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RESEARCH ARTICLE

Drying rate analysis of three fish species dried using an amendedbiomass (charcoal) dryer

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ABSTRACT

This study was on improved design and development of a convectional biomass (charcoal) fish dryer. The dimension of the dryer was 600 mm x 600 mm x 800 mm with a truncated pyramid connecting duct that conveyed and dispersed hot air over trays. The dryer was evaluated by drying Nile Tilapia, Giraffe Catfish, and Mud Catfish. The data were analyzed using, Statistical Package for Social sciences (SPSS) version 25.The Nile Tilapia moisture content was reduced from 77.13 to 12.98% wb for six hours, the Giraffe Catfish moisture content was reduced from 79.31 to 13.26% wb for six hours while the Mud Catfish moisture was also reduced from 81.07 to 13.25% wb for eight hours. The charcoal was fed into the charcoal chamber as one Kg per hour with a maximum temperature of 130ºC. The maximum drying rate was 134 g/h recorded during the Giraffe Catfish drying. The sun-drying took 26 hours to reduce the moisture content of Nile Tilapia from 77.34 to 22.06% wb, the Giraffe Catfish moisture content was reduced from 78.86 to 26. 08% wb while the Mud Catfish moisture content was also reducing from 81.03 to 31.26% wb.

Keywords: Charcoal, drying, fish, rate, sun

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INTRODUCTION

Drying is one of the oldest and cheapest food preservative methods according to food preservative history. Science and technology have upgraded some aspects of drying operation and it remains the most widely used method of food preservation. The drying process is a heat and mass transfer phenomenon. Due to the application of heat energy, moisture veers from the inner part of the product and moves to the surface from where it is evaporated by diffusion. Heat transfer occurs to change the temperature of the product to be dried while mass transfer occurs when moisture is removed from the produce. Food drying reduces the surplus waste of produce; make it lighter, smaller and easy to handle in terms of transportation. To achieve a successful drying, careful attention must be given to the supply of heat to the product in order not to cook or surface cake the product being dried and the adequate dry air circulation to release moisture from the drying chamber. Food spoilage is a common problem that affects a wide range of people even from developed countries (Arena et al., 2012).

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There are two common methods of drying namely: Open-air/ direct sun-drying and Enclosed container smoking or drying. Open-air/ direct sun-drying is probably the oldest method used for preserving fish and other foodstuffs such as meats, vegetables, cereals, etc. and is used in the developing countries because it is the simplest and cheapest method of preserving fish (es).

This traditional/open-air drying method involves the spreading of produce on the ground or a rock in the open air/sun or on a local stone stove for smoking. Some disadvantages of open-air/sun drying pointed out are: exposure of the fish to rain and dust, uncontrolled drying; exposure to direct sunlight which is undesirable for some foodstuffs; infestation by an insect; attack by an animal, etc.

However, there have been periods when climatic factors slow down the drying process such that grains and other fresh agricultural produce failed to dry properly in the fields (Axtell, 2002). In these circumstances, men have attempted to assist the natural process by artificially supplying regulated heat in an enclosed body to harness the drying process. The enclosed container drying is designing an enclosed compartment to restrict the flows of heat and the escape of moisture to facilitate efficient mass reduction. Also, the use of driers has not gained popularity in our developing countries. The reasons according to (Bassey, 1989) can be attributed to poor problem definition which makes the developed dryers technically inadequate and economically unviable; inappropriate dryer designs due to the choice of construction materials; inadequate understanding of the operation of dryers and lack of design procedures.

In simplicity, most people designed dryers for most products without the knowledge of drying behavior of the product and engineering needs for the design in detail. These have caused most dried products to go with very low qualities.

There exists a period when climatic conditions slow down the drying process (Arena et al., 2012). In such a case, there is a need for a different source of heat or energy to help in supplying the required hot air for the drying purpose. The biomass and other energy sources set in to help continue the drying.

A dryer designed by Deepak (2013) was tested and the data showed that the bottom tray from where the hot air flows received the hottest air followed by the middle tray and the top tray respectively due to a narrow (10 cm diameter) iron pipe conveying the hot air from the charcoal chamber to the drying chamber. Other studies conducted by Engineering Toolbox (2003) and Green and Schwarz (2001) showed the uneven dispersion of hot air into these dryers due to the use of the iron pipes with a diameter of 10 cm to 15 cm. In all convectional dryer reviewed and even in the markets, designers used similar iron pipes of 10 to 15 cm in diameter as conveying duct. This design pattern has posted huge losses to farmers and the users of these dryers.

This improved convectional biomass fish dryer will help fish farmers by closing the gap between industrial drying techniques and the traditional sun-drying methods. The dryer will disperse hot air over trays with no significant difference statistically.

MATERIALS AND METHODS

Materials used for the construction of the improved dryer were plywood, aluminous sheet, stainless wire mesh, PVC valve, the fibre glass, metal sheet, binding wire, steel angle bar, and bearings.

The wire mesh was used for the trays while the plywood was for the construction of the dryer fitted with the valve at the bottom to discharge the oil out. The aluminous sheet was used within the dryer to retain or conserve the heat from been absorbed by the plywood.

The metal sheet was used for the construction of the charcoal chamber and the truncated pyramid connecting duct. The fibre grass was filled within the connecting duct since it was double. The steel angle bar served as the stand for the charcoal chamber and the dryer. The bearings were fitted within the charcoal chamber to aid the easy steering of the charcoal in releasing ashes.

Data collection

The experiment was conducted in Benue State University, Makurdi (7°41'N Latitude and 8°37'W Longitude) and the testing were done from the 15^{th} to the 27^{th} of July 2019. The samples dried were Nile Tilapia(*Oreochromis niloticus*), Giraffe Catfish (*Auchenoglanisoccidentalis*), and Mud Catfish(*Clariasgariepinus*), procured from Wadata Market in Makurdi Metropolis as freshly harvested from ponds and brought to the market. Proud to the drying process, the fishes were degutted, washed with clean water, salted with 50 g of table salt (NaCl) for 30 minutes(7).Fish were placed on a tray for draining of water for 15 minutes and loaded in the dryer while charcoal ignited into the charcoal chamber was connected to the dryer for heating. The parameters considered for data collection were initial mass, final mass, initial moisture content, final moisture content, quantity of oil extracted and also the quantity of charcoal burnt per sample drying. An empty dish was weighed and recorded as initial weight of dish. The oil extracted was discharged through the PVC valve to an empty dish which was weighed and recorded as final weight.

Drying rate

The drying rate is a fundamental parameter in the evaluation of the drying process. Olayemi (2012) evaluated the drying rate(Rd) as the decrease in the water concentration during the time interval between two subsequent measurements divided by time interval. In that direction, the drying rate(Rd) can be expressed as:

$$Rd = \frac{\Delta m}{T} \quad (12)$$

For the drying process, the initial moisture content is always greater than the final moisture content because the moisture is reduced. Therefore, the final moisture content is subtracted from the initial moisture content.

$$\Delta m = mi - mf$$

Where: Rd = drying rate, (kg/h)

Δm = Change in mass, (kg)

T = time interval, (h)

mi = initial mass, (kg)

mf = final mass, (kg)

There are two drying rates always discussed in the drying of produce. These rate periods are constant and falling rate. Meanwhile, the falling rate is a section in two stages known as the first falling rate and second falling rate.

Quantity of charcoal needed for combustion

To determine the quantity of charcoal needed for the drying process, the quantity of heat energy required is needed which is paramount in determining the quality of the product and also calculated as:

$$Q = maf\ (h_2 - h_1) \qquad (7)$$

Q = amount of heat energy in KJ/kg

m_{af} = air flow rate in Kg/s

H_1 = specific enthalpy of air at inlet in KJ/Kg

H_2 = specific enthalpy of air at the drying temperature in KJ/ Kg

The quantity of charcoal needed to be burned in the combustion chamber is now determined by the equation as (9):

$$Q_c = \frac{Q}{C_c} \qquad (8)$$

Where:

Q_C is the charcoal needed to be burned in Kg

C_C is the calorific value of charcoal in KJ/Kg (28.3MJ/Kg) = 28,300KJ/Kg

Source: Engineering Toolbox (2003)

Data analysis

Data reading were done in triplicate and results were subjected to formulae for computation. The results are presented in graphs.

RESULTS AND DISCUSSIONS

Drying rates profile for the improved convectional fish dryer and open sun drying per species

The drying rates profile for sun-dryingis illustrated in Figure 1 against the various time taken to dry the products. The 3 species dried by the sun-drying had a similar pattern of moisture removal since they were subjected to the same atmospheric condition at the same hours. The initial drying rates were 18, 15 13 g/h while the final rates were 4, 5 and 2 g/h for Nile Tilapia, Giraffe Catfish and Mud Catfish during the 1st and 26th hours of drying for the species respectively. The drying rate initially started with 119, 76 and 79 g/h for Nile Tilapia, Giraffe Catfish and Mud Catfish respectively and ends with 2, 2, and 1 g/h respectively. The steepest slopes were observed in the dryer for the three species between the 3rd and 4th hours of drying. The dryer took 6 hours for Nile Tilapia and Giraffe Catfish while the Mud Catfish took 8 hours. The sun-drying took 26 hours for both 3 samples but still could not attain safer moisture content until the samples spoiled. The performances indicated from the drying rates between the sun-drying and the improved dryer consented that the improved dryer performed better than the sun-drying of the samples.

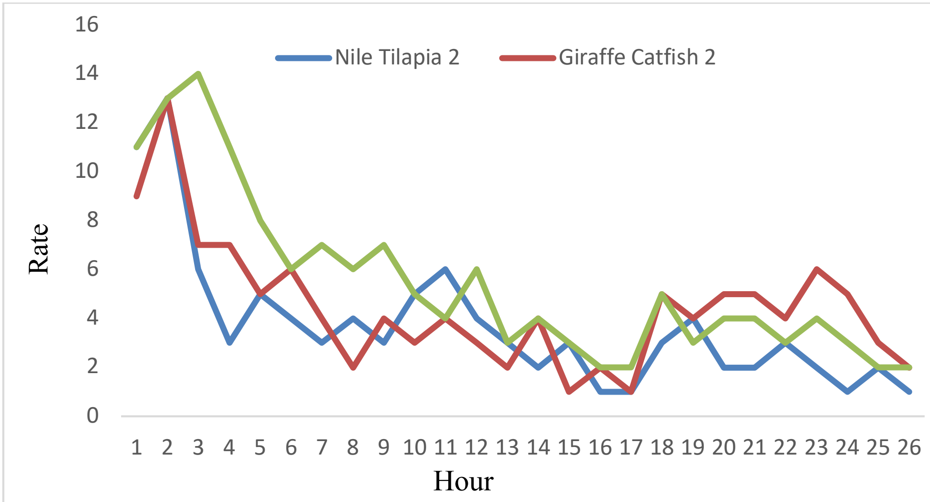

Figure 1: Drying rate profile for open sun drying of three fish species

The drying rate profile for the improved dryer is shown in table 2 against the hours. The results indicated that the Nile Tilapia drying rate started from 107 g/hr and rose to 119 g/hr. The rate gradually declined to 109.33 g/hr during the third hour and steeply declined to 16.33 g/hr as indication that mass of water was sharply reduced. The final drying rate was recorded as 1.67 g/hr.

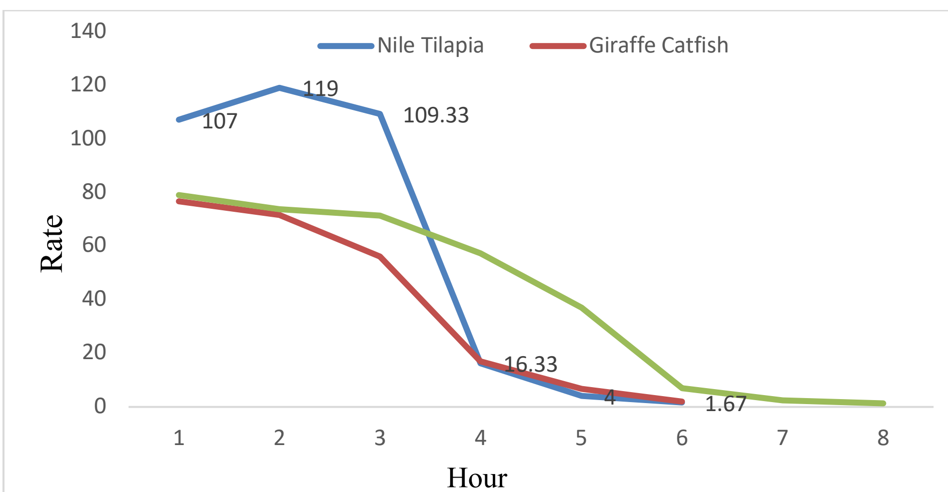

Figure 2: Drying rate profile for the improved convectional fish dryer of three fish species

Quantity of charcoal burned

The charcoal burned was loaded on an hourly basis as 1 kg for every hour. This was to minimize the quantity of heat to avoid burning. The dryer was pretested per charcoal to evaluate the quantity of heat being generated into the dryer. The charcoal burned was 0.5 Kg per 1 hour had a maximum temperature of 61ºC, 1kg burned also had a maximum temperature of 130ºC while 1.5 kg had 215ºC for the same 1 hour inside the dryer as reported by a previous researcher (Kituu et al., 2010). From these outputs, the researcher used the 1 kg to experiment. Therefore, the Nile Tilapia and Giraffe Catfish dried for 6 hours each, burning 6 kg of charcoal for each sample while the Mud Catfish dried for 8 hours, burning also 8 kg of charcoal.

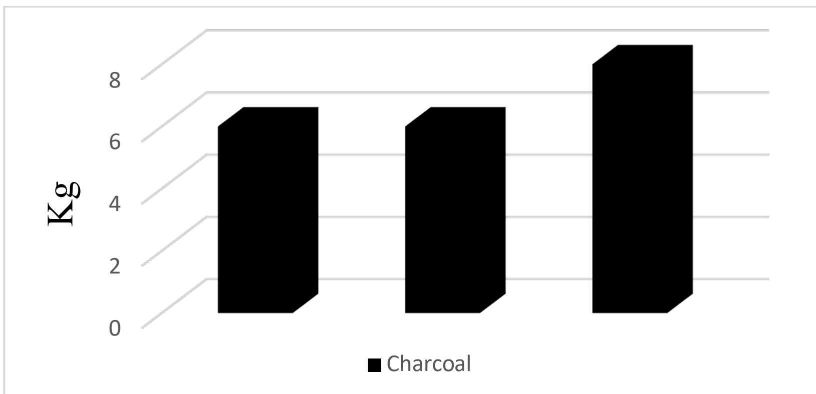

Figure 3: Quantity of charcoal burned

CONCLUSIONS

The 3 species of fish dried by the sun-drying method had a similar pattern of moisture removal since they were subjected to the same atmospheric condition at the same hours and location. The initial drying rates were 18, 15 13 g/h while the final rates were 4, 5 and 2 g/h for Nile Tilapia, Giraffe Catfish and Mud Catfish during the 1st and 26th hours of drying for the species respectively. The steepest drying rate slopes were observed in the dryer for the three species between the 3rd and 4th hours of drying. The dryer took 6 hours for Nile Tilapia and Giraffe Catfish while the Mud Catfish took 8 hours to be dried. The drying rate profile for the improved dryer is shown in table 2 against the hours. The results indicated that the Nile Tilapia drying rate started from 107 g/hr and rose to 119 g/hr. The rate gradually declined to 109.33 g/hr during the third hour and steeply declined to 16.33 g/hr as indication that mass of water was sharply reduced. The final drying rate was recorded as 1.67 g/hr. The charcoal burned was loaded on an hourly basis as 1 kg for every hour. This was to minimize the quantity of heat to avoid burning. The charcoal burned was 0.5 Kg per 1 hour had a maximum temperature of 61ºC, 1kg burned also had a maximum temperature of 130ºC while 1.5 kg had 215ºC for the same 1 hour inside the dryer. From these outputs, the researcher used the 1 kg to experiment.

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