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Research Article

Design, construction and evaluation of solar dryer

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Abstract

This research work aims at designing a solar dryer to reduce agricultural produce waste and improve their storage conditions. The solar drying system utilizes solar energy to heat up air and dry any agricultural substance loaded which is beneficial in reducing wastage of agricultural produce and also helps in preservation, shelf-life extension of agricultural produce. Due to limitations of the traditional sun drying such as exposure to direct sunlight, pests and rodents attack, improper monitoring and high cost of imported mechanical dryers. A solar dryer was therefore developed to proffer solution for these limitations. The design was based on the geographical location which is Kainji and meteorological data were obtained for proper design specification. The dimensions of the dryer was 40 x 40 x 50 cm. Locally available materials were used for the construction, chiefly comprising of wood (Gmelina), polyurethane glass, aluminium metal sheet and metallic net for trays. The optimum temperature of the dryer was 74.5ºC with a corresponding ambient temperature of 30.5ºC. The mass of water removal of 199.9g in vegetable using the solar dryer was achieved. The rapid rate of drying in the dryer reveals, its can dry food items reasonably rapidly to safe moisture level.

Keywords: Design; Radiation; Vegetables; Solar panel; Temperature; Blower.

Introduction

Preservation of vegetables and other Agricultural products are essential for long time storage without further deterioration in the quality of the product. Several process technologies have been employed on an industrial scale to preserve Agricultural products; the major ones are canning, freezing, and dehydration. Among these, drying is especially suited for developing countries with poorly established low temperature and thermal processing facilities [1]. Drying is an excellent way of preserving food and solar dryers are appropriate food preservation technology for sustainable development. It provides an effective and practical means of preservation which reduces post-harvest losses and offset the shortages in supply. Drying is a simple process of moisture removal from a product in order to reach the desired moisture content and is an energy intensive operation. Drying by solar energy is a rather economical procedure for agricultural products, especially for medium to small amounts of products. Drying was probably the first ever food preserving method used by man, even before cooking [2].

Drying has been and continues to be a major method of preserving agricultural products especially in developing countries like Nigeria. Preservation of food stuffs is necessary in Nigeria because production is mainly seasonal whereas consumption is year-round. Drying is considered the best locally available module for preservation of agricultural products. Drying is practically the major preservation method in widespread use because of its simplicity and low energy cost [3]. The climate in Nigeria, with its long dry season characterized by high ambient air temperatures and very low relative humidities (in many parts of the country), is particularly favourable to the technique of drying, whereas other preservation techniques, such as refrigeration and freezing are more difficult and less economical [4]. The selection of drying

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method depends on the physical nature of the raw materials, capacity of operation, consumer requirements in terms of quality and economic considerations. Some of the problems associated with traditional open-air sun drying can be solved with a solar dryer, which comprises of collector, a drying chamber and sometimes a chimney [5].

In the recent years, a lot of research works have been centered on the solar power and its potential as an alternative power source in African due to epileptic power supply. Depending on its usage, the solar dryer should be capable of drying various Agricultural products: (i) it reduces moisture level thereby reducing weight and makes handling easier, (ii) prolongs shelf life, (iii) preserves nutritional quality of food, and (iv) reduces risk of contamination by toxic moulds, etc. Water content of properly dried food varies from 5 to 25 percent depending on the food type. Solar dryers are specialized devices that control the drying process and protect agricultural produce from damage. In comparison to traditional “sun drying”, solar dryers generate higher temperatures, lower relative humidity, lower product moisture content and reduced spoilage during the drying process. In addition, it takes up less space, takes less time and relatively inexpensive compared to artificial mechanical drying method. Thus, solar drying is a better alternative solution to all the limitations of traditional drying and artificial mechanical drying. The solar dryer can be seen as one of the solutions to the world’s food and energy crises.

Solar dryer requires solar energy for its operation, which is readily available in the Kainji lake basin area, in the Northern parts of Nigeria, and is a clean form of energy. It protects the environment and saves cost and time spent on open sun-drying methods, which dries agricultural produces more slowly. The products are also better protected in the solar dryer than in the open sun-drying, thus minimizing pest and insect attack and other forms of contamination. Therefore, in order to alleviate some of the problems associated with losses in open sun drying method, solar drying techniques are being considered.

Materials used for fabrication of solar dryer

The following materials were used for the construction of the efficient solar dryer: Wood, Glass, Galvanized steel (GS), Nails and glue, Hinges and handle Paint (black and grey). Copper tubes, Mesh wire, Wheels and Blower.

Design consideration

Temperature

The minimum temperature for drying food is 30°C and the maximum temperature is 60°C, therefore. 45°C and above is considered average and normal for drying vegetables, fruits, roots and tuber crop chips, crop seeds and some other crops.

Design

The design was made for the optimum temperature for the dryer. T_0 of 60°C and the air inlet temperature or the ambient temperature T_1 = 30°C (approximately outdoor temperature).

Air gap

It is suggested that for hot climate passive solar dryers, a gap of 5 cm should be created as air vent (inlet) and air passage.

Glass or flat plate collector

It suggested that the glass covering should be 4-5 m thickness. In this work, 5 mm thick transparent glass was used. Also suggested that the metal sheet thickness should be of 0.8 –1.0 m thickness; here a Galvanized steel of 0.8 mm thickness was used. The glass used as cover for the collector was 80.5 × 40.5 mm.

Blower

The design of the solar dryer provides the opportunity for it to be used in either the natural convective drying mode or the forced convective drying mode. The forced convective mode that gives quicker drying process uses an external direct correct blower powered by a small mono-crystalline solar panel. This is aimed at providing the necessary power to drive the blower hence increasing the air inlet. In addition, for better efficiency, a 12V 7AH battery keeps the fan running for optimum ventilation when there is cloud cover in order to reduce moisture deposit on the glass cover. The selection was based on the characteristics of centrifugal blower performance curve based on the recommendation of Henderson and Perry.

Drying Chamber

This is the place or space where dehydration of vegetable occurs. The design of the drying

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chamber was done to permit the user to use it as in-bin storage dryer. Since the dryer is a prototype and drying is to be done in racks, five racks were arranged, at a distance of 10 cm in the drying chamber. The dimensions of the racks were taken as 37 x 37 x 10 cm. This is in line with the recommendation of Badger and Badero that dryer racks should be optimally loaded to 7-12% of their volumes. The drying chamber consisted of a square box of dimensions: 40 x 40 x 50 cm. In order to minimize heat loss by conduction to the ambient environment, it was painted black both inside and outside to increase its heat absorption. The drying chamber had in addition, a "thermometer/hygrometer" (graduated in ^{o}C and ^{o}F) inserted inside the drying chamber in order to measure the temperature of the drying air and humidity in the dryer chamber. The roof of the dryer chamber was given a trapezoidal configuration (a hood with height, 10 cm) so as to serve as a guide to the exiting drying air in the chamber through the chimney. The side and front view of the solar dryer is shown in fig. 1 and 2.

Fig. 1. Side view of solar dryer

Experimental procedure

The tests were conducted between the periods of 4th of December 2020 and 11th of December 2020. A preliminary test (or no-load test) was first conducted for seven bright days to evaluate the thermal profile of the solar collector from 7:00 am to 6:00 pm. The ambient air conditions were noted and recorded by the use of a hygrometer, as well as their corresponding drying chamber temperature. Some Vegetables of the same weight (three different species: Spinach, pumpkin and Cabbage) bought from a New Bussa Monday market (Kainji market) were used to determine the maximum amount of vegetable that can be handled per batch for optimal drying base on the quantity of heat produced as well as the drying time. A maximum of 300g of vegetables were sufficiently dried.

Fig. 2. Front view of the solar dryer

At the start of the solar drying test, the fabricated solar dryer was positioned at a distance reasonable enough from trees and buildings in order to prevent shading effect. The dryer was positioned to align with the North-South axis and with the solar collector tilted to face the South Pole. The moisture content of the three vegetables species was determined by weighing the fresh vegetables and drying them until no significant weight loss was observed. The weight was measured and recorded in 2 hours intervals with the use of an electronic weighing balance.

Before the commencement of each solar drying test, the respective masses of the vegetables were recorded. Then the weighed tagged vegetable were put into the drying chamber, the starting time was recorded. The temperature in the solar collector chamber and the ambient air temperature were measured with a Digital thermometer and hygrometer respectively.

At the end of each test, which lasted for 5 - 6 hours, the moisture content was calculated as a percentage of the initial dried mass of the vegetable; and the difference between the initial mass and the hourly measured masses was used to calculate the percentage weight loss for each vegetables species.

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Performance evaluation

The performance evaluation of the solar-dryer was evaluated in terms of the throughput capacity of the dryer, i.e. the maximum amount of vegetables samples that can be dried per batch; drying rate, and drying efficiency.

Experimental results

The temperature profile of the solar-dryer was obtained under no-load condition by measuring the temperature inside the drying chamber and the hourly ambient air between 7 am and 4 pm (local time). The technical performance of the solar-system of the dryer is as presented in Table 1. Tray 1 receives the highest convective heat due to its closeness to the heat source than tray 2. This is as a result of the increased difference in the quantity of heat produced by the solar heat source as evidenced in the Table 1. The solar-dryer chamber temperature is always higher than the ambient temperature - an indication of greater prospects of the solar-dryer system. This therefore signifies that the solar-dryer system is functional.

Table 1. Technical performance of the solar-system of the dryer

Operation Time (hr)	Average Ambient Temp (°C)	Average Relative Humidity (%)	Dryer chamber 1 Temp (°C)	Relative Humidity (%)	Dryer chamber 2 Temp (°C)	Relative Humidity (%)
7:00	28.3	86.6	34.9	71.0	34.8	71.6
8:00	32.7	81.4	45.8	68.3	39.8	70.0
9:00	35.4	77.6	68.9	59.4	62.6	59.0
10:00	39.7	73.8	71.7	33.4	68.9	53.4
11:00	43.5	71.7	74.9	31.6	69.5	47.8
12:00	51.6	69.1	79.6	30.5	73.7	46.3
13:00	63.1	68.8	85.7	28.4	79.9	32.8
14:00	59.5	67.6	88.5	25.4	81.3	29.3
15:00	52.1	66.8	90.3	23.6	84.2	27.9
16:00	50.3	64.2	93.8	20.3	84.8	27.1

Generally, the drying rate of the three vegetables species is dependent upon the drying chamber temperature and ambient air conditions as seen in tables above. The Spinach has a softer skin which allows for easy penetration of heat and consequent loss of internal water. This accounts for spinach's higher percentage weight loss than the cabbage. The moisture content of the vegetables decreases with the drying time [6]. This was found to be 13.33% and 16%wb for the Spinach and Cabbage respectively.

CONCLUSION

A solar-dryer has been designed and constructed. The system was tested using fresh vegetables species. The solar-dryer could serve as a prototype model of a commercial vegetable dryer used in vegetable processing firms, and could also be employed as laboratory demonstration equipment in agricultural engineering workshop. However, results obtained show that under favourable weather condition, it was possible to dry a 300 g vegetable effectively using the solar-dryer. Statistical analyses show that there is a significant heat contribution by the solar collector to the drying chamber. Energy/heat source and vegetables species were shown to have a significant effect on the drying rate as well as the Percentage weight loss of the vegetables samples. Generally, the daily ambient air conditions contributed significantly to the drying chamber temperature and as such, regarded as the pivot of natural solar dryer. This study, therefore, revealed that Spinach dried faster than the Cabbage. It was indicated that the taste, texture of vegetables samples were the same. Based on the above stated observations, the following recommendations were made concerning a solar-dryer in Kainji, New Bussa: In designing a solar-drying system for rural dwellers, the financial resources of most of the vegetable processing farmers should always be kept in mind and improvement on the quality of the dried products and labour reduction may be of more importance. The following are therefore recommended for future research work in this field: performance of the dryer using different vegetable species of various sizes and weights; sliced root and tuber crops; and experimental

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study of the effect of various design parameters on the technical performance of a solar-dryer.

Conflict of interest

The authors declare no conflict of interests.

References

[1] Nwa Kay TM, Mann Khant TP, Yin Marl W. Design, construction and performance Test of Potato Solar Dryer. ICONIC Research and Engineering Journal 2019;3: 501-5.

[2] Emetere ME, Osunlola T, G Otoko G. Design and Construction of Fruit Solar Drier, Procedia Manufacturing 2019;35:674-80.

[3] Promise JE, Akichukwu BE, Kayode JS. Design and development of an active indirect solar dryer for cooking banana. Scientific African 2020;8: e00463. https://doi.org/10.1016/j.sciaf.2020.e00463

[4] Akinola AA, Ayo DB, Ezeorah SN. Temperature Dependence of the Effective Moisture Diffusivity of Yam (Dioscorea rotundata) Slices Dried Using a Refractance Window^{TM} Dryer. The Journal of the Association of Professional Engineers of Trinidad and Tobago 2018;46(1):30-4.

[5] Akinola AA, Adehoun SO, Ezeorah SN. Effect of Temperature on Okra (*Abelmoschus esculentus*) Fruit Slices Dehydrated Using a Refractance Window^{TM} Dryer. SUST Journal of Engineering and Computer Science 2018;19(1):13-21.

[6] Nwakuba NR, Asoegwu SN, Nwaiguk KN, Chukwuezie. Design and Development of a Hybrid Solar-electric Dryer for sliced vegetable crops. Journal of Agricultural Engineering and Technology 2017;23:48-64.

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