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ORIGINAL RESEARCH ARTICLE

RECENT ADVANCES IN SOLAR DRYING OF AGRICULTURAL PRODUCE IN NIGERIA: NSPRI EXPERIENCE

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ABSTRACT

Agricultural products are dried to enhance storage stability, in order to reduce post harvest losses, minimize packaging requirement and reduce transport weight. Crop drying through the sun is the most common practice in the country due to its no energy cost but often result in poor quality, unhygienic and contaminated products. This has been a major threat to food safety. Energy consumption and quality of dried products are critical parameters in the selection of drying process. An optimum drying system for the preparation of quality dehydrated products is supposed to be cost effective with less drying time and damage to the product. To reduce the energy utilization and operational cost as well to further produce high quality safe products, new trends in solar drying system were developed by the Nigerian Stored Products Research Institute (NSPRI) in order to proffer solutions to the threat in food safety as well as farmers and processors quest for drying with minimal energy cost. The technologies include mobile solar tent dryers, green house solar tent dryers and parabolic solar tent dryers. These entire dryers have great scope for the production of quality dried products and powders. These advancements have taken the advantage of material selection, design calculations to improve on the technology in order to achieve quality output in terms of environmental parameters and product quality. The advancement has also taken care of times of low solar irradiance especially during the rainy season which is highly humid. The temperature range obtained from the mobile, green house and parabolic solar dryers are 20 – 59.5°C, 21.5 - 68°C, and 25-78°C respectively while their respective average relative humidity are 71.64%, 60.21%, 49.77%. The ambient temperature range and relative humidity are 20 – 42.5°C and 74.88%. Experimental studies on the performance of the varied solar tent dryers were conducted using Chilli Pepper, Yam, Meat, Fish, Vegetables and plantain have been carried out the Beef meat, Chilli pepper and *Telefeiria occidentalis* vegetable were dried in the mobile solar tent dryer, greenhouse solar dryer and parabolic solar dryer. The beef of 71.243% initial moisture content was dried to 12.15%, 12.01% and 10.09% in the aforementioned respective dryers within a period of 5 days. Also the chilli pepper of 89.40% initial moisture content was dried to 12%, 11.3% and 9.3% moisture content respectively in the dryers within a period of 8 days; while the *Telefairia occidentalis* vegetable of 11.0% initial moisture content was dried within a period of 5 hours to 6.0%, 5.5% and 4.0% moisture content

1.0 Introduction

The preservation of foods by drying is without doubt the oldest method practised and it remains most commonly used method worldwide (Mujumdar and Sakamon, 2012). Drying, which affects the physical parameters food products, by removal of water causes weight reduction and increased storability (Robert et al,. 2014). While grains and pulses are the most important, in term of tonnage, the range of products dried is wide and includes meats, fish, fruits, vegetables, spices, and nuts. The conventional drying system to preserve fruits, vegetables, grains, fish, meat, wood and other agricultural products is sun drying which is a free and renewable source of energy. But, for large-scale production, there are various known limitations of sun drying as damage to the crops by animals, birds and rodents, degradation in quality due to direct exposure to solar radiation, dew or rain, contamination by dirt, dust or debris. Also this system is labour- and time intensive, as crops have to be covered at night during bad weather, and have to be protected from attack by domestic animals. There is also a chance of insect infestation and growth of micro-organisms due to non-uniform drying. The advancement of sun drying is solar drying systems whereby products are dried in a closed system in which inside temperature is higher (Rajkumar, 2007; Kumar and Shrivastava, 2017). Major advantage includes protection against flies, pests, rain or dust. Several significant attempts have been made in recent years to harness solar energy for drying mainly to preserve agricultural products and get the benefit from the energy provided by the sun. Sun drying of crops is the most widespread method of food preservation in Nigeria because of solar irradiance being very high for most of the year. Due to no energy cost, it is more beneficial to the small scale farmers who can't afford the electricity or other fuel for drying. If it is necessary to dry product in the night or during bad weather, an additional bio-fuelled heater can be used for heat supply. The high temperature dryers used in industrialized countries were found to be economically viable, in developing countries only on large agro sectors and generally it is not affordable by small and medium entrepreneurs because of high cost and process variability (Ibrahim *et al,* 2009). Therefore, the introduction of low cost and locally manufactured solar dryers provides a promising alternative to reduce the grand postharvest losses. The opportunity to produce high quality marketable products appears to be a chance to improve the economic status of the farmers. Taking into account the low income of the rural population in developing countries, the relatively high initial investment for solar dryers still remains a barrier to a wide application (Chapman et. al., 2006). However, if it is manufactured by locally available material such as wood, glass etc., it will be economically affordable for the farmers. Amongst all, with the submission of Kumar and Shrivastava, (2017), the objective of a solar dryer is to provide ample amount of heat more than ambient heat under given humidity. This heat increases the vapour pressure of the moisture confined within the product and decreases the relative humidity of the drying air as to increase the moisture carrying capacity of the air.

2.0 Description of solar dryers

2.1 Mobile Solar Tent Dryer (MSTD)

A mobile greenhouse solar tent dryer (MSTD) of 8ft x 4ft is made of polyurethane insulators. This material makes up the walls and floor of the solar tent dryer. It is comprised of a drying platform made of steel with 6 drying trays. The inner surfaces are painted black to increase the rate of heat absorption while the top frames were made of ½ inch galvanised hollow pipes to form arcs which serve as a support for the transparent sheet/film. The top of the MSTD is installed with a pneumatic extractor fan which absorbs the moisture from the products being dried (Plate 1). All

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the parts of the MSTD are dismountable for easy carriage from one location to the other and better erected in an East-West direction for effective solar radiation.

Plate 1: NSPRI's Mobile Solar Tent Dryer

2.2 Greenhouse Solar Dryer

The greenhouse dryer was designed to combines the function of the solar collector with a greenhouse system. The roof and wall of this dryer can be made of transparent materials such as glass, fibre glass, UV stabilized plastic or polycarbonate sheets. The transparent materials are fixed on a steel frame support or wooden roofs with bolts and nuts and sealed to prevent humid air or rain water leaking into the chamber other than those introduced from the inlet opening. The surface of the floor is painted black in order to increase absorption rate. Inlet and exhaust fans are placed at proper position within the structure to guarantee even distribution of the drying air.

NSPRI has developed a natural convection greenhouse dryer with dimension (12 x10)ft2 and dwarf wall of 3.3ft high (Plate 2). The drying chamber consists of two parallel rows of 4 drying platforms made up of 24 trays with an effective drying space of 112ft2. The construction materials were greenhouse film, wooden supports, a manual extractor fan, wooden drying racks with galvanised mesh as trays, a black surface painted with food grade enamel paint. This dryers were erected in East-West longitudinal and North South width direction for efficiency.

The floor of the solar dryer is made of concrete floor sandwiched with a polyurethane material to serve as an insulation to prevent heat sink and painted with black food grade enamel paint. The drying chamber is made of 24 trays and a wind power extractor fan to remove moisture out of the drying chamber, 6 vents to induce required air flow in the system, a black surface to absorb heat energy, and a greenhouse film to trap solar radiation. Air is drawn through the dryer by natural convection or sometimes by a fan. It is heated as it passes through the collector and then partially cooled as it catches moisture from the material. The green house film which is the transparent material is laid on the wooden roof. The inclined transparent roof allows solar radiation over the product. Vents with shutters at the outer length sides of the building regulated the air inlet while a pneumatic extractor fan is place at the centre of the ridge of the roof to extract moisture from the products being dried. As this heated air rises and flows up the hurricane to the outside of the dryer, fresh replenishing air is drawn in through the vents for the drying process to continue.

Figure. 2: The NSPRI's Greenhouse Solar Tent Dryer

2.3 Parabolic Greenhouse Solar Dryer (PGSD)

NSPRI has developed a Parabolic Greenhouse Solar Tent dryer. The PGSD is a 26ft x18ft with an effective drying area of 22ft x14ft as depicted in (plate 3). The frame supports are made of steel which had been shaped into a parabola of height 7.5ft. It has 2 drying racks made of steel which comprise of 56 trays with an effective drying space of 224ft2. The floor of the PGSD is a concrete floor sandwiched with polyurethane to avoid heat sink. The concrete floor is tiled with glazed black tile which was painted with food grade black enamel paint. The transparent material is made of a 2mm thick acrylic material with the trademark name Perspex. The Perspex sheet were laid on the parabolic frame support and fixed with bolts and nuts.

The PGSD is installed with 2 blowers powered by 100amperes solar battery which is being charged by 2 units of 180W solar panels. These blowers serve as a dehumidifier which will enhance the drying process during the rainy season. The top of the PGSD is also installed with 2 units of pneumatic extractor fans of diameter 18'' to aspirate the moisture being driven out by the hot air from the products undergoing drying process.

Plate. 3: NSPRI's Parabolic Greenhouse Solar Tent Dryer

3.0 Evaluation of the solar dryers

3.1 Evaluation of the Solar Dryers at No-Load Test

The solar dryers were evaluated at a no load test. The dryers were installed with data loggers to record the temperature and relative humidity of the solar dryers and the ambient conditions and

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comparisons of their environmental conditions were defined as shown in figure 1, 2, 3, 4 and table 1.

3.2 Evaluation of the Solar Dryers Loaded with Agricultural Products

The following products Telefaria occidentalis, Meat and Chilli pepper were dried using the solar dryers. The samples of products were sorted, cleaned and weighed. The initial moisture content of the products were also determined using the oven dried method as prescribed by ASABE 2007 prior to drying in the solar dryers.

The vegetables were sorted, washed, drained and shredded with knives into thickness of 10mm. Its moisture content were determined using the oven method and products were weighed and put in dryers simultaneously to dry appropriately. Also weighed portions were kept in the open sun as control. Weights of the vegetables were monitored periodically.

The beef meat was procure and cleaned to remove fat deposits. Meat was thinly filleted into 2mm. The moisture content was determined using the oven method. Meat was weighed, spread on trays in all the solar dryers and also in the open sun as control. Weights were monitored periodically.

The chilli pepper were procured, sorted, cleaned, and blanched at a temperature of 80°C. Moisture contents of pepper was determined using the ASABE 2007 standard, weighed and spread on trays in the solar dryers and also in the open sun simultaneously as control.

The final moisture contents of the products and the duration of the drying from the different solar dryers are depicted in table 2.

4.0 Results

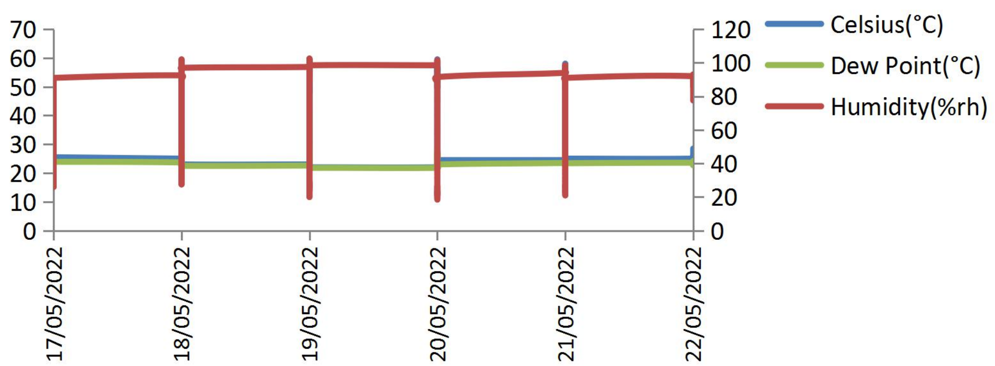

Figure. 1: The No Load Test of the Environmental Conditions of the Mobile Solar Tent Dryer for duration of 5 days.

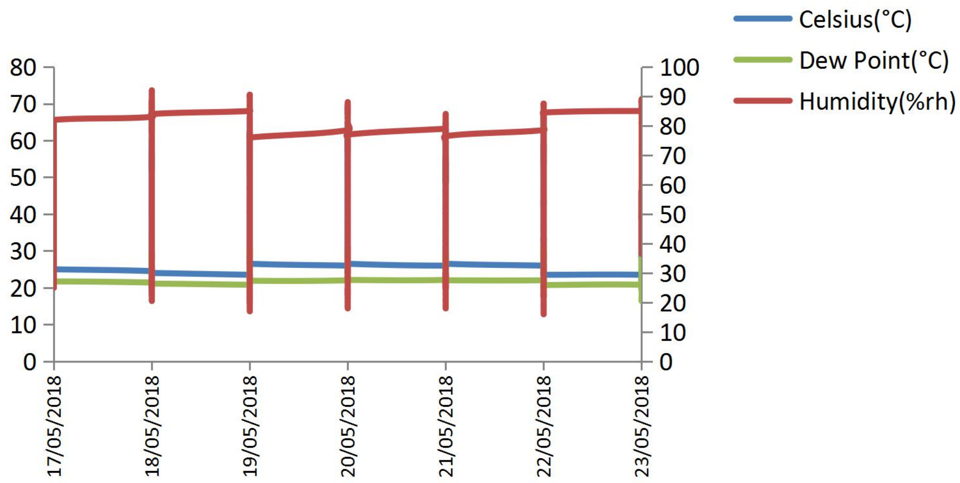

Figure. 2; The Chart of the No Load Test of The Environmental Conditions of the Greenhouse Solar Tent Dryer for Duration of 5 Days

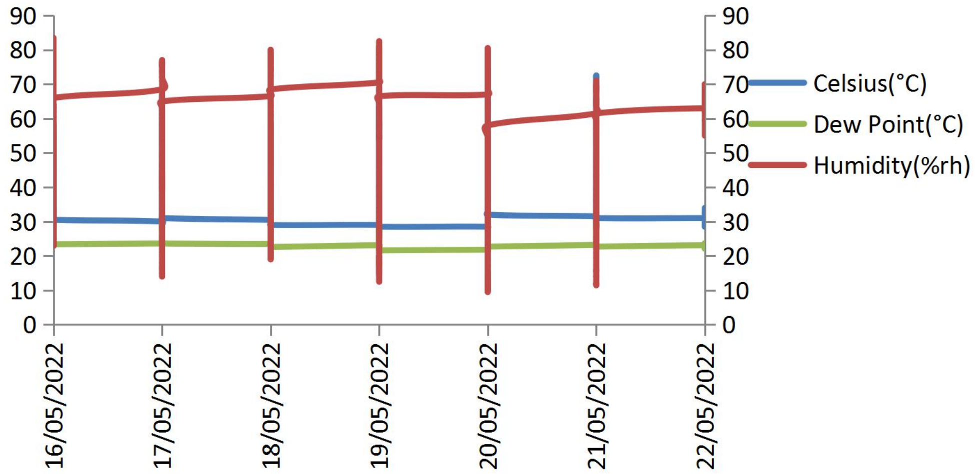

Figure. 3: The No Load Test of the Environmental Conditions of the Parabolic Solar Dryer for duration of 5 days

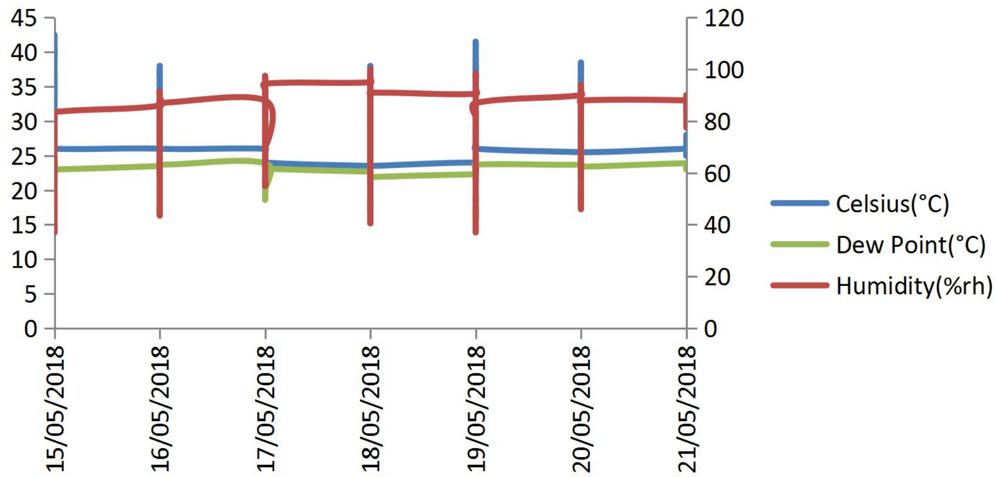

Figure. 4: Chart of Environmental conditions of The Ambient

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Table 1: F-Test of the Environmental conditions of all the solar dryers in NSPRI

Dryers	Temperature °C	Humidity %	Dew Point °C
Mobile tent	33.28±12.61b	70.15±30.68c	24.24±2.48b
Greenhouse Solar Tent	35.72±13.67b	60.48±25.44 b	24.26±3.32b
Parabolic	40.5±15.15c	48.49±23.25a	23.96±2.17b
Ambient Control	28.39±5.06a	63.85±26.87d	23.17±0.78a
F-value	31.354	44.244	8.502
Sig. value	0.000	0.000	0.000

Environmental conditions (Columns) with the same alphabet are the same while those with different alphabet are different at Pvalue=0.05
Ho: There is significance difference in the environmental conditions
H1: There is no significance difference in the environmental conditions

Table 2: Moisture Contents of Different Products dried in the Solar Dryers

Products	Moisture Contents of products					
	Fresh products %	Parabola %	Greenhouse Dryer %	Mobile Solar Dryer %	Control %	Drying Duration
Beef (Meat)	71.243	10.09	12.01	12.15	71.243	5 days
Chilli Pepper	89.4	9.3	11.7	12	27.67	8 days
Telefairia Occidentalis vegetable	11	4	5.5	6	6.3	5 hours

4.0 Discussion

The different solar dryers developed by the Nigerian Stored Products Research Institute have proven to have better environmental conditions in terms of temperature and relative humidity for drying of agricultural produce.

The no load test carried out on the MSTD depicted a minimum temperature of 20.4°C and a maximum temperature of 59.5°C with an average of 32.49 ± 12.10°C. The relative humidity recorded a mean relative humidity of 71.64 ± 29.65%.

The graphical illustration depicted in figure 2 for the Greenhouse Solar Dryer shows that the temperature range is 21.5-68°C and a mean relative humidity of 60.21% while the figure 3 for the Parabolic Greenhouse Solar Dryer has a temperature range of 25.0 -78°C. It has an average temperature of 39.4±14.24°C. The relative humidity had a minimum of 14.5% and a maximum of 83.5% and mean value of 49.77 ± 22.64%.

The ambient environmental conditions as illustrated graphically in figure 4 has an average temperature of 28.56 ± 5.15°C while it has a minimum and a maximum temperature of 20°C and 42.5°C respectively. It has an average relative humidity of 74.88 ±17.94%.

The statistical analysis to compare the environmental conditions in the different solar dryers which are implied in Table 1 above indicates that in terms of temperature, there is no difference in the mobile solar tent and greenhouse solar tent while a significant difference exists between the temperature obtained in the parabolic solar dryer and other solar dryers. Also there is a significant difference in the relative humidity observed in all the dryers as indicated in table 1.

The Parabolic solar dryer has the highest temperature followed by solar tent but the least is control followed by mobile. Also the parabolic solar dryer has the least relative humidity while the mobile solar tent has the highest humidity followed by control. These environmental conditions exhibited by the parabolic solar dryer makes it highly effective for high moisture crops.

In the advances, the average relative humidity in the Greenhouse parabolic solar dyer is 48.49%. This indicates that the products that will be obtained in the parabolic solar dryer can be considered safe from a microbiological point of view since they are characterized by a low water activity (aw), and usually no growth occurs below water activity of about 0.62 (Sagar and Kumar, 2010).

The table 2 which indicate the moisture contents and the drying duration of the agricultural products (beef meat, chilli pepper, and *Telefairia occidentalis* vegetable) showed that products dried well in all the solar dryers. The beef meat, chilli pepper and *telefeiria occidentalis* vegetable were dried in the mobile solar tent dryer, greenhouse solar dryer and parabolic solar dryer. The beef of 71.243% initial moisture content was dried to 12.15%, 12.01% and 10.09% in the aforementioned respective dryers within a period of 5 days. Also the chilli pepper of 89.40% initial moisture content was dried to 12%, 11.3% and 9.3% moisture content respectively in the dryers within a period of 8 days; while the *Telefairia occidentalis* vegetable of 11.0% initial moisture content was dried within a period of 5 hours to 6.0%, 5.5% and 4.0% moisture content. Among solar dryers, the parabolic solar dryer attained a lower moisture content followed by those in the green house dryers, that of the mobile solar dryers and the control which were placed under direct sun. This implies that the parabolic solar dryer has the best and optimal performance as compared with the other solar dryers. It is therefore imperative to know that the choice of materials used in the parabolic solar dryers have given it an advancement over the two other solar dryers.

5.0 Conclusion

Various model of solar dryers developed by NSPRI was found to have better performance in comparison to the conventional open air system practice. The choice of the different construction materials for the solar tent dryers developed by NSPRI has played a very major role in the achievement of the optimal environmental condition gotten in the dryers. It has also further enhanced the advances in the development of solar dryers. These advances, which has gotten to the height of the parabolic greenhouse solar dryer, although expensive but with a higher life span has made it possible to be able to carry out drying process even in the humid season of the year; thereby taking care of the shortcomings of the low solar irradiance.

References

ASABE standards 2007. D245.6. Moisture Relationships of plant based Agricultural Materials and their Products. St. Joseph Mich; ASABE

Kumar, A. and Shrivastava, V. 2017. Historical Trends and Recent Developments in Solar Greenhouse Dryer Operated Under Active Mode: A Review. Indian Journal of Science and Technology, Vol 10(33), 10.17485.

Mujumdar, AS. and Devahastin, S. 2012. Fundamental Principles of Drying. Department of Mechanical Engineering National University of Singapore AY 2011/2012

Corresponding author's e-mail address: snoyeengr@gmail.com

Banout J. Havlik J., Kulik M., Kloucek P. and Lojka B. 2010. Effect of solar drying on the composition of essential oil of sacha culantro (Eryngium foetidum L) grown in the peruvian amazon. J Food Process Eng 33: 83-103.

Boughali, S., Benmoussa, H., Bouchekima, B., Mennouche, D. and Bouguettaia, H. 2009. Crop drying by indirect active hybrid solar - electrical dryer in the eastern Algerian septentrional Sahara. Solar Energ 83: 2223-2232.

Chapman, K., Twishsri, W., Marsh A, Naka, P. and Ngangoranatigarn, P. 2006. Robusta coffee drying alternatives in South Thailand International.

Ibrahim, M, Sopian, K, Daud, WRW, Alghoul, MA. 2009. An experimental analysis of solar-assisted chemical heat pump dryer. Int J Low- Carbon Technol 4: 78-83.

Jayaraman P. and Gupta, D. 1995. Handbook of industrial drying. Marcel Decker Inc, New York.

Olayemi FF. and Akinnusi O. 1991. Development of low Cost Dryer for Humid Area of Nigeria. Annual Report of Nigerian Stored Products Research Institute.

Rajkumar, P. 2007. Drying kinetics of tomato slices in vacuum assisted solar and open sun drying methods. Drying Technology 25: 1345-1357.

Robert, D., Stephanie, C., Stephanie J., and Buddhi L. 2014, Food Processing: Principles and Applications, Second Edition. Edited by John Wiley & Sons, Ltd. Published by John Wiley & Sons, Ltd.

Sagar, VR., Suresh Kumar, P. 2010. Recent advances in drying and dehydration of fruits and vegetables: A review. Journal Food Sci. Technol. 47(1):15–26.