Journal of Agricultural Science; Vol. 6, No. 11; 2014
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Effects of Smoking and Freezing on the Nutritive Value of African Mud Catfish, *Clarias gariepinus* Burchell, 1822

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Received: May 16, 2014 Accepted: August 17, 2014 Online Published: October 15, 2014

doi:10.5539/jas.v6n11p143 URL: http://dx.doi.org/10.5539/jas.v6n11p143

Abstract

Post-harvest loss of fish is a major factor of economic and protein wastages in the developing countries. In this study, the effects of two common methods of preservation, smoking and freezing on the nutritive value of the African mud catfish, *Clarias gariepinus* were determined. Live samples of *C. gariepinus* were obtained from the fish farm of the Department of Environmental Biology and Fisheries, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria, and were transported to the laboratory of the Department. One portion of the harvested fish was smoked, using a smoking kiln (model: ELC 1600) at 60-70 ^{o}C for 24 hours and stored in a polythene bag for further use. Another batch of *C. gariepinus* was preserved immediately after harvest in the freezer (Haier Thermocool, BD-428A) at less than -0 ^{o}C for 20 days. The third batch of the live fish was sacrificed immediately and prepared for biochemical analysis. The proximate compositions of the fish samples were determined according to AOAC (1995). The percentage moisture, protein, lipid, ash, crude fibre and carbohydrate contents obtained in the smoked fish samples were statistically different ($P > 0.05$) to the fresh fish samples (control). Similarly, there were significant differences in the percentage protein, lipid and crude fibre values in the frozen fish samples when compared to the fresh fish samples but there were no significant changes ($P < 0.05$) in the moisture, ash and carbohydrate contents of the frozen fish samples in comparison to the control. The proximate values of the frozen fish evoked significant differences in comparison to the smoked samples except in the crude fibre and lipid contents. Phosphorous content was highest in the smoked fish samples and lowest in the fresh fish samples while the values of iron, potassium and vitamin C contents were generally low in all the samples. Smoking demonstrated a better efficient method of fish processing in terms of the retention of protein value and reduction in the moisture content. The information obtained in this study could be useful to fish consumers, processors and nutritionists in the efficient management of fish resources.

Keywords: proximate, smoking, freezing, preservation, catfish

1. Introduction

Fish are highly nutritious and provide animal proteins that consist of all the essential amino acids in relatively high concentrations, low in cholesterol and saturated fats, and are also rich in key fatty acids, minerals and vitamins (Murray & Burt, 1991). According to Adekoya and Miller (2004), globally, fish and fish products constitute more than 60% of the total protein intake in adults, especially in the rural areas. Fish has the potential to be considered as a balanced food and can therefore be expected to provide relief from malnutrition (Ogundiran, Adewoye, Ayandiran, & Dahunsi, 2014). It also has a high economic value for many countries because it represents the largest share among agribusiness products on the global market (Silva, Silva, Andradel, Veloso, & Santos, 2008). Rahji and Bada (2010) reported that while Nigeria requires about 1.5 million tonnes of fish annually and is expected to meet FAO's recommended minimum fish consumption rate of 12.5 kilograms per head yearly to satisfy basic protein needs, the nation currently imports up to 400,000 tonnes to bridge the fish supply-demand gap. The inclusion of fish in the diets of people in the developing countries is particularly valuable for the vulnerable groups of people, such as, pregnant and nursing mothers, infants and pre-school children because fish contains polyunsaturated fatty acids which are essential in the development of the brain and nervous system (Steffens & Wirth, 1997). However, there could be a high risk of heavy metal bioaccumulation, such as, mercury in certain fish species if mercury is released from the air (where it naturally occurs) or through industrial pollution and accumulates in streams and oceans (Smith, 2012; Guedenon, 2012).

Therefore, USDA (2011) recommended that pregnant women and nursing mothers should follow dietary guidelines of 8 oz per week of low mercury seafood for adults and up to 12 oz per week and that smoked meats should be eaten in moderation due to a possible cancer link.

The principal components of fish muscle include water, protein and fat while the minor components include carbohydrates, minerals and vitamins, and extractives, such as, sugars, free amino acids and nitrogenous bases (FAO, 2014). The composition of a particular species varies from one fishing ground to another, and from season to season, but the basic causes of change in composition are usually variation in the amount and quality of food that the fish eats and the amount of movement it makes. However, these fish components must be preserved with little or no changes in quality after the fish has been harvested in order to prevent the gradual development of undesirable flavours, softening of the flesh and eventually substantial losses of fluid containing protein and fat (FAO, 1997; Huss, 1988). In the high ambient temperature of the tropics, spoilage could occur within 12 to 20 hours depending on species, method of catch and chemical composition, while deterioration takes less than 2 days to about 6 days in colder climates (Adejumo, 1997). Fish perishability is due to its high susceptibility to degradable organisms which are present in the slime, gills and intestine and on the surface of the fish.

A number of processing techniques, such as, smoking, freezing, chilling, salting, drying and fermentation are employed by fish processors in Nigeria. However, smoking is the affordable and most widely used method for fish preservation in Nigeria, Ghana and other West African countries (Adeyemi, Osilesi, Onajobi, Adebawo, & Afolayan, 2013; Nyarko, 2011). Ward (1995) reported that up to 70% of the total fish catch in several communities in the third world are smoked. Smoked fish is also considered a delicacy in Alaska and the Pacific Northwest (Cooperative Extension Service, 2012). Smoking involves the application of heat to remove water and inhibits bacterial and enzymatic action on fish. In addition, Cooperative Extension Service (2012) observed that smoking fish for a short time offers the best quality product for canned fish. However, smoking may present some potential health issues to smoked food consumers. The process of smoking fish or meat involves the use of sodium, sometimes through curing before smoking. Fish, for example, is usually marinated in brine or packed with salt and can trigger high blood pressure in high doses (Nummer & Andress, 2002). In addition, improper fish curing before smoking presents the risk of food poisoning that can lead to bacterial infection, listeriosis in the consumer and bacterial or fungal growth on the fish (Steck et al., 2007). However, the authors noted that if properly prepared and eaten in moderation, the highlighted problems may be mitigated. Presently, the only means of preserving fish in its original fresh state is by freezing. The aim of freezing of food items is to combine shelf life extension with maintenance of sensory and nutritional characteristics. Jones (1996) reported that at low temperature (that is, below -10 ^{o}C), bacterial action will be hindered by the freezing process.

Clarias gariepinus is a highly relished freshwater species and is very important in commercial fisheries due to its wide distribution, resilience, fast rate of reproduction and growth (Popma & Masser, 1999). In Nigeria, fish is mainly eaten fresh or smoked and forms a much cherished delicacy that cuts across socio-economic, age, religions and educational barriers However, among African catfish, *C. gariepinus* is the most common and of highly commercial value (Adebayo-Tayo, Onilude, & Patrick, 2008). The desire to consume fish in the fresh condition has also made freezing a popular choice of preservation. Adewumi, Adewumi and Olaleye (2011) reported that Nigeria is the largest importer of frozen fish in the world with a demand of between 106,200 – 128,052 metric tonnes year from 1991-2000.

However, empirical research database on the nutritional value of processed fish in Nigeria is just growing. Therefore, this study was carried out to complement efforts aimed at ascertaining the effect of smoking and freezing on the nutritive value of catfish. The major objective of this study was to establish the qualitative difference in the biochemical composition of freshly harvested, smoked and frozen catfish, *C. gariepinus.* The knowledge obtained will aid fish consumers, nutritionists and processors in determining the nutritional values of stored smoked and frozen fish.

2. Materials and Methods

2.1 Preparation of Fish Samples

The samples of the African mud catfish (*C. gariepinus*) (body weight between 800-900 g and body length between 40-45 cm) were obtained from the fish farm of the Department of Environmental Biology and Fisheries, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria. The fish samples were transported live to the laboratory and divided into three batches: two batches were prepared separately for smoking and freezing while the third was sacrificed immediately and analyzed for proximate, mineral and vitamin compositions.

2.2 Smoking Technique

The fish samples were killed, gutted and washed thoroughly with clean water and were laid on the racks of the smoking kiln (model: ELC 1600). Heat was generated by the burning of charcoal from logs of wood and smoking of the samples was carried out at 60-70 ^{o}C for 24 hours. After smoking, the products were packed in polythene bags to reduce pest/microbial infestation and kept in the refrigerator (Hajer Thermocool) at 1-5 ^{o}C for 20 days.

2.3 Freezing Method

The fish specimens were killed, gutted and washed with clean water to remove traces of blood and spilled enzymes, wrapped tightly in plastic wrap, and were stored immediately in the freezer (model: Haier Thermocool BD-428A) for 20days at below 0 ^{o}C.

2.4 Proximate Analysis

The proximate compositions were assayed as described by AOAC (1995) and all the chemicals used were of analytical grade. Each analysis was carried out in triplicates.

2.4.1 Determination of Potassium (K) and Iron (Fe) Contents

2 g of the sample was weighed into small a porcelain crucible and ashed in the furnace at 650 ^{o}C for three hours. The ash was extracted by half filling the crucible with 2 ml HCl, boiled gently and the solution was transferred to a 50 ml beaker using Pasteur pipette. The precipitates were washed with distilled water, filtered into the filtrate and solution made up to 50 ml mark distilled water. Blanks were prepared using only distilled water. K was determined using flame photometer (model: Jenway PFP 7) with standard solutions while Fe was determined by Atomic Absorption Spectrophotometer (AAS) Bulk Scientific model 210/211 VGP with standard solutions.

2.4.2 Determination of Phosphorus Content

5 g of fish samples solution (from dry digestion) was pipetted into a 50 ml volumetric flask and 30ml of distilled water was added. Within 5 minutes, 10ml of vanado-molybdate reagent was added, contents were mixed and allowed to stand for 10 minutes before the transmittance percent was determined at 400 mm.

2.4.3 Determination of Vitamin C

Vitamin C content of the aqueous extract was determined using the method of Gokoglu, Verlikaya and Cengiz (2004). The absorbance was measured at 520ml in the Jenway UV-visible Spectrophotometer (model: N324Rh).

2.5 Statistical Analysis

The design was completely randomized. Analysis of variance was performed by one-way ANOVA procedures (SPSS 11.0 for windows) and where differences existed at 0.05 significance level, the treatment means were separated by Tukey's Test. The results presented are means of each determination ± standard error of mean (SEM).

3. Results and Discussion

The proximate compositions of smoked and frozen samples of catfish (*C. gariepinus*) are presented in Table 1. The proximate values of the smoked fish samples in all the parameters studied were statistically significant to those in the fresh fish samples (control). The moisture (5.885 ± 0.034), protein (32.728 ± 0.573), crude fibre (1.036 ± 0.119) and carbohydrate (5.169 ± 0.966) contents of smoked fish samples were found to be significantly lower in comparison to the respective values found in fresh fish samples. However, statistically higher values of lipid (35.603 ± 0.069) and ash (15.836 ± 0.446) were found in the treated fish samples in comparison to 33.324 ± 0.227 and 8.192 ± 0.272 respectively found in the fresh fish samples. Conversely, the moisture (8.640 ± 0.101), ash (8.220 ± 0.249) and carbohydrate (21.900 ± 0.210) contents in the frozen fish samples were not significantly different to 8.629 ± 0.196, 8.192 ± 0.272 and 22.990 ± 0.454 respectively recorded in the fresh fish (control). While the frozen fish samples evoked significantly lower protein (24.160 ± 0.562) and crude fibre (0.980 ± 0.094) contents than 34.277 ± 0.547 and 1.330 ± 0.11obtained in the control, the lipid content (36.410 ± 0.400) in the frozen fish was statistically higher than the fresh fish (33.324 ± 0.227). The results obtained in Table 2 indicate a decreasing order of phosphorous in the smoked (5.60), frozen (3.45) and fresh (1.56) fish samples while iron, potassium and vitamin C contents were generally low in all the samples but the values obtained were significantly different ($P < 0.05$).

Fish protein is of high quality and contains sufficient amounts of all the essential amino acids required by the body for growth, maintenance of lean muscle tissue and active metabolism (Talabi, 1995). In this study, the observed significant increase in the protein level in smoked catfish, when compared with the frozen catfish,

suggests that protein was not lost during smoking. This finding is in agreement with the observations of Puwastien et al. (1999). Similarly, Fapohunda and Ogunkoya (2006) reported that smoke drying methods increased the protein, ash and fat contents of *C. gariepinus*. Salan, Juliana and Marilia (2006) observed decrease of moisture, carbohydrate, lipid, potassium and vitamin C contents and increase of protein, ash, crude fibre, phosphorus and iron contents in smoked *C. gariepinus*. The authors further noted that the increase in the ash content in the smoked fish was due to the loss of humidity and that the significant reduction in the moisture content when the fish was smoked was as a result of the loss in moisture during hot smoking. Doe and Olley (1983) reported that smoking resulted in the concentration of nutrients, such as, protein and ash.

However, some studies have reported reductions in the quality of protein as a result of smoking. The loss in available lysine may vary from 6-33% at 25 ^{o}C to 53-56 % at 40 ^{o}C during hot smoking (Dvorak & Vognarova, 1965) and a 25% loss of available lysine on the surface and a 12% loss at the center of hot smoked fish (Clifford, Tang, & Eyo, 1980). Akande, Oladosu, and Tobor (1998) observed that lysine reduction was directly proportional to the temperature and duration of smoking. The positive effect of heat intensity on the shelf life of smoked product has been reported by several researchers. CO_2 is reported to have an important effect on microbial growth, exerting a selective inhibitory action (Huss, 1992; Molin, Stenstrom, & Ternstrom, 1983). Olley, Doe, and Heruwati (1988) and IMPPFA (2010) noted that the components in the wood/charcoal via pyrolysis are broken down in the process of burning to form smoke, thus it gives the fish a unique aroma and, improves its taste and colour because of the presence of a range of phenolic compounds, nitrites and formaldehyde present in the smoke.

The observation of lower protein contents in frozen fish in comparison to the fresh fish is in agreement with the finding of Arannilewa (2005) who reported that protein decreased with increasing duration of frozen storage in *Sarotherodon galileaus*. Balogun (1986) observed that *C. gariepinus* stored at 0 ^{o}C was accompanied with a decrease in the levels of total protein and crude fibre as a result of microbial, enzymatic and decomposition leading to autolysis. Eyo (2001) reported low protein, crude fibre, ash and high moisture, carbohydrate and lipid contents in frozen fish. It has been observed that the gradual denaturation of protein leads to a decrease in water holding capacity, thus when frozen fish is thawed, drip is produced and nutritional substances are drained away with the drip (Ciarlo, Boeri, & Giannini, 1985).

Table 1. Percentage mean proximate values of smoked and frozen catfish, *Clarias gariepinus*

Sample	Moisture	Protein content	Lipid content	Ash content	Crude fibre	Carbohydrate
Smoked	5.885±0.034^{b}	32.728±0.573^{b}	35.603±0.069^{a}	15.836±0.446^{b}	1.036±0.119^{a}	5.169±0.966^{b}
Frozen	8.640±0.101^{a}	24.160±0.562^{c}	36.410±0.400^{a}	8.220±0.249^{a}	0.980±0.094^{a}	21.900±0.210^{a}
Control	8.629±0.196^{a}	34.277±0.547^{a}	33.324±0.227^{b}	8.192±0.272^{a}	1.330±0.11^{b}	22.990±0.454^{a}

Values are means of triplicate samples followed by the standard error of means. Means in the same vertical column with different superscripts are significantly different ($P \leq 0.05$) by Tukey's Test.

Table 2. Mineral (μg/ml) and Vitamin (mg/ml) compositions of smoked and frozen catfish, *Clarias gariepinus*

Sample	Mineral Elements			Vitamin C
	Phosphorus	Iron	Potassium	
Smoked	5.60±1.08^{a}	0.56±0.01^{a}	1.25±0.03^{b}	0.38±0.00^{a}
Frozen	3.45±0.10^{b}	0.35±0.00^{b}	2.57±0.02^{a}	0.13±0.02^{b}
Control	1.56±0.08^{c}	0.16±0.07^{c}	0.95±0.03^{c}	0.03±0.01^{c}

Values are means of triplicate samples followed by the standard error of means. Means in the same vertical column with different superscripts are significantly different ($P \leq 0.05$) by Tukey's Test.

It has been reported that improper chilling or temperature abuse will shorten the freshness period of a product, while superchilling will extend it. Lauzon et al. (2010) observed that the freshness of fillets of cod frozen at 2 °C, -0.9 °C and -1.3 °C increased to 6 days, 7.5 days and 10 days respectively.

In this study, the values of phosphorus and potassium obtained in the fish samples were higher than the iron

content. This is in agreement with Effiong and Fakunle (2012) who observed high values of phosphorous and low iron contents in the three tropical smoked freshwater studied. However, Eyo (2001) reported low phosphorus and iron contents but high potassium and vitamin C contents in frozen fish. Freshwater fish meat is a particularly valuable source of calcium and phosphorus as well as iron, copper and selenium (FAO, 2014). Onyia et al. (2010) reported similar findings and observed that the dominance of mineral elements in a fish depends on the water body where the fish lives. In general FAO (2014) reported that the vitamin content of white fish muscle is similar to that of lean meat and, with the exception of vitamin C, can usually make a significant contribution to the total vitamin intake of man and domestic animals and that the vitamin content of fish is not markedly affected by smoking or sun drying, provided storage is not very prolonged.

4. Conclusion

In conclusion, the results obtained in this study showed that there were significant influences of smoking and freezing on the nutritional value of the catfish, *C. gariepinus*. The results indicated that the two processing methods are efficient in the post harvest management of fishery products. Smoking demonstrated a better efficient method of fish processing in terms of the retention of the protein value and reduction in moisture content. The knowledge obtained in this study could improve the preservative strategies of dried fish and thus prolong the shelf life of one of the commercially important food commodities in the tropics.

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