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DESIGN AND FABRICATION OF GRAIN DRYER UTILIZING CHARCOAL AS FUEL

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ABSTRACT

A grain dryer that uses charcoal as fuel was constructed. The dryer has three component parts namely: drying chamber, heating chamber and heat exchanger The dimensions of the dryer are; height 124.5cm, breadth 41.5cm and length 51.5cm respectively. The body of dryer was made with mild steel and lagged with paper and cotton material. Drying efficiency of the dryer was 63%, while the average drying rate was 0.12g/sec, with a moisture content reduction of 14.2% over period of 70minutes.

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INTRODUCTION

Drying is one of the best methods of processing agricultural products to prevent them from deterioration and wastage. It involves heat and mass transfer phenomenon brought about by the application of heat energy (Husain, 2008; Shafizadeh, 1981). Most grains such as maize, soybean, beans, groundnut, wheat, etc. are prone to deterioration a short time after harvest and therefore need to be preserved by drying to prevent spoilage. However ordinary unregulated sun drying of agricultural products leads to poor quality products with contaminations (Okoroigwe *et al* 2013; Ratti and Mugunda, 1997; Prasad *et al*., 2006). Grain in the field dries naturally as the crop matures, giving up moisture to the air until the grain moisture content is in equilibrium with the moisture in the air (Equilibrium moisture content) and cannot dry any further (Brooker et al 1974; Hall 2006; Nnolim 1998). However, there is need to use artificial dryers to help dry the grain to a safe moisture content level for storage. The length and time grain can be stored without significant deterioration is determined by temperature and the moisture content at which it is stored (Onwualu *et al* 2006).

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There is need for development of a mechanical equipment for faster drying of grains in Nigeria. The dryer should be simple and affordable to the farmers. According to Eke (1991), drying is one of the cheapest and appropriate methods for preserving agricultural products to keep them safe for some months beyond the peak period of harvest. Most available dryers use electricity which is irregular in supply or solar energy through use of solar panels which are expensive and imported (Akangbe *et al* 2013). Development of dryers using charcoal (which is readily available locally) as the fuel will be a better and cheaper means of drying grains in our country. Therefore, this research involves the design and fabrication of a grain dryer using charcoal as the fuel.

MATERIALS AND METHODS

Design Consideration: During the development of the dryer the following factors were considered; the environmental factors like temperature, the use of charcoal as heat source due to its affordability and availability, avoidance of contact of the grains with smoke for hygienic drying, fabrication with locally available materials, the drying chamber is to be designed for batch operation, so that the dryer can be operated by one person. The construction of the heating chamber for easy evacuation of ashes, the cleaning is also considered for quick escape of humid air from the drying chamber to prevent condensation of vapour within the drying chamber.

Description of Machine: The grain dryer consists of three 3 major functional units which are, Drying chamber, Heating chamber and Heat exchanger. (i) Drying Chamber comprises of 3 trays of dimensions 500mm x 560mm x 40mm (height), the temperature regulator is also incorporated in the chamber. The hot air inside the dryer absorbs the moisture from the grains being dried in the chamber and escapes through the air outlet (vent) of the drying chamber. This chamber is enclosed in a rectangular cabinet. The cabinet is made from mild steel plate and lagged with insulator material (cardboard paper and cotton material). (ii) Heating Chamber – this comprises the combustion device (burner) that produces hot air for the drying. The heat source is charcoal which is burnt within the chamber. The heating chamber produces hot air for drying to take place. The heated air in the heating chamber moves by natural drift through the space created between the walls into the drying chamber where the grains are placed. (iii)Heat Exchanger (Chimney) which comprises of the heat exchange pipe that conducts the smoke to the outdoor surroundings/environment. This is incorporated upward the chamber to aid continuous evacuation of the smoke generated by the combustion of the charcoal. It is made up of a cleaning pipe and cone to allow the passage of saturated hot air from the dryer. The walls of the dryer are insulated to prevent heat and energy loss. These units are presented in isometric and orthographic views in Figs 1 and 2. The materials specifications and quantities for construction of the grain dryer are shown in Table 1.

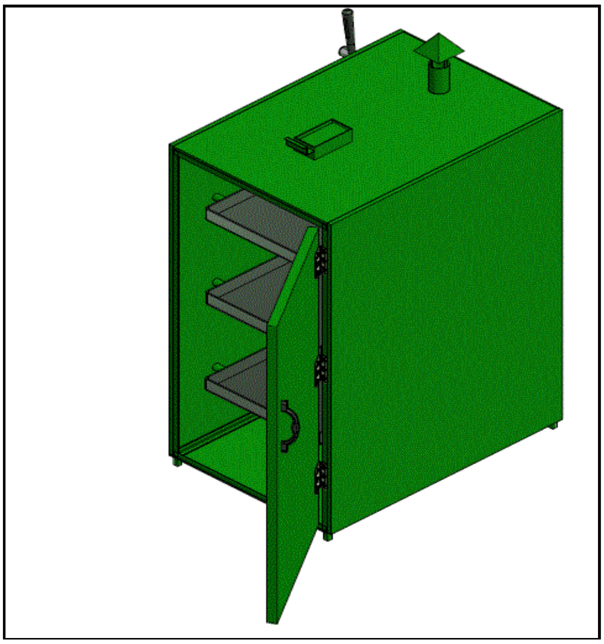

Fig. 1. Isometric Drawing of the Grain Dryer

Table 1. Materials and Specifications

Materials	Specifications	Quantity
Angle Iron	25 x 25mm mild steel	1
Square Pipe	25 x 25mm mild steel	1
Mild steel rod	8mm	½ standard length
Mild steel sheet plate	0.9mm thickness	2 ½ standard sheet
Lagging material	Cardboard paper/cotton	3kg
Pair of hinges	75mm size	1
Bolts and nuts	M18	22
Galvanized pipe	Φ 12mm	1
Painting	Finishing paints	3litres

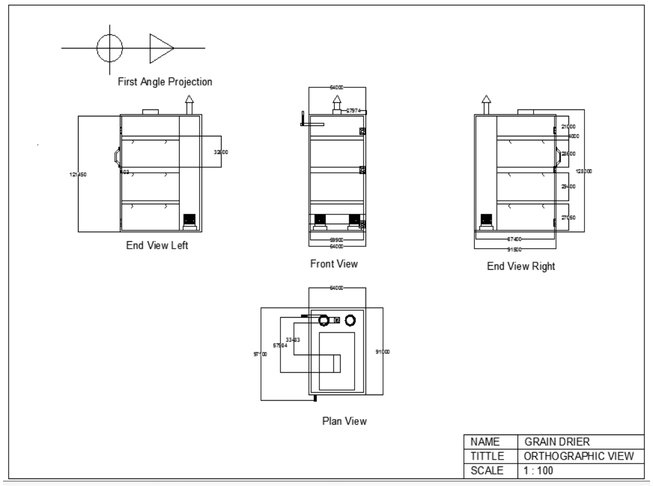

Figure 2. Orthographic View of the Grain Dryer

Fig 3: The Fabricated Grain Dryer

Design Equations and Calculations

Component Design determination

Size of the Grain Dryer: The respective sizes of the components are calculated with the following equations given by Khurmi and Gupta (2008);

For Heating Chamber: Volume (V) =1xbxh.
For Heat Exchanger Pipe (Chimney) Area (and Volume =
For Drying Chamber: Area,

Where A= Area, b=Breath, l=Length, h=Height, V=Volume, r=Radius and π=3.142

Moisture Content Determination

The moisture content of the grain is calculated with the relationship given by Babatunde 1997, as;

The weight loss during drying is given as;

Where; =the moisture content on wet basis (%)
= the initial weight in grams (g)
= the final weight in grams (g)
= the initial moisture content, w.b (%)
=the final moisture content, w.b (%)

Operational Principles: After the design, the machine was fabricated in the Workshop of Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture Umudike, Nigeria, Strict adherence to design details were done during the fabrication. The dryer is designed to utilize charcoal to generate heat energy for drying grains for local farmers. The burner (charcoal chamber) heat up the air surrounding the heating chamber (made with mild steel plate). This hot air travels by means of natural convection. There is a demarcation between the back side of the drying chamber and the heating chamber. Humidified air or saturated vapour generated in the drying chamber as a result of pressure build up escapes through the (vent) opening of the chimney at the top of the dryer. During operation, the combustion chamber is filled with about 4.05kg of charcoal, compacted and ignited. The trays are set in position and the door of the dryer is closed. After some time, the initial charcoal load is replaced with a new charcoal. During the process moisture of the grain is reduced gradually.

RESULTS AND DISCUSSION

Test Procedure: The dryer was tested on the basis of output capacity, temperature increase with drying time and moisture loss over time.3.5kg of groundnuts was purchased from Ndoro Market in Ikwuano Local Government Area of Abia state. These were weighed prior to drying using a digital weighing balance Cammry ACS-50. The groundnuts were loaded on the trays inside the chamber and dried. The drying was achieved by spreading them on the drying trays in the drying chamber. The initial weight and the final weight were recorded at every 10 minutes' interval of drying. From Figure 4, the ambient air temperature fluctuates and not on steady state, as the time of drying increases, the ambient temperature decreases. Figure 5, shows the variation in temperatures with time. Here, the drying chamber temperature are found to be highest at peak of drying time thus there is rise in temperature of the drying chamber as a result of rapid and faster drying rate on the dryer. This is in agreement with the findings of Keey,1978.

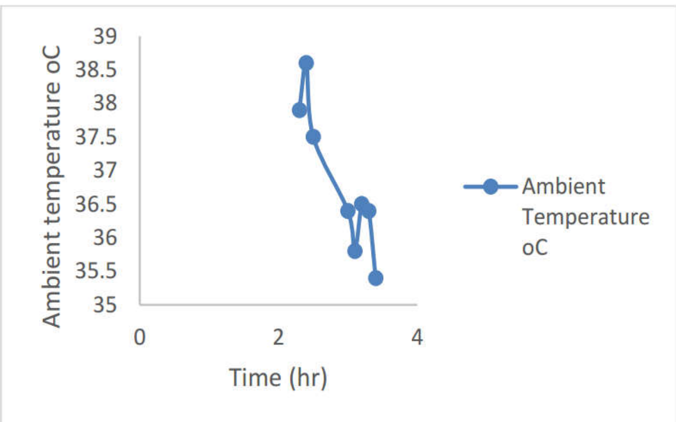

Fig. 4. Variation in Ambient temperatures and Time

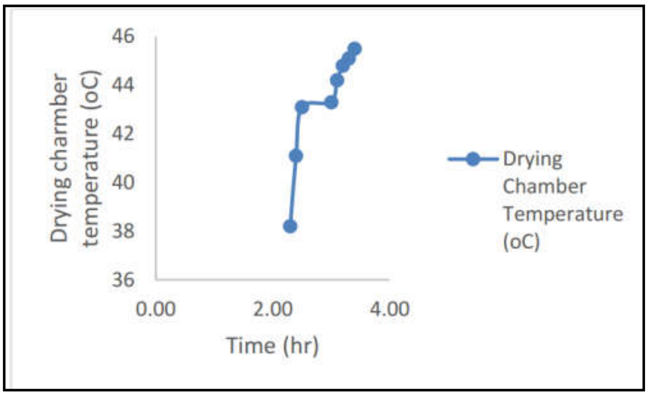

Fig. 5. Variation in Drying Chamber Temperatures and Time

Figure 6, shows the variation in the weight of the groundnuts with time. It was found that the drying time rapidly increased as the weight of the product decreases. This is in line with the findings of Eke, 1991. Here reduction in moisture depends on the time of drying. Figure 7, shows the variation in weight and drying chamber temperature. Here, it was found that the drying chamber temperature increases as the weight of the product decreases which tends to facilitate the drying process of the product.

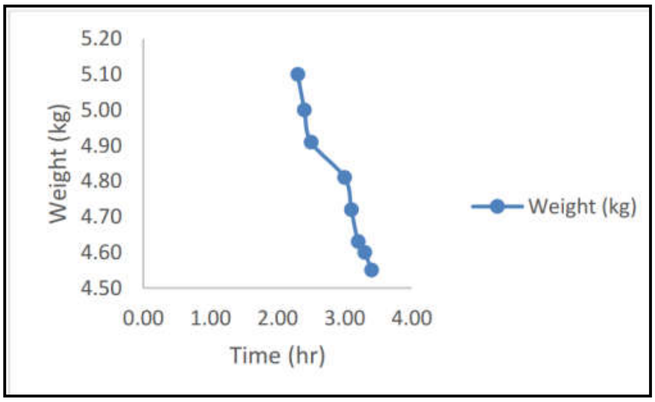

Fig. 6. Variation in Weight and Time

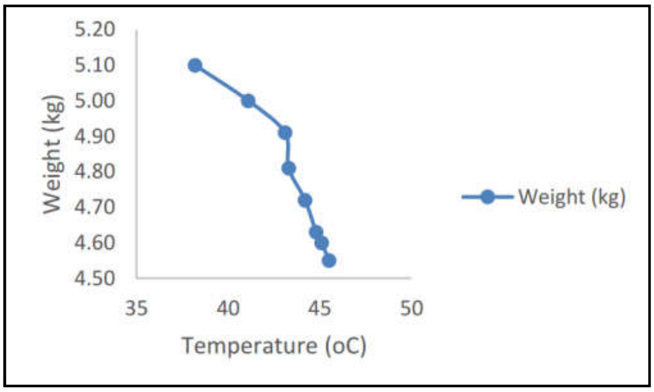

Fig. 7. Variation in Weight and Drying Chamber Temperature

Drying Efficiency

This was calculated from test results as follows using the method of Keey 1978;

$$DE = \frac{heat\ generated - heat\ lost}{heat\ generated} X \frac{100}{1}$$

$$= \frac{8055.6 - 3012.6}{8055.6} X \frac{100}{1}$$

$$= \frac{5042.98}{8055.6} X \frac{100}{1}$$

$$= \frac{504298}{8055.6}$$

$$= 63\%$$

Conclusion

In this work, a grain dryer that utilizes charcoal as fuel was developed and tested. The fabrication of the dryer does not require sophisticated technology. It also has low maintenance cost. The dryer was tested and the following conclusions were drawn: the developed grain dryer dries faster than sun drying. After I hour 10 minutes of drying, the initial and final weights of groundnuts obtained were 3.5kg and 3.0kg respectively (drying rate of 0.12g/sec) and a drying efficiency of 63% was calculated, while the moisture content reduced by 14.2%. Therefore, this grain dryer will be a veritable option for adoption by small and medium scale farmers in Nigeria to help reduce post-harvest losses and increase the nutritional values of agricultural products.

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