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FISH PROCESSING AND NUTRIENT AVAILABILITY: A STUDY ON THE EFFECT OF DRYING METHODS ON THE NUTRITIONAL CONTENT OF SELECTED FISH SPECIES

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Abstract: *Fish spoilage is one of the greatest challenges confronting the fishing industry globally, and efforts aimed at its reduction through various food processing methods have impacted on the nutritional composition of fishes. This study investigates the effects of oven-drying and smoke drying methods on the nutritional composition of fish species and their nutrient availability to meeting the required nutritional intake (RNI) for consumers. Results showed a significant variation in the nutritional composition of Clarias gariepinus and Tilapia zillii processed by oven drying and smoke drying. The increase in protein content of C. gariepinus (from 15.79% to 16.62%) and T. zillii (from 16.68% to 17.29%); and mineral contents in oven-dried samples as compared to the reduced protein content in C. gariepinus (from 15.79% to 14.62%) and T. zillii (from 16.68% to 13.76%) of smoked dried samples, makes oven-dried samples good sources of dietary protein and mineral elements for human consumption. Potential contribution to RNI showed that oven-dried and smoke dried C. gariepinus meet ≥ 25% of RNIs for iron and zinc in children. Oven-dried and smoke dried T. zillii meet ≥ 25% of the RNI of iron in pregnant and lactating women (PLW) and children; and meet ≥ 25% of the RNI of zinc in children only. This indicate the need for increased per capital consumption of fish in Nigeria. It is therefore recommended that the traditional method of smoke drying should be discouraged in lieu of its diminutive effect on nutritional composition of fishes, environmental pollution and health risk.*

Keywords*: Clarias gariepinus; Food processing; Human nutrition; Tilapia zillii; Nutrient composition; Recommended nutrient intakes (RNIs)*

1. Introduction

Fish processing can be defined as procedures which are applied to the fish from time of harvest to the consumption period [1]. The processing and preservation of fresh fishes are important as they highly susceptible to deterioration immediately after harvest and also to prevent economic losses [2]. Fish spoilage is one of the greatest problems affecting the fishing industry all over the world and efforts at reducing fish spoilage to the barest minimum through various preservation and processing techniques have impacted on the nutritional composition of fishes [3,4]. The nutritional value of harvested fish meat comprises the contents of moisture (66 - 81%), protein (16 - 21%), lipids (0.2 - 25%), ash (1.2 - 1.5%), vitamins, minerals and the caloric value of the fish [5 – 8]. The need for the knowledge of the effects of various fish processing methods of the nutritional

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composition of fish is paramount. As nutritional studies have demonstrated that nutrient contents in fish that are required by the consumers are either increased [9,10] or reduced during processing, thereby impacting on the total nutritive value of the fish [11 – 15]. Fish processing methods vary between different countries and within the same country depending on the species of fish used and the type of product desired.

Smoke drying is a method of fish processing which utilizes locally built fire place with firewood as the source of heat. It preserves and increases the shelf life of fish by drying, cooking, acting as an effective antioxidant, bacteriostatic and bactericidal agent [16,17]. The drawbacks to this method of fish processing include time consumption, deposits of vaporized chemical constituents of firewood on the fish, air pollution, health risk to fish processors and unregulated drying temperature resulting in the denaturing of important nutritional constituents of fish. While fish processing by oven drying is the use of drying ovens in the removal of moisture from fish. This method of fish processing is less time consuming, human and environmentally safe; and the heating temperature is regulated to preserve the integrity of important constituents such as protein and minerals, which can easily be denatured with heat. In Nigeria, smoke drying is the commonly utilized method for fish processing; as smoked fish products are the commonest form of fish product available to consumers, which accounts for 61% of the 194,000 metric tons of dry fish produced in Nigeria [18].

The smoke-drying method has been an age long traditional practice for processing fish and other aquatic organisms in order to improve their shelf life. Increasing concerns on air pollution and wood consumption in the processing of food materials by smoking, has led to the introduction and usage of the oven-drying method as an alternative fish processing method. The poor technology assimilation and usage of the oven-drying method as an alternative to smoke drying among local fish processors, has necessitated this study to investigate the effects of oven-drying and smoke-drying methods on the nutritional composition of commercial fish species and their nutrient availability to meeting the required nutritional intake (RNI) for adults, pregnant and lactating women (PLW) and children in Nigeria.

2. Matherials and methods

***Collection of fish samples*:** Fresh fish samples of *Clarias gariepinus* (Burchell, 1822) and *Tilapia zillii* (Gervais, 1848) were procured from two (2) identified inland freshwater fish landing sites in Edo State, Nigeria. Fish samples were collected monthly for a period of six (6) months, February to July, 2018. Fish samples were preserved in ice blocks and transported to the Central laboratory of the Department of Animal and Environmental Biology, Faculty of Life Sciences, University of Benin where they were properly identified using taxonomic guides [19].

In the laboratory, morphometric measurements of standard length, total length and body weight of all fish specimens were taken to the nearest 0.1cm and 0.1g using a metre rule and digital electronic weighing balance [Mettler Toledo (PL203 model)] respectively.

***Experimental set-up*:** The fish samples were divided into three batches. This is important for valid conclusions to be drawn. Each batch contained three (3) specimen each of *Clarias gariepinus* and *Tilapia zillii*

Batch I: Fresh fish samples in batch I served as control for proximate and mineral analyses.

Batch II: Fish samples in batch II were oven-dried at a temperature of 105^{o}C for 6 hours using an electric oven [Bran drying oven (DHG-9023A model)]. After drying, fish samples were placed in the desiccator to cool down and were immediately analysed for fat, protein and ash content.
Batch III: Fish samples were smoked - dried by local fish farmers and sellers using locally built fireplace which utilizes firewood for heat production.

Analytical Methods: Nutritional composition analysis of moisture content, crude protein and crude fat were carried out as described in detail by AOAC [20] and Reksten *et al.*[21]. Mineral contents were analysed using the inductively coupled plasma optical emission spectrometry (ICP-OES) method [22].

Calculation of potential contribution to Recommended Nutrient Intakes (RNI): The potential contribution of the nutritional content of fresh, oven dried and smoked samples of *C. gariepinus* and *T. zilli* to daily recommended nutrient intake (RNI) for each nutrient as recommended for pregnant and lactating women (PLW), adults/ adolescents (8 years and above) and children (1 – 7 years) was estimated as described by Egun and Oboh [23] and Egun *et al.* [24]. The per capital consumption of fish as food in Nigeria is 13.3 kg, which is equivalent to 36.4g portion per day [25]. The micronutrients of interest in this study are calcium, iron and zinc. These micronutrients were identified based on several reported literatures of their deficiencies especially among children, pregnant and lactating women (PLW) in Nigeria [26 – 31].

Data Analysis and Presentation: All statistical analysis were computed using Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 21. The composition values gotten from fish samples in batches I – III were analysed for their range values, mean and standard errors. One way analysis of variance (ANOVA) was used to test for significant difference ($p< 0.01$) between means and the source of significant differences identified using Duncan's Multiple Range (DMR) test.

3. Results and discussion

Results

The summary of the proximate and mineral composition of fresh, oven dried and smoked samples of *C. gariepinus* and *T. zillii* are presented in Tables 1 and 2. In *C. gariepinus*, mean values for moisture content was 64.78% (fresh), 9.80% (oven-dried) and 4.73% (smoked); protein content was 15.79% (fresh), 16.62% (oven-dried) and 14.62% (smoked); lipid content was 6.57% (fresh), 5.36% (oven-dried) and 4.43% (smoked); ash content was 3.99% (fresh), 4.27% (oven-dried) and 6.05% (smoked) were recorded with observed significant difference ($p < 0.01$) between the means of the different treatments. For mineral contents, significant difference ($p < 0.01$) was observed in the mean contents of iron and magnesium, while there was no significant difference ($p > 0.01$) in the mean contents of zinc, calcium, sodium and potassium in the fresh, oven dried and smoked samples of *C. gariepinus.*
In *T. zillii*, mean values for moisture content was 66.48% (fresh), 9.79% (oven-dried) and 4.61% (smoked); protein content was 16.68% (fresh), 17.29% (oven-dried) and 13.76% (smoked); lipid content was 1.64% (fresh), 1.35% (oven-dried) and 0.86% (smoked); ash content was 4.94% (fresh), 3.93% (oven-dried) and 4.58% (smoked) were recorded with observed significant difference ($p < 0.01$) between the means of the different

treatments. For mineral contents, significant difference ($p < 0.01$) was observed in the mean contents of iron, zinc, calcium, magnesium, sodium and potassium in the fresh, oven dried and smoked samples of *T. zillii.*

The potential contribution of the fish samples from the various treatments to the recommended nutritional intake (RNI) of calcium, iron and zinc in adults, pregnant and lactating women (PLW), and children are presented in Tables 3 to 5. Fresh, oven-dried and smoked samples of *C. gariepinus* and *T. zillii* did not meet ≥ 25% of the RNI for calcium in adults, PLW and children (Table 3).

Table 1

Summary of the proximate and mineral composition of fresh, oven-dried and smoked *Clarias gariepinus*

	Fresh	Oven dried	Smoked	*P Value*
	Mean ± SE	**Mean ± SE**	**Mean ± SE**	
Moisture (%)	64.78 ± 0.84^{c}	9.80 ± 0.09^{b}	4.73 ± 0.08^{a}	$p < 0.01$
Protein (%)	15.79 ± 0.21^{b}	16.62 ± 0.14^{c}	14.62 ± 0.15^{a}	$p < 0.01$
Lipid (%)	6.57 ± 0.14^{c}	5.36 ± 0.09^{b}	4.43 ± 0.08^{a}	$p < 0.01$
Ash (%)	3.99 ± 0.13^{a}	4.27 ± 0.11^{a}	6.05 ± 0.16^{b}	$p < 0.01$
Iron (mg/100g)	6.17 ± 0.29^{b}	4.81 ± 0.08^{a}	4.43 ± 0.08^{a}	$p < 0.01$
Zinc (mg/100g)	2.60 ± 0.12^{a}	2.76 ± 0.06^{a}	2.40 ± 0.06^{a}	$p > 0.01$
Calcium (mg/100g)	4.21 ± 0.20^{a}	5.24 ± 0.56^{a}	4.84 ± 0.56^{a}	$p > 0.01$
Magnesium (mg/100g)	3.31 ± 0.15^{a}	3.47 ± 0.24^{ab}	4.29 ± 0.30^{b}	$p < 0.01$
Sodium (mg/100g)	4.61 ± 0.07^{a}	6.08 ± 0.82^{a}	6.66 ± 0.81^{a}	$p > 0.01$
Potassium (mg/100g)	7.90 ± 0.14^{a}	7.05 ± 0.33^{a}	7.57 ± 0.41^{a}	$p > 0.01$

Note: Similar letters (superscripts) indicate values that are not significantly different from each other (p < 0.01)

Table 2

Summary of the proximate and mineral composition of fresh, oven-dried and smoked *Tilapia zillii*

	Fresh	Oven	Smoked	*P Value*
	Mean ± SE	**Mean ± SE**	**Mean ± SE**	
Moisture (%)	66.48 ± 0.89^{c}	9.79 ± 0.25^{b}	4.61 ± 0.20^{a}	$p < 0.01$
Protein (%)	16.68 ± 0.26^{b}	17.29 ± 0.37^{b}	13.76 ± 0.70^{a}	$p < 0.01$
Lipid (%)	1.64 ± 0.08^{b}	1.35 ± 0.16^{b}	0.86 ± 0.12^{a}	$p < 0.01$
Ash (%)	4.94 ± 0.25^{a}	3.93 ± 0.57^{a}	4.58 ± 0.66^{a}	$p > 0.01$
Iron (mg/100g)	8.19 ± 0.10^{b}	8.46 ± 0.12^{b}	7.56 ± 0.17^{a}	$p < 0.01$
Zinc (mg/100g)	1.88 ± 0.10^{a}	3.15 ± 0.10^{b}	2.28 ± 0.07^{a}	$p < 0.01$
Calcium (mg/100g)	2.56 ± 0.10^{a}	6.73 ± 0.13^{c}	5.86 ± 0.14^{b}	$p < 0.01$
Magnesium (mg/100g)	2.50 ± 0.10^{a}	3.47 ± 0.13^{b}	4.27 ± 0.27^{c}	$p < 0.01$
Sodium (mg/100g)	4.76 ± 0.11^{a}	7.03 ± 0.18^{b}	7.52 ± 0.22^{b}	$p < 0.01$
Potassium (mg/100g)	9.86 ± 0.22^{b}	7.37 ± 0.25^{a}	8.09 ± 0.27^{a}	$p < 0.01$

Note: Similar letters (superscripts) indicate values that are not significantly different from each other (p < 0.01)

Table 3

Potential contribution of fish in a Standard Portion, and to average daily RNI (%) of Calcium

	Fresh			Oven - dried			Smoked - dried		
	Adults	**PLW**	**Children**	**Adults**	**PLW**	**Children**	**Adults**	**PLW**	**Children**
Average daily RNI	1000	1040	700	1000	1040	700	1000	1040	700
Clarias gariepinus	1.53 (0.15%)	2.11 (0.20%)	1.53 (0.22%)	1.91 (0.19%)	2.62 (0.25%)	1.91 (0.27%)	1.76 (0.18%)	2.42 (0.23%)	1.76 (0.25%)
Tilapia zillii	0.93 (0.09%)	1.28 (0.12%)	0.93 (0.13%)	2.45 (0.25%)	3.37 (0.32%)	2.45 (0.35%)	2.13 (0.21%)	2.93 (0.28%)	2.13 (0.30%)

**Assumed standard portion is equivalent to 36.4g/ day for Nigerians*
**PLW – Pregnant and lactating women from a standard portion of 50g/day [32]*
**RNI – Recommended Nutritional Intake*

Fresh, oven-dried and smoked samples of *C. gariepinus* meet ≥ 25% of the RNI of iron and zinc in children only. Fresh, oven-dried and smoked samples of *T. zillii* meet ≥ 25% of the RNI of iron in PLW and children; while oven-dried and smoked samples of *T. zillii* meet ≥ 25% of the RNI of zinc in children only (Tables 4 and 5).

Table 4

Potential contribution of fish in a Standard Portion, and to average daily RNI (%) of Iron

	Fresh			**Oven – dried**			**Smoked - dried**		
	Adults	**PLW**	**Children**	**Adults**	**PLW**	**Children**	**Adults**	**PLW**	**Children**
Average daily RNI	16	15	7	16	15	7	16	15	7
Clarias gariepinus	2.24 (14%)	3.09 (20.6%)	2.24 (32%)	1.75 (10.94%)	2.41 (16.07%)	1.75 (25%)	1.61 (10.06%)	2.22 (14.80%)	1.61 (23%)
Tilapia zillii	2.98 (18.63%)	4.10 (27.33%)	2.98 (42.57%)	3.08 (19.25%)	4.23 (28.20%)	3.08 (44%)	2.75 (17.19%)	3.78 (25.20%)	2.75 (39.29%)

**Assumed standard portion is equivalent to 36.4g/ day for Nigerians*
**PLW – Pregnant and lactating women from a standard portion of 50g/day [32]*
**RNI – Recommended Nutritional Intake*

Table 5

Potential contribution of fish in a Standard Portion, and to average daily RNI (%) of Zinc

	Fresh			**Oven - dried**			**Smoked - dried**		
	Adults	**PLW**	**Children**	**Adults**	**PLW**	**Children**	**Adults**	**PLW**	**Children**
Average daily RNI	10	7.9	3	10	7.9	3	10	7.9	3
Clarias gariepinus	0.95 (9.50%)	1.30 (16.46%)	0.95 (31.67%)	1.01 (10.01%)	1.38 (16.07%)	1.01 (33.67%)	0.87 (8.70%)	1.20 (15.19%)	0.87 (29%)
Tilapia zillii	0.68 (6.80%)	0.94 (11.90%)	0.68 (22.67%)	1.15 (11.5%)	1.58 (20%)	1.15 (38.33%)	0.83 (8.30%)	1.14 (14.43%)	0.83 (27.67%)

**Assumed standard portion is equivalent to 36.4g/ day for Nigerians*
**PLW – Pregnant and lactating women from a standard portion of 50g/day [32]*
**RNI – Recommended Nutritional Intake*

Discussion

Fish Processing and Nutritional Composition

The main principle involved in fish processing by oven-drying or smoking is the creating of an unfavourable environment for microbial growth by reducing the fish moisture content through heating, thereby prolonging shelf life [33]. Fish processing by oven-drying or smoking have been reported to enhance the flavour, taste, and promote digestibility of protein [9,10,34]. However, a substantive magnitude of nutrient loss occurs due to application of heat thereby decreasing the concentration of some nutrients especially protein [35]. The nutritional composition of *C. gariepinus* and *T. zillii* showed significant variation during processing by oven drying and smoking.

The process of oven-drying and smoke drying significantly reduced the moisture and lipid contents in *C. gariepinus* and *T. zillii*. The low moisture and lipid content observed in oven-dried and smoked samples is of advantage as it safeguards fish samples from microbial attack and and rapid spoilage due to lipid

dehydrogenation. Protein content showed a remarked increase in oven-dried samples of the fishes when compared to the smoked samples which recorded the lowest. Nutritionally, protein content is the most essential constituent which defines the wholesomeness and quality of fish meat. It is generally present in the range of 16 – 18% [36]. The significant increase in protein of *C. gariepinus* (from 15.79% to 16.62%) and *T. zillii* (from 16.68% to 17.29%); and their mineral contents - iron, zinc and calcium in oven-dried samples, makes them good sources of dietary protein and mineral elements for human consumption. Conversely, the reduced protein content in *C. gariepinus* (from 15.79% to 14.62%) and *T. zillii* (from 16.68% to 13.76%) makes the smoked samples of *C. gariepinus* and *T. zillii* inadequate sources of dietary protein. The increased ash content in oven-dried and smoked samples of *C. gariepinus* and *T. zillii* which is indicative of higher mineral contents is attributed to the decreased moisture content, concentration of chemical components in the fish samples and oxidation of polyunsaturated fatty acids (PUFA) [37]. High ash content has been reported to lower bacterial and fungal activities leading to better shelf life in fishes [38].

Potential Contribution to Required Nutrient Intake (RNI)

Fishes provide a good supply of mineral elements which are essential to the proper growth and development of the human body in a readily usable form [39]. The insufficient intake of essential nutrients such as calcium, iron and zinc have been associated to major developmental health issues.

The calcium content in the oven-dried and smoked samples of *C. gariepinus* and *T. zillii* did not provide the required proportional nutrient intake (≥ 25%) for adults, pregnant and lactating women (PLW) and children (Table 3). With reported clinical prevalence of hypocalcaemia among pregnant women in sub-Sahara Africa [40], and incidences of rickets among children particularly from poor households [41], the processed fish species should not be solely relied on to meet dietary calcium intake.

Reported high prevalence of iron deficiency anemia (IDA) in PLW especially in rural communities, and among children have been linked with adverse foetal, maternal and child development outcomes [30, 42 – 44]. Iron content in oven-dried and smoked samples of *C. gariepinus* meet ≥ 25% of the RNI for iron in children, while oven-dried and smoked samples of *T. zillii* meet ≥ 25% of the RNI of iron in PLW and children (Table 4). This implies that the consumption of the processed fishes will contribute substantially to ameliorating IDA in PLW and children.

Zinc content in oven-dried and smoked samples of *C. gariepinus* and *T. zillii* meet ≥ 25% RNI of zinc in children only (Table 5). The reported clinical studies on the prevalence of maternal zinc deficiency (hypozincemia) among the socio-economically disadvantaged PLW, adults and children in developing countries such as Nigeria [29,31,45,46], is indicative that the processed fish samples cannot be relied upon to meet dietary zinc requirements particularly for pregnant and lactating women.

Study Insights

The study has provided an insight on the advantage of oven-drying method in preserving and improving the nutritional quality of fish when compared to the smoked dried method of fish processing. Therefore, there is need for increased knowledge awareness among local fish processors, and encouraging them to adopt

the oven-drying method through the provision of technology and equipment support. This will improve the nutritional quality of dried fish products available to consumers in the Nigerian markets, and increase foreign income earnings. The nutrient availability in the processed fish samples to meeting the required nutrient intake (RNI) for mineral elements in adults PLW and children was found to be dependent on the per capita fish consumption.

4. Conclusion

This study has investigated the effect of oven-drying and smoke drying fish processing methods on the nutritional composition and nutrient availability of commercial fish species. The increased protein and mineral contents - iron, zinc and calcium in oven-dried samples of *C. gariepinus* and *T. zillii* when compared to smoke dried samples makes them good sources of dietary protein and mineral elements for human consumption. It is therefore recommended that the traditional method of smoke drying should be discouraged in lieu of its diminutive effect on nutritional composition of fishes, environmental pollution and health risk. Also, increased sensitization of local fish processors on the advantageous use of oven drying method and making the oven dryers available at affordable cost is expedient. Increased per capita consumption of fish and fish products in Nigeria is encouraged to increase nutrient availability in meeting the required nutrient intake (RNI) for mineral elements in adults PLW and children.

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Disclosure of interest

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