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Effects of Different Final Cooking Methods on Physico-chemical Properties of Breaded Fish Fillets

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Abstract: Breaded black pomfret (*Parastromateus niager*) fillets were pre-fried for 30 sec in sunflower oil and palm olein and stored at -20°C for one week prior to the final cooking. They were finally cooked by microwave, oven and deep-fat frying. Moisture loss, fat uptake, fatty acid, texture and color of the pre-fried and all completely cooked samples were evaluated. Final cooking methods resulted in the change in the fat and fatty acid composition of the pre-fried fillets. The least changes were observed in the oven cooked samples. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in oven cooked samples were significantly ($p<0.05$) higher than the other cooked samples. They also had lower ratio of n-6/n-3 and lower thermal oxidation. The hardness was found highest in the final fried and lowest in the microwaved samples. Significant differences on the color of the final cooked samples were obtained among the different cooking methods.

Key words: Cooking methods, sunflower oil, palm olein, breaded fish fillets, texture, color

INTRODUCTION

Pre-fried frozen battered and breaded foods are popular because of their unique texture and flavor properties (Fiszman and Salvador, 2003), the crispiness is the most appreciated characteristics. Pre-frying stage is commonly carried out at the manufacturing end and the final cooking is carried out at the consumers' end. Pre-frying process is normally accomplished by frying at 180-200°C for about 30 sec to coagulate the coating materials around the food substrate as such a consistent coating is achieved before the subsequent freezing (Sanz *et al*., 2004). The pre-fried frozen battered and breaded foods are finally cooked by various methods. Microwave, oven cooking and deep-frying are among the methods employed for the final cooking. The surface appearance, texture and fat content of these foods can be affected by the final cooking methods (Sunderman, 1983).

The beneficial effect of seafood consumption has been mainly ascribed to its n-3 fatty acids, i.e., the eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Arts *et al*., 2001; Broadhurst *et al*., 2002). However, this beneficial effect could be lessened since these fatty acids can be affected during the heating process (Michail *et al*., 2007). The effects of different cooking methods on the fat content and fatty acid composition of non-breaded and non-pre-fried fish have been investigated by Agren and Häninen (1993), García-Arias *et al*. (2003) and Nalan *et al*. (2004). Proximate composition was investigated in cooked (baked, grilled, microwaved and fried) African catfish by Beyza and Akif (2009) and reported that the protein and ash contents increased, while moisture content decreased in all cooked fish. The fat content increased only in fried fillets. The fatty acid composition of Atlantic salmon after pan-frying with a novel EPA+DHA enriched margarine was

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examined by Alex *et al.* (2009). Pan-frying without oil, with canola oil and with stick margarine resulted in significantly lower levels of EPA+DHA (738±181, 723±94 and 704±75 mg/100 g salmon, respectively) as compared with raw salmon (1202±191 mg/100 g salmon). Pan-frying with EPA+DHA margarine prevented the decrease of EPA+DHA in salmon (924±162 mg/100 g salmon).

The influence of seven cooking methods (boiling, conventional baking, microwave baking, grilling, deep-frying in soybean oil, canola oil, or partially hydrogenated vegetable oil) on the oxidation, proximate and fatty acid composition of silver catfish (*Rhamdia quelen*) fillets was evaluated by Jucieli *et al.* (2008). They found that all the treatments reduced moisture and increased the protein content. Boiling, baking and grilling did not affect the silver cat fish fillets fatty acid composition. Frying in canola oil increased n-3/n-6 ratio, while frying in soybean oil increased the general polyunsaturated fatty acid content and frying in hydrogenated vegetable oil incorporated trans fatty acids in the fillets.

However, the quality attributes of the pre-fried and final cooked breaded fish fillets has not been reported. Therefore, the aim of this study was to evaluate the effects of the three selected final cooking methods on the physical and chemical properties of the fillets focusing on the changes in the fat content, fatty acid composition, texture and color of the pre-fried breaded black pomfert (*Parastromateus niager*) fillets.

MATERIALS AND METHODS

Fresh black pomfret (*Parastromateus niger*) weighting 340±5 g and 23±2 cm in length were purchased from the local wholesale market (Pasar Brong) in Malaysia at Jun of 2006. The fish was manually filleted and washed under running tap water and dripped dried for 10 min. The fillets were packed in polyethylene bag, sealed and stored at -20°C. They were used within 2 weeks. Sunflower oil (LAM SOON edible oil SDN BHD, Malaysia) and palm oil (Seri Murni, Thinkglobal Food Processing- Malaysia) which were used for the frying were purchased local markets (Seri Kembangan, Malaysia). The ingredients for the breading materials (wheat flour, corn flour, salt and breadcrumbs) were purchased from the local supermarket.

Breading of Fillets

Batter formulation was prepared according to our experiences with ingredients recommended by (Fiszman and Salvador, 2003) but with slight modification. The batter consisted of 75% wheat flour, 24.5% corn flour and 0.5% salt. Water was added at the ratio of 1:1.4 dry ingredients to water. The ingredients and water were mixed in a kitchen blender (National, MX-897 GM) for 3 min. Frozen fillets were thawed overnight in the cold room (4°C). The surfaces of the thawed fillets were then dabbed with paper towel before dipping the fillets into the prepared batter and the excess batter was dripped off for 30 sec. Battered fillets were then coated with bread crumbs prior to pre-frying.

Pre-Frying

Pre-frying was carried out in a 3 L capacity deep-fryer (PHILUX, Model Df30AIT). The temperature of the frying oil was set at 180±2°C which was monitored with a metal thermometer. The fillets were fried for 30 sec in sunflower oil and palm olein. The oil was used only once. Two liter of oil was used for each batch of frying where one batch consisted of 12 fillets.

Final Cooking Methods

Microwave cooking was carried out in a microwave oven (Panasonic, MN-KS 73MF) at a frequency of 2450 MHZ set at high power. The oven cooking was carried out in a combination oven (Combi-CPC61, Model RATONAL) at 180°C in dry mode (no moisture) and for the deep-frying, the

same condition as the pre-frying step was employed. All the pre-fried frozen fillets were cooked to a core temperature of about 65-70°C (Garica-Arias *et al*., 2003). A thermo probe (Model HANNA Checketemh, Portugal) was used to measure the core temperature. It took 2.5, 7 and 3 min to reach the desired temperature for the microwave cooking, oven cooking and for the deep-fat frying, respectively. Once the fillets were cooked, they were cooled at room temperature for 10 min before any analysis was carried out.

Moisture and Fat Content Determinations

Moisture and fat content were determined by the oven and Soxhlet method (AOAC, 1990).

Fatty Acid Analysis

Lipid for Fatty Acid (FA) analysis was extracted according to Kinsella *et al*. (1977). Sodium methoxied and hexane were used for the preparation of the Fatty Acid Methyl Esters (FAME). The fatty acid methyl ester of samples was analyzed by the gas chromatography (HEWLET PACKARD, HP 6890 Series, USA) which was equipped with Flame Ionization Detector (FID). A capillary column (SGE, 50 m length and 0.22 mm diameter) was used to separate the FA components. The temperature of the injection port and detector was set at 260°C. The oven temperature was programmed to increase from 50 to 230°C at a rate of 4°C per min. One microliter of each sample was injected manually in duplicates with the split 40. Fatty acid peaks in the samples were identified by comparing the retention times with that of the standard mixture of FAME (Supleco TM 37 component FAME MIX) which contained FAs of C4:0 to C22:6n-3.

Thermal Oxidation Determination

C22:6n-3/C16:0 ratio of the samples was used as thermal oxidation indicator during different final cooking methods was determined according to García-Arias *et al*. (2003).

Texture Profile Measurement

Texture Profile Analysis (TPA) was evaluated using a Texture Analyzer TA-XT2 (Stable Micro Systems, Surrey, England) according to the manual provided by the manufacture. A load cell of 30 kg and a cylindrical plunger P/0.5 (12.5 mm diameter) was used. The plunger punched into the fillets at a constant speed of 1 mm sec^{-1} until it reached 80% of the sample height (Anna *et al*., 2003). Six breaded fillets with 11±0.5 cm length and about 4 cm wide were used for the sampling. Two measurements were made in the thickest part of the fillets at about 3 cm apart.

Color Measurement

Color of the samples was measured using a minolta chroma meter (CR-300 Minolta, Japan). The color readings were expressed by CIE (L* a* b*) system (Rafael *et al*., 2004). L*, a* and b* indicates whiteness/darkness, redness/greenness and blueness/yellowness, respectively. The maximum value for L* is 100, which would be a perfect reflecting diffuser. The minimum for L* would be zero, which would be black. The a* and b* axes have no specific numerical limits. Positive a* is red and negative a* is green. Positive b* is yellow and negative b* is blue. Six breaded fillets were used for each treatment and the L* a* b* values were measured directly on three different positions on both sides of the fillets.

Statistical Analysis

The statistical analysis for the one-way and two-way Analysis of Variance (ANOVA) were performed using MINITAB version 14 software (MINITAB Inc., Pennsylvania, USA). The Tukey's test was used for mean comparison if a significant ($p<0.05$) variation was found.

RESULTS

Effect of Final Cooking Methods on the Fat and Moisture of the Samples

These values varied from 8.8 to 13.5 g/100 g for the fat content and 32 to 70 g/100 g for the moisture. All finally cooked samples had higher fat contents and lower moisture contents as compared to the pre-fried samples. The biggest moisture loss and fat uptake was observed in the deep-fat fried samples. Slightly higher changes in the fat and moisture content were obtained in the microwaved samples as compared to oven cooked samples (Table 1).

Effect of Final Cooking Methods on the Fatty Acid Composition of the Samples

The pre-fried samples had different fatty acids compositions. C16:0, C18:1 and C18:2n-6 was the main fatty acids in both pre-fried samples. Sunflower oil pre-fried samples had significantly higher MUFA and PUFA than palm olein pre-fried samples. During the different final cooking processes, the concentration of most of the fatty acids in the pre-fried samples were significantly ($p<0.05$) changed, although, the pattern of changes was not similar (Table 2). A slight decrease in the amount of the SFA and an increase in the amount of the MUFA were observed in all the final cooked samples. The change in the oven cooked samples was the least.

Final frying resulted in higher changes in the fatty acid composition of the samples as compared to the other two methods. This method markedly increased the content of oleic acid (C18:1n-9) and linoleic acid (C18:2n-6) in the samples. Oven and microwave cooking methods showed marginal change in the fatty acids composition.

Pre-fried samples in both oil had the same amount of EPA and DHA. These two fatty acids decreased dramatically by the final frying and microwave cooking. However, their values were not significantly ($p<0.05$) change by the oven cooking. The oven cooking method produced significantly ($p<0.05$) lower loss in the amounts of the EPA and DHA as compared to the microwave cooking.

Effect of Final Cooking Methods on n-6/n-3 Ratio of the Samples

The ratio of n-6/n-3 was significantly ($p<0.05$) higher in the sunflower oil pre-fried samples as compared to the palm olein pre-fried ones (Fig. 1). Pre-frying followed by final frying and microwave cooking significantly ($p<0.05$) increased the n-6/n-3 ratio. However, final cooking by oven method did not significantly change the ratio of n-6/n-3 of the samples fried in both oil.

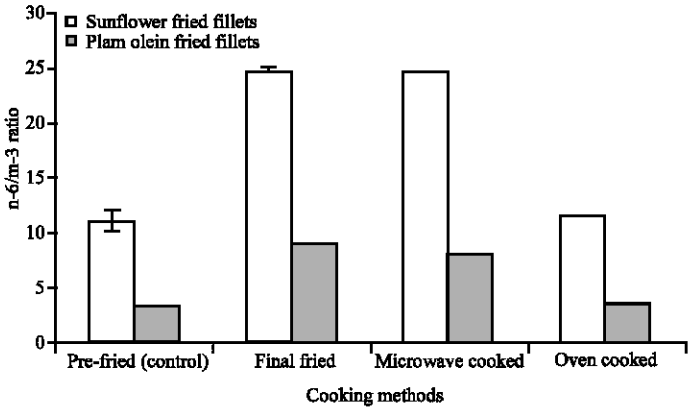

Fig. 1: The n-6/n-3 ratio of the pre-fried and final cooked samples

Table 1: Effects of different final cooking methods on the fat and moisture contents[1] of the pre-fried breaded fillets (g/100 g wet. weight)

	Pre-fried (control)		Microwave cooked		Oven cooked		Final fried	
Components	SO[2]	PO[2]	SO	PO	SO	PO	SO	PO
Moisture	57.70±0.40Aa	57.33±1.20Aa	45.47±0.40Ab	44.50±1.10Ab	56.28±1.65Ac	55.74±1.40Ac	35.00±0.45Ad	33.00±0.95Bd
Fat	8.80±0.10Aa	8.84±0.70Aa	9.95±0.30Ab	10.33±0.62Ab	9.10±0.12Ac	9.53±0.27Ac	10.75±0.36Ad	13.45±0.88Bd

[1]Values are Mean±SD of three measurements. Means with capital letter(s) in the same row are significantly ($p<0.05$) different between two frying oil for the same cooking method. Means with small letter(s) in the same row are significantly ($p<0.05$) different between final cooking methods for the same frying oil. [2]SO, PO-samples pre-fried in sunflower oil and palm olein, respectively

Table 2: Effects of different final cooking methods on the fatty acid composition[1] of the pre-fried breaded fillets (g/100 g fatty acid)

	Pre-fried (control)		Microwave cooked		Oven cooked		Final fried	
Fatty acids	SO[2]	PO[2]	SO	PO	SO	PO	SO	PO
C12:0	Nd[3]	0.38±0.03a	nd*	0.290±0.00Bb	nd*	0.36±0.02Ba	nd*	0.33±0.00Ba
C14:0	0.75±0.40Aa	1.45±0.06Ba	0.20±0.00Ab	0.950±0.01Bb	0.64±0.01Ac	1.35±0.04Ba	0.18±0.00Ab	0.97±0.00Bb
C15:0	0.56±0.01Aa	0.51±0.01Aa	0.19±0.00Ab	0.240±0.00Ab	0.34±0.07Ac	0.47±0.01Ba	0.23±0.00Ad	0.28±0.00Ab
C16:0	11.94±0.46Aa	35.80±0.39Ba	8.49±0.17Ab	35.790±0.22Ba	10.59±0.14Ac	36.37±0.10Ba	8.78±0.06Ab	35.63±0.02Ba
C17:0	0.51±0.01Aa	0.37±0.00Ba	0.15±0.00Ab	0.140±0.00Ab	0.44±0.00Ac	0.38±0.00Aa	0.13±0.00Ab	0.15±0.00Ab
C18:0	0.17±0.03Aa	4.60±0.07Ba	0.36±0.03Ab	5.160±0.00Bb	1.00±0.10Ac	4.32±0.08Ba	0.65±0.01Ad	5.17±0.02Bb
Σ SFA	13.93±0.49Aa	43.10±0.40Ba	9.07±0.17Ab	42.600±0.22Ba	11.85±0.17Ac	43.12±0.08Ba	9.34±0.07Ab	42.52±0.01Ba
C14:1	0.34±0.05Aa	0.24±0.03Ba	0.04±0.00Ab	0.070±0.00Ab	0.29±0.04Ac	0.24±0.03Aa	0.07±0.00Ab	0.10±0.00Bb
C16:1	0.39±0.00Aa	0.25±0.00Ba	0.10±0.00Ab	0.051±0.00Ba	0.23±0.01Ac	0.23±0.00Ac	0.08±0.00Ab	0.07±0.00Aa
C18:1n-9	43.36±0.27Aa	39.72±0.44Ba	48.24±0.92Ab	42.200±0.05Bb	45.70±0.29Ac	40.66±0.34Ba	51.20±0.25Ad	42.48±0.08Bb
C20:1	5.32±0.01Aa	4.77±0.05Aa	3.75±0.02Ab	4.200±0.02Ab	5.42±0.69Ac	4.90±0.00Ba	3.78±0.02Ab	4.21±0.01Ab
C24:1	0.47±0.00Aa	0.36±0.01Aa	0.21±0.00Ab	0.140±0.00Bb	0.42±0.00Ac	0.40±0.00Ab	0.18±0.00Ab	0.14±0.00Aa
Σ MUFA	49.90±0.20Aa	45.35±0.46Ba	52.35±0.35Ab	46.950±0.01Ba	51.68±0.32Ac	46.28±0.10Ba	55.32±0.30Ad	46.71±0.01Ba
C18:2n-6c	31.64±0.07Aa	8.30±0.15Ba	34.54±0.95Ab	8.930±0.01Ba	32.17±0.08Ab	8.83±0.04Ba	32.91±0.07Ab	8.96±0.00Ba
C20:4n-6	0.91±0.02Aa	0.55±0.02Aa	0.39±0.01Ab	0.320±0.00Ab	0.67±0.01Ac	0.46±0.01Bc	0.35±0.00Ab	0.28±0.00Ab
C20:5n-3	0.65±0.17Aa	0.42±0.02Aa	0.12±0.01Ab	0.130±0.01Ab	0.38±0.00Ac	0.41±0.00Ac	0.16±0.00Ab	0.11±0.00Ab
C22:6n-3	2.29±0.07Aa	2.34±0.05Aa	1.30±0.018Ab	0.990±0.02Bb	2.44±0.06Aa	2.14±0.01Aa	1.17±0.01Ab	0.91±0.00Bb
Σ PUFA	35.49±0.34Aa	11.70±0.14Ba	36.34±0.98Ab	10.370±0.05Bb	36.17±0.98Ab	11.45±0.49Ba	34.60±0.08Aa	10.26±0.00Bb
Σn-6	32.55±0.09Aa	8.83±0.14Ba	34.90±0.96Aa	9.240±0.01Bb	33.35±0.62Aa	9.29±0.02Bb	33.26±0.06Aa	9.24±0.00Bb
Σn-3	2.95±0.25Aa	2.75±0.03Aa	1.41±0.02Ab	1.030±0.04Bb	2.83±0.07Aa	2.55±0.01Aa	1.34±0.01Ab	1.02±0.00Bb
PUFA/SFA	2.56±0.12Aa	0.28±0.02Ba	4.03±0.06Ab	0.240±0.00Bb	3.05±0.00Aa	0.26±0.01Ba	3.71±0.02Ab	0.24±0.00Bb

[1]Values are Mean±SD of three measurements. *Means with capital letter(s) in the same row are significantly ($p<0.05$) different between two frying oil for the same cooking method. Means with small letters in the same row are significantly ($p<0.05$) different between final cooking methods for the same frying oil, [2]SO, PO-samples pre-fried in sunflower oil in palm olein, respectively, [3]Nd: Not detected

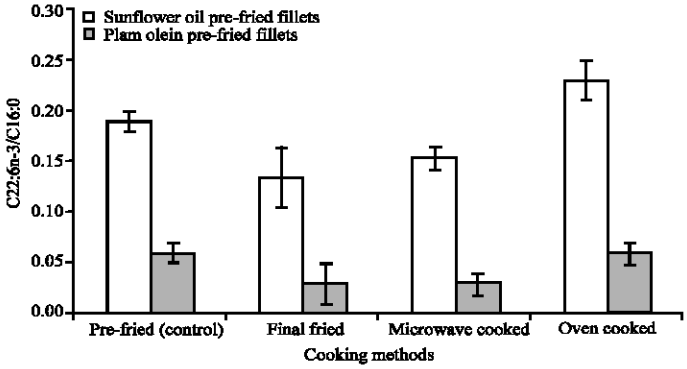

Fig. 2: The thermal oxidation of the pre-fried and final cooked samples

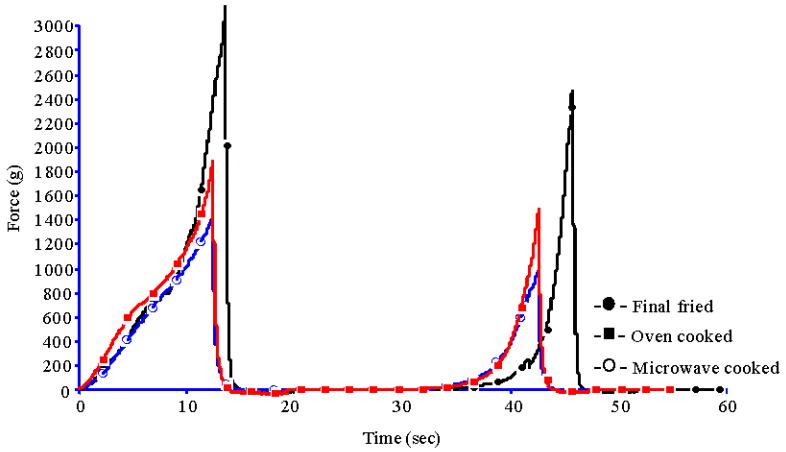

Fig. 3: Compression of TPA curve of different final cooked samples

Thermal Oxidation Produced in the Samples

The C22:6n-3/C16:0 was used as an oxidation index during thermal process. The ratio decreased for all samples for both pre-fried and final cooking stages (Fig. 2). The lower reduction in the oven cooked samples suggested that lower thermal oxidation took place in those samples.

Effect of Cooking Methods on the Texture Profile of the Samples

Texture profiles of all samples are as shown in Table 3 and the trace for the Texture Profile Analysis (TPA) is as shown in Fig. 3. Most of the TPA parameters of pre-fried samples were significantly ($p<0.05$) changed after all final cooking methods. Results from the two-way ANOVA indicated that types of frying oil did not significantly change the TPA of the final cooked samples. However, different final cooking methods significantly affected the hardness, adhesiveness, chewiness and the cohesiveness f the samples. Fracturability was the texture characteristics found only in the final fried samples. The biggest value of the hardness of the final cooked samples was observed in the final fried followed by oven cooked and microwaved samples (Fig. 3).

Effect of Final Cooking Methods on the Color of Pre-fried Samples

The influences of different final cooking methods on the values for lightness (L*), redness component (a*) and yellowness component (b*) are shown in Table 4. All values were significantly

Table 3: Effects of different final cooking methods on the texture profile of pre-fried breaded fillets

	Pre-fried (control)		Microwave cooked		Oven cooked		Final fried	
Texture characteristics[1]	SO[2]	PO[2]	SO	PO	SO	PO	SO	PO
Hardness[3]	1590.0±139Aa	1687.5±113Aa	1440.700±132Ab	1398.100±120Ab	1627.200±180Aa	1685.900±135Aa	2715.700±201Ad	2491.800±206Ad
Fracturability[3]	Nd	Nd	Nd	Nd	Nd	Nd	841.200±146.4	920.700±151
Adhesiveness[3]	-51.00±3.50Aa	-67.50±4.90Aa	-45.600±2.50Ab	-41.300±4.40Ab	-41.200±2.20Ab	-46.100±4.30Ab	-28.400±5.90Ad	-34.300±6.10Ad
Springiness	0.742±0.114Aa	0.798±0.053Aa	0.851±0.052Ab	0.866±0.020Ab	0.882±0.050Ab	0.874±0.051Ab	0.840±0.091Ab	0.842±0.050Ab
Chewiness	332.4±23.7Aa	377.9±21.7Aa	405.000±53.0Aa	350.200±45.8Aa	536.600±58.0Aa	489.000±22.0Aa	633.000±79.2Ad	598.200±68.0Ad
Cohesiveness	0.244±0.001Aa	0.236±0.004Aa	0.370±0.041Ab	0.341±0.034Ab	0.370±0.034Ab	0.326±0.027Ab	0.309±0.059Ad	0.280±0.034Ad
Resilience	0.043±0.010Aa	0.047±0.002Aa	0.050±0.008Aa	0.046±0.008Aa	0.047±0.006Aa	0.043±0.013Aa	0.046±0.011Aa	0.034±0.004Aa

[1]Values are Mean±SD of twelve measurements. Meanswith capital letter(s)in the same row are significantly ($p<0.05$) different between two frying oil for the same cooking method. Means with small letter(s) in the same row are significantly ($p<0.05$) different between final cooking methods for the same frying oil. [2]SO, PO-samples pre-fried in sunflower oil in palm olein, respectively 3 g sec^{-1} force (units for the texture characteristics) Nd: Not detected

Table 4: Effects of different final cooking methods on color of pre-fried breaded fillets

	Pre-fried (control)		Microwave cooked		Oven cooked		Final fried	
Hunter lab values[1]	SO[2]	PO[2]	SO	PO	SO	PO	SO	PO
L*	64.95±2.15Aa	62.93±2.05Aa	59.35±3.27Ab	56.93±4.35Ab	60.33±3.77Ab	57.89±3.98Ac	46.60±3.60Ad	44.51±2.53Ad
a*	10.78±1.75Aa	8.82±1.96Aa	4.40±1.85Ab	5.90±2.62Ab	14.32±4.55Ac	13.71±1.37Ac	8.90±1.90Ad	11.43±1.52Ad
b*	32.20±2.00Aa	29.43±4.26Aa	47.70±2.34Ab	50.1±2.57Ab	59.15±2.43Ac	57.01±4.14Ac	38.37±2.82Ad	36.35±1.83Bd

[1]Values are Means±SD of thirty-six measurements. *Means with capital letter(s) in the same row are significantly ($p<0.05$) different between two frying oil for the same cooking method. Means with small letter(s) in the same row are significantly ($p<0.05$) different between final cooking methods for the same frying oil. [2]SO, PO-samples pre-fried in sunflower oil and palm olein, respectively

($p<0.05$) changed in the final cooked samples as compared to the control. The b* values increased in all the final cooked samples, while L* values showed a decrease. Oven cooking method had higher L*, a* and b* values compared to the other cooking methods. Comparison between two different frying oil showed that the b* of the sunflower oil final fried samples was significantly ($p<0.05$) higher than the palm olein final fried samples. However, using two types of frying oil could not affect the other Hunter lab values.

DISCUSSION

Fat and Moisture Content of the Samples

Moisture contents decreased and fat content increased in the pre-fried samples after all final cooking methods due to moisture loss and fat uptake during frying process (Table 1). The biggest moisture loss and fat uptake was observed in deep-fat fried product due to the increasing frying time. The fat and moisture content were least changed by the oven cooking method. This to be related to the slower rat of food temperature changes in oven cooking methods than other methods. Slightly higher changes in the fat and moisture content were obtained in the microwave cooking. Similar results were observed by García-Arias *et al*. (2003) when they reheated the fried-frozen sardine fillets in the microwave and the conventional oven. They found that in the conventional oven reheating, minor changes in the moisture content was obtained when it was compared to those reheated in the microwave.

Fatty Acid Composition of the Samples

Final frying resulted in higher changes in the fatty acid composition of the samples as compared to the other two methods which was due to the higher fat uptake by the fried samples. This method markedly increased the content of oleic acid (C18:1n-9) and linoleic acid (C18:2n-6) in the samples. Oven and microwave cooking methods showed marginal change in the fatty acids composition due to the lower dehydration produced in these methods, even though slightly higher changes in the fatty acids contents was observed in the microwave cooked samples. The benefits of fish consumption are related to the presence of EPA and DHA fatty acids in the fish muscle. Pre-fried samples in both oil had the same amount of EPA and DHA. These two fatty acids decreased dramatically by the final frying and microwave cooking. However, their values were not significantly ($p<0.05$) change by the oven cooking. The oven cooking method produced significantly ($p<0.05$) lower loss in the amounts of the EPA and DHA as compared to the microwave cooking. During the reheating study that was carried out by García-Arias *et al*. (2003), they found that the conventional oven reheating minimally affected the fried sardine fillet fatty acid content when compared to the microwave reheating. The results obtained in this study thus confirmed their report. Recently, Türkkan *et al*. (2008) also reported that pan frying, microwave and oven baking had considerable effects on the proximate and fatty acid compositions of seabass (*Dicentrarchus labrax*) and losses of n-3 fatty acids content in the microwave cooking were higher than that observed in the other two methods studied.

The increase in the n-6/n-3 ratio could be explained by the absorption of the C18:2n-6 fatty acid from the frying oil during final frying. Vegetable oil rich in n-6 PUFA should be avoided in pan and deep-fat frying if an increase of n-3 PUFA intake is desired (Agren and Häninen, 1993).

The lower reduction in the oven cooked samples suggested that lower thermal oxidation took place in those samples. Similar result was found by García-Arias *et al*. (2003) during reheating of fried-frozen sardines in conventional and microwave oven. According to the positive health effects attributed to DHA (Arts *et al*., 2001), oven cooking would be preferred for final cooking in pre-fried samples.

Texture Profile of the Samples

Kulp and Loewe (1990) reported that the optimum processing method to obtain crispy food is to rapidly fry in high temperature at 170-240°C. Oven heating is the method for producing a moderately acceptable product in terms of crispness, color and flavor. Although, the heating rate is slower than that of deep-fat frying, the elevated chamber temperature of the oven causes some evaporative drying of the coating, resulting in the perception of crispness. Fiszman and Salvador (2003) reported that pre-fried products cooked in microwave ovens tend to be undesirably soft and soggy because in this type of heating water is conducted from the inside to outside. Final fried sample had significantly ($p<0.05$) lower adhesiveness than oven and microwave cooked samples. Cohesiveness is describing the ability of fillets to recover from deformation and offer resistance to subsequent deformation (Jon and Ole, 1999). This parameter of TPA was significantly ($p<0.05$) lower in the final fried samples than the other two methods.

Color Properties of the Samples

The color of a battered product is directly related its external appearance and therefore, its acceptance by the consumers. The final color of the fried product depends on the absorption of oil and the chemical reactions of browning of reducing sugar and protein sources. The development of color is the result of the chemical browning reactions of reducing sugar and protein sources and to a lesser extent, of the absorption of frying oil and the density and thickness of the batter coating (Loewe, 1993). Color development during frying is the main parameter chosen by the consumer to control the optimal frying time. The ideal color is a light golden brown (Sanz *et al*., 2007).

CONCLUSION

Final cooking by frying and microwave produced higher changes in the fatty acid composition in the pre-fried samples as compared to that of oven cooking. The concentration of DHA and EPA in the samples final cooked by oven method was double compared to the other methods. Lower thermal oxidation and lower n-6/n-3 ratio were also observed in the oven cooked samples. Final fried samples gave the highest hardness which was followed by oven and microwave cooked samples. Significant differences on the color of the final cooked samples were obtained among the different cooking methods. The oven cooking could be recommended to be the best method for final cooking due to the least change in the fatty acid composition of pre-fried fillets. For crispy product, the final frying method would be recommended; however, the samples were higher in fat content.

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