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RESEARCH ARTICLE

Efficiency analysis of an improved biomass (charcoal) dryer constructed at the Center for Food Technology and Research, Benue State University, Nigeria

James Flomo Gaydaybu[1,2], Orseer Achimba [1,3], Ifeyi Udefi[1,4], Mobolaji Rasheed Nuredee[1], Coolaid Aham Obahi[1,5], Geoffrey A. Tsenzughui[1], Solomon Ujah[1]

[1] Centre for Food Technology and Research, Benue State University Makurdi, Nigeria
[2] Bong County Technical College, Gbarnga, Liberia
[3] Benue State Agricultural Research Development Authority, Makurdi, Nigeria
[4] Nigeria stored Products Research Institute, Lagos, Nigeria
[5] University of Jos, Plateau State, Nigeria

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ABSTRACT

The dryer was evaluated by drying Nile Tilapia, Giraffe Catfish, and Mud Catfish all procured from the Wadata market, Makurdi Metropolis. The data were analyzed using, Statistical Package for Social sciences (SPSS) version 25, Analysis of Variance (ANOVA) Post hoc Games Howell and Fisher's Least Significant Difference (F-LSD) tests and means were also separated at 95% confident interval. 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 using the Improved Dryer. The charcoal was fed into the charcoal chamber as one Kg per hour with a maximum temperature of 130°C. The maximum drying rate was 134 g/h recorded during the Giraffe Catfish drying and the dryer mean efficiency was 69.25%. The maximum relative humidity was 76%while also the maximum ambient temperature was 40°C. The data analyzed showed that there were no significant differences in the temperature means per tray statistically. 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. The sun-drying couldn't dry the samples to recommend safer moisture content for fish.

Keywords: Drying, efficiency, biomass, fish and moisture

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INTRODUCTION

Agricultural produce harvested are vulnerable to deteriorations due to the high moisture content present in them. Microorganisms take advantage of these high moisture contents and by invade the produce causing damages and food spoilage. Food scientists have found out that by reducing the moisture content of produce between 10 to 20 percent will

* *For correspondence*: J. F. Gaydaybu (Email: jfgaydaybu@gmail.com)
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prevent the produce from spoiling. According to the Merriam Webster dictionary, drying is “having no or very little water or liquid” and also the World Web dictionary defines drying as “to remove moisture from”. Drying is one of the oldest and cheapest food preservative methods according to food preservative history. 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).

MATERIALS AND METHODS

Materials

The materials used to conduct the research experiment were fish and charcoal. All were procured in Makurdi Metropolis, Nigeria.

Instrument used for data collection

The instruments can be analog or digital apparatus that will be used for collecting reliable data. The parameters considered for the evaluation of the dryer included the weight of materials to be dried, moisture content of the sample, the relative humidity of the testing environment and temperature (both inlet and outlet). The weighing scale was for measuring sample weight (g). The moisture meter was to measure the moisture content of the sample before and after drying. The hygrometer also for measuring the relative humidity of the environment and the thermometer is for measuring temperature.

Data collection

The experiment was conducted in Benue State University, Makurdi (7°41'N Latitude and 8°37'W Longitude). The tests were done from the 15th to the 27th of July 2019. The samples dried were Nile Tilapia (*Oreochromis niloticus*), Giraffe Catfish (*Auchenoglanis occidentalis*), and Mud Catfish (*Clarias gariepinus*), all procured from Wadata Market, Makurdi Metropolis, as freshly harvested from ponds and brought to the market.

A pre-trial test was carried out to determine the quantity of charcoal to be fed into the charcoal chamber hourly that would produce a temperature range safe for drying fish. And one Kg of charcoal was accepted with a maximum temperature of 130°C.

Proud to the drying process, the fishes were degutted, washed with clean water, salted with 50 g of table salt (NaCl) for 30 minutes (Oyer et al., 2012) and finally washed with clean water. After the washing process, fish were placed on a tray for draining of water for 15 minutes. The charcoal was ignited into the charcoal chamber without been connected to the drying charcoal for the leased of smoke and later connected to the drying chamber to heat the drying chamber before placing the fish into the dryer. The empty trays were weighed, the samples were also weighed separately and later the samples were placed on trays for another weighing to confirm the mass of samples. The empty trays weights were subtracted from the weight of

trays with samples and recorded as an initial mass of the sample. The loaded trays were removed from the drying chamber hourly, weighed and the initial empty weight of trays were subtracted from the loaded weight according to tray number.

The parameters measured for data collection were initial mass, final mass, inlet air temperature, outlet air temperature, temperature over each tray, ambient temperature, relative humidity, the mass of charcoal loaded and volume of oil extracted per sample.

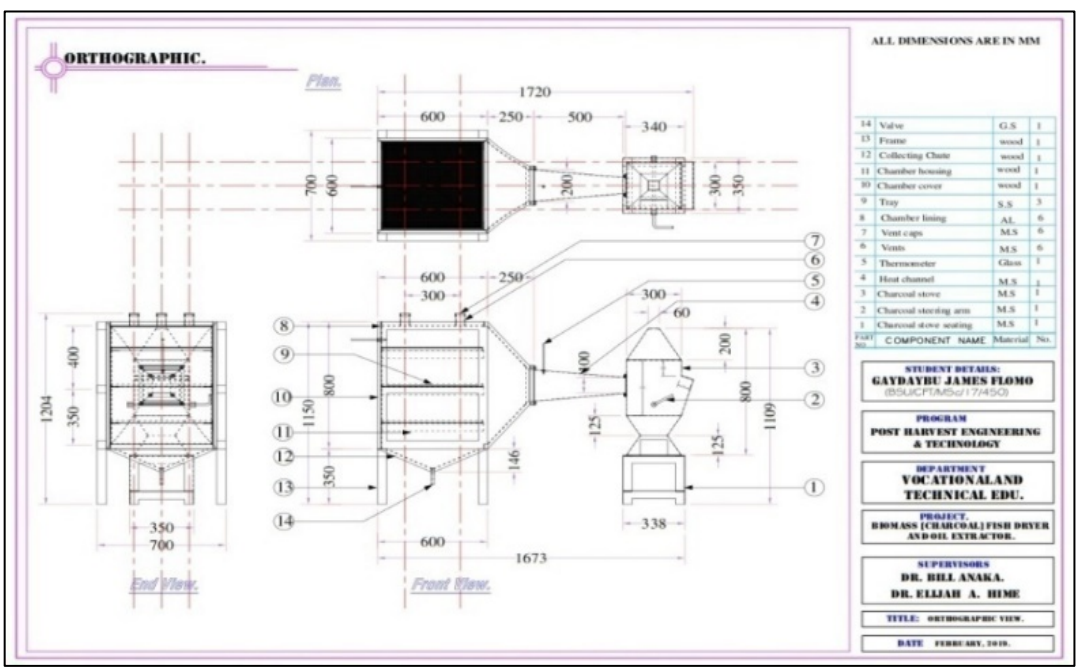
The tests were divided into three phases as a Pre-trial Test, Dry Performance Test (DPT) and Wet Performance Test (WPT). The pre-trial test helps to determine the quantity of charcoal burned hourly in respect to the quantity of heat produced, the DPT was to check the performance of every component of the equipment without raw material and was conducted for longer hours and the WPT was the test runs when the equipment was loaded with raw material to produce products.

Data analysis

The data collected were subjected to the formula given as $\eta d = \frac{t_1 - t_2}{t_1 - t_a} x\, 100$ where ηd is dryer efficiency, t_1 is inlet air temperature, t_2 is the outlet air temperature while t_a is the ambient temperature (Brennforfe et al. 1987) and (Dhanushkodi, Watson and Sudhakar, 2015).

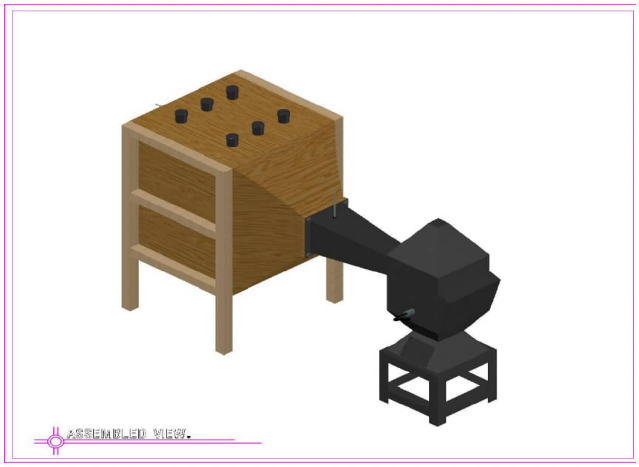
Working Drawing and Structural View of Project

This section gives the pictorial views of the drying chamber and the charcoal chamber. All software designs were done using Auto-CAD, version, 2007.



Assembly/ Practical View of the Project

The viewing of the proposed dryer is showing with the parts designed using AutoCAD version 2007 software.



RESULTS AND DISCUSSION

Dryer Efficiency

The dryer efficiency was computed based on the inlet air temperature, outlet air temperature, and ambient air temperature. The efficiency of the dryer per fish species is illustrated in Figure 1. The Nile Tilapia had the highest overall efficiency value of 71.3%, and the Giraffe Catfish was 70.5% while the Mud Catfish was 66.8%. Initially, the Giraffe Catfish had a higher value than the Nile Tilapia but as drying progressed the dryer performed best for the Nile Tilapia. The highest efficiency value per drying time was recorded in the 3rd hour from the Giraffe Catfish as 77%. The researcher could not establish the fish drying efficiency per tray in that the outlet air temperatures were recorded directly from the dryer. As per evaluating the overall performance of this dryer efficiency, the efficiency value was 69.25% which signifies that the dryer performed better as compared with previous researchers (Ehiem et al., 2009).

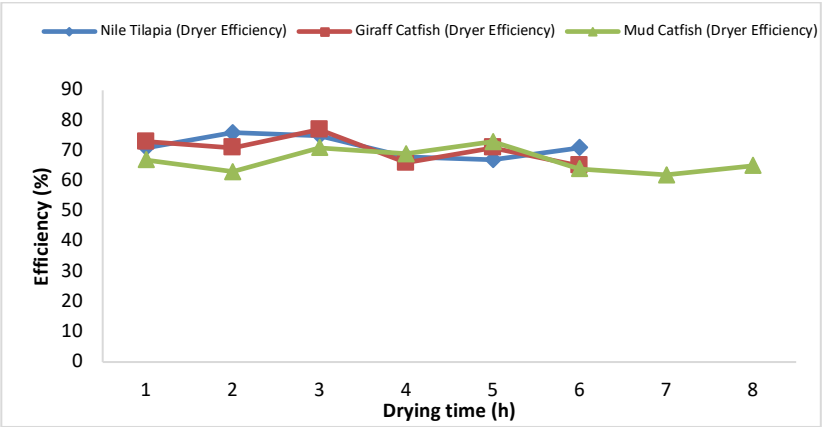


Figure 1: Dryer efficiency per species dried

Temperature Variation Profile and Relative Humidity for drying of Mud Catfish using Improved Dryer

The observations recorded are also shown in Appendix E and illustrated in Figure 2. The temperature recorded for the trays were fluctuating and increased gradually as shown in Figure 8. The maximum temperature was recorded as 105°C during the 5th drying hour in the top tray.

The bottom tray had the lowest temperature of 88°C during the 1st drying hour and gradually increased as drying time was increased as previously reported by Idi-Ogede et al. (2018). The following moisture contents were recorded on a wet basis for fish on tray 1, 2, and 3 as 83.04%, 80.76%, and 79.43% respectively. The fish were dried to the final moisture contents of 13.51%, 13.07% and 13.19% for tray 1, 2, and 3 respectively as consented with previous research conducted by Adamu et al. (2012). The relative humidity and the ambient temperature were shown an opposite trend. The relative humidity had a steep downward movement from the 1st hour to the 2nd hour of drying time from 62% to 41% respectively. During the 4th hour of drying, the lowest relative humidity was recorded as 40% and the highest was recorded as 63% during the 7th hour of drying. There was also a sharp upward movement from the 5th to the 6th hours of drying as recorded from 41% to 59% respectively. The ambient temperature had increased from 33°C to 39°C during the 1st and 4th drying times respectively and later continued to decrease until it reached 31°C during the 7th hour of drying as the lowest ambient temperature.

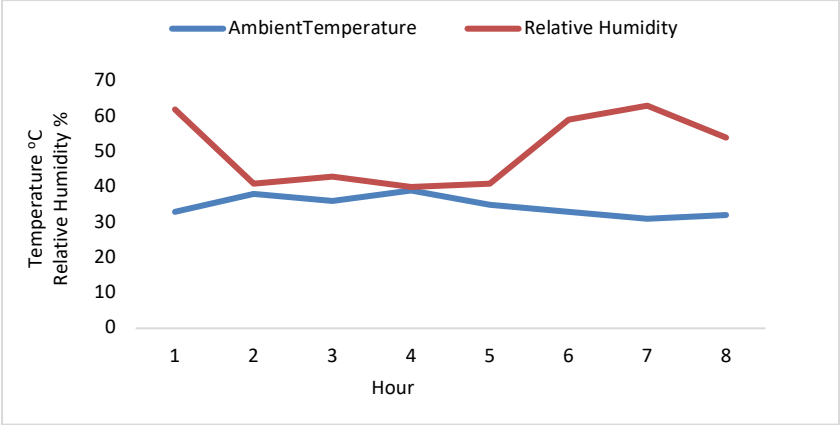


Figure 2: Hourly Ambient Temperature Variation and Relative Humidity for Mud Catfish drying

Temperature variations profile and Relative Humidity for drying Giraffe Catfish using Improved Dryer

The observations recorded are shown in Appendix D and illustrated in Figure 3. The lowest temperature reading was recorded from the middle tray as 91°C during the 2nd drying hour. The maximum drying temperature for the bottom tray was 97°C recorded during the 3rd and the 4th hours of drying time. The maximum drying temperature for the dryer during the Giraffe Catfish drying was 99°C recorded from the top tray during the 1st and 3rd drying times. The temperature variations between the 3 trays were waving in motion movement as the drying time was increased. The initial moisture contents were 79.07%, 80.05%, and 78.83% for fish on tray 1, 2, and 3 respectively on a wet basis. The products were dried to a final moisture content of 12.81%, 13.10% and 13.89% for tray 1, 2, and 3 respectively on the wet basis. These final moisture contents agreed with previous researcher's reports by Alakali et al. (2014) and Shallcross (2017).

The relative humidity and ambient temperature were giving opposite results as relative humidity increased the ambient temperature decreased. The relative humidity initially started from 54% to 79% during the 1st and 6th drying hours respectively. The ambient temperature started from 34°C to 25°C during the 1st and 6th hours of drying time respectively. The lowest ambient temperature was recorded as 24°C during the 5th drying time.

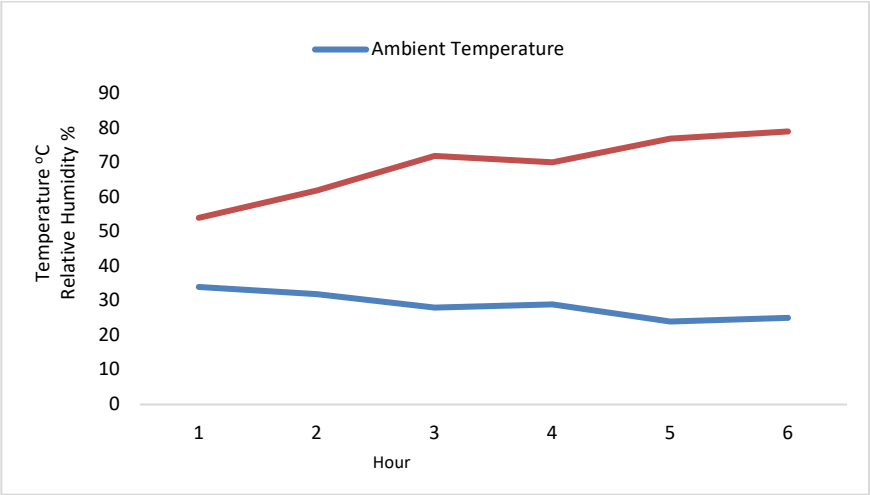


Figure 3: Hourly Ambient Temperature Variation and Relative Humidity for Giraffe Catfish Drying

Temperature Variations profile and Relative Humidity for drying Nile Tilapia using Improved Dryer

The initial mass of Nile Tilapia was 1,524 g which was reduced to 402 g within 6 hours. The observations recorded during the testing of the dryer with the Nile Tilapia fish are shown in Appendix C and illustrated in Figure 4. The results showed that the top tray had the highest drying temperature of 104°C during the 6th hour of drying time as compared with previous results from Hilderbrand (2001) and Ashaolu, (2014) while the lowest temperature was recorded as 87°C in the middle tray during the 2nd hour of drying time as a research result reported previously by Idah and Nwankwo, (2013).

The initial moisture contents were 76.31%, 78.07% and 77.02% for tray 1, 2 and 3 respectively on wet basis which were dried to the final moisture contents of 12.11%, 13.08% and 13.77% for tray 1, 2 and 3 respectively as agreed with a research conducted by Modibbo et al. (2014).

The lowest ambient temperature was recorded during the 1st hour of drying as 31°C while the highest ambient temperature was recorded during the 3rd hour of drying time as 37°C. As the drying time increased in the day the ambient temperatures were increasing gradually and later dropped to 33°C during the late evening. There were variations in the ambient temperature throughout the drying process of the Nile Tilapia as shown in Figure 4.

The maximum relative humidity was 67% at the 1st hour of drying and the minimum was 41% during the 4th hour of drying. As the ambient temperature increases the relative humidity decreases and 41% relative humidity was recorded as the lowest relative humidity for the entire drying time. Figure 4 shows the opposite movement of ambient temperature and relative humidity graphs.

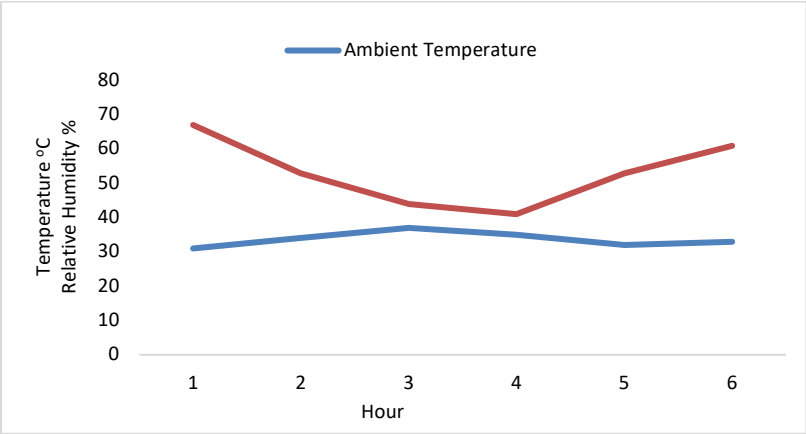


Figure 4: Hourly Ambient Temperature Variation and Relative Humidity for Tilapia Drying

CONCLUSIONS

The results of the present study showed that there were no significant differences in the temperature means per tray. 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. The sun-drying couldn't dry the samples to recommend safer moisture content for fish. The dryer efficiency was 69.25% rating its performance better among other dryers.

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