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Production of Canned Tuna using Local Tuna Species

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Research Article

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Abstract

Albacore and mackerel tuna were used to produce local canned tuna. After canning process, total volatile nitrogen basis, trimethyl amine, free fatty acid, peroxide value and thiobarbituric acid values were within the acceptable limits for both tuna species. Canned tuna showed lower content of total saturated fatty acids but higher content of poly unsaturated fatty acids than raw tuna. Cadmium and mercury levels of canned tuna were in the permissible limits. In contrast, lead concentrations in all tested samples were exceeded the prescribed legal limits. Lightness (L^*) and Whiteness were recorded significantly ($p < 0.05$) lower values for the processed albacore than the imported samples for both tuna species. All tested tuna samples were negative for *Cl. botulinum*. Sensory results declared no significant differences were found between the processed albacore and the imported sample. For mackerel tuna, results indicated that soaking in solution contains wheat flour, ascorbic acid and vinegar before canning improved the sensory characteristics.

Keywords: Albacore; Mackerel Tuna; Canning; Fatty Acid; Heavy Metals; Color

Introduction

Egypt has two long coasts extending over the Red Sea and the Mediterranean, each with a length of about 1000 km, which provides an enormous opportunity to catch many types of fish, including tuna fish. Two types of tuna: albacore (Thunnus alalunga) and mackerel tuna (Euthynnus affinis), which roam the Egyptian coasts in search of food, giving a great opportunity to produce canned tuna as a local alternative and to save foreign currency that goes for canned tuna imports.

Albacore or long-finned tuna is important in many commercial fisheries worldwide. This species is global in tropical and temperate waters of all the oceans including the Mediterranean Sea, the Pacific range and the Atlantic. Albacore fishing is a conventional activity for a number of fishing fleets including those of Spain, Italy, Cyprus, Greece, and Malta. However, ICCAT statistics are considered insufficient due to unreported catches and the lack of information in some years. Even though catches of Mediterranean albacore have been increasing for the past few years, there is a lack of general information about this stock and biological information [1]. The world catch has been gradually declining from a peak of about 257 053 t in 2012 to a low of about 208 217 t in 2016 [2]. This species is range in size between 10 to 70 lbs. It is well appreciated worldwide because of its sensory characteristics (white color, flavorful flesh and firm texture) and high nutritional value. In order to expand its production throughout the year, frozen albacore tuna is used as raw material in the canning industry [3].

Mackerel Tuna, also known as Kawakawa or Black Skipjack, is a highly migratory fish. It is marketed in assortment of products, and reported around the world landings are increasing. Currently, there is no data on population patterns [4]. This species spreads across the Arabian Sea, extending from the coasts of Eastern Africa, the Arabian Peninsula, the Indian subcontinent and the

Malaysian peninsula. It is also exist in the Red Sea, Persian Gulf, and off islands in the Indian Ocean [4]. It can grow to 100 cm long and about 20 kg in weight but are more commonly around 60 cm and 3 kg. Mackerel tuna has great commercial and economic importance and demand for the species has increased dramatically over the past 5 decades, which has resulted in global capture production of mackerel tuna increasing to approximately 366,159 tons as of 2016 [5]. Recently, it has attracted attention as a new target species for aquaculture due to its fast development and the growing demand associated with it. Its flesh tastes like a Pacific blue fin tuna taste and the market price of farmed mackerel tuna is higher than that of either red sea bream or yellowtail [6]. However, it has dark muscles which break down rapidly resulting in poor marketability. The pale color of the meat, high proportion of red meat and the generally unacceptable taste and flavor reduces its overall acceptability either for fresh consumption or processing. It has been noticed that if a better flavor and appearance has improved, even black meat species of tuna would find acceptance. This will guarantee the economic utilization of the unexploited black meat tuna resources and will also help in the diversification of the seafood canning industry. Several attempts to improve the color and flavor of canned mackerel tuna were reported by Bertoldi, et al. [7], Maheswara, et al. [8].

The aim of this study is to shed light on tuna species in both the Red and the Mediterranean seas as an economically unexploited species, in fish processing that can take advantage of its natural occurrence through the Egyptian coasts to develop local canned tuna. In addition, several pre-canning treatments have been made in order to improve the quality characteristics of canned mackerel tuna.

Materials and Methods

Materials

Albacore Tuna was purchased from a fisherman in Alexandria while mackerel Tuna was purchased from Al-Obour market, Cairo, both tuna species were purchased during July 2017. The fish were put in ice box and immediately transported to meat and fish department laboratory, Agriculture research center. Fork length and weight were recorded and then they were washed and kept frozen at -18°C until processing and analysis.

Salt, wheat flour, vinegar and refined sunflower oil (Afiae Oil Processing CO., Egypt) were purchased from the local market at Giza, Egypt. Ascorbic acid was obtained from Adwic Laboratory Chemicals Co., Cairo, by the laboratories of Food Technology Research Institute, Egypt. Liquid smoke was produced in meat and fish department laboratory. Wide-mouth standard new glass canning jars (half pint) were purchased from the local market. Imported commercial canned tuna (first grade canned albacore and dark meat canned skipjack) were purchased within their validity dates from the supermarket and were used to compare the results.

Jars Preparation

All jars were thoroughly washed and inspected for cracks or nicks on the rim. Jars were sterilized through emerging in boiled water for 10 minutes, then drained and flipped over until fully filtered from the water. The lids were preheated for 10 minutes in hot water and left to air dry.

Tuna Canning

Fish were defrosted overnight at 4±1°C, washed and filleted. Fillets were subdivided into white and red muscle. The dissected parts were each weighed. White muscle was then rinsed with cold water for the removal of blood and used for tuna canning. Each jar was filled with 93.33% tuna meat, 5.67 % oil and 1% salt. Treatment A was composed of raw albacore meat put in sunflower oil and salt. Treatments M1, M2, M3 and M4 were composed of raw mackerel tuna meat but with different additives. Treatment M1 was consisted of raw mackerel tuna meat put in sunflower oil and salt. Treatment M2 was consisted of raw mackerel tuna meat put in aromatized sunflower oil and salt. Aromatized oil prepared as follows: liquid smoke was shaken with sun flower oil, and then oil was washed with warm water and added to the tuna flesh in jars. Treatment M3 was consisted of raw mackerel tuna meat put in sunflower oil (4%), 1.67 % vinegar and salt. In treatment M4 raw mackerel tuna meat was previously soaked in solution containing 0.5 % wheat flour, 0.3 % ascorbic acid and 0.5 % vinegar for 20 minutes then rinsed with tap water, kept to drain before packing with sunflower oil and salt. After filling the jars, 1 inch of head space were left for each jar. The lids were attached. Precooking step was carried out at 100 °C for 90 minutes. Then jars were immediately subjected to high pressure thermal sterilization on 121°C/ 15 min in autoclave. At the end of the processing time, jars were left to cool for 6 to 8 hr., and then they kept stored under refrigeration at 4°C. Canned tuna was left to ‘‘age’’ for 10 days at 4°C, allowing the fill oil and salt to be distributed uniformly and absorbed by the meat. Before analysis, the jars were opened and the oil was allowed to drain for about 30 sec. For each treatment, a mixture of contents was prepared. For all measurements, the experiment was performed in triplicate.

Chemical Composition

Proximate composition: Moisture, protein (N×6.25), ether extract, and ash contents were determined using the methods of the AOAC [9].

pH Value

The pH value was estimated by using a calibrated pH meter (Jenway, 3510, UK) according to the method described by Goulas & Kontominas [10].

Chemical properties

Total volatile nitrogen (TVN) was determined by macro-distillation method as described by Pearson [11].

Trimethylamine nitrogen (TMAN) was determined using the above mentioned TVBN method after appropriate modification: formaldehyde was used to block the primary and secondary amines [12].

Free fatty acids (FFA) and Peroxide values were determined according to the standard titration method [9]. Peroxide value (PV) was expressed in units (meq oxygen/kg fat).

Thiobarbituric acid (TBA) values were estimated by colorimetric method at 538 nm using BECKMAN DU 7400 spectrophotometer (as mg malonaldehyde / kg sample); according to the method described by Pearson [11].

Fatty acids

Lipid was extracted from samples with a mixture of chloroform : methanol (2: 1 v/v) according to the method described by Bligh & Dyer [13]. Fatty acid methyl esters were prepared from extracted lipids according to ISO 12966-2 [14]. Isooctane (2 ml) was added to 0.1 g of the oil then the tube was shaken. Methanolic potassium hydroxide solution (0.1 ml, 2 N) was added and shaken vigorously for 30 seconds. The upper layer containing the methyl ester was decanted. The isooctane solution is suitable for injection into the gas chromatograph. Fatty acid methyl esters were injected into (HP 6890 series GC) apparatus provided with a DB-23 column (60m × 0.32 mm × 25 µm). Carrier gas was N2 with flow rate 2.2 ml/min, splitting ratio of 1:50. The injector temperature was 250 ° C and that of flame Ionization Detector (FID) was 300 °C. the temperature setting was as follows: 150 °C to 210 °C at 5 °C /min, and then held at 210 °C for 25 min. peaks were identified by comparing the retention times obtained with stander methyl esters. The ratio of ω-3 to ω-6 fatty acids as well as of PUFA to saturated fatty acids (SFA) (P: S) were calculated.

Heavy metals

Digestion of samples for estimation of cadmium (Cd), lead (Pb) and mercury (Hg) was carried out according to the methods described by Al-Ghais [15]. Two to three grams of muscle tissue were digested in 10 ml of a nitric/ per chloric acid mixture (4:1 v/v) at room temperature for 3 hr., then heating at 40 oC for 1 hr. The temperature was raised to 70-80 oC until the digestion completed. After cooling, the volume was made up to 20 ml with deionized water. One blank sample was run under identical experimental conditions. Concentrations (mg/kg of wet weight) of Cd, Pb and Hg were measured according to AOAC [9] using Atomic Absorption Spectrophotometer "ICP" (Optima 2000 DV- Perkin Elmer).

Color

Color was measured using a hand- held tristimulus reflectance colorimeter Minolta chromameter (model CR-400; Konica Minolta, Ramsey, N.J., Japan), which provided CIE L* (lightness), a* [chromaticity on a green (-) to red (+)] axis, b* [chromaticity on a blue (-) to yellow(+)] axis, chroma (C* = [a*2 + b*2]1/2) which indicates the intensity or color saturation, and hue angle (hº = tan-1 b*/a*). Whiteness of tuna was integrated in the formula: Whiteness=100–[(100–L) 2 + a2 +b2]1/2 [16].

Detection of Cl. Botulinum

Detection of *Cl. botulinum* presence was performed according to the method described by Sarvestani Sadeghi, et al. [17] using BIORAD T100 Thermal Cycler PCR (made in Singapore). The samples were initially enriched in cooked meat broth for 7 days at 30 °C in an anaerobic condition followed by subculture onto blood agar. DNA of the samples were then extracted for further mPCR assay using three species-specific pair of primers to amplify the 782, 205 and 389 bp fragments corresponding to the A, B and E types of the microorganism.

Organoleptic Evaluation

Organoleptic evaluation of tuna samples was carried out according to Watts, et al. [18] by aid of ten members of the Meat and Fish Res. Dep., Food Technology Research Institute. Judging scale for each factor was as follows: Excellent (8-9), Very good (7-<8), Good (6-<7), Fair (5-< 6), Poor (4-<5) and Rejected (<4).

Statistical analysis

Data were subjected to Analysis of Variance (ANOVA). Means comparison was performed using Duncan's test at the 5 % significance level of probability as reported by Snedecor & Cochran [19].

Results and Discussion

Percentage of Body Parts

The percentage of different body parts of both tuna

species are presented in Table 1. Data showed that the average body weight and fork length of albacore tuna were 8.63 kg and 86 cm, respectively. While those values recorded 3.90 kg and 60 cm, respectively for mackerel tuna. The differences in body weight and fork length for both tuna species may arise due to different fishing regions/seasons since those fish species are highly migratory and develops separate life history groups at particular stages of its life cycle with different spawning and feeding grounds [20]. The yield of tuna flesh (fillet) was 50.75 % and 50.51 % for albacore and mackerel tuna, respectively. The separated white and dark meat yield were 42.99 % and 7.76 % for albacore tuna and 39.74 % and 10.77 % for mackerel tuna. The ratio of dark to white meat revealed that albacore tuna contains less dark meat (1: 5.54) than that for mackerel tuna (1: 3.69).

Type of fish	Albacore (6 fish)		Mackerel (6 fish)	
Fork length (cm)	86 ± 5.5		60 ± 3	
Body part	Weight (kg)	(%)	Weight (kg)	(%)
Whole fish	8.63 ± 0.43		3.90 ± 0.21	
Head	1.70 ± 0.87	19.7	0.82 ± 0.30	21.03
Viscera	0.71 ± 0.06	8.23	0.37 ± 0.88	9.49
Skin & non-fillet flesh	1.08 ± 0.22	12.51	0.40 ± 0.31	10.26
Bones	0.58 ± 0.70	6.72	0.29 ± 0. 44	7.44
Fins & tail	0.18 ± 0.33	2.09	0.05 ± 0.12	1.28
Fillet	4.38 ± 0.03	50.75	1.97 ± 0.20	50.51
White muscles[a]	3.71 ± 0.40	42.99	1.55 ± 0.05	39.74
Dark muscles	0.67 ± 0. 46	7.76	0.42 ± 0.07	10.77
Ratio of dark meat/white meat	1 / 5.54		1 / 3.69	

Table 1: Components of tuna body parts by percentage of total fish weight.
[a]White muscles in albacore tuna but Red muscles in mackerel tuna.

Chemical Composition

The proximate composition of fresh and canned tuna for both tuna species are given in Table 2. Moisture content was found to be 70.17 % and 68.76 % for raw albacore and mackerel tuna, respectively. Both types of tuna species did not show much variation in the moisture content. Crude protein content in the raw samples was found to be 25.74 % and 24.67 % for albacore and mackerel tuna, respectively. Raw albacore tuna showed slightly higher content of protein, while, mackerel tuna contained higher amount of crude fat (4.97 %) than albacore (2.73 %). Olgunoglu [21] reported that fish species with darker meat (such as herring, salmon, mackerel and bluefish) contain a higher total fat content than fish species with leaner and lighter colored meat (such as cod, flounder and Pollock). Ash content recorded 1.36 % and 1.6 % for raw albacore and mackerel tuna, respectively. Variations in proximate composition of both tuna species are principally dependent on species and place of catch and seasonal variation [22]. Saito, et al. [23] found that E. affinis contained higher total lipid content (5.5%) than that of the other tuna species which had lipid content less than 3.0%. On the contrary, Mohanty, et al. [24] found that E. affinis contains 1.9 % of the crude fat. The main challenge facing canned fish manufacturers is the seasonality of the raw material. This is due to the differences in fish composition throughout the year. This phenomenon has been observed in all fish species but it is more important for fatty fish during migrations or the spawning period. Differences in composition mainly affect water and fat fragments, which may account for about 80% of the meat composition. Water and fat compensate for each other which lead to differences in composition and technological properties of the final product.

After canning, all tuna treatments lost moisture. Canned albacore lost 7.7 % of its original moisture content. For mackerel tuna, treatment M4 recorded the lower moisture loss (6.45%). This is probably due to pre-canning treatment. Soaking tuna meat (in solution containing wheat flour, ascorbic acid and vinegar) may have resulted in an improvement in the ability of the meat to retain water. Water loss in canned tuna meat is probably due to the effect of heat treatment on the deterioration of muscle protein, leading to a decreasing in water holding capacity of the myofibrillar protein [25]. According to Bell, et al. [26] thermal heating of muscle proteins is the main mechanism that leads to moisture loss. Moisture content located within the narrow

channels among protein filaments of myofibrils releases due to the protein denaturation and subsequent contraction of myofibrils. Similar results reported by Rasmussen & Morrissey [27] for canned albacore and Stephen, et al. [28] for canned skipjack. For all canned treatments, the decrease in moisture content resulted in an increase in protein, fat and ash contents. However, the protein content decreased despite the loss of water. In dry weight, the protein content decreased after canning process. Castrillon, et al. [25] reported that during cooking, food composition may vary due to lose or gain components by dilution or by absorption of material from the cooking medium. Results showed that tuna meat lost protein and water during thermal processing. Thus fat content increased notably. Since tuna was canned in sunflower oil and salt, differences in fat and ash contents were observed. The salt added to the jars increased the ash content in all canned samples. During the thermal treatment, the salt is absorbed into tuna meat [25]. For all samples, both the wet and dry matter showed an increase in fat content that could be explained by the migration of the fill oil into the fish meat [28]. Therefore, increases in fat and ash decreased the protein content in the canned tuna.

Sample		Moisture%	Protein%	Fat%	Ash%	Protein%	Fat%	Ash%
		(wet weight)			(dry weight)			
Albacore	Raw	70.17^{a} ± 0.34	25.74^{b} ± 0.22	2.73^{b} ± 0.15	1.36^{b} ± 0.06	86.29	9.15	4.56
	A	64.77^{b} ± 0.19	28.85^{a} ± 0.33	4.41^{a} ± 0.11	1.97^{a} ± 0.02	81.89	12.52	5.59
Mackerel	Raw	68.76 ^{a} ± 0.25	24.67 ^{c} ± 0.31	4.97 ^{c} ± 0.23	1.60 ^{c} ± 0.03	78.98	15.9	5.12
	M1	62.7 ^{d} ± 0.14	27.91 ^{a} ± 0.18	7.05 ^{a} ± 0.08	2.34 ^{a} ± 0.02	74.83	18.9	6.27
	M2	63.1 ^{d} ± 0.27	27.7 ^{a} ± 0.25	6.86 ^{a} ± 0.17	2.34 ^{a} ± 0.08	75.07	18.59	6.34
	M3	63.72 ^{c} ± 0.05	27.68 ^{a} ± 0.28	6.41 ^{b} ± 0.20	2.19 ^{b} ± 0.07	76.3	17.67	6.04
	M4	64.33 ^{b} ± 0.43	27.14 ^{b} ± 0.16	6.26 ^{b} ± 0.27	2.27 ^{ab} ± 0.11	76.09	17.55	6.36

Table 2: Proximate composition of fresh and canned tuna fish.
Values with different superscripts letters within the same column for the same tuna species are significantly difference ($p < 0.05$).

Chemical Quality

Chemical quality parameters of raw and canned tuna are presented in Table 3. The pH of the raw tuna meat was around 6 suggesting the muscles used were of good quality. The pH values of canned tuna were significantly ($p<0.05$) decreased after canning for both tuna species. This decrease may be due to the degradation of lipids and laxity of some fatty acids during the thermal treatment.

Sample		pH	TVN (mg N/100g)	TMA (mg N/100g)	FFA (% as oleic acid)	P V (meq O2/kg oil)	TBA (mg malonal. /kg)
Albacore	Raw	5.98 ^{a} ± 0.03	18.79 ^{b} ± 0.62	1.09 ^{b} ± 0.30	3.22 ^{b} ± 0.43	2.67 ^{b} ± 0.53	2.12 ^{b} ± 0.17
	A	5.88 ^{b} ± 0.01	27.89 ^{a} ± 0.51	3.7 ^{a} ± 0.21	6.33 ^{a} ± 0.48	3.74 ^{a} ± 0.32	5.78 ^{a} ± 0.21
Mackerel	Raw	6.06 ^{a} ± 0.07	16.41 ^{d} ± 0.52	2.18 ^{c} ± 0.41	2.85 ^{c} ± 0.38	1.40 ^{c} ± 0.15	0.82 ^{d} ± 0.19
	M1	5.97 ^{b} ± 0.03	26.8 ^{a} ± 0.40	9.5 ^{a} ± 0.25	4.67 ^{b} ± 0.43	3.43 ^{ab} ± 0.20	2.09 ^{ab} ± 0.13
	M2	5.93 ^{b} ± 0.02	24.66 ^{b} ± 0.37	9.62 ^{a} ± 0.27	4.28 ^{b} ± 0.20	2.87 ^{b} ± 0.19	1.62 ^{c} ± 0.16
	M3	5.81 ^{c} ± 0.02	25.50 ^{b} ± 0.60	9.59 ^{a} ± 0.44	5.95 ^{a} ± 0.52	3.8 ^{a} ± 0.38	2.24 ^{a} ± 0.24
	M4	5.92 ^{b} ± 0.04	23.34 ^{c} ± 0.44	7.82 ^{b} ± 0.20	4.51 ^{b} ± 0.35	3.25 ^{ab} ± 0.50	1.8 ^{bc} ± 0.08

Table 3: Chemical quality of fresh and canned tuna species.
Values with different superscripts letters within the same column for the same tuna species are significantly difference ($p < 0.05$).

Total volatile nitrogen (TVN) is a chemical parameter considerably used as a freshness index for raw fish. The TVN values (mg/100g) recorded for raw albacore and mackerel tuna were 18.79 and 16.41, respectively. It is clearly noticed that TVN values of both fresh tuna species were higher than that of other fresh fish species. Several authors suggested that TVN and TMAO are not good spoilage indicators of albacore tuna and black skipjack (Euthynnus lineatus). Since the TVN content in fresh tuna is quite high compared with that in other species of fish [29,30]. In general, for fresh or frozen fish, a TVN value of less than 30 mg N/100g is considered acceptable as evidence of freshness [31]. This indicated that the raw tuna of both species were of high quality.

TVN content of all canned samples were significantly ($p < 0.05$) increased after canning. The increases in TVN may be due to the thermal breakdown of TMAO during the cooking and sterilization steps [32]. It was found that if good quality raw material was used (25–30 mg TVN/100 g muscle) and a convenient sterilization treatment was applied, TVN of canned samples would be within the acceptable range (40 mg TVB/100 g muscle) [33]. It was noticed that, through mackerel tuna treatments, M4 had the lowest TVN value indicating that pre-packing treatment led to a significant ($p < 0.05$) decrease in TVN value.

TMA is predominantly considered as a freshness index for fish. It is mainly generated during post mortem as a result of bacterial reduction of TMAO and by endogenous enzymes [29]. Initial levels of TMA in raw albacore and mackerel tuna were very low (1.09 and 2.18 mg N /100g), indicating limited bacterial growth before freezing and that the tuna meat used in the study was in fresh condition. A significant ($p < 0.05$) increase of TMA content was found in all canned samples as compared to raw tuna. The increase in TMA content in canned samples can be explained as a result of TMAO breakdown during the thermal treatments [34]. On the other hand, among canned mackerel tuna samples, a significant ($p < 0.05$) differences were found between treatment M4 and the other treatments. This decrease in TMA content may be due to soaking treatment prior to canning that may reduce TVN and subsequently TMA.

Since quality deterioration of fish muscle is related to lipid hydrolysis and oxidation, determination of FFA, peroxide (PV) and TBA values were needed to evaluate initial conditions and to assess any changes after canning (Table 3). The FFA contents were 3.22 and 2.85% (% as Oleic acid) for raw albacore and mackerel tuna, respectively. Peroxide values were 2.67 and 1.4 (meq O2/kg oil) for raw albacore and mackerel tuna, respectively. The initial FFA levels and peroxide values for both raw albacore and mackerel tuna were in the range of those reported by Aubourg [32] for albacore & Maheswara, et al. [8] for mackerel tuna. This result indicated that lipid hydrolysis and oxidation were beginning in the fresh samples. The quality guideline for edible crude fish oil recommended that the FFA and PV contents should be in the range of 2–5% and 3–20 meq O2/kg, respectively [35]. Raw tuna contained TBA values of 2.12 and 0.82 mg malonaldhyde/kg for raw albacore and mackerel tuna, respectively. The TBA value of raw tuna was well below the acceptable limit of 4.5 mg of malonaldehyde/kg of fish meat [36].

It is obviously cleared that thermal treatment caused a significant ($p < 0.05$) increase in FFA, PV and TBA values in the canned tuna samples of both species. This increase is probably due to the breakdown and oxidation of fish lipids occurred during thermal process. Previous studies reported a significant formation of FFA occurred during the sterilization of albacore and mackerel tuna [8,32]. Nevertheless, the PV value of all samples did not exceed the upper limit of 5 meq O2/kg lipid that indicates that fish products are not suitable for human consumption [37]. Heavy metals found in tuna tissue such as lead and mercury can also be involved in lipid oxidation [38]. Numerous studies have assured that during canning process, pressure increases the lipid oxidation rate, mainly due to the moisture content and/or metal ions liberated from protein complexes during pressure treatment [39]. Stephen, et al. [28] reported that during tuna caning, the increase in the temperature over 115°C had increased TBA values. Naseri, et al. [40] found a considerable increase of TBA values in silver carp canned with sunflower oil, soybean oil and brine. Among canned mackerel tuna treatments, M3 seemed to have the highest ($p < 0.05$) values of FFA, PV, and TBA. This may be due to the effect of vinegar (added to tuna meat during filling) which may have contributed to more hydrolysis and breakdown of fatty acid chains, resulting in more FFA content which exposed directly to the effect of pressure and heat leading to increase the values of PV and TBA. On the contrary, M2 recorded the lowest ($p < 0.05$) levels of FFA, PV, and TBA. This may be due to the effect of aromatized oil (added to tuna meat during filling) that may contain some phenolic compounds which act as antioxidants.

Fatty Acids Fraction

Marine lipids have long been known for its beneficial health effects. The fact that marine lipids contain significant quantities of polyunsaturated fatty acids (PUFA) such as eicosapentaenoic acid (EPA, C20:5 n-3) and docosahexaenoic acid (DHA, C22:6 n-3) makes it matchless compared to other lipid sources [41].

The FA composition of raw and canned tuna species is given in Table 4. In raw tuna samples, 26 and 28 fatty acids were identified for albacore and mackerel tuna, respectively. The major fatty acids were C16:0; C18:0; C18:1,n-9; C22:0

and DHA (C22:6, n-3). These fatty acids are accounted for approximately 78.63% and 68.60 % of total fatty acids for albacore and mackerel tuna, respectively. Similar fatty acid profiles were reported in studies on albacore tuna [42] and mackerel tuna [24].

F. A (%)	(*Thunnus alalunga*)		(*Euthynnus affinis*)				
	Raw	A	Raw	M1	M2	M3	M4
C14:0	2.27	1.07	4.82	4.4	4.33	3.96	4.28
C14:1	0.11	0	0.15	0	0.1	0	0.09
C15:0	0.66	0.46	0.85	0.3	0.5	0.18	0.3
C16:0	19.21	16.4	22.75	19.5	18.6	18.44	18.12
C16:1	3.55	1.3	4.8	4	3.9	3.73	4.32
C16:2n4	1.18	0.82	0.87	0.51	0.67	0.68	0.7
C17:0	1.21	0.4	1.55	0.9	1.02	0.88	0.63
C17:1	0.8	0.12	0.75	0.17	0.35	0.11	0.48
C18:0	5.54	5.22	8.38	7.89	7.61	7.66	7.5
C18:1 n7	0	0	5.1	5.16	5.4	4.86	4.98
C18:1 n9	23.42	28.8	10.43	11.24	14.04	13.2	15.1
C18:2 n6	1.28	8.33	1.25	14.11	14.06	14.7	14.83
C18:3 n6	0	0	0.21	0	0	0	0
C18:3 n3	0.37	3.05	0.56	0.47	0.64	0.4	0.5
C18:4 n3	0.52	0.5	0.45	0.38	0.41	0.33	0.43
C20:0	0.41	0	0.49	0.11	0.36	0.15	0.08
C20:1	1.33	1.1	0.57	0.48	0.31	0.42	0.61
C20:2	0.37	0	0.2	0	0.11	0	0.08
C20:4	1.39	0.8	2.64	2.02	2.37	2.42	2.2
C20:3n3	0.16	0	0.12	0	0	0	0
C20:5 n3	0.42	0	0.27	0.07	0.18	0.03	0.11
C22:0	5.11	1.93	4.82	1.58	1.5	1.64	1.41
C22:1	0.06	0	0.07	0	0	0	0
C22:3n3	0.15	0	0.08	0	0	0	0
C22:4n6	0.12	0	0.12	0	0	0	0
C22:5n3	1.68	1.31	2.39	2	2.11	1.86	2.28
C22:6n3	25.34	19.24	22.23	17.62	18.8	17.55	18.57
C24:0	1.27	0.4	1.83	0.96	0.91	0.78	0.58
∑ SFA	35.69	25.88	45.48	35.64	34.83	33.69	32.9
∑ MUFA	29.27	31.32	21.85	21.05	24.1	22.32	25.58
∑ PUFA	32.97	34.05	31.39	37.18	39.35	37.97	39.7
∑n-3	28.21	24.1	25.83	20.47	21.96	20.14	21.78
∑ n-6	1.4	8.33	1.58	14.11	14.06	14.7	14.83
n-3/n-6	20.12	2.89	16.35	1.45	1.56	1.37	1.47
P/S	0.92	1.32	0.69	1.04	1.13	1.13	1.21

Table 4: The fatty acid composition (% total fatty acids) of raw and canned tuna.

The major saturated fatty acid was palmitic acid (C16:0), content of which varied from 19.21% to 22.75% for albacore and mackerel tuna, respectively. Stearic acid content (C18:0) recorded 5.54% and 8.38% for albacore and mackerel tuna, respectively. These values were similar to those described for marine fish species [43]. Meristic acid content (C14:0) was higher (4.82 %) in mackerel tuna than in albacore tuna. The rest of the saturated fatty acids (C17:0, C15:0, C20.0 and C24:0) were found in minor quantities in both tuna species.

Among the monounsaturated fatty acids (MUFA), Oleic acid (C18:1 n9) was found to be the major constituent (23.42% and 10.43% in albacore and mackerel tuna, respectively). Similar results were found for albacore [32] and mackerel tuna [44]. Concerning PUFA, the principal components were DHA (25.34 % and 22.23%) in albacore and mackerel tuna, respectively. High DHA content in albacore tuna may be attributed to cooler water temperatures that affecting accumulation of subcutaneous fat, in addition to feeding on prey containing higher DHA content than species existing in warmer waters [23]. Furthermore, it has been thought that DHA is progressively accumulated during massive migration of many tuna species such as albacore, skipjack and yellowfin [45]. In case of mackerel tuna, Saito, et al. [23] stated that E. affinis contains high DHA level (21.3%) as similar as that of other migratory tuna species belonging to the tribe Thunnini. Unexpectedly, EPA content was found in very small proportions (0.42% and 0.27% in albacore and mackerel tuna, respectively). Wheeler & Morrissey [42] found that for albacore tuna, total DHA and EPA content were ranged from 1.4 and 0.6 g/100 g tissue to 2.3 and 0.9 g/100 g tissue. Several studies investigated the lipid content and fatty acid distribution in tuna tissue, they concluded that it depends on different factors among and within the species according to environmental conditions such as the water temperature and salinity, life stage, diet and habitat, season, but also relay on that whether the fishes are carnivorous, herbivorous or omnivorous (Olgunoglu, 2017). In general, the SFAs and MUFAs are normally plentiful in fish from warm or temperate zones, whereas PUFAs show higher contents in fish from cold zones [46].

In Table 5, fatty acid composition is summarized, according to the degree of unsaturation, in groups of saturated, monounsaturated and polyunsaturated fatty acids, and specifically n-3 PUFA, such as DHA and EPA. Total omega-3 percentage was 28.21 % and 25.83% for raw albacore and mackerel tuna, respectively. Other studies recorded a range of total ω-3 fatty acids from 29.1% to 43.8% for albacore tuna [32]. These values are higher than those recorded for salmon (17.6% to 28%) [47]. The ratio of n-3: n-6 is a very helpful indicator to determine the nutritional value of fish lipid because of their health effects. The ratio of n-3: n-6 was 20.12 and 16.35 for raw albacore and mackerel tuna, respectively. These results are in agreement with those recorded for marine fish species which generally ranged between 5 and 19.5 [21]. The ratio of PUFAs: SFAs was 0.92 and 0.69 for raw albacore and mackerel tuna, respectively. The proportion of PUFAs: SFAs and the ratio of n-6: n-3 are important indicators for optimal balance of metabolism within the body. To avoid cardiovascular disease, the ratio of PUFAs: SFAs consumed should be < 0.45 and within the PUFAs, and the n-6: n-3 ratio should not be more than 4.0 [21].

After canning, the SFA content decreased in both tuna species. The SFA decreased to 25.88% for canned albacore (A) and to 35.64 %, 34.83%, 33.69 % and 32.9% for canned mackerel tuna treatments, respectively. This loss was particularly due to C14:0, C16:0, C18:0 and C22:0. The MUFA content decreased initially upon canning due to the decrease in C16:1 and C17:1 fatty acids and later, increased due to the absorption of C18:1 fatty acid from sunflower oil used as filling medium. The PUFA content also showed an increase to a maximum of 39.7%. These results are in accordance with those obtained by Medina, et al. [48] who found a high content of PUFA in canned tuna. The reason for high PUFA is mainly due to the uptake of C18:2, γC18:3, C18:3 and C20:4 fatty acids from filling oil as reported by Aubourg [32]. Complete destruction of EPA fatty acid (C20:5) was found in canned albacore, whereas, a noticed decrease was found in canned mackerel treatments. For mackerel tuna treatments, the loss of C20:5 was less in tuna processed with aromatized sunflower oil (M2) and pre-soaked tuna (M4) than the loss of C20:5 in the other treatments. In both tuna species, DHA fatty acid C22:6 decreased in all treatments. These results are confirmed with Aubourg [32] who pointed out that there was a proportional reduction in C14:0, C16:0, C20:5 and C22:6 fatty acids in canned albacore. Canned tuna of both species contained high percentage of the ω-3 fatty acid (20.14–24.10%) due to the high content of DHA fatty acid.

Heavy Metals

Results related to heavy metals (Cd, Pb and Hg) levels (mg/kg, wet weight) in canned tuna samples as compared to imported tuna (C1 and C2) are presented in Table 5. Data revealed that the highest mean levels of cadmium were recorded for C2 (0.14) in particular and to a lesser extent in M2 treatment (0.05). Concentration of cadmium in tuna treatments were found to be safe for human consumption, there was no tuna sample showed cadmium concentration exceeding permissible limits stipulated by the Commission of the European Communities [49] of 0.05 mg Cd/kg. However, the peak permitted values stipulated by Egyptian Organization Standardization and Quality Control [50] is 0.1 mg Cd/kg. The world health organization/ Food and Agricultural Organization [51] have established a provisional

tolerable weekly intake (PTWI) of 490 µg of cadmium for 70 kg person. This amount is equivalent to 7 µg Cd / kg body weight/ week.

Treatment		Cd (mg/kg)	Pb (mg/kg)	Hg (mg/kg)
Albacore	A	0.0299	0.3438	0.011
	C1	0.0219	0.3816	0.0034
Mackerel	M1	0.0295	0.1857	0.0046
	M2	0.0475	0.5968	0.007
	M3	0.0295	0.331	0.0031
	M4	0.014	0.3411	0.0001
	C2	0.143	0.7216	0.0008
Maximum permissible limit (mg/kg) [a]		0.1	0.1	0.5

Table 5: Heavy metals (Cd, Pb and Hg) levels (mg/kg) in canned tuna as compared to imported canned tuna.
[a]Egyptian Organization of Standardization [50]
C1 = imported albacore tuna, C2 = imported skipjack tuna.

The total lead concentration (mg/kg) in all examined samples was ranged from 0.19 for M1 to 0.72 for C2. The total led limit, regulated by EOSQ [50] is 0.1 mg/kg of fish. Lead concentration in all samples exceeded the prescribed legal limits of EOSQ. Even though, it was found that all proceeded samples contained less lead levels than imported samples for both fish species. These results were similar to those recorded by Saad, et al. [52]. Lead levels in edible fish tissue over permissible limits are implicated in chronic lead toxicity results in anemia, abdominal pain, encephalopathy, renal damage, palsy. Recently lead is considered as one of immune suppressive agents in animal and human [49].

The total mercury concentrations (mg/kg) in all tuna samples were ranged from 0.0008 to .011. The Food and Drug Administration (FDA) has set a maximum total mercury level of 1 (mg/kg wet weight) in fish [53]. In Egypt, the total mercury limit, regulated by EOSQ [50] is 0.5 (mg/kg wet weight) of fish. On this basis, all tuna samples had mercury concentrations lower than the prescribed legal limits. The differences in total mercury concentration between different fish species are probably due to the variation in their behavior and habits during migration and feeding, as well as various metabolic and excretion rates. Moreover, they possess different spot in the marine food. Rasmussen & Morrissey [27] reported similar observations. A joint advisory published in 2004 by the FDA /Environmental Protection Agency warned pregnant women and young children to minimize their weekly consumption of albacore tuna [54]. The advisory was based on canned albacore tuna reported to contain 0.35 ppm mercury (action limit is 1 ppm methylmercury) [53].

Color

Color parameters represented by L* (lightness), a* (redness), b* (yellowness) of canned tuna from both tuna species were measured and the results are tabulated in Table 6. The results showed that L*, hue angel and whiteness recorded significantly ($p<0.05$) lower values for the processed albacore compared with the control sample (C1). While a* value recorded significantly ($p<0.05$) higher value for the processed albacore indicating a decrease in the greening (the industrial name given for the off-color reaction in cooked tuna) compared to control. Results revealed an increase of the greening in control sample compared to canned albacore (A). This may be due to the severity of thermal treatment in case of imported tuna. According to Naughton, et al. [55] the color of the reduced hemochrome is the normal pink that is considered commercially desirable. A green pigment was produced when tuna myoglobins, TMAO and cysteine were heated together. One off-color was due to the oxidation of the ferri-state of the desirable ferrohemochromes, the pigments responsible for normal tuna color [56]. It turns out that L*, a*, and b* values of the control (C1) resulted in a lighter and whiter muscles than that of canned albacore (A). These results are probably due to the differences between manufacturing steps used prior to canning and conditions of thermal treatment (pressure &temperature) used in this study and those used for commercial production. According to Ramirez-Suarez & Morrissey [16] color parameters L, a, and b of canned albacore influenced by processing conditions such as pressure and holding times. As the pressure and/ or holding time increases, a lighter and whiter product is obtained.

Treatments		*L*	*a**	*b**	*Chroma*	*Hue*	Whiteness
Albacore	A	74.84 [b] ±0.37	3.21 [a] ±0.15	21.26 [a] ±0.52	66.90 [b] ±0.12	74.84 [b] ±0.37	3.21 [a] ±0.15
	C 1	76.90 [a] ±0.51	2.33 [b] ±0.16	22.48 [a] ±0..89	67.67 [a] ±0.34	76.90 [a] ±0.51	2.33 [b] ±0.16
Mackerel	M1	55.66 [d] ±0.67	10.26 [c] ±0.58	12.98 [b] ±0.78	52.66 [c] ±0.34	55.66 [d] ±0.67	10.26 [c] ±0.58
	M2	57.01 [c] ±0.05	15.34 [a] ±0.11	15.92 [a] ±0.57	51.65 [d] ±0.26	57.01 [c] ±0.05	15.34 [a] ±0.11
	M3	53.18 [e] ±0.35	7.77 [e] ±0.23	9.59 [c] ±0.25	51.58 [d] ±0.42	53.18 [e] ±0.35	7.77 [e] ±0.23
	M4	59.08 [b] ±0.41	13.11 [b] ±0.39	16.18 [a] ±0.58	54.08 [b] ±0.6	59.08 [b] ±0.41	13.11 [b] ±0.39
	C 2	71.75 [a] ± 0.77	9.24 [d] ±0.63	15.74 [a] ±0.44	66.36 [a] ±0.63	71.75 [a] ± 0.77	9.24 [d] ±0.63

Table 6: Color parameters of canned tuna as compared to imported canned tuna.
C1 = imported albacore tuna, C2 = imported skipjack tuna.
Values with different superscripts letters within the same column for the same tuna species are significantly difference ($p < 0.05$).

Generally, L∗ value was used to demonstrate the variations in lightness and even whiteness [57]. Results obtained for canned mackerel tuna illustrated that for all color parameters, significant ($p<0.05$) differences were found between all canned treatments and the control sample (C2). Among all treatments, treatment M4 significantly ($p<0.05$) showed to be lighter than other treatments as L* value was higher. Significant differences ($P<0.05$) of whiteness were observed between untreated (M1) and treated samples. However, treatment M4 was whiter than treatment M2 and treatment M3. This is probably due to the role of ascorbic acid as a reducing agent on the reduction of the myoglobin (pigment of muscle) to more stable composite which is ferryl-myoglobin. The latter in time can be transformed into metmyoglobin through reduction. These results agree with Chaijan & Panpipat [56] who reported that the green color development could be prevented by the addition of a suitable reducing agent into tuna meat prior to cooking.

Furthermore, peroxides formation during lipid oxidation is an important element associated with greening of yellow fish tuna (Neothunnus macropterus) as reported by Chaijan & Panpipat [56]. The oxidation of unsaturated fatty acids (USFA) to peroxides is stimulated by heme complexes and this reaction is accompanied by the oxidation of the heme. Consequently, the resulting oxidized fatty acids (hydroperoxide) play a significant role in the impairment of heme pigments particularly myoglobin. Naughton, et al. [55] also found that a high peroxide content give rise to the off-color and green in tuna flesh. Indeed, results of the PV and TBA values of processed canned tuna supported the color results obtained for both tuna species.

Detection of *Cl. botulinum*

Foodborne botulism occurs when food containing botulinum toxin was ingestion. The toxin is produced by *Cl. botulinum* in foods that have not been properly handled or canned as canned fish, meat and vegetables [58]. Multiplex PCR has the advantage of simultaneous detection of several clostridia possessing type A, B and E botulinum neurotoxin genes. Therefore, it can be used to test food samples in case of outbreaks or in regular surveillance inspections [59]. Results of Multiplex PCR analysis revealed that all canned tuna samples were negative for *Cl. botulinum*. Indicating sanitary handling and good hygiene practices were applied before and during tuna canning process and adequate thermal treatment and its efficiency to eliminate *Cl. botulinum* spores. Dowell [60] declared that spores of *Cl. botulinum* are heat-resistant, easily surviving 100 ºC at one atmosphere for five or more hours. However, spores can be destroyed by heating to 120ºC for five minutes.

Organoleptic Evaluation

The organoleptic scores of different canned tuna samples are given in Table 7. Results declared that for canned albacore, there were no significant differences ($p > 0.05$) between treatment A and control (C1) sample in sensory scores for all organoleptic characteristics except for the taste characteristic where the processed treatment (A) was significantly ($p < 0.05$) higher than the control sample. This is probably due to the acquisition of tuna meat for metallic taste from cans or may be due to the effect of the severe thermal treatment on taste properties in case of control sample. Generally, results indicate that sensory properties of canned albacore tuna in this study are similar in its quality to a large extent of those imported. As for mackerel tuna, data revealed that there were no significant differences ($p > 0.05$) in the appearance, odor, texture and overall palatability of treatment M4 and the control sample (C2). However, taking into consideration the diversity of tuna species, taste scores for control sample recorded higher ($p < 0.05$) values compared to canned mackerel tuna treatments. On the other hand, significant differences ($p < 0.05$) were found among mackerel tuna treatments. Moreover, M4 recorded higher

($p < 0.05$) values for all sensory characteristics compared to other treatments. It was found that tuna meat soaked in solution contain ascorbic acid, wheat flour and vinegar had a better appearance as it works on lightening the brownish color of the fish meat, whereas in treatments M1, M2 and M3, the brownish color of the meat was visible through the oil. Taste, odor and overall palatability were better in M4 indicating that this treatment achieved the target goal of improving the sensory properties of mackerel tuna meat in order to suit consumer taste.

Treatments		Appearance	Taste	Odor	Texture	Palatability
Albacore	A	$8.03^{a} \pm 0.24$	$8.26^{a} \pm 0.34$	$7.88^{a} \pm 0.32$	$8.01^{a} \pm 0.15$	$8.05^{a} \pm 0.16$
	C1	$8.15^{a} \pm 0.71$	$7.7^{b} \pm 0.48$	$7.75^{a} \pm 0.19$	$8.00^{a} \pm 0.19$	$8.20^{a} \pm 0.42$
Mackerel	M1	$5.50^{c} \pm 0.22$	$5.80^{e} \pm 0.23$	$6.17^{c} \pm 0.34$	$6.41^{c} \pm 0.2$	$6.33^{c} \pm 0.32$
	M2	$6.32^{b} \pm 0.55$	$6.61^{c} \pm 0.35$	$6.70^{b} \pm 0.27$	$6.30^{c} \pm 0.28$	$7.15^{b} \pm 0.23$
	M3	$6.20^{b} \pm 0.35$	$6.30^{d} \pm 0.29$	$6.33^{c} \pm 0.37$	$7.16^{b} \pm 0.22$	$6.55^{c} \pm 0.24$
	M4	$7.85^{a} \pm 0.51$	$8.00^{b} \pm 0.13$	$8.06^{a} \pm 0.19$	$7.90^{a} \pm 0.29$	$8.20^{a} \pm 0.23$
	C2	$8.10^{a} \pm 0.21$	$8.30^{a} \pm 0.32$	$7.84^{a} \pm 0.16$	$8.00^{a} \pm 0.2$	$8.30^{a} \pm 0.18$

Table 7: Organoleptic scores of canned tuna samples.
C1 = imported albacore tuna, C2 = imported skipjack tuna.
Values with different superscripts letters within the same column for the same tuna species are significantly difference ($p < 0.05$).

Production Cost

Production costs will vary depending on local' conditions (prices. wages, etc.). The estimated production cost (EP) for processed tuna of both species as compared to imported tuna were calculated according to the raw materials prices at the processing time as presented in Table 8.

Data shows a huge difference in the production cost of canned tuna between the processed tuna and the imported samples. It has been proved that local canning of tuna can reduce the cost of production and thus the final price of canned tuna, as well as reduce the depletion of foreign currencies necessary for the import.

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Ingredients	Jar	Oil	Salt	Tuna white flesh/kg	
				Albacore	Mackerel
Price (EP)	1.25	0.36	0.01	81.41	70.45
Weight of imported tuna	Albacore tuna (Net wt. ≈ 200 g, Drained wt. 70 %)			Mackerel tuna (Net wt. ≈ 140 g, Drained wt. 70%)	
Imported tuna (EP)	48.85			15	
Processed tuna (EP) *	13.017			8.52	

Table 8: Production cost (EP) of canned tuna.
*Estimated production cost corresponding to the same weight of imported tuna.

Conclusion

In this study, two types of tuna: albacore and mackerel tuna were canned. It turns out the possibility to produce local canned albacore with luxury specifications comparable to their imported counterparts. In addition, results demonstrate the possibility of utilizing mackerel tuna, which is available at low prices, to produce local canned tuna with acceptable quality specifications. In order to overcoming the unacceptable taste and flavor of mackerel tuna, several pre-canning treatments have been made in order to improve the quality characteristics. Results showed that soaking of mackerel tuna flesh in a solution containing wheat flour, ascorbic acid and vinegar before canning resulted in an improvement of chemical and sensory quality properties. It has been proved that local canning of tuna can reduce the

production costs and thus the final price of canned tuna, as well as reduces the depletion of foreign currencies necessary for the import.

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Declaration of Competing Interest

The author declares no conflict of interest.

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