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Development of Improved Artisans Fish Smoking Machine: An Innovation in Agriculture

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Abstract
The objective of the study was to develop an improved artisan's fish smoking machine (IAFSM) with micro environment type of smoking chamber for fish smoking and incorporated a sawdust stove with inlet vents to produce hot and non-dense smoke under natural influence at high temperature and velocity. A wooden frame was developed according to the required dimensions; internal walls were nailed to the frame from inside; the internal walls were made of stainless metal sheets that were cut into required sizes. Thin layer of dried and powdery red clay soil was formed within the thickness of the wall frame after some quantity of the material was poured, and a thick layer of cotton wool was placed on it thereafter, plywood was fixed to the frame from outside to cover these lagging materials. These sets of activities were repeated for the remaining three sides including the door, top and the lowest flat parts of the machine. The dried sawdust was compressed in the IAFSM's stove with the volume 1.25 × 108 mm^3, flux guide, and a fire screen. An outlet vent is located at the top of the machine. When the compressed dried sawdust was

ignited with dried pieces of paper when the door was closed; the fuel burns *under natural influence without the use of fan in any form. The exhausted flux escaped via the outlet vent and away from the artisans, as soon as, its cooks the fish. A hot and non - densed smoke generator has been developed to smoke fish at a cheaper and faster rate with heat energy and non - densed smoke delivered to the fish at the rate between 86.9 J/S and 92 J/S from the heat energy delivered to the smoking chamber at a rate between 108.6 J/S and 127.8 J/S. Satisfactory taste reports were received after the interview granted by the 20 members of the public randomly selected and served with the samples of the smoked fish. The developed mechanical aid: Is environmentally friendly; Uses coal or similar fuel material that can smoulders; and Smokes fish faster than any devices in the existing literature, less than an hour, with significant moisture loss.*

Keywords: Artisans, Sawdust, Heat flux, Natural influence, Fish smoking

Introduction

According to literature studied, smoking is impacting flavour to fish using hot densed, less-densed, and non-densed smoke including the use of other types of smoke. Smoked products are from broad range of foodstuffs. Torry kiln provided a modern way of smoking foods (Tahir, Salengke, Mursalim, Metusalach and Caesarendra, 2020).
In several artisans' designs and methods, fish smoking houses use natural air circulation that was opened to the environment. The reason for longer smoking times due to low hot airflow over the smoked products (Tahir et al., 2020).

Energy based on wood was used by households, industries, commercial enterprises and artisans to meet the energy requirements for production of smoked fish. Effort was used to acquire the woods, the cause of deforestation on about 13 million hectares per year worldwide. Forest plantations and its natural expansion have reduced as a result while the loss of forest area is significant problem (Fabiao, 2014).

Modern ovens were fuelled by gas or electricity and used for baking and roasting (Okafor, 2014) but sawdust heaps were readily available in the South Western parts of Nigeria. It is alternative and reliable replacement for gas, charcoal and electricity. It is cost efficient and sustainable sawn wood dust, waste from wood planing, is in various sizes. Saw-wood-dust is used when dried under room temperature for few days to remove moisture (Zuriyanie, 2015).

The technology that uses use natural air circulation that is opened to the environment, and biomass is not cost-effective for enterprises. Differences in configuration and sizes of ovens, the combustors of woods, behave differently (Fabiao, 2014).

The use of biomass as fuel is preferred over fossil fuels for sustainable society. Biomass is a highly reactive fuel compared to coal and has higher content of oxygen, high hydrogen-to-carbon ratio and high content of volatile substances. The bulk composition of biomass in terms of carbon, hydrogen and oxygen (CHO) do not differ much between various sources of biomass. The air-to-fuel ratio is expressed as the mass of air (kg) used to burn a unit of fuel (kg); an important factor for achieving efficient combustion. The heat energy received from efficient combustion is given as:

$Q = mcT$..(1)

Where m = mass of saw dust in kg,

c = specific heat capacity of saw dust J/kg°C, and

T= Temperature range in °C (Fabiao, 2014).

The heat and smoke source is the key factor that affect the fish smoking process. Coconut shell is a heat source available locally, a biomass fuel is used because of its high heating value and good smoke quality and lower ash content (Tahir et al., 2020).

The issue of environmental safety is most important to the modern man and improvements on wood stoves to reduce the density of smoke and convey the less or non- dense smoke emitted away from the artisans are of interest and the direction the research findings

look. Solar ovens are used in heating and cooking, adapted to domestic use, and not suitable for commercial purposes. Oven provided heat through burning of fuel, such as, wood, gas, oil or electricity. Insulator or lagging materials help in preventing heat loss from the oven (Adegbola, Adogbeji, Abiodun, and Olaoluwa, 2012; Okafor, 2014).

Prepared fish are hung on hangers to optimise the smoke-heat-air contact with a narrow gap between fishes. The introduction of any device within the vertical pathways in the smoking chamber will affect the airflow velocity and non-uniform circulation results. (Tahir et al., 2020).

The three important factors that affect fish product characteristics and quality are salt, smoke, and heat. The use of hot smoke for treating fish requires two sequential processes which are smoking, and cooking. The length of smoking depends on the desired flavor and moisture level of the smoked product while the length of cooking phase depends on the smoke temperature. The temperature within the smoking chamber must be increased to 85 °C or higher, so that, the internal temperature of fish reaches 68 to 72 °C. This peak cooking temperature should be held for at least 30 min to ensure the fish is cooked thoroughly. The smoking process increases the concentration of some basic nutrients and reduced the water, fat, and mineral contents in fish meat (Fabiao, 2014; Tahir et al., 2020). These are the functions the developed artisans fish smoking machine will carry out.

In direct-fired artisans' oven, heat is introduced to the inside of the smoking chamber from sawdust stove. In other ovens; wood, gas burners or electric heating elements can be used and located above and below the chamber (Fabiao, 2014). Digital anemometer measures the smoke velocity in the smoking chamber outlet (Tahir et al., 2020). Opening the door affects the flow of combustion gases within the micro environment (Fabiao, 2014).

The objective of this research work is to develop an Improved Artisans Fish Smoking Machine (IAFSM) with heat source, micro-environment and the heat source transferring heat energy under Controlled Technology Conditions (CTC) to conserve our environment and soil, reduce cost and time for smoking fish. The heat transferred method was used to smoke fish, reduced soot deposition and charring of the smoked fish.

Materials and Methods

The study area and the description of the facility

The study was conducted in the Department of Agricultural Education, Sikiru Adetona College of Education, Science and Technology (The Former Tai Solarin College of Education), Omu Ajose, Ogun State, Nigeria.

The materials used for the development of the Artisans Fish Smoking Machine

The appropriate sheet metal for the research work is 4 inches thick black steel sheet. It is not easily corroded and it does not turn black after heating (Ejiko et al., 2018), but used and refused corrugated aluminum sheets removed by strong wind and found within the campus. They were straightened, cut as required into sizes and fixed as internal walls. also, some were formed into fire screen and biomass stove with new structure to enhanced environmental control and sustainability. Other materials of construction required are wooden planks, plywood, nails, a pair of hinges, thick wire mesh, fasteners and lagging materials namely: laterite and cotton wool.

IAFSM Configuration

The IAFSM configuration consists of a stove section, a micro-environment section, a door, a $1.25 \times 108\ mm^3$ biomass stove, four inlet vents, an outlet vent, hot smoke guides, a fire screen, a handle, and a pair of hinges. The configuration of the IAFSM is a rectangular house unit, looking from all sides.

When the biomass stove is placed in the stove section, the IAFSM configuration is a continuous structure. The micro-environment internal section is bigger and it is for smoking and cooking fish and with other foodstuffs. The dimensions of the micro environment section are: 500 mm × 500 mm × 108 mm and it is rectangular in shape. The biomass stove has 1.25×10^8 mm^3 volume capacity for dried and compressed sawdust to produce the hot and non - densed smoke (Hot smoke flux) in the generator. This stove supplies the smoking chamber with hot and non - densed smoke flux for its operation, the smoking and drying of fish and other foodstuffs.

Description of the Micro Environment

This micro environment consists of four walls when the door is closed, vertical rack, a pair of wooden frames, a door, padlock hook, lagging materials, external walls made of plywood, outlet vent, and a door handle. The micro environment is made of aluminum metal sheets.

The Biomass Stoves

The stove dimensions are 500 mm × 500 mm × 500 mm, square in shape when viewed from all sides and it consists of inlet vents and vertical walls made from aluminum sheets. The stove uses sawdust as fuel and generates hot and non - dense smoke flux under natural influence, as soon as, the door was closed after the fuel was ignited under load and no-load conditions.

Dried and compressed sawdust was ignited when the door was closed, hot and non-dense smoke was produced from the smoldering biomass in the stove and moved through the sawdust air channels to the micro environment. The resulted hot and non-dense smoke flux in the micro environment smokes and cooks the fish loaded in the smoking chamber.

The exhausted heat and smoke escaped through the outlet vent. The IAFSM is equipped with hot smoke guides and a fire screen to

conduct and distribute the hot and non - dense smoke flux before it was delivered to the chamber to attain uniformity in the smoked products.

When the IAFSM door was opened, the micro environment was not sustained and whenever it is opened, the smoking chamber conditions are not sustainable. The padlock hook and a pair of hinges were fixed to sustain air-tight and stability in the micro environment when the door is closed properly. The four legs allowed the stability of the whole machine structure.

An increase in air flow velocity increases the circulation and effective thermal conductivity of the hot gases within the the micro environment (Fabiao, 2014). The heat flux in the IAFSM housing unit is caused by the difference in atmospheric pressure between the inlet and the outlet vents (Farinde et al., 2008). The pressure at any height is given as

$P = h\rho g$ ——————————————————— (2)

P is air pressure at the inlet vents, h is the column of fluid (air), ñ is atmospheric pressure, g is acceleration due to gravity.

Efficiency is the time taken to smoke a batch of fish to the desired taste, colour, texture and moisture content. It is relatively easy to measure temperature, but much more difficult to measure heat flux rate (Okafor, 2014).

Electric ovens' micro environment takes longer time to heat up compared to other types of ovens. The wood fire has longer smoking time, its smoked products were not uniformly smoked and changed the original flavor of the product (Ganitha et al., 2014) but IAFSM smokes fish uniformly.

The test Conducted on the Developed Machine

Fresh quality fish, 5000 g, bought from the nearest Degun fish auction site in Ijebu-Ode was thoroughly cleaned, soaked in 15 % brine for 40 min, drained, and arranged in the smoking chamber for smoking

in a single batch. Tahir et al. (2020) reported that fresh fish, thoroughly cleaned, soaked in 15 % brine for 40 min, and drained can be arranged in the smoking chamber for hot smoke treatment.

Thereafter, samples of the treated fish were physically observed and tasted after 30 minutes of treatment with hot and non-dense smoke. In the following 15 minutes, the physical observation was repeated during which traces of burnt were observed on the sides of the fish on the lowest rack against the flux. Consequently, the treated fish were removed from the chamber.

The samples of the treated fish were given to 20 people who were randomly selected. Satisfactory taste reports were received from the people and the physical observations confirmed that the fish were cooked and there was significant moisture reduction of the fish; the smoking of the fish was thoroughly done. A hot and non - dense smoke generator has been developed to smoke fish at a cheaper and faster rate with heat energy and smoke produced and delivered to the fish at the rate between 86.9 J/S and 92 J/S from the heat energy conveyed to the smoking chamber at a rate between 108.6 J/S and 127.8 J/S. The rack was made of metal.

The Bill of Engineering Measurements and Evaluations (BEME) for IAFSM

The plywood cost ₦4,500; pictorial views of IAFSM cost ₦700; typing cost ₦1,100; aluminum sheets cost ₦2,000; electronic messages cost ₦500; nails cost ₦800; 4 pieces of planks cost ₦1,200; padlock hook cost ₦150; a metal handle cost ₦250; a pair of hinges cost ₦350; transport cost₦700; and total cost was ₦12,250:00.

Total engineering evaluation of Artisan fish smoking machine are stated in Table 1 below.

Table 1: Total Engineering Evaluation of Artisans Fish Smoking Machine

S/N	DESCRIPTION	AMOUNT (₦)
1	Construction	9,950:00
2	Pictures	700:00
3	Typing and Electronic messages	1,600:00
	Total cost	**12,250:00**

Results and Discussion

Functionality of the IAFSM structure

The materials used for the development of IAFSM were selected to guarantee stability, functionality and cheaper cost of production. The stability of the IAFSM is satisfactory based on the physical observations made during the test.

From the physical observation results, the smoked fish texture was tough, significantly and acceptably dried, tasted fine and the physical appearance was appealing.

The above results confirmed that the developed Artisans Fish Smoking Machine (IAFSM) was functional for generating hot and non - dense smoke from the dried and compressed sawdust. The flux was hot enough to melt part of the metal screen as the flux was conducted through the vertical column of the entire smoking chamber to smoke and cook the fish; fasterand cheaper than any artisan fish smoking machine in literature. The smoked fish have good qualities and the machine was operated with much convenience; and the exhausted heat and smoke were conducted away from the artisans during the fish smoking operations.

Heat transferred to the external walls, made of plywood, was insignificant because it has no burning effect nor can it injure anybody in contact. There was no deformation of any kind done by the hot and non - dense flux to the internal and the external walls made from the refused corrugated aluminum roofing sheets and the plywood bought.

Conclusion

The IAFSM developed operates with cheap fuel that can be purchased at almost no cost for the production of hot and non-dense smoke for better environmental control, and good operating conditions for the artisans. The physical observations of the IAFSM during and after smoking the fish indicated effective performance of the mechanical aid.

The biomass stove, heat guide, and the fire screen developed enhanced smooth, good and safe machine operation, distribution and concentration of the hot and non-densed smoke in the smoking chamber while the interactions between the inlet and outlet vents resulted to production of hot and non-dense smoke flux at very high velocity.

5 kg fish was smoked in less than an hour, the structure of the smoked fish was significantly tough and of acceptable degree. The exhausted hot and non-dense smoke escaped through the outlet vent and conducted away from the artisans; there was no contact between the artisans and the exhausted hot and non - dense smoke during and after fish smoking operation. IAFSM is convenient, faster and cheaper to smoke fish and foodstuffs.

The micro environment restricted the interactions of the flux to the internal walls, rack, lagging materials, the smoked items in the chamber when the door was closed and in limited form to the external wooden walls. The hot and non-dense smoke released enough heat energy and smoke for drying, smoking, and cooking the fish.

Recommendations

The mechanism for the control of the heat flux under natural influence should be develop and incorporated. Furthermore, the IAFSM performance evaluation test should further be conducted to determine more operational parameters while the government should create enabling environment for its mass production for

domestic cooking, smoking of food items and industrial use, as heat energy and smoke generator, for agricultural and non-agricultural heat and smoke treatments of materials.

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