 0.58$	$_{A}18.26^{a} \pm 0.14$	$_{A}17.36^{a} \pm 0.53$
T2	$_{A}52.89^{abc} \pm 1.53$	$_{A}49.89^{bc} \pm 0.31$	$_{A}14.39^{a} \pm 0.11$	$_{A}13.87^{a} \pm 0.16$	$_{A}15.25^{a} \pm 0.99$	$_{A}14.75^{a} \pm 0.08$
T3	$_{A}58.89^{abc} \pm 3.86$	$_{A}58.38^{abc} \pm 3.39$	$_{A}2.16^{b} \pm 0.50$	$_{A}2.65^{b} \pm 0.09$	$_{A}17.92^{a} \pm 0.21$	$_{A}18.40^{a} \pm 1.23$
T4	$_{A}49.41^{abc} \pm 0.14$	$_{A}50.23^{c} \pm 3.49$	$_{A}13.85^{a} \pm 0.55$	$_{A}15.23^{a} \pm 0.36$	$_{A}16.18^{a} \pm 1.40$	$_{A}15.94^{a} \pm 1.20$

Data are expressed as means of triplicate determinations.

Levels not connected by the same letter are significantly different ($p \leq 0.05$) \pm SD.

Capital letter within the same row with different superscript letters have significant differences between storage periods using LSD ($p \leq 0.05$) Small letter within the same column with different subscript letters have significant differences between treatments using LSD ($p \leq 0.05$).

T1: whole chicken muscle (WCM) mortadella (control 1); **T2:** mechanically deboned chicken meat (MDCM) mortadella (control 2); **T3:** WCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%); **T4:** MDCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%).

Sensory Evaluation:

Sensory evaluation scores of the examined chicken mortadella are shown in Table 7. According to the results obtained, appearance and flavor scores were not significantly affected ($p \geq 0.05$) by the addition of flaxseed

oil and thyme oil or by the type of chicken meat used (WCM and MDCM). However, juiciness, texture, and overall liking scores were significantly different ($p \leq 0.05$) among the samples.

Table 7: Sensory scores of chicken mortadella (made from whole chicken muscle and mechanically deboned chicken) prepared with the addition of flaxseed oil and thyme oil.

Treatments	Appearance	Flavor	Juiciness	Texture	Overall liking
T1	$6.84^{a} \pm 1.67$	$6.44^{a} \pm 1.98$	$5.64^{b} \pm 1.65$	$5.92^{b} \pm 1.77$	$6.44^{ab} \pm 2.20$
T2	$7.52^{a} \pm 1.35$	$7.36^{a} \pm 1.52$	$7.36^{a} \pm 1.28$	$7.48^{a} \pm 1.32$	$7.40^{a} \pm 1.68$
T3	$6.88^{a} \pm 1.56$	$6.44^{a} \pm 1.55$	$5.68^{b} \pm 1.54$	$6.56^{ab} \pm 1.63$	$6.32^{b} \pm 1.06$
T4	$7.16^{a} \pm 1.51$	$6.36^{a} \pm 2.17$	$6.72^{a} \pm 1.79$	$7.0^{a} \pm 1.84$	$7.0^{ab} \pm 1.91$

Data are expressed as means of triplicate determinations.

Levels not connected by the same letter are significantly different ($p \leq 0.05$) \pm SD.

T1: whole chicken muscle (WCM) mortadella (control 1); **T2:** mechanically deboned chicken meat (MDCM) mortadella (control 2); **T3:** WCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%); **T4:** MDCM mortadella with flaxseed oil (2g/100g) + thyme oil (0.15%).

Appearance scores of the mortadella treatments ranged from 6.8 to 7.5 ($p \geq 0.05$). The lack of significant differences between the control and experimental samples

indicates that flaxseed oil and thyme oil did not affect the appearance of mortadella. This agrees with the results of Ahlawat et al. (2019).

The flavor scores among samples ranged from 6.44 to 7.36. Regardless of the high TBA values recorded in MDCM samples, no significant difference ($p \geq 0.05$) was detected in flavor scores between the WCM and MDCM samples. This probably was due to the flavor of spices added to mortadella which might have covered that rancidity. There was no significant difference ($p \geq 0.05$) in the flavor ratings between the control and experimental samples. A similar finding was found by Ahlawat et al. (2019) who noted that adding 2% of flaxseed powder and 0.10% of thyme oil to chicken nuggets showed a flavor similar to the control treatment. Flavor scores were in disagreement with those of Bolger et al. (2017) who noted that the addition of 2% flaxseed oil to chicken sausages affected the flavor, which could be due to the masking of the pronounced aroma of one EO by another, which might be explained by synergistic interactions of major and minor constituents present in flaxseed and thyme oils (Sharma et al., 2019).

The scores of the texture parameter showed that WCM mortadella samples had significantly lower scores (5.9 – 6.56) than MDCM samples (7 – 7.4). This could be due to the relatively high protein content and low-fat content in WCM since a high protein content has been found to increase the emulsion matrix and thus the hardness of the final product (Srinivassane, 2011). Moreover, the absence of fat might have impaired the softness that was expected for chicken mortadella (Prestes et al., 2014), since reduced fat content results in increased firmness (Yilmaz, 2005). Also, Mohd Abdullah (2007) noted that the increased moisture and fat contents of processed meats can improve the texture of the final product. Depending on the results obtained, the addition of flaxseed oil and thyme oil to the modified chicken mortadella samples (T3 and T4) resulted in a texture statistically similar ($p \geq 0.05$) to those of the control treatments (T1 and T2). This is in agreement with Bolger et al. (2017) who, after the addition of flaxseed oil (2%), did not detect any effect on the texture of chicken sausages. Ahlawat et al. (2019) reported that the addition of flax powder with the combination of three oils (rosemary, thyme, and oregano)

to chicken nuggets resulted in texture scores comparable with the control.

Regarding the juiciness attribute, MDCM samples had higher scores than WCM samples ($p \leq 0.05$), which was expected since MDCM showed the highest fat content which imparts desirable juiciness (Auriema et al., 2019). Mohd Abdullah (2007) indicated that moisture content might be considered an important determinant of juiciness; however, WCM samples with the highest moisture content had the lowest juiciness scores, so it is possible that the juiciness parameter could be identified by the synergetic effect of both moisture and fat content on the juicy mouth feel. According to the juiciness scores obtained, there was no significant difference ($p \geq 0.05$) between control samples (T1 and T2) and treated samples (T3 and T4). In agreement with our data, Srinivasan (2011) found that the addition of flax oil (1.2% and 2.4%) to chicken frankfurters resulted in a juicier product similar to the control. Also, Ahlawat et al. (2019) reported that flaxseed powder and essential oils (rosemary, thyme, and oregano) added to chicken nuggets did not affect product juiciness.

The overall liking parameter for all samples showed that the obtained values were above the acceptable limit for the product (score 5; which indicates “neither like nor dislike”). According to the data collected, there was a significant difference ($p \leq 0.05$) only between T2 and T3. Formulation T2 showed the highest overall liking score, and there was no significant difference between MDCM samples (T2 and T4). Our results were similar to those of Bolger et al. (2017) who also found that control sausages scored the highest in all sensory categories.

Both WCM samples (T1 and T3) showed the lowest overall liking scores as a result of low texture and juiciness scores, indicating that the chemical composition of chicken meat used (MDCM and WCM) appeared to have greatly influenced the overall liking of the product, which was in disagreement with Mohd Abdullah (2007). It is concluded that MDCM mortadella was the most acceptable product regardless of the addition of flaxseed and thyme oils that were added to both types of mortadella.

Conclusions:

The results obtained from this study showed that the addition of flaxseed oil to WCM and MDCM mortadella led to an increase in essential fatty acids (e.g. omega-3). The added thyme oil preserved it without affecting the sensorial characteristics and color, in addition to delaying lipid oxidation during processing and refrigerated storage. In comparison with WCM mortadella, MDCM mortadella was exposed to a higher level of oxidation during processing and continued during storage, where the fortified sample had lower oxidation than the control. From a nutritional point of view, WCM was a good raw material to manufacture mortadella. Nevertheless, it is recommended to add 10% of fat to WCM (e.g. vegetable oil or chicken skin) to raise the sensorial and quality characteristics to be similar to MDCM, since the MDCM samples had a fat content of 10% resulting in higher scores in texture and juiciness in comparison with WCM.

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تعزيز المواد الكيميائية والغذائية ونوعية المرتديلا قليلة الدسم المصنوعة من عضلات الدجاج الكاملة منزوعة العظم ميكانيكياً مع إضافة زيت بذور الكتان والزعر

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ملخص

تهدف هذه الدراسة إلى مقارنة مرتديلا الدجاج قليلة الدسم المصنوعة من لحوم الدجاج الكاملة (WCM) ولحم الدجاج منزوعة العظم ميكانيكياً (MDCM) المدعم بزيت بذور الكتان وزيت الزعر. تم تصنيع أربعة أنواع من مرتديلا: WCM 100% (T1)، MDCM 100% (T2)، WCM 100% + 2% زيت بذور الكتان + 0.15% زيت زعر (T3)، و MDCM 100% + 2% زيت بذور الكتان + 0.15% زيت زعر (T4). تم فحص عينات المرتديلا لمعرفة التركيب التقريبي، تقدير قيمة حمض الثيوباربيتوريك (TBA)، قياس الرقم الهيدروجيني، تنميط الأحماض الدهنية، قياس اللون، التقييم الحسي، وتحليل التباين (ANOVA) للنتائج. تأثر التركيب التقريبي بنوع لحم الدجاج (WCM مقابل MDCM). كانت قيم TBA للعينات المضاف إليها الزيوت أقل مقارنةً بقيم العينات الشاهدة. كانت قيم الرقم الهيدروجيني لمرتديلا WCM أقل ($p \leq 0.05$) مقارنةً مع MDCM، حيث لم يكن للزيوت أي تأثير على الرقم الهيدروجيني خلال فترة التخزين. أدت إضافة الزيوت إلى زيادة إجمالي الأحماض الدهنية المتعددة غير المشبعة (PUFA) وخفض إجمالي الأحماض الدهنية المشبعة (SFA). درجة حمرة MDCM أعلى من عينات WCM، بالإضافة إلى ذلك، لم يؤثر التخزين والزيوت المضافة على اللون. أظهرت النتائج الحسية أن درجات العصارة والنسيج والإعجاب بشكل عام كانت مختلفة معنوياً.

الكلمات الدالة: مورتديلا الدجاج، زيت بذور الكتان، زيت الزعر، التركيب الكيميائي، أكسدة الدهون، الأحماض الدهنية، الحالة التغذوية.

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