Effect of Frying in Different Cooking Oils on the Fatty Acid Profile of Nile Tilapia (*Oreochromis niloticus*) Fillets

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***Abstract*—This study was conducted to determine the effects of frying with three different cooking oils (soybean oil, sunflower oil, and coconut oil) on the fat content and fatty acid profile of Nile tilapia fillets. The fat content of Nile tilapia fillets increased after frying, irrespective of the cooking oil used ($p < 0.05$). Frying led to exchange of fatty acids between the Nile tilapia fillets and cooking oils. As a result of interactions, PUFA and ω-6 fatty acid contents and PUFA/SFA ratio of samples fried in soybean and sunflower oils significantly increased while the SFA contents decreased ($p < 0.05$). Frying had a negative effect on the ω-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) concentrations in all fried samples. Deep frying in the PUFA-enriched cooking oils increased the PUFA proportion in tilapia fillets but ω-3/ω-6 ratio in raw tilapia fillet was found to be reduced in all evaluated samples after deep frying. Maximum reduction in EPA and DHA content was observed when soybean oil was used as the frying medium. Coconut oil can be recommended for deep frying of Nile tilapia fillets as it resulted in a higher ω-3/ω-6 ratio than the recommended WHO standard (0.2).**

***Index Terms*—Nile tilapia fillets, fatty acids, deep frying, coconut oil, sunflower oil, soybean oil**

I. Introduction

Aquatic ecosystems are known to be the main source of polyunsaturated fatty acids (PUFA) [1] and people in developing countries including Sri Lanka gain major part of essential fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) by consuming fish. EPA and DHA have proven to play a vital role in ontogenesis, especially neural development, functioning of cardiovascular and immune systems [2]. ω-3 and ω-6 PUFA are considered essential since they cannot be synthesized in the human body so that they must be obtained through diet [3]. However, type of fish species and method of cooking may be important factors for the content of essential fatty acids in final products [3].

Among the various fresh water fish supporting the Sri Lankan fresh water fishery, Nile tilapia (*Oreochromis niloticus*) is an extensively cultured freshwater fish species [4]. Fillets—the main product of tilapia processing [5]—can be prepared for consumption by different cooking methods such as boiling, baking, grilling, roasting and frying [6]. However, tilapia fish is commonly consumed in fried form by many households in Sri Lanka. There are two most predominant types of frying methods of food as shallow or pan frying and deep frying [7]. Frying, specially deep fat frying is widely used to prepare fish for consumption [3], [8] due to easiness of preparation, rapidness and higher palatability of fried product [3]. However, deep frying leads to an interaction between frying oil and the food at high temperature. The optimum temperature of deep frying is 175^{o}C and it may range from 150 to 200^{o}C [9].

Different cooking oils such as coconut, soybean, canola, cottonseed, corn, sunflower, olive, safflower and peanut oils are generally used as the frying medium in food preparations. Among these, soybean, sunflower and coconut oils are widely used due to their favorable characteristics on final products. However, the fatty acid profile of the cooking oil is a vital factor determining the taste of fried food and its stability [10]. Since frying oil is exposed continuously to high temperatures with the presence of atmospheric air and moisture of food during the deep frying process, many reactions including oxidation, hydrolysis, and polymerization can occur [11] and produce certain harmful toxic compounds to human health such as oxidized fatty acids, acrylamide, malonaldehyde, trans fatty acids, and polar compounds [8]. In addition, changes in overall fatty acid profile may cause different adverse effects on human health. Therefore, scientists have defined nutritional quality indices (NQI) with related to fatty acid profiles and their biological functions. NQI are estimated by several indices of a fatty acid profile such as PUFA/saturated fatty acid (SFA), ω-3/ω-6 and EPA+DHA [12]. At present this is of great concern all over the world and a plenty of studies has been conducted to assess the alterations in fatty acid profiles and to evaluate their impacts on human health [8].

The aim of this study was to study how deep fat frying in different cooking oils (sunflower oil, coconut oil, and soybean oil) affected the fatty acid profile of Nile tilapia (*O. niloticus*) fillets, with special emphasis on the contents of PUFA, EPA and DHA, and ω-3/ω-6 ratio changes.

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II. Materials and Methods

A. Preparation of Tilapia Fillets

Twelve kilograms of Nile tilapia (*O. niloticus*, 24-30 cm long and weighing 350-550 g) were purchased from a local fish market in Badulla, Sri Lanka and transported under chilled condition to Meat Processing and Research Laboratory of Uva Wellassa University, Sri Lanka. After washing the purchased fish with potable water, head, scale, viscera, and tail were removed, and two fillets were obtained from each resulting fish. Fillets (70-130 g) were subsequently divided into four homogeneous groups of 1 kg each. One group (1kg) was kept raw and used as the reference and the other three groups were used for deep frying.

B. Deep Frying

Nile tilapia fillets were fried in a deep fryer at 160°C for 4 min [3] using three cooking oils: coconut oil, sunflower oil, and soybean oil, separately. Cooking oils were purchased from a local store in Badulla, Sri Lanka and used with the food/oil ratios being 250g/L [3]. The fillets were gently drained for 5 minutes after frying to remove the excess oil.

C. Analysis of Fat Content and Fatty Acid Profile

Analysis of fat content and fatty acid profiles of four replicates from each of four groups were conducted at Analytical Chemistry Laboratory in National Aquatic Resources Research and Development Agency (NARA), Colombo, Sri Lanka. Lipids were extracted from the raw and fried tilapia samples following the method described by Ref. [13] and the total fat content of each sample was determined by the gravimetric method as a percentage value [14].

The fatty acid methyl esters (FAME) of the fish fats were then analyzed by capillary gas chromatography. The gas chromatograph (GC-2014, Shimadzu, Kyoto, Japan) was equipped with a fused silica DB wax capillary column (30 m × 0.32 m, film 0.25 μm) and a flame ionization detector. The initial temperature of the column was set at 160 ℃ and finally increased to 240 ℃ at a rate of 3 ℃ min^{-1}. The detector temperature was set at 270 ℃, while the temperature at the injection port was maintained at 240 ℃. Helium was used as the carrier gas at 14 psi. Relative quantities were expressed as weight percent of total fatty acids identified via comparison of retention times to known FAME standards (17 fatty acid methyl esters mix, Sigma–Aldrich).

D. Statistical Analysis

Data were subjected to one-way analysis of variance (ANOVA) by the procedure of General Linear Model using SAS program version 9.1. Comparison of means was performed using Duncan's multiple range tests at $p < 0.05$.

III. Results and Discussion

A. Total Fat Content

The choice of cooking oils used in the present study was based on their fat profile: high in saturated fatty acids (SFA) in coconut oil, very high in ω-6 PUFA in sunflower oil, and considerable amount of ω-3 PUFA in soybean oil. The changes of fat contents between raw and fried samples are shown in Table I. The average fat content of raw tilapia samples (1.43%) in the present study was slightly less than that reported by Ref. [15] for Nile tilapia. These differences may occur due to various biological and environmental factors which affect on the lipid content of fish flesh [16]. Furthermore, Ref. [15] has classified tilapia as a lean fish because of their low lipid content.

The lipid content increased significantly in all evaluated samples after frying ($p < 0.05$). This is in well agreement with the findings of Ref. [3], [17]. The increase in lipid content could be due to two mechanisms, namely the loss of water during frying and the absorption of cooking oils [18], [19]. However, fat exchanges and interactions between the cooking oils and that of the fish when frying can be influenced by the fat content and fatty acid profile of raw fish [20].

TABLE I. Total Fat Content of Raw and Fried Nile Tilapia Fillets

Sample	%
Raw	1.43[b]
Soybean oil-fried fillets	12.87[a]
Sunflower oil-fried fillets	11.42[a]
Coconut oil-fried fillets	10.17[a]
SEM	0.85

[a,b] Mean values in the same column with different superscripts differ significantly ($p < 0.05$).

B. Fatty Acid Profile

The fatty acid profile of raw and fried tilapia samples is shown in Table II. In the present study, 17 fatty acids were identified in tilapia samples.

The most abundant fatty acids found in raw tilapia fillets were palmitic acid (C16:0), oleic acid (C18:1, ω-9) and palmitoleic acid (C16:1, ω-7). Furthermore, raw tilapia fillets showed considerable amounts of DHA (C22:6, ω-3), stearic acid (C18:0), linoleic acid (C18:2, ω-6), myristic acid (C14:0) and EPA (C20:5 ω-3). These findings are in agreement with those obtained by Ref. [21]-[23]. In raw fillet samples of Nile tilapia, SFA content was higher than MUFA and PUFA contents (Table II). The major proportion of SFA was contributed by palmitic and stearic acids whereas oleic acid was the main representative fatty acid among the MUFA. In addition, the ω-3 fatty acid content was higher than ω-6 fatty acid content in raw fillets (Table II). Similar findings were detected by Ref. [3] regarding ω-3 and ω-6 fatty acid contents of silver carp.

As shown in Table II, frying has significantly altered the fatty acid profile of Nile tilapia fillets. The fatty acid profiles have been differently altered in the frying process with soybean, sunflower and coconut oil. Most of the fatty acid concentrations including palmitic acid, stearic acid, palmitoleic acid, arachidonic acid, EPA, and DHA were decreased in all fried fillet samples in comparison with raw fillet sample (Table II).

The samples fried in coconut oil showed a higher SFA content and a lower PUFA content than the raw fillets (*p*

< 0.05; Table II). This might be due to higher SFA content of coconut oil [24]. Content of myristic acid (C14:0) showed a significant increase in coconut oil-fried fillets; however a decrease was observed in soybean and sunflower oil-fried samples. Frying with soybean and sunflower oils resulted in a considerable decrease in the SFA content and an increase in PUFA content of fillet samples ($p < 0.05$). Frying in PUFA-enriched cooking oils caused a decline in the proportion of SFA, while the proportion of PUFA markedly increased in sardines [20]. The level of palmitic acid—the predominant SFA present in the raw fillets—decreased during the deep frying process. Similar observations were found by Ref. [3], [17], [20]. Fillets fried in soybean oil showed a significantly higher linolenic acid (C18:3 ω-3) content. This can be attributed to the higher content of linolenic acid in soybean oil and possible migration of fatty acids between fish fillets and cooking oils [3].

TABLE II. FATTY ACID PROFILE (%) OF RAW AND FRIED NILE TILAPIA FILLETS

Fatty acid	Raw fillet	Fillet fried in soybean oil	Fillet fried in sunflower oil	Fillet fried in coconut oil	SEM
C14:0	4.54[b]	0.47[c]	0.39[c]	21.14[a]	0.39
C15:0	1.35[a]	0.15[b]	0.14[b]	0.20[b]	0.13
C16:0	30.84[a]	11.68[c]	8.27[d]	22.8[b]	0.62
C16:1	10.76[a]	1.65[b]	1.21[b]	1.45[b]	0.99
C18:0	6.52[a]	4.02[c]	3.86[c]	5.41[b]	0.16
C18:1 ω-9	14.94[c]	29.67[b]	26.54[b]	36.88[a]	1.45
C18:1 ω-7	3.66[a]	1.92[b]	0.98[c]	0.96[c]	0.09
C18:2 ω-6	4.92[d]	41.88[b]	56.08[a]	6.81[c]	0.32
C18:3 ω-3	3.59[b]	6.15[a]	0.35[c]	0.55[c]	0.21
C20:1 ω-9	0.53[a]	0.43[ab]	0.19[b]	0.31[ab]	0.09
C20:4 ω-6	0.63[a]	0.12[b]	0.10[b]	n.d.[e]	0.11
C20:5 ω-3	4.04[a]	0.41[b]	0.51[b]	0.81[b]	0.63
C22:4 ω-6	1.68[a]	0.21[b]	0.21[b]	0.35[b]	0.22
C22:5 ω-6	3.65[a]	0.40[b]	0.41[b]	0.72[b]	0.21
C22:6 ω-3	7.79[a]	0.83[b]	0.79[b]	1.59[b]	0.68
∑ SFA	43.26[b]	16.34[c]	12.67[d]	49.51[a]	0.55
∑ MUFA	29.90[bc]	33.68[b]	28.94[c]	39.46[a]	1.26
∑ PUFA	26.31[c]	49.98[b]	58.39[a]	10.85[d]	1.65
∑ ω-3	15.43[a]	7.39[b]	1.66[c]	2.96[c]	1.17
∑ ω-6	10.88[c]	42.59[b]	56.73[a]	7.89[d]	0.53
∑ PUFA/SFA	0.61[c]	3.06[b]	4.61[a]	0.21[d]	0.07
∑ ω-3/ω-6	1.40[a]	0.17[c]	0.03[c]	0.37[b]	0.05

[a-d] Mean values in the same raw with different superscripts differ significantly ($p < 0.05$).
[e] n.d. = not detected.

Raw Nile tilapia fillets had a relatively high content of long chain PUFA such as DHA (7.79%), EPA (4.04%), docosapentaenoic acid (3.65%), docosatetraenoic acid (1.68%) and arachidonic acid (0.63%; Table II). This can be acceptable since long chain PUFA predominantly found in fish and fish oil [22]. However after the frying process, their contents were markedly decreased in all fried samples ($p < 0.05$). Maximum reduction in EPA and DHA content was, however, observed when soybean oil was used as the cooking oil. The reduction in the content of long chain PUFA may be due to high susceptibility of these fatty acids to oxidation during heating [19], [21]. In addition, this reduction may have been caused by the migration of fatty acids from fish fillets to cooking oils [3]. Similarly, previous investigations showed that frying decreased EPA and DHA contents in sardines and mackerel [20], [25]. In contrast, no significant changes in EPA and DHA content occurred in humpback salmon during frying process [26].

Several studies have shown that the fatty acid profile of fried fish can be related to the particular cooking oil which is used for frying. In addition, fatty acid profile depends on initial fat content of the flesh and the fillet thickness [3], [21]. According to the results of the current study, deep frying has caused a significant reduction in total ω-3 fatty acids content in all fried samples. These findings are in agreement with that obtained by Ref. [12] for silver carp. Again, this finding can be due to the migration of ω-3 fatty acids from fish fillets to cooking oils [3]. In addition, Ref. [18], [26] demonstrated that only frying resulted in a marked decrease in ω-3 fatty acid content out of the heat treatment methods used including boiling in water, roasting, grilling, oven-baking, and microwave cooking. Additionally, Ref. [27] reported that frying in hydrogenated vegetable oil caused a decrease in the ω-3 fatty acid content in silver catfish fillets.

Frying in PUFA-enriched cooking oils caused an increase in linoleic acid (C18:2 ω-6) content in tilapia fillets (Table II). This led to an increase in total ω-6 fatty acid content of tilapia fillets fried in soybean and sunflower oils. These results were in accordance with the values reported by Ref. [12], [20], [27].

The extent of the increase or decrease of a particular fatty acid during frying was relative to the fatty acid gradient from the cooking oil to the fish fillet [3]. As indicated in Table I, frying involves an exchange of fatty acids between cooking oils and tilapia fillets. The interaction between the two components caused an increase in the proportion of the fatty acids in tilapia muscle which are abundant in the cooking oils.

C. Nutritional Quality Indices (NQI)

PUFA/SFA ratio in raw tilapia fillets was 0.61 and this increased to 3.06 and 4.61 after frying in soybean and sunflower oils, respectively. This could be attributed to the reduction of SFA and the increase of PUFA during deep frying process (Table II). These changes were similar to those found by Ref. [3] for silver carp when soybean and sunflower oils were used as the medium of frying. Since coconut oil is rich with SFA [24], PUFA/SFA ratio of coconut oil-fried fillets was decreased.

In addition to PUFA content in a food, ratio of ω-3/ω-6 has been proven to be of dietetic importance. The results showed that Nile tilapia fillets had a high ω-3/ω-6 ratio

(Table II) which is similar to the same parameter of silver carp [3]. However, the ω-3/ω-6 ratios were reduced to 0.17, 0.03, and 0.38 after frying in soybean, sunflower, and coconut oils, respectively (Table II). This can be attributed to the negative effect caused by increasing levels of linoleic acid on the ω-3/ω-6 ratio during deep frying of tilapia fillets. A similar reduction in ω-3/ω-6 ratios was observed by Ref. [3] when silver carp fillets were fried in olive, sunflower, and corn oils. WHO recommends that ω-3/ω-6 ratio should not be lower than 0.2 [28]. According to the results shown in Table II, only coconut oil-fried tilapia samples have a higher value than the recommended standard.

IV. Conclusion

Deep frying led to exchange of fatty acids between Nile tilapia fillets and the cooking oils used. The fatty acid profile of Nile tilapia fillets was affected by those of frying oils used. Results showed that the fat content of tilapia fillets were comparable after deep frying, irrespective of the cooking oil used. Deep frying in the PUFA-enriched cooking oils increased the PUFA proportion in tilapia fillets but had a negative effect on the ω-3/ω-6 ratio. The ω-3/ω-6 ratio in raw tilapia fillet was found to be reduced in all evaluated samples after deep frying. Maximum reduction in EPA and DHA content was observed when soybean oil was used as the frying medium. Coconut oil can be recommended for deep frying of Nile tilapia fillets compared with soybean and sunflower oils as it resulted in a higher ω-3/ω-6 ratio than the recommended WHO standard (0.2).

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