Performance Evaluation of a Small-Medium Scale Yam Chips Dryer

J.T Liberty, C.E Odo, S.A Ngabea

Abtract-The design, construction and performance evaluation of a yam chips dryer using fuel wood as source of heat was undertaken with a view to helping small scale farmers process yam chips. The dryer consists of a frame, drying chamber, tray, fuel wood housing, perforated air space and 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 71.05% (wb) was reduced to 17.23% , the drying capacity was 6kg per loading and the time taken to dry the chips was increased to about 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 76%. The evaluation of the dryer shows that it can be used for small scale drying of yam chips

Key words: batch type dryer, fuel wood, small scale, performance evaluation, yam chips.

I. INTRODUCTION

Yams (*Dioscorea* species) constitute the predominant starchy staple in sub-Saharan Africa where food security for a growing population is a critical issue. It is among the oldest recorded food crops and rank second after cassava in the study of carbohydrates in West Africa (Nweke et al., 1999; Agwu and Alu, 2005). It also forms an important food source in other tropical countries including East Asia Africa, South America, South East Asia ,including India (Agwu and Alu, 2005; Iwueke et al., 2003). Nigeria is the largest producer of the crop in the world with about 71% of the world output, producing about 38.92 million metric tonnes annually (FAO,2008).Six species, namely white yam *(Dioscorea rotundata*), yellow yam (*Dioscorea cayenensis*), water yam (*Discorea alata)*, Trifoliate or threeleaved yam (*Dioscorea dumentorum).* Arial yam (*Dioscorea bulbifera*) and Chinese yam (*Dioscorea esculenta*) can be considered the principal edible yams of the tropic (Agwu and Alu, 2005; Iwueke et al., 2003).

Yam tubers are eaten boiled, roasted, fried or pounded and could be chipped, dried and produced into yam flour. Yam represents about 20% of the daily calorie intake of Nigerians living in the forest and savannah region (Nweke et al., 1999).Yam constitutes a major staple food for the majority of inhabitants of Nigeria. It has potential for livestock feed and industrial starch manufacture.

Manuscript received on June 2013.
J.T Liberty, Department of Agricultural & Environmental Resources Engineering, Faculty of Engineering, University of Maiduguri, P.M.B 1069, Maiduguri, Borno State, Nigeria.
C.E Odo, Department of Biochemistry, Faculty of Biological Sciences, University of Nigeria, Nsukka
S.A Ngabea Department of Agricultural & Bioresources Engineering, University of Nigeria, Nsukka

As a food crop, the place of yam in the diet of the people in Nigeria cannot be overemphasized. It contribute more than 200 dietary calorie per capital daily for more than 150 million people in west Africa while servicing as an important source of income to the people (Babaleye, 2003). Yam has some inherent characteristics, which make it attractive, first, it is rich in carbohydrate especially starch consequently has a multiplicity of end use. Secondly, it is available all year round making it preferable to other seasonal crops (FAO, 1987)

According to Oyenuga (1968), yam contains a higher value in protein (2.4%) and substantial amount of vitamins (Thiamine, Riboflavin and Ascorbic acid) and some other minerals like calcium, phosphorus and iron than any other common tuber crop. It is also comparable to any starchy root crop in energy and the fleshy tuber is one of the main sources of carbohydrate in the diet of many Nigerian. CGIAR (1996) also reported that yam tends to be higher in protein and minerals like phosphorus and potassium than sweet potatoes though the latter is richer in Vitamin A and C.

It is a preferred food and a food security crop in some Sub-Saharan African countries (IITA, 1998). Yam could be eaten as boiled yam or fried in oil. It can also be processed into yam flour or pounded yam. Moreover, yam is also a source of industrial starch, the quality of which varies with the species, although the quality of starch of some species is said to be comparable to cereal starchy (Osisiogu and Uzo, 1973). Apart from this, yam also plays vital roles in traditional culture, rituals and religion as well as local commerce of the African people (Coursey, 1967). Yam is reported to be part of the religious heritage of several Nigeria tribe and up to date often play a key role in religious ceremony (Sanusi and Salimonu, 2006). Worthy of note is the fact that many important cultural values are attached to yam, especially during wedding and other social ceremonies. In many farm communities in Nigeria and other West Africa countries, the size of the yam enterprise that one has a reflection of one social stature. Due to the importance attached to yam many communities celebrate the new yam festival annually.

Yam production in Nigeria has more than tripled over the past 40 years from 6.7 million tonnes per annum in 1961 to 27 million tonnes per annum in 2001(FAO, 1999). This increase is however attributed to larger hectares of land planted to yam than to increased productivity. This decline in average yield per hectare in Nigeria has been rather drastic dropping from 14.9% in 1986 -1990 to -2.5% in 1999 (CBN, 2002). Since yam remains a major staple food in Nigeria based on based on its cultural role (Nweke *et al*, 1992), contributing immensely to rural and regional economies (Kalu and Erhabor, 1992) and its significance among the food crops in Nigeria.However, the production of yam 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 of between 50 and 80 %, which makes it susceptible to deterioration (Opara, 1999). 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.

Drying is a universal method for conditioning foods by the elimination of the water until a level that allows its balance with the ambient air, in such a way that preserves its physical and chemical characteristics (Ruiz & Montero, 2005). The removal of water in the solid foods arises initially, like a form of reduction of the water activity, inhibiting the microbial growth; therefore, it passes to also have significant importance in the reduction of energy costs, of transport, packing and storage of the foods that with high quantities of water (Cardoso and Asis, 2004).

Dried and milled yam is less perishable and can be consumed throughout the year, mainly to produce starch (Akingbala, Oguntimehin & Sobande, 1995; Akissoe et al., 2001). Therefore, this research is aimed at the design and construction of a yam 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.

II. MATERIALS AND METHODS

A. Theoretical Background

The design and construction of fuel wood yam 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.

A. Design Considerations

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

1. Types of product to be dried which is yam. Yam 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. Yam has to be dried under good hygiene condition to avoid contamination from dust, dirt and debris.

B. 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.

C. 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 yam 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 yam 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 yam 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.

D. Performance Evaluation Of The Dryer

The dryer was evaluated with 5.5kg of yam chips obtained from Maiduguri market at a moisture content of 71.05% (wb).

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The moisture content was determined at an interval of one hour until the chip was dried to 17.23 % moisture content.

E. Design Calculation

In determining the area of yam 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 yam chip was 50mm
The average width of the yam chip was 10mm
The average thickness of the yam chip was 5mm.
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

$V_T = 2, 500 \times 300$

$V_T = 750, 000mm^3$

F. 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 yam to dry shall be 6kg at 71% 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 71%, and M_{C2} is the final moisture content of chips which is 17%.

$M_{C1} = 71\% = 0.71$;

$M_{C2} = 0.17$; $M = 6kg$

$M_w \; 6\left[1 - \frac{1-0.71}{1-0.17}\right]$

$M_w = 6[1 - 0.3494]$

$M_w = 6(0.6506)$

$M_w = 3.9036kg$

G. Drying time (T)

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

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:

$W = 6(1 – 0.71)$

$W = 1.74kg$

$$M_1 = \frac{0.71}{1-0.71}$$

$M_1 = 2.45kg$

$$M_2 = \frac{0.17}{1-0.17}$$

$M_2 = 0.20kg$

$Mc = kgA (H_s – H_a)$ ………..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.

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

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

$Mc = 0.000269kg/s$

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

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

$$T = 2.1\left\{\frac{2.45-0.25}{2.69x10^{-4}}\right\}$$

$$T = \left\{\frac{2.2}{2.69x10^{-4}}\right\}$$

T = 8178.4387sec

T = 2.30 hrs

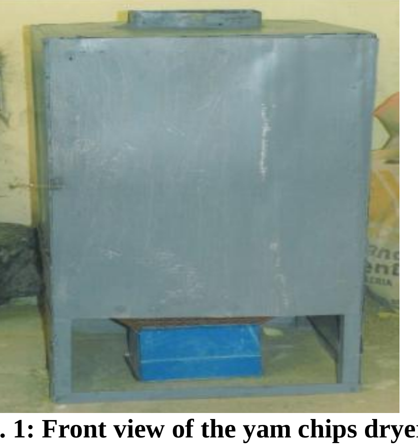

Fig. 1: Front view of the yam chips dryer

Fig. 2: Side view of the yam chips dryer

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

III. DISCUSSION

A. Moisture Content

Moisture content of yam chips (kg)				
Time (hrs)	First Trial	Second Trial	Third Trial	Average
0	71.05	71.05	71.05	71.05
1	57.03	58.25	58.37	57.88
2	38.58	39.27	39.35	39.07
3	25.30	25.41	25.55	25.42
4	16.77	17.06	17.23	17.02

Table 3.1 Moisture content of yam chips at one hour interval

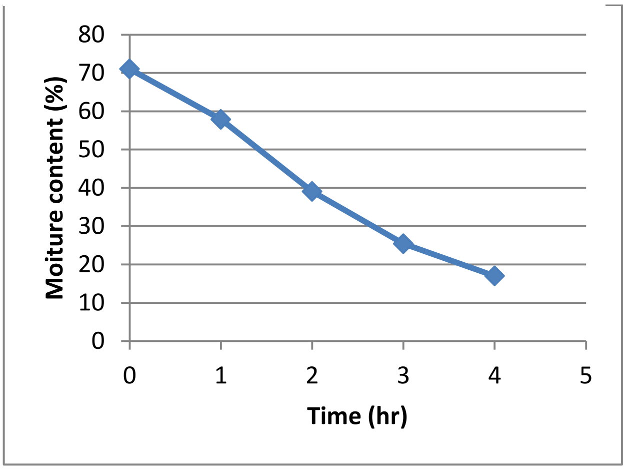

Fig7: Graph of Cassava drying rate

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;

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

Where:

Moisture removed = initial moisture content – final moisture content

Moisture removed = 0.7105 – 0.1723

$$\therefore \eta = \frac{0.5382}{0.7105}$$

= 75.75%

Drying efficiency is 76%

D. Discussion of Results

The initial moisture content of the yam was found to be 71.05%. The moisture content was reduced to 17.23% 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 76%.

IV. 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.

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 tuber 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.

REFERENCES

1. Akingbala, J., Oguntimehin, T., and Sobande, A. O., Physicochemical properties and acceptability of yam flour substituted with is flour. Plants Foods for Human Nutrition, 48(1), pp. 73-80, 1995.
2. Akissoe, N., Hounhonigan, D. J., Brias, N., Vernier, P., Nagô, C. M. and Olorunda, A. O., Physical chemical and sensory evaluation of dried yam (Dioscorea rotundata) tubers flours and "amala" a flour derived product. Tropical Science, 41(1), pp. 151-155, 2001
3. Montes, E., Torres, R., Andrade, R., Perez, O., Marimon, J. and Meza, I., Models of desorption isotherms of yam (Dioscorea rotundata). Dyna, 76(154), P. 146, 2009.
4. Opara, L., Yam storage in Agriculture processing. Handbook of agricultural engineering, IV, pp. 182-214. 1999
5. Ruiz, A., and Montero, I., Drying lot of industrial residuals of the olive. Alimentación equipos y tecnología, 24, pp. 122-134, 2005.
6. Cardoso, A., and Asis, F., Comparison of mathematical models of isothermic heat of desorción in pulp of Guava. Brazil journal storage, 29(1), pp. 28-34, 2004.
7. Babaleye, T. (2003). "West Africa; Improving Yam Production Technology". ANB – BIA supplement Issue/Edition Nr 463.
8. Central Bank of Nigeria (2002). Statistical Bulletin, CBN Publication, 252 -260pp.
9. CGIAR (1997). Priorities and Strategies for resource allocation during 1998 – 2000. www.igiar-org, Consultative Group on international Agricultural Research.
10. Food and Agriculture Organisation (FAO) (1987). "Formulation Reports: Roots and Tubers Expansion Programme". FAO, Rome, Italy.
11. Food and Agriculture Organisation (FAO) (2002). Food and Agriculture Organisation year book Volume 56.
12. International Institute of Tropical Agriculture (IITA) (1998). Annual Report, IITA, Ibadan, 1- 15 pp.
13. Kalu, B.R and Erhabor, P.O. (1992). Production and Economic evaluation of white guinea yam minisett under ridge and bed production system in a tropical guinea savanna location, Nigeria. Tropical Agriculture, Trinidad, 61 : 78 – 81
14. Osisiogu I.U.W, Uzo, J.O. (1973). Industrial Potential of some Nigeria Yam and Cocoyam Starches, Tropical Science, 15 : 353 – 359
15. Oyenuga, V.A. (1968). Nigeria Food and Feedstuff, University Press, Ibadan, pp 20 – 27
16. Nweke FI, Ugwu BO, Asadu CL, Ay P. Production cost in the yam based cropping system south western Nigeria. Research monograph No. 6 IITA Ibadan, Nigeria 1991; pp 4-12
17. Agwu AE, Alu JI. Farmers perceived constraints to yam production in Benue state, Nigeria. Proceedings of the 39th Annual Conference of the Agricultural society of Nigeria 2005; pp 347-50.
18. Iwueke CC. Mbata EN, Okereke HE. Rapid Multiplication of seed yam by minisett technique National Root Crops Research Institute, Umudike Abia State, Nigeria. Advisory Bulletin 2003; No. 9 pp 5.
19. Food and Agricultural Organization (FAO) (2008) FAOSTAT Statistical Division of the FAO of the United Nations Rome, Italy 2008; www.faostat.org

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication