INDIAN JOURNAL OF
ENGINEERING

18(49), 2021

Evaluation of an experimental fish dryer

Yusuf KA[1]✉, Oladipupo RA[2], Oladipo Ajayi[3], Olawepo BB[4]

To Cite:
Yusuf KA, Oladipupo RA, Oladipo Ajayi, Olawepo BB. Evaluation of an experimental fish dryer. *Indian Journal of Engineering*, 2021, 18(49), 232-239

Author Affiliation:
[1,3]Agricultural and Bio-Environmental Engineering Technology Department, Auchi Polytechnic, P.M.B 13, Auchi Edo State, Nigeria
[2]Department of Food, Agric. and Bio Engineering, Kwara State University, Malete Kwara State, Nigeria
[4]Department of Mechanical Engineering Technology, Auchi Polytechnic, Auchi, Edo State Nigeria

✉**Corresponding Author:**
Agricultural and Bio-Environmental Engineering Technology Department, Auchi Polytechnic, P.M.B 13, Auchi Edo State, Nigeria
Email: kamyuf@gmail.com

Peer-Review History
Received: 24 May 2021
Reviewed & Revised: 25/May/2021 to 16/June/2021
Accepted: 17 June 2021
Published: June 2021

Peer-Review Model
External peer-review was done through double-blind method.

ABSTRACT

Drying has been described as a process of reducing the moisture content in a product in other to reduce the reactions of microorganism that may leads to the product deterioration. Studies have shown that the lysine content of the fish decreases with increase in temperature and duration of drying. In this study, an experimental fish dryer was developed and evaluated for it performance. During the design of the dryer, considerations were given to ease of loading and offloading the fishes, easy mechanism of turning the fish during drying and mechanism to control the drying temperature of the fish. The performance evaluation of the dryer was carried out by considering drying the fishes in whole and in part (i.e. head, middle and tail) to determine the effects of drum numbers on the drying rate of the fish and the drying efficiency of the dryer. The data obtained for drying the whole fish was subjected to a regression analysis and that of drying of the part was considered as a factorial experiment in a Randomized Complete Block Design (RCBD) with drum number as the blocking factor using SSPSS 21.0 software. The result of the analysis shows that the drum number has no effect on the drying rate of the whole fish and the drying efficiency of the machine. The regression model and corresponding R^2 value for the drying rate of the whole fish and the drying efficiency of the dryer were Y=0.008x+10.97, R^2=0.024 and Y=-0.406x+81.78, R^2=0.014 respectively. Also, the result of drying the fish in parts reflects that the drum number has a significant effect on the drying rate of the fish in parts but has no significant effect on the drying efficiency of the dryer at 5% confidence limit. The optimum drying rate and drying efficiency obtained during the experiment for the whole fish are 11.04g/h and 82.56% respectively and for the fish in part, the optimum drying rate and drying efficiency are head 4.15g/h, middle 4.17g/h, tail 3.92g/h and head 87.82%, middle 87.81%, tail 90.14% respectively.

Keywords: Fish Dryer, Cat Fish, Drum Number, Drying Rate, Drying Efficiency

1. INTRODUCTION

Drying is a method of food preservation which inhibits the growth of microorganisms. Open air drying using sun and wind has been practiced since ancient times to preserve food among rural farmers. Fish are highly perishable, and they will spoil rapidly if improperly handled. The world fish

DISCOVERY
SCIENTIFIC SOCIETY

production from capture fisheries and aquaculture has researched 121 tones FAO (2007). The majority of these are found in tropical waters. Fresh fish rapidly deteriorates unless it is preserved. The drying of fish can simply be done by exposure to the sun. Despite the rudimentary nature of the process of this traditional method, lack of control over the drying rate, sometimes results in under-drying or over-drying, exposure of the fish to unexpected winds, dust, dirt, insect infestation and contamination such as flies. This method still remains predominant in Nigeria.

The main principle in fish preservation is the prevention of microbial spoilage by reduction in water activity or simply creating unfavourable environment for microbial growth. It was reported that the post-harvest methods of preserving fish include refrigeration (4°C) and freezing which is effective when such fish is conditioned to a temperature of about - 10°C to -3 0°C. Other methods frequently employed include salting, sun-drying and smoke-drying all associated with increased germicidal action with increasing temperature, irradiation and canning.

A higher temperature involved in smoking and drying, affects the amino acid profile of the fish and also leads to protein denaturation. Before smoking, fish products are placed in racks and allowed to drip dry which results in some nutrients being lost in the exudates and the process also fosters microbial growth that induces proteolysis.

Ayolabi and Fagade (2010) reported that the post-harvest methods of preserving fish include refrigeration (4°C) and freezing which is effective when such fish is conditioned to a temperature of about - 10°C to -3 0°C. Other methods frequently employed according to Ayolabi and Fagade include salting, sun-drying and smoke-drying all associated with increased germicidal action with increasing temperature, irradiation and canning.

About 25-30% of the present world catch for human consumption are dried, salted, smoked, or treated by some combinations of these processes each year (Azam *et al.*, 2003). Davies and Davies (2009) reported that out of all the preservation methods in Nigeria, smoke-drying remains the most prominent. This was attributed to the fact that most of the fish communities have no access to electricity to freeze their products and electricity itself is fast becoming a less reliable source of energy. The moisture of the dried products varies between an estimated 40% for higher temperature ranges and 10-20% in the lower ranges. The quality of these products is judged by degree of drying, appearance and damage (Davies and Davies, 2009).

According to Eyo (2001), the drying rate of thin fish or piece of fish is faster than a thick fish of the same weight because a thin fish has proportionately greater surface area and the diffusion path of the surface is shorter; fish with lower fat content dries faster due to faster diffusion of water to the surface of the fish and consequently faster drying rate. Fish has considerable amount of fat, as a result if fish is dried at a high temperature (above 40°C) or at a low relative humidity, the outer layer become cooked or altered so as to be almost impervious to water which is termed case hardening. The result of case hardening is that the outer layer dries well whereas water is trapped inside causing insufficient drying and early spoilage. These are factors affecting the drying rate of fish.

2. MATERIALS AND METHODS

The experimental dryer is made up of three (the heating, blowing and drying) chambers. The heating chamber is trapezoidal in shape and made up of two parallel connected heating elements which serve as a medium through which heat is generated in the fish dryer. The blower chamber is made up of a straight blade centrifugal fan for efficient transfer of the heated air from the heating chamber to the drying cabinet. The drying chamber is a rectangular shaped box and is made of mild steel sheet having a double wall with thickness of 1.5mm and 2.0mm lagged with sawdust, to conserve energy, prevent excessive heat loss from the dryer and to make the working environment conducive for the user. It also comprises of three (3) rotating drums connected with sprocket and chain which are 10mm apart and are controlled with the turning handle located at the outer part of the chamber. During the operation of the dryer, the drying chamber was preheated and regulated to the desired temperature of 55°C with the aid of temperature regulatory device (thermostat and thermocouple) which are connected to the heating element, the fishes were stacked to the rotating drums with the aid of hooks and the turning operation was carried out at an interval of 8, 10 and 12 hours respectively. The pictorial view of the dryer is as shown on Figure 1.

Performance Evaluation of the Dryer

Extensive performance evaluation of the dryer was carried out to determine the effects of drum number on the drying rate of the fish and efficiency of the dryer using an African catfish.

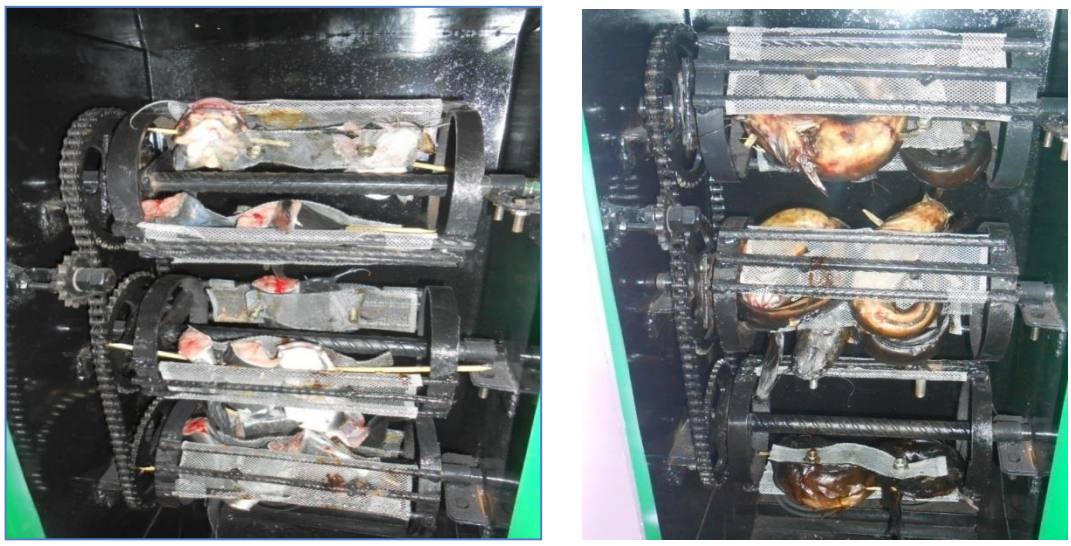
ISSN 2319–7757 EISSN 2319–7765 | OPEN ACCESS

Sample Preparation

The Africa catfish used for the evaluation of the dryer was purchased from a fish merchant in Uchi market, Auchi Edo State, Nigeria. The fish after purchase were divided into two sets. The first was dried as whole fish while the other was killed and butcher into three pieces (i.e. the head, middle and tail) before drying as shown in Figure 2.

Figure 1: Pictorial view of the Experimental Fish Dryer

The samples were subjected to pretreatment by dipping and washing with salt solution to reduce the slippery nature of the skin and microbial effect on the fish before drying begin. The weight of the samples was taking and recorded before being arranged in the dryer.



(a) Head, Middle and Tail Drying Process **(b) Whole Fish Drying Process**

Figure 2: Pictorial view showing the Two Drying Processes

Evaluation Procedure

The evaluation was carried out to determine the drying rate of the fish and the drying efficiency of the machine. During the evaluation process, the dryer was connected to an electrical source to power the heating element inside the heating chamber of the

ISSN 2319–7757 EISSN 2319–7765 I OPEN ACCESS

dryer. The drying cabinet of the dryer was then preheated to a desired drying temperature of 55^0c using a temperature regulatory device (thermostat and thermocouple) as reported by Omodara, 2012 that the optimum quality of dried fish can be attained when the drying temperature is regulated to 55^0c. The first set of fish was stacked to the drums with the aid of hooks (Figure 2b). The drying cabinet was then closed and the blower was switched on for proper circulation of heated air. The drying period of 15hours was adopted as recommended by Omodara, 2012. The weight of the samples was determined before and after drying. The drying rate of the fish and the drying efficiency of the dryer was calculated and recorded. The procedure was repeated for drying of the other set of the fish as shown in Figure 2(a).

Measurement and Calculation

(a) Determination of Fish Drying Rate.

The drying rate of the sample inside the cabinet was determined as a function of weight lost obtained using the relation reported by Yusuf, *et al.,* 2014.

$$D_R = \frac{W_1 - W_2}{T}, (Marcin\ and\ lund, 2003) \quad (1)$$

Where,

$D_R = Drying\ rate\ (g/h)$

$W_1 = initial\ weight\ of\ the\ sample\ (g)$

$W_2 = final\ weight\ of\ the\ sample\ (g)$

(b) Determination of Drying Efficiency of the Dryer

The drying efficiency of the dryer is defined as a function of the fish moisture content, initial and final weight of the fish as shown below.

$$DE = \frac{M_L}{M_T} \times 100\% \quad (2)$$

Where,

$DE = Drying\ efficiency\ (\%)$

$M_L = Moisture\ loss\ from\ the\ fish\ (\%)$

$M_T = Total\ moisture\ content\ of\ the\ fish\ (\%)$

$= moisture\ content\ of\ catfish\ (69.85\%)$ Omodara $et.al; 2016$

3. RESULTS AND DISCUSSIONS

3.1 Statistical Analysis

The data generated for the calculated values of average of fish drying rate and the drying efficiency of the dryer when the fishes were dried as whole and when it was cut in to head, middle and tail before drying is as shown on Table 1 and 2 respectively.

Table 1: Effects of Drum Numbers on the Whole Fish Drying rate and Drying Efficiency of the Machine

DRUM NO	DRYING RATE (g/h)			DRYING EFF (%)		
	A	B	C	A	B	C
1	10.99 ±0.065	10.95±0.044	10.95±0.040	81.72±5.649	82.56±4.478	81.11±1.814
2	11.00±0.000	11.04±0.075	11.00±0.000	80.15±2.218	80.91±1.420	79.39±1.315
3	10.97±0.040	10.98±0.040	11.00±0.000	80.75±2.162	80.79±0.393	81.42±5.068

Each value is the mean of triplicate ± standard deviation

Table 2: Effects of drums Numbers on the Fish part Drying Rate and Drying Efficiency of the machine

DRUM NO	DRYING RATE (g/h)			DRYING EFF (%)		
	Head	Middle	Tail	Head	Middle	Tail
1	4.03±0.361	4.15±0.197	3.56±0.407	85.33±1.805	87.81±2.532	86.61±4.153
2	3.73±0.241	4.17±0.465	3.457±0.457	84.17±2.151	87.80±2.789	88.82±5.272
3	4.15±0.468	3.96±0.204	3.923±0.538	87.82±2.265	87.64±2.672	90.14±3.073

Each value is the mean of triplicate ± standard deviation

ISSN 2319–7757 EISSN 2319–7765 | OPEN ACCESS

3.2. Analysis of Variance (ANOVA)

3.2.1. Analysis of Variance of the Effects of Drum Numbers on the Whole Fish Drying Rate and Drying Efficiency of the Machine

The ANOVA of the effects of drum numbers on the Whole Fish drying rate and the drying efficiency of the machine are as shown on the Tables 3 and 4 respectively.

Table 3: Effects of Drum Numbers on the Whole Fish Drying Rate

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	.622	.438 NS
	Residual	.050	25	.002		
	Total	.051	26			

**Significant at P ≤ 0.05; NS-Not Significant*

Table 4: Effects of Drum Numbers on the Drying efficiency of the machine

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.969	1	2.969	.361	.553NS
	Residual	205.664	25	8.227		
	Total	208.633	26			

**Significant at P ≤ 0.05; NS-Not Significant*

3.2.2. Analysis of Variance of the Effects of Drum Numbers on the Drying Rate of Fish Parts and drying efficiency of the machine

The ANOVA of the effects of drum numbers on the drying rate of the fish parts and the drying efficiency of the machine are as shown on the Tables 5 and 6 respectively.

Table 5: ANOVA of the effects of drum numbers on the drying rate of the fish parts

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
DRUM_NUMBER	.442	2	.221	1.359	.267NS
FISH_PART	1.916	2	.958	5.889	.005*
DRUM_NUMBER * FISH_PART	1.015	4	.254	1.561	.201NS
Error	7.319	45	.163		
Total	832.968	54			
Corrected Total	10.692	53			

**Significant at P ≤ 0.05; NS-Not Significant*

Table 6: ANOVA of the effects of drum numbers on the drying efficiency of the machine

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
DRUM_NUMBER	29.341	2	14.671	1.511	.232 NS
FISH_PART	57.500	2	28.750	2.961	.062 NS
DRUM_NUMBER * FISH_PART	46.434	4	11.609	1.195	.326 NS
Error	436.990	45	9.711		
Total	413449.704	54			
Corrected Total	570.265	53			

**Significant at P ≤ 0.05; NS-Not Significant*

ISSN 2319–7757 EISSN 2319–7765 | OPEN ACCESS

The Analysis of Variance (ANOVA) reviled that the drum number has no significant effects on the drying rate and efficiency of the machine when the fish was dried as a whole (Table 3 and 4). Also, Table 5 and 6 revealed that the drum numbers, fish part and interaction between them have no significant effects on the drying efficiency of the machine, only the fish parts has a significant effects on the drying rate of the fishes at 0.05 confidence limit.

3.3. Duncan New Multiple Range Test (DNMRT)

The DNMRT for the effects of drum numbers and fish parts on the drying rate and the drying efficiency of the machine is as shown on the Table 7 and 8 respectively.

Table 7: DNMRT for the effects of drum numbers on the drying rate and the drying efficiency of the machine

Drum number	Drying rate	Drying efficiency
1	3.9111[a]	86.9111[a]
2	3.7828[a]	86.9283[a]
3	4.0083[a]	88.4833[a]

**means with the same letters are not significantly difference but means with different letter are significantly different at 5% confidence level.*

Table 8: DNMRT for the effects of fish parts on the drying rate and the drying efficiency of the machine

Fish part	Drying rate	Drying efficiency
Head	3.9689[b]	86.0506[a]
Middle	4.0922[b]	87.7522[ab]
Tail	3.6456[a]	88.5200[b]

**means with the same letters are not significantly difference but means with different letter are significantly different at 5% confidence level.*

Further analysis of the result using Duncan New Multiple Range Test (DNMRT) as shown on table 7 reveal that there is no significant difference in the drying rate and drying efficiency obtained at different drum numbers but in the case of Table 8 the drying rate obtained for fish head and middle are significantly the same and different from that of the tail. Also, the drying efficiency of the head is significantly different from the tail but same as the middle and that of the tail is same as the middle but significantly different from the head.

3.4. Effects of Drum Number on Drying Rate and Drying Efficiency of Whole Fish

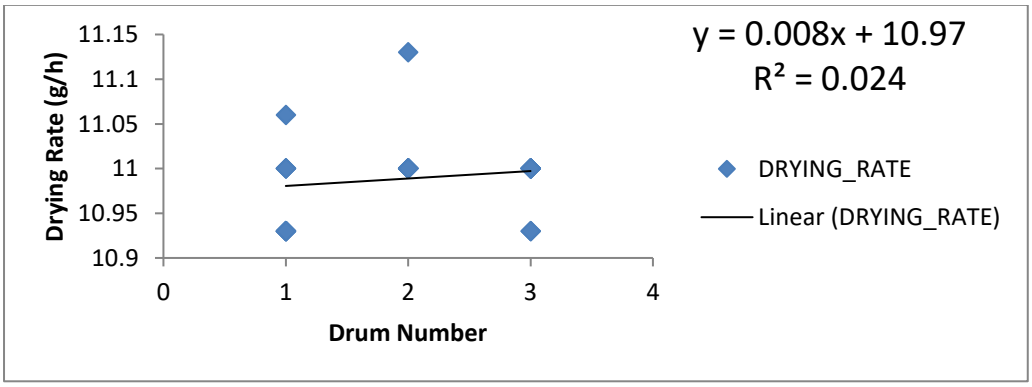


Figure 3: Effects of Drum Number on Drying Rate of Whole Fish

The effects of drum number on the drying rate and drying efficiency is as shown on figure 3 and 4 respectively. The charts show the regression models that reflect the relationship between the drum number and the drying rate of the whole fish and drying efficiency of the machine.

ISSN 2319–7757 EISSN 2319–7765 I OPEN ACCESS

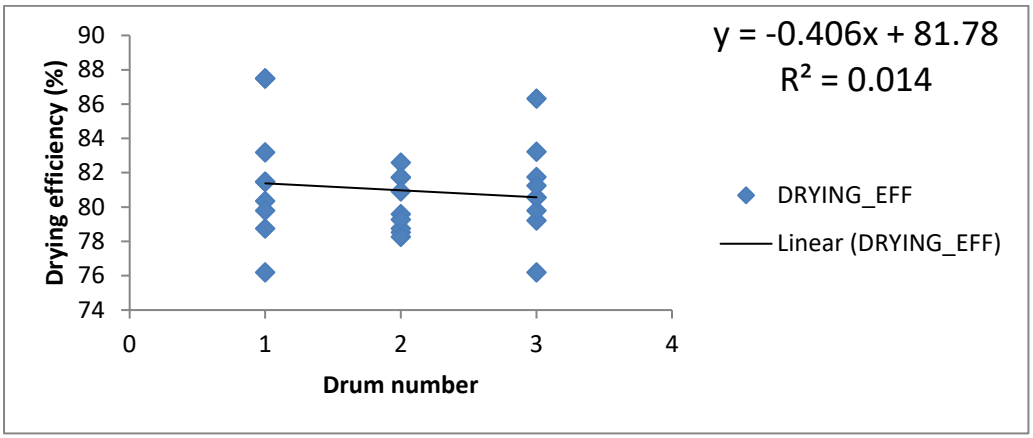


Figure 4: Effects of Drum Number on Drying Efficiency of Whole Fish

3.5. Effects of Drum Number on Drying Rate and Drying Efficiency of Fish Parts

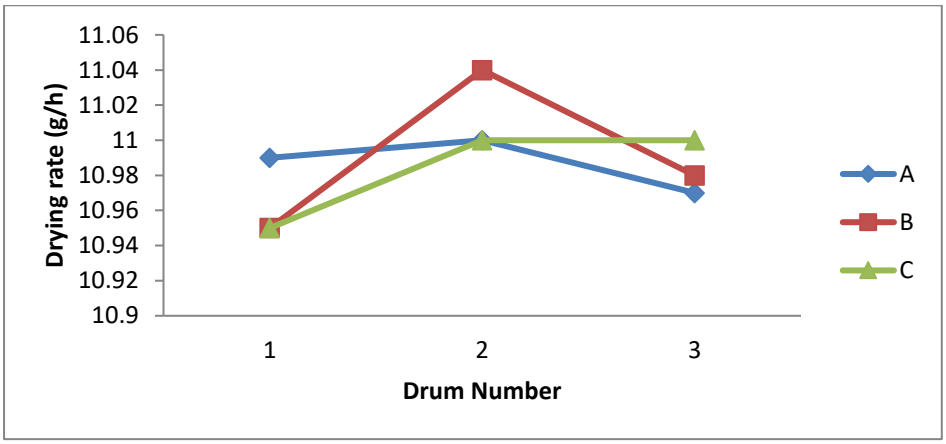


Figure 5: Effects of drum numbers on drying rate of fish parts
A=Head; B= Middle; C=Tail

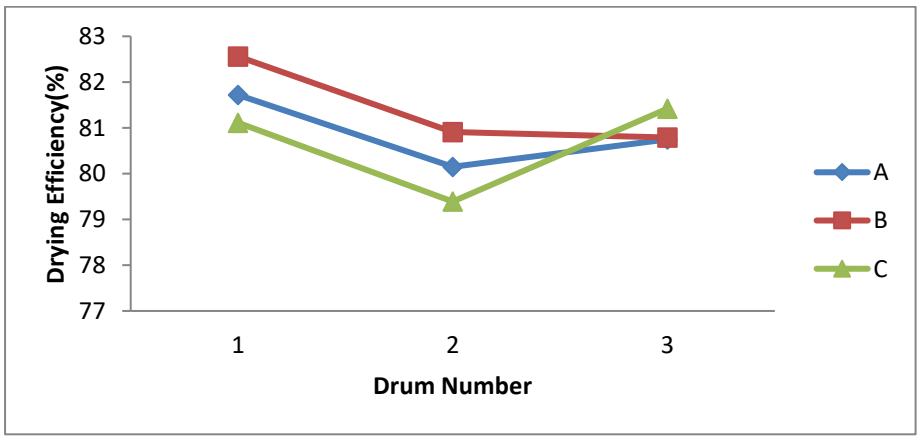


Figure 6: Effects of drum numbers on drying efficiency of the machine
A=Head; B= Middle; C=Tail

The effects of drum number on drying rate and drying efficiency is as shown on figure 5 and 6 respectively.

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

The experimental fish dryer was developed and its performance evaluated. During the design and fabrication of the dryer, it was ensured that the turning drums were properly centralized and turning mechanism was achieved with the aid of chain and sprocket.

The performance evaluation was carried out for the effects and relationship between the drum number and drying rate and efficiency of the dryer using whole fish and fish in parts. The result of the evaluation shows that the dryer is capable of drying the catfish at an appreciating efficiency. The result of the statistical analysis using SPSS software 21.0 shows that the drum number has no significant effects on the drying rate of fish and drying efficiency of the machine when the fish were dried as a whole. But in the case of drying the fish in parts (head, middle and tail), the drum number has significant effects on the drying rate of fish parts but has no significant effects on the drying efficiency of the dryer.

Recommendations

Based on the evaluation of the dryer, the following recommendations were made:

1. That an oil collector should be incorporated for collecting the oil droppings during drying.
2. That the same experiment be repeated for other species of fish like tilapia and panla and other locally sourced fishes.

Funding

This study has not received any external funding.

Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Aminullah-Bhugan AKM, Ratnayake WMN, Ackman RG (2006). Effect of smoking on proximate composition of Atlantic Mackerel. J.Food Sci. 51(2):327-329.AOAC (2005). Official Methods of Analysis (18th edition) Association of Official Analytical, Chemists International, Maryland, USA.
2. Chukwu O, Shaba IM (2009). Effects of drying methods on proximate composition of catfish (Clarias gariepinus). World J. Agric. Sci. 5(1):114-116.
3. Clifford MN, Tang SL, Eyo AA (1980). Smoking of foods. Process Biochem. June/July. p. 8. Desrosier NN, Desrosier JN (1977). The Technology of Food Preservation, 4th Edition, AVI publication Co. Inc. Westport Connecticut. pp. 343-347.
4. Efiuwevwere BJO, Iweanoge HA (1991). Microbioloical and physicchemical quality of various tissue types of fresh potassium sulphate treated and untreated smoked (Mugilcephalus). World J. Microbiol. Biotechnol. 7(5):562-566.
5. Eyo AA (2001). Fish processing technology in the tropics. National Institute for Freshwater Fisheries Research. University of Ilorin Press. pp. 10-70.
6. FAO (2007). Fermented fish in Africa. FAO Corporate Document Repository, Rome, Italy. pp. 1-7.
7. FAO (1971). Fermented fish products, FAO Fisheries Paper No. 100, (Rome, FAO).
8. Glomset J (1986). Nutrition research. New England. J. Med. 312:1253- 1254.
9. Ojutiku RO, Kolo RJ, Mhammed ML (2009). Comparative study of sun drying and solar tent drying of Hyperopisus bebeoccidentalis. Pak. J. Nutr. 8(7):955-957.
10. Okafor N, Nzeako BC (1985). Microbial floral of fresh and smoked fish from Nigerian freshwater. Food microbial. 2:71-75.
11. Olayemi FF, Adedayo MR, Bamishaiye EI, Awagu EF (2011). Proximate composition of catfish (Clarias gariepinus) smoked in Nigerian stored products research institute (NSPRI) developed kiln. Int. J. Fisheries Acquacult. 3(5):96-98.
12. Omodara MA, Olaniyan AM (2012). Effects of pre-treatments and drying temperatures on drying rate and quality of African catfish (Clarias gariepinus). J. Biol. Agric. Healthcare 2(4):1-11.
13. Yusuf, K.A, Adebayo, A.A and Okafor, M.C (2014), Design and Construction of a Passive Solar Dryer for a Small-Scale Farmer in Auchi Edo State, Nigeria. Proceedings of the Nigeria Institution of Agricultural Engineers, 15th International Conference Akure, Nigeria.

ISSN 2319–7757 EISSN 2319–7765 | OPEN ACCESS