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Efficiency of wood wastes as alternative energy sources to fuel wood in fish smoking in view to optimize the utilization of wood resources

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This study was conducted to determine and compare the suitability and efficiency of wood wastes (sawdust and wood shavings) as alternative energy sources to fuel wood in fish smoking with a view to enhancing optimal utilization of the wood resource. Fish samples collected were smoked with fuel wood, sawdust and wood shavings using Kainji portable smoking kiln. Proximate compositions of the samples were determined and the results subjected to statistical analysis using One-way Analysis of variance (ANOVA). Except their moisture contents, the samples were not significantly different ($p>0.05$) in crude protein lipid and ash contents. The samples were also not significantly different ($p>0.05$) in their sensory properties. However, the Specific Fuel Consumption (SFC) recorded were 7.40, 17.14 and 8.57 kg/kg of fresh fish smoked with fuel wood, sawdust and wood shavings at the costs of ₦284.49k, (1.43 USD) ₦145.57k (0.73 USD) and ₦67.31k (0.34 USD), respectively. The time spent to smoke 1 kg of fish with the various wood materials gave the following results: fuel wood 242 min, sawdust 960 min and wood shaving 363 min. It was therefore, concluded that both wood shavings and sawdust could efficiently be used as alternatives to fuel wood in fish smoking. Although a better result was obtained with wood shavings in terms of higher combustion rate and smoking duration. Nevertheless, the recommendation focused on the need to consider the alternative in sawdust and wood shavings in smoking fish so as to optimize the utilization of the wood resource reduces energy scarcity and promote environmental friendly practice in waste management.

Key words: Optimal, utilization, wood waste, alternative, smoking.

INTRODUCTION

Fish is a highly nutritious food (Ojutiku et al., 2009; Kawarazuka, 2010). It is particularly notable for providing proteins of high quality compared to those of meat or eggs. However, fish is one of the most perishable of all staple commodities. They are therefore suitable media for the growth and proliferation of microorganisms (Jay, 1986; Ghaly et al., 2010). Losses arising from bacterial and autolytic spoilage are enormous hence, the need for preservation. Smoking is one of the preservative methods employed by traditional fishermen to preserve fish using traditional kilns of various types depending on the locality (Adelowo, 2005). Wood has been one of the oldest sources of energy known to and used by man for centuries after the discovery of fire itself (Danshehu,

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1995). Wood is the most commonly used source of energy in the world (FAO, 1981). For the inhabitants of developing countries, it is much more than that: it is the staple energy sources of three quarters of the population. In some poorest African nations, it still counts for more than 90% of national energy consumption (Sambo, 2009).

However, World wood resources are depleting at a rapid rate and the food and Agricultural organization (FAO) of the United Nations during the United Nation's conference on New and Renewable sources of energy held in Nairobi in 1981, estimates, that nearly one billion are living in regions with either acute scarcity or deficit wood supply situation (Danshehu, 1995). Deforestation is continuing at an alarming rate. Once distributed over half of the planet, forests, now cover only a quarter of its land surface and forest loss, particularly in the tropics. The rate of natural tropical forest loss is about 13 million hectares each year – equivalent to 30 football fields in a minute (FAO, 2005).

In Nigeria, the responsibility for the enforcement of federal laws and regulations on environment is vested on Federal Environmental Protection Agency (FEPA). The agency as a body stands to protect the laws relating to air, water, human beings, flora and fauna, which are integral parts of human environment and life (Lawrence et al*.,* 2004). However, the activities of FEPA left a lot more to be desired.

Nevertheless, the unending need to preserve fish, particularly, the local preference for smoked fish in our diet and the relatively cheaper energy source available in wood made fish smoking inevitable in the developing countries.

The availability of sawdust and wood shavings in rural areas was as a result of the location of timber industries in rural communities close the sources of raw material (the forests). Besides, most of the wood exploitation activities take place in rural communities where wood resources abound and the wastes (sawdust and wood shavings) are usually discarded as waste products.

Some wood species are believed to have substances which could have negative effects on the heart and allergies in consumers of fish smoked with such wood. Examples of such wood include: the latex of *Hevea brasilensis* (Euphorbiaceae): softwood and the mansonine of *Mansonia altissima* (Sterculiaceae) (Adeoti et al., 2010). The symptoms noted during the surveys include colds, headaches and eye stingings (Kouassi et al., 2012).

Studies have shown the possibility of synthesizing dangerous molecules like Polycyclic Aromatic Hydrocarbons (PAHs) during smoking transformation, over food cooking, particularly during processes of smoking, drying and cooking such as roasting, oven cooking, frying and grilling and that the PAHs content in smoked fish is four times high as the one found in the flesh of fresh fish (Ake, 2010). There is clear evidence of *in vivo* mutagenicity and genotoxicity of PAHs on animals as liposoluble substances; absorbed by particles and organic matter or dissolved in an oily matrix. In addition, Millard reactions may appear during mild heating of fish rich in carbohydrates (Ehilé, 2009). The observed parameters which contribute to the appreciation of the safety of the finished product regarding PAH contamination level include: fish species (fresh, frozen), fat cover, length and thickness of fish, place of fishing, time and temperature for smoking (Huss, 1988; Ake, 2014).

The smoke of plant species contains many toxic substances such as tar. Once the wood is carbonized, it has properties used in medicine as it absorbs toxic molecules; so it is the lack of awareness of matrices, smoking materials and good processing practices which could turn a danger into a real risk and cause a public health problem (Ake, 2014).

This research was conducted to determine and compare the suitability and efficiency of wood wastes (sawdust and wood shavings) as alternative energy sources to fuel wood in fish smoking as a strategy to optimize the utilization of wood resources.

MATERIALS AND METHODS

The experiment was carried out at the Federal University of Technology Teaching and Research farm. A Complete Randomized Design (CRD) consisting of three (3) treatments was used. Each treatment had three (3) replicates of five pieces of *Nile tilapia* (*Oreochromis niloticus*) randomly distributed. Forty-five samples of *O. niloticus* weighing between 75-130 g each were procured from Mobil Fish Market, Minna, Niger state, Nigeria. It is important to note that *O. niloticus* was chosen for this research on the basis of its relative abundance and availability in local markets, easy to source as specimen for research, commercial importance to local fisheries as well as their being considered as one the most important native fish species wildly accepted by local consumers.

Kanji portable smoking kiln was used in smoking the experimental fish samples. This instrument is a cubical metal structure with three functional sections: a fire-box, smoking chamber (with three layers of racks) and a chimney at the roof. The kiln has a cover at the front side. The fuel compartment is the rectangular shaped fire-box which gets air supply by conventional air flow through it opening. The Smoking Chamber has three layers of racks on which fish for smoking are placed while the chimney serves as the vent which allows excess burnt gasses to pass out.

The smoking process

The following procedures were adopted for the smoking of fish samples in the experiment. *O. niloticus* samples for the experiment were gutted, washed and brined for 30 min before being fed into the kiln for smoking. Prior to weighing and smoking, the fish samples were pre-dried in shade for 1 h to enhance the surface gloss of the product and prevent case-hardening.

During the experiment the wood materials were produced from *Daniellia oliveri* plant, which is one of the common wood species used in fish smoking in the savannah zone of Nigeria. In addition, the species is a hardwood known to be preferable for smoke concentration than soft wood and may give products with lower pH

Table 1. Summary of specific fuel consumption, cost, smoking duration and smoking temperature of *Oreochromis niloticus* smoked with fuel wood (T1), sawdust (T2) and wood shavings (T3).

Parameter	T1	T2	T3
Weight of fresh fish smoked (kg)	0.45	0.42	0.42
Weight of wood material used (kg)	3.33	7.20	3.60
Cost of wood material used (₦)	128.02	61.14	28.27
Weight of fuel/kg of fresh fish (kg)	7.40	17.14	8.57
Cost of fuel/kg of fresh fish (₦)	284.49k	145.57k	67.31k
Smoking duration (minutes)	242	960	363
Smoking temperature (°C)	60 –70	45 – 54	46 - 60

Note: ₦ = Naira (Nigerian currency) k= Kobo.

and more bacteriological stability (Adelowo, 2005). Then three groups were selected: T1 = Treatment I (fuel wood), T2 = Treatment II (sawdust), and T3 = Treatment III (wood shavings). The total batch of each replicate fish samples were weighed and laid on racks. The fuel materials were also weighted before ignition. The racks of fish were placed into the oven over a smouldering fire. The fish and oven temperature were recorded at approximately 30 min intervals and used to calculate the average temperatures. The samples were removed as soon as they were properly smoked and weighed immediately and reweighed after cooling. The length of time taken to smoke each batch of fish samples with each treatment was recorded.

Measurement of specific fuel consumption (SFC)

Consumption of the various wood materials were measured by weighing a load of each wood material at the beginning of the smoking process and weighing any remaining and partial burnt at the completion of smoking. SFC was computed as:

$$\text{Weight of wood material per kilogram of fish smoked} = \frac{\text{Weight of fresh fish smoked (kg)}}{\text{Weight of wood material used (kg)}} \times 1$$

Sensory evaluation

A panel of twenty volunteers evaluated the sensory attributes of the samples. Some of the panelists have previously participated in sensory evaluation of fish. The samples were evaluated for visual appearance, taste, colour, flavor, and overall acceptability on a 5-point scale where 1=poor, 2=fair, 3=very good and 5=excellent (Afolabi et al., 1984).

Proximate composition

The proximate composition of the samples (moisture, ash, lipid and crude protein content) was determined using the standard method of association of official analytical chemists (George, 2012).

Cost of wood materials

The indices used for the cost analysis include cost of wood materials and cost of transportation of wood materials as expressed below:

Cost of fuel materials per/kg of fish smoked = Weight of fresh fish smoked (kg) × 1

Cost of fuel material used (₦)

$$\frac{\text{Cost of wood material used}}{\text{Weight fish smoked (kg)}}$$

Statistical analysis

The data collected were subjected to statistical analysis using one-way Analysis of variance (ANOVA) and Duncan Multiple Range Test used for mean separation. The statistical analysis was conducted by using SPSS 16.0 software.

RESULTS

Results of the analysis of fuel wood, sawdust and wood shaving consumption, smoking duration and temperature in the smoking of *O. niloticus* (Table 1) showed that 0.45, 0.42 and 0.42 kg each of fuel wood, sawdust and wood shavings were used to smoke 1 kg of fish samples at average temperature ranges of 60-70°C, 45-54°C and 46-60°C, respectively. The costs of smoking 1 kg of the fish samples using the various wood materials were: ₦ 284.49k ₦145.57k and ₦67.31k, respectively. While the length of time taken to smoke each of the samples using fuel wood, sawdust and wood shavings were: 242, 960 and 363 min, respectively.

The results of statistical analysis of the proximate composition of the experimental samples in Table 2 showed that the samples were not significantly different ($p>0.05$) in their crude protein, lipid and ash contents. Significant difference ($p<0.05$) was recorded only in the moisture content of Treatment II (sawdust).

The results of statistical analysis of the organoleptic analysis of the experimental samples in Table 3 showed that the samples were not significantly different ($p>0.05$) in all the parameters assessed.

DISCUSSION

Fuel wood burned more rapidly than sawdust and wood shavings and hence produced higher degrees of differential temperatures (DT). This is due to the passage of conventional airflow within the loosely packed materials

Table 2. Summary of mean (S.E) percentage proximate composition of *O. niloticus* smoked with fuel wood, sawdust and wood shavings.

Parameter (%)	T1	T2	T3
Moisture	7.60±0.20[a]	6.15±0.07[b]	7.27±0.29[a]
crude protein	74.46±3.11[a]	72.12±1.8[a]	74.33±2.84[a]
Lipid	11.08±2.10 [a]	10.68±3.74[a]	7.33±0.67[a]
Ash	7.28±1.27[a]	7.09±0.22[a]	5.77±0.99[a]

Mean with the same superscripts are not significantly different (p>0.05).

Table 3. Mean percentage organoleptic analysis of *O. niloticus* smoked with fuel wood, sawdust and wood shavings.

Parameter	T1	T2	T3
Appearance	3.65±0.23[a]	3.59±0.23[a]	3.29±0.31[a]
Flavor	4.12±0.66[a]	3.53±0.24[a]	3.41±0.23[a]
Taste	3.65±0.24[a]	3.59±0.23[a]	3.71±0.25[a]
Texture	3.76±0.25[a]	3.76±0.16[a]	3.65±0.24[a]
Overall acceptability	3.76±0.20[a]	3.71±0.24[a]	3.88±0.28[a]

Mean with the same superscript do not differ significantly (p>0.05).

in the Fire-box. This corroborates the findings of Bello and Adegbulugbe (2010) stated that Saw dust is more or less a bulk material and has a higher density and less pore spaces. According to them, the combustion rate (CR) of sawdust and wood shavings are generally slower and even much slower with sawdust when compared to Fuel wood and produced a lot of smoke due to inadequate air for complete combustion; a known precursor for the production of PAHs (Ake, 2014) in smoking process.

Fuel wood has a higher differential temperature (DT): 60-70°C because it generated the greater amount of heat within the Smoking Chamber with less smoke, hence, drying of the samples was achieved within the shorter period of time (242 min). Similar observation was made by Idah and Nwankwo (2013) reporting that safe moisture contents can effectively be achieved by smoke-drying fish at smoking temperature of 60°C. Consequently, PAHs may be produced by pyrolysis of aromatic alkenes or alkyls (absence of oxygen) following high temperature (hot smoking) pyrosynthesis between radicals previously formed. Sawdust and wood shavings generated lesser DT (45-54°C and 46-60°C, respectively), smoked for longer periods (960 and 363 min), emitted greater exhaust gases and produced the lower drying rates as a result of low DT as observed by (Bello and Adegbulugbe, 2010). Thus, fuel wood appeared to be more environmental friendly and could be suitable for indoor heating, though, with a likely health implication of PAHs production due high DT. Sawdust and wood shavings have less thermal capacity and longer combustion period, which is better suited for long process operations. It was however, argued that heat treatment does not only remove water but excess of such heat can affect the nutritional content of the dried fish. Researchers have revealed that heat treatment causes some decrease in available lysine and that the loss of lysine is proportional to the smoking temperature as stated by (Aitken, 1967; Eyo, 2001; Idah and Nwankwo, 2013). Eyo (2001) reported that heating alone was capable of rendering lysine unavailable in the absence of Millard reaction, and that the intensity of heat applied in smoking greatly affects the fish protein concentration.

With regards to SFC, lower SFC was achieved with fuel wood (7.40 kg)/kg of smoked fish as compared to sawdust (17.14 kg) and wood shavings (8.57 kg). This confers an advantage on fuel wood against the wood wastes (sawdust and wood shavings). However, the poor performance of the wood wastes with respect to SFC is more than compensated for when the cost of fuel/kg of smoked fish are factored in. Hence, the wood wastes were more cost effective. In a nut shell, the SFC is inversely related to the DT and CR but directly connected to SD.

Except for the moisture content of samples smoked with sawdust, the samples were not significantly different (p>0.05) in crude protein, lipid and ash. However, the samples showed some degree of variations in their proximate compositions. The variation between treatments may be due to variation in the level of dehydration, heat treatment, size and age of fish samples, duration of smoking, drip loss due to thawing and state of the raw fish prior to smoking. Ranges of the lipid content were however lower than the result obtained by Onyejiaka (2001) and Abah (2002) with ranges 12.30 to 19.17% and 8.70 to 14.30%, respectively. This may be attributed to processing or smoking duration. While the ranges of the crude protein value obtained were a bit higher than that of Abah (2002) (ranges 62.44 to 66.89%). This may be connected to the higher level of dehydration achieved in this work which agrees with Afolabi et al. (1984). They stated that crude protein content of fish increases with decreasing moisture content. Variation of the proximation composition the smoked samples may as well be linked to a number of other factors such as: type and nature of wood materials with influence on the DT, species of fish used; whether pelagic which are usually fatty or demersal with a less fatty characteristic as well as the type of smoking process employed (hot or cold smoking).

Conclusion

From the research conducted, it could be concluded that sawdust and wood shavings are suitable alternatives to fuel wood, particularly in heat process operations, which requires less heat-processing condition such as cold smoking (20 to 30°C) and pasteurization of food stuff. Fuel wood on the other hand has higher thermal values of heat generation, hence, suitable for hot smoking process (70 to 80°C) of fish and could be used for domestic cooking and boiling.

Although, the smoke of wood species are reported to contain a number of toxic substances such as tar. Once the wood is carbonized, it has properties used in medicine as it absorbs toxic molecules; so it is the lack of awareness of matrices, smoking materials and good processing practices which could turn a danger into a real risk and cause a public health problem.

RECOMMENDATION

Fish processors should be encouraged to embrace the alternative use of wood waste in fish smoking because it optimizes the use of wood resource, reduces energy cost and as well promotes environmental friendly practice in waste management.

However, it is necessary to adequately estimate the quality of the products and the smoking processes so as to inform the stakeholders and the authorities in charge of food safety and public hygiene, sensitize them about any potential risks they run by consumption of the product.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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