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Development of maize– on – cob dryer for small scale farmers

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ABSTRACT

A maize-on-cob dryer was designed, fabricated and evaluated at the Agricultural and Biosystems Engineering department, Landmark University, Omu-Aran, Kwara state. The main objective of this research was to utilize maize residues as source of heat for maize drying and ensure continuous availability of maize during off season. The dryer consists of a drying chamber, chimney, five trays, electric motor and fan and corn waste container. The dryer contains five trays; each tray in the maize dryer was loaded with 2 kg of maize cobs and was dried at the interval of an hour with maize residue consumption rate of 1.5 kg/hr. It was evaluated for 7 hours within 3days to dry maize on cob from moisture content of 76.80% (wet basis) to 13.32% (wet basis) which is the safe storage moisture content for maize. Results of the evaluation showed that drying temperature was within the range of 42°C - 73°C.

Key words: *Maize on cob, Corn waste,* ***Drying****, Dryer, Evaluation*

Introduction

Maize (Zea mays L.) is a member of the grass family (gramineae). It originated from South and Central America. It was introduced to West Africa by the Portuguese in the 10th century (). Maize is one of the most important grains in Nigeria, not only on the basis of the number of farmers that engaged in its cultivation, but also in its economic and nutritional value. Maize is one of the most important cereal crops cultivated in the rainforest and the derived savannah zones of Nigeria (Oladejo and Adetunji, 2012). Maize has been in the diet of Nigerians for centuries, initially produced at subsistence quantity and has gradually become one of the most important crops. Maize is now grown to a commercial quantity on which many agro-based industries depend on as raw materials (Iken and Amusa, 2004; Oladejo and Adetunji, 2012). Maize is a staple food of great socio-economic importance in developing countries and it has a wide range of uses, these includes; baking, brewing industries and livestock feed. It is an important source of carbohydrates, protein, iron, vitamin, and minerals (Kudi et al., 2011). Despite the economic importance of maize to the teeming populace in Nigeria, it has not been produced to meet food and industrial needs of the country. This could be attributed to low productivity from maize farms or that farmers have not adopted improved technologies for maize production. (Onuket al., 2010).

Major steps involved in the processing of maize are harvesting, drying, de-husking, shelling, storing and milling **(**Nwakaire et al., 2011**)**. At harvest, maize usually contains too much moisture (about 20%-25%) which is a favorable environment for the growth of molds (fungi) and insects that normally cause grain damage. In order to avoid this, drying of the maize must be done to reduce the moisture content to about (11.8%-13%) for safe year-round storage (Folaranmi, 2008; Ndirika, 1988). Grain drying is the process for conditioning the grains for safe storage. Correct drying method preserves the quality, nutritive value and viability of grain. (Sahay, 2010).Over 90% of agricultural products are sun dried (Arinze et al., 1990). Ordinary sun drying of maize is very tedious, time wasting, having low hygienic level and has brought about reduction of nutritional contents such as vitamins in the dried maize as a result of it direct exposure to sunlight or more specifically ultraviolet radiation (Arinze et al., 1990). Also, maize harvested during the rainy seasons are usually sold at cheap prices to corn roasters and used for other delicacies (Folaranmi, 2008; Olutoye et al., 2012).Farmers loose considerable amount of food crops annually due to primary factors such as insect infestation, rodent attack, molding during storage and transportation, deterioration in quality and an increase in broken and cracked grains (Ndrika, 1988). Most dryer are too big and too expensive for farmers. Nigeria produces large quantities of maize yearly. Therefore, this project will ensure maize sufficiency during the scarce period and also help value better utilization of corn residues as source of heat and reduction in the dumping of corn residues on the farm.

Drying is a process performed for safe storage of food and feed stocks. It involves the removal of moisture from agricultural products or other materials to a predetermined level (Lawson, 2009). Drying is also a thermo-physical and physio-chemical operation by which the excess moisture from a product is removed (Sahay and Singh, 1994; Misha et al, 2013). Drying makes the food grains and other products suitable for safe storage and protects them against attack of insects, molds, and other micro-organisms during storage. Maskan (2001) asserted that improvement in product quality and process applications could lead to an increase in the market acceptability of dehydrated foods. A basic requirement for preserving quality of agricultural products is the control of moisture content during pre-processing storage. Most agricultural products must be dried to and maintain a moisture content of 12% to 14%, or lower, wet basis, depending on the specific crop and length of storage. For example, maize or corn must be dried to moisture content of 14 to 15% or lower for safe keeping (Kenneth, 2013; Igbeka, 2013).The main objective of this study was to design a maize dryer that will use corn waste as heat source.The specific objectives were to design, fabricate and evaluate the performance of the maize dryer.

Materials and Method

Machine Description and Working Principles

The maize dryer consists of a combustion chamber, drying chamber, a fan and a chimney at the top. It has five (5) trays; the size of the dryer was estimated based on the tray size. Maize cobs wereplaced on the trays and warm dry air was forced up through the heating element, the source of heat wascorn waste. The wall of the dryer was insulated with fibre glass to prevent heat loss. The heated air warms the maize and absorbs some of its moisture, and in turn the air was cooled. In this manner, drying proceeds until the desired level of moisture content is attain. Drying starts from the lower part of the drying chamber to the upper part, and when it reaches the upper tray, the maize is dry. Figure3 and Figure 4 show the isometric views of the maize-on-cob dryer respectively.

Components of the dryer

Drying chamber: It was constructed with mild steel metal plate. The overall dimension of the drying chamber is 610 mm x 610 mm x 1370 mm. It has an opening which was also made of mild steel lagged with fibre glass (Figure 3). The drying chamber houses other components such as the trays and corn waste container.

Drying trays:The dimension of the tray constructed is 570 mm x 570 mm x 30 mm. The frame of the trays was constructed with mild steel. The frame is square in shape and it has a 160mmx 160mm net hole used as the base of the tray (Figure 4).

Fan:The fan is an axial fan with rectangular shaped blades and the fan is powered by an electric motor of 1hp.

Heat Source/combustion unit: The combustion unit consists of the corn waste container and the air duct under the chamber. The total height of the combustion unit is 300mm. The lower surface of the corn waste container was perforated to facilitate ash release, which can be emptied regularly.

Methods

Design Considerations

The following werecarefully considered in the design of the maize –on-cob dryer for effective and reliable performance of its various components;

Selection of materials that are resistant to heat, corrosion, water proof, non-toxic and durable,

Use of locally available materials to reduce overall cost thereby making the dryer affordable to small scale farmers,

Provision of chimney that allows free escape of smoke from the drying chamber

The inner and outer wall of the dryer were painted and fully lagged to prevent loss of heat by conduction, convection and radiation,

Provision of fan, which serves as a heat distribution device to ensure even distribution of hot air in the drying chamber thereby ensures even drying of maize on cob during drying.

Design of the air ducts, combustion chamber and drying unit was based on the air flow requirements. The estimated air flow rate for combustion was 2.88 m^3/min and the estimated air flow for drying was 3m/min, the direction of airflow was upward

Design Calculations

Estimation of the capacity

The tray has a square cross section of length (L) and width (B) and depth of 30mm.The dimension of the tray was computed using the equation (1);

$$V = L \times B \times H \qquad (1)$$

Where; V= volume occupied by the grain (mm^3), L= length of the tray (mm), B=width of the tray (mm), H = height of the tray (mm)

Determination of bulk density of grain

Since the dryer would be used for different sizes weight of maize with cob. Each tray is expected to contain 2kg of maize cob. Volume of tray was assumed to be $9.747 \times 10^{-3} \mathrm{m}^3$

$\rightarrow$ bulk density $= \frac{\text{mass}}{\text{volume}} = \frac{2.0\ \text{kg}}{9.747 \times 10^{-3} \mathrm{m}^3} = 205.1913\mathrm{m}^3$

Estimation of the Airflow rate at the exit of the fan

The required air flow rate at the exit of the fan can be estimated using the relation;

$Q = A \times V \times n$ (2)

Where; A= cross sectional area (m^2), V = air velocity (m/min), n = no of fan blade.

Quantity of air required

$Q_a = \frac{M_w}{H_{r1} - H_{r2} n}$ (Adopted from Ajisegiri et al., 2006; Adamade and Olaoye, 2014) (3)

Where; H_{r1} = initial humidity ratio (kg/kg dry air), H_{r2} = final humidity ratio (kg/kg dry air), M_w = amount of moisture to be removed (kg)

Weight and dimension of the fan blades

The material of the blade is 20guage mild sheet metal. Blade shape is rectangular and the number of blade is 4. Fan should be axial.

Height of the blade = 70 mm, Length of blade = 300 mm

Weight of each blade can be calculated using the relation

$W = egV$ (4) (Adopted from Khurmi and Gupta, 2005)

Where; W = weight of material, e = density of material (7.83×10^3 kg/m^3), g = acceleration due to gravity, Thickness of blade = 0.163cm, Volume of blade =7.987cm^3

Weight of each blade = 0.61N

Total weight of blade = 4 x0.61 = 2.44N

Evaluation Procedures

Maize-on-cobs with husk were purchased and put in a plastic bucket and brought to the laboratory where they were transferred into a refrigerator in order to preserve and maintain their moisture content. Dried corn wastes were collected from Landmark University Teaching and Research farm. The initial moisture content of maize on cob and dried corn waste were determined using a moisture analyzer. The maize on cobs and the corn wastes were weighed differently using a weighing balance and loaded into the drying trays and corn waste container respectively. After which the corn waste was ignited and allowed to turn red hot, before placed in the combustion chamber. The fan was switched on so as to avoid condensation and allow easy circulation of heat in the drying chamber. The temperature of the chimney chamber, drying chamber and combustion chamber were taken at interval of an hour respectively using a thermometer. The final moisture content, final weight of maize after drying and time required for complete combustion were recorded.

Results and Discussion

Results

The results of this study was subjected to analysis of variance (ANOVA) while significant means were separated with the Duncan's Multiple Range Tests using SAS (2005) on the mean values obtained from the experiment in order to compare the mean drying rates of maize on cob samples at the drying temperature used. The analysis showed that all the parameters have significant effects on the drying rates at 5%.

Discussion

Fig. 1 shows the relationship between moisture content and time. It was observed that the final moisture content (wet basis) reduced as the time of drying increased. This showed that as the moisture content (wet basis) in the maize-on- cob decreased, it attained only a falling rate during the drying period. Drying continued till the rate of evaporation of water from the maize-on-cob reaches critical moisture content (wet basis). The moisture removed with increase in drying time increased initially because of the high moisture content (wet basis) of the maize, which after sometime, the rate of moisture removed decreased due to reduction in the maize-on –cob moisture content (wet basis).

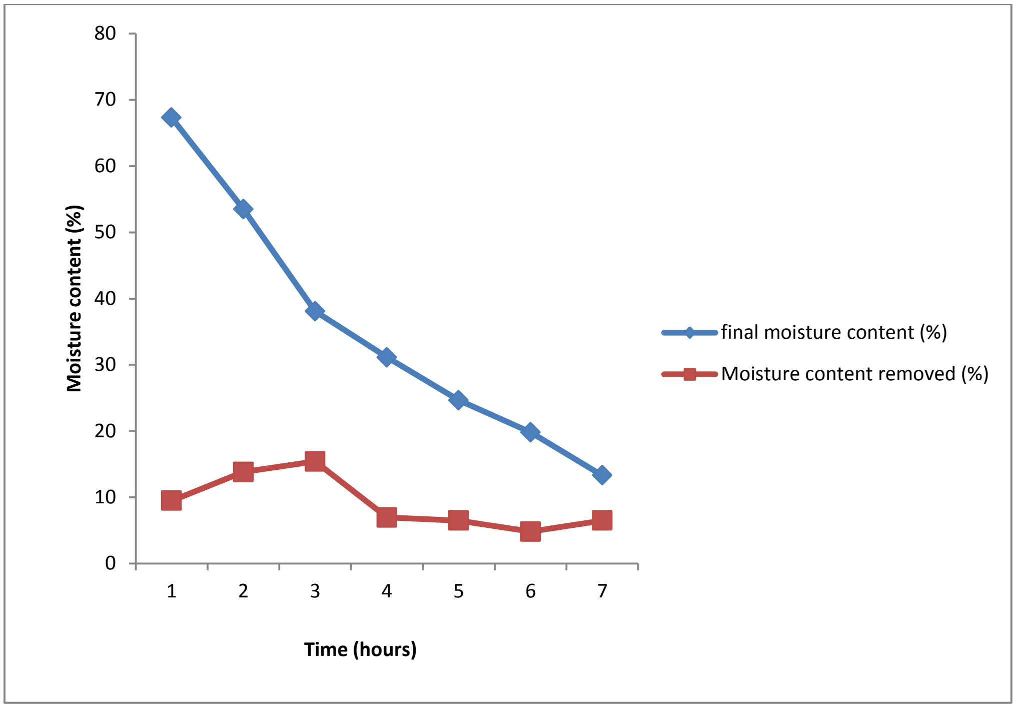

Figure 1.relationship between moisture content and time

Fig. 2 shows the relationship of time and drying temperature, chimney temperature and combustion temperature. It was observed that the combustion chamber had the highest temperature due to the fact that it was the heat source. Also, the drying chamber had temperature lesser than the combustion chamber but it was higher than that of the chimney temperature because work is done on the maize- on –cob in the drying chamber. It was also observed from Fig. 2 that there was fluctuation in temperature. This was because the heat cannot be regulated. At the initial state during drying, the temperature increased because the heat had circulated round the drying chamber. The temperature began to decrease due to the product gains more heat from chamber, this results in decrease of the temperature of the drying chamber.

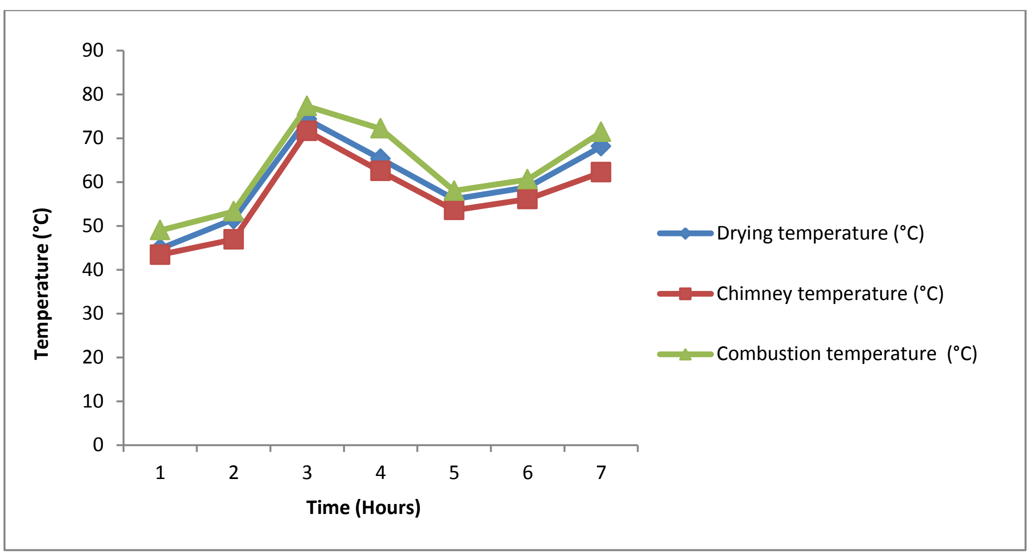

Figure 2.relationship of time and drying temperature, chimney temperature and combustion temperature

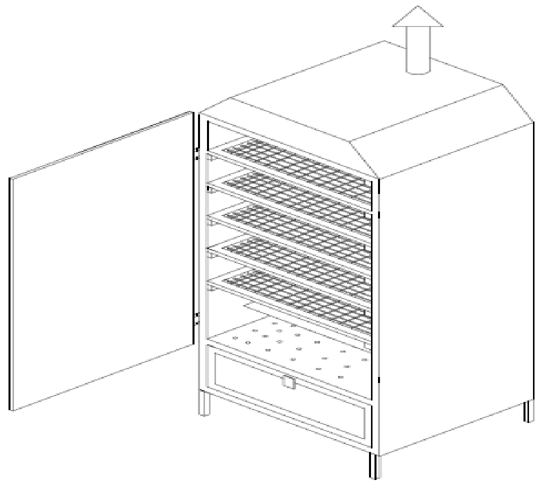

Figure 3. Isometric view of maize- on- cob dryer

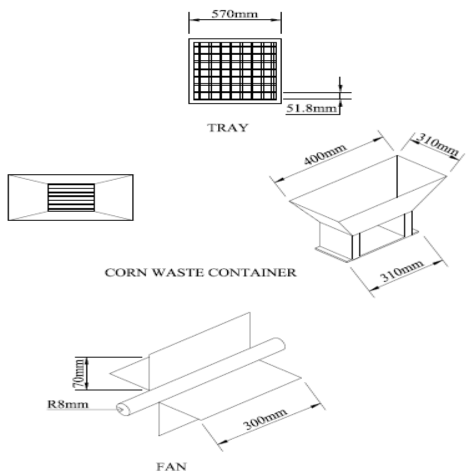

Figure 4. Components of maize-on-cob dryer

Figure 5. Drying trays with maize-on-cobs

Plate 1. A pictorial view of the fabricated maize-on-cob dryer

Plate 2. A pictorial view of the interior part of the fabricated maize-on-cob dryer

Conclusions

A dryer was designed and fabricated to dry fresh maize on cob at varying drying air temperatures. The dryer was simple in design, fabricated mainly with locally available materialsand was primarily intended for small scale farmers as no technical knowledge is required for its operation. The drying capacity is 1.8kg/hr. The moisture content (wet basis) of the maize on cob was reduced from 75.10% to13.29% in sevenhours. The corn waste has high combustion rate, it has a moisture content of 10.14%. 1.50kg of corn waste can burnt in one hour at a combustion rate of 1.50 kg/hr.

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