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Full Length Research Paper

Effects of smoke-drying temperatures and time on physical and nutritional quality parameters of Tilapia (*Oreochromis niloticus*)

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Effects of smoke-drying temperatures and duration of drying on the quality of Nile tilapia (*Oreochromis niloticus*) samples were investigated by smoke–drying Tilapia fish under three different temperatures (50, 60 and 70°C) and three drying times (5, 10 and 15 h) using modified drum kiln dryer. The proximate compositions of the fresh and dried fish were evaluated and the sensory evaluation of the organoleptic parameters was assessed. The drying temperatures and duration of drying have different effects on the quality of the smoke-dried fish. The moisture contents of the samples were reduced from the initial value of 75.11% to average safe storage values of 15.30 and 17.95% after smoke-drying at 60°C for 15 h and at 70°C for 10 h, respectively. The results showed that the crude protein, crude fibre, crude lipid and ash contents of the dried fish generally increased from the initial values as the moisture content decreased. It can be concluded from the results of this study that the best smoked fish with good quality parameters in terms of nutrient and organoleptic parameters were the products dried at 60°C for 15 h and 70°C for 10 h.

Key words: Fish, smoke-drying, drying temperatures, drying time, proximate composition, organoleptic parameters.

INTRODUCTION

Fish is a highly nutritious food and it is particularly valued for its protein which is of high quality compared to those of meat and egg (Ojutiku et al., 2009). It contains high quality protein, amino acids and absorbable dietary minerals (Bruhiyan et al., 1993). Fish is currently being used as a good tool for food therapy and source of therapeutic substances for the treatment of coronary diseases, auto-immune diseases, anemia and protein energy malnutrition (Glomset, 1986). However, fish is highly perishable because it provides favourable medium for the growth of microorganisms after death (Ojutiku et al., 2009; Aliya et al., 2012; Oparaku and Mgbenka, 2012). It has become increasingly important to ensure that fish once caught is fully and efficiently utilized to avoid deterioration.

To prolong the shelf life of fish, it is preserved by many processes including sun drying, solar drying, canning and smoking among others. Dried fish is a major component of harvested fisheries in many countries including Nigeria. About 25 to 30% of the world fish catch is con-sumed in the dried, salted, smoked form or combination of these processes (Aliya et al., 2012). Some of these processes, though important for preservation have various effects on the physical and nutritional quality of fish because it has been observed that different processing and drying methods have different effects on the nutritional compositions of fish (Oparaku and Mgbenka, 2012).

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Fish smoking and its effect have been of interest toseveral researchers (Efiuwevwere and Iweanoge, 1991; Aminullah et al., 2006; Ahmed et al., 2011; Olayemi et al., 2011; Aliya et al., 2012; Omodara and Olaniyan, 2012; Okafor and Nzeako, 1985). Many of these authors have reported that smoking of fish accelerates drying (that is, lowers moisture content or water activity) and prevents microbial activities on the fish.

Preservation methods such as canning and freezing are relatively expensive in developing countries. Among the several methods of long term preservation of fish, smoking is perhaps the simplest method as it does not require sophisticated equipment or highly skilled workers (Olayemi et al., 2011). Methods of drying and smoking fish vary between different countries and within same country depending on the species of fish and the type of product desired (Chukwu and Shaba, 2009). Smoking as a method of preservation produces commonly acceptable products since it imparts desirable colour and flavor.

Smoked fish constitutes an important diet of many low income earners in the developing world, and traditional methods are well suited to local circumstances, as they are cheap and require only simple equipment or facilities (Ames et al., 1999).

The shelf-life of smoked fish product is usually extended primarily due to the reduced water activity. To ensure short time storage of dry fish that is safe from moulds and bacteria infestation, the moisture content must be less than 30% (Eyo, 2001)

Acceptability of smoked fish in developing countries is well known (Philip and Willbridge, 1977). Smoked seafood products vary widely in microbial stability, but this depends on the nature and degree of severity of smoking. Heavily salted, hard smoked products have water content that is too low to support microbial growth and present little or no public health hazards.

However, the application of heat to dehydrate fish does not only remove water but excess of such heat can affect the nutritional content of the dried fish. Studies have shown that smoking causes some decrease in available lysine and that the loss of lysine is proportional to the temperature and duration of smoking (Eyo, 2001). Clifford et al. (1980) reported a 25% loss of available lysine on the surface of hot smoked fish fillet and a 12% loss at the center. Other basic amino acids were reduced by 6.6% on the surface but remained unchanged at the center. It has also been reported that in the absence of millard reaction, heating alone was sufficient to render lysine unavailable (Eyo, 2001). It has been observed that the intensity of heat applied during processing greatly affects the fish protein concentration. It is therefore important to ascertain how the drying temperatures and time affect some of the nutritional properties of smoke-dried fish. The objective of this study was to investigate the effects of smoke-drying temperatures and drying time on some quality parameters of dry fish, and hence determine the optimum drying time and temperatures that will give the best quality product.

MATERIALS AND METHODS

Sample collection

Thirty kilogramme (30 kg) of Nile tilapia (*Oreochromis niloticus*) were purchased from the local market in Kainji town in Niger State of Nigeria. The samples were taken to the laboratory of the National Institute for Fresh water and Fishery Research (NIFFR), New Bussa where the experiment was carried out. The fish were washed, cleaned, gutted and sprinkled with salt. Prior to smoking, the fresh samples were analysed for proximate compositions.

Smoking process

The modified drum kiln was used for the smoke-drying process. It was made from a 400 L drum with 90 cm length and 58 cm diameter. The drum was cut open midway. The base was used as the combustion chamber with a firebox of 22 × 22 cm^2. An internally built damper made of perforated metal plate was installed above the fire box. The smoking chamber was separated into three compartments using “chicken” wire mesh 10 cm above the damper. Fire wood was set up in the combustion chamber and then lighted. The temperature of the smoke generated was monitored in the smoking chamber until the required temperature was obtained using a thermometer. The fish samples were then placed on the mesh in the kiln after weighing. The burning wood was adjusted continuously to maintain the required temperature in the chamber during the smoking period. In this study, smoking temperatures of 50, 60 and 70°C and smoking time of 5, 10 and 15 h were investigated.

Proximate composition and sensory analysis

For the samples smoked at each of the temperatures and time, the moisture content, crude protein, crude lipid, crude fibre and ash content were analysed using the method of analyses by Association of Official Analytical Chemists (AOAC, 2005) as follows:

$$\text{Protein (\%)} = \frac{(V2 - V1) \times N \times 14 \times 100 \times 6.25}{1000 \times W}$$

Where, *V1* = volume of HCL used in the blank titration; *V2* = volume of HCL used in the test titration; 14 = conversion factor from ammonium sulphate to nitrogen;n 6.25 = conversion factor from nitrogen to protein; *N* = Nomality of HCL used in titration; *W*= weight of dried sample

$$Fat(\%) = \frac{Weight\ of\ ether\ extracted\ fat}{Weight\ of\ sample} x100$$

$$Ash(\%) = \frac{Weight\ of\ ash}{Weight\ of\ sample} x100$$

$$Moisture(\%) = \frac{Initial\ weight - oven\ dried\ weight}{Initial\ weight} x100$$

Each analysis was carried out in triplicate.

The colour or appearance, aroma texture, taste and the overall acceptability of the smoked fish was evaluated using a ten point grading Hedonic scale (poor (1 to 3), fairly good (4 to 5), good (6 to

Table 1. Mean values of proximate composition of Nile tilapia (*Oreochromis niloticus*) smoked at different temperatures and time.

Temperature (°C)	Time (h)	Moisture content (%)	Crude protein (%)	Crude fibre (%)	Crude lipid (%)	Ash content (%)
Fresh	0	75.11	20.14	0.70	2.20	0.80
	5	71.85	22.53	1.10	2.40	1.00
50	10	45.00	35.53	1.20	2.90	14.09
	15	32.65	48.87	1.00	3.05	16.11
	5	40.80	34.97	0.90	5.70	21.12
60	10	36.55	42.18	0.71	9.05	14.34
	15	15.30	49.40	1.20	12.35	21.61
	5	35.55	39.20	0.90	7.95	15.52
70	10	17.95	56.70	0.80	7.85	18.04
	15	6.75	64.90	1.30	9.60	16.14

Table 2. Mean values of sensory evaluation of Nile tilapia (*Oreochromis niloticus*) smoked at different temperatures and times.

Quality	50°C			60°C			70°C		
	5 h	10 h	15 h	5 h	10 h	15 h	5 h	10 h	15 h
Colour/appearance	8.9	8.8	9.4	8.0	8.7	7.9	8.8	7.3	4.3
Flavour	7.5	7.4	7.2	8.3	9.1	8.9	9.0	7.4	4.3
Texture	5.7	7.1	9.2	7.9	8.2	8.7	8.7	8.3	5.2
Taste	7.0	7.7	8.8	7.4	8.6	8.5	8.9	8.9	4.6
Over all acceptability	8.2	7.5	8.7	7.4	8.6	8.5	8.9	8.0	5.0

7) and very good (8 to 10) conducted by a 10- man panelist (Desrosier and Desrosier, 1977).

RESULTS

Proximate composition

The results of the proximate analysis carried out on the fresh and smoked fish are presented in Table 1, while that of sensory analysis are given in Table 2. Table 3 shows the results of the statistical analysis carried out to ascertain the variation between the means values of the parameters of the samples dried at various temperatures and time.

The average values of moisture content, protein, crude fibre, crude lipid and ash content of the fresh fish were, 75.11, 20.14, 0.70, 2.20 and 0.80%, respectively. These average values fall within the range given by various authors in earlier studies (Oparaku and Mgbenka, 2012, Olayemi et al., 2011; Mohammed and Karrar, 2012; Akhter et al., 2009). The results showed that there was a drastic moisture reduction as the smoking temperature and time increased. However, the crude protein, fibre, lipid and ash contents generally increased as the smoking temperature increased.

DISCUSSION

Moisture content

The effects of smoke-drying temperature and time on moisture content of the Nile tilapia (*O. niloticus*) are shown in Table 1. The results showed that for tilapia smoked at 50°C, there was a gradual reduction (4.3%) in the moisture content during the first 5 h of smoking. However, after 10 h of smoke-drying, the moisture content reduced from the initial value of 75.11 to 45% (that is about 40% reduction). After 15 h of smoking at this temperature, this value reduced to 32.65%.

For the fish smoked at 60°C, the rate of moisture removal was higher within the first 5 h of drying as there was 45% reduction in moisture from the initial value of 75.11 to 40.8%. However, only 10.42% of moisture was removed between 5 and 10 h of smoke-drying. For the sample smoke-dried at 70°C, the first 5 h recorded moisture reduction of 53% from the initial value. After 15 h of smoke-drying, the moisture content was reduced to 6.75%. The moisture content of 75.11% determined for the fresh fish (*O. niloticus*) is close to those found by Ahmed et al. (2011) for *O. noliticus.* Moisture is one of the factors that increases muscle spoilage in fresh fish. It can be seen from Table 3 that the moisture contents of

Table 3. ANOVA of effects of temperature and time on the nutritional contents of dried tilapia.

Nutritional parameter	Time (h)	Temperature (°C)		
		50	60	70
Moisture content (%)	5	71.85[a]	40.80[b]	35.55[c]
	10	45.00[b]	36.55[c]	17.95[d]
	15	32.65[c]	15.30[d]	6.75[e]
Crude protein (%)	5	22.53[a]	34.97[b]	39.20[c]
	10	35.53[b]	42.18[c]	56.70[d]
	15	48.87[c]	49.40[d]	64.90[e]
Crude fibre (%)	5	1.10[a]	0.90[b]	0.90[b]
	10	1.20[b]	0.71[ab]	0.80[c]
	15	1.00[a]	1.20[c]	1.30[d]
Crude lipid (%)	5	2.40[a]	5.70[b]	7.95[c]
	10	2.90[b]	9.05[c]	7.85[d]
	15	3.05[c]	12.35[d]	9.60[e]
Ash content (%)	5	1.00[a]	21.12[b]	15.52[c]
	10	14.09[b]	14.34[c]	18.52[d]
	15	16.11[c]	21.61[d]	16.14[e]

Means with the same letters along the rows are not significantly different (p ≤ 0.05) for samples dried for the same time at the various drying temperatures while those along the columns are not significantly different (p ≤ 0.05) for samples dried at the same temperature at various drying time.

the samples dried at the three temperatures and time differed significantly (p ≤ 0.05).

It has been noted that a fish well dried with moisture reduced to 25% (wet basis) will not be affected by spoilage organisms like mould and that if further dried to moisture content of 15%, the growth of mould will cease and the shelf life will increase (Oparaku and Mgbenka, 2012). It can be seen from these results that these safe moisture contents can effectively be achieved by smoke-drying the fish at smoking temperature of 60°C for 15 h and at 70°C for 10 h (Oladele and Odedeji, 2008). However, smoke-drying at 70°C beyond 10 h although reduced the moisture content further, but it greatly reduced the visual quality as obtained from the sensory analysis.

Crude protein

The effects of smoke-drying temperature and time on crude protein of tilapia (*O. niloticus*) are shown in Table 1. The results showed that crude protein increased with increase in temperature and time and the average values obtained at the three temperatures and time differed significantly (p ≤ 0.05). From the initial value of 20.41%, the crude protein increased to 48.87, 49.40 and 64.90% after 15 h of smoke-drying at 50, 60 and 70°C, respectively. This result is in agreement with earlier studies (Oparaku and Mgbenka; 2012, Ahmed et al., 2011; Aliya et al., 2012; Olayemi et al., 2011; Akhter et al., 2009; Afolabi et al., 1994) which all observed that smoking/drying increases crude protein, crude lipid, crude fibre and ash content of fish and meat products. It is also observed (Akhter et al., 2009) that wood smoke contains pyroligenous acid which may have an added preservative effect on smoked dried meat. It is observed that protein contents increased with decrease in moisture content (Aliyaet al., 2012).From the results (Table 1) it can be seen that smoke-drying for a period of 10 h at these smoking temperatures is adequate for both safe storage and maintenance of the desirable nutritive quality of the dried products. Generally, the values obtained where within the standard provided by FAO (2007).

Crude fibre

The effects of smoking temperature and time on crude fibre of Nile tilapia (*O. niloticus*) are shown in Table 1. Though there were slight increases in the values of the crude fibre from the initial value of 0.70%, the results do not differ significantly (p ≤ 0.05) between the samples dried at 60 and 70°C after 5 h of smoke-drying. The effect of drying time was however well pronounced (Table 3). While the values increased from the values of 0.70% to 1.20 and 1.30% after 15 h of drying at 60 and 70°C, respectively, those of samples dried at 50°C was not consistent over the drying period. However, the results of the increase in crude fibre are in agreement with those obtained in earlier studies (Afolabi et al., 1994) as it is stated that moisture removal leads to concentration of all nutrients present in fish products.

Crude lipid

The results (Table 1) generally indicate a continuous increase in crude lipid in the smoked tilapia samples dried at 50 and 60°C. This is also in agreement with Afolabi et al. (1994). The results (Table 3) showed that the crude lipid of the samples of tilapia smoke-dried at the three different temperatures over the three periods were significantly different ($p \leq 0.05$).

The initial value of crude lipid was 2.2% and the average obtained after 15 h of smoke-drying at 60°C was 12.35%. The reduction in crude lipid of the tilapia smoked at 70°C compared to the other two temperatures could be attributed to possible loss of fat due to the high temperature as observed in earlier studies (Ahmed et al., 2011). The values obtained were also within the FAO standard (FAO, 2007).

Ash content

The initial value of ash was 0.8%. The results generally showed an increase in the ash content of the smoked tilapia. This result is in agreement with earlier studies (Oparaku and Mgbenka, 2012) which stated that the ash content of fresh *Clarius gariepinus* increased from 1.79% (fresh) to 4.85% (solar dried) and 3.08% (electric oven dried). The average values of the ash contents of 10.40, 19.02 and 16.57% for samples smoke-dried at 50, 60 and 70°C respectively, fall within the values (16.1%) given for salted, fermented and sun-dried tilapia (FAO, 2007).

The higher values of ash contents may be due to the presence of salt because in the same literature, that of unsalted, fermented and sun-dried tilapia was 6.8%. The average ash contents obtained for the samples dried at different temperatures over different time (Table 3) also differed significantly ($p \leq 0.05$).

Whereas, those smoked at 50°C showed a steady increase in the values during the drying period, the samples smoked at 60 and 70°C did not have continuous increase over the drying time.

Sensory analysis

Colour/appearance

From the sensory evaluation results (Table 2), the colour or appearance of the smoked tilapia at 70°C for 15 h was of poor quality. This was as a result of over smoking. The best in terms of appearance was tilapia smoked at 50°C for 15 h with a rating of 9.4 acceptability. Other tilapia samples dried at other temperatures and time were rated above average. Generally colour/ appearance is one of the quality parameters that consumers use in accepting or rejecting products, hence this is crucial in quality evaluation.

Flavour

The flavour of the fish product smoked at 60°C for10 h showed a very good quality as far as the assessment was concerned. The tilapia smoked at 70°C for 15 h was rated very poor. This may be due to the same reason of over smoking, as the product had a burnt flavour. The flavour of tilapia smoked for 5 h at 50°C was also rated higher than the product smoked for 10 and 15 h under the same temperature. Odour is an important quality parameter, as poor odour will discourage people from accepting food products.

Texture

The textures of all the fish samples were rated above average. The best texture rated smoked tilapia was at 50°C for 15 h having a partially firm skin which was not easily removed from the muscles and suitable for eating. The texture of the tilapia smoked at 70°C for 15 h was of poor quality and had the lowest rating; the reason may be that at this drying temperature and time, the product became very brittle. Normally these products are difficult to handle and package which usually results to losses.

Taste

The best rated tilapia in terms of taste were samples smoked at 50°C for 15 h, 60°C for 10 h and 70°C for 5 h with average rating value of 8.8, 8.6 and 8.9, respectively on the scale. The samples were neither burnt nor fresh and hence possessed good cooking attribute. The fish smoked for 15 h at 70°C had the lowest taste rating; this may be because it had a burnt taste.

Overall acceptability

From the assessment, the best smoked samples with very good acceptable quality attributes like firm-juicy textured skin, nice odour, and reddish brown colour, were those dried at 70°C for 5 h, 50°C for 15 h and 60°C for 10 h having the average rating of 8.9, 8.7 and 8.6, respectively. The general acceptability of the fish were high, this is because the temperature used in smoking were not excessively high and was constantly controlled. This made most of the nutritive and physical qualities to be retained at the end of smoking, giving rise to products that were very delicious and attractive.

Results obtained were also similar to those reported by FAO (2007) and other works as previously reviewed. Some of these results as reported for hot smoked cured products are as follows: 8.3 as an excellent quality for flavour, 7.7 as a very good quality for colour, 6.9 as a very good quality for taste, 6.7 as a good quality for texture and 7.8 as a very good quality for overall acceptability.

Conclusion

Smoke-drying temperatures and time influence the nutritive and physical quality parameters of dried tilapia. Moisture content decreased with increasing temperature and drying time while crude protein, crude lipid, crude fibre, and ash content increased with increasing temperature and time. The best smoked tilapia with very good quality were samples smoke-dried at 60°C for 15 h and 70°C for 10 h because the moisture contents obtained at these temperatures and time fall within the recommended safe storage levels of water activity for dried fish while fish smoked at 70°C for 15 h had poor quality attributes and was rated lowest. Therefore the optimum drying temperatures and time from the results obtained were 60°C for 15 h and 70°C for 10 h.

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