Research Article

Changes in the Proximate Composition, Fatty Acid and Mineral Contents of *Catla catla* of Loktak Lake by Different Cooking Methods

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ABSTRACT

Cooking methods are invariably found to influence the nutritional composition of protein and oil-rich food such as fish. The effects of four different cooking methods (steaming, microwave cooking, frying and currying) were investigated on an important food fish, *Catla catla,* obtained from the Loktak lake, Manipur, India. The mean moisture, protein, fat and ash content of the raw fish were 79.69±0.06%, 15.50±0.03%, 1.45±0.20% and 1.26±0.11%, respectively. Significant changes were observed in the proximate composition, fatty acids and mineral content in the cooked samples. The moisture content was found to decrease in all the cooked fish compared to raw fish and the lowest moisture content was observed in fried fish samples. The protein and ash contents increased in all the cooked fish samples. Fat content was found to increase significantly in the fried fish sample compared to other fish samples. A significant reduction in n-3/n-6 and EPA + DHA/ C16 ratio was observed in the curried fish compared to others, whereas PUFA/SFA ratio increased in all cooked samples. An increase in the HH (hypocholesterolaemic/ hypercholesterolaemic fatty acid) ratio was observed in the fried and curried fish sample. Na content increased in the cooked sample whereas Ca, K, P, Fe and Cu were found to decrease. Zn content of steamed and curried samples did not differ compared to the raw sample and the microwave-cooked sample recorded highest value. The results of the study may be useful in selecting and designing proper cooking methods for the efficient utilization of nutrients in the fish Catla.

Keywords: *Catla catla*, Cooking methods, PUFA, Proximate composition, Fatty acids.

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INTRODUCTION

Fish is a popular and important source of high-quality protein, fatty acids and essential micronutrients worldwide. The health benefits of regular fish consumption are largely attributed to their high concentration of long-chain polyunsaturated fatty acids (PUFA) especially eicosapentaenoic acid (EPA or 20:5 n-3), docosahexaenoic acid (DHA or 22:6 n-3) and docosapentaenoic acid (DPA or 22:5 n-3) found in fish oils. PUFA is reported to be associated with the reduction of several cardiovascular diseases risk in humans.[1-2] Since these PUFAs are not synthesized in the human body, their inclusion in human diets is, therefore, essential,[3] and fish can be good source for these PUFAs. Fish are also considered a very rich source of minerals and vitamins. Mineral elements such as sodium, potassium, magnesium, calcium, iron, phosphorus and iodine are important for human nutrition.[4]

Fishes are rarely eaten raw and are normally consumed in different cooked forms. The heat utilized in different cooking methods like boiling, steaming, grilling, baking or frying helps in neutralizing harmful microorganisms thereby increasing the shelf life of the food, and additionally, cooking also enhances the flavor of the food.[5-6] Suitable cooking method enhances

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the digestibility of a particular food and also reduces the loss of nutrients.[7] On the other hand certain cooking method especially for fish and meat, may result in formation of detrimental byproducts. Thus, it is important to understand the different changes in nutritional content of food such as fish under various cooking methods for selection of the most suitable cooking method to preserve and enhance the nutritional quality of the fish. The effects of different processing and cooking methods on nutritive values of different fish species have been reported in many studies.[8-10] However, there is no such report available on the changes in the nutrient profile of *Catla catla* of the Loktak lake cooked by different methods. The Indian major carp, *C. catla* belongs to Order Cypriniformes and Family Cyprinidae, and it is an economically important freshwater food fish of Manipur. It does not possess a stomach and is characterized by the presence of a diffused hepatopancreas. Adults are surface feeder and planktivorous in feeding habit with a preference for zooplankton. Given the popularity of this fish amongst the population, the present investigation, therefore, aims to evaluate the effects of different cooking methods on the proximate composition, fatty acids profile and mineral content of this species compared to the raw fish.

MATERIALS AND METHODS

Fish Collection, Sample Preparation and Cooking

Samples of *C. catla* weighing 500-600 g with standard length 25.0-27.5 cm were collected from the Loktak lake, Manipur, with the help of local fishermen living in and around the lake. The fish were kept in an ice box and transported to the laboratory at the Department of Life Sciences, Manipur University. The fish were washed thoroughly with potable water to remove blood and slime. The head parts, scales and viscera were removed, and the fish muscles were cut into pieces (steaks). Subsequently, the cut pieces were divided into five groups. The first group was named as raw or uncooked fish. The other four groups were processed in the following cooking methods: steaming, microwave cooking, frying and currying. Steaming was performed at a temperature range of 99 - 101°C till three whistles in a kitchen food pressure cooker (Hawkins Ltd., India). Microwave cooking of steaks was performed in a microwave oven (Whirlpool, India) with the temperature set at 204°C to 230°C for 16 min. The frying of steaks was performed in a domestic frying pan of 2 L capacity at an approximate temperature of 170°C for 8 min. Rice bran oil was used as the medium for frying. Currying of fish steak was performed in a local pan of 2 L. For analysis of proximate composition, fatty acids and minerals, the fresh and cooked fish samples were de-boned manually and grounded in a mortar pestle to ensure homogeneity, and representative samples were taken for analysis.

Proximate Composition Analysis

Proximate composition analysis of raw and cooked *C. catla* were done in triplicate for moisture, protein, lipid and ash contents. Moisture was measured by following the methods of the Association of Official Analytical Chemists, AOAC.[11] Total lipid was extracted from the muscle tissues by following the method of Singh *et al*.[12] The nitrogen content of the samples was estimated by Micro-Kjeldahl's method.[11] Crude protein content was calculated by multiplying the nitrogen (N) content by a conversion factor (6.25). Ash was measured by heating the sample in a muffle furnace at 550°C for 3 hr to obtain carbon-free white ash.[11]

Fatty Acid Analysis

For fatty acid analysis, 150-250 mg of the lipid extract was taken to prepare fatty acid methyl ester (FAME). FAME was prepared by transesterification of the extracted lipid using the boron-trifluoride methanol method.[13] The fatty acid methyl esters were analyzed by gas chromatography (Shimadzu GCMS-QP2010 Plus), which was equipped with a flame ionization detector and fitted with Rxi-5Sil MS capillary column (30m × 0.25mm 0.25um). The following operating conditions were employed during the analysis: helium gas was used as carrier gas at a constant flow of 1.21ml/min and an injection volume of 2µl was employed (split ratio 10.0), injector temperature 260°C; ion source temperature 230°C. After injection (2µl), the column temperature was held at 140°C for 5 min, then increased to 280°C at 4°C degrees/min and held at this temperature for 10 min. Fatty acids were quantified by comparing the spectrum of unknown fatty acids with the spectrum stored in the National Institute of Standards and Technology (NIST) library and then each fatty acid was expressed as a percentage of the total fatty acids quantified.

Nutritional Quality Indices (NQI)

The nutritional quality of lipids in the raw fish and samples cooked by different methods were evaluated using four indices. The n-3/n-6 gives a relative comparison of total n-3 FAs over total n-6 FAs, while the EPA + DHA/C16 ratio implies relative value of total EPA and DHA over the C16 fatty acid. PUFA/SFA refers to the comparison between all the PUFAs and SFAs present in the sample. The

HH (hypocholesterolemic/hypercholesterolemic fatty acids) ratio was calculated according to Santos-Silva *et al.*[14] using the following formula:

HH = (C18:1n-9 + C18:3n-6 + C18:3n-3 + C20:5n-3 + C22:6n-3) / (C14:0 + C16:0).

Mineral Element Analysis

For mineral analysis, 1g of the sample was taken. It was digested with 8ml of concentrated nitric acid (TraceMetal™ Grade, Fisher Scientific) and 2ml of hydrogen peroxide (30-32%, Optima, Fisher Scientific) in a microwave (Milestone START D, Italy) for 40min. The digested residue was then transferred to a 50 ml volumetric flask and made up to volume using Milli-Q water. Then, the mineral content were measured using inductively coupled plasma optical emission spectroscopy (iCAP 6300 Duo, Thermo Fisher Scientific, Cambridge, England) with dual configuration (axial and radial) and iTEVA (version 2.8.0.97) operational software. Multielement standard solution (CertiPUR, Merck) was used for the preparation of calibration solutions and Yttrium as internal standard.

Statistical Analysis

Statistical analysis was performed with the Statistical package for the Social Sciences (SPSS) version 16.0 for windows. The effect of different cooking methods on the proximate composition, fatty acid composition and mineral content of *C. catla* were analyzed using one-way analysis of variance (ANOVA), and the significant differences between means were determined by post hoc Duncan's multiple range test. Differences were considered to be significant when $p<0.05$.

RESULTS

Proximate Composition

The results of the proximate composition analysis of raw and cooked *C. catla* are elaborated in Table 1. The average moisture content in raw *C. catla* was found to be 79.69±0.06%, and the lowest moisture content was found in fried fish sample (58.83±0.60%). The moisture contents in microwave cooked and fried sample (66.55±0.39 and 58.83±0.60%, respectively) were found to be significantly ($p<0.05$) lower compared to the raw sample. However, the moisture content of steamed (76.78±0.15%) and curried *C. catla* (71.20±0.45%) did not show any significant ($p>0.05$) difference. Crude protein was found to be significantly ($p<0.05$) higher in microwave cooked (25.75±0.12%) and fried sample (24.44±0.09%) when compared to the remaining samples. There were no significant ($p>0.05$) difference in the protein contents of steamed and curried sample as compared to the raw fish. The lipid content was found to be highest in fried (8.35±0.23%) and curried fish (8.25±0.05%). The lipid content of raw and steamed samples were 1.45±0.20% and 1.85±0.10%, respectively while the value was 2.80±0.09% in microwave cooked sample. Ash content was significantly ($p<0.05$) higher in fried sample (2.63±0.14%) and the lowest ash content was observed in raw *C. catla* (1.26±0.11%).

Fatty Acid Composition

The fatty acid (FA) composition of raw *C. catla* and samples cooked by different methods are represented in Table 2. The FA composition of raw *C. catla* followed a relative pattern with Saturated Fatty Acid (SFA) > Polyunsaturated Fatty Acid (PUFA) > Monounsaturated Fatty Acid (MUFA). The saturated FA, palmitic acid (C16:0) was detected the highest among all the seven saturated FAs observed in the samples. SFAs C19:0 and C20:0 were detected the least among all the SFA, and they were not detected in any of the cooked fish sample. Our results showed that among the different MUFAs (C16:1, C18:1 and C20:1), oleic acid (C18:1) was predominantly present in both the raw and different cooked forms. Overall highest amount (34.87±0.49%) of MUFA was observed in curried fish sample. As many as 11 different types of n-3 and n-6 PUFAs were detected in all the samples in the present study, ranging from C18 to C22 with different degrees of unsaturation. Among the n-3 PUFA, docosahexaenoic acid (DHA) was found to be the highest followed by Eicosapentaenoic acid (EPA)

Table 1: Proximate composition (%) of raw and cooked samples of *Catla catla* (*n*=3) obtained from Loktak lake, Manipur.

Proximate composition	Raw	Steamed	Microwave-cooked	Fried	Curried
Moisture	79.69±0.06^a	76.78±0.15^a	66.55±0.39^b	58.83±0.60^b	71.20±0.45^a
Protein	15.50±0.03^b	16.79±0.03^b	25.75±0.12^a	24.44±0.09^a	15.75±0.05^b
Lipid	1.45±0.20^c	1.85±0.10^c	2.80±0.09^b	8.35±0.23^a	8.25±0.05^a
Ash	1.26±0.11^c	1.79±0.02^b	1.84±0.10^b	2.63±0.14^a	1.86±.04^b

Data represented as mean ± SD. Means within the same row having different superscripts are significantly different ($p<0.05$).

Table 2: Fatty acid composition (%) of raw and cooked samples of *Catla catla*.

Fatty acids	Raw	Steamed	Microwave-cooked	Fried	Curried
C14:0	3.7±0.07^{d}	1.51±0.02^{c}	1.22±0.05^{b}	0.97±0.06^{a}	ND
C15:0	2.06 ±0.07^{b}	0.91±0.05^{a}	1.01±0.06^{a}	ND	ND
C16:0	23.89±0.25^{a}	24.73±0.86^{a}	27.59±0.43^{b}	28.36±0.51^{b}	28.77±0.51^{b}
C17:0	2.95±0.07^{d}	2.02±0.02^{c}	1.88±0.04^{b}	1.15±0.06^{a}	ND
C18:0	10.3±0.09^{c}	12.42±0.14^{d}	11.34±0.13^{e}	9.62±0.12^{b}	8.70±0.09^{a}
C19:0	0.64±.06^{a}	ND	ND	ND	ND
C20:0	0.43±0.07^{a}	ND	ND	ND	ND
∑SFA	**43.97±0.45^{e}**	**41.61±0.91^{c}**	**43.04±0.37^{d}**	**40.1±0.40^{b}**	**37.5±0.31^{a}**
C16:1	8.5±0.08^{c}	4.88±0.11^{b}	ND	1.97±0.06^{a}	2.09±0.06^{a}
C18:1n-7	3.74±0.05^{d}	3.06±0.12^{c}	2.53±0.05^{b}	1.67±0.07^{a}	ND
C18:1n-9	12.40±0.12^{a}	16.68±0.55^{b}	18.49±0.19^{c}	22.76±0.28^{d}	32.78±0.43^{e}
∑MUFA	**24.64±0.12^{b}**	**24.62±0.78^{b}**	**21.02±0.24^{a}**	**26.4±0.42^{c}**	**34.87±0.49^{d}**
C18:2n-6	3.36±0.05^{b}	2.73±0.03^{a}	5.48±0.05^{c}	8.82±0.09^{d}	13.23±0.15^{e}
C18:4n-3	0.93±0.06^{b}	0.78±0.05^{a}	ND	ND	ND
C20:2n-6	0.31±0.07^{a}	ND	ND	ND	ND
C20:3n-6	0.81±0.06^{a}	ND	ND	ND	ND
C20:4n-6	6.10±0.05	8.53±0.25	8.15±0.07	6.89±0.07	4.56±0.06^{a}
C20:4n-3	0.62±0.06^{a}	ND	ND	ND	ND
C20:5n-3 (EPA)	4.23±0.05^{c}	5.17±0.12^{e}	4.56±0.05^{d}	3.77±0.06^{b}	2.28±0.06^{a}
C22:4n-6	0.74±0.06^{a}	0.77±0.05^{a}	0.79±0.06^{a}	ND	ND
C22:5n-3	3.98±0.05^{b}	4.89±0.11^{d}	4.82±0.05^{d}	4.32±0.06^{c}	2.72±0.06^{a}
C21:5n-3	2.46±0.05^{c}	2.02±0.01^{b}	2.02 ±0.05^{b}	1.53±0.07^{a}	ND
C22:6n-3 (DHA)	6.70±0.06^{b}	8.18±0.24^{c}	9.39±0.09^{d}	8.16±0.09^{c}	4.88±0.06^{a}
∑PUFA	**30.24±0.75^{b}**	**33.07±0.64^{c}**	**35.21±0.42^{e}**	**33.49±0.10^{d}**	**27.67±0.22^{a}**
∑n-3	18.92±0.41^{c}	21.04±0.41^{e}	20.77±0.01^{d}	17.78±0.03^{b}	9.88±0.19^{a}
∑n-6	11.32±0.34^{a}	12.03±0.23^{b}	14.42±0.04^{c}	15.71±0.07^{d}	17.79±0.03^{e}

Values are represented as mean values ± SD (n=3). Means within the same row having different superscripts are significantly different (p<0.05). ND= not detected

in all the samples. All the cooked methods showed a significant (p<0.05) increase in total PUFA amount except curry cooked fish sample, where the values decreased (27.67±0.22%). Fried and curried fishes were found to have significantly higher (p<0.05) levels of palmitic and linoleic acid content among all samples. Steaming and microwave cooked fish sample showed significantly (p<0.05) higher n-3 content, whereas frying and curried sample showed lower n-3 content. The most significant (p<0.05) reduction of n-3 was found in currying method. The values of n-6 PUFA was found to be significantly (p<0.05) higher in all the cooked samples compared to the raw fish, and the highest value (17.79±0.03%) was observed in fish cooked by currying method.

Nutritional Quality Indices (NQIs)

The n-3/n-6 ratio in all cooking methods was found to be significantly (p<0.05) lower (0.56±0.01) in curried fish compared to other samples (Table 3). The value was found to be 1.75±0.00, 1.44±0.00, 1.13±0.00, 1.75±0.00 in steamed, microwaved and fried fish samples, respectively. The PUFA/SFA ratio was observed to be 0.69±0.01 in raw fish, and the value ranged between 0.74±0.01 to 0.83±0.01 in the remaining samples without any significant (p>0.05) difference. The highest value was observed in fried (0.82±0.01) and microwave cooked (0.83±0.01) samples. The EPA + DHA/C16 ratio did not differ significantly (p>0.05) in all the analyzed samples except curry cooked fish, where the value was significantly (p<0.05) lower than the other samples. The highest EPA + DHA/C16 ratio was found in steam cooked fish (0.54±0.00). The HH ratio was highest in curried fish sample (2.12±0.00), and the ratios were 1.03±0.00, 1.59±0.02, 1.63±0.00 and 1.81±0.01 in the raw, steamed, microwaved and fried fish samples, respectively.

Table 3: Nutritional quality indices of raw and cooked samples of *Catla catla*. Values are represented as mean values ± SD (*n*=3).

Nutritional quality indices	Raw	Steamed	Microwave-cooked	Fried	Curried
n-3/n-6	1.67±0.01^{a}	1.75±0.00^{a}	1.44±0.00^{ab}	1.13±0.00^{ab}	0.56±0.01^{c}
EPA + DHA/C16	0.46±0.00^{a}	0.54±0.00^{a}	0.51±0.00^{a}	0.42±0.00^{a}	0.25±0.00^{b}
PUFA/SFA	0.69±0.01^{b}	0.80±0.00^{a}	0.82±0.01^{a}	0.83±0.01^{a}	0.74±0.01^{a}
HH	1.03±0.00^{d}	1.59±0.02^{c}	1.63±0.00^{c}	1.81±0.01^{b}	2.12±0.00^{a}

Means within the same row having different superscripts are significantly different (p<0.05).

Table 4: Mineral compositon (mg/kg) of raw and cooked samples of *Catla catla*. Values are represented as mean values ± SD (*n*=3).

Minerals	Raw	Steamed	Microwave-cooked	Fried	Curried
Sodium	953.31±15.14^{a}	5259.96±34.21^{c}	6100.01±52.24^{d}	4566.7±24.13^{b}	7359.53±37.12^{e}
Calcium	1105.23±30.25^{c}	375.06±4.12^{a}	1300.94±21.35^{d}	339.98±11.45^{a}	604.8±14.21^{b}
Phosphorous	8291.37±10.52^{d}	8291.37±35.13^{d}	7813.76±25.46^{c}	5990.8±43.12^{b}	4452.24±13.2^{a}
Potassium	9780.6±15.65^{e}	9414.93±29.38^{d}	8142.2±56.24^{c}	6530.2±31.12^{b}	4729.3±12.34^{a}
Magnesium	886.35±23.5^{d}	695.97±13.56^{b}	929.17±15.48^{e}	743.45±12.24^{c}	595.61±5.64^{a}
Zinc	28.35±3.2^{ab}	26.6±2.6^{ab}	30.02±5.2^{c}	20.133±1.41^{a}	21.25±4.2^{ab}
Iron	24.14±2.1^{b}	21.38±4.8^{ab}	21.37±3.2^{ab}	14.04±2.3^{a}	22.04±3.21^{ab}
Manganese	2.75±0.3^{bc}	1.25±0.15^{ab}	3.38±0.25^{cd}	1.02±0.15^{a}	3.51±1.23^{d}
Copper	1.23±0.25^{b}	1.16±0.12^{ab}	1.14±0.32^{ab}	0.5333±.063^{a}	1.07±0.12^{ab}
Selenium	1.38±0.26^{a}	1.32±0.2^{a}	1.42±0.14^{a}	1.31±0.46^{a}	1.4±0.4^{a}

Means within the same row having different superscripts are significantly different (p<0.05).

Minerals

The relative concentrations of all the minerals analyzed in the raw sample were found to be as follows: K>P>Ca>Na>Mg>Zn>Fe>Mn>Se>Cu (Table 4). Among all the minerals analyzed, Na, K, Ca, P and Mg were present in significantly (p<0.05) higher amount compared to others. Mn, Cu and Se content were found to be lowest in all the samples. All the minerals except Na, K and P were found to be present significantly (p<0.05) higher in microwave cooked fish sample compared to remaining treatments. P and K were present significantly (p<0.05) higher in steam cooked and raw fish sample, whereas Na was present highest in curried fish. The Ca content was lower in steamed, fried and curried fish compared to the raw fish. Microwave-cooked fish sample showed higher Ca content. There was a significant (p<0.05) decrease of P content in all the cooking methods except for the steamed sample. The iron and copper content of all cooked samples were not significantly different (p>0.05) except the fried sample which recorded lowest value. The decrease in copper and zinc content in the fried and the curried sample was significant (p<0.05) compared to other samples. Steaming or currying had no significant (p<0.05) effect on the zinc content. Manganese content decreased in all cooked samples except microwave and curried samples where the values increased.

DISCUSSION

Proximate Composition

The proximate composition analysis of raw and cooked *C. catla* showed variations indicating changes due to the different cooking methods. Significant (p<0.05) reduction in moisture content was observed in microwave cooked or fried fish. This may be due to loss of water during the process. The results of our experiments are in agreement with findings reported on various fish species.[15,16] Significantly (p<0.05) higher crude protein observed in microwaved and fried samples corresponds to the reduction of moisture in these samples, and may be due to high loss of moisture resulting in subsequent dehydration of the meat cooked by these methods. The high lipid content observed in fried and curried fish may be due to the absorption of oil by fish during the process of frying and currying as rice bran oil was used as the medium for both the cooking methods. There was no significant (p>0.05) difference in

ash content of steamed, microwaved and curried *C. catla* sample. However, an increase in ash content was noticed in all the cooked samples compared to the raw fish, and the highest was recorded in the fried fish sample. Increased ash content may be attributed to the high inorganic matter content in them.[17,18]

Fatty Acid Composition

The ratio of long-chain n-3, n-6 fatty acids (n-3/n-6) is considered important for evaluating the fatty acid composition of a food. PUFA of the n-6 and especially of the n-3 family are recognized as essential components of the human diet. They are effectively synthesized only by aquatic organisms. Also detailed information about lipid components and their fatty acid constituents are essential to understand mechanisms to diminish oxidative or hydrolytic factors which affect the fish quality.[19] The SFA analysis showed that all the cooking methods resulted in loss of C10:0 and C:20 SFA, which were present in the raw sample. Palmitic acid (C16:0) was abundantly observed in all the samples. DHA and EPA from fish and fish oil are essential for human development and in the amelioration of many common diseases.[20] Results from our study indicate that *C. catla* is a good source of MUFAs and PUFAs which were retained in all the different cooking methods evaluated. The essential fatty acids EPA and DHA are reported to be effective in reducing the risk of human cardiovascular diseases making it important for human diet.[21] Significantly higher ($p<0.05$) levels of palmitic and linoleic acid content in fried and curried fish samples may be due to the absorption of oil while frying and currying. Rice bran oil is a good source of palmitic and linoleic acid and the same was used for frying and currying the fish. All cooking methods resulted in lower n-3 fatty acid content of the fish except steaming method, and the highest reduction was recorded in currying method. Reduction of n-3 during the cooking method may be due to a combination of factors like high amounts of unsaturated fatty acids, and low amounts of natural antioxidants, auto oxidization at a faster rate than other kinds of lipids.[22] Oil absorption by fish during frying seems to be the most important probable factor which reduces total n-3 content as compared to other cooking methods (boiling, baking, and microwave cooking), in which the reduction of n-3 FA depended on fatty acid composition and sensitivity of them to oxidation.[23] Hence, with regards to n-3 fatty acids, steaming and microwave cooking are better method for their retention in the cooked fish. Better use of antioxidants may be evaluated to mitigate loss of the n-3 FA in currying method.

Nutritional Quality Indices (NQIs)

The Nutritional Quality indices (NQIs) values are important in understanding the nutritional quality of a food. The n-3/n-6 ratio is one of the useful indicators of the relative nutritional values of fish oils, and the daily ratio should not be higher than 1.5 as per WHO recommendations. It is the key factor for the balanced synthesis of eicosanoids in organisms, and for the normal growth and development of the human body.[24,25] Steamed fish was found to preserve and enhance the n-3/n-6 ratio in the present study indicating the importance of this cooking method. Significant ($p<0.05$) decrease in the ratio observed in all other methods may be due to an increase in n-6 FA and/or decrease in n-3 FA.

The PUFA/SFA ratio indicates the relative abundance of PUFA over SFA, and this helps us in understanding the major type of FA found in the sample. Raw *C. catla* was observed to be a good source of PUFA as indicated by PUFA/SFA ratio. The minimum recommended ratio for PUFA/SFA is 0.45.[26] This ratio was found to be significantly ($p<0.05$) increased in all the cooking methods. The highest increase was observed in fried and microwave cooked samples which indicates the importance of this cooking method. These results may be associated with the increase in total PUFAs observed earlier and also with the use of rice bran cooking oil since the oil is a known source of PUFAs. Similar observation of increase in this ratio was reported in previous studies.[9,15,27] Our results indicate that all the cooking methods studied preserve the availability of PUFA in the fish.

The EPA + DHA/C16 ratio is a good index to evaluate lipid oxidation.[28] The higher value of this ratio in a sample indicates higher lipid oxidation activities in the sample. In the present investigation, the highest EPA + DHA/C16 found in steam cooked fish indicate a higher lipid oxidation rate in steam-cooked fish compared to the other samples.

The HH ratio is a useful index in indicating PUFA fatty acids as hypocholesterolaemic, which decreases cholesterol level, and two saturated fatty acid myristic acid (C14:0) and palmitic (C16:0) as hypercholesterolaemic.[29] Higher values of HH ratio are desirable considering the specific effects of fatty acids on cholesterol metabolism. In this study, the HH ratio significantly ($p<0.05$) increased in all the cooked fish samples, and the highest increase was found in fried and curried fish sample. Therefore, all the cooking methods in the present study maintained a healthy HH ratio, and frying and currying

results in enhanced HH ratio compared to the other cooking methods.

Minerals

Minerals play important role in the maintenance of certain physicochemical processes essential to life. Deficiency of essential minerals like Na, K, Ca, Fe etc. can disrupt enzyme-mediated metabolic functions resulting in organ malfunctions, chronic diseases and ultimately death.[30] K and P were present higher compared to others, and Cu and Se the lowest in all the samples. Our results indicate that microwave cooking method showed retention of most minerals which were analyzed. Steam cooking method was found to be effective in retaining the P and K. The increase in Na content after cooking in different methods may be due to the salt added during the cooking methods to make it more palatable. The highest Na content was observed in the curried fish sample. Steaming, frying and currying methods resulted in reduced Ca contents when compared to the raw fish samples. Similar observations were reported by Koubaa *et al*.[27] However, microwave cooking increased the Ca content of fish samples which was in agreement with results reported by Ersoy *et al*.[31] However, Badiani *et al*.[32] reported that the Ca content of European sea bass did not change after cooking. In the present study, all cooking methods reduced the K content. Similar findings were reported by Ersoy.[27] On the other hand, Gokoglu *et al*.[33] reported that the K content of fried samples did not show any change. Increase K content of cooked fish samples have also been reported in some studies.[31,34] Frying and currying methods resulted in loss of Cu and Zn. Similar observations were made by Koubaa *et al*.[6] and Gokoglu *et al*.[33] Our results indicate that raw *C. catla* is a good source of important macrominerals like Na, K, Ca, Mg and P. Among the microminerals Zn and Fe were found be present highest, and Cu, Mn and Se were present in significantly low amount compared to other microminerals. Cooking methods were found to considerably influence most of the macro and microminerals present in raw fish.

CONCLUSION

The different cooking methods (steam, microwave, frying and curry) evaluated in the present study were found to have considerable effects on the nutrient composition of *C. catla*. Proximate analysis of the raw fish revealed that it is a good source of n-3 PUFA, mainly the long-chain acids. The proximate composition, fatty acid, NQIs and mineral compositions of the fish changed significantly corresponding to the different cooking methods employed. Loss of moisture was found highest in fried sample. Fatty acids compositions were observed to undergo variation according to the cooking method, but were most affected by the currying method of cooking compared to the other methods. There was no significant decrease of PUFA in all the cooked samples, except for the currying method, because the EPA and DHA were well retained in these methods. However, the significant increase in the n-3/n-6 ratio in steamed fish may be indications of the enhanced nutritional value of *C. catla* cooked by this method. Both macro and microminerals were detected in raw fish and their composition varied with the type of cooking method. This study has provided valuable information on the nutritional value and their changes in *C. catla* of Loktak lake under different cooking methods. This information may be useful in selecting proper cooking method for the fish to design nutritional strategies based on retention of nutrients for various categories of people.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

FA: Fatty Acid; **PUFA:** Polyunsaturated Fatty Acid; **MUFA:** Monounsaturated Fatty Acid; **SFA:** Saturated Fatty Acid; **EPA:** Eicosapentaenoic Acid; **DHA:** Docosahexaenoic Acid; **FAME:** Fatty Acid Methy Ester; **HH:** Hypocholesterolemic/Hypercholesterolemic.

SUMMARY

The effect of different cooking methods on the nutritional composition of *Catla catla* from Loktak lake was evaluated. The proximate composition, fatty acid, Nutritional Quality Indices and mineral compositions were found to change significantly under the different cooking methods employed. Loss of moisture was found highest in fried sample, and fatty acids compositions were most affected by the currying method of cooking compared to the other methods. Except for curried fish, PUFA were retained in all the cooked samples. Macro

and microminerals composition varied with the type of cooking method. This study has provided important information on the effect of different cooking methods on the nutritional value of *C. catla* of Loktak lake. This information may be useful in developing nutritional strategies for various categories of people.

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