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Moisture, fat content and fatty acid composition in breaded and non-breaded deep-fried black pomfret (*Parastromateus niger*) fillets

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Abstract: Effects of breading materials and deep-fat frying on fat uptake, moisture content and fatty acid composition of the black pomfret (*Parastromateus niger*) fillets. Black pomfret fillets both breaded and non-breaded were deep-fat fried in sunflower oil and palm olein. Fat uptake, moisture content and fatty acid composition in the fillets were determined. Total fat content in the fillets of both breaded and un-breaded fillets increased significantly ($p<0.05$); approximately 10 times in the non-breaded fillets and less than twice in the breaded fillets. Saturated fatty acids (SFA) of raw fillets significantly ($P<0.05$) decreased when fried in sunflower oil. However, it slightly increased during deep-frying in palm olein. A significant ($P<0.05$) increase in the monounsaturated fatty acids (MUFA) was observed in both oils fried samples. The amount of polyunsaturated fatty acids (PUFA) increased in sunflower oil fried fillets and decreased in palm olein fried ones. The n-6/n-3 ratios were observed to increase in both sunflower oil and palm olein fried fillets. The increases were significantly ($P<0.05$) less in breaded than those in the non-breaded fillets. Breaded fillets had lower changes in the fatty acid composition than non-breaded fillets.

Keywords: Fatty acid profile, Deep-fat frying, Fat uptake, Sunflower oil, palm olein, breading, Black pomfret

Introduction

Lipids play many essential roles in cell biology such as structural materials, barrier for ion separation, temperature sensors and as a substrate for eiosanoids (Slabas *et al*., 2001). The n-6 and n-3 fatty acids can not be synthesized by animals; therefore, they have to be derived from a diet. Increasing the dietary intake of 20:5n-3 (EPA) and 22:6n-3 (DHA) can decrease the production of various 'stress related' eicosanoids involved in cardiovascular and inflammatory disorders (Sargent and Henderson, 1995). Aquatic organisms are known to be the main source of PUFAs, thereby humans obtain principal part of EPA and DHA by consuming fish (Arts *et al*., 2001).

Deep-fat frying is one of the oldest and most common unit operation used in the preparation of foods which results in products with a unique flavor-texture combination (Varela, 1988). Breaded foods are popular worldwide; therefore, studies should be carried out to see their influences on the food characteristics. Numerous studies have revealed that deep-fat frying processes could change the initial concentration of the fatty acid profiles and decrease the n-3 PUFA in fried fish. These changes were mostly related to the types of frying oils and the amount of the fat uptake during deep-fat frying (Kinsella *et al*., 1990; Makinson *et al*., 1987; Francisco *et al*., 1992; Candela *et al*., 1998; Candela *et al*., 1997).

The use of edible coating or batters or breading materials has been suggested for reducing the amount of fat absorbed by the deep-fat fried foods (Wills *et al*., 1981) by limiting moisture and oil transfer during frying (Holownia *et al*., 2000; Albert and Mittal, 2002). Several investigations have been documented on the effects of deep-fat frying on the fatty acid concentration in fish; however, the effects of breading and deep-fat frying on the fat uptake and fatty acid profile in black pomfret (*Parastromateus niger*) which is one of the commercial marine fish in the Asian countries has not been extensively reported. Therefore, the objective of this study was to determine the effect of deep-fat frying in the fat uptake and lipid characteristics in breaded and non-breaded fillets using two different oil media.

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Materials and Methods

Materials

Fifteen fresh Black pomfret fish (*Parastromateus niger*) weighting 340 ± 15 g and 20 ± 3 cm in length were purchased from the wholesale market (Pasar, Brong, Serdang Malaysia). The fishes were manually filleted on both sides. Each piece of fillet was again cut into halves. The fillets were then washed under running tap water and dripped dried for 10 min in a colander. Six fillets were randomly picked and packed in polyethylene bags and stored at -20°C. They were used within 2 weeks. Sunflower oil (LAM SOON edible oils SDN BHD, Malaysia) and palm olein (Seri Murni, Thinkglobal Food Processing, Malaysia) which were used for frying were purchased locally (Seri Kembangan, Serdang, Malaysia) and stored in the cold room (~ 8°C) until used. Breading materials containing wheat flour, corn flour, salt and bread crumbs were purchased from the local supermarket (Seri Kembangan, Serdang, Malaysia).

Experimental design

Twelve raw fillets were used as the control. The remaining 48 fillets were divided into equal groups of 24 fillets. One group was breaded and the other was not breaded. Twelve fillets of each group were deep-fried in sunflower oil and other 12 fillets were deep-fried in palm olein. After frying, fried fillets were allowed to drain in a strainer for 5 min. The fried fillets were packed in polyethylene bags and stored at -20 ºC until analysis. The non-breaded fried fillets were analyzed for evaluate the fat uptake, moisture content and fatty acid composition directly and for the breaded fried fillets; the breading materials were carefully removed for separate analysis.

Fillet breading

Batter formulation was prepared according to recommendation Fizman and Salvador (2003) in the Food processing Lab by using 75% wheat flour, 24.5% corn flour and 0.5% salt. All ingredients in the ratio of 1:1.4 (w/w) dry matters were mixed thoroughly for 3 min in a kitchen blender (National, Model MX-897 GM Japan). Frozen fish fillets were thawed overnight in the cooled room (4°C). The surfaces of thawed fillets were then dabbed with paper towels before dipping the fillets into the batter and the excess batter was dripped off for 30 s. Battered fillets were then coated with bread crumbs prior to deep-fat frying.

Deep- fat frying

Deep-fat frying was carried out in a 3 L capacity deep-fryer (PHILUX, Model Df30AIT, LIBERTRONIC SDN BHD, Seri Kembangan, Selangor, Malaysia). Sunflower oil and palm olein were used as the frying oils. The temperature of the frying oil was set at 180 ± 2°C which was monitored with a metal thermometer. 2 L of the frying oil was used for each experiment which consisted of 12 fillets. The Frying was performed in three batches and four fillets were fried in each batch. Frying oil was used only once. The fillets were fried until the core temperature was about 65-70°C (Garíca-Arias *et al.*, 2003). A thermo probe (Model HANNA Checketemh, Portugal) was used to measure the core temperature. It took 2.5 and 3 min to reach the desired temperature for the non-breaded and breaded fillets, respectively.

Fat and moisture content

Fat and moisture content were determined by the Soxhlet and oven method (AOAC,1990), respectively

Fatty acid analysis

Lipid for fatty acid analysis was extracted according to Bligh and Dyer (1959). Sodium methoxied and hexane were used for the preparation of the fatty acid methyl esters (FAME) (Timms, 1979). The fatty acid methyl ester of palm olein, sunflower oil and fillets were analyzed by gas chromatography (GC) (Hewllet Packard, HP 6890 Series, USA) equipped with a flame ionization detector (FID). The column used was a capillary column (SGE, 50 m length and 0.22mm diameter). The temperature of injection port and the detector was set at 260ºC. The oven temperature was programmed to increase from 50ºC to 230°C at a rate of 4 ºC/min. One µL of sample was injected manually in duplicate with the split 40. Fatty acid peaks in the samples were identified by comparing the retention times of the samples with that of the standard mixture of FAME (Supleco TM, 37 component FAME MIX) which contained from C4:0 to C22:6n-3.

Statistical analysis

Statistical software Minitab ® Release 14, Copyright 2003-2005 (Minitab Inc, Pennsylvania) was used to analyze the data in two and one way analysis of variance (ANOVA) for fat, moisture and fatty acids composition in samples.

Results and Discussion

Fat and moisture content

The fat and moisture contents of different samples are shown in Table 1. The moisture content in samples varied from 33.0 to 78.8 g/100g on a wet weight basis. Frying resulted in the reduction of moisture contents

Table 1. Fat and moisture content in raw and fried samples (g/100g)

Components	Raw fillets	Fried in sunflower oil	Fried in palm olein
1. Moisture			
Non-breaded fillet	78.77 ± 0.13Aa	46.57 ± 0.50Ab	44.00 ± 1.50Ac
Breaded fillet	78.80 ± 0.13Aa	69.70 ± 0.10Bb	70.00 ± 0.10Bb
Breading materials	41.44 ± 0.70Ca	35.00 ± 0.45Cb	33.00 ± 0.40Cc
2. Fat			
Non-breaded fillet	1.54 ± 0.07Aa	13.85 ± 0.66Ab	15.74 ± 0.20Ac
Breaded fillet	1.50 ± 0.06Aa	2.26 ± 0.30Bb	2.17 ± 0.16Bb
Breading materials	0.54 ± 0.10Ca	18.00 ± 0.40Cb	20.2 ± 0.30Cc

-Values are means ± deviations
-Values in the same column bearing different capital letters are significantly different (P<0.05).
-Values in the same row bearing different small letters are significantly different (P<0.05).

in all samples with a concomitant increase in their fat content. A significant (P<0.05) higher moisture loss was observed in non-breaded fillets fried in palm olein as compared to the sunflower oil fried samples. Raw fillets contained 1.50 g/100g fat. Their fat content increased approximately 12-14 times in non-breaded and only less than twice in the breaded fillets after frying. However, it increased about 1g/100g in the breaded samples. Palm olein fried samples had significantly (P<0.05) higher fat content in the non-breaded and breading materials than the sunflower oil fried ones. Fransisco *et al.* (1992) reported that sardines when deep-fried for 4 min at 180 ºC in olive oil, sunflower oil and lard, the fat pike-up was found 39, 35 and 46/ g/ 100g of dry matter in olive oil, sunflower oil and lard fried samples , respectively.

It was also observed that the presence of breading material prevented the oil uptake by the fillet. The oil uptake was found highly in the breading material. Makinson *et al*. (1987) reported battering or battering plus bread crumbs reduced the fat absorption in fish sticks. It has been suggested that the use of coating has the potential to reduce the amount of fat absorbed by deep-fat fried foods (Wills *et al.,* 1981). Sánchez-Muinez *et al*. (1992) reported that fat penetration in fried food was heavily dependent on whether the food is fried in batter or not and in battered fish, fat did not penetrate into the food but remained on the outside coating.

During deep-fat frying, moisture content is an important factor in determining oil uptake. Moisture loss creates cavities or capillary pores and through them the oil penetrates during frying. Foods with high moisture normally result in high oil uptake. Several authors (Krokida *et al*., 2000) reported a liner relationship between the fat absorption and moisture loss in the deep-fat fried products. In this study a strong inverse linear relationship (r = -0.80) was established between moisture and oil content in raw and fried samples.

Fatty acid Composition (FA)

The fatty acid compositions of all samples are shown in Table 3. The value of saturated fatty acids (SFA), mono-unsaturated fatty acids (MUFA) and poly-unsaturated fatty acids (PUFA) in the raw fillets were 38.8, 28.7 and 32.5g/100g, respectively. Similar findings were reported by Tengku and Rozaina (2007). The most abundant fatty acid in the raw fillet was C16:0 which amounted to 30.9 g/100g. The second most abundant fatty acid was C22:6n-3.

A dramatic decrease of SFA was observed when fillets were fried in sunflower oil. This decrease was about 30g/100g and 27g/100g in non-breaded and breaded fried fillets respectively. However, it increased about 4g/100g in non-breaded and about 1g /100g during deep-frying in palm olein. C16:0 and C18:0 were observed to increase and other the

Table 2. Fatty acid composition[a] in raw and fried fillet (% of FA)

		Fried in sunflower oil		Fried in palm olein	
Fatty acid	Raw fillet	Non-breaded	breaded	Non-breaded	breaded
C12:0	nd*	nd*	nd*	0.29 ± 0.00d	0.20 ± 0.00e
C14:0	2.20 ± 0.03a	0.11 ± 0.00b	0.32 ± 0.05c	1.03 ± 0.00d	1.34 ± 0.02e
C15:0	1.80 ± 0.03a	0.14 ± 0.00b	0.50 ± 0.05c	0.27 ± 0.00d	0.83 ± 0.01e
C16:0	30.9 ± 0.23a	7.57 ± 0.21b	10.20±0.11c	35.97±0.30d	33.85±0.24e
C17:0	2.50 ± 0.08a	0.12 ± 0.01b	0.31 ± 0.03c	0.21 ± 0.00d	0.83 ± 0.00e
C18:0	1.35 ± 0.05a	0.66 ± 0.00b	0.54 ± 0.20c	4.45 ± 0.02d	3.25 ± 0.05e
∑ SFA	**38.80±0.20a**	**7.98 ± 0.06b**	**11.35±0.11c**	**42.23±0.34d**	**39.89±0.90a**
C14:1	1.10 ± 0.11a	0.04 ± 0.00b	0.17 ± 0.14c	0.10 ± 0.00d	0.44 ± 0.01e
C16:1	2.25 ± 0.03a	0.07 ± 0.00b	0.30 ± 0.02c	0.12 ± 0.00d	0.72 ± 0.00e
C18:1n-9	11.80±0.11a	50.36±0.50b	43.67±0.08c	41.77 ±1.13d	30.73±0.30e
C20:1	10.26±0.11a	3.75 ± 0.02b	5.08 ± 0.03c	4.62 ± 0.02d	7.36 ± 0.09e
C24:1	3.28 ± 0.02a	0.22 ± 0.00b	0.87 ± 0.01c	0.34 ± 0.00d	1.47 ± 0.02e
∑ MUFA	**28.70±0.13a**	**54.44±0.47b**	**50.10±0.11c**	**46.95± 1.15d**	**40.20±0.41e**
C18:2n-6	3.26 ± 0.21a	35.43±0.52b	30.76±0.08c	7.66 ± 0.30d	6.66 ± 0.00e
C18:3n-3	1.60 ± 0.10a	0.05 ± 0.04b	0.08 ± 0.02c	0.05 ± 0.03b	0.15 ± 0.01e
C20:4n-6	7.92 ± 0.02a	0.40 ± 0.00b	1.53 ± 0.03c	0.65 ±0.00d	3.06 ± 0.03e
C20:5n-3	3.70 ± 0.02a	0.17 ± 0.01b	0.66 ± 0.03c	0.29 ± 0.00d	1.41 ± 0.01e
C22:6n-3	17.80±0.18a	1.25 ± 0.02b	5.24 ± 0.08c	1.92 ± 0.00d	7.57 ± 0.15e
∑ PUFA	**32.55±0.25a**	**37.25 ±0.54b**	**38.20±0.05c**	**10.50±0.26d**	**18.65±0.12e**
∑ n-3	23.05±0.083a	1.48 ± 0.01b	5.96 ± 0.06c	2.25 ± 0.00d	9.13 ± 0.15e

[a]-Values are means ± standard deviation of two measurements. Values in the same row bearing different alphabets are significantly different (P< 0.05 one-way ANOVA test). nd*: Not detected

fatty acids decreased in the palm olein fried samples. The amount of SFA in the breaded fried fillets was significantly (P<0.05) lower than the non-breaded fillets.

Total percentage of MUFA in the breaded and non-breaded fillets were significantly (p<0.05) increased when fillets were fried in both oils. This increase was between 26 - 22g/100g in sunflower oil fried samples and between 16g-12g / 100g in the palm olein fried samples. Oleic acid (C18:1n-9) content of all fried samples increased substantially. This could be due to the large percentage of these fatty acids in both frying oils (Table 2) which absorbed by the fillets during deep frying. Breaded fried samples absorbed less C18:1n-9 than those of the non-breaded samples. Therefore, the level of MUFA in the breaded samples were significantly (p<0.05) lower than the non-breaded samples.

Samples fried in sunflower oil had a significant (p<0.05) increased (about 7g 100g) in the PUFA concentration as compared with fillets fried in the palm olein. PUFA concentration in palm olein fried samples decreased drastically when compared to that of the raw sample. The quantity of C18:2n-6 in fried fillets showed an increase in all samples as compared to its content in the raw fillets. Raw fillets had 23g/100g of n-3 PUFA. Frying resulted in the substantial reduction of these fatty acids. The reduction of n-3

Table 3. Fatty acid composition[a] in cooking sunflower and palm oil (% of FA)

Fatty acid	Sunflower oil	Palm olein
C12:0	nd*	0.25±0.00
C14:0	nd*	0.89±0.00
C15:0	nd*	0.16±0.00
C16:0	6.80±0.00a	37.72± 0.10b
C18:0	0.78±0.03a	4.52±0.10b
∑ SFA	**7.60±0.02a**	**43.30± 0.50b**
C18:1n-9c	55.90±0.20a	45.20±0.73b
∑ MUFA	**55.90±0.20a**	**45.20±0.73b**
C18:2n-6c	36.88±0.22a	10.81±0.67b
C18:3	0.55±0.00a	0.34±0.00b
∑ PUFA	**37.40±0.23a**	**11.20±0.67b**

[a]-Values are means ± standard deviation of two measurements. Values in the same row bearing different alphabets are significantly different (P< 0.05) one- way ANOVA tests). nd*: Not detected

PUFA was significantly (p<0.05) higher in sunflower oil fried fillets as compared to the palm olein fried samples. Similar results were reported by Francisco *et al.* (1992) where the losses of DHA and EPA in fried sardine fillets were significantly lower in sunflower and olive oil as compared to that fried in lard. Ǻgren and Hänninen (1993) established that vegetable oils rich in n-6 PUFA should be avoided in pan and deep-fat frying if an increase of n-3 PUFA intake is desired. The decreases of these fatty acids in breaded fillets were 4 times less than the non-breaded fillets. Dobarganes *et al.* (2000) concluded that the fatty acid composition of the oil taken up by a fried food does not differ from that of the fatty acid composition of the frying medium. Earlier work by Mey *et al.* (1975) also reported that fish with a low fat content tend to end up with a fatty acid composition similar to that of the fat used for frying. On the overall, it was observed that changes in all the fatty acids in the beaded fried fillets both oils were significantly (p<0.05) lower than that of the non-breaded fillets. This can be explained by the role of the breading material on the reduction pattern of fat migration into and out of the fillets during deep-fat frying.

PUFA/SFA and n-6/n-3 ratio

The ratio of n-6/n-3 can be used to facilitate identification of high n-3 PUFA foodstuff (Zdzisław and Anna, 2003). The ratio of n-6/n-3 was increased in both breaded and non breaded fillets when fried in both the sunflower oil and palm olein (Fig 1). These increases were approximately 50 and 7 times for non-breaded fillets when fried in sunflower oil and palm olein, respectively. However, breaded samples contained approximately 4 times less n-6/n-3 than non-breaded. The amount of n-6/n-3 in fried fillets was related to the quantity of C18:2n-6 in the frying oils (Table 2). Sunflower oil had more C18:2n-6 than palm olein. Therefore, fried fillets in sunflower oil absorbed a higher amount of C18:2n-6 and this resulted in an increase of the n-6/n-3 in the samples. Candela *et al.* (1998) indicated that deep-fat frying of fish leads not only to an increase in total amount of fat but also to an increase in the n-6/n-3 PUFA ratio, thus limiting the positive effects of the high n-3 PUFA level of raw fish. A recommended ratio of n-6/n-3 has not been established; although a few recommendations have been made. Budowski and Crawford (1985) suggested that the desirable ratio of dietary n-6/n-3 fatty acids should be about 5.0. While Kinsella (1987) indicated that the desirable ratio was 1.0. WHO recommendation is the daily ratio of n-6/n-3 in total human diet should be no higher than 5.0 (Vujkovic *et al.,* 1999).

The ratio of PUFA/SFA was highly increased in the sunflower oil and decreased in the palm olein fried samples (Fig 1). These results are due to the migration of large quantities of PUFA and SFA into the fillets during frying in sunflower oil and palm olein, respectively. Francisco *et al.* (1992) indicated that

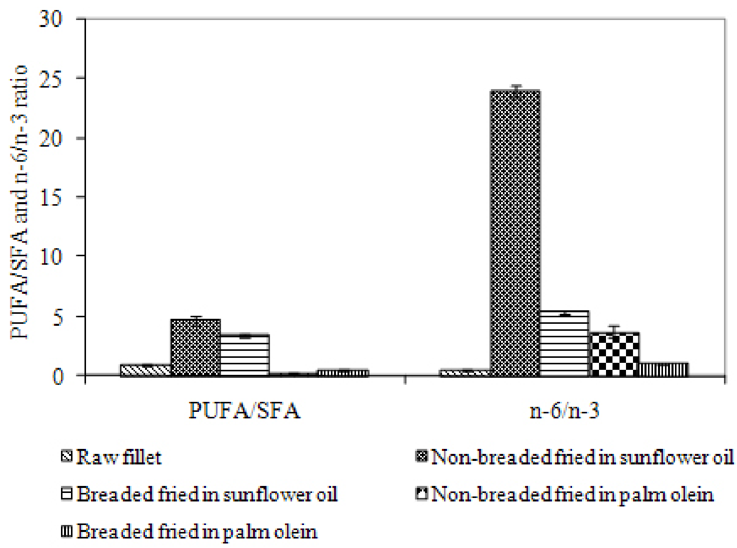

Figure 1. PUFA/SFA and n-6/n-3 ratio in raw and fried samples

PUFA/SFA ratio in raw sardines increased more than 3.0 times with sunflower oil frying and decreased by 47 % with lard. Similar results were reported by other authors during frying of fish in different oils (Gall *et al.,* 1983). The PUFA/SFA ratios in breaded fillets were also found to be lower than the non-breaded fillets. The ideal diet should consist of one third SFA, one third MUFA and one third PUFA, if this goal was achieved, the ratio of PUFA/SFA in the dietary lipid should be 1, and PUFA content should be 10% of the energy intake (Roman, 2003).

Conclusion

Fat absorption and fatty acid composition in the fried fillets were strongly related to the breading and the frying oils composition. Breaded fries fillets had about 11g/100g and 13g/100g higher fat content than non-breaded fillets when fried in sunflower oil and palm olein, respectively. MUFA increased in fillets when fried in both oils whereas SFA decreased in sunflower fried samples and slightly increased in the palm olein fried ones. PUFA was found to increase when fried in sunflower oil and decrease in palm olein. The use of breading resulted in the smaller changes of fatty acid compositions and oil uptake in the fried fillets during frying in both oils. A higher fat uptake and a bigger change of fatty acids compositions PUFA/SFA and n-6/n-3 ratios were observed in non-breaded fried fillets for both oils. Breaded fillets can be recommended for deep-fat frying because they had lower fat content, smaller changes in the fatty acid composition and lower n-6/n-3 ratio than non-breaded fillets.

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