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Original Research Article

Assessment of the impact of locally fabricated oven and sun drying method on the proximate, mineral and microbiological composition of *Clarias gariepinus* (catfish)

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Abstract

Drying is an age long practice which prevent fish from deterioration and spoilage, however, traditional drying is usually practiced in rural settings with poor hygienic conditions, thus, the nutritional and microbial quality of such products is uncertain. Therefore, the present study was aimed at evaluating the impact of a locally fabricated oven and sun drying method on the proximate, mineral and microbial composition of *Clarias gariepinus* (Catfish) using standard laboratory procedures. The results of the proximate analysis showed that the oven dried fish had the highest crude protein content (66.43 ± 3.37 %), crude lipid content (8.27 ± 0.28 %) and carbohydrate content (4.50 ± 0.22 %) which were statistically significant ($p<0.05$) when compared to the sun dried fish, while the sun dried fish had the highest ash content (16.30 ± 2.48 %) and moisture content (14.30 ± 0.82 %) which were statistically significant ($p<0.05$) when compared to the oven dried fish. Also, the mineral analysis showed that the oven dried fish had the highest calcium (821.49 ± 1.10 mg/kg), phosphorus (86.04 ± 0.83 mg/kg), potassium (254.72 ± 0.40 mg/kg), iron (40.73 ± 0.23 mg/kg), manganese (0.95 ± 0.01 mg/kg) and selenium (14.15 ± 0.39 mg/kg) content which were statistically significant ($p<0.05$) when compared to the sun dried fish, while the sun dried fish had the highest sodium (173.52 ± 0.12 mg/kg), cupper (0.87 ± 0.12 mg/kg), magnesium (39.01 ± 0.43 mg/kg) and zinc (2.83 ± 0.23 mg/kg) content which were also statistically significant ($p<0.05$) when compared to the oven dried fish. The study also showed that the total viable bacterial count was higher in the sun dried fish (6.23×10^5 cfu/g) which was not statistically significant ($p<0.05$) when compared to the oven dried fish (5.65×10^5cfu/g), while the fungal count was higher in the oven dried fish (6.55×10^5 cfu/g) which was also not statistically significant ($p<0.05$) when compared to the sun dried fish (5.01×10^5 cfu/g). The findings in this study showed that the locally fabricated oven was remarkably effective, yielding fish with significantly enhanced nutritional profiles and minimal microbial contamination. This approach offers a superior method for fish preservation, providing a promising alternative for improving food safety and nutritional quality.

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Keywords: *Deterioration, nutritional profiles, microbial, preservation, spoilage*

INTRODUCTION

Fish provides a substantial amount of protein from animal sources, and it has been widely recognized as an excellent provider of protein and other vital nutrients essential for the maintenance of healthy body. Fish is a healthier, cholesterol free alternative for protein intake, and an exceptionally rich source of calcium, phosphorus, iron, fats and vitamins (Fagbenro *et al*., 2005; Akinneye *et al*., 2007).

Clarias gariepinus is commonly known as Catfish, it is a highly valued freshwater fish in Nigeria which enjoy a wider acceptability due to its unique taste, flavor and texture and its cultivation is also very easy (Alfa *et al.*, 2014). When the post-harvest is not managed properly, the biochemical breakdown of protein and fat content contribute to the quick spoilage of catfish coupled with microbial contamination (Adams and Moss, 2008). The quality of raw fish can be compromised by poor fishing practices, rough handling during transport, and inadequate storage before processing (Okereke *et al*., 2014).

Various methods have been utilized to keep fish safe and extend its shelf life while preserving its quality. However, limitations in storage facilities such as refrigeration, particularly in developing countries compel small scale fish producers to explore alternative preservation techniques. Among these, fermentation, drying and smoking are the most employed methods. Notably, traditional drying method is considered as the most cost-effective approach to fish preservation, making it's a vital strategy for small scale producers in resource constrained settings (Gutema and Hailemichael, 2021). It is an age long practice which prevent fish from deterioration and spoilage and reduce post-harvest losses and make it available in times of shortage (Balachandran, 2001). However, traditional drying methods, commonly used in rural areas, often take place in unsanitary conditions making them susceptible to microbial contamination. This can lead to high levels of harmful microorganisms which can pose health risks to the consumers. Also, exposure to environmental contaminants like as air, dust and polluted soil can also affect the quality of dried fish products (Asharaful and Khan, 2002).

On the other hand, oven drying is a method of preserving and dehydrating fish which utilizes controlled heat from an oven to remove moisture from fish. The key principle behind oven drying is to create an environment where moisture is efficiently removed from the fish, preventing the growth of microorganisms that lead to spoilage, and extending the shelf life of the product. This method offers advantages in terms of consistent temperature control, which ensures uniform drying, and the ability to regulate environmental conditions for optimal results. However, there are challenges associated with oven drying method which include higher energy consumption compared to some alternative methods, as well as the potential for alterations in the nutritional composition and sensory attributes of the dried food due to prolonged exposure to heat (Olagbemide *et al*., 2019). Limited information is available on the nutritional and microbial composition of dried fish products in Kano State, Nigeria, therefore, the present study was aimed at evaluating the effects of a locally fabricated oven and sun drying method on the proximate, mineral and microbial composition of *Clarias gariepinus*.

MATERIALS AND METHODS

Collection of the samples

Fresh *Clarias gariepinus* (Catfish) were collected from the Aquatic Bioresources Division of

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Bioresources Development Centre, Kano, National Biotechnology Development Agency (NABDA). The fishes were gutted, scaled and washed with clean tap water, and then divided into two portions (10 fishes per portion); the fishes in the first portion were dried with a locally fabricated oven, while those in the second portion were sun-dried.

1- Proximate analysis

i- Determination of moisture content

The moisture contents of the samples were determined using a specialized moisture analyzer, and the moisture content of each sample was recorded as percentage moisture (Ooi *et al*., 2012).

ii- Determination of crude lipid content

The crude lipid contents of the samples were determined using the method described by Noureddini and Byun 2010, using a SoxtecTM 8000 automated analyzer (FOSS Analytical, Hillerød, Denmark). Petroleum ether was used for the extraction, and the percentage of crude lipid content of each sample was measured using the formula below:

$$Percentage\ Lipid = \frac{Weight_{extraction\ cup+residue} - Weight_{extraction\ cup}}{Weight\ sample} \times 100$$

iii- Determination of crude protein content

The crude nitrogen content in each sample was determined using the method described by Ng et al. (2008), using Kjeltec 8400 Auto Distillation Unit (FOSS Tecator Line), and a nitrogen-to-protein conversion factor of 6.25 was used for the determination the percentage of crude protein each sample;

$$\text{Percentage Nitrogen} = \frac{0.014 \text{ x Molarity X Volume}}{\text{Weight of the sample}} \quad \text{X} \quad 1000$$

Therefore,

% crude protein = 6.25x % Nitrogen

iv- Determination of ash content

The ash content of each sample was evalauted using dry ashing method (AOAC, 2000), each sample was incinerated in a furnace at 550 °C, and the remaining inorganic material was cooled, weighed and the ash content was determined as follows;

$$\text{Percentage Ash} = \frac{\text{Weight after ashing } (W_3) - \text{Weight of empty crucible } (W_1)}{\text{Weight of crucible + sample before ashing } (W_2) - \text{Weight of empty crucible } (W_1)} \quad \text{X} \quad 100$$

v- Determination of crude fibre

The crude fibre content of each sample was determined using the method described by Noureddini and Byun (2010), using a Fibretec 8000 auto fibre analysis system (FOSS Analytical, Hillerød, Denmark). Approximately 2 g of the sample was placed into a round bottom flask and mixed with 100 ml of 0.25 M H_2SO_4 solution. The mixture was then boiled for 30 minutes under reflux. The hot solution was quickly filtered under suction, and the insoluble matter was washed several times with hot water until it was acid free. It was transferred into the flask and 100 ml of 0.31 M NaOH solution was added and the mixture was again boiled for 30 minutes under reflux and filtered under suction. The residue was washed with boiling water until it was base free, which was then dried in

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an oven at 100 °C, cooled and weighed (W_1). The weighed sample (W_1) was then incinerated in a muffle furnace at 550 °C for two hours, cooled and reweighed (W_2). The percentage crude fibre was calculated as follows;

$$\text{Percentage Fibre} = \frac{W_2 - W_1}{\text{Weight of the sample}} \times 100$$

vi- Carbohydrate

The total carbohydrate content (%) in each sample was calculated by difference method as follows;
Percentage Carbohydrate = 100 - (% moisture + % ash + % protein + fibre + % lipid)

2-Mineral analysis

The method described by Li et al (2013) was employed for the determination of the mineral elements in each sample; 200 mg of each was weighed and transferred into 90 ml microwave digestion vessel, 10 ml mixture of 15.9 N trace metal grade nitric acid, hydrogen peroxide and perchloric acid (7:2:1) were added to the vessel. After standing for an hour, the sample underwent microwave digestion, which involved heating it from room temperature to 200 °C over 20 minutes, followed by a hold at 200 °C. Once digested, the sample was cooled to around 50 °C or lower before being handled. It was then transferred to a 50 ml volumetric flask, diluted to 50 ml with deionised water and filtered, and the mineral contents which include calcium, potassium, magnesium, sodium, phosphorus, iron, selenium, copper, nickel, zinc, chromium, sulphur, manganese and cobalt were analyzed using Agilent Micro Plasma Atomic Emission Spectrometer (MP-AES, 4210) available at the Centre for Dryland Agriculture, Bayero University, Kano, Nigeria.

3-Microbial analysis

i- Media preparation

Potatoe dextrose agar (PDA), blood agar, MacConkey agar and Sabourauds dextrose agar (SDA) were prepared according to the manufacturer's instructions.

ii- Aerobic mesophilic bacterial count

This was conducted according to the method described by Triphaty et al. (2015). About 1 g each of each sample was weighed and dissolved in 9 ml of sterile peptone water tubes, the sample was then shaken, and 1 ml of the mixture was transferred into another 9 ml peptone water test tube, this was repeated to obtain up to 10^{-5}-fold dilution. About 20 ml of freshly prepared sterile cooled nutrient agar, was poured into the various labeled plates containing the diluted samples corresponding with dilution factor of plates, this was mixed and allowed to solidify. The Plates were incubated at 37 °C for 24 hours to detect the bacterial growth. Following incubation, the number of colonies were determined for each dilution and the results were expressed as colony forming units (CFU) per gram. Each sample was cultured, and total viable counts was done in duplicate for both bacteria (Erik, 1989).

iii- Fungal plate count

About 1 g each of sample was weighed and dissolved in 9 ml of sterile peptone water tubes, the sample was then shaken, and 1 ml of the mixture was transferred into another 9 ml peptone water test tube, this was repeated to obtain up to 10^{-5}-fold dilution which served as serial dilution. About 20 ml of freshly prepared sterile potato dextrose agar (PDA) which was allowed to cool was poured into various labeled plates containing the diluted samples corresponding with dilution factors, this

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was mixed and allowed to solidify. The plates were then incubated for 5 to 7 days at 28 ^oC to detect fungal growth. After incubation, colony counts were performed on each dilution and colony forming units (CFU) per gram (Skinner and Lovelock, 2010).

iv- Isolation and characterization of the bacterial isolates

Isolation of suspected bacterial species from the samples was done by using different selective media such as Eosine Methylene Blue agar (EMB*)* for the detection of *Escerichia coli, Salmonella Shigella* agar (SSA) for the detection of *Salmonella typhi,* Mannitol Salt Agar (MSA) for the detection of *Staphylococcus aureus* and MacConkey agar (MA) for the detection of *Klebsiella pneumoniae*. Also, gram staining and biochemical tests were used to characterize the bacterial isolates present in the samples.

viii- Statistical analysis

The analysis of proximate and mineral content was conducted in three replicates, and the results were expressed as mean ± standard deviation (SD). The level of significance was tested using t-test at 95 % confidence level using statistical package for the social sciences (SPSS) version 25.

RESULTS

Proximate composition of oven and sun-dried fish

The proximate analysis showed that the oven dried fish had the highest crude protein, crude lipid and carbohydrate contents which were statistically significant ($p<0.05$) when compared to the sun drying method. On the other hand, the sun-dried fish had the highest ash and moisture contents which were also statistically significant ($p<0.05$) when compared to the oven drying method. However, there is no significant difference in the crude fibre content of both samples as presented in Table 1;

Table 1: Proximate composition of oven and sun-dried fish

S/N	Parameters	Oven Dried Fish (%)	Sun Dried Fish (%)	P-Value
1	Ash	14.29 ± 0.98	16.30 ± 2.48	0.001
2	Crude fibre	2.15 ± 0.426	2.16 ± 0.26	0.870
3	Crude lipid	8.27 ± 0.28	2.75 ± 0.32	0.001
4	Moisture	4.36 ± 0.06	14.30 ± 0.82	0.001
5	Crude protein	66.43 ± 3.37	61.15 ± 3.89	0.001
6	Carbohydrate	4.50 ± 0.22	3.34 ± 0.19	0.001

All values were mean ± standard deviation of triplicate determinations

Mineral analysis

The mineral analysis showed that the oven dried fish had the highest calcium, phosphorus, potassium, iron, manganese, sulphur and selenium contents which were statistically significant ($p<0.05$) when compared to the sun-dried fish. On the other hand, the sun-dried fish had the highest sodium, cupper, magnesium and zinc content which were also statistically significant ($p<0.05$) when compared to the oven dried fish as presented in Table 2;

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Table 2: Mineral composition of oven and sun-dried fish

S/N	Minerals	Oven Dried Fish (mg/kg)	Sun Dried Fish (mg/kg)	P-Value
1	Ca	821.49 ± 1.10	791.16 ± 1.02	0.001
2	P	86.04 ± 0.83	71.47 ± 1.61	0.001
3	S	0.68 ± 0.17	0.42 ± 0.10	0.622
4	Se	14.15 ± 0.39	13.41 ± 0.51	0.003
5	Zn	2.31 ± 0.30	2.83 ± 0.23	0.006
6	Fe	40.73 ± 0.23	18.14 ± 0.02	0.001
7	Cu	0.83 ± 0.10	0.87 ± 0.12	0.420
8	Ni	0.29 ± 0.03	0.27 ± 0.05	0.134
9	K	254.72 ± 0.40	223.75 ± 0.43	0.001
10	Co	ND	ND	
11	Mg	38.04 ± 0.21	39.01 ± 0.43	0.001
12	Mn	0.95 ± 0.01	0.72 ± 0.02	0.021
13	Cr	0.46 ± 0.05	0.63 ± 0.05	0.014
14	Na	99.33 ± 0.16	173.52 ± 0.12	0.001

All values were mean ± standard deviation of triplicate determinations
Key:
ND = Not Detected

Microbial composition of oven and sun-dried fish

i- Bacterial and fungal counts of oven and sun-dried fish

The bacterial and fungal counts of oven and sun-dried fish samples were presented in Table 3. The total viable bacterial count (cfu/g) was higher in sun dried fish sample (6.23×10^5) which was not statistically significant ($p<0.05$) when compared to the oven dried fish sample (5.65×10^5). On the other hand, fungal count (cfu/g) was higher in oven dried fish sample (6.55×10^5) which was also not statistically significant ($p<0.05$) when compared to the sun-dried fish sample (5.01×10^5).

Table 3: Bacterial and fungal counts of oven and sun-dried fish colony forming unit per gram (CFU/g)

Parameters	Oven Dried Fish	Sun Dried Fish	P-Value
Total Viable Bacterial Count (cfu/g)	5.65×10^5	6.23×10^5	0.979
Fungal Count (cfu/g)	6.55×10^5	5.01×10^5	0.988

Microscopic and biochemical characterization of the bacterial isolates

The results of the microscopic and biochemical analysis were presented in Table 4 and 5 respectively. The microorganisms identified include *Staphylococcus aureus*, *Escherichia coli*, *Salmonella typhi* and *Klebsiella pneumoniae.*

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Table 4: Microscopic characteristics of bacterial species isolated from the samples

	Colony Appearance	Gram's Appearance	Possible Bacterial Species
1.	Circular, yellowish colonies grown on mannitol salt agar plate after 24 hours incubation	Gram-positive, cocci, clusters and pairs	*S. aureus*
2.	Black golden metallic shiny color grown on EMB.	Gram-negative, short and plump rods cells in sizes	*E. coli*
3.	Black and smooth colonies observed on *Salmonella* and *Shigella* agar plates after 24 hours incubation	Gram-negative, short and plump rods cells in sizes	*S. typhi*
4.	Light pink to red, viscid mucoid with yeasty Oduor grown on MacConkey agar.	Gram-negative, long rods and capsulated non-motile	*K. pneumoniae*

Table 5: Biochemical characterization of the bacterial isolates

S/N	Tests	*Staphylococcus aureus*	*Escherichia coli*	*Salmonella typhi*	*Klebsiella pneumonia*
1.	Indole	-	+	-	-
2.	Methyl red	-	+	+	-
3.	Voges proskauer	-	-	-	+
4.	Citrate	-	-	-	+
5.	Catalase	+	-	-	-
6.	Coagulase	+	-	-	-
7.	Glucose	+	-	-	-
8.	Mannitol	+	-	-	-

Keys: (+) = Organisms are reactive, (-) = Organisms are non-reactive

DISCUSSION

The present study investigated the impact of a locally fabricated oven and sun drying method on the proximate, mineral and microbial composition of Catfish. The results of the proximate analysis showed that the oven dried fish had the highest crude protein content of 66.43 ± 3.37 %, which was statistically significant ($p<0.05$) when compared to the sun drying method (61.15 ± 3.89 %.). The higher protein content of oven dried fish is likely due to thorough drying process, which significantly reduced the moisture content to 4.36 ± 0.06 %, and this is in agreement with the previous studies which established an inverse relationship between the moisture and protein content of dried fish; the lower the moisture content, the higher the protein content dried fish: as moisture content decreases, protein content increases, and vice versa (Jahan *et al*., 2018; Jahan *et al*., 2019; Al Banna *et al*., 2022). The lower moisture content in oven dried fish suggests a high-quality storage condition, characterized by minimal risk of microbial growth (Hassan and Umar, 2004). Also, the moisture content (14.30 ± 0.82 %) of sun-dried fish was higher than the values reported by other workers, and did not fall within the allowable limit of 6-8 % (Olayemi *et al*., 2012; Ndife *et al*., 2019).

The study also showed that the oven dried fish had the highest crude lipid content of 8.27 ± 0.28 % which was statistically significant ($p<0.05$) when compared to the sun drying method (2.75 ± 0.32 %). Many studies reported that the amount of lipid in a dried fish could vary according to the method of drying (Pigott and Tucker 1990; Majumdar 2017). The higher crude lipid content detected in the oven dried fish suggests that oven dried fish could be a better source of lipid and/or energy than the sun-dried fish. On the other hand, the lower crude lipid content detected in the sun-dried fish may be due to lipid oxidation during the drying process (McGill *et al*., 1974; Akinneye

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et al., 2010).

Ash content is a key component of proximate analysis, a standard method used to evaluate the quality of food products, including fish. It represents the total mineral content in foods; higher ash content indicates higher mineral contents, and vice versa (Harris and Marshall, 2017). The present study showed that the sun-dried fish had the highest ash content of 16.30 ± 2.48 %; previous studies revealed that fish that was sun dried has been shown to have higher ash content than those dried using other methods of drying (Fitri *et al*., 2022). However, it was also observed that there were no significant differences in the carbohydrate and crude fibre content of both samples, and this suggests that both drying methods have a similar effect on the carbohydrate and crude fibre content of the fish.

The study also showed that the oven dried fish had the highest calcium (821.49 ± 1.10 mg/kg), phosphorus (86.04 ± 0.83 mg/kg), potassium (86.04 ± 0.83 mg/kg), iron (40.73 ± 0.23 mg/kg), sulphur (0.68 ± 0.17 mg/kg) and selenium (14.15 ± 0.39 mg/kg) content which were statistically significant ($p<0.05$) when compared to the sun-dried fish. On the other hand, the sun-dried fish had the highest sodium (173.52 ± 0.12 mg/kg), magnesium (39.01 ± 0.43 mg/kg) and zinc (2.83 ± 0.23 mg/kg) content which were also statistically significant ($p<0.05$) when compared to the oven dried fish.

The microbial analysis showed that the total mean bacterial count was higher in sun dried fish (6.23×10^5 cfu/g) when compared to the oven dried fish (5.65×10^5 cfu/g); these values were slightly above the maximum recommended value (5×10^5) of bacteria count for good quality fish products. However, the total mean bacterial count of both oven and sun-dried fishes were within the recommended value (less than 10^6) in microbiological guideline for ready to eat food (MGREF, 2007). The presence of *S. aureus, E. coli, S. typhi* and *K. pneumoniae* which are indicative organisms further confirmed that there was contamination with enteric organisms by the handlers during the drying processes (ICMSF, 1986; Olayemi *et al*., 2012). The presence of these organisms in dried fish products were also reported by many workers (Oku and Amakoromo, 2013; Nagwekar *et al*., 2017; Al-Saadi *et al*., 2021). *S. aureus* is specifically known for its unique ability to survive in harsh conditions; therefore, dried fish products should be well cooked before consumption to ensure safety (Gutema and Hailemichael, 2021).

The present study also showed that the fungal count (cfu/g) was higher in oven dried fish sample (6.55×10^5) compared to sun dried fish sample (5.01×10^5), the value observed in sun dried fish was very close to the maximum recommended value (5×10^5), while that of oven dried fish was slightly above the maximum recommended value (ICMSF, 1986). Also, the fungal count of sun-dried fish was within the recommended value (i.e less than 1×10^6) in microbiological guideline for ready to eat food (MGREF, 2007).

CONCLUSION

The findings in this study revealed that the locally fabricated oven was remarkably effective, yielding fish with significantly enhanced nutritional profiles and minimal microbial contamination. This approach offers a superior method for fish preservation, providing a promising alternative for improving food safety and nutritional quality.

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