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Nutritional Properties of Atlantic Mackerel and Salmon as Affected by Traditional Cooking Methods

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***Abstract**: The present study investigated the changes in nutritional quality of Atlantic mackerel (scomber socombrus) and Salmon (*Oncorhynchus tshawytscha*) as affected by cooking methods popularly practiced in homes of Nigerian consumers. Smoked, boiled, and fried mackerel and salmon samples were subjected to assessment of proximate and fatty acid compositions. Uncooked (raw) fish samples were also subjected to analyses, and served as control. Findings from this work indicate that moisture content ranged from 22-73% (vs. 68% for the control) and 31-75% (vs. 68% for the control) for cooked mackerel and salmon respectively. Moisture content was generally higher in boiled samples than in smoked and fried samples. Cooked samples showed increase in protein content, with the highest increase being observed in smoked (22.23%) and fried (21.60%) salmon, followed by smoked (20.5%) and fried (20.0%) mackerel. Fat content increased as a result of cooking and showed inverse relationship with moisture content. Fried samples had higher fat contents (11.6 and 13.60% for fried salmon and fried mackerel respectively, vs. 6.3 and 5.0% for the control samples) which can be attributed to oil uptake brought about by water loss. Ash content of cooked samples did not record major change; while fibre content ranged from 0.6-5.7% for the cooked samples vs. 4.2 and 5.0% for raw mackerel and raw salmon respectively. Both mackerel and Salmon were low in omega-6 PUFA and high in omega-3 PUFA, with the predominant omega-3 being eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA); and the predominant omega-6, linoleic acid (LA). All cooking methods led to substantial decrease in EPA, DHA and LA, with frying resulting to the greatest decrease. Omega-3 and omega-6 decreased from 22-2% and 3-0.55% respectively in fried mackerel; and from 21-2.5% and 7-1.0% respectively in fried salmon; The above findings suggest that frying led to up to 88% decrease in essential fatty acids, up to 63% increase in crude fat, and up to 15% increase in crude protein; Smoking resulted to up to 80% loss in essential fatty acids and up to 18% increase in crude protein, while boiling led to up to 82% decrease in omega-3 and omega-6 and up to 9% decrease in crude fat.*

***Keywords:** Atlantic mackerel; Salmon; Cooking method; Eicapentaenoic; Docosahexaenoic.*

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I. Introduction

Fish consumption is gaining wide prominence particularly in developing countries where 40% or more of their protein are obtained from fish[1]. Nutritionists frequently emphasize the importance of fish in the diet due to their rich content of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) which are widely distributed in various proportions in different fish species but are more concentrated in oily fishes such as mackerel, sardines, and salmon. The oil extracted from these fishes has been used either for edible purpose or in the form of supplements due to their rich contents of omega-3 and omega-6 fatty acids. These omega-3 and omega-6 fatty acids distinguish fish lipids from plant and animal lipids; and have been reported to have several dietary benefits such as alleviating, preventing or reducing cardiovascular disease[2,3], high blood pressure, clotting[4] and cancer[5]. Although fish oils have been cited to have pharmacological and neutracuetical interventions, they are prone to rapid oxidation due to their large number of double bonds and their position within the fatty acid chain[6]. Consumption rate of Atlantic mackerel in Nigeria is currently high especially in rural communities where they are sold frozen in open markets. The high consumption rate of this specie can be attributed to its availability and affordability, compared to catfish for instance[7]. They are usually subjected to various cooking methods (such as smoking, frying, boiling and steaming) using traditional techniques according to the consumer's desire and preference. As is common with food products, when fish is subjected to cooking or high temperature processing, chemical and physical reactions take place which improve or impair the nutritional value. Hence, assessing the nutritional quality of fish after it has undergone various traditional cooking methods so as to identify the cooking method that retains more of the key nutrients becomes indispensable. Several studies have been conducted to assess the effects of different cooking methods (mostly frying, steaming, roasting and microwave cooking) on the nutritional composition and fatty acid profiles of fish species[8,9,10]; these studies suggest that cooking leads to decrease in long chain PUFA including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The most common methods prevailing in the homes of Nigerian consumers include smoking, boiling, and frying; hence their choice for this study. Smoking of fish has a long history in Nigeria as a preservation technique. In recent times however, it is not only done for the purpose of preservation but also for the unique taste and flavour imparted by the smoking process. Boiling involves dipping fish in water and cooking at the boiling point of water until required consistency is achieved; while frying involves cooking fish in fat or vegetable oil at the temperature of 170^{o}C and above. The present study therefore aimed at evaluating the impact of traditional cooking methods (smoking, frying and boiling) on the nutritional quality of mackerel, the most popular fish species in many Nigerian rural communities.

II. Materials And Methods

3.1 Source and Preparation of Raw Material

The Atlantic mackerel and salmon used in this study were purchased frozen from an open market in Abakaliki, Ebonyi State, and transferred to the Lab where the fish species were allowed to thaw; then degutted, beheaded, washed thoroughly and each fish was divided into four equal portions. The first portion was cooked at the boiling point of water for 10 minutes; the second was immersed in preheated soybean oil and deep-fried at 175-180^{o}C in a frying pan for 5 minutes using firewood as heat source, while the third portion was smoked for 2 day using fire wood. The fourth portion (raw fish) did not undergo any thermal processing and served as the control. Both cooked and raw samples were then subjected to analyses as described below.

3.2 Proximate Composition

Proximate composition was evaluated according to AOAC official methods of analysis[11]. Crude protein content was determined using micro-Kjeldahl method, crude fat was determined by Soxhlet extraction method, ash by incinerating samples at 600 °C in a muffle furnace and moisture content in a convection oven; while carbohydrate was calculated by percentage difference.

3.3 Fatty Acid Analysis

Oil was extracted from fish samples using chloroform/methanol (1:1, v/v) according to the method described by Poe et al.[10]. The fatty acid profiles of the extracted fish oil were then evaluated by GC analysis of methylated samples according to AOCS Official Method Ce 1h-05[12]. FAMEs were analyzed on a HP 6890 GC system from Hewlett Packard, using a DB-23 capillary column (60m x 0.32mm x 0.25µm film thickness) from Agilent Technologies, using FID detector. FAMEs were identified by comparison with the retention times of a standard mixture of 37 fatty acid methyl esters (Supelco, Germany). All reagents were of analytical grade and purchased from Merck (Darmstadt, Germany).

3.4 Statistical Analysis

Analytical data were processed using SPSS 16.0 for windows (SPSS, Chicago, IL, USA) and are expressed as means of three replicates. One way ANOVA was used to test differences and significance was established at $P<0.05$.

III. Results And Discussion

The results of proximate composition of cooked and uncooked samples are shown in table 1, while the corresponding fatty acid profiles are shown in tables 2-4. When compared to the uncooked samples of each species (raw mackerel (MCT) and raw salmon (SCT)), the cooked samples generally exhibited increase in protein content with a concomitant decrease in moisture content. This is in line with literature report[13] which indicated that decrease in moisture content is the most important change causing significant protein increase in cooked fish. The highest increase in protein was observed in smoked mackerel (MSK) (10% increase) and boiled salmon (SBL) (13% increase) while the highest moisture contents (75 and 71% for MBL and SBL respectively) were observed in boiled samples and could be attributed to water absorption during the course of boiling. The protein values recorded in this study are in agreement with the values (18.4-21.9%) reported for fish species from Caspian seas[14] but in disagreement with 22.8-27.9% reported for fish species consumed in the Arabian Gulf[15]. This discrepancy further stresses that species in addition to cooking methods are among the factors affecting protein content of fish. On the other hand, the lowest moisture values were observed in the fried samples (MFR and SFR) (table 1) and are in line with the increased fat contents exhibited by these fried samples. As frying takes place, water is lost and this facilitates the transfer of frying oil (soybean oil in this case) into the fried fish[15]; thus, as moisture content decreases, fat content increases. Smoking also resulted to increase in fat content but to a lesser degree, while boiling which led to the highest increase in moisture content, resulted to decrease in fat content (table 1). There was no significant difference ($P>0.05$) between the fat content of MBL (4.5%) and that of the control (MCT) (5.0%). In terms of ash, frying resulted to about 70% decrease in ash content for salmon, while smoking and drying appeared to have no impact (table 1). Fibre contents of cooked samples did not follow a clear trend; however, in contrast to smoking and frying, boiling led to substantial decrease (82 and 88% loss for MBL and SBL respectively) in fibre. This could be attributed to water-soluble nature of some fibres.

Table 1. Proximate and composition of mackerel and salmon (g/100g)

Sample	Moisture	Protein	Fat	Ash	Fibre
MCT	$69.31^{b}\pm1.01$	$18.2^{a}\pm0.83$	$5.0^{a}\pm0.14$	$1.8^{a}\pm0.27$	$4.5^{b}\pm0.50$
MSK	$24.29^{c}\pm0.60$	$20.5^{b}\pm2.17$	$9.0^{cd}\pm0.41$	$1.5^{b}\pm0.29$	$5.2^{a}\pm0.76$
MBL	$75.05^{a}\pm1.30$	$18.9^{a}\pm1.29$	$4.5^{a}\pm0.07$	$1.0^{c}\pm0.10$	$0.8^{d}\pm0.29$
MFR	$32.26^{d}\pm1.10$	$20.0^{b}\pm0.12$	$13.6^{f}\pm0.10$	$1.5^{b}\pm0.71$	$2.8^{c}\pm0.29$
SCT	$65.41^{b}\pm1.60$	$18.8^{a}\pm1.09$	$6.31^{b}\pm0.12$	$1.76^{a}\pm0.26$	$5.0^{b}\pm0.90$
SSK	$25.20^{c}\pm1.40$	$22.23^{c}\pm2.01$	$8.30^{c}\pm0.60$	$1.80^{a}\pm0.26$	$5.4^{a}\pm0.24$
SBL	$71.44^{a}\pm1.60$	$19.8^{ab}\pm0.69$	$5.76^{a}\pm1.80$	$1.82^{a}\pm0.75$	$0.6^{d}\pm0.19$
SFR	$32.70^{c}\pm0.80$	$21.6^{c}\pm1.18$	$11.6^{e}\pm0.24$	$0.50^{d}\pm0.07$	$2.2^{c}\pm0.72$

Values are Means ±SD (n=3). Values with difference superscripts on the same row are significantly different ($P<0.05$). MCT= Mackerel Control (unprocessed), MSK= Mackerel Smoked, MBL= Mackerel Boiled and M.FR = Mackerel Fried.

The fatty acid composition of mackerel (tables 2 and 4) indicates that mono-unsaturated fatty acids (MUFA) were the predominant fatty acids (36%), followed by saturated fatty acids (SFA) (32%) and lastly by poly-unsaturated fatty acids (PUFA) (27%); while for salmon (tables 3 and 4) MUFA (41%) was the predominant fatty acid, followed by PUFA (32%) and then SFA (24%). Total SFA was comprised mainly of palmitic acid (16:0), MUFA of oleic acid (18:1), while PUFA was comprised mainly of omega-3 fatty acids namely eicosapentaenoic (20:5ω3) and docosahexaenoic acids (22:6ω3). Linoleic acid (18:2ω6) was also detected, and made up 3% of the total fatty acid composition of raw mackerel (MCT) and 7% of raw salmon (SCT) (tables 1 and 2). In all samples, total unsaturated fatty acids were higher than total saturated fatty acids. This is in conformity with literature report[16]. Changes occurring in fatty acids indicate that boiling and frying increased the level of SFA while smoking had no meaningful impact (table 4). Frying increased total MUFA by about 1.5% while boiling and smoking decreased MUFA by 24 and 30% respectively. PUFA on the other hand, and particularly EPA, DHA and LA, decreased substantially irrespective of cooking method, with frying being the most detrimental cooking method to these essential fatty acids. Frying led to up to 90% decrease in omega-3 and up to 83% decrease in omega-6 (table 4).

Table 2. Fatty acid composition of raw and cooked mackerel

Fatty acid (%w/w)	MCT	MBL	MSK	MFR
14:0 (Mystristic)	6.50	8.98	3.84	2.67
16:0 (Palmetic)	22.10	24.97	23.33	29.94
16:1 (Palmitoleic)	6.11	0.91	5.77	1.01
18:0 (Stearic)	3.58	2.19	5.11	2.72
18:1ω9 (Oleic)	25.05	24.33	16.74	32.37
18:2ω6 (Linoleic)	3.02	2.65	tr	0.51
20:1 (Ecosenoic)	4.77	2.11	2.50	3.02
18:3ω3 (Linolenic)	1.72	0.96	0.70	0.50
20:2 (Ecosedienoic)	0.63	1.39	1.94	1.47
22: 2 (Docosadienoic)	0.96	3.32	3.21	2.44
20:5ω3(Eicosapentaenoic) EPA	5.21	0.58	0.37	Tr
22:6ω3 (Docosahexaenoic) DHA	15.10	2.47	2.30	2.10
Total identified fatty acids	94.75	74.86	65.81	78.75

Values are means of douplicate determination. MCT= Mackerel Control (unprocessed), MSK= Mackerel Smoked, MBL= Mackerel Boiled and M.FR = Mackerel Fried.

Although frying of food is an important application of vegetable oils, it is a process accompanied by multitude of reactions and formation of complex compounds. During frying, unsaturated fatty acids, particularly PUFA undergo oxidative breakdown to form mixtures of compounds including monomeric and polymeric compounds[17,18] which are not evaluated by the gas-chromatographic method (section 3.3) used in the present study. The substantial loss in PUFAs particularly omega-3 and omega-6 of fried samples (MFR and SFR); as well as the reduction that occured in total identified fatty acids (tables 2 and 3) can therefore be attributed to thermal oxidative breakdown. Oxidation also occurs at temperatures below frying temperature and may account for the loss observed in the PUFAs of boiled and smoked samples (table 4). During oxidation PUFA can oxidize to MUFA, which in turn can oxidize to SFA (resulting to increase in the level of SFA)[6,19]. The increase observed in SFA of the cooked samples coincides with loss in PUFA of the raw samples (table 4) and therefore suggests that this increase was brought about by oxidation of MUFA and PUFA. In the species studied, the predominant omega-3 fatty acids were eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA); and the predominant omega-6, linoleic acid (LA). All cooking methods (boiling smoking and frying) led to substantial decrease in these essential fatty acids.

Table 3. Fatty acid composition of raw and cooked Salmon

Fatty acid (%w/w)	SCT	SBL	SSK	SFR
14:0 (Mystristic)	7.02	6.88	6.64	2.23
16:0 (Palmetic)	14.67	19.07	18.34	26.61
16:1 (Palmitoleic)	7.54	1.23	1.74	1.38
18:0 (Stearic)	2.11	2.36	2.43	1.21
18:1ω9 (Oleic)	20.32	20.73	20.17	30.6
18:2ω6 (Linoleic)	6.88	1.58	1.37	1.16
20:1 (Ecosenoic)	12.80	5.66	6.71	9.07
18:3ω3 (Linolenic)	2.22	1.24	0.93	0.65
20:2 (Ecosedienoic)	2.35	0.82	1.06	0.68
22: 2 (Docosadienoic)	1.75	0.45	0.53	Tr
20:5ω3 (Eicosapentaenoic) EPA	5.76	0.70	0.30	0.29
22:5ω3 (Docosapentaenoic)	0.50	Tr	Tr	Tr
22:6ω3 (Docosahexaenoic) DHA	12.55	1.38	1.91	1.61
Total identified fatty acids	96.47	62.10	62.17	75.49

Values are means of duplicate determination. MCT= Mackerel Control (unprocessed), MSK= Mackerel Smoked, MBL= Mackerel Boiled and M.FR = Mackerel Fried.

Table 4. Total fatty acid composition of raw and processed mackerel and salmon

	Fatty acid composition (%w/w)					
Sample	∑ SFA	∑ MUFA	∑ PUFA	∑ ω-3	∑ ω-6	EPA+DHA
MCT	32.18	35.93	26.64	22.13	3.02	20.31
MSK	32.28	25.01	8.52	3.37	tr	2.67
MBL	36.14	27.35	11.36	4.01	2.65	3.05
MFR	35.33	36.40	7.02	2.10	0.51	2.10
SCT	23.80	40.66	32.01	21.03	6.88	18.31
SSK	27.41	28.62	6.14	3.18	1.37	2.25
SBL	28.31	27.62	6.17	3.32	1.58	2.08
SFR	30.05	39.07	4.39	2.55	1.16	1.9

MCT= Mackerel Control (unprocessed), MSK= Mackerel Smoked, MBL= Mackerel Boiled and M.FR = Mackerel Fried. SFA=Saturated fatty acid; MUFA=Monounsaturated fatty acid; PUFA=Polyunsaturated fatty acid.; EPA and DHA=Eicosapentaenoic and Docosahexaenoic acids respectively

IV. Conclusion

Results from the present study indicate that traditional cooking methods practiced in the homes of many Nigerian have substantial impact on the nutritional quality of mackerel and salmon. Moisture content was generally higher in boiled samples than in smoked and fried samples. Compared with the raw sample of each species, cooked samples showed increase in protein content with the highest increase occuting in smoked and fried mackerel. Fat content increased as a result of cooking and showed an inverse relationship with moisture content. In all samples studied frying led to highest fat contents. Mackerel and Salmon were poor in omega-6 PUFA but rich in omega-3 PUFA, with the predominant omega-3 being eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA); and the predominant omega-6, linoleic acid (LA). In the samples studied, smoking, boiling and frying led to substantial decrease in EPA, DHA and LA, with frying resulting to the greatest decrease, followed by boiling. In terms of proximate composition, frying led to the highest increase in fat content followed smoking, while smoking and frying resulted to the highest increase in crude protein. Boiling led to decrease in crude fat content.

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