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RESEARCH ARTICLE

Comparative Studies of the Drying Efficiency of Cassava and Plantain Chips Using a Solar Dryer

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Abstract

In the present study, we report on the performance of a solar dryer that was fabricated using locally available materials and then characterised by investigating the drying efficiency of cassava and plantain chips. The same materials (cassava and plantain chips) were also subjected to open sun drying (OSD) to serve as control. The results show that the dryer retained ample heat with a maximum temperature of 58 ^{o}C when the ambient temperature was 45 ^{o}C. The drying efficiency of the plantain and cassava chips (dried using the solar dryer) were obtained to be 53.6% and 67.5% respectively. In the open drying case, the drying efficiency was typically less than 30 %, indicating the improved performance and the effectiveness of using the former compared to the latter.

INTRODUCTION

One of the commonest problem affecting farmers especially in developing countries is that of effective preservation of their farm products. Most farmers encounter serious losses due to the utilisation of very poor and primitive preservation techniques in preserving their farm produce. Cassava (manihot utilissima) is a member of the family Euphorbiaceae and is a perennial woody shrub that produces very large tuberous roots especially when grown in a fertile soil (Anyanwu et al, 1982). The maturity period of cassava tubers is typically ≥ 9 months depending on the species (Anyanwu and Komolafe, 2003; Ogwueche, 2000). In Nigeria, one of the most popular agricultural products is cassava. Cassava is widely consumed by both the rich and the poor in Nigeria, and mostly processed in different forms as: chips, "fufu" (pounded cassava), "eba" (garri), and cassava flour. Although Garri (also known as gari, garry, or tapioca) is one of the most popular West African food made from cassava tubers, the use of cassava tubers to make palatable chips is gradually gaining grounds both for local consumption and export in Nigeria. Other important derivatives from cassava tubers include; cassava starch, cakes, flakes, cubes, peeler**,** and pellets. Cassava chips are non fermented oblong-shaped products of very few thickness usually obtained by slicing freshly harvested cassava roots after removing the bark (Zvinavashe et al, 2011).

Cassava is useful to man in so many areas which include; as livestock feeds, industrial raw material such as in the production of adhesives bakery products, dextrin, dextrose glucose, lactose and sucrose, as a binding agent (dextrin) in the paper and packaging industry and adhesive in cardboard, plywood and veneer binding, in the food and beverage industries where the use of cassava products is employed in the production of jelly caramel and chewing gum, in the pharmaceutical and chemical industries where ethanol derived from cassava are used in the production of cosmetics and drugs, and in the social sectors for the manufacture of school chalk. It has been reported (Aloys and Angeline, 2009; Aloys et al, 2006; Bolaji and Olalusi, 2008; Adegoke and Bolaji, 2000) that Nigeria produces over 10 million tones of cassava every year. In recent times, cassava chips are becoming popular in Nigeria and all over the world because; production of cassava chips is not capital intensive, it is used as snacks and also in the production of ethanol and as bio-fuels.

Plantain belongs to the family of the musa species with the major species to be musa acuminate and musa balbisiana (Anyanwu and Komolafe, 2003). It is widely used as food (in different forms) in all parts of the world, as herbs, as drinks and in the pharmaceutical industries. Plantain chips is one of the major recipe that is used to garnish rice to a more palatable state and is also commonly used as snacks (dried plantain chips). Plantain plantations are very common in some West African countries such as Ghana where they serve as potential export commodities. These chips are also processed into powdery form and used as food in a pounded form. Plantain chips is widely eaten in Venezuela, Mexico, Colombia, Cuba, Honduras, Ecuador, Guyana, India, United States of America, Central American, South American countries, and in other parts of the world. In Nigeria, plantain is also roasted and eaten exactly the way yam (some plant species that belongs to the genus - Dioscorea (family - Dioscoreaceae) that form edible tubers) is done. Roasted plantain serve mostly for domestic consumption or commercial purposes, employing some significant percentage of food hawkers and fast-food sellers especially in third world countries.

One of the major method of removing moisture from agricultural products in most parts of Nigeria is by open sun drying. This method is not only very primitive and barbaric but also exposes the products to dust, stains, rodents, birds, and flies, such that the product becomes a potential vector for different diseases. The major aim of this study is to develop a cost effective way of preserving local agricultural products through a modern and cost-effective drying equipment in order to reduce the food waste and food contamination that is usually encountered by farmers through open sun drying in the under-developed countries.

Material and Methods

The solar dryer used in the study was constructed with cheap and locally available materials. The most important parts of the constructed solar dryer include; the collector, drying cabinet, and drying trays. It has been reported in the literature (Adegoke and Bolaji, 2000) that the best stationary orientation for solar dryers is to face it due south in the northern hemisphere and due north in southern hemisphere and with a tilt > the local latitude of the study area. The study area (Abakaliki, Ebonyi State, Nigeria) is located on 6.3333° N, 8.1000° E, (Menakaya, 1980; hence the solar collector is oriented south with a tilt of 20.33^o for increased air circulation and performance of the dryer.

Different design equations exist in the literature for solar dryers. However, careful analysis indicate that the method utilised in the literature (Okonkwo and Okoye, 2005) and that by other research groups (Henry and Price, 1999; Bolaji and Olalusi, 2008; Adegoke and Bolaji, 2000) could serve as useful tool in the present study. Thus the optimum angle of inclination of the collector was 20.33^o (local latitude + latitude of Abakaliki), determined using the relation (Okonkwo and Okoye, 2005);

$$\theta = L + 15 \tag{1}$$

where θ is the tilt angle and L is the local latitude of the study area.

The dryer efficiency, (η_D) can be deduced from the relation given as;

$$\eta_D = \frac{\Delta M \ L}{A I_D \ t} \tag{2}$$

where ΔM is the change in the mass of the crop, (L) is the latent heat of vaporization of water, (M), (t) is the time of drying, (I_D) is the insolation received by the dryer and (A) is the effective area of the dryer.

The moisture content (MC) from the crop is calculated using the formula given in (Kumar and Tiwari, 1996; Tiwari 2002; Okonkwo and Okoye, 2005);

$$MC\,(\%) = \left[\frac{M_i - M_f}{M_i}\right] x\,100\% \tag{3}$$

where M_i = mass of sample before drying and M_f = mass of sample after drying.

The three major modes of heat energy transfer are radiation, convection and conduction. The sum of these and other processes taking place in the system is necessary to determine the energy balance of the device. According to the literature (Aloys et al, 2006; Bolaji and Olalusi, 2008; Adegoke and Bolaji, 2000; Forson et al, 2007; Gatea, 2011; Alkilani et al, 2011), the energy loss in a solar collector due to conduction, convection and radiation can be unified to a simplified form as;

$$Q_L = Q_C + Q_V + Q_R \tag{4}$$

In equation 4, Q_C in watts (W), gives the rate of heat loss from the absorber due to conduction, Q_V in watts (W), is the rate of heat loss from the absorber due to convection, Q_R in watts (W), gives the heat loss from the absorber due to re-radiation of long wavelengths. Research done by Ekechukwu and Norton, (1999), and Bansal et al, (1999), indicate that Equation (4) can be written in the form:

$$Q_L = U_L \; A_C (T_C - T_{amb}) \tag{5}$$

where A_C is the effective collector area, T_C is the collector temperature, and T_{amb} is the ambient temperature.

Equations (1) to (5) were used in the design considerations and analysis. The temperatures, relative humidity of the dryer and ambient conditions were monitored with thermometers (laboratory type mercury bulb thermometers with an accuracy ± 0.5 ^oC) and a relative humidity sensor. The thermometers were inserted inside the cabinet and the average rise in temperature T_{ave} was used. Some thermometers were also attached on the outside walls of the solar dryer to measure the heat loss/absorption and another also inserted in the control (OSD). The chips (cassava and plantain) were carefully sliced into uniform dimensions of approximately 2.25 cm^2 by surface area, and 500 g of the sliced cassava and plantain chips was also measured out. The dryer trays were then lightly filled with the cassava and plantain chips. The control experiment contained similar quantity and size of cassava and plantain chips but were spread outside on a clean mat and then subjected to open sun drying. The temperatures and relative humidity were recorded at regular interval of one hour between the hours of 0.800 am in the morning to 17.00 pm local time in the evening.

Result and Discussion

Figure 1 gives the variation of the temperature with the time of the day. The result show that an optimum temperature of ≈ 60 ^oC was recorded in the collector at 15.00 pm. This implies that the collector retains a large amount of heat, such that effective drying takes place longer. The difference between the ambient temperature and the dryer is very wide (20 ^oC), indicating the effectiveness of the dryer.

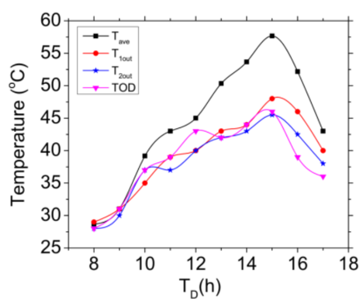

Figure 1. Variation of temperature with time of the day.

From Figure 1, it is clearly shown that the ambient temperature and the temperature obtained from the control (open sun drying) is within the same range, with a difference of ± 3 ^oC. This relatively small value also show that the heat loss from the walls of the dryer is small compared to the overall temperature recorded inside the dryer cabinet. This could be attributed to the nature of the materials used in the construction of the dryer. The results (Figure 1) also show that the temperature inside the dryer was still high enough during the end of the experiment for each day (≈ 45.5 ^oC) while the temperature recorded for the open sun drying was approximately 35.5 ^oC. This gives a wide temperature difference of 10 ^oC, implying that the solar dryer can retain heat effectively for useful drying even at night time. The difference in the temperatures recorded externally (T_{1out} and T_{2out}) and that (TOD) obtained in open sun drying show a relatively small difference (± 2 ^oC). This is due to the proximity in the test environment (where the solar dryer is mounted and where the plantain and cassava chips are spread on a mat) such that the weather variables are almost the same.

Figure 2 show the variation of the relative humidity with time of the day. The relative humidity increases with time of the day up to 15.00 pm and then decreases. Variation in the relative humidity of any place at any instant depends on the atmospheric and weather conditions of that place amongst other factors. Some research groups (Bolaji and Ayoola, 2008) observed an initial decrease before an increase as the time of the day progresses. The relative humidity is usually least at noon as the atmosphere is clearest at noon but can be significantly affected by the atmospheric and weather variables. However the values observed for the solar dryer is relatively higher compared to that obtained for the open sun drying. This can be attributed to the difference in the atmospheric conditions of the open environment compared to the solar dryer.

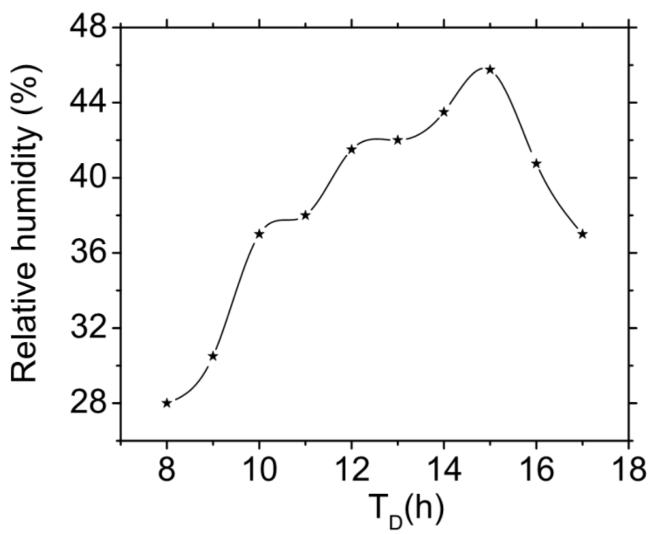

Figure 2. Variation of the relative humidity with time of the day.

Figure 3 gives the result of the mass loss in grams, of the cassava and plantain chips dried using the solar dryer. The results of the solar dryer show that the mass loss was more pronounced compared to the open sun drying method. The cassava chips dried faster, resulting in zero mass loss from the 15th day while the plantain chips exhibited zero mass loss on the 18th day. Physical observation of the cassava and plantain chips dried using the solar dryer, show that both maintained their colour while those dried under open sun drying conditions indicated a colour change from white to milky-brown for the cassava chips and a change from brownish-yellow to brownish-black for the plantain chips. This was attributed to some dust particles and debris that it picked up during the open sun drying process, a non-uniform temperature distribution arising from surface interaction in the open environment, or other related phenomena. Also some signs of contamination and smell was also noticed, indicating that the cassava and plantain chips are gradually attaining stages of deterioration and decay. This is possibly due to infection from flies and other vectors/rodents that perch on them as they were exposed to the open environment. The control (open sun drying) exhibited a zero mass loss on the 20th day and was not included in Figure 3, due to the aforementioned observation. This wide difference in the zero mass day is a clear indication that the drying done using the solar dryer is more efficient, less time consuming, less energy demanding and more cost effective compared to the open sun drying approach.

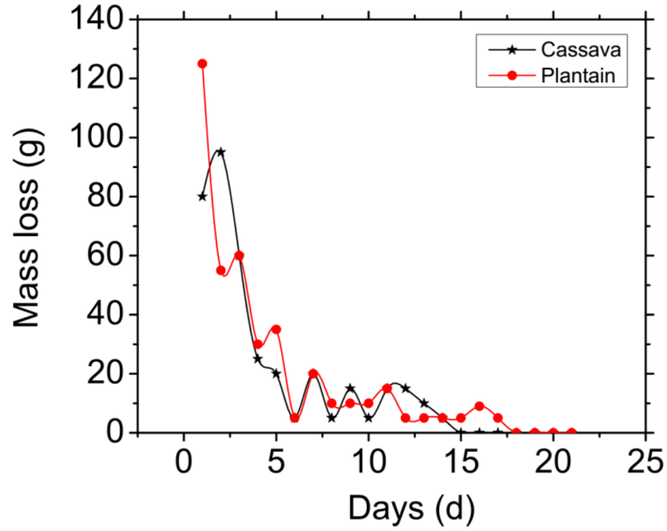

Figure 3. Variation of the mass loss with number of days.

The difference in days at which both materials (cassava and plantain chips) attained a zero mass loss was explained on the basis of the difference in the chemical constituents of the cassava and plantain chips.

Wastage of food and agricultural products due to poor preservation techniques can add significantly to the build-up of municipal solid wastes especially in third world countries where unsustainable waste management is common. Several scholars have reported on the negative consequences of poor waste management to man and to the environment, and on the need for energy and environmental sustainability (Elom, 2013; Nwofe, 2013; Nwofe, 2014; Nwofe and Ekpe, 2014; Nwofe, 2015). Fabrication of a cost-effective solar dryer can augment significantly in reduction of this colossal food wastes if commercialised in a way that local farmers can afford. The results of the this study is a clear evidence that the use of solar dryer gives faster drying process, yields high quality products, eliminates food waste and contamination, and is time saving compared to open air sun drying. In this regards, the author strongly recommends for a speedy government intervention in research in preservation of agricultural products, subsidizing of such preservation equipments at an affordable scale, dissemination of information on the new practice, and comprehensive preservation education of the local farmers by agricultural extension officers. This will go a long way in solving the problems of acute food shortage and contamination in regions with such agricultural product preservation issues.

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