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PERFORMANCE EVALUATION OF A DEVELOPED FISH SMOKING KILN IN BENUE STATE, NIGERIA

Agim, M. U[a]., Adikwu I. A[a]., Chiekyula J.O[b]., Kwaghvihi, O. B[a].

a. Department of Biological Sciences, Benue State University Makurdi, Nigeria
b. Department of Fisheries and Aquaculture, University of Agriculture Makurdi, Nigeria
Corresponding Author's Email: **agimmarcel@gmail.com**

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Abstract: Performance evaluation of a designed and developed smoking kiln was carried out on *Labeo coubie* using three different charcoals and woods from Gmelina, African birch and Mahogany spp as energy sources. The kiln fabricated with locally available materials proved to be effective in the preservation of fish product by reducing the moisture content leading to reduced weight of fish from 337.4g to 167.6g within 14.44hrs. Proximate composition revealed increase in crude protein, fat and ash contents at decreased moisture content. Phytochemical examination of the wood revealed the presence of alkaloids, saponins, phytosterol, phenol, tanins, flavonoid, protein, terpenoid, glycosides, oil and carbohydrates which has great biological importance. Therefore, this kiln is capable of improving the quality of fish, reducing the drudgery associated with traditional fish drying methods and consequently reducing post-harvest losses.

Keywords: Charcoals; Moisture; Phytochemical; Smoking kiln.

Postal Address: P.O.Box 23, Obudu Cross River State Nigeria, Mobile: +2348032212454, +2347089578380

INTRODUCTION

Fish has been an important source of human food since ancient times, and contains high quality proteins, vitamins, and omega-3 fatty acids (Gang, 2013). It is widely accepted on the menu card and form a much-cherished delicacy that cuts across socio-economic age, religious and educational barriers (Olorunfemi *et al.,* 2014). Though, the gap between the demand and supply of fish is increasing due to increase in population, poor postharvest handling and lack of processing facilities. Smoking has been used for the preservation of food for centuries (Huong *et al.,* 2013). Smoking gives special colour, texture and flavour to the food (Alcicek and Atar, 2010) and extends its shelf-life via the effects of dehydration, anti-microbial and anti-oxidant of the smoke compounds (Pagu *et al*., 2013; Visciano *et al*., 2008). The combination of drying and decomposition of naturally produced chemicals resulting from thermal breakdown of wood affects preservation (Tobor, 2004). Smoking activities are carried out using locally constructed oven such as the traditional mud ovens and cut-up drum barrels (Essuman, 1992). Traditional fish smoking kilns are poorly constructed and lack mechanisms for the control of smoke and heat production, all of which affect the efficacy of smoking and the quality of the final products. A combination of smoke, salt, and drying is one of the earliest recorded methods of fish preservation and it is receiving great attention because of its simplicity and acceptability by consumers (Rorvik, 2000; Swastawati *et al.,* 2000). Nowadays, fishermen form the habit of smoking their fish rather than disposing it fresh because it adds value and attracts more income. Fish species are preserved and processed via distinct means such as drying, frying, freezing, salting and smoking in order to ensure sustainable supply of fish all year round and to meet up with post-harvest loss challenges in Nigeria which had reached about 25 to 50% (Ikenweiwe *et al.,* 2010; Magawata and Oyelese, 2000; Goulas and Kontominas, 2005).

Nigeria's fish smoking practices are yet to gain prominence on a commercial scale due to lack of appropriate technological approach to assist the fish farming business. Traditional methods such as drum, stone and firewood are predominantly used and these affected the quantity and quality of fish processed due to inherent limitations: high product losses ensue from inadequate drying which results in fungal attacks, insects, birds and rodent's encroachment, unexpected down pour of rain and other weathering effects (Ekechukwu and Norton, 1999). Quality control and improved hygienic condition are difficult to sustain while market value diminishes due to damage and non-attractive appearance of the processed fish (Ames *et al.,* 1999). In such conditions, artificial dryers increasingly appear to be attractive as viable alternative to open sun drying, where a quicker and controlled dying process can be achieved, and the products are well protected from insects, pests, rodents, dust rain *etc.* during the process.

EXPERIMENTAL

Location of the Study: The construction and utilization of the smoking kiln was carried out at the welding and fabrication Department of the Technical College of Benue State University, while laboratory analysis was done at the Biological Sciences and Chemistry Department laboratories of the Benue State University Makurdi, Benue State. Benue state is located in the North Central Zone (Middle Belt area of Nigeria). It is situated between latitudes 6^0 25' and 8^0 8', and Longitudes 7^0 47' E and 10^0E. Benue State is situated along one of Nigeria's major rivers – River Benue and this probably is the reason why fishery activities are prominent within the state.

Description of the Developed Fish Smoking Kiln: The construction of this new fish smoking kiln (Figure 1) wouldn't have been possible without the works of Magawata and Musa (2015) and Ikeweiwe *et al.* (2010). However, due consideration such as economic status, literacy level of the fishers and the need to reduce post-harvest losses within the study area and Nigeria in general were born in mind before coming up with this kiln. The fish smoking kiln is comprised of two major components, each with a specific function and they include the charcoal/ wood stove (Abacha stove) and the drying chamber (kiln).

Charcoal/Wood Stove (Abacha Stove): The stove's major components included ash tray, charcoal/wood unit and chimney were measured, machined, welded and assembled according to the design specification.

Ash Tray: The ash tray which is rectangular in shape is located at the base of the stove. It was constructed using 1mm mild steel material. An opening is made on one side of the tray unit to serve as door for ash evacuation. 4mm perforations are made all over this unit to enhance ventilation.

Stove stand: A rectangular stand made from angle iron bar with the dimension of 320mm x 320mm x 213mm was constructed to place the stove on.

Charcoal/Wood Tray: This is located at the middle region of the stove. This is the chamber for burning the charcoal/wood to provide energy for smoking/drying the fish. It is constructed with mild steel of 1mm thick. It has the dimension of 320mm x 324mm x 230mm. and above this unit is the chimney which is constructed using mild steel of 1mm.

Drying Chamber: This is a wooden box made from hardwood of 25mm thick. The box has a dimension of 750x600x80omm. The inner part of the box is covered with galvanized sheet of 1.8 gauge and in between the inner walls of the box and the galvanized sheet are wood shavings (insulator). A door is fitted at one side of the box with the help of 100mm metal hinges while a thermometer is hung at the inner wall of the door.

Detachable Fish Trays: This is a flat wire mesh platform in which the prepared fish is placed and loaded unto the drying chamber for drying or smoking Four detachable fish trays of 700mm x 500mm x 5mm dimension each are constructed using galvanized 2mm mesh material and 5mm rods to form its frame. The fish trays are demarcated from each other by 138mm distance and fitted inside the box to rest fish on.

Fish Oil Collector: This is a piece of 1.8mm galvanized sheet slantingly fixed at the outer part of the drying chamber's floor to collect fish oil that dribs from the fish to the floor of the chamber. This sheet is attached with the help of copper nails. As the oil drops on the floor, it rolls by gravity to the fish oil collector which is then collected from the tilted end of the collector.

Heat Conveyor Pipe: A heat conveyor pipe of 75mm galvanized material was constructed; this pipe has an inner pipe of 50mm galvanized material. In between the inner and outer pipe, fibre glass materials are tugged in and sealed at both ends by welding to serve as insulator. This pipe is then attached to the charcoal unit by welding while the other end of the pipe has a ring welded at 2mm distance to serve as a stop. The ring side of the heat conveyor pipe is then inserted into a 76mm hole made behind the drying chamber.

Heat/Smoke Regulator: The heat regulator in the charcoal unit is a 1mm flat sheet of mild steel material fitted over the inner part of the heat conveyor pipe to regulate heat passing through this pipe. The sheet is calibrated or marked to indicate closed, opened and half opened or half closed by sliding.

Wire mesh Screen Protector: Wire mesh of 2mm is placed at the stove end of the heat conveyor pipe to prevent charred particles with flames into the drying chamber. This also prevents rodents from gaining access to the drying chamber when not in use.

Drying Chamber Stand: A stand was constructed using iron angle bar. The dimension of the stand is 780x550x200mmThe drying chamber is rested on this stand to suspend it from the ground.

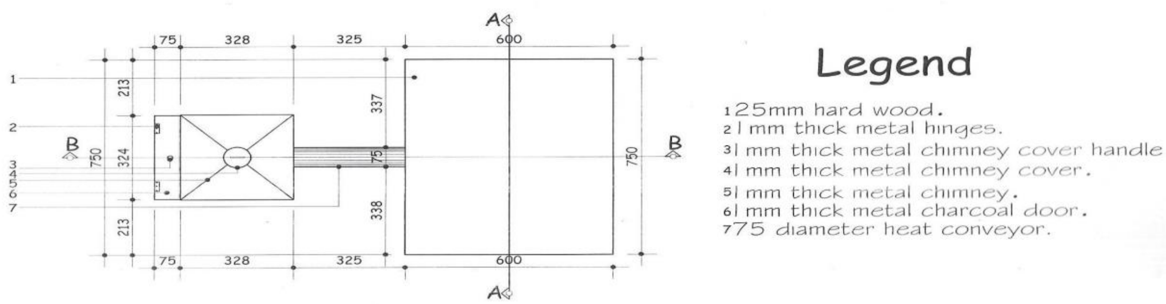

Figure 1. Floor Plan of the new Fish Smoking Kiln

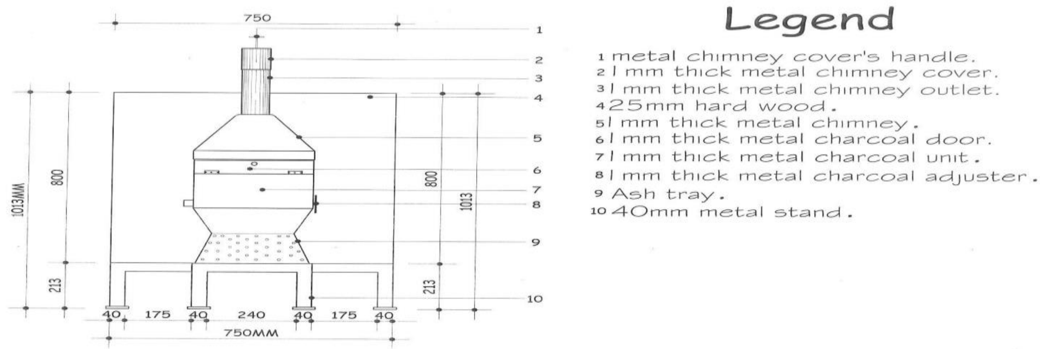

Figure 2. Back Plan View of the New Smoking Kiln showing Stove

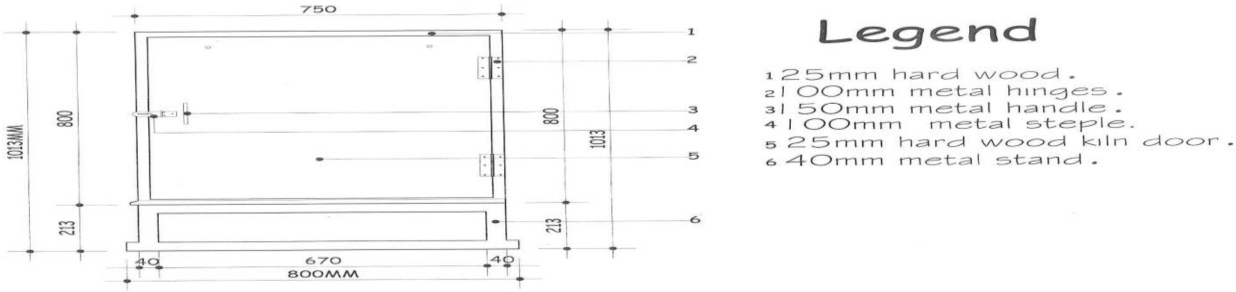

Figure 3. Front Plan View of smoking Kiln Drying Chamber

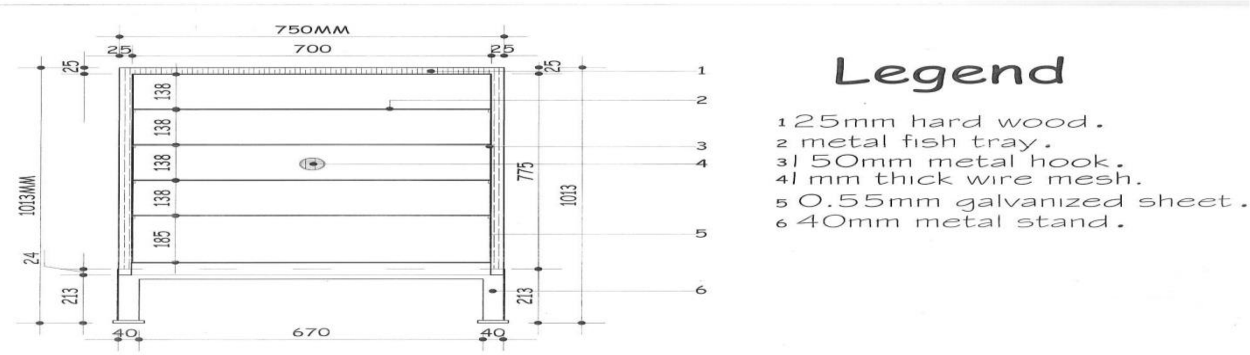

Figure 4. Plan Showing Detachable Fish Trays in the Drying Chamber

Performance Evaluation of the Developed Smoking Kiln

Sample Collection and Preparation: In determining the performance of the smoking kiln, *Labeo coubie* was procured alive from Wadata market in Makurdi Benue state. This species is common, abundant and widely cherished by the populace. The sample was killed, eviscerated and washed in clean water, salted and allowed to stay for a period of 30 minutes before laying in the kiln.

Smoking Process: The detachable fish trays were greased with groundnut oil to prevent the fish from sticking unto the mesh in the kiln. Charcoal of each wood variety was put into the charcoal/wood tray and ignited with the help of kerosene; the ignited charcoal/wood was allowed to burn for 10 to 15 min to allow the kerosene odour to be exhausted. More charcoal/wood was added to the burning ones to intensify the heat and smoke.

The first set of the prepared *Labeo coubie* was weighed using a Scout – Pro 600g digital scale obtained from the Department of Biological Sciences of the Benue state University and then put on the heated trays. *Labeo coubie* was treated to Mahogany, African birch and melina woods respectively while the same quantity of fish was treated to Mahogany, African birch and Melina charcoals respectively. During the smoking or drying process, the fish was turned regularly to enable uniform smoking/drying and to avoid charring. Similarly, the weight of the fish was determined intermittently whenever the position of the fish was changed and the corresponding moisture content determined according to the method of AOAC (2002). This continued until the final weight and hence the final moisture content was determined. The final moisture content that is safe moisture content (10 to 15%) (Ikenweiwe *et al.,* 2010) was calculated using Equation (i) when there was no further reduction in the moisture content. The time taken for the smoking was the total time taken including the time for the intermittent determination of moisture content and that of changing the position of the fish. After smoking/drying and determination of final moisture content, the fish was then ascertained dried. Phytochemical screening of the wood samples was carried out. Moreover, biochemical analysis was carried out on both fresh and smoked fish sample. Weight loss of the fish samples was equally determined.

Final Moisture content:

$$Mc_{db}\,(\%) = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Final Weight}} \times 100 \qquad \text{(i)}$$

Where,
Mc_{db}= Moisture content dry basis in %
Initial Weight= Weight of sun-dried fish (kg)
Final Weigh= Weight of smoked fish (kg)

Determination of Weight Loss:
The weight loss was determined using following eq. (ii)

Weight Loss= Initial Weight - Final Weight (ii)

The percentage weight loss was determined using eq. (iii)

$$\%\ \text{Weight Loss} = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100 \qquad \text{(iii)}$$

Biochemical Analysis for three Fish Samples: Proximate composition was carried out for moisture, ash, fat, and protein contents using the method described by AOAC (2000).

Phytochemical Analysis for three wood Samples: Qualitative analysis was carried out following the methods described by Trease and Evans (1989), Harborne (1998) and Kokate (2001). The concentration of each compound was determined according to Mariita *et al.* (2010).

Cost implication of the new developed fish smoking kiln: The cost implication of the new fish smoking kiln was derived by summing up the cost of all material for the construction and the cost of workmanship for the Carpenter and Fabricator.

Statistical analysis: The data obtained from the proximate analysis in triplicate were subjected to analysis of variance using Gen Stat Discovery Edition (Version 2012).

RESULTS AND DISCUSSION

The weight loss for *Labeo coubie* used in this study is presented in Table 1 The results revealed that there was a drastic weight reduction. The total weight of the fresh fish sample was 337.4 g and was dried to 167.6 g after 14.44hrs at about 80 ^{0}C. The proximate composition of *Labeo coubie* before smoking is shown in table 2. The moisture content was 27.50%, protein content 23.90%, ash content 0.660% and fat content was 2.00%. The proximate composition of smoked *Labeo coubie* using varying charcoal sources showed significant difference (0.05) across the parameters except for moisture content which had no significant difference. The highest moisture content of *Labeo coubie* was recorded in Melina charcoal (9.533%) while the lowest was recorded in African birch charcoal (9.443%). Crude protein content was highest in Mahogany charcoal (38.12%) while African birch charcoal recorded the least values (34.92%). Ash content was highest in Melina charcoal (16.28%) while Mahogany recorded the least ash content (6.80%). Fat content was highest in Mahogany charcoal (6.10%) while Melina charcoal recorded the least (4.47%) (Table 3). Proximate composition of *Labeo coubie* using varying wood sources showed significant difference (0.05) across the parameters for ash and fat contents while moisture and crude protein contents had no significant difference (0.05) across the parameters. The highest ash content of *Labeo coubie* was recorded in African birch wood (15.46%) while Melina wood recorded the least ash content (8.05%). Fat content was highest in Mahogany wood (9.22%) while African birch wood recorded the least (7.85%) (Table 4). There was increase in protein content, ash content and fat content after smoking with both charcoal and wood whereas, moisture content reduced drastically. The phytochemical analysis of the wood (Table 5) revealed that alkaloids, saponins, phytosterol, phenol, tanins, flavonoid, protein, terpenoid, glycosides, oil and carbohydrate were present in the sample. Amino acid was not detected in Mahogany wood while oil was not detected in Mahogany and African birch. The result showed that phytosterol, flavonoid, protein and carbohydrate were found in low concentration for all the parameters. Saponins, phenol, tanins, terpenoids and glycosides had moderate concentration for Mahogany and African birch while alkaloids had moderate concentration for Melina. Table 6 showed the cost implication of the new developed kiln. The entire cost for carpentry work, miscellaneous expenses, thermometer, materials procurement and total cost for welding and procurement of materials are ₦17,500, 5,000.00, ₦1000.00 and ₦45,800.00 respectively, thus making a gross total of ₦69,300.00 only.

Table 1. Determination of Fish Weight Loss from the Improved Smoking Kiln.

Fish species	No of fish	Initial average weight (g)	Final average weight (g)	Weight loss (%)	Smoking time (h)
Labeo coubie	10	337.4	167.6	101.3	14.44hrs

Table 2. Proximate Composition of the Fresh Fish Sample

Parameters	Moisture (%)	Protein (%)	Ash (%)	Fat (%)
Labeo coubie	27.50	23.90	0.660	2.000

Table 3. Proximate Composition of Smoked *Labeo coubie* using varying Charcoal Sources

Fish Species	Charcoal Type	Moisture Content (%)	Crude Protein (%)	Ash Content (%)	Fat Content (%)
Labeo coubie	Melina	9.533	37.36	16.28	4.47
	African Birch	9.443	34.92	14.03	4.93
	Mahogany	9.473	38.12	10.66	6.10
LSD (0.05)		0.4034	1.496	3.870	1.904

Table 4. Proximate Composition of *Labeo coubie* using varying woods

Fish Species	Wood Type	Moisture Content (%)	Crude Protein (%)	Ash Content (%)	Fat Content (%)
Labeo coubie	Melina	9.493	36.46	8.05	7.85
	African Birch	9.521	35.54	15.46	6.85
	Mahogany	9.458	36.53	8.28	9.22
LSD (0.05)		0.2233	0.643	1.779	1.006

Table 5. Phytochemical Analysis of Wood

Phytochemical	Melina	Mahogany	African Birch
Alkaloids	++	+	+
Saponins	+	++	++
Phytosterol	+	+	+
Phenol	+	++	++
Tanins	+	++	++
Flavonoid	+	+	+
Protein	+	+	+
Amino acid	+	-	+
Terpenoid	+	++	++
Glycosides	+	++	++
Oil	+	-	-
Carbohydrate	+	+	+

Key: +: Low concentration, ++: Moderate concentration, - absent

Table 6. Cost implication of the New kiln

S. No.	Item(s)	Cost
1.	2.5 number pieces of hard wood	₦2,500.00
2.	2 number hinges	
3.	Nails	
4.	1 number galvanized sheet	
5.	12 number fish tray hooks	
6.	Wood gum	
7.	Cost of items 2-6 plus Carpenter's workmanship	₦15,000.00
8.	Cost of workmanship, materials for welding stove, fish trays and iron stands.	₦45,000.00
9.	A 50kg bag of charcoal	₦800.00
10.	Miscellaneous expenses	₦5,000.00
Total		**₦69,300.00**

The developed fish smoking kiln proved to be effective in the preservation of fish product to a safe and suitable state for prolonged utilization. This was achieved by the reduction in moisture content leading to reduced weight. The time taken to achieve the weight loss in *Labeo coubie* was less than 24hrs. This was more preferable in order to preserve the protein contents of the fish and to retain its characteristic flavour and golden colour. According to Ikenweiwe *et al.* (2010), during dehydration process in fish smoking, autolytic reactions take place in the muscle that breaks down nitrogenous compound to produce free amino acids and results in an improvement in the taste of smoked fish. *Labeo coubie* had high percentage weight loss. This showed that in 14.44 hours of smoking this species, water content of the fish was reduced significantly and thus increased the shelf life of the fish giving an improved golden-brown colour which will attract customers using the smoking kiln. The water content reduction depends on the chamber temperature. Davies and Davies in Magawata and Musa (2015) and Osuji in Magawata and Musa (2015) made a similar observation that the weight loss of the smoked fish was as a result of the drying or dehydration effect from the burning charcoal or wood. According to Nwakoba (2016), the drying rate of fish increases with drying time and chamber temperature, and begins to decrease as the required storage moisture level is achieved until a point of inflexion is reached. Beyond this point, the drying rate of fish reduced with the dryer chamber temperature and further increase in the drying time. The result of the proximate composition of smoked fish sample revealed increased in crude protein, fat and ash contents at decreased moisture content.

This is in agreement with the work of Fapohunda and Ogunkoya (2006); Awogbemi and Ogunleye (2009); and Mohammed and Sharif (2012). Doe and Olley (1983); Aberoumad and Pourshafi, (2010) reported that smoking resulted in the concentration of nutrients due to low residual moisture level. The moisture content of fresh of *Labeo coubie* was 27.50% while the moisture content obtained after smoking ranged from 9.443% to 9.533%. Islam (1982) reported 9.07% moisture content for traditionally smoked fish. Faturoti (1985) showed that the gutted dried and smoked fish samples of African catfish (*Clarias nigrodigitus)* had moisture content as 6.27 to 10.92%. The market samples of sun-dried *Gudusia chapra* had moisture ranging from 9.61 to 18.64% (Bhattacharyya *et al.*, 1985). Haque (2004) stated that normally smoked fishes contain an average of 10 to 20% moisture content. In the present experiment moisture percentage of the dried fishes were found approximately similar to the referred values. Low values of moisture reduce the microbial activities and increase the shelf life of the fish. The significant increase in protein levels in *Labeo coubie* when compared with the raw fish, suggested that protein nitrogen was not lost during smoking. This is in agreement with the works of Puwastien *et al.* (1999), Gokoglu *et al.* (2004), Tao and Linchun (2008) and Olayemi *et al*. (2011). The high fat content indicates that these fishes contains reasonable amount of omega-3 fatty acids. Omega-3 fatty acids from fish oil could lower triglyceride levels by 25%-30% (Simopoulos, 1997). Chang *et al.* (2009) reported that increased fat in human diets provides and sustains energy in the body. Fat is also important for normal functioning of the brain which is made up of nearly 60% fat (Kaunitz and Dayrit, 1992). Importantly, fat helps in boosting the immune system (Black and Sharpe, 1997). The high values of ash are an indication that these fishes contain good sources of minerals. This is in agreement with the work of Ande *et al,* (2012) and Abolagba *et al.* (2015). Omotosho *et al.* (2011) noted that ash is a measure of the mineral content of any food including fish. It is the inorganic residue that remains after the organic matter has been burnt off (Andres, 2000; Canli, 2003).

Phytochemical analysis of the wood used in this study revealed the presence of alkaloids, saponins, phytosterol, phenol, tanins, flavonoid, protein, terpenoid, glycosides, oil and carbohydrate. These chemical constituents have been assessed for their biological effects (Krishmaswamy and Raghuramulu, 1998; Ajaiyeoba *et al*., 2003; Nwokonkwo, 2009; 2013). Edeoga and Enata (2001) reported that alkaloids are powerful pain relievers, have an antipyretic action, a stimulating effect and can act as topical anesthetic in ophthalmology. Saponins, flavonoids and phenols in plant may suggest that they possess antibacterial potentials against human pathogens (Nwokonkwo, 2014). Steroidal compounds have importance and interest in pharmacy due to sex hormones (Okuwa *et al*., 2001). Tannins are forms of natural high molecular weight polysaccharides (like starch and cellulose) and molecules having high molecular weight are useful coagulating agents as they contribute to coagulation process by increasing the number of active sites available for particle adsorption. Dangoggo *et al*. (2001) reported Tannins and glycosides of having antibacterial potentials. Tannins are polyphenol compounds and tannins in plants are safe (USEPA, 2006), (Seghosime *et al.,* 2017). In general, there were significant influences of smoking on proximate compositions of *Labeo coubie*. Lack of negative influence of the smoking processes and energy sources (wood) on the moisture, protein, lipids and ash contents of *Labeo coubie* in the developed smoking kiln is of great practical importance to recommend it for use. The cost implication of constructing this new fish smoking kiln indicates that, a total cost of ₦69,300.00 only can produce this kiln and also, this kiln has a capacity to smoke about 20kg of fish per set for approximately 17 hours (depending on the fish species) with charcoal of about ₦800.00 only. Considering this cost implication, the cost of producing and operating this kiln is relatively cheap.

CONCLUSION

The performance evaluation showed that the new developed fish smoking kiln was effective in drying the *L. coubie* to safe moisture content. It also showed that varying charcoal and wood sources can be used in the kiln as fuel thereby reducing the cost of production; hence there is no negative effect on the smoked fish product from phytochemical examination of the woods. The proximate analysis of the samples showed an increase in protein, ash and fat content while there was decrease in moisture content. The study has established that the new developed fish smoking kiln is the most effective to the local fishers with respect to drying rate, hygiene, proper monitoring and nutritional attributes of the smoked fish. The cost implication of this new developed kiln showed that, the kiln is relatively cheap and affordable by the local fishers.

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