FATTY ACID PROCESSING YIELD OF SMOKE-DRIED *CLARIAS GARIEPINUS* (BURCHELL, 1822) USING TWO DIFFERENT SMOKING KILNS AT VARYING TEMPERATURES

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ABSTRACT

Smoke-dried fish is an integral protein source in many Nigerian diets, processed by smoke-drying and sold for income. The study aimed to describe the fatty acid yield of smoke-dried African mudfish (average weight of 350 ± 100 g) using traditional drum kiln (TDK) and eco-friendly kiln (EFK) while storing at ambient (28^0C) and control (14^0C) temperatures. In the smoke-dried mudfish, a total of 25 fatty acids (7 Saturated, 9 Monounsaturated and 9 polyunsaturated) were identified. Under ambient temperature storage, saturated fatty acid (SFA) was found to be higher in fish smoked with TDK than fish smoked with EFK. Palmitic acid was the main component of saturated fatty acid followed by stearic acid. Under control temperature, unsaturated fatty acid content was found to be higher in EFK-smoked fish than in TDK-smoked fish, and these values were higher compared to those of SFAs. Petroselinic acid has been noted as a dominant MUFA in both TDK (16.08 ± 0.23 %) and EFK-smoked (16.98 ± 0.19 %) samples. Among the PUFAs, docosahexaenoic, arachidonic and eicosapentaenoic acids were the dominant in the smoke-dried fish. The results indicate that kiln type and different storage temperature affect the fatty acid composition of Clarias gariepinus.

Keywords: African mudfish, *Clarias gariepinus***,** Smoke-dried fish, Fatty acids yield, Traditional drum, Eco-friendly kiln

INTRODUCTION

African mudfish (*Clarias gariepinus*, Burchell 1822) also called African sharp tooth catfish is a species of catfish of the family Clariidae or the air breathing catfishes. It is an air-breathing catfish with a scaleless, bony elongated body with long dorsal and anal fins and a helmet-like head (Ikpeme *et al.*, 2015). Colour varies dorsally from dark to light brown and is often mottled with shades of olive and grey, while the underside is usually pale cream to white in colour (Skelton, 2001). *C. gariepinus* is known to have higher nutrient components such as amino acids as well as a greater ratio of polyunsaturated fatty acids to saturated fatty acids over other fishes such as *Tilapia zilli, Pseudotolithus typus* and *Pentanemus quinquarius* (Osibona, 2011). Fresh and processed catfish can be found in many markets in Nigeria and is considered a delicacy in Nigerian dishes.

C. gariepinus is presently the most successfully cultured fish in Nigeria because of its resilient nature, ability to thrive under stressful conditions such as low oxygen concentrations and its high feed to muscle conversion ratio (Agbede *et al.*, 2003). However, there is a major challenge of high incidence of post-harvest losses as a result of spoilage of fresh fish after harvesting. Up to 50 % of the total fish catch in Nigeria is lost annually due to inadequate or poor handling, preservation and/or processing of the freshly harvested fish by both artisanal fishermen and farmers who own or run fish farms (Olatunde, 1998; Akinneye *et al.,* 2007). The oldest and most widely practiced form of fish processing particularly in the tropics is smoke-drying. Smoke-drying is the main traditional processing method used in extending fish shelf life in Nigeria with a percentage of about 45 % as against 27 % eaten fresh (Eyo, 1991). Smoke-dried fish is an integral part of the diet of many Nigerians and processing by smoke-drying is the main source of income for many people, especially in rural areas (Ogunbambo, 2019). Smoking kilns can generally be classified into three mainly on the basis of carrying capacity and efficiency into traditional, improved traditional and mechanical smoke-drying kilns (Eyo, 2001). Relative humidity plays an important role on how quickly smoke-dried fish spoils and is different in wet and dry seasons in Nigeria (Odekunle, 2004).

There is however little information of fatty acid composition of smoke-dried fish with respect to kiln type and storage temperature and this study reports such changes in *C. gariepinus* using two different smoking kilns.

MATERIALS AND METHODS

Construction of Smoke-Drying Kilns: The Traditional Drum Kiln (TDK) (Figure 1) was built according to the specifications as used in fishing villages in Lagos State, Nigeria.

Figure 1: Traditional drum kiln (Ogunbambo *et al.,* 2018)

It comprised of a cylindrical metal drum with dimensions 72 cm height, 187 cm circumference and 55 cm diameter. The aperture through which wood fuel was placed was of diameter 36 cm. A circular rack of diameter 76.5 cm was placed on the open end for smoke-drying the catfish samples. Eco-Friendly Kiln (EFK) (Figure 2) was built to comprise of three chambers namely the flame, drying and electronic.

Figure 2: Ecologically friendly kiln (Ogunbambo *et al.,* 2018)

The flame chamber was constructed with dimensions 93.1 x 77.5 x 85.2 cm^3 using interlocking bricks coated with lagging material composed of clay, sawdust and silicon carbide in the ratio 4:2:0.5. The wood fuel used for smoke-drying was arranged in it via an aperture with dimensions 29.6 x 16.8 cm^2. The drying chamber was separated from flame chamber at the back with the use of smoke filters size 0.3 cm, was built from a metal drum with same dimensions as TDK and was coated with same lagging material as the flame chamber. A drying rack composed of three layers with dimensions 44.3 x 44.2 cm^2 on lowest layer, 40 and 49.5 cm diameters in middle and topmost layers respectively was then placed in the drying chamber. The electronic components comprised of a temperature sensor built as a nub that was placed in smoke-drying catfish sample mouth. The nub transmitted heat message to visual light emitting diode and also an audio alarm which made no sound when the smoke-drying temperature was less than 60 ^{0}C, made a beeping sound with a second interval at optimum drying temperatures of 60 - 85 ^{0}C and a loud blaring sound when the drying temperature rose above 85 ^{0}C.

Sample Collection and Preparation: Catfish samples were obtained live from the Aquaculture Unit of the Department of Marine

Sciences, University of Lagos and were of average weight of 350 ± 100 g. The fish were humanely frozen and later tore and degutted using knife, thoroughly washed with clean pipe borne water and then bent into horse shoe shapes. The catfish samples were not seasoned with salt or any other condiment. The prepared catfish were placed on metallic iron racks which were then arranged in the two kilns and the fresh catfish were smoke-dried at a stretch at a temperature range of 60 – 80^0 C (Ogunbambo *et al*., 2018) till the weight of the fish was almost constant. The smoke-drying process started from about 7 a.m. and lasted 24 ± 3 hours using both kilns.

Laboratory Analysis: On getting the fat extract from the fish specimen using chloroform/methanol (2/1; v/v) according to the method of Folch *et al.* (1957), fatty acid methyl esters (FAME) were prepared by trans-esterification using trimethylsulfonium hydroxide (Spiric *et al.,* 2010). The Shimazu Gas Chromatograph (GC-2010) (Kyoto, Japan) used for FAME determination was equipped with a split injector, fused silica cyanopropyl HP-88 column (length 100 m, i.d. 0.25 mm, film thickness 0.20 µm, J&W Scientific, USA), and flame ionization detector and workstation (Shimadzu GC Solution Version 2.3). The injector temperature was 250° C and detector temperature was 280° C. The carrier gas was nitrogen at a flow rate of 1.33 mL min-1 and injector split ratio of 1:50. Injected volume was 1 µL. The chromatographic peaks in the samples were identified by comparing relative retention times of FAME peaks with peaks in a Supelco 37 Component FAME mix standard as described by Spiric *et al.* (2010). The relative amount of each fatty acid methyl ester was expressed as a percentage of the total amount of fatty acids in the analysed sample.

Statistical Analysis: Data for the fatty acids of the smoke-dried catfish were analyzed using T-test carried out using Microsoft Excel. For all analyses significant difference was set at p<0.05. Results were presented as means ± standard error (SE).

RESULTS

The result of the fatty acid compositions of smoke-dried *C. gariepinus* using TDK and EFK (stored at ambient temperatures) is presented in Table 1. In the smoke-dried fish, a total of 25 fatty acids (7 Saturated, 9 Monounsaturated and 9 polyunsaturated) were identified. Saturated fatty acid (SFA) content was found to be higher in fish smoked with TDK than fish smoked with EFK. Palmitic acid (20.78 ± 0.53 % in TDK and 17.75 ± 0.53 % in EFK) was the main component of saturated fatty acid followed by stearic acid (7.60 **±** 0.14% in TDK and 5.78 ± 0.16 % in EFK).

Petroselinic acid has been noted as dominant mono-unsaturated fatty acid in both fish smoked with TDK (20.78 ± 0.53 %) and fish smoked with EFK (17.19 ± 0.17 %). Among the poly-unsaturated fatty acids, docosahexaenoic acid, arachidonic acid and eicosapentaenoic acid were the dominant fatty acids in fish smoked with both TDK and EFK. There were significant differences in contents of arachidonic acid, docosadienoic acid and linoleic acid between fish smoked with TDK and EFK.

Furthermore, the fatty acid compositions of smoke-dried *C. gariepinus* using TDK and EFK (Stored at controlled temperatures) is shown in Table 2. A total of 25 fatty acids were identified in both fish smoked with TDK and EFK. In the smoke-dried *C. gariepinus*, palmitic acid (22.91 **±** 0.40% in TDK and 18.62 **±** 0.50 % in EFK) was the main component of saturated fatty acid followed by stearic acid (7.08 **±** 0.11 % in TDK and 4.87 **±** 0.19 % in EFK) and there were no significant difference in contents of these fatty acids between TDK and EFK-smoked fish

In this present research, petroselinic acid has been noted as a dominant mono-unsaturated fatty acid in both TDK (16.08 ± 0.23 %) and EFK-smoked (16.98 ± 0.19%) samples. Among the poly-unsaturated fatty acid, docosahexaenoic acid, arachidonic acid and eicosapentaenoic acid were the dominant fatty acids in fish smoked with both TDK and EFK. There were significant differences in contents of erucic acid (mono-unsaturated fatty acid), palmitoleic acid (mono-unsaturated fatty acid) and eicosapentaenoic acid (poly-unsaturated fatty acid) between fish smoked with TDK and the fish smoked with EFK.

Table 1: Fatty acid compositions of smoke-dried *Clarias gariepinus* using traditional and eco-friendly kilns and stored at ambient temperatures (28° C)

Fatty Acid Class	Fatty Acids (% total fatty acid weight)	Traditional Drum Kiln	Ecofriendly Kiln
Saturated (SFA)	Arachidic acid	0.03 ± 0.00	0.04 ± 0.00
	Behenic acid	0.02 ± 0.00	0.04 ± 0.00
	Lauric acid	0.02 ± 0.00	0.03 ± 0.00
	Lignoceric acid	0.00 ± 0.00	0.00 ± 0.00
	Myristic acid	1.75 ± 0.05	1.47 ± 0.04
	Palmitic acid	20.78 ± 0.53	17.75 ± 0.53
	Stearic acid	7.60 ± 0.14	5.78 ± 0.16
	Mean Total SFA	30.20	25.11
Mono-Unsaturated (MUFA)	Elaidic acid	0.00 ± 0.00	0.00 ± 0.00
	Erucic acid	1.55 ± 0.01	1.49 ± 0.00
	Gondoic acid	3.06 ± 0.03	3.23 ± 0.05
	Myristoleic acid	0.03 ± 0.00	0.01 ± 0.00
	Nervonic acid	0.00 ± 0.00	0.00 ± 0.00
	Oleic acid	8.32 ± 0.10	8.46 ± 0.05
	Palmitoleic acid	6.64 ± 0.03	6.64 ± 0.23
	Petroselinic acid	16.88 ± 0.30	17.19 ± 0.17
	Trans-Petroselinic acid	0.01 ± 0.00	0.02 ± 0.00
	Mean Total MUFA	36.49	37.04
Poly-Unsaturated (PUFA)	Arachidonic acid	9.05 ± 0.05*	8.79 ± 0.00
	Docosadienoic acid	0.07 ± 0.00	0.08 ± 0.00*
	Docosahexaenoic acid	16.20 ± 0.14	17.26 ± 0.17
	Eicosapentaenoic acid	7.80 ± 0.12	6.77 ± 0.01
	Eicosatrienoic acid	0.02 ± 0.00	0.03 ± 0.00
	Linoleic Acid	0.06 ± 0.00	0.09 ± 0.00*
	γ-Linolenic Acid	0.04 ± 0.00	0.06 ± 0.00
	Dihomo-γ -linolenic Acid	0.05 ± 0.00	0.08 ± 0.00
	α-Linolenic Acid	0.03 ± 0.00	0.05 ± 0.00
	Mean Total PUFA	33.32	34.74

Keys: *mean ± standard error, p<0.05*

Table 2: Fatty acid compositions of smoke-dried *Clarias gariepinus* using traditional and eco-friendly kilns and stored at controlled temperatures (14^0 C)

Fatty acid class	Fatty Acids	Traditional Drum Kiln	Eco-Friendly Kiln
Saturated	Arachidic acid	0.02 ± 0.00	0.06 ± 0.00
	Behenic acid	0.02 ± 0.00	0.05 ± 0.00
	Lauric acid	0.09 ± 0.00	0.07 ± 0.00
	Lignoceric acid	0.00 ± 0.00	0.01 ± 0.00
	Myristic acid	2.17 ± 0.08	2.23 ± 0.02
	Palmitic acid	22.91 ± 0.40	18.62 ± 0.50
	Stearic acid	7.08 ± 0.11	4.87 ± 0.19
	Mean Total SFA	32.29	25.91
Monounsaturated	Elaidic acid	0.00 ± 0.00	0.00 ± 0.00
	Erucic acid	0.86 ± 0.02	2.03 ± 0.06*
	Gondoic acid	3.52 ± 0.01	4.96 ± 0.08
	Myristoleic acid	0.00 ± 0.00	0.01 ± 0.00
	Nervonic acid	0.00 ± 0.00	0.01 ± 0.00
	Oleic acid	8.50 ± 0.07	9.74 ± 0.06
	Palmitoleic acid	8.46 ± 0.28	10.38 ± 0.14*
	Petroselinic acid	16.08 ± 0.23	16.98 ± 0.19
	Trans-Petroselinic acid	0.01 ± 0.00	0.01 ± 0.00
	Mean Total MUFA	44.12	45.93
Polyunsaturated	Arachidonic acid	8.68 ± 0.02	8.96 ± 0.03
	Docosadienoic acid	0.13 ± 0.01	0.07 ± 0.00
	Docosahexaenoic acid	15.01 ± 0.07	15.79 ± 0.10

	Eicosapentaenoic acid	5.51 ± 0.02	8.54 ± 0.11*
	Eicosatrienoic acid	0.01 ± 0.00	0.03 ± 0.00
	Linoleic Acid	0.07 ± 0.00	0.12 ± 0.00
	γ-Linolenic Acid	0.03 ± 0.00	0.06 ± 0.00
	Dihomo-γ -linolenic Acid	0.14 ± 0.00	0.15 ± 0.00
	α-Linolenic Acid	0.02 ± 0.00	0.07 ± 0.00
	Mean Total PUFA	29.6	33.79

Keys: *mean ± standard error, p<0.05*

The least occurred mono-unsaturated fatty acid was elaidic acid with 0.00 ± 0.00 %) in the smoked-dried fish regardless of kiln type.

DISCUSSIONS

Under ambient temperatures storage, palmitic and stearic acids were the dominant saturated fatty acid. Stearic acid is known to be a very stable saturated fatty acid (Zilic *et al.,* 2010; Moruf and Lawal-Are, 2019) and little changes in its content may have been due to the effects of high temperature during the smoking process. It should be mentioned that stearic acid is regarded as a neutral fatty acid which has no effect on blood cholesterol levels in human in contrast to myristic and palmitic acids, which have a strong influence (Hodson *et al.,* 2008). Petroselinic acid has been noted as dominant mono-unsaturated fatty acid in this study, while significant differences in contents of arachidonic acid, docosadienoic acid and linoleic acid were observed. This finding was in line with the report of Obande *et al*. (2012) in their study of the nutritive values of *C. gariepinus* smoke-dried at a temperature of 500^0 C for twenty-four hours using the traditional drum kiln found that there was very high nutrient loss (73.58 %). In this study, the fish smoked with TDK had higher mean total saturated fatty acid than fish smoked with EFK. However, there were no significant differences (p<0.05) in contents of these fatty acids between fish smoked with TDK and fish smoked with EFK. This was similar to the report of Ljubojevic *et al.* (2016) on the fatty acid composition, chemical composition and processing yield of traditional hot smoked common carp. Under control storage temperature, unsaturated fatty acid content was found to be higher in EFK-smoked fish than in TDK-smoked fish, mainly due to increasing contents of both mono and poly-unsaturated fatty acids, and these values were higher compared to those of saturated fatty acids. In the study conducted by Colakoglu *et al.* (2011) after hot-smoking of thornback ray (*Raja clavata*) and spiny dog fish (*Squalis acanthias*), palmitic acid increased significantly, while no significant differences in total MUFA and Elaidic acid between fresh and smoked fish were observed. Colakoglu *et al.* (2011) observed that total PUFA content in marinated and smoked fish decreased significantly compared to that in fresh fish. Ohshima *et al.* (1996) also found decreases in PUFA levels of salmon after grilling and Ozden (2005) noted that PUFA content in marinated anchovy and rainbow trout were lower than that in fresh fish. On the other hand, Stolyhwo *et al.* (2006) reported that smoking techniques did not significantly affect PUFA content in Atlantic mackerel. Observed differences may be species specific or due to variations in hot processing methods that may have a profound effect on the stability of PUFAs.

Conclusion: The results of the present research indicate that kiln type and storage temperature affect fatty acid composition of smoke-dried African Mudfish. Data on the fatty acid yield of final products are very important for fish processing and analysis of production economic feasibility. With the eco-friendly kiln it is possible to produce the smoke-dried African mudfish with a favorable chemical content and with respectable and satisfactorily healthy fatty acid composition. The low cost of constructing materials and maintenance for TDK and its minimal maintenance of Traditional Drum Kiln (TDK) is one of the major reasons why it is the most acceptable smoke-drying technology in Nigeria. The adoption of a new technology is often a difficult transition as many fish processors are not lettered and gained knowledge only from their own parents such that it is almost a tradition. The construction of the Eco-Friendly Kiln with the same drum as used for the TDK and its similar mode of operation to TDK means little training is required and would make its adoption a much easier process.

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