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Case Study

Alternative sources of energy for fish smoking: Microbial, proximate and sensory attributes of the products

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Abstract

Organic waste materials can play a vital role as alternative energy sources for fish processing and adding value to fish products. This study assessed the efficiency of carbonated and non-carbonated briquettes from a mixture of rice husks, saw dust, pine needles, chopped leaves and grass as an alternative energy sources in fish smoking using improved smoking kilns. The quality of fish produced with respect to microbial, proximate and sensory attributes were evaluated and found acceptable. The amount of carbonated briquettes as a source of energy was 55 % less than the non-carbonated form used for the same quantity of fish. Smoked products using carbonated briquettes recorded total bacterial counts of log 6.8 cfu/g to log 1.7 cfu/g, and log 5.2 cfu/g using carbonated and non-carbonated briquettes, respectively; the values were below the threshold considered safe for human consumption. Similarly, lower levels of fat were recorded in smoked products using carbonated briquettes than non-carbonated and were significantly different (P=0.004). The smoked products recorded significantly lower (P<0.05) moisture content from carbonated than non-carbonated briquettes. Consumers showed a significantly higher (P<0.05) preference for smoked products from carbonated than non-carbonated briquettes. Carbonated briquettes were found to be a superior alternative fuel source for smoking fish products than firewood. This study demonstrates that use of alternative fuel sources from briquettes made from organic waste enhances food safety and nutrition; this energy source was readily available and affordable in several sites in Malawi. Furthermore, briquettes provide diversity to energy sources for low-income processors. Research on compounds being emitted from carbonated briquettes could be informative.

Keywords: Briquettes, Fish smoking, Fish value chain, Post-harvest losses.

INTRODUCTION

In Malawi, postharvest losses among fish are high, estimated at 30-40% of the total catch, however, more recent information is that 22.25% is lost across the value chain (FAO, 2017). The use of solar tent drying is reported to have improved processing time, product value and enhanced marketability of Lake Chilwa *Clarias spp*. Fish species are an important source of protein, omega-3 poly unsaturated fatty acids and micro-nutrients such as calcium, selenium, phosphorus, potassium, iron and iodine and vitamins especially A, B, D, B_6 and B_{12} A, B and D (FAO 2013; Chiwaula et al., 2018). Fish is crucial to food security of many developing countries, therefore reducing losses is important in Malawi. However, fish is an extremely perishable commodity having a relatively short shelf-life due to high water activity, neutral pH, autolytic enzymes, and quality losses occur very rapidly after catch (**Dewi et al., 2011**). The need for processing to enhance quality and safety is a major concern due to increasing trade of fish

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products. It is also a major concern of international bodies as reflected in the FAO Code of Conduct for Responsible Fisheries (CCRF) which promotes technologies used in the reduction of fish losses (Singini et al., 2013**,** Kolding et al., 2019).

Different initiatives have been made by the Malawi government and development partners to improve fish processing using different post-harvest technologies (Lilongwe et al., 2018). For example, energy efficient fish smoking kilns have been introduced to help reduce fish post-harvest losses and ease climate change related effects. A smoking kiln has been adapted and tested in the Lake Chilwa basin (Lilongwe et al., 2018). The latest Fish Smoking kiln has been adopted from Ghana; it is more efficient than the local kilns. It is more efficient regarding use of firewood, achieving a reduction of 30% compared to the Traditional smoking kiln. The new kiln is less labour intensive with low exposure of fish processors to heat and smoke, thereby reducing the health risk of fish processors (Lilongwe et al., 2018). Smoking fish products has been a traditional practice of preservation from time immemorial because it enhances flavour, texture, and shelf-life of the products. However, with the use of wood as fuel sources lead to environmental problems leading to deforestation (UNDP 2014). Fire wood sources are becoming scarce and expensive in many fish landing sites in Malawi. Therefore, the need to find alternative sources of fuel that are more sustainable, efficient, and affordable is prevalent. Briquettes are touted to provide compressed blocks of organic waste materials such as sawdust, rice husks, coconut shells and paper. Briquettes have several advantages over wood and charcoal, such as higher calorific value, lower moisture content, longer burning time, easier storage and transportation, and lower cost (Gebrezgabher et al., 2018). Briquettes can also reduce the amount of smoke and polycyclic aromatic hydrocarbons (PAHs) produced during the smoking process to improve the quality and safety of the smoked products (FAO 2015).

This study was aimed at evaluating the use of briquettes as alternative fuel sources (made from pigeon pea sticks, briquettes, maize stocks, rice husks) for smoking fish using an improved fish smoking kiln. Use of briquettes has the potential to make fish smoking cheaper compared to firewood, which has other competitive uses. When using firewood in fish smoking means causing deforestation, therefore has direct consequences on the environment leading to climate change and global warming. Increased deforestation for fuel wood, including in protected/ restricted areas for smoking fish is also posing a considerable threat to environmental sustainability, affecting the vegetation around the lake, and contributing to problems of soil erosion and the siltation (Chiwaula et al., 2019).

Consequently, this study aims to optimize alternative fuel sources in smoking processing method with the aim of achieving a new quality and safe value-added product along the value chain of Malawi while conserving the environment and mitigating climate change (Doyle 2007).

MATERIALS AND METHODS

The briquette production process

Waste papers were placed in a bucket and covered with water, allowed to soak for two days. This allowed the papers to soften and also releases fibers which act as binding agents for the briquettes. This also improved its physical and mechanical properties. The soak materials were then worked into a porridge-like paste. Thereafter, organic materials such as saw dust, pine needles, rice husks, or chopped leaves and grass were added. The organic materials were burnt into charcoal for carbonated and not burnt for non-carbonated briquettes. Water was then added and mixed thoroughly. The mixture was molded into sizeable briquettes using soda bottles and dried in the sunlight resulting into structures as shown in **Figure 1** below.

The smoking process

Fresh fish were taken immediately after harvest and were subjected for smoking accordingly to the following schedule (**Table 1**).

This cycle was conducted in improved smoking kiln. The smoked samples were then taken to the laboratory for chemical and microbiological analyses after grinding using a waring blender (**Figure 2**).

Quality analysis of processed fish products

Proximate composition

Proximate analysis of smoked samples was conducted following standard methods outlined by AOAC (2003). The processed fish products were analyzed for crude protein, crude fat, moisture content and ash content.

Microbial analyses

Fish sample (1g) (fresh, smoked) was separately removed and mixed in a sterile mortar then ascetically transferred to a sample vial containing 9 ml of 0.1% sterile peptone water. The vial was closed and shaken thoroughly for 10 minutes and allowed to stand for 20 minutes, after which a 6-fold serial dilution was carried out in triplicates. Total viable bacterial counts were enumerated in standard plate count agar after incubation at 37°C for 48 hours and results were reported in CFU/g. Morphological characteristics of the various bacterial isolates in vitro were observed on agar plates under a microscope. After staining reactions and several biochemical tests to allow for individual microbial species to be identified.

Figure 1: Non-carbonated briquettes (L) Carbonated briquettes (R).

Table 1. Temperature and duration of the process.

Temperature	Duration in minutes	
300C	30	Drying
500C	30	Cooking
800C	60	Smoking

Figure 2. Burning of briquettes during fish processing process of fish products.

Sensory evaluation

Smoked samples were labelled and prepared for consumer tasting without adding spices. A 5-point hedonic scale of taste in ascending order for each sensory attribute was used by all participants to indicate their liking for each product with respect to a specific attribute (smell, texture, color, taste and overall quality) of each product prepared (5= very good) to the least preferred (1= very poor), on a questionnaire (**Figure 3**).

DATA ANALYSIS

Data was analyzed using IBM statistical package for social Scientists (SPSS) version 20. Level of significance for proximate content and sensory quality data was analyzed using analysis of variance ANOVA tests at $p<0.05$ level of significance. Microbiological data was log transformed (cfu/g) to give clear picture of the phase growth for microorganisms in smoked products. Proximate, and microbial analysis data will be determined using one-way analysis of variance 95% confidence value (P=0.05).

RESULTS

Briquettes as fuelwood usage

Briquettes are compressed blocks of organic material that are used as fuel for cooking or other purposes. They have several advantages over conventional fuels, such as wood, charcoal, or kerosene, especially for fish smoking. The mean difference in fuel usage for smoking fish products were found to be significant (p=0.031). ISK uses less briquettes than more fire wood per kg of fish processed. Average amount of briquettes as energy used for smoking fish products was 55 % less than the amount of fire wood was used in smoking same quantity of fish (**Table 2**) (**Figure 4**).

Microbiological quality

The microbiological quality of smoked fish products is presented in **table 3**. The results indicate significant (P=0.0021) higher total viable counts of log 1.7 cfu/g and log 5.2 cfu/g for products smoked using carbonated and

Figure 3: Facilities for the Chemical Analysis of fish products.

Table 2. Fuel utilization efficiency during fish smoking.

Fish Species			P value
	Carbonated Briq.	Non-carb briq.	
Copadichromis	4.458±0.18ab	7.2135 ±0.16a	.008
Diplotaxodon	3.324±0.13b	8.4203±0.04a	.031

Means with same superscripts in a row are not significantly different (P>0.05)

Figure 4. Fish Smoked products.

Table 3. Microbiological quality (log colony forming units per gram) from fresh and smoked products.

Treatment	TVC	Total coliform	Fecal coliform	*Salmonella*	*E. coli*	*L. monocytogene*	*Bacilus spp*
Fresh	6.8	4.8	1.3	2.6	1.3	0	1.8
Carbonated	1.7	1.2	0	0	0	0	0
Non-carb	5.2	2.4	1.6	2.3	3.5	0	1.3
P-value	0.003	0.001	0	0.004	0.031	0.004	0.011

Table 4. Proximate composition (%) of fresh and smoked fish products.

Treatment	Moisture	Crude Protein	Crude Fat	Ash
Fresh	90.4±0.40^{a}	62.23±0.06^{a}	17.7±0.53^{a}	13.8±0.41^{a}
Carbonated	10.12±0.31^{c}	65.59±0.40^{b}	13.55±0.14^{b}	14.08±0.52^{b}
None carbonated	15.82±0.34^{b}	40.94±0.12^{c}	16.55±0.12^{c}	11.07±0.17^{c}

[1]Data represent means ± standard error of three measurements.

[2] Means with the same superscript along rows are not significantly different (p>0.05)

Table 5. Mean sensory scores of smoked and cooked fish products.

Treatment	Smell	Colour	Texture	Overall quality
Carbonated-TSK	4.05±0.12	4.17±0.14	4.25±0.15	4.22±0.14
Non-carbonated-ISK	3.82±0.34	2.94±0.12	3.31±0.12	3.47±0.11

Means in the same row and type of fish column followed by different letters are significantly different at * P<0.05, **P<0.01 and ***P<0.001.

non-carbonated briquettes. The bacteria populations were above the acceptable norms for fish products processed using non-carbonated briquettes. The pathogenic enteric bacteria and spoilage species isolated in smoked non-carbonated smoked products were Escherichia coli, Total coliform, Fecal coliform, Salmonella, and Bacillus spp. The levels are significantly higher (P=0.001) in products smoked using non-carbonated briquettes.

Proximate composition of smoked fish products

Table 4 indicate a summary of proximate composition results for crude protein, crude fat, ash, moisture of smoked fish products. High protein levels were nevertheless observed in smoked fish than in fresh samples. Lowest levels of fat were recorded in smoked products using carbonated briquettes and were significantly different (P=0.004) from non-carbonated and unprocessed fresh fish. There were significant differences (P=0.001) in moisture content for O. shorans where lowest levels were recorded Copadichromis species.

Sensory quality of smoked fish products

The qualitative evaluation of sensory properties such as smell, texture, color, and overall quality of the smoked fish products assessed by volunteers showed that smoked products from carbonated briquettes had significantly (P<0.05) higher sensory quality scores than products from non-carbonated briquettes (**Table 5**).

DISCUSSION

Briquettes from local organic materials were successfully used as energy sources for smoking fish. These are energy-dense and cheaply constituted from waste materials, and it has once again been demonstrated that they have the potential to replace firewood in fish smoking. Furthermore, elsewhere studies have shown that briquettes can be made from various sources of organic materials such as water hyacinth, sawdust, rice husk, coconut shell, depending on availability (Ayuba et al., 2022; Gebrezgabher et al., 2018). Briquettes were produced locally using simple technology and equipment, reducing the cost and dependence on imported fuel sources. Carbonated briquettes produced a cleaner fish product than non- carbonated forms and met safety standards. There was little or no smoke, soot, or carbon deposits on the latter carbon products as burning was more complete neither do they emit harmful gases or chemicals. Consequently, health risks were minimized and so were environmental impacts leading to deforestation, greenhouse gas emissions. It was also shown that carbonated briquettes were more efficient and effective than other fuels. They had a high calorific value and low moisture content. This improves the quality of smoked fish products, as well as reducing energy consumption and cost. The fact that they were more uniform in shape renders them easy to handle and store.

Fish smoking increased protein content of the product, hence increasing its nutritional value. Moisture content is critical in assessment and control of fish products' quality and safety with respect to microbial load. The range of energy states of the water in fish products and the relationship of water activity to moisture content is a non-linear relationship known as the moisture sorption isotherm curve. Water activity in the fish product also impacts storage.

Microbiological results show a correlation with microflora of the flora of the raw material, processing techniques, preservation, and storage conditions. The quality of raw material used was good and fit for smoking, indicated by the low number of bacteria. It was observed that after smoking, the total viable counts were further reduced. Pathogenic bacteria were found to be at relatively low levels. These bacteria flora are responsible for loss of quality in smoked fish products. Huss 1995 for human safety, it is important to analyze total microbial counts, identify specific spoilage organisms and pathogens. This gives an indication of the expected quality of the processed fish products. Sensory parameters of taste, smell, colour, texture, and overall quality of smoked fish products were found to be acceptable to consumers. This indicates that processing methods used were good and comparable to other studies. To complete the fish value chain development, sensory quality characteristics of the finished products are critical for marketing purposes. They are dependent on the freshness before processing, safety and shelf-life during later storage. Salting, drying and heating are important, the former should beaded with caution. It is, therefore, essential to use sensory assessment methods to evaluate and control the quality of the smoked fish products. Studies have reported that sensory characteristics are intrinsic quality cues that are highly related with consumers' expectations of quality. Several studies have evaluated the performance and impact of briquettes as source of energy for fish smoking under different scenarios. For example, a study in Ghana compared the adoption and economic impact of briquettes among women fish processors and showed that they were more profitable than wood and charcoal, and reduced exposure to smoke (Gebrezgabher et al., 2018). In Nigeria, the study compared physicochemical and sensory properties of fish smoked with biomass-sourced from sawdust, wood, and charcoal (Ayuba et al., 2022). The results indicated that carbonated briquette-smoked fish had better quality attributes than non- carbonated briquettes. This is important in the fish value chain development and has been gaining more attention in Malawi as post-harvest losses are impacting supply.

CONCLUSION

The formulation of briquettes from a mixture of organic materials can overcome problems associated with the energy shortages being encountered in the Malawi fisheries sector where processing fish products and cooking are needed for consumer acceptance and longer shelf-life. Briquettes are a potential alternative source of fuel for smoking fish products and offers economic, environmental, and health benefits. The fish smoked with carbonated briquettes were of good quality. The cost of using briquettes is less compared to firewood. Therefore, the use of briquettes as an alternative source of fuel in fish processing is cost effective and environmentally friendly. In order to popularize this practice, there is need for making briquette making machines available, standardization and regulation of briquette quality and safety is important. Consumer awareness and acceptance of briquette-smoked products is important including other social and cultural factors that could influence the adoption of the briquettes technology.

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