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Fabrication of Mirror Stainless Steel Oven Drying Machine- A Technology for Sustaining and Preserving Fish Production

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Abstract

This study is the fabrication of a mirror stainless steel oven drying machine, the present day technology for the preservation of fish and sustenance of fish production. It is energy efficient and eliminates the common challenges of high fuel cost due to heat loss, and it provides alternative energy source which sparked its widespread use as both domestic and industrial choice machine. The oven is fuelled by natural gas and charcoal, which can burn simultaneously or independently, depending on the choice of the user. The main material for the drier is mirror stainless steel pan and square pipes which are sourced at relatively cheap cost in the local market. The primary advantage of this dryer is its energy efficiency due to the reflective property of mirror stainless steel which reflects most of the generated heat back from the walls to concentrate in the drying chamber for a better drying effect. Heat is also conserved by the vacuum created between the double walls to reduce heat loss by conduction and convection into the surrounding. This oven is fabricated to 150 capacity, meaning it dries 150 fishes per time. It can also be fabricated to higher or smaller size and the efficiency of the machine would still be intact. The mirror stainless oven is safe as the temperature of the oven body is not hot that can harm the operators, and the temperature control valve is located outside the oven. The test results showed that this model of oven has drying rate of 1.90g/h- 6.0g/h for Catfish, and 1.2g/h – 4.5g/h for Tilapia. The quality of dried fish was very good, indicating good taste and long shelf life.

Keywords: Mirror stainless steel, fish dryer, Catfish, Tilapia, drying rate

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1.0 Introduction

Fish drying has been used as a traditional method of food preservation for generations. It entails drying fish to maintain nutritional content, increase mobility, and extend shelf life. In areas with limited access to refrigeration or other contemporary preservation techniques, fish drying is extremely important.

However, fish is prone to spoil as soon as it is harvested hence the urgent need for preservative measures. Akinola , Akinyemi, and Bolaji (2006) reported 50% annual loss of fish in Nigeria to post harvest spoilage irrespective of the method of preservation employed. . Oladapo et al. (2020), suggests that fish preservation enables communities to have access to fish even during seasons with poor fish availability. According to Banigo et al. (2017), the fact that dried fish is not only delicious but also simple to transport and store makes it a useful item for international trade

High ambient temperatures and humid tropical conditions speed up spoilage rates in fresh water fishes (Datta & Rakesh, (2018). According to Facts, (1996), the limited shelf life of dead fish of 16-20 h in Southern part of Nigeria and 20-36 h under conditions in the Northern part are basically due to biochemical changes after death. According to Adebaye-Tayo et al, (2008) states that thr rate at which fish spoils relates to the hygienic conditions, storage temperature, acidity and the structure of the muscular tissue.. The **c**hemical breakdown of protein content, fat content and the water content/ are al factors leading to quick spoilage of fish (Nowak, D. & Lewicki, 2004).

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Fish preservation can be achieved by the removal of water from it, since microbial organisms require moisture for active growth including enzymatic hydrolysis of the food components (Ogbonna, 1987). To avoid fish spoilage which leads inevitably to post harvest losses several methods of preservation can be employed to prolong the shelf life of fish. These include drying, smoking, salting, freezing, canning (Akinola, 2006).

Adesoji,(2014) fabricated a drying oven fired with charcoal for drying fish and other agricultural product such as okra, tomatoes, etc. C.A. Komolafe et al (2011) did a study on the design and fabrication of a convective fish dryer. Again, Emmanuel, M. A. et al (2015) undertook the design, fabrication and operation of a smoking kiln. All these researchers achieved success based on their set objectives. It is worthy of note that no previous studies have attempted to fabricate a dual fuel source oven that can burn simultaneously and independently for easy and economic usability. Also, none of the previous studies tried to use mirror stainless steel material for the entire body of the oven as well as a double pan wall that creates a vacuum for better energy efficiency.

This study therefore examines the benefits of mirror stainless steel ovens for drying fish and evaluates their effects on the economy, society, and environment in comparison to more conventional fish-drying techniques and existing oven models. By fulfilling these goals, this research hopes to advance the field of food preservation and provide workable ways to enhance the drying of fish.

2.0 Methodology

2.1 Design/Operating Principles

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The 150 capacity fish drying oven is made up of mirror stainless steel metallic material because of its good heat transference properties. The oven is made up of double wall stainless steel sheet laminate that serves as heat insulator to minimize the heal loss to the environment and provide maximum heat efficiency. The oven operates by natural convection of heat from two heat sources; natural gas and charcoal, which can burn simultaneously or independently. The gas burner is located at the bottom centre of the oven, while, two rectangular stainless steel collectors, one at the bottom right hand side and the other at the bottom left hand side, contain the charcoal. It is followed by a rack which houses the mirror stainless steel oil collecting pan, which collects oil from the fish and it is drained away via the oil outlet at the back of the oven. Immediately above the oil pan is a set of 5 mirror stainless steel grids/racks (30fish per rack) which permits the oven to accommodate up to 150 fishes at a time. The rack makes it possible for air to circulate freely by convection from the bottom around the entire interior of the oven to facilitate drying.

The oven is also made up of double walled mirror stainless steel laminate fitted with an insulated handle to avoid burns, and it has set of flexible hinges to allow for 180^o swing of the door. The double wall of the oven casing creates a vacuum which minimizes heat loss by conduction and convection from the drying chamber (Poh Liong Yong, et al 2002). The temperature gauge is fitted on the door and the door allows for the selection of oven temperature, alarms and other operational parameters. The oven operates from room temperature up to a maximum temperature of 350^{o}C.

2.2. Materials

The main material for the fabrication of the 150 capacity fish dryer is mirror stainless steel metallic sheet//pan, square frames and ribs for racks/grids, all of which is mirror metallic stainless steel. All the materials were obtained from Araria metal spare parts market, Aba, Nigeria The oven

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measures 126cm high, and the width and breath are 76cm and 60cm respectively (with internal dimensions of 120height, 70cm width and 54cm breath respectively). The mirror stainless steel pan was selected because of its reflective property that allows heat to be reflected and retained in the drying chamber for effective heat concentration and drying as illustrated in schematic in Figure 1.

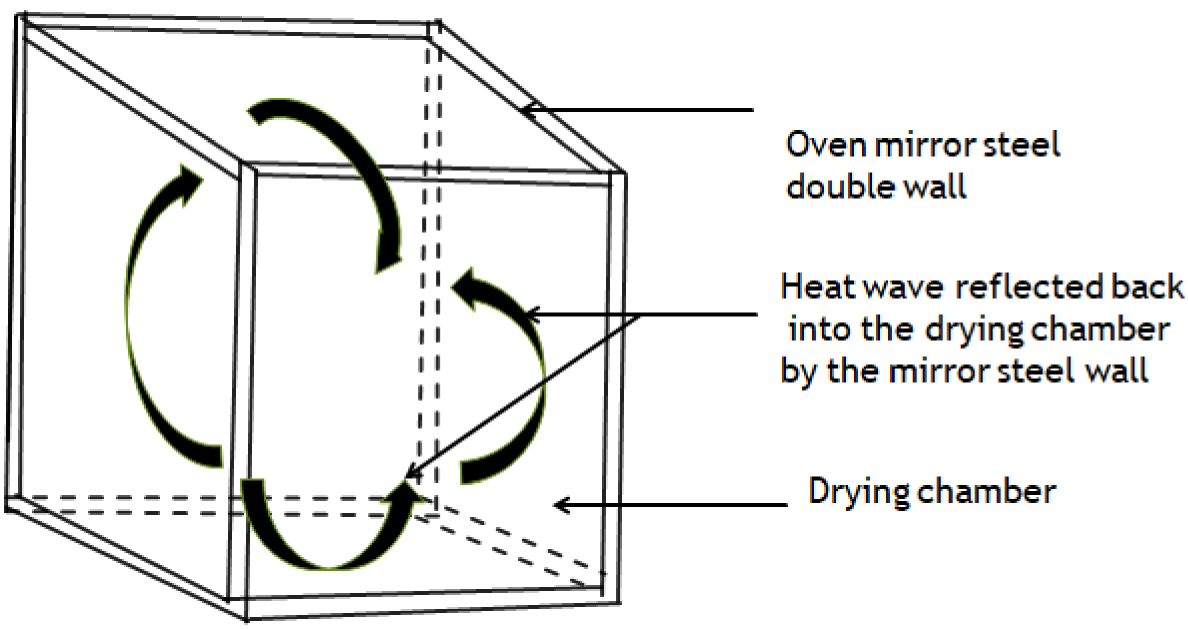

Figure 1 Reflection of Heat wave from the oven walls

2.3 Drying Chamber

The drying chamber consists of 5 set of mirror stainless steel grids/racks spaced 15cm from each other. Each grid is carefully welded into a net or mesh with mirror stainless steel ribs, and it is removable by sliding through the angle channels provided at the two sides. Each grid/rack is capable of accommodating 30 fishes (whether tilapia or cat fish). The grid steel ribs and the meshed or netted grid is as shown in Figure 2

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Steel ribs   Formed and netted rack/grid

Figure 2 Stainless steel ribs and the netted grid

2.4 The Frame

The frame of the oven is made up of four vertical stainless steel pillars (mirror reflective as well). The pillars are 40mmx40mm square pipes of thickness 1½" .The top and bottom of the oven are welded with 30mmx30mm square steel pipe (also mirror reflective) of 1½" thickness to form the rectangular column of the oven.

The external body of the oven, both the door is made with double mirror stainless steel pan which is skillfully welded to the square frames. The door is fitted on two stainless steel flexible hinges that makes for 180^{o} opening to allow for unrestricted access the oven space.

2.5 Heat Source

The oven can operate two sources of heat, the gas burner and the charcoal burner. Both of the heat sources can burn simultaneously or one at a time, depending of available fuel and the level of drying required.

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2.5.1 Gas Burner

This is the common industrial kitchen burner incorporated with temperature control knob. It is fitted at the central bottom of the oven which allows the generated heat to be evenly distributed upwards across the whole space of the oven for effective drying. The gas burner is as shown in Figure 3

Figure 3 Gas burner and Temperature control knob

2.5.1 Charcoal Burner

The charcoal burner is made up of two chambers of hardened mirror stainless steel rectangular bowls measuring 57cm length by 22cm width and 12cm deep. They are positioned at the bottom left and right corners of the oven, which are loaded to capacity with charcoal for maximum drying.

2.6 The Oil Collector

The oven is fitted with a sliding tray slightly below the last grid/rack. Its function is to collect the oil that drains off the fish. It is designed bevel and at the extreme right corner it is fitted with exit

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from where, the oil drops off.

2.7 Design Parameters and Considerations

In the design of the oven, various parameters were taken into consideration, which form the basis for the design solution. These include the capacity of the oven, N (average numbers of fishes it can dry at a time), the drying rate, *Dr*, (in terms of moisture content it dries at a given time), and the energy requirement, Q for (both gas and charcoal).

2.7.1 Drying Capacity

In the design for the capacity of the oven, a market survey was done by collecting some of the common sizes of cat fish and Tilapia, and they were used as samples for design and fabrication of the oven.

Feature of the Fish Sampled

Average mass of fish = 0.57kg

Average length of fish, L = 210mm

Average width of fish, B = 60mm

Average thickness of fish = 46mm

We determined average number of fish that can be accommodated per time in one rack/grid.

Each rack/grid measures 70cm x 54cm (*Lr* X *B*r).

Since the distance between one rack and the other is quite large, we only consider the horizontal are available to accommodate the fish rather than the volume of the rack in deriving the capacity of each rack.

The quantity of fish in numbers is determined by the equation 1

$$X(LxB) = LrxBr \quad \ldots 1$$

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Where, X = expected capacity of each rack, (no. of fishes)

L = average length of fish

B = average width of fish

Lr = length of rack/grid

Br = width of rack/grid

Inserting the known variables into equation one gives:

$$X(210mm \ x \ 60mm) = 700mm \ x \ 540$$

Hence,

$$X \ = 378{,}000/12{,}600$$

$$X \ = 30 \text{ fishes/rack/grid}$$

Therefore, the 5 racks/grids of the oven would carry (30x5) fishes = **150 fishes = N,** which is the total capacity of the oven.

2.7.2 Oven Drying Rate, *Dr*

The drying rate of the oven in terms of the average moisture content it can dry out of the fish is determined by analyzing the variable data from the collected fish samples into equation 2.

$$Dr = \frac{dM}{dt} = \frac{Change\ in\ Weight}{Drying\ time} = \frac{Mo=Md}{t} \text{ (Adesoji, 2014)…………………2}$$

Where,

Dr is the drying rate , which is taken in g/h due to sensitive nature of scale.

Mo = original weight of fish(g)

Md = weight of the dry fish (g)

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t = time taken to dry the fin (h)

dM = change in weight of fish

dt = change in time while drying

2.8 Energy Requirement

2.8.1 Quantity of Natural Gas

The amount, or quantity of energy from natural gas, Q needed for the combustion is given by the equation 3

$$Q = ma(Ho - Hf) \qquad \ldots 3$$

Where,

Q = amount of heat energy required (KJ/s)

ma = mass flow rate of natural gas (Kg)

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Figure 4 Picture View of the Fabricated Oven

3.0 Results and Discussion

From the testing of the oven using common catfish and tilapia, the average drying rate for Catfish was 1.90/h- 6.0g/h, while that of Tilapia was 1.2g/h – 4.5g/h. The total capacity of the oven as determined is 30 fishes (Catfish or Tilapia). The results show that the double wall reflective nature of the oven had significant advantage in the drying rate and quality of the dried fish as the drying rate is record high and the appearance of the dried fish very good with high shelf life. Therefore the oven performed effectively by creating high fuel efficiency as heat loss to the surrounding by conduction and convection is significantly eradicated. However, the design did not incorporate any means of heat transfer from the generating zone to the drying area by way of Fan or any suction device. This is therefore a area for improvement which will further enhance the drying efficiency through increased heat transfer. The operation of the oven justifies the objectives of the fabrication

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of the machine by showing that an oven with mirror stainless and double walls enhances drying efficiency. It is also an oven of choice as users can operate it with any available fuel sources (gas and charcoal) as compared to other ovens with only one fuel option.

4.0 Conclusion

The Fabrication of a mirror stainless steel fish drying oven with double as presented by this paper proved to be the technology of this present time, useful for preserving fish and sustaining fish production in Nigeria. The machine is energy-efficient and requires very low maintenance. The oven is durable and has long lifespan as all the parts are made with stainless steel, which is resistant to all oxidation activities posed by heat, moisture and oil drain for the fish. The test carried out with samples of Catfish and Tilapia proved that the machine performed efficiently with little room for improvement in area of control of heat transfer as observed earlier.

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