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Design, Construction and Performance Evaluation of Cassava Chips Dryer Using Fuel Wood

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Abtract-The design, construction and performance evaluation of a cassava chips dryer using fuel wood as source of heat was undertaken with a view to help small scale farmers' process cassava chips. The dryer consists of a frame, drying chamber, a tray, fuel wood housing, perforated air space and a chimney. The dryer was evaluated in terms of final moisture content, drying capacity, time taken to dry the chips and the quality of the chips. Results showed that the moisture content of 65.03% (wb) was reduced to 13.11%, the drying capacity was 6kg per loading and the drying time which was supposed to be 3 hrs was increased to 4hrs due to difficulty in regulating the heat produced by the fuel wood. Compared to other types of dryers (solar dryer, platform dryer, flat – bed dryer, continuous dryer e.t.c), the batch type dryer is preferred due to its ability to be used during rainy season and in the absence of electricity. The quality of the chips was found to be good. The dryer has an efficiency of 80%. The evaluation of the dryer shows that it can be used for small scale drying of cassava. chips.

Key words: batch type dryer, cassava chips, fuel wood, performance evaluation.

I. INTRODUCTION

Cassava (*Manihot esculanta*) is a root crop, a single specie plant belonging to the family of Euphorbicease and is the most important root crop in the tropics (Enwere, 1998; Anikwe and Onyia, 2005). Cassava represents the main source of energy for 200 to 300 million people all over the world (Adeluyi et al. 2006).

Cassava was introduced into Nigeria over 300 years ago although its cultivation was generally accepted and practiced to the late 1890s (Hahn, 1998; Grace, 1977). Cassava is an important economic crop cultivated in many tropical countries such as Thailand, Brazil, India and several West African countries including Nigeria, which presently ranks as the number one producer in the world. The plant itself is classified as perennial semi shrub. Its high energy carbohydrate- rich roots can be processed into a wide variety of products from food to industrial starches, which make cassava important economically. This root crop may range in length between 30cm and 120cm and 4cm to 15cm in diameter (Grace, 1977)

II. PRODUCTION AND ECONOMIC IMPORTANCE OF CASSAVA

The total world cassava production was estimated at 180 million tonnnes from about 16.9 million hectares of land in 2002 (FAO, 2003). Africa produced about 54% followed by Asia (29%) and South America (17%).

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The total production in Africa has increased from 35 million tonnes in 1965 to 97 million in 2002 albeit; the production increase was ascribed to Nigeria, which has increased its share from 22% to 35%.

Nigeria has maintained its production as the world largest producer of cassava, accounting for about 35% of the production output of the world and Africa respectively. Production has increased only by 33%, while the area under production figure for Nigeria has risen to about 38 million tonnes in 2005 (FAO, 2006). An increase in cassava processing has been shown to contribute to sustained growth in cassava production in Nigeria (Ugwu and Ukpai, 2002).

Cassava is the fourth most important energy staple food in the tropics and the sixth global source of calories as human diets apart from rice and wheat (FAO, 1999). It is cultivated for its roots, which provide a cheap source of energy consumed as vegetable, supply protein, vitamins and essential minerals (Dahmiya et al. 1994; Berry, 1993). Cassava leaves are also useful as livestock feed supplements (Ukpai and Ejiofor 1997).

In southern Nigeria, reported that cassava contributes about 70% of the total energy requirement of over 50% of the population. It is utilized as food for humans in processed form such as gari, lafu and fufu while some sweet (low cyanide) varieties are eaten raw, boiled or roasted as snacks (Ugwu et al.1998).

A. Dried Cassava Chips:

This refers to non-fermented rectangular shaped chips of about 3.5mm diameter from freshly harvested cassava roots. The dried chips are usually white or creamy brown. The chips are considered dried when they are easily broken but too hard to be crumbled with hand. Chips dried on trays are better in appearance and more uniformly dried than those dried on concrete floors. (Njie et al. 1998).

B. Why dry cassava chips:

Processing fresh cassava roots into dry chips does not usually aim at reducing their susceptibility to storage insects but rather to increase the self-life of the roots, improve palatability and reduce their cyanogenic potential (Bokanga, 1994). The dried cassava chips can be used for the following purposes:

i. Cassava chips are used for edible purposes and for preparation of flour.
ii. Dried chips are also used in animal feed formulation.
iii. In industry, the chips are the raw material for manufacturing starch, dextrin, glucose and ethyl-alcohol (Osuntokun et al. 1981).

However, the production of cassava in Nigeria, has not been fully exploited due to inadequate processing technology as obtained in other developing countries storage of this product is very difficult due to high moisture content.

As such, the major option left to the peasant farmers is sun-drying which takes chips two to three days to dry. Unreliable climate conditions also render continuous sun-drying difficult. Contamination by airborne, dust and debris cannot be entirely avoided during sun-drying especially in windy days. Artificial drying has certain advantages. Besides saving time and floor space requirements, artificial drying allows for the continued drying at night time, especially during peak period of harvest. For this reason, a tray-batch dryer type was constructed. This type of dryer is preferred to other types (solar dyer, automatic batch dryer, platform dryer, flat-bed dryer etc) for the reason that it can be used even during raining season and has no need of electricity as it uses fuel wood as source of fuel.

Therefore, this research is aimed at the design and construction of a cassava chips dryer using fuel wood and to evaluate the performance of the dryer in terms of:

i. Capacity of the dryer
ii. Final moisture content achieved
iii. Drying rate
iv. Quality of chips.

III. MATERIALS AND METHODS

A. *Theoretical Background*

The design and construction of fuel wood cassava chips dryer is based on the understanding of the principles that governs heat and mass transfer in food processing. Heat transfer is a dynamic process in which heat is transferred spontaneously from hot body to cooler body. The rate of heat transfer depends upon the difference in temperature between the bodies.

B. Design Considerations

In design of the cassava chips dryer, certain factors were put into consideration. They include:

1. Types of product to be dried which is cassava. Cassava being a highly perishable product with no way of conserving it in raw state has to be properly dried to avoid spoilage.
2. The volume of the product to be dried which depends on the capacity of the dryer. The volume of the dryer was so chosen for the purpose of small scale production and domestic needs.
3. The tray-batch was so chosen due to the fact that little technicality is involved in its operation as compared to other types of dryers (platform dryer, flat-bed dryer, continuous flow dryer etc) and can be used during rainy season.
4. Fuel wood was chosen as source of heat against other fuels (diesel, gas or kerosene) considering its cheaper cost and availability.
5. Labour cost: The specification of improved technology is to reduce labour cost. As much as possible labour requirement for this dryer will be in the loading and unloading of the chips and also the routine maintenance which were all put into consideration and were found to be minimal.
6. Hygiene condition of the product. Cassava has to be dried under good hygiene condition to avoid contamination from dust, dirt and debris.

C. Choice of Materials

1. Availability and cost of materials.

This is important for selecting material for construction of engineering devices. The choice of the material is specifically based on the readily available and easy access to materials that will ultimately perform the desired function.

2. Ease of construction
3. Good conductivity
4. Durability

Based on above factors, the following materials were chosen.

i. Gauge 14 galvanized sheets was used to construct the frame.
ii. Latex was used as lagging material due to its ability to conserve heat.
iii. Stainless steel was used to construct the drying tray to ensure good quality of product.
iv. Angle iron was used to provide support for the drying tray.
v. Gauge 16 galvanized sheets was also used to construct a trapezoidal frame to house the fuel wood.

D. Description Of The Dryer's Components

Frame: This a part of the machine on which other parts are attached. It is welded in a skeleton fashion to provide support to the load acting on the machine from within and outside.

Drying chamber and Tray: These are units where the cassava chips are exposed to heat and it is composed of triple walls; an outside layer made of mild steel, a middle layer properly insulated with latex as lagging material and inner layer of galvanized metal sheet. The inside of the chamber allows a tray to be arranged at a time. The chamber has one door to allow the tray to be placed inside.

Chimney: This serves as a vent through which the moisture from the cassava escapes to the atmosphere.

Fuel wood housing: This is a trapezoidal frame that houses the fuel wood. It is placed at a proper clearance to ensure quality drying of the cassava chips; if the clearance is small it will roast the chips and if it's large, it will cook the chips instead of drying the chips.

Perforated air space: This is for continuous glowing of the fuel wood.

It can be noted however, that the heat produced by the fuel wood is regulated by either withdrawing the fuel wood housing, reducing the fuel wood or adding fresh fuel wood as it may be required.

E. Performance Evaluation Of The Dryer

The dryer was evaluated with 5.5kg of cassava chips obtained from Maiduguri market at a moisture content of 65.03%. The moisture content was determined at an interval of one hour until the chip was dried to 13.11 % moisture content.

F. Design Calculation

In determining the area of cassava chips, five chips were selected at random and their length, width and thickness were measured and their average value calculated.

The average length of the cassava chip was 50mm

The average width of the cassava chip was 10mm

The average thickness of the cassava chip was 5mm.

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The area covered by a chip is given as:

$A = L \times W$……………….1

$A = 50 \times 10$

$A = 500mm^2$

The researcher assumed the total number of chips in the dryer to be 300; it implies that the area of the tray is A_T

$A_T = 500 \times 300$

$A_T = 150,000mm^2$

The volume occupied by a chip is calculated by multiplying the area of a chip and its thickness.

Volume of chip = 500x5

Volume of chip = $2,500mm^3$

Total volume of chips, V_T = volume of chip x No. of chips

$V_T = 2,500 \times 300$

$V_T = 750,000mm^3$

C. Design Of The Dryer Capacity

Average weight of one chip is 0.020kg. Assuming the tray will accommodate 300 chips, then,

Dryer capacity = mass of chips x No. of chips

= 0.020 x 300

= 6kg.

Therefore for the purpose of the design, the mass of cassava to dry shall be 6kg at 65% moisture content on wet basis.

Amount of water to be removed from chips:

$M_w = m\left[\frac{(1-M_{cl}}{1-M_{cl}}\right]$ ………………..2

Where M_w is the amount of water to be removed in kg, M is the mass of chips in kg, M_{C1} is the initial moisture content of the chips which is 65%, and MC2 is the final moisture content of chips which is 13%.

$M_{C1} = 65\% = 0.65$;

$M_{C2} = 0.13$; M = 6kg

$M_w\ 6\left[1 - \frac{1-0.65}{1-0.13}\right]$

$M_w = 6[1 - 0.4023]$

$M_w = 6(0.5877)$

$M_w = 3.586kg$

D. Drying time (T)

$$T = W\left\{\frac{M_1 - M_2}{\frac{dw}{d\theta}}\right\} \quad \ldots\ldots\ldots\ldots.3$$

Where W is the amount of dry material in the chip in kg; M_1 is the mass of initial moisture; M_2 is the mass of final moisture $dw/d\theta$ is the rate of mass transfer (Mc).

$W = M(1 - M_{c1})$ ……………4

Where M is the mass of chips to be dried; M_{c1} is the initial moisture content:

$W = 6(1 – 0.65)$

$W = 2.1kg$

$$M_1 = \frac{0.65}{1-0.65}$$

$M_1 = 1.86kg$

$$M_2 = \frac{0.13}{1-0.13}$$

$M_2 = 0.15kg$

$Mc = kgA(H_s – H_a)$ ……….5

Where kg is the mass transfer coefficient in (kg/m^2s); A is the area of drying screen (m^2); H_2 is saturated humidity; H_a is air humidity and Mc is the rate of evaporation or mass transfer.

$Kg = 0.083\ kJ/m^2S$

$Mc = 0.083 \times 0.81(0.021 – 0.017)$.

$Mc = 0.000269kg/s$

$Mc = 2.69 \times 10^{-4}kg/s$

$$T = W\left\{\frac{M_1 - M_2}{\frac{dw}{d\theta}}\right\}$$

$$T = 2.1\left\{\frac{1.86-0.15}{2.69x10^{-4}}\right\}$$

$$T = \left\{\frac{3.591}{2.69x10^{-4}}\right\}$$

T = 13349.442sec

T = 3.70hrs

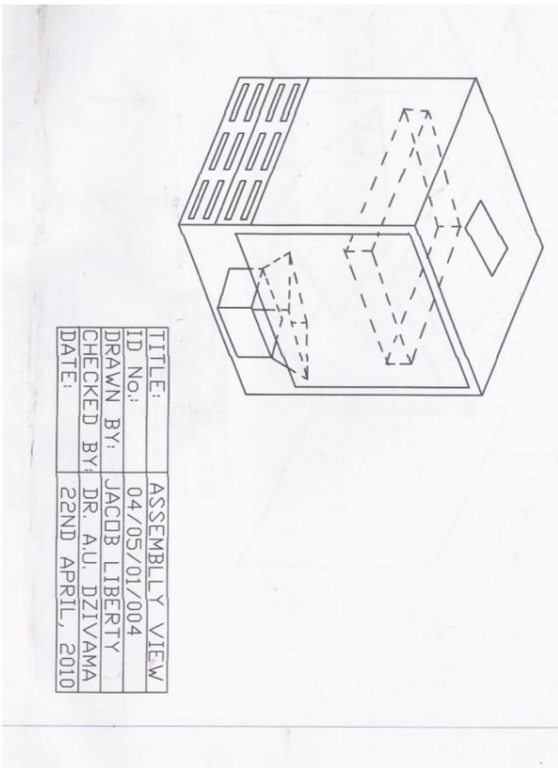

Fig. 1: Assembly view of the fuel wood dryer

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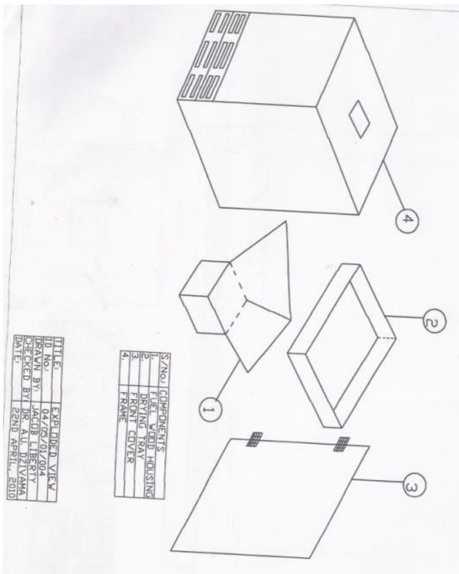

Fig. 2: Exploded view of the fuel wood dryer

IV. RESULT AND DISCUSSION

A. Moisture Content

Moisture content of cassava chips (kg)				
Time (hrs)	First Trial	Second Trial	Third Trial	Average
0	65.03	65.03	65.03	65.03
1	52.71	53.13	53.33	53.06
2	34.28	35.11	35.22	34.87
3	21.39	21.46	21.51	21.45
4	12.85	13.02	13.11	13.99

Table 3.1 Moisture content of cassava chips at one hour interval

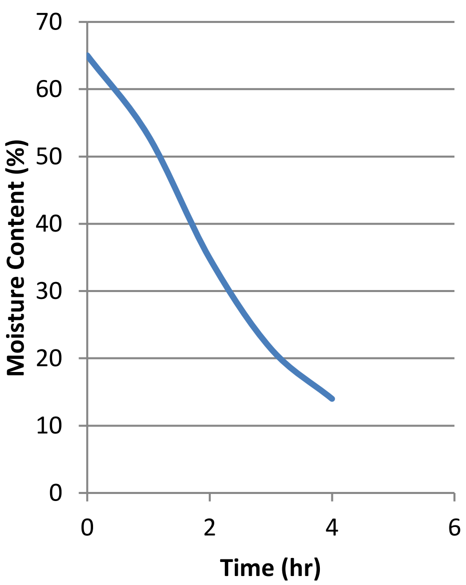

Fig3 : Plot of cassava drying rate

B. Drying Time

The time taken by the dryer to dry the chips was four (4) hours.

C. Drying Efficiency

The efficiency of the drying is given by;

$$\eta = \frac{moisture\ removed}{initial\ moisture\ content} x\ 100 \ldots\ldots 11$$

Where:

Moisture removed = initial moisture content – final moisture content

Moisture removed = 0.6503 – 0.1311

$$\therefore \eta = \frac{0.1592}{0.6503}$$

= 80%

Drying efficiency is 80%

D. Discussion of Results

The initial moisture content of the cassava was found to be 65.03%. The moisture content was reduced to 13.11% and the drying time which was supposed to be 3 hrs was increased to 4hrs due to difficulty in regulating the heat produced by the fuel wood. It is of immense importance to know the efficiency of the constructed dryer so as to ascertain the dryer's capacity. Considering different parameters, the efficiency of the drying was calculated to be 80%.

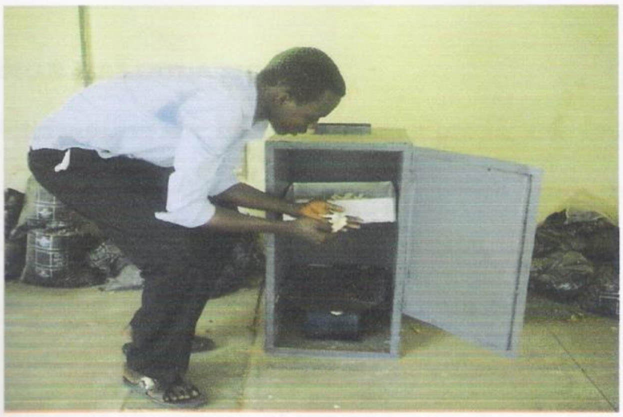

Plate 3.1: Front view of Cassava Chips Dryer Using Fuel Wood

Plate 2: Dried Cassava Chips

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V. CONCLUSION AND RECOMMENDATION

A. Conclusion

Standard method and technology have been employed in the design and construction of the dryer. The capacity of the dryer is 6kg per loading. The drying rate is a function of chemical composition of the cultivars, the drying time is a function of the moisture content and it was observed from the chips that at interval of 1hr the moisture content reduce. Evaluation of the dryer shows that it can be used for small scale drying of cassava chips.

B. Recommendation

1. A better means of regulating the heat produced by the fuel wood should be set-up. Further performance evaluation test should be carried out on the dryer using other root crops.
2. Thermometer can be installing to determine the actual temperature in the dryer at a point.
3. Other lagging material such as glass fibre, cottonwood and sawdust can be used.

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