

Design and construction of biomass powered fish dryer

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Abstract:

In this study, a simple biomass fish dryer was designed, manufactured and tested to reduce the problems associated with fish processing. The biomass fuel powered fish dryer has a closed rectangular drying chamber in which hot air is generated from the heating compartment (furnace). Its principle of operation is based on heat transfer from one place to another by convection. The heat needed to dry fishes is usually obtained from heat energy source (briquette) releases in heating compartment (furnace). After construction of the biomass dryer, a temperature reading of the various component of the dryer were recorded at every 30 minutes (from 12:00pm to 06:00pm). Performance of the dryer was evaluated by drying two species of fish (cat and scumbia). The result obtained (mass of the fishes reduced significantly from 0.16 to 0.02% as time increases from 30 to 300 minutes) shows that the performance of the biomass powered fish dryer is dependent on heat radiation incident in the drying chamber and ambient temperature. The moisture content of each fish depends on the fish species because some fish have high moisture contents.

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1. Introduction

Post-harvest losses in developing countries contribute significantly to the problem of food scarcity. According to [1], estimates of these losses are in the range of 4% but can in extreme situations be as high as nearly 100%. A significant percentage of these losses are attributed to untimely or improper drying of foodstuff such as fish, meat, cereals and others. Fish which supplies approximately 6% global protein is an important component of the diet for people throughout the world. However, it is an extremely perishable food which becomes inedible within twelve hours from the time it dies at tropical temperatures. Fish spoilages begin as soon as it dies, therefore processing should be done quickly to prevent the growth of spoilage bacteria [1].

The use of appropriate methods of preservation which aim is to reduce the moisture content can result in the increase of the amount of fish available for human consumption. There are many preservation methods some of which are; cooking, smoking and drying. This study will focus on drying as a means of fish preservation. Thermal (Heat) drying is a water removal process commonly applied in both agricultural and industrial processes, in which heat is used to displace water particles from objects through evaporation. The purpose of drying is to reduce the moisture content of the product to a level that prevents deterioration within a certain safe period of time [1].

There are two usual methods of fish drying: open air or sun drying and smoking. Open air drying is the oldest method used in the preservation of fish and other perishable foodstuffs. This method though simple and cheap, exposes the fish to rain, dust and infestation by insects and attack by

animals. Open air drying is also uncontrolled [2]. Sun drying as a method of drying also suffers from a high labour requirement and excessive crop handling particularly in periods of inclement weather which result in high costs, crop damage and a loss in quality.

Other alternatives which seem promising such as coal, firewood and petroleum products are inefficient, inadequately available, ever rising cost or harmful to the environment due to their high carbon and other harmful gases emissions [3].

Appropriate combustion properties of fuel materials are essential during drying, blanching and storage operation and are equally necessary in the design and analysis of the numerous machines and processes involving heat treatment [4]. Thus, the need for efficient and environmentally friendly use for domestic and cottage level industry drying techniques becomes necessary.

Biomass (wood chips, sawdust or agricultural waste) an organic matter derived from living organisms, such as plants, animals and microorganisms is a renewable, carbon neutral energy source that can be used to produce heat with lesser greenhouse emissions. Residues of maize cobs, coconut shells, cereal straws, rice husks, which are locally available and cheap can be used as fuel for biomass gasification thereby reducing operating costs [5].

Biomass powered fish drying machines are expected to provide a reliable and efficient way to dry fish resulting in production of high quality dried fish and reduction in fish spoilage and post-harvest losses. Using biomass-powered fish drying machines can create employment opportunities and provide energy access in rural areas [6, 7, 8]. In this

study therefore an attempt will be to design and construct a biomass powered fish dryer using locally available materials. In biomass dryer biomass chamber comes into picture. Fuels like coal, briquettes are going to act as the source of energy for the dryer. Coal, firewood or briquette is going to be fed to the dryer through the door which is been provided at the bottom of the drying chamber.

Though the biomass mode of drying serves as alternate mode of drying of food, it is not always environmental friendly as some of the fuels burnt such as firewood liberate flue gases which are harmful to the atmosphere [9]. The firewood used is also going to increase deforestation process. The aim of the study is to design and construct a biomass powered fish dryer.

2. Materials and methods

The following materials were used in this study for the construction of the biomass dryer.

2.1 Materials used

2.1.1 Aluminium metal wire net

The wire net of 13.7x40 inches was used as the dryer tray. It is selected because it has holes which will aid the flow of air. It is readily available in the market and does not cause any harm to the health of the person using it.

2.1.2 Hinges:

It was used for the door of the drying chamber to aide easy opening and closing of the door.

2.1.3 Black paint:

It was used to coat the absorber surface. The color was selected because black surfaces have the ability to absorb solar radiation effectively.

2.1.4 Sheet metal:

This was used for the construction of the inner and outer surfaces of the dryer.

2.2 Design of the machine

2.2.1 Amount of moisture content removed

The formula to calculate the total amount of moisture content to be removed (M.C) is given by [10], as:

$$M.C. = \left[\frac{M_i - M_f}{M_i} \right] \times 100 \quad (1)$$

Where M_i = Mass of sample before drying (kg), M_f = Mass of sample after drying (kg)

2.2.2 Average drying rate

The average drying rate in kg/hr for drying the product is:

$$d_A = \frac{M_W}{t_d} \quad (2)$$

Where, M_W = Mass of moisture removed from the fish (kg), t_d = Drying time (hrs)

2.2.3 Dryer Efficiency:

The dryer efficiency will be computed as:

$$\eta_d = \frac{ML}{I_C A_c t_d} \quad (3)$$

Where, M = mass of the fish (kg), L = latent heat of vaporization of water KJ/Kg of water, t_d = drying time(s).

The latent heat of vaporization is given by [10] as:

$$L = 4.186 \times 10^3 \{597 - 0.56(T_p)\} \quad (4)$$

Where T_p = Product temperature (K)

2.2.4 Design of Drying Chamber

Plate 1 shows the drying chamber of the constructed dryer.



Plate1: Drying chamber

The drying chamber of biomass powered fish dryer which is a heat retaining chamber, the hot gases produce by burning of briquette are discharge through plate heat exchanger into the drying chamber by conduction. This hot gas diffuses into the chamber and touch the fish to be dried.

To design the volume of drying chamber. It was considered to be inform of two rectangles (drying chamber and combustibles unit) open cylinder (chimney) and conical shape of chimney cap.

The volume can be determined as follows:

Volume of the drying chamber (V) =

volume of the drying zone +

volume of the briquette zone +

the volume of chimney + volume of chimney cap .

That is:

$$V = V_d + V_v + V_p \quad (5)$$

i. Volume of the drying zone, $V_d = \text{Length} \times \text{Breadth} \times \text{height}$

$$V_d = L_1 \times B_1 \times H_1 \quad (6)$$

ii. Volume of the briquette zone (furnace)

$V_b = \text{Length} \times \text{Breadth} \times \text{height}$

$$V_b = L_2 \times B_2 \times H_2 \quad (7)$$

iii. Volume of chimney.

$$V_v = \pi r^2 h \quad (8)$$

Where, r is the radius of the chimney and h its height

iv. Volume of the chimney cap.

$$V_p = \frac{1}{3} \pi r^2 h \quad (9)$$

Where, (r) is the radius of the chimney cap and (h), is the height of the chimney cap.

2.3 Design Procedure

The design of the biomass fuel powered fish dryer took into consideration different design criteria and parameters. Some of these design criteria and parameters were from literature review while others were determined using a series of mathematical calculations. These design parameters included environmental conditions of the test location, drying temperature, amount of moisture to be removed, heat energy requirement and determination heat requirement

2.3.1 Construction of the fish dryer

The components of biomass powered fish dryer, biomass powered fish dryers are mainly made up of three parts. These are burning chamber, drying chamber and chimney. These parts are briefly discussed below.

2.3.1.1 Burning Chamber

The size of burning chamber was rectangular in nature were the biomass (agricultural waste briquette) were burned to generate heat and smoke in the chamber.

2.3.1.2 The Chimney

The chimney was constructed from sheet metal that was bent to form the required shape. The chimney was painted black to facilitate the flow of hot air through the drying chamber.

2.3.1.3 Drying Chamber

The drying chamber was made from sheet metal with the support of three-quarter Bororo hallowed pipe. It consisted of two trays, each with size of 78 x 15mm, for the produce to be dried. The trays are made of wire net. The hallow pipes were used to pass a smoke and hot air and heat into the chamber by convection when drying was on. At the side of the drying chamber a door will provide a means for loading and removing the material to be dried.

2.3.2 Production method

The biomass fuel powered fish dryer was generally constructed using sheet metal and Bororo three-quarter metal pipe because it is readily available, light in weight and not costly. The major construction works of project is welding and fabrication work.

The construction was sequenced as follows for the wood work:

- Marking out on the Bororo hallowed metal pipe to cut into desired shape size.
- Cutting out the already marked out parts properly.
- Joining the cut part of the Bororo hallowed metal to produce a desired shape frame.
- Welding the sheet metal on in and outside the frame to construct the drying chamber
- Fixing up the pipes through which the hot air and smoke will pass through them to avoid chemical contamination on the fish

2.4 No-Load test

The first performance test was the no-load test, where the temperature in the dryer was measured without materials to be dried. The temperature variation in drying chamber and ambient temperature values were recorded every 30 minutes' interval. The no-load test helped to know the maximum possible temperature rise in the drying chamber as compared to the corresponding ambient value. Parameters such as temperature and heat radiation recorded during this test were used to determine the biomass powered fish dryer efficiency.

A temperature reading of the various components of the dryer was recorded at every 30 minutes of interval from 12:00pm to 06:00 pm. Performance of the dryer waste using cat and scumbia fish, being placed on tray 1 and tray 2 in the drying chamber. This will enable quick drying and easy circulation of air within the drying chamber.

3. Results

3.1 No-Load Test

The first performance test was the no-load test, where the temperature in the dryer was measured without materials to be dried. The temperature variation in drying chamber and ambient temperature values were recorded every 30minutes' interval. The no-load test helped to know the maximum possible temperature rise in the drying chamber as compared to the corresponding ambient value. Parameters such as temperature and heat radiation recorded during this test were used to determine the biomass powered fish dryer efficiency. The construction of the dryer was successfully completed; different tests were conducted in order to evaluate its performance. Cat and scumbia fish were used during the test period. The results of the tests performed are presented below.

Figures1 and 3 are plots of mass of cat fish against time in trays 1and 2 while Figures 2 and 4 show plots of mass of scumbia fish against time in trays 1 and 2.

3.2 Dryer Efficiency

Figure 5 presents the graph of amount of water removed from catfish against time in tray1, Figure 6 presents the graph of amount of water removed from scumbia fish against time in tray 1. Figure 7 demonstrates the graph of amount of water removed from catfish against time in tray 2. Figure 8 is the graph of amount of water removed from cat fish against time in tray 2. Plate1and 2 show the images of cat and scumbia fish respectively

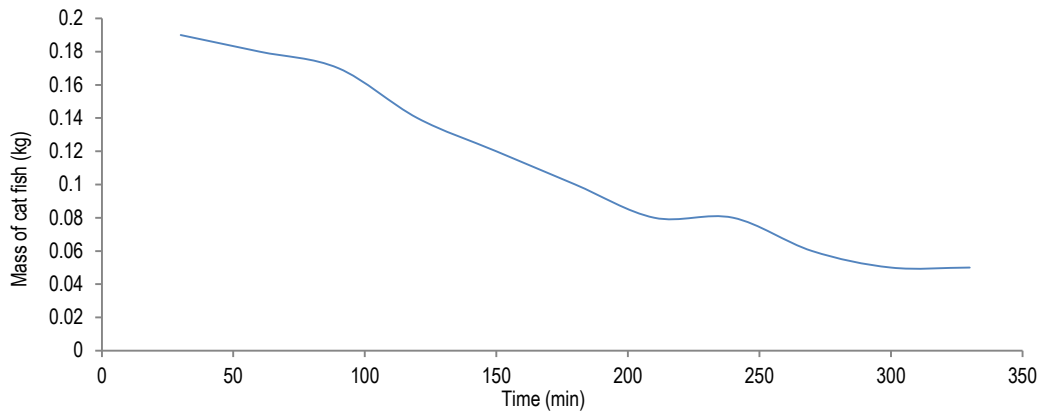


Figure 1: Graph of mass of cat fish against time in tray 1

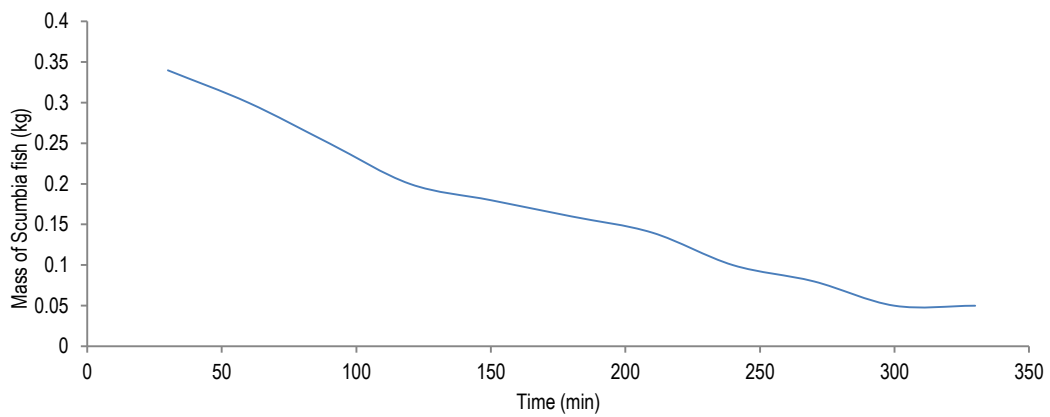


Figure 2: Graph of mass of scumbia fish against time in tray 1

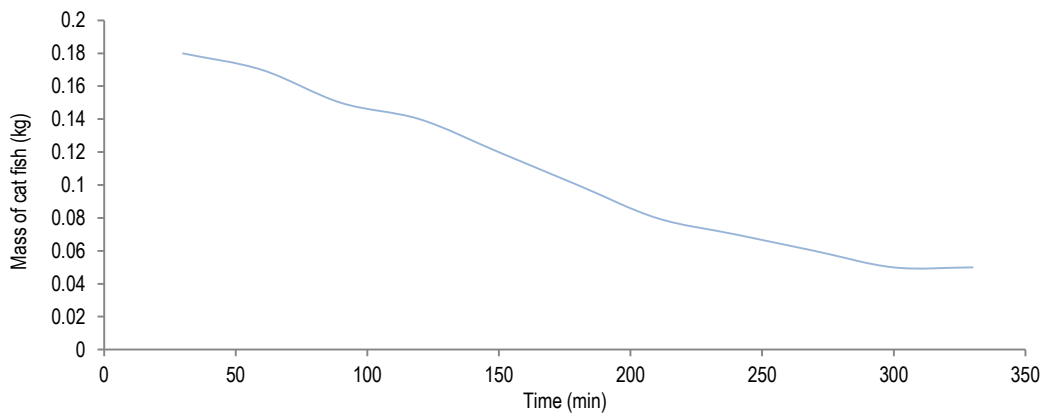


Figure 3: Graph of mass of cat fish against time in tray 2

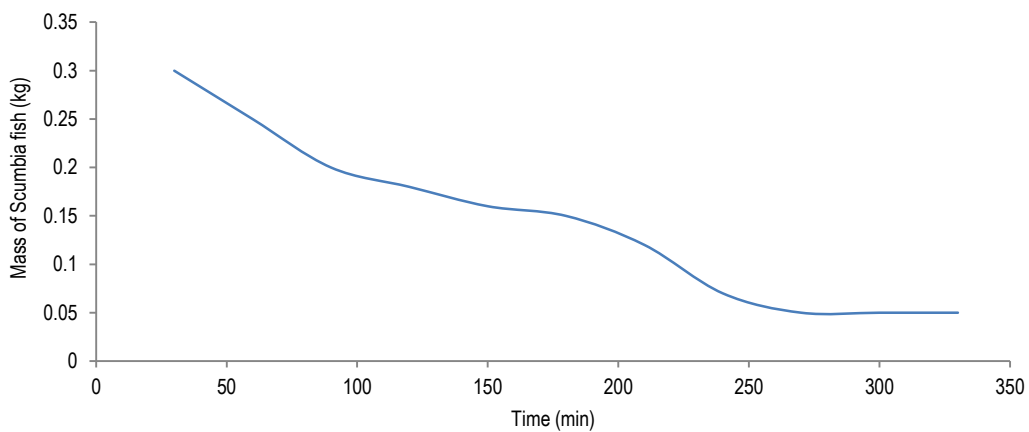


Figure 4: Graph of mass of scumbia fish against time in tray 2

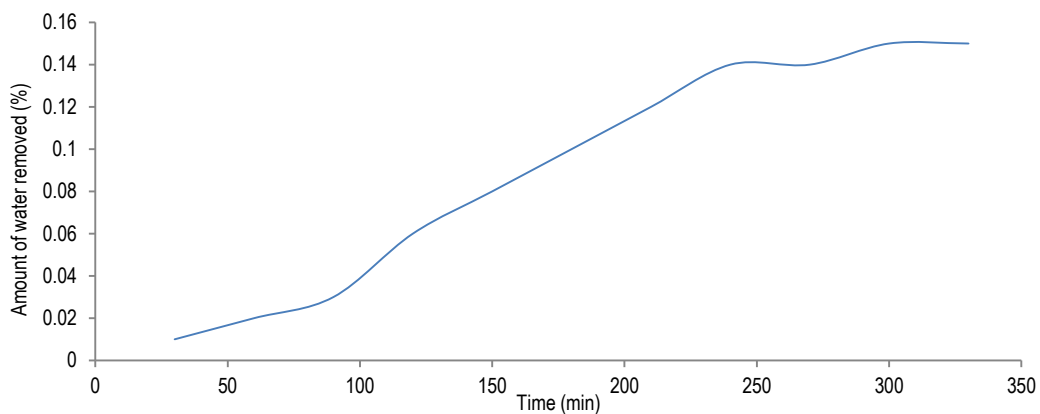


Figure 5: Graph of Amount of water removed from catfish against time in tray 1

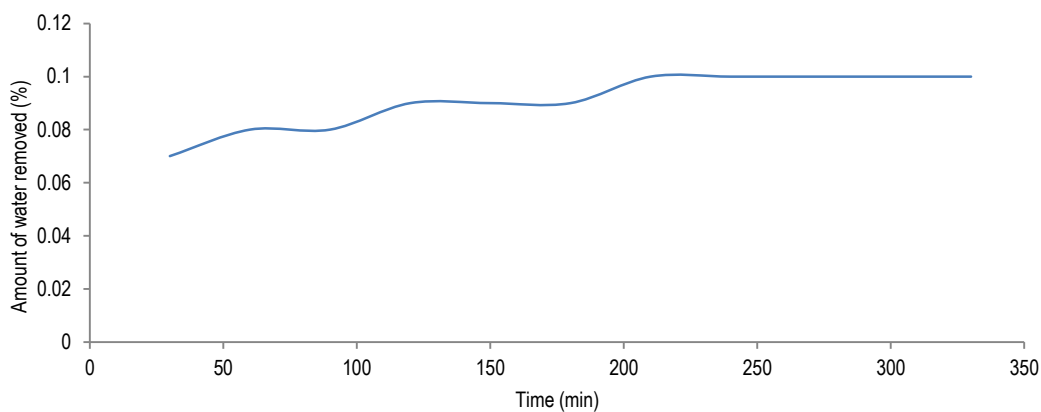


Figure 6: Graph of amount of water removed from scumbia fish against time in tray 1

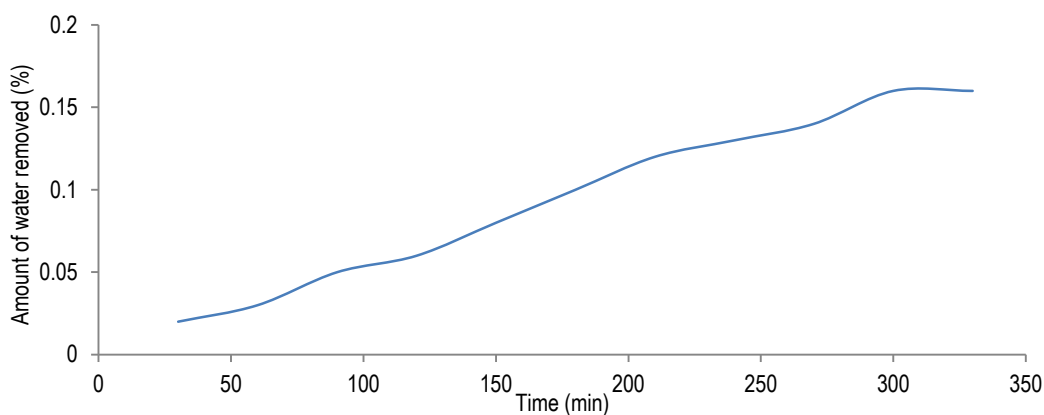


Figure 7: Graph of amount of water removed from cat fish against time in tray 2

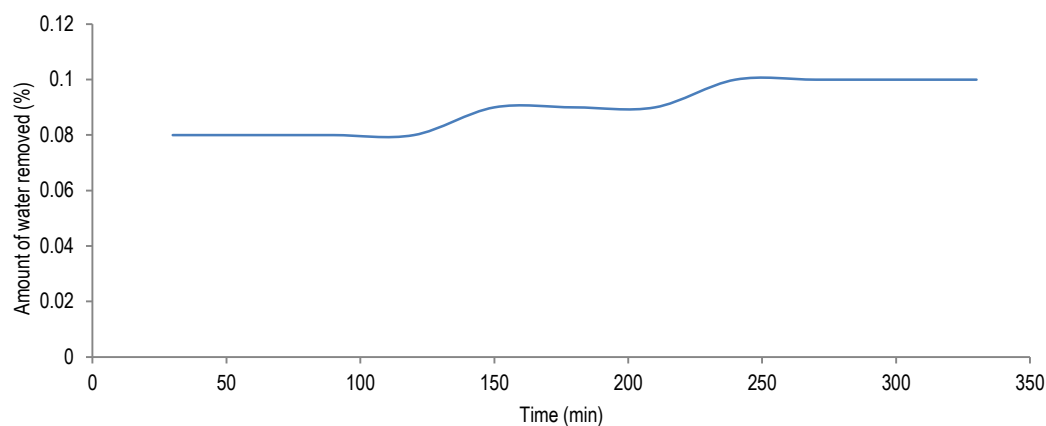


Figure 8: Graph of amount of water removed from scumbia fish against time in tray 2



Plate1: Dried Scumbia fish



Plate 2: Dried Cat Fish

4. Discussion of Result

It can be observed from Figure1-4, as the time increases from 0 to 330 minutes with interval of 30 minutes, the mass of both fishes (cat and scumbia fish in tray 1 and 2) decreases significantly and this result concur with [11]. This shows that as the fishes stayed longer under the sun, the mass of the fishes reduces with respect to time. It can be deduced from figure1-4 when the time reaches around 300 to 330 minutes the mass of the both fishes remain constant (0.05kg).

It can be seen from Figure 5 for cat fish as the time increase from 0 to 300 minutes, the amount of water removed in tray 1 reduced significantly from 0 to 0.16% and it was steady from 300 to 330 minutes. And also from Figure 6, as the time increases from 0 to 240 minutes (Scumbia fish), the amount of water content removed significantly up to 0.1% but from there, it was steady up to a time of 360 minutes. The result obtained was similar to what was reported by [12].

It can also be observed from Figure 7 that the amount of water removed from the catfish in tray 2 reduced significantly from 0.16 % to 0.02 % as the time increase from 0 to 300 minutes, and was steady from 300 to 330 minutes. Figure 8, also shows that the amount of water removed from scumbia fish was 0.08 and was steady from 30 to 120minutes and increases up to 0.1% from 120 to 240 minutes. Then the amount of water removed from the scumbia fish in tray 2 remained constant from 240 to 330 minutes.

The result obtained shows that the performance of the biomass powered fish dryer is dependent on heat radiation incident in the drying chamber and ambient temperature. Also the amount of water removed from the dryer obtained was uniform due to the result obtained from Figure1 to 4.

5. Conclusion

Based on the results of the design, fabrication and testing of the biomass fish dryer the following conclusions can be drawn;

- The biomass dryer successfully dried fish to a moisture level of 15%, indicating its effectiveness in preserving fish.
- The biomass combustion system provided sufficient heat for drying, demonstrating efficient energy utilization.
- The dryer maintained a consistent temperature (60-70°C) and humidity level (40- 50%) ensuring optimal drying conditions.
- The dryer reduced drying time by 40% compared to traditional sun drying methods.
- The dried fish showed improved texture, color and shelf life indicating enhanced product quality.
- The use of biomass as a renewable energy source and the reduced drying time make the dryer a cost-effective solution for fish drying

Recommendation

- This project is recommended that the modification of this project should base on how to control the heat in the chamber
- It recommended that the internal temperature of the drying zone should be taking without opening the door rather than taken the temperature reading at the chimney.
- It is recommended that the door should be closed tightly in order to minimize heat loss to the environment.
- It is recommended that the prototype should be produced in large quality to reach those who are in producing drying fish to reduced high rate of contaminated fish in the society.

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