

AN EXPERIMENTATION INVESTIGATION OF SOLAR ENERGY UTILIZATION FOR DRY AGRICULTURAL PRODUCTS.

ABSTRACT

An experimental solar dryer was developed and comparison between using solar energy and air-sun drying methods with sliced plantain and maize (shelled corn) were assessed. The dryer consist of a solar collector panel (concentrator type), a thermal storage unit and a drying chamber. The parabolic was tilted at 7° to the horizontal with the aid of four supports at two differ. A transparent PVC film, 0.15 mm was used as the cover plate materials. The parabolic was tilted at 7° to the horizontal with the aid of four supports at two different heights. The absorber material used was aluminium pipe 145 cm long of external diameter 5 cm, painted black and fixed at the focal point of the parabolic mirror. The thermal storage unit and the drying chamber were built of wood because of its good insulation properties. Results showed the collector outlet, storage unit and drying chamber temperatures ranged from $37 - 47^{\circ}\text{C}$, $36 - 46^{\circ}\text{C}$, and $33 - 45^{\circ}\text{C}$ respectively. About 70.1 % of moisture evaporated using solar dryer for plantain as compared to 45 % using open air drying. Also more moisture evaporated from the maize (100 %) using solar dyer than using open air drying (65 %). The degree of variation between using solar dryer and open air drying was found to be statistically significant ($t = 2.5$; $p = 0.05$) for both treatments. Results showed that using solar collector / dryer evaporated more moisture from the products than using the open –air sun drying.

Key Words: Agricultural products, Development, Moisture, Solar dyer, Air–sun drying

Introduction

Nigeria by virtue of its position in the tropics is blessed with sunshine for than 95 % period of the year. Climatic data collected from the metrological station at Ikeja in Lagos State showed that the lowest mean monthly sunshine hours during the year are 111 hours on September (wet cloudy season). The amount of solar radiation received at a particular station is a major controlling factor in the designs of any solar energy system. From a purely technical standpoint, solar energy conversion is potentially capable of producing the bulk of the world's future energy demand if it is properly harnessed. In 2012, the world's total energy consumption of about 5.6×10^{20} Joules (IEA, 2013). The total energy consumed equal to solar energy received every year by an area of $44,000\text{km}^2$ in a desert region. In other words, solar radiation absorbed on earth is 20,000 times the world's energy consumption. Solar energy is fast becoming an alternative source of energy in view of the high rate of depletion of the convectional energy source and negative effect on climate change by some other sources of energy (Brian, 2009).It was estimated that the world's petroleum will last for

another 30 years, coal deposits for 300 years, natural gas for 48 years and nuclear energy reserves for 90 years at known levels of technology. Although there are some other alternative sources of energy like wind and shale, solar energy has attained the first phase on the list of preference due to the fact that it is vast and inexhaustible (Wolteng, 2008). Sun-drying has been used universally as a method of preserving agricultural produce, but is not universally applicable to a common standard of efficiency and reliability. In many countries, therefore, it has been largely superseded by drying processes in which biomass or fossil fuels are used as sources of energy. The biomass option regarded as an indirect method of solar-drying. In the simplest traditional sun-drying process, produce is spread in thin layers on the ground, turned occasionally and covered or moved to a shelter when rain falls. It exposes the produce for extended periods to risks of deterioration caused by dust and dust borne organisms and to the depredation of insects, rodents, birds and other animals (FAO, 2003; Gyabaah, 2013; Makwaia, 2013; Samu-Negus, 2013). For fruit and vegetable produce the simple process may entail a loss of nutritive value such as destruction of vitamin C or provitamin A and may lead to discolouration and the development of off-flavours (Curran et al., 2002; Duff et al., 2008; Makwaia, 2013). Michael et al., (2006) and Taiwo, (2013) highlighted that when ambient humidity is high the simple sun drying process may be unreliable, even where solar radiation levels are high and extensive mould growth may take place in the produce under these conditions. Best R, (2009); Curran C.L and D.S Trim, (2002) and Spies C.I and H.C. Coote. (2006); Onwuka et al., 2002; ILO, (2009), and Thanh, N.C and S. Muttamara, (2008) highlighted some methods used for improved sun-drying are as follows:

- (1) use of drying floors and platforms
- (2) use of blackened surfaces
- (3) use of woven matting and
- (4) Use of wire mesh trays mounted on bamboo pole supports.

Solar drying can be considered as an elaboration of sun drying and is an efficient system of utilizing solar energy (Bala, 2000). Most of the advantages of solar energy are so much a part of our daily lives that we often overlook them. Some of the outstanding obvious characteristics of solar energy were highlighted by McVeigh (2009) are as follows:

- The raw material (solar energy) is free of cost and requires no purification
- The raw material is often delivered to where we want to use it, which means no transportation costs.
- The supply is essentially unlimited and is not affected by the amount used.
- Most solar energy applications are free of pollution and have no danger of fire or other hazards.
- The political problems associated with its use are minimal since no one owns the sun.
- The direct use of solar energy does not deplete the resources of earth.
- Equipment which depends on solar energy as the energy source involves no running costs, only routine maintenance cost is incurred. Therefore, the development of efficient solar drying processes would help to increase the production of dried agricultural and food products while reducing the dependence of industries on fossil

fuels. Gallali et al., (2000) and Itwange, S, V and S, Adebayo (2009) highlighted the compared products dried by solar dryers and natural sun drying. Their study indicated that using solar dryers gives more advantages than natural sun drying, especially in terms of drying time and moisture removal. The study was performed to develop batch drying processes for agricultural and food products that will be economically feasible for the rural farmers and compatible with solar limitations. Hence no auxiliary equipment and other energy source are needed other than solar energy. This paper reported a preliminary study of rates of drying maize and sliced plantain tests which were conducted in May and June when the rainy period was picking up momentum.

Materials and Methods

Description of Solar products Dryer.

The design concept of the solar dryer is to collect the solar energy through a solar collector and use it to heat up a mass of air and pass it through a drying chamber by natural convention established by buoyancy of airflow. The experimental solar dryer was made up of a collector and a drying chamber as presented in Figure 1. The collector which makes use of a stationary non-tracking concentrator was constructed from four reflective sheets of tin-plates mounted on a parabolic frame structure with 4 cm thick coconut fibre insulation between them. The frame structure was made from plywood. The parabolic frame formed has a focal length of 25 cm and the square shape structure with dimension of 120 cm x 120 cm x 60 cm. The collector was made from aluminium pipe 145 cm long of external diameter 5 cm painted black and fixed at the focal point of the parabolic mirror. The pipe was placed concentrically in a glass tube, 129 cm long 8.8 cm diameter with the aid of two wooden corks. A transparent PVC film, 0.15 mm was used as the cover plate materials. The parabolic was tilted at 7° to the horizontal with the aid of four supports at two different heights. The base of the supports was fitted with rollers for easy movement. The drying chambers were constructed from 1.27 cm thickness of plywood and of square shape with dimensions 48 cm x 48 cm x 123 cm. It rests on 43 cm supports and has a plenum chamber 48 cm x 48 cm x 25 cm. The aluminium pipe from the collector goes into the plenum chamber from the rear of the drying chamber through a 5.3 cm hole. The outlet air vent is the chimney which is situated on the top of drying chamber. It is made of PVC tube, 15 cm long and 10 cm diameter with PVC lip cover. Lagos State is situated in the South West of Nigeria. It falls within longitudes $030^{\circ} 50'E$ and $030^{\circ} 38'E$ and latitudes $060^{\circ} 20'N$ and $060^{\circ} 18'N$. The mean daily sunshine hours in Ikeja-Lagos State for 30 years (1985 – 2014) is presented in Table 1.

Experimental Procedure

Preliminary tests were carried out to determine the temperature profile and history of the drying chamber. This was to get an ideal of the temperature distribution across and along the chamber during day (7 .00 am – 7 .00 pm). Drying tests were performed with maize faro 6

and yellow plantain sliced into 5 mm thickness. The maize was loaded in the tray to 4 mm initial bed depths and the sliced plantain was loaded in single layer 5 mm bed depth. The plantain tests were conducted in May and those of maize were done in June. Moisture contents of both the wet and dried products were determined from weights of samples before and after drying by an oven at temperature of 80°C. Moisture content was calculated as kg/kg dry solids. The loss in product moisture during drying was assumed to be equivalent to the product weight loss. Drying was done for a total 9 hours and four tests were performed for each product. The first three (1, 2, 3) tests was done using solar dryer and fourth (4) was done using open air-sun drying as control. The moisture content of the maize was brought to the required value by wetting it with the approximate amount of water and freezing it for 9 weeks. The loaded open-air tray was appropriately supported, so that the air could flow through the top and below. Temperatures were measured using mercury in bulb thermometers. Ambient air temperature was measured from a wet and dry bulb thermometer. The ambient air, collector outlet, storage unit and dry chamber temperatures were all manually measured hourly between 8. 00 am to 7.00 pm. The results were presented in Tables 2 and 3 respectively.

Table 1: Mean daily sunshine hours in Ikeja-lagos State for thirty years (1985 – 2014)

Months	Hours	% of possible sunshine hours
January	6.11	56
February	6.50	55
March	6.45	53
April	5.25	43
May	6.25	57
June	4.33	34
July	4.96	40
August	3.76	38
September	3.48	29
October	5.23	44
November	6.90	58
December	6.93	34
Mean	6.40	54

Source: Department of Metrological Services, Lagos.

Table 2: Showed the variation of the dryer mean system temperatures with the drying conditions for the products

Product	Test No.	Initial Moisture (kg/kg)	Tray Loading (kg.m ²)	Ambient Temp. (°C)	Collector Temp. (°C)	Storage unit Temp. (°C)	Drying Chamber Temp. (°C)
Plantain	1	7.33	16.2	32	45	36	44
	2	7.33	16.2	34	47	46	45
	3	7.33	16.2	30	42	40	38
	4	7.33	16.2	29	37	36	33
Maize	1	0.58	10.1	32	45	36	44
	2	0.58	10.1	34	47	46	45
	3	0.58	10.1	30	42	40	38
	4	0.58	10.1	29	37	36	33

Results and Discussion

Table 1 showed the means daily hour sunshine in the studied area. The means daily sunshine hour ranged from 3.48 – 6.93 hours and the minimum and maximum daily sunshine hours occurred at months of September and December respectively. Table 2 showed the variation of the dryer mean system temperatures. The result shows that the average ambient air temperature ranged between 29 – 34°C, collector outlet temperature ranged from 37 – 47 °C, storage unit temperature ranged from 36 – 46 °C and drying chamber temperature ranged from 33 – 45 °C. The result also indicated that the air heater (collector) has the capacity to heat air between 7 – 12 °C depending on solar energy or insolation. Table 3 shows the hourly experimental results which also indicate the weights of the final product in each test. The

initial moisture content of sliced plantain was 80 % (wet basis) or 73 % (dry basis) and that of maize was 36 % (wet basis) or 56 % (dry basis). Because the months of May and June are the period of rains appreciable overcasts were present during the drying tests. Therefore, the mean sunshine hours were about 60 % of that expected on a clear dry season, hence the solar energy or insolation was about 60 to 70 % of a normal clear dry day. Figure 2 shows the drying curves of the sliced plantain and maize. It shows that the open air tray was slower in drying than any of the three other trays in the solar dryer. The trial products moisture content at the end of the day was higher in the open air tray than the solar drying chamber. One reason for this is likely causes low ambient air temperature. Because of the season (rainy season) the mean ambient air temperature was low (34 °C) compared to that in the drying chamber of the solar dryer (45 °C). Although the final moisture content required for the safe storage of the plantain sliced (8 % wet basis) was achieved in both drying in open air and solar drying, it is important to note that about 70 % of the total required moisture was evaporated in the drying chamber , 9 hours of tests. On the other hand only 45 % of the total required moisture was evaporated in the open air tray. Similarly, drying curves for maize shows the same trends as on plantain, but here, the trial moisture content required (10 % wet basis) achieved by the seventh hours of the test in the solar drying chamber, whereas this was not achieved in the open air drying throughout the 9 hours of the test. Therefore, the difference between results for tests with solar drying chamber and those of open air drying were greater in the maize tests. The total amount of moisture evaporated in the solar drying chamber was far more than that evaporated in the open air drying (100 % vs 65 %). These findings collaborate with other researchers (Bala, 2000; Gallali et al., 2000, and Intwange and Adebayo, 2009) that solar dryer gives mores advantages than sun drying in terms of moisture removal, efficient and drying time. These preliminary drying tests have shown that solar concentrators is more efficient for drying than open air drying and have provided guidance for further process development.

Table3: Products Weights during drying tests.

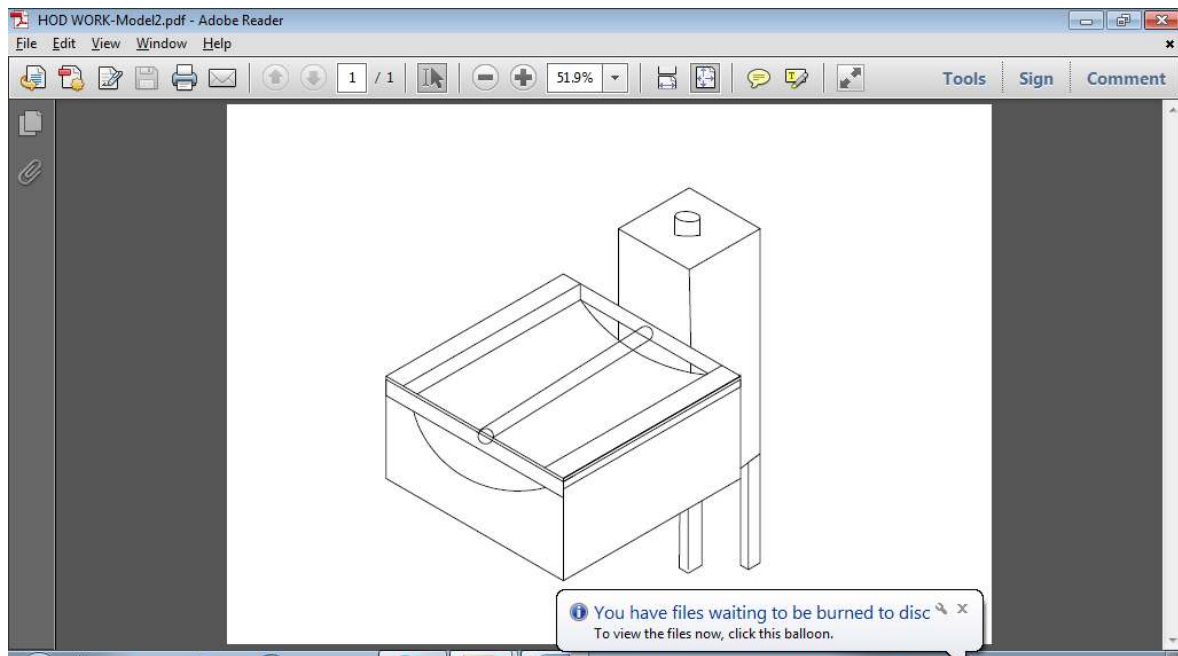
Time (Hr)	PLANTAIN (kg)				MAZE (kg)			
	1	2	3	4	1	2	3	4
0	3.28	3.28	3.28	3.28	2.05	2.05	2.05	2.05
1	2.91	2.98	2.90	3.14	1.94	1.95	1.94	2.00
2	2.64	2.61	2.63	2.91	1.80	1.82	1.81	1.89
3	2.24	2.20	2.21	2.60	1.68	1.67	1.67	1.75
4	1.92	1.90	1.92	2.26	1.58	1.58	1.57	1.70

221	5	1.67	1.68	1.67	1.99	1.52	1.52	1.53	1.67
222	6	1.45	1.47	1.44	1.75	1.49	1.49	1.49	1.64
223	7	1.25	1.28	1.25	1.56	1.47	1.47	1.47	1.62
224	8	1.11	1.13	1.11	1.46	1.46	1.46	1.46	1.61
225	9	0.99	0.99	0.99	1.39	1.45	1.44	1.45	1.61

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231 Fig. 1: Solar Dryer

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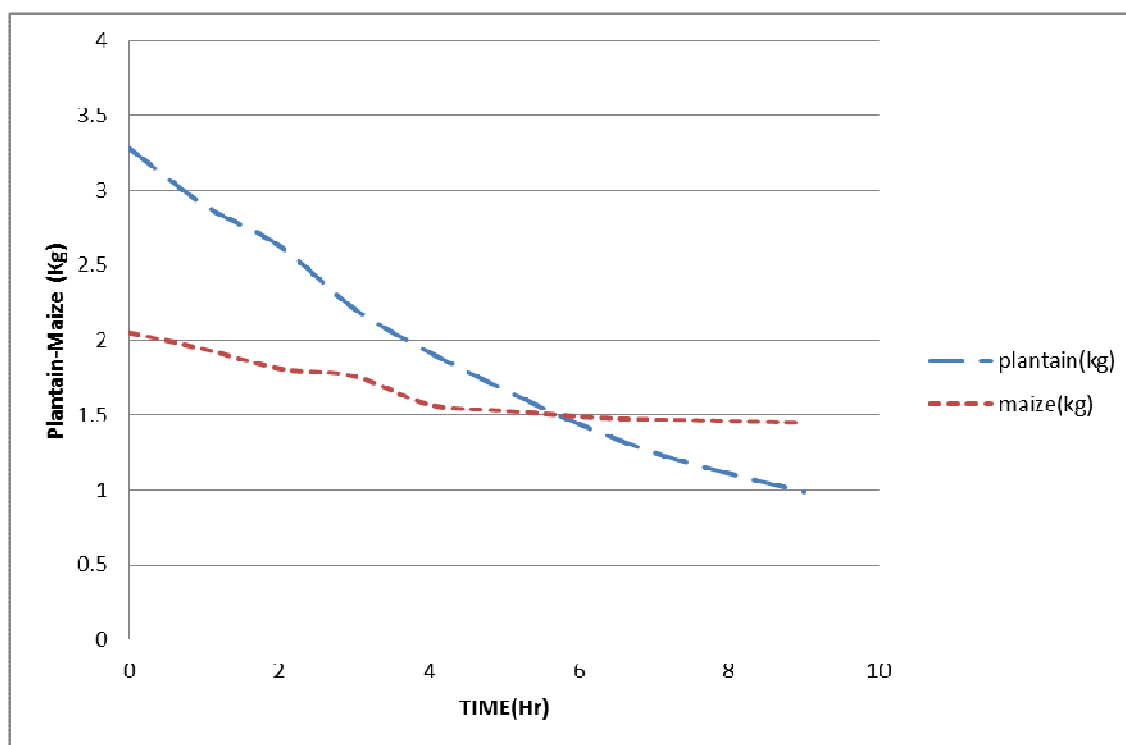


Fig 2 : Drying curves for maize and plantain

CONCLUSION

The result of this study showed that:

- (1) Solar dryer was developed using local materials.
- (2) Solar concentrator was more efficient for drying than open air drying
- (3) Saving in time was achieved by using the solar dryer against open sun drying.
- (4) More moisture was removed in the products by using solar drying.
- (5) The parabolic reflector should be increased to provide a large surface area.
- (6) The diameter of the concentration should be increased to allow in more air.
- (7) The use of a fan is very essential to ensure adequate circulation. This will then require another type of energy to power the fan. This economics of this should be studied, vis-à-vis the effect on the cost of the design. This is necessary as the aim is to make the dryer within the economic reach of the rural farmers.
- (8) Additional studies with different products at several levels of process variables should be investigated.

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