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*Full Length Research Paper*

# Design, construction and performance evaluation of a passive solar dryer for maize cobs

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Abstract

**Farmers in Nigeria encounter the problems of loss of their produce during post harvest and storage. Freshly harvested maize cobs with high moisture content is susceptible to rot and fungi infestation. Most farmers therefore accomplish their drying by hanging on wooden platforms for sun drying. This simple method allows the maize to be contaminated by insects and rodents. For good storage condition and availability of produce all year round, improved drying techniques are essential. Electricity and other sources of power, especially motorized power, are out of reach for most maize farmers. Passive Solar dryers which do not need electricity or other source of power have been recommended for maize drying by several authors. A Passive solar dryer for maize cobs was constructed and tested at the College of Engineering, University of Agriculture, Makurdi. The sides of the dryer were made of plywood coated with white emulsion paint, with an inner drying tray made of wire mesh. The top of the collector was made of a layer of 4 mm thick, 100 cm x 70 cm colourless glass sheet which served as the cover plate. A 0.5 mm thick, 100 cm x 70 cm Zinc roofing sheet painted black served as the absorber. Sun drying which is the popular practice by farmers in Nigeria was used to compare the performance of the developed solar dryer. Freshly harvested maize cobs with moisture content of 30.3 % were used for the performance evaluation of the developed solar dryer. Results showed that, it took 3 days to dry the maize cobs to a moisture content of 13.3 %, while it took 6 days to sundry the maize cobs to 13.4 % moisture content. The dryer can be made in commercial sizes for rural community to fast track drying operations. The cost of construction is ₦12,000:00.**

**Key words:** Development, evaluation, solar, dryer, maize, cobs.

## INTRODUCTION

The technique of drying is probably the oldest method of food preservation practiced by mankind. The removal of moisture during drying prevents the growth and reproduction of microorganisms which cause decay and minimize many of the moisture deterioration reactions. Drying brings about substantial reduction in weight and volume thereby reducing packing, storage and transportation costs. It also enables the storability of the product under ambient temperatures. (Daughty, 1995).

The basic function of a dryer is to supply the product more heat than is available under ambient conditions, thereby increasing sufficiently the vapour pressure of the moisture held within the crop and decreasing significantly the relative humidity of the drying air and thus increasing its moisture carrying capacity and ensuring sufficiently low equilibrium moisture content. (Irtwange, 1991; Folaranmi, 2008).

In the process of drying, heat is necessary to evaporate moisture from the material and a flow of air helps in carrying away the evaporated moisture. There are two basic mechanisms involved in the drying process. They are migration of moisture from the interior of an individual material to the surface, and the evaporation of moisture from the surface to the surrounding air (Youcef-Ali et al., 2001). The drying of a product is a complex heat and mass transfer process which depends on external variables such as temperature, humidity and velocity of the air stream. The importance of solar drying is increasing worldwide, especially in areas where the use of the abundant, renewable and clean solar energy is

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essentially advantageous. The supply of solar energy is abundant in most locations in Nigeria where solar heat is intense virtually all the year round. (Irtwange, 1991; Folaranmi, 2008; Yohanna et al., 2011).

Maize (Zea mays) or corn is one of the most important cereal crops in the world today. It is the world's most diverse crop species (Frey and Olson, 1987). Maize has been the diet of many Nigerian families for centuries. It started as a subsistent crop and has gradually become a very important staple crop. Maize has now risen from the status of a commercial crop on which many agro based industries depend on as raw material (Fakorede et al., 1993).

Maize cultivation has spread widely in Nigeria due to the fact that, farmers like its vigor and adaptation to wide spacing and intercropping system. The crop is fairly easy to weed and competes well with weeds because of its rapid vertical growth. (Van Eijnatten, 1965).

Dry maize is relatively easy to transport and does not deteriorate rapidly in storage. Consumers appreciate the low cost of maize and find it to be an appealing base for a wide array of local preparations.

Farmers in Nigeria face the problem of loss of their produce during post harvest and storage. Freshly harvested maize with high moisture content is susceptible to rot and fungi infestation.

Most farmers therefore accomplish their drying by thin layer spreading of their maize on disused roads, shoulders of tarred roads and hanging on wooden platforms. This simple method however allows the maize to be contaminated by dust, pebbles, stray animal droppings, insects, rodents and other animals (Akintaro, 1999; Itodo, 2007). The development of improved drying techniques are aimed at maintaining the maize in a clean, healthy, edible and storage condition and also ensure the availability of the maize all year round.

The objective of this study is to design, construct and evaluate a passive solar dryer for maize cobs for use in rural communities where electricity and other sources of power are not available.

## Description of the passive solar dryer

The dryer was made of wood with a box-like drying chamber with the top tapering towards a chimney, where condensed air could move out. The components of the dryer are as follows;

### The solar collector

This is where the solar energy is trapped and channelled into the drying chamber. Air passing through the collector is heated. The collector consists of a glass cover plate, an absorber plate and insulator. A colourless glass of 4 mm thickness is used for the cover plate. It is 100 cm long and 70 cm wide. It traps solar energy from the sun and prevents it from escaping. It is placed 4 cm above the absorber plate, this collects solar radiation.

The absorber plate is made of a zinc sheet painted black measuring 100 cm by 70 cm. It is placed below the cover plate to absorb incident solar radiation transmitted by the glass cover plate and heats the air passing between it and the cover plate.

### The air passage

The gap between the cover plate and the absorber plate measuring 10 cm forms the air passage.

### The drying chamber

This is made of plywood with the outside coated with emulsion paint to avoid wetting and subsequent soaking of the wood if used during the rainy season. The plywood minimizes the heat lost by radiation. It has a door at the back where the drying layer is accessed. The drying layer is made of stainless steel wire mesh.

### The chimney

This is an outlet for heated air to escape. It is made of aluminium sheet metal which is painted black. It is situated at the top of the dryer.

Figure 1 shows the isometric view of the solar dryer, figure 2 is the orthographic projection and figure 3 is the photograph.

The cost of construction which includes materials cost, labour cost and contingencies, at the current market price, is ₦12,000.00.

## Evaluation of the Dryer

Evaluation of the dryer was centred on the moisture content reduction and temperature variations. The performance of the developed dryer was compared with sun-drying which is the popular method of drying employed by maize farmers in Nigeria. 5 kg of fresh maize cobs was used for evaluation.

### Temperature

Temperature was taken using a mercury-in-glass thermometer. Temperatures of the drying chamber, solar collector and ambient air were taken daily using thermometers on an hourly basis from 9:00 am to 5:00 pm.

### Moisture content

Moisture content was taken at the beginning and at the end of each drying day using the oven drying method and calculated using the following equation.

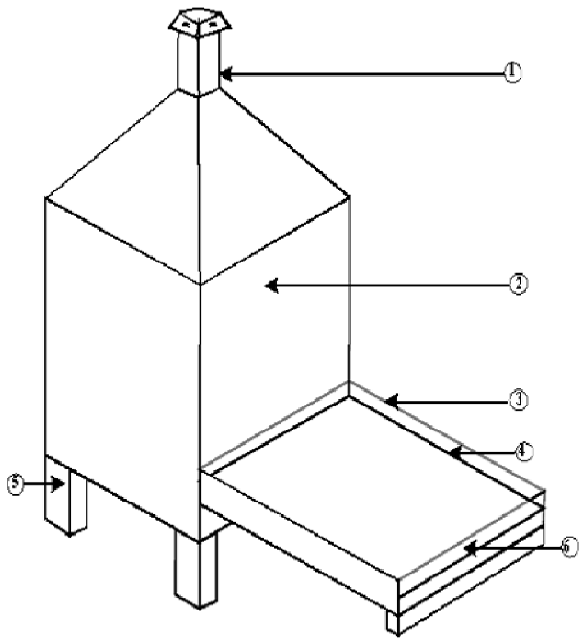


**Figure 1.** Isometric view of the solar dryer

| | |
|---|---|
| 1 | Chimney |
| 2 | Drying chamber |
| 3 | Glass cover plate |
| 4 | Absorber plate |
| 5 | Dryer stands |
| 6 | Air gap |

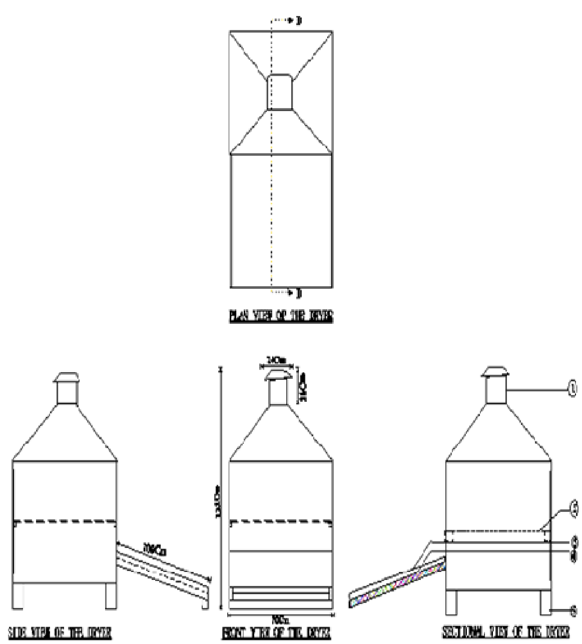


**Figure 2.** Orthographic projections of the solar dryer  Scale: 1:1

| | |
|---|---|
| 1 | Chimney |
| 2 | Drying layer |
| 3 | Glass cover plate |
| 4 | Absorber plate |
| 5 | Dryer stands |

**Figure 3.** A photograph of the dryer

**Table 1.** Variations of temperature with time

| Time (hrs) | Ambient (°C) | Collector (°C) | Drying Chamber(°C) |
|---|---|---|---|
| 9am | 30.0 | 40.0 | 35.0 |
| 10am | 33.7 | 42.2 | 37.2 |
| 11am | 35.5 | 47.9 | 39.8 |
| 12:00 | 37.9 | 58.4 | 47.7 |
| 1pm | 38.0 | 59.0 | 48.0 |
| 2pm | 37.7 | 58.7 | 47.9 |
| 3pm | 36.4 | 58.8 | 47.8 |
| 4pm | 36.9 | 55.2 | 45.3 |
| 5pm | 35.8 | 49.7 | 43.4 |

Moisture content = $\left(\frac{Mi-Mf}{Mi}\right) \times 100$
(Forson et al., 2007)

Where:
Mi = Mass of sample before drying
Mf = Mass of sample after drying

## RESULTS AND DISCUSSION

The initial moisture content of the harvested fresh maize was 30.3 %. Variations in temperature were observed as shown in Table 1 and Figure 4. Lower temperatures were recorded during the morning and evening hours with the morning hours recording the lowest temperatures. At 9:00 am, the ambient temperature was 30 °C, while the solar collector recorded 40 °C and the solar drying chamber had 35 °C. At 5:00 pm, the temperatures were 35.8 °C, 49.7 °C and 43.4 °C for ambient, solar collector and drying chambers respectively.

It is observed from Table 1 that, the temperatures in the solar collector and drying chamber were higher than the ambient temperatures, with the solar collector recording the highest temperature at each reading followed by the drying chamber. The highest temperatures were recorded during noon. At 1:00 pm, the ambient temperature was 38 °C while the solar collector recorded 59 °C and the solar drying chamber had 48 °C.

Variations in moisture content were observed as shown in Table 2 and Figure 5. The moisture content of the freshly harvested maize cobs was 30.3 %. At the end of drying for the first day at about 5:00 pm, the moisture content of the maize in the solar dryer reduced to 25.4 % while that of sun-drying reduced to 28.2 %.

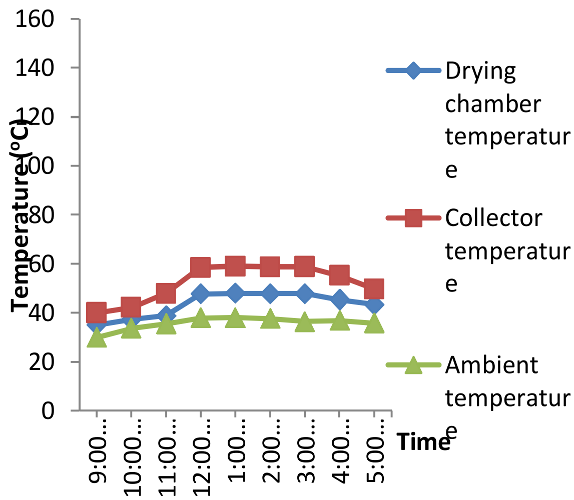


**Figure 4.** Graph of the various Temperatures against Time

**Table 2.** Variations of moisture content and time for the drying days

| Moisture Content (%) | | | | |
|---|---|---|---|---|
| | Developed dryer | | Sun drying | |
| **DAY** | At 9:00 am | At 5:00 Pm | At 9:00 am | At 5:00 pm |
| **One** | *30.3 | 25.4 | *30.3 | 28.2 |
| **Two** | 23.6 | 19.7 | 28.1 | 26.0 |
| **Three** | 18.2 | 13.3 | 25.9 | 22.7 |
| **Four** | 13.3 | 13.3 | 22.1 | 19.9 |
| **Five** | 13.3 | 13.3 | 19.7 | 17.2 |
| **Six** | 13.3 | 13.3 | 16.8 | 13.4 |

*Initial moisture content of the harvested maize before drying = 30.3%

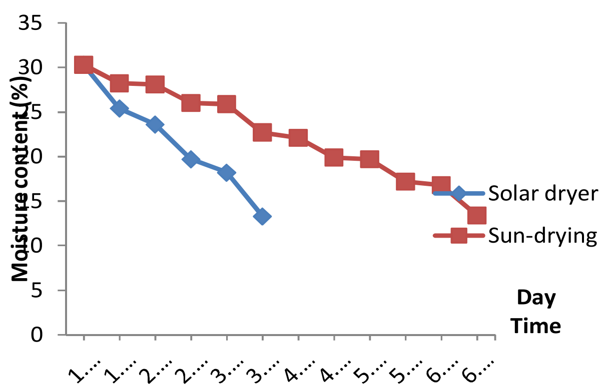


**Figure 5.** Graph of Moisture content against Time for the period of drying (6 days)

On the 3rd day, at about 5:00 pm, the moisture content of the maize in the solar dryer further reduced to 13.3 % which is safe moisture content for storage (Appert, 11987; Gallali et al., 2000), while that of sun-drying reduced to 22.7 %. Sun drying eventually recorded 13.4 % at the end of the sixth day of drying. Generally, it was observed that drying occurred faster in the solar dryer than the sun drying method. Moisture content of the maize cobs in the developed dryer stabilized at 13.3 % for days 4, 5 and 6 and further reduction was not observed.

The better drying performance of the solar dryer was possible because temperatures in the drying chamber were higher at 36-48 °C while the ambient temperature ranged between 30-38 °C .There was also a little drop in moisture content at the interval between the end of each drying day and the beginning of the subsequent drying day. Furthermore, the maize cobs which were sun dried had to be taken into shelter at the end of each drying day to prevent dew from dropping on them. The cobs in the solar drying chamber looked cleaner than the cobs which were sun dried since they were placed in the drying chamber away from the effects of dust and dirt.

## CONCLUSION AND RECOMMENDATION

A Passive solar dryer was designed and constructed and its performance was evaluated using about 5 kg of maize cobs. Savings in time were achieved as against sun drying as it took 3 days to dry the maize cobs to a moisture content of 13.3 % from 30.3 % using the passive solar dryer while it took 6 days to dry the cobs to 13.4 % under sun drying. Since the developed dryer does not use electricity, it can be used by farmers in rural communities. Physical observation showed that, the maize cobs in the dryer looked cleaner than those which were sun dried. The performance of the dryer should be evaluated over a longer period of time of about one month as a result of changes in weather to ascertain its maximum performance. Bigger sizes could be constructed to accommodate large quantity of maize cobs. It cost ₦12,000:00 to construct the solar dryer.

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