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Research Article

Fatty Acid-Related Health Lipid Index of Raw and Fried Nile Tilapia (*Oreochromis niloticus*) Fish Muscle

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Fried food consumption is popular in most parts of the world including Ethiopia. Among many fried products available in Ethiopia, fried fish is most commonly consumed in Hawassa Town due to the easy access to the fish from the lake. Recently, there is growing concern among fryers to recycle the oil while frying fish. However, there is limited evidence about the frying effect on the fatty-acid-related health lipid index of fried fish. Thus, the study was aimed to determine the fatty acid profile and the fatty-acid-related health lipid of raw and fried fish. Raw and fried fish were taken from the Hawassa open fish market. Fatty acid profiles were analyzed using a gas chromatography-mass spectrophotometer (GCMS), and the health lipid index was determined by calculation using the recommended formula. JMP pro 13 version software was used for data analysis. Our result showed that raw fish had a high amount of essential fatty acid, nutritive value index, hypocholesterolemic ratio, and peroxidizability index. In contrary to this, the fried fish had a high amount of *trans*-fatty acids, nonessential fatty acids, atherogenic index, and thrombogenic index. In conclusion, the fried fish loses its fatty-acid-related nutritional quality in uncontrolled frying conditions. Therefore, frying needs to be controlled, as it risks human health otherwise.

1. Introduction

Fish is a source of essential nutrients and is highly promoted by nutritionists and health-care workers because it has a high amount of double-bonded fatty acids and plays an important role in chronic disease prevention [1]. According to Leung et al. [2], complimentary food including fish for infants is highly recommended. However, according to Gadiraju et al. [3], fish is highly susceptible to safety and quality deterioration, and this leads the fish to lose its nutritional quality due to processing.

Currently, fried food consumption is highly accustomed as it has a good sensory appeal, such as crispy texture, color, and taste [4], and consumption of fried fish has become more common in the world including Ethiopia. Oke et al. [5] stated that changes such as fat absorption, moisture loss, and oxidation reactions occur during frying, and this generates free radicals that affect the safety of fish and considered a risk factor for chronic diseases which can limit the life span of the consumer. Thus, according to FAO [6], a risk inspection and control system should be established for minimizing such problems.

People living around the lake Hawassa (Ethiopia) are highly vulnerable to the health problem associated with fried fish consumption. Around the lake, in the open fish market, three main products are served (fish soup, fried fish, and fish fillet), and Nile tilapia fish is one of the important commercial fish at lake Hawassa [7].

The main fish processing method across Hawassa open fish markets is frying, and no studies have been conducted about identifying the impact of frying on the nutritional quality of fish muscle from the Hawassa open fish market; thus, it is necessary to study the fatty-acid-related nutritional quality of fish muscle, and this would in turn help in identifying the key risks and intervene across the fish value chain, mainly frying in the open fish market. Therefore, the current study aims to characterize the fatty acid profile of raw and fried fish from the Hawassa open fish market and identify the nutritional quality index to show the risk and direction of the management system.

2. Materials and Methods

2.1. Description of the Sample Collection Area. Hawassa is the capital city of the southern region and Sidamo regional state of Ethiopia. Hawassa city is 275 km far from the capital city of Ethiopia (Addis Ababa), and the city is known by its lake called Lake Hawassa, which is about 95 sq km wide and stretches 16 km from northeast to southwest and 8 km from east to west [8]. The lake depth is 21.6 m. Geographically, Lake Hawassa is found in 6 033′–7 033′ N and 38 022′–38 029′ E. The lake has no outflow and receives inflow from the factory via the *Tikur Wuha* River [9]. The lake is named *yefiker Hayek* in Amharic meaning adorable lake. The lake is very useful economically for the entrepreneurs. The lake has more than three fish species, and Nile tilapia (Koroso) is the dominant fish species found in the lake [8]. The lake serves three types of fish products, fillet, fried fish, and fish soup [10].

2.2. Sample Collection and Preparation. Sampling operation was carried out during the dry season. Raw fish was collected from Hawassa Lake (*Gudumale Park*), and the fishes were immediately dissected in the field and cleaned, descaled, and eviscerated manually using a sterile plastic knife [11]. The edible part (flesh and skin) was transferred into plastic bags and kept in an icebox at a temperature of 4°C with a fish/ice ratio of 1 : 2 and then transported to the laboratory. The fried fish was randomly collected from the Hawassa fried fish selling market (*Fikir Hayik*). Raw and fried fishes were grounded to 0.3 mm size, and the powder was stored in desiccators for analysis. Samples were homogenized by passing them twice through a mincer with 4 mm holes and mixed thoroughly. Uniformity of the homogenate was ensured by further mixing. The resultant homogenate was packed into several small, convenient sterile containers and stored at 0°C until analysis. The experiment was conducted in duplicate for all analyses.

2.3. Determination of Fatty Acid Profiles. The fatty acid profile was determined by using a gas chromatography-mass spectrophotometer (GCMS). Lipid was extracted following the standard procedure in [12]. A homogenized fried fish sample of 5 g was weighed into a conical flask and dried for 1 hr at 105°C. The flask was cooled to room temperature, and 50 ml of 4 M hydrochloric acid was added; then, the solution was boiled for 1 hr. Water (150 ml) was added, then the solution was filtered by fluted filter paper, and washed until a neutral reaction to litmus paper. The filter paper was dried for 1 hr at 105°C and inserted into an extraction thimble of the Soxhlet apparatus. Fat extraction was continued with hexane using a Soxhlet for 6 hr. Hexane was evaporated using a rotary evaporator after extraction, and it was kept for derivatization.

Exactly 200 mg of oil was weighed into the bottom of the screw-capped tube (Teflon-lined). 2 ml of 2N KOH was added in methanol. The tube was closed tightly and heated by shaking on a water bath at 80oC for 1 hr and cooled, and then, 5 ml of 5% HCl was added in methanol. The tube was closed tightly again and heated by shaking on a water bath at 80°C for 1 hr. After cooling, 5 ml of hexane and 5 ml of water were added to the tube and mixed, and then, hexane was collected from the layer after short centrifugation. The solvent layer was washed by diluting potassium bicarbonate to remove excess acid and dried over anhydrous sodium or magnesium sulfate. Potassium bicarbonate was recovered after removal of the solvent by evaporation under reduced pressure on a rotary film evaporator. Then, the extract was transferred into a GC vial and injected into it. All the analyses were carried out in triplicates.

2.4. Indexes of Lipid Quality. From fatty-acid composition data, the atherogenicity index and thrombogenicity index were calculated as follows:

Atherogenicity index (AI): it is the relationship between the sum of the main saturated fatty acids and main classes of unsaturated, the former being considered proatherogenic (favoring the adhesion of lipids to cells of the immunological and circulatory system) and the latter being antiatherogenic (inhibiting the aggregation of plaque and diminishing the levels of esterified fatty acid, cholesterol, and phospholipids, thereby preventing the appearance of micro- and macrocoronary diseases [13].

The following equation was applied:

$$\mathrm{IA} = \frac{[(12{:}\ 0 + 4 \times \mathrm{C}14{:}\ 0 + \mathrm{C}16{:}\ 0)]}{[\sum \mathrm{MUFA}s + \sum \mathrm{PUFA}n6 + \mathrm{PUFA}n3)}. \tag{1}$$

Thrombogenicity index (TI): is the tendency to form clots in blood vessels. It is defined as the relationship between prothrombogenic (saturated) and the antithrombogenic fatty acids (MUFAs, PUFAs–*n*6, and PUFAs–*n*3) [13].

$$\mathrm{IT} = \frac{\mathrm{C}14{:}\ 0 + \mathrm{C}16{:}\ 0 + \mathrm{C}18{:}\ 0}{0.5 \times \sum \mathrm{MUFA}s + 0.5 \times \mathrm{PUFA}n6 + 3 \times \mathrm{PUFA}n3 + (\mathrm{PUFA}n3/\mathrm{PUFA}n6)}. \tag{2}$$

Hypocholesterolaemic index (h/HI): it is the cholesterol/saturated fat index. Low CSI indicates low saturated fat and cholesterol and low atheroginicity [14].

$$\mathrm{hHI} = \frac{(\mathrm{C18{:}\ 1n-9 + C20{:}\ 1(n-9) + 22{:}\ 5}(n-3) + 22{:}\ 6(n-3) + \mathrm{C18{:}\ 3n-6} + 20{:}\ 4(n-6) + 18{:}\ 2(\mathrm{n}-6) + 20{:}\ 5(n-3))}{\mathrm{C14{:}\ 0 + C16{:}\ 0}}. \quad (3)$$

Nutritive value index [15]:

$$\mathrm{NVI} = \frac{\mathrm{C18{:}\ 0 + C18{:}\ 1}}{\mathrm{C16{:}\ 0}}. \quad (4)$$

Peroxidizability index [16]:

$$\begin{aligned}\mathrm{PI} = {} & \text{mononoic acid} * 0.025 + \text{dienoic acid} * 1 \\ & + \text{trienoic acid} * 2 + \text{tetranoic acid} * 4 \\ & + \text{pentanoic acid} * 6 + \text{hexanoic acid} * 8.\end{aligned} \quad (5)$$

2.5. Data Analyses. The analyses were performed twice for all samples, and closely agreeing replicates were obtained. The data were analyzed using JMP pro 13, one-way ANOVA. The means were separated using Tukey's HSD test at $p < 0.05$.

3. Result and Discussion

3.1. Assessment of Consumption, Frying, and Marketing of Fish at the Hawassa Lakeside. A preliminary study about the consumption, frying, and marketing of fish at the Hawassa lakeside (*Gudumale Park, Tikur wuha, and Fikir Hayik*) was conducted. There are more than 18 unions on the lakeside. The preliminary assessments showed more than 60 fishes are fried at the lakeside by each union. Thus, more than 1080 fried fishes are marketable per day. At a time, a maximum of 5 fishes are fried using a metal pan after 5 min of catching, and the frying time is 10 min. The most commonly fried, consumed fish in the lakeside is Nile tilapia (*Koroso*), and palm oil is the commonly used oil for frying at the lakeside. After frying, all unions put fried fishes in the open air by hanging on wood to collect the oil leaked from fried fish, and the maximum duration of storing fried fishes before serving to customers is 30 min. The unions use the oil several times as they are not well informed about food safety. Thus, the fish can be exposed to many quality and safety degradation.

3.2. Identified Fatty Acids in Raw and Commercial Fried Fish. A total of 22 fatty acids were identified in raw and fried Nile tilapia fish muscles (Table 1). Lauric acid (12 : 0), myristic acid (14 : 0), pentadecanoic acid (15 : 0), palmitic acid (16 : 0), margaric acid (17 : 0), stearic acid (18 : 0), methyl stearate (19 : 0), arachidic acid (20 : 0), behenic acid (22 : 0), and lignoceric acid (24 : 0) are the identified saturated fatty acids. Palmitoleic acid (16 : 1*n*–7), *cis*-10-heptadecenoic acid (17 : 1*n*–10), oleic acid (18 : 1*n*–9), gondoic acid (20 : 1*n*–9), and linoleic acid (18 : 2*n*–6) are the identified *cis*-fatty acids. Docosapentaenoic acid (22 : 5*n*-3), docosahexaenoic acid (22 : 6*n*–3), and eicosapentaenoic acid (20 : 5*n*–3) are the identified omega-3 fatty acids. Linoleic acid (18 : 2*n*–6), Gamma-linolenic acid (18 : 3*n*–6), and arachidonic acid (20 : 4*n*–6) are the identified omega-6 fatty acids. *trans*-13-Octadecenoic acid (18 : 1*n*–13) and *trans*-10-heptadecenoic acid () are the identified *trans*-fatty acids in raw and commercial fried Nile tilapia fish (*koroso*).

Among the identified fatty acids, *cis*-monounsaturated and -polyunsaturated, omega-3, and omega-6 are the most important contributors to the enrichment of aromatic components [17] and are considered as highly nutritional because of their protective role against cardiovascular diseases and the ability to reduce susceptibility to mental illness, decrease brain and eye function in infants, and alleviate rheumatoid arthritis symptoms [18]. On the contrary, saturated fatty acids cause a rise in the blood cholesterol level as they are easily deposited on the walls of the arteries [19].

3.3. Fatty Acid Composition of Raw and Commercial Fried Nile Tilapia Fish (Oreochromis niloticus). The detailed fatty acid profile is presented in (Table 2). Raw and commercial fried fish had ten saturated fatty acids, and the dominant saturated fatty acids in raw and commercial fried fish are palmitic acid (30.92%–37.01%), methyl stearate (3.64%–7.92%), and myristic acid (1.57%–2.78%). Among the identified *cis*-fatty acids in raw and commercial fried fish, the dominant *cis*-fatty acids are palmitoleic acid (4.92%–1.66%), oleic acid (38.05%–33.55%), and linoleic acid (11.99%–9.99%). *trans*-13-Octadecenoic acid and *trans*-10-heptadecenoic acid are identified as *trans*-fatty acid, and *trans*-13-octadecenoic acid is higher which is ranged from 0.12%–1.62%. Omega-3 and omega-6 fatty acids were also identified in raw and commercial fried Nile tilapia fish. The highest omega-3 fatty acid was decosapentanoic acid varying from 1.08%–0.21%, and the highest omega-6 fatty acid was linoleic acid varying from 11.99%–9.99%.

Saturated fatty acids and *trans*-fatty acids of commercially fried tilapia fish were higher as compared to raw fish. The increase in saturated fatty acids might be because the frying oil is palm oil, and palm oil is high in saturated fat. Similarly, the uncontrolled frying method might result in a high amount of saturated fatty acids in commercially fried fish. Wang et al. [20] stated that a higher temperature can accelerate the reaction rates of oxidation, and more *trans*-fat could be generated in the frying oil and penetrate the frying fish. A similar finding was reported in [21]. Conversely, *cis*-

Table 1: Identified fatty acids in raw and commercial fried Nile tilapia (*Oreochromis niloticus*) fish muscles.

Formula	Level of saturation	Raw	Commercial fried
12 : 0	Saturated	√	√
14 : 0	√	√	√
15 : 0	√	√	√
16 : 0	√	√	√
17 : 0	√	√	√
18 : 0	√	√	√
19 : 0	√	√	√
20 : 0	√	√	√
22 : 0	√	√	√
24 : 0	√	√	√
16 : 1*n*−7	*cis*-Monounsaturated	√	√
17 : 1*n*−10	√	√	√
18 : 1*n*−9	√	√	√
20 : 1*n*−9	√	√	√
18 : 2*n*−6	*cis*-Polyunsaturated	√	√
18 : 1*n*−13	√	√	√
17 : 2 (8, 10)	*trans*-Monounsaturated	√	√
22 : 5*n*−3	Omega-3	√	√
22 : 6*n*−3	√	√	√
20 : 5*n*−3	√	√	√
18 : 3*n*−6	Omega-6	√	√
20 : 4*n*−6	√	√	√

Table 2: Fatty acid composition of raw and commercial fried fish.

Formula	Raw	Commercial fried
12 : 0	0.25 ± 0.01	0.65 ± 0.05
14 : 0	**1.57 ± 0.14**	**2.78 ± 0.025**
15 : 0	**0.19 ± 0.011**	**0.43 ± 0.021**
16 : 0	30.92 ± 0.47	37.01 ± 1.02
17 : 0	0.49 ± 0.03	0.96 ± 0.012
18 : 0	**0.11 ± 0.014**	**0.29 ± 0.018**
19 : 0	3.64 ± 0.71	7.92 ± 0.042
20 : 0	0.68 ± 0.07	0.69 ± 0.024
22 : 0	0.14 ± 0.02	0.47 ± 0.028
24 : 0	0.10 ± 0.012	0.40 ± 0.014
16 : 1*n*−7	4.92 ± 0.56	1.66 ± 0.72
17 : 1*n*−10	0.75 ± 0.012	0.10 ± 0.02
18 : 1*n*−9	38.05 ± 0.58	33.58 ± 0.98
20 : 1*n*−9	0.86 ± 0.08	0.10 ± 0.04
18 : 2*n*−6	11.99 ± 1.4	9.99 ± 0.79
18 : 1*n*−13	0.12 ± 0.01	1.62 ± 0.029
17 : 2 (8, 10)	0.01 ± 0.001	0.31 ± 0.035
22 : 5*n*−3	1.08 ± 0.014	0.21 ± 0.012
22 : 6*n*−3	1.02 ± 0.023	0.20 ± 0.03
20 : 5*n*−3	0.82 ± 0.12	0.10 ± 0.04
18 : 3*n*−6	1.06 ± 0.04	0.10 ± 0.03
20 : 4*n*−6	0.87 ± 0.028	0.10 ± 0.02

and essential fatty acids were lower in the fried fish compared to raw tilapia fish. The decrease in *cis*- and essential fatty acids are associated with the increase in *trans*- and saturated fatty acids. According to Saguy [22], the increase in *trans*-fatty acids might be due to the decrease in *cis*-fatty acids by thermal oxidation, and *cis*-fatty acids can be converted or isomerized into *trans*-fatty acids. The increment of saturated fatty acids and *trans*-fatty acids was supported by a strong significant negative correlation with the decrement of essential fatty acids (omega-3 and omega-6) and *cis*-fatty acids (%) at both $\alpha = 0.05$ and 0.01 with rcalc = −1.

3.4. Nutritional Quality Index (NQI) of Raw and Commercial Fried Fish. Fried fish consumption is popular worldwide including in Ethiopia. Recently, a few studies have been conducted and stated that Nile tilapia fish is the major fish being fried and consumed in the Hawassa open market

(Ethiopia) [7]. The frying oil used in an open fish market is palm oil because the oil is cheap and provided through cooperatives easily; this oil has been reused for a long time, and this might affect the fatty-acid-related nutritional quality index. Our study showed, in commercially fried fish, the saturated fatty acid, atherogenic index, thrombogenic index, and hypercholesterolemic index have been increased. On contrary to this, the unsaturated fatty acid, hypocholesterolemic index, and nutritive value index have been decreased. Therefore, frying noticeably decreases the nutritional quality of fish muscle. The summation of saturated fatty acids, unsaturated fatty acids including essential, *trans*-, and *cis*-fatty acids, and the nutritional quality index is detailed in Table 3.

The total saturated fatty acids, *cis*-fatty acids, *trans*-fatty acids, omega-3 fatty acids, and omega-6 fatty acids of raw and commercial fried fish were ranging from 38.27–52.07%, 56.57–45.43%, 0.13–1.93%, 2.92–0.51%, and 13.92–10.19%, respectively. Similarly, the summation of monounsaturated and polyunsaturated fatty acids varied from 44.71–37.37% and 16.85–10.71%, respectively. The $\sum$PUFA/SFA and $\sum\omega$-3/ω−6 are commonly used parameters to judge the nutritional quality and healthiness of intramuscular fat for human consumption. Kang *et al.* [23] reported that a balanced intake of dietary $\sum$PUFA/SFA is very important in regulating serum cholesterol.

Indeed, the ratio of $\sum$UFA/SFA and $\sum$PUFA/SFA greater than 0.45 is recommended in human diets for cardiovascular (CVD) and chronic disease prevention [24]. In the meantime, a diet with a ratio of $\sum$UFA/SFA and $\sum$PUFA/SFA below 0.45 is considered undesirable for consumption due to its potential to induce cholesterol increase in the blood [25]. The result of this study showed that the $\sum$UFA/SFA and $\sum$PUFA/SFA of raw fish are about 1.16% and 0.44%, which is beneficial for human health. However, the ratio of $\sum$PUFA/SFA for commercially fried fish is 0.20 which is below the recommended level, and the commercially fried fish is not considered as a balanced human diet and it cannot improve the balance of fatty acids in the tissue. According to Wood et al., 2003, the recent focus of nutritionists is omega-3 and omega-6 fatty acids, and the high proportion of PUFA is not necessarily healthy unless it is not balanced with the ω−3/ω−6 ratio.

Omega-3, omega-6, and the ratio of ω−6/ω−3 are principal fatty acids to control the hypocholesterolemic index. Omega-3 and omega-6 fatty acids regulate the thrombogenic and atherogenic index, respectively. Wolosyzyn et al. [24] reported that healthy meat and meat kind products are characterized by a low atherogenic index and high h/H index. Attia et al. [26] also reported that meat and meat kind products with a low thrombogenicity decrease threat of atrial fibrillation. According to Fernandes et al. [14], if the ratio of ω−6/ω−3 is less than 4, then the diet has a desirable quantity of omega-3 and omega-6 fatty acids and reduces cardiovascular diseases. In our study, the ratio of omega-6 and omega-3 fatty acids of raw and commercial fried Nile tilapia fish was 4.76% and 19.98%, respectively, and this showed that raw fish is good and beneficial for human health since the ratio is not as such deviated from the standard. However, the ratio ω−6/ω−3 for commercially fried fish is significantly higher than the standard value, and consumption of the commercially fried fish couldnot be beneficial for human health and can expose to noncommunicable diseases.

In addition to the ratio of $\sum$UFA/SFA, $\sum$PUFA/SFA, and $\sum\omega$−6/ω−3, it is important to evaluate DHA, EPA, atherogenicity, thrombogenicity, nutritive value, and hypocholesterolemic/hypercholesterolemic index (HH) as they indicate the contribution of fish fatty acids to human health. Maki et al. [27] reported that DHA decreases the concentration of low-density lipoprotein cholesterol in plasma and EPA is recognized as the most important essential fatty acid of the ω−3 series in the human diet because it is the precursor to the formation of ω−3 series eicosanoids [28]. In the study, DHA and EPA of raw and commercially fried Nile tilapia fish vary from 1.02–0.25% and 0.82–0.1%, respectively. The study revealed that raw fish had higher DHA and EPA compared to commercially fried fish. The lower DHA and EPA in commercially fried fish might be because double bonds are highly labile for oxidation during heating, owing to the presence of (pi) bonds, which consequently produces degradable products, though the essential fatty acid would be degraded [29].

3.5. Nutritive Value of Raw and Commercial Fried Fish. The ratio of the nutritive value index of raw and commercial fried fish is shown in (Figure 1). Atherogenicity indicates the adhesion of lipids to cells of the immunological and circulatory system, inhibiting the aggregation of plaque and diminishing the levels of esterified fatty acid, cholesterol, and phospholipids, thereby preventing the appearance of micro- and macrocoronary diseases, and myristic and palmitic acids are among the most atherogenic agents [30].

Thrombogenicity showed the tendency to form clots in the blood vessels [31]. Stearic is thought to be neutral to atherogenicity but considered to be thrombogenic [32]. According to Estuary et al. [33] and Karimian et al. [34], the higher index of atherogenicity and thrombogenicity values is responsible for the formation of atheroma and stimulates the aggregation of platelets in the cardiovascular system. Hence, the lower values are desirable in the prevention of cardiovascular disorders. The current study showed IA and IT of raw and commercial fried Nile tilapia fish ranged from 0.60–1.01% and 0.85–1.58%, respectively. This indicates frying leads to increase IA and IT which is considered to be low in nutritional quality.

The index of the ratio between hypocholesterolemic and hypercholesterolemic of fatty acid (h/H index) is another indicator of the effect of specific fatty acids on cholesterol metabolism. The higher value of this index is considered to be desirable. Thus, nutritionally higher h/H values are considered more beneficial for human health. In the current study, the h/H index obtained in raw fish is about 1.81 and the h/H index for commercially fried fish is 1.15. This indicates raw fish is more healthy and beneficial as compared to fried ones. The highest NVI value was found in raw fish

Table 3: Nutritional quality indices of lipids in raw and commercial fried fish.

Item	Raw fish	Commercially fried fish
∑SFA	38.27 ± 0.04	52.07 ± 0.07
∑MUFA	44.71 ± 0.026	37.37 ± 0.02
∑PUFA	16.85 ± 0.14	10.7 ± 0.13
∑MUFA/SFA	1.16 ± 0.12	0.711 ± 0.14
∑PUFA/SFA	0.44 ± 0.001	0.20 ± 0.001
∑omega-*3*	2.92 ± 0.01	0.51 ± 0.02
∑omega-6	13.92 ± 0.56	10.19 ± 0.28
$\sum\omega{-}3/\omega{-}6$	0.21 ± 0.01	0.05 ± 0.001
$\sum\omega{-}6/\omega{-}3$	4.76 ± 0.21	19.98 ± 0.68
∑*cis*	56.57 ± 0.015	45.43 ± 0.03
∑*trans*	0.13 ± 0.007	1.93 ± 0.03
IA	0.60 ± 0.001	1.01 ± 0.002
IT	0.85 ± 0.02	1.58 ± 0.21
h	55.75 ± 0.06	44.083 ± 0.01
H	32.49 ± 0.001	39.79 ± 0.002
h/H	1.71 ± 0.001	1.10 ± 0.001
NVI	1.23 ± 0.003	0.91 ± 0.001
PI (%)	38.27 ± 0.21	15.45 ± 0.16

∑SFA, saturated fatty acid; ∑MUFA, monounsaturated fatty acid; ∑PUFA, polyunsaturated fatty acid; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; IA, atherogenic index; IT, thrombogenic index; h/H, hypocholesterolemic/hypercholesterolemic index; NVI, nutritive value index; PI, peroxidizability index.

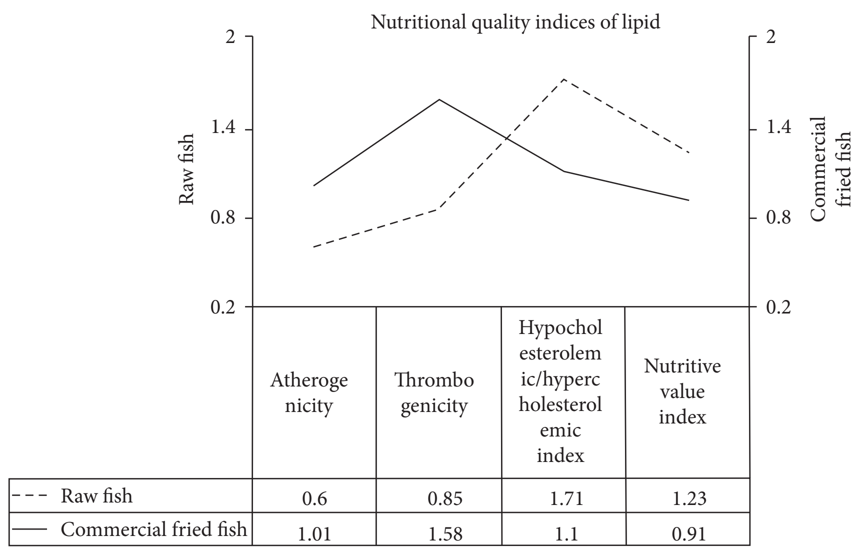
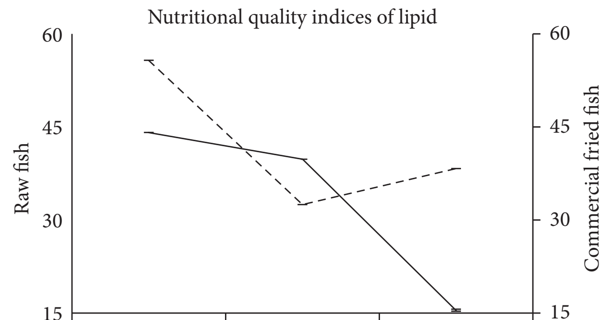


Figure 1: Nutritive value index of raw and commercial fried fish.

which about 1.23 as compared to commercially fried Nile tilapia fish whose NVI value is 0.91. The highest NVI value in raw fish is because raw fish had the highest proportion of C 18 : 0, C 18 : 1*n*−9, and the lowest percentage of C 16 : 0.

3.6. Comparison of the Hypocholesterolemic and Peroxidizability Index of Raw and Commercial Fried Fish. The hypocholesterolemic, hepercholestrolemic, and peroxidizability index of raw and commercial fried fish are shown in Figure 2. Peroxidizability index (PI) is another parameter to indicate the relationship between the fatty acid composition of a tissue and its susceptibility to oxidation. The PI index assesses the stability of PUFA included in food products and protects from possible oxidation. The higher PI value is equivalent to the greater protective potential for coronary artery disease. According to Kang et al. [23], Sinanoglou et al. [35], and Ska1ecki et al. [36], excessive intake of PUFA leads to oxidative stress because lipid is susceptible to lipid peroxidation. Oxidative stress is associated with the formation of lipid peroxides, and has been suggested as contributing to pathological processes in aging and many diseases such as atherosclerosis.

In the current study, the PI value of raw and commercial fried fish ranged from 38.27%–15.45%. Thus, the study revealed that commercially fried Nile tilapia fish had a lower PI value compared to raw fish, and the lower PI value indicates low level of PUFA for auto-oxidation. However, raw



	Hypocholesterolemic index	Hypercholesterolemic index	Peroxidizability index
Raw fish	55.75	32.49	38.27
Commercial fried fish	44.083	39.79	15.45

Figure 2: Hypocholesterolemic and peroxidizability index of raw and commercial fried fish.

fish had high PUFA and susceptible to auto-oxidation. The higher tendency to lipid oxidation was found in different kinds of marine fish fillet by Ghaeni et al. [31] and in crab edible tissue by Fernandes et al. [14].

4. Conclusions and Recommendations

The dominant saturated fatty acids found in Nile tilapia fish were palmitic, myristic acid, and methyl stearate. Oleic acid, linoleic acid, and palmitoleic acid were the highest *cis*-fatty acids. Saturated and *trans*-fatty acids were correlated positively. Similarly, unsaturated and *cis*-fatty acids were found to have a positive correlation. Regarding the nutritional quality index, raw fish was found with a high amount of essential fatty acids, h/H index, nutritive value index, and peroxidizability index which is considered beneficial for human health. Conversely, in the commercially fried fish, a high amount of IA and IT was found, which could have a negative influence on human health. Thus, it could be recommended to set the frying time and temperature during fish frying, and further analysis should be conducted about the frying oil's effect on the nutritional composition of fried fish.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding authorship and/or publication of this article.

Authors' Contributions

Aemiro Tadesse is the principal investigator, designed the study, took part in the sample collection process and laboratory experiment, entered and analyzed the data, and wrote the manuscript of the current study. Derese Tamiru oversaw the whole sample collection process, giving comments and suggestion during the manuscript write up. The authors read and approved the final manuscript to be submitted.

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