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ORIGINAL RESEARCH ARTICLE

EVALUATION OF NSPRI SOLAR DRYERS FOR YAM CHIPS PRODUCTION (ELUBO)

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ABSTRACT

This study evaluated the two solar dryers developed at Nigerian Stored Products Research Institute (NSPRI) - Parabolic Shaped Solar Dryer (PSSD) and Solar Tent Dryer (STD). The evaluation was conducted using yam chips (Elubo) in Ilorin. The yam chip was soaked in water at three different temperatures: 80, 90 and 100°C, and allowed to cool in the water for 15 hours prior to drying. The yam samples were then spread on trays in each of the PSSD, STD dryers and Ambient. A TEKCOPLUS THTK-6, K- Type 4-channel thermocouple was fitted in each of the dryers to monitor the drying temperature inside the dryers and ambient. The study considered sun drying as the control. The product samples were subjected to proximate composition determination. The moisture content of the samples was also monitored daily. Means of data collected were compared using graphs and 2-way ANOVA using Microsoft Excel 2016 and SPSS version 20. The results showed higher temperatures recorded in the dryers (PSSD= 40.77 ± 1.24°C and STD= 34.62 ± 0.70°C) compared to what was obtained in the ambient (33.59 ± 0.38°C). This resulted in a higher drying rate in PSSD and STD at an average of 0.57 kg/day and 0.52 kg/day respectively compared to the control (0.46 kg/day). Drying in PSSD was completed in 3 days with final moisture content of 7.53%, while it lasted for 4 days in STD and Control with final moisture contents of 8.98% and 9.37% respectively. Similarly, carbohydrate and crude protein were found to be significantly higher in samples dried in PSSD compared to STD and the Controlled samples (P≤0.05). The result of microbial quality evaluation revealed that the bacteria and fungi counts of the dried yam chip samples inside PSSD and STD were within the acceptable standard of ≤ 300 Cfu/ml, lower than that of the control sample where higher value (1.80 x 10^3 Cfu/ml) was recorded. Therefore, both PSSD and STD are potentially viable for safe production of yam chips of high quality for human consumption.

1.0 Introduction

Drying of agricultural produce is a simple process through which agricultural products can be preserved for future use by removing available moisture in the crops to avoid deterioration (Ohijeagbon et al., 2016). Among the common methods used in drying and preserving agricultural products are open air and uncontrolled sun drying (Toshniwal and Karale, 2013; Aderinlewo et al., 2013). Previous studies have reported that these methods could pose serious challenge on food quality with respect to product contamination due to dust, insect infestation and animal contact which invariably can lead to product degradation (Ratti and Mujumdar, 1997; Okoroigwe et al., 2013). This might compromise the food quality and causes reduction in the market value of such commodity (Toshniwal and Karale, 2013; Sadodin and Kashani, 2016).

Forced-air drying which uses artificially heated air and fan for drying still seems to be a better way of drying produce. However, the cost of acquiring and operational expertise makes it unaffordable as an alternative to unhygienic road-side and bear ground drying common to farmers in developing countries such as Nigeria. The use of solar energy is another affordable, cost effective and readily available alternative in this part of the world. Solar energy is a major area of interest within the field of agriculture, particularly in the area of produce drying as it is viewed as a viable technique of preserving agricultural products. The use of heat energy from solar could be applied through direct sun drying or indirect with specific designed solar dryers to prevent postharvest losses which are a common phenomenon in many developing countries (Okonkwo and Okoye, 2005; Mustayen et al., 2014; Ringeisen, et al., 2014).

Despite the abundance of solar energy in tropical countries, the direct sun drying being practiced in these areas does not allow efficient and effective utilization of the energy. Thus, making the products susceptible to environmental contamination which makes them unsafe for human consumption (Sadodin and Kashani, 2016). Lack of efficient and affordable solar dryers for community drying has been a challenge among farmers in Nigeria. In view of the above, Nigerian Stored Products Research Institute (NSPRI) developed Parabolic Shaped Solar Dryer (PSSD) and Solar Tent Dryer (STD) for drying of agricultural products. Therefore, the aim of this study was to evaluate the effectiveness of the dryers (PSSD and STD) for production of yam chip with respect to drying time, drying rate, proximate and microbial qualities.

2.0 Methodology

2.1 Location of the Experiment

The Study was conducted during the harmattan season in the premises of Nigerian Stored Products Research Institute (NSPRI), Ilorin, Nigeria (N 8° 27'14.77"; E 4° 33'21.47").

2.2 Description of the Solar Dryers

The Parabolic Shaped Solar Dryer (PSSD) has a structural dimension of 8 m x 4 m x 2.4 m with the longer side facing the East-West direction for maximum reception of solar radiation. It has a black floor for heat collection and an underlying insulation that prevents heat sink. It has a parabolic shaped structural frame of 2.4 m height made of galvanized steel pipes. The roof is covered with transparent acrylic material. The drying chamber has 2 drying racks with 4 layers each made of mild steel angle iron and 56 trays of 0.55 m x 0.55 m made of square pipe and wire mesh. The dryer has an effective drying area of 16.94 m2. There are two (2) inlet vents with installed solar powered blowers. The top is fitted with two (2) pneumatic aspirators for extraction of moisture from drying chamber. An access door is also provided at one end of the structure (Figure 1a).

The Solar Tent Dryer (STD) has structural dimensions of 3.2 x 4 x 3.1 m with the longer side facing the East-West direction for maximum reception of solar radiation (Figure 1b). It has a black floor for heat collection and an underlying insulation that prevents heat sink as obtainable in PSSD. It was constructed of wooden posts erected on a dwarf block wall of 0.8 m height. The dryer is covered with transparent UV screened polycarbonate film. The drying chamber has a drying rack with 3 layers made of wood and 12 trays of 0.70 m x 0.75 m and 6 trays of 0.55 m x 0.75 m made of wood and wire mesh. The dryer has an effective drying area of 8.48 m2. There are 3 adjustable inlet vents on each side of the dwarf walls. The top is fitted with one pneumatic aspirator for extraction of moisture from drying chamber. An access door is also provided at one end of the structure.

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Figure 1a: Parabolic Shaped Solar Dryer

Figure 1b: Solar Tent Dryer

2.3 Collection and Preparation of Experimental Materials

The yam tubers used for the experiment were procured from a market in Alapa village via Ilorin, Kwara State, Nigeria. The yam tubers were sorted, peeled and washed with potable water before slicing. The cleaned tubers were sliced into 20 mm thickness. The yam slices were divided into three lots and soaked in water at temperatures; 80 °C, 90 °C and 100 °C respectively (Oyewole et al., 2013). It was then allowed to cool in the water for 15 hours. The initial moisture content of the soaked samples was determined using the oven-drying method (AOAC, 2005).

2.4 Drying of Samples and Temperature Monitoring

The drying was carried out using three drying systems namely; PSSD, STD and Ambient (control). Samples were spread on trays and placed in PSSD, STD and Ambient. A TEKCOPLUS THTK– 6 K-Type 4-channel SD thermocouple was installed in each of the dryers as well as Ambient to monitor the drying temperature (Figure 2).

Figure 2: Sliced yam chips during drying in PSSD and STD dryers

2.5 Determination of Proximate Composition and Microbial Analysis

The initial and final proximate compositions of the samples were determined (AOAC, 2005). Also the microbial quality was determined using Microbiological Guidelines for Food (CFSFEH, 2014).

2.6 Weight Loss and Drying Rate Determination

Trays from each of the drying system were weighed daily to monitor moisture loss. Drying continued until moisture content of the samples falls below 10% (Ukpabi et al., 2018). The drying rate was determined using Equation 1.

$$DR = \frac{M_i - M_f}{t} \tag{1}$$

where: DR is the drying rate in g/day, Mi is initial weight of sample, Mf is final weight of sample and t is the time in day.

2.7 Statistical Analysis

Graphs were plotted using Microsoft Excel version 2016 to compare means. SPSS version 20 was used to determine Analysis of Variance (ANOVA) and means separation.

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3. Results and Discussion

3.1 Effect of Water Temperatures and Drying Media on Drying Rate of Yam Chip Samples

In all the drying systems, the highest drying rate was recorded on the first day (Figure 3). The highest drying rate was recorded in the Control on the first drying day regardless of the water treatment temperature considered (Figures 3 and 4). This could be attributed to easy removal of surface moisture on the product by air in the ambient immediately after loading, while reduction in temperature and increase in humidity was experienced during the same period in the two dryers. Thereafter, there was reduction in the drying rate of the Control throughout the remaining drying period. The result further shows that for all water treatment temperatures, the PSSD recorded the highest drying rate of 0.57 Kg/ day while the lowest with an average value of 0.46 kg/ day was obtained in the Control. STD had an average drying rate of 0.52 Kg/ day. The higher drying rate observed in the dryers can be attributed to the higher temperature maintained in them. PSSD had an average temperature of 40.77°C, STD recorded 34.62°C and Control had 33.59°C. This resulted in reduced drying time in the PSSD which took 3 days compared to 4 days in STD and Control (Figure 3 and 4). This agrees with earlier studies conducted on PSSD and STD where higher temperatures were reported over the ambient (Control) (Ade et al., 2018; Oyewole et al., 2019). Table 1 shows the result of ANOVA for the effect of water temperatures (80°C, 90°C and 100°C), drying media (PSSD, STD and Control) and their interaction on drying rate. The result shows that the effect of drying system on drying rate was significant at $P \leq 0.05$; while the effect of water temperature and its interaction with drying system was not significant at $P \leq 0.05$. This is an indication that the type of dryer used for production of yam chip will have effect on number of days required for drying among other relevant factors.

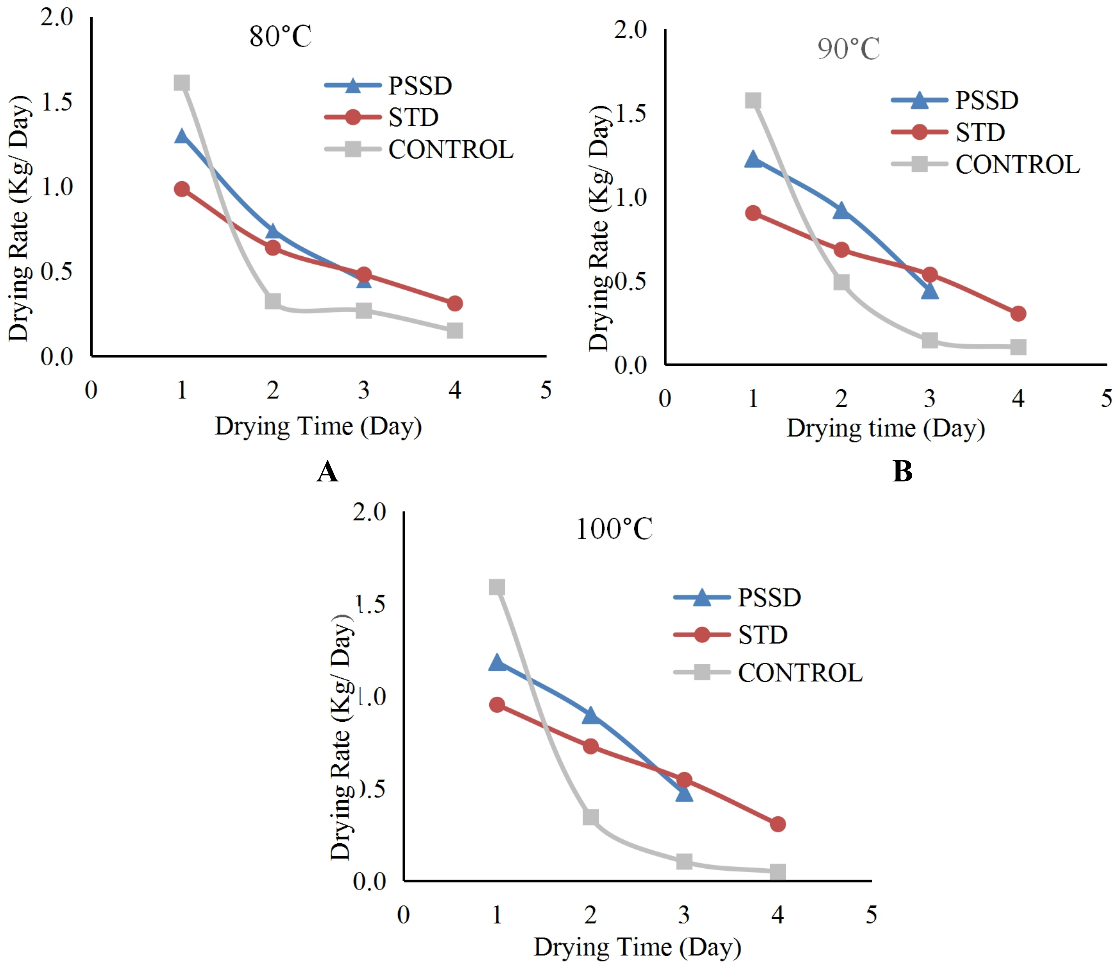

Figure 3: Drying rate versus Drying time

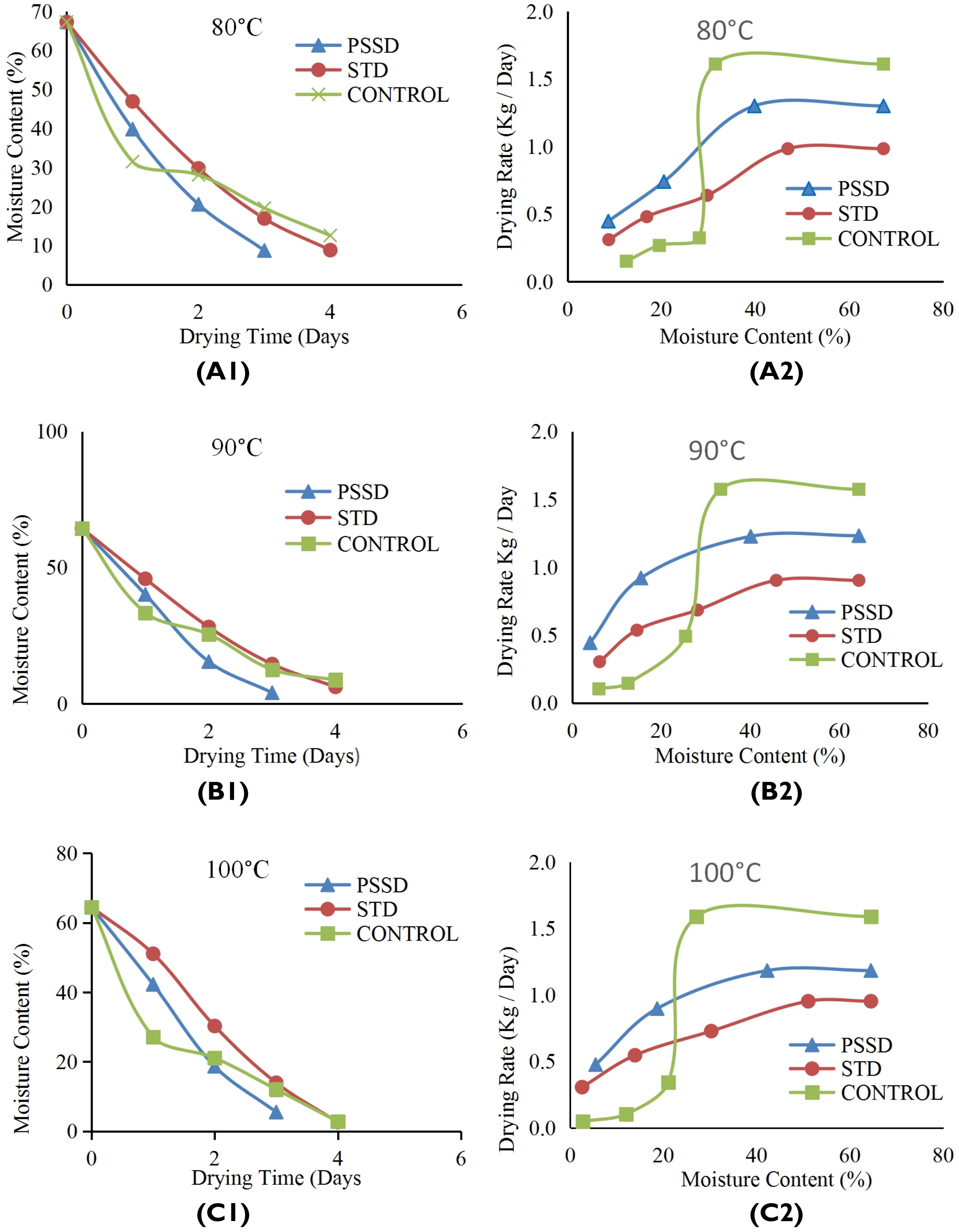

Figure 4: Moisture content versus Drying time and Drying rate versus Moisture content

Table 1: Analysis of Variance for Drying Rate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Drying System	.075	2	.038	171.278	.000*
Water Temperature	3.889E-5	2	1.944E-5	.089	.915
Drying System * Water Temperature	.001	4	.000	1.627	.196
Error	.006	27	.000		
Total	9.744	36			

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3.2 Effect of Water Temperature and Drying System on Proximate Composition

The proximate composition of all samples regardless of the drying system and water temperature treatments gave carbohydrate, crude fibre and ash contents range of 80 – 84%, 1.1 – 2.0% and 1.1 – 1.5% respectively (Table 2). These values are very close to those reported by Adejumo et al. (2013) and Fashina et al. (2017) where carbohydrate, crude fibre and ash contents ranged between 78 – 84%, 1.1 – 2.0% and 1.1 – 2.3% respectively. The result further shows increase in ash, crude fibre, crude protein and fat content and decrease in carbohydrate as water temperature increases in PSSD, while there was no defined trend in STD and Control. There was no significant difference in crude fibre and ash content in all drying media at all water temperature treatments ($P \leq 0.05$) (Table 3). Carbohydrate, crude fibre and crude protein differ significantly in STD at 80°C, 90°C and 100°C respectively. These results agree with the reports of Leng et al. (2011) and Fashina et al. (2017).

Table 2: Effect of Water temperature and Drying Media on Proximate Composition of the Dried Yam Chips

Yam chip	Crude Ash (%)	Crude fibre (%)	Crude protein (%)	Crude fat (%)	Carbohydrate (%)
PSSD 80	1.25±0.12a	1.38±0.21a	4.15±0.35a	1.14±0.04a	84.38±0.81a
STD 80	1.35±0.12a	1.79±0.13a	4.78±0.38a	1.23±0.08a	80.68±0.26b
Control 80	1.25±0.08a	1.49±0.01a	4.28±0.03a	1.23±0.08a	82.11±0.14b
PSSD 90	1.26±0.13a	1.69±0.09a	4.70±0.29a	1.19±0.09a	83.05±0.32a
STD 90	1.38±0.16a	1.19±0.08b	4.14±0.22a	1.60±0.23a	81.98±0.37a
Control 90	1.53±0.13a	1.92±0.02a	4.33±001a	1.24±0.03a	81.92±0.16a
PSSD 100	1.42±0.20a	1.75±0.16a	5.37±0.13a	1.50±0.15a	81.95±0.30a
STD 100	1.08±0.02a	1.47±0.15a	4.48±0.27b	1.32±0.24a	81.86±0.87a
Control 100	1.17±0.07a	1.32±0.02a	4.51±0.03b	1.41±0.04a	81.81±0.13a

(Means ± S.E. within a column followed by different letters differ significantly at $P \leq 0.05$)

Table 3: Analysis of Variance for Proximate Composition

		Sum of Squares	df	Mean Square	F	Sig.
Ash	Between Groups	.584	8	.073	1.391	.245
	Within Groups	1.417	27	.052		
	Total	2.002	35			
Fibre	Between Groups	1.917	8	.240	5.102	.008*
	Within Groups	1.268	27	.047		
	Total	3.185	35			
Protein	Between Groups	4.790	8	.599	3.369	.005*
	Within Groups	4.799	27	.178		
	Total	9.589	35			
Fat	Between Groups	.775	8	.097	1.918	.098
	Within Groups	1.364	27	.051		
	Total	2.140	35			
Carbohydrate	Between Groups	32.899	8	4.112	6.022	.000*
	Within Groups	18.440	27	.683		
	Total	51.339	35			

*significant at $P \leq 0.05$

3.3 Effect of Water Temperature and Drying Media on Microbial Loads

The result of microbial quality evaluation shows that the bacteria and fungi counts of the dried yam chip samples inside PSSD and STD were within the acceptable limit of ≤ 300 Cfu/ml and lower than that of the Control sample where higher value above recommended standard was recorded (Table 4) (CFSFEH, 2014). The relative decrease in the bacteria and fungi counts in samples dried in PSSD and STD might be due to the higher drying rate and structure's enclosure against agents of contamination which could not be obtained in the Control under ambient condition. The earlier the moisture in product undergoing drying is removed the better to prevent its susceptibility to microbial infection (Adeniji, 1996).

Table 4: Microbial quality evaluation of the yam chip

Yam chip	Bacterial (Cfu/ml)	Fungi (Cfu/ml)
PSSD 80	0.23×10^3	0.20×10^3
STD 80	0.26×10^3	0.40×10^3
Control 80	1.80×10^3	TNTC
PSSD 90	0.30×10^3	0.15×10^3
STD 90	0.29×10^3	0.60×10^3
Control 90	1.80×10^3	2.00×10^3
PSSD 100	0.25×10^3	0.20×10^3
STD 100	1.25×10^3	0.30×10^3
Control 100	1.50×10^3	1.60×10^3

Note: TNTC = Too Numerous To Count; CFU/ml = Colony Forming Unit per mil.

4.0 Conclusion

Drying systems were found to have significant effect on drying rate of the yam chips. Maximum drying rate was recorded in PSSD with average value 0.567 Kg/ day while control had the lowest (0.46 Kg/ day). Drying was completed in PSSD in 3 days while it took 4 days in STD and Control. Also, carbohydrate, crude fibre and protein contents were significantly affected by the drying. Maximum carbohydrate content of 84.38% was recorded in PSSD at 80°C and minimum value of 81.81% was recorded in Control at water treatment temperature of 100°C. There were acceptable microbial loads in both the PSSD and STD dried chips after the tests and are considered safe for human consumption.

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