International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 2394-2397

Received: 09-09-2018
Accepted: 13-10-2018

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Performance evaluation of solar hybrid dryer for drying of pineapple slices

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Abstract
In many countries most of the harvested fruits and vegetable are weak to deterioration due to poor preservation. The agriculture products are to be stored for longer length of time, it is necessary to remove the moisture level. In many types of dryer, drying is not continuous and during night time moisture is absorbed by the product. Due to this total fungal count and total microbes count increases. To overcome this problem, electric heater can be used to make drying continuous and during night times or off sunshine hours electric heater can be used for the drying of pineapple slices. The 8 kg pineapple slices was dried in solar hybrid dryer from initial moisture content of 84% (wb) to final moisture content of 9.91% (wb) in 10 h and electricity consumed 3 kWh. The dried products in solar hybrid dryer were contained negligible bacteria and fungi as compared to solar cabinet dryer. The bacteria count for the solar hybrid dryer was 0.1×10^3 CFL/gm. The developed solar hybrid dryer system was economically as well as technically feasible. The main of this study to increases the quality of dried products and reduces bacterial and fungal attack.

Keywords: solar hybrid dryer, solar cabinet dryer, pineapple, an electric heater, solar water heater

1. Introduction

In India pineapple is most important commercial fruit crop. After banana and citrus, the third important tropical fruit is pineapple. The name pineapple is derived from Spanish name ‘‘Pina’’, given to the plant, based on the shape of the product, which look like a pine cone. The name Ananas, is derived from Tupi Indian name “Nana”. Pineapple belongs to *Farinosae* and family *Bromeliaceae*. Pineapple species are classified into different categories - *bracteatus, fruitzmuelleri, comosus, erectifolius,* and *ananassoides*. Origin of pineapple (*Ananas comosus* L.) was in Paraguay. A natural change in the wild seeded pineapple is the result of cultivated seedless pineapple. The height of pineapple plant is about 90-100 cm. It is a perennial, self-sterile, herbaceous, monocotyledonous plant. The plant is spreading leaves, which look like rosettle appearance. A single fruit can bear a plant on a peduncle. The fruit is forms by different mixture of fruitlets created by each flower. After the flowering of 5- 6 months many fruits are fully grown.

In world the pineapple producing countries are Thailand, Philippines, Brazil, India, Nigeria, China, Indonesia, Columbia, USA and Vietnam. Major pineapple producing region is Asia, contributing 57.89 % of the world production. In the world, India has fourth largest pineapple producing country having a share of 7.10 % in production. The world production of pineapple is 13147 metric tons. The pineapple is grown in India 78,200 ha area with production of 12.211 lakh metric tons. The pineapple producing state are West Bengal (2, 79,500 tons), Assam (2, 16,100 tons), Kerala (84,600 tons), Meghalaya (81,700 tons) and Karnataka (81,193 tons) (Rashmi *et al*. 2005) [13].

Pineapple is a superior source of carotene, ascorbic acids and rich in vitamin complex. It has good flavor, good taste, and absence of seeds. It contains phosphorus and minerals like calcium potassium iron and magnesium. (Rashmi *et al*, 2005) [13]. It gives satisfactory roughage to anticipate clogging. Pineapple juice provides cooling and energizing impact, particularly in summer. Pineapple has great nutritive ingredients. Bromelain is a proteolytic enzyme derived from the juice and stem of pineapple fruits (Gautam *et al.*, 2010) [6]. It has mostly used fruit in baking processes, meat tenderization, and prevention of browning of apple juice, in beer to increase the solubility of gelatine for drinking and in leather-tanning process. In recent therapy, bromelain is used as an active ingredient used in the cosmetic industries.

The pineapple fruit is used as food and steam is a source for bromelain production (Tochi *et al*, 2008) [14].

Solar energy has been used to dry foods for thousands of years. Solar energy transfer heat during the drying process, so whether the product is laid out in the sun (ambient) or placed in a dryer, the heat for drying comes from the same source. Drying involves extraction of moisture from the product by heat and removal of that moisture by a flowing air mass.

Rural electricity supply in India is suffering both in terms of availability for a measured number of hour and penetration level. Hence the renewable energy is the better alternative source of energy that is both economic and environmental friendly which is important for increasing agricultural productivity. Solar energy is the only dependable source in present and future. It is abundant and easily accessible.

There are many types and designs of solar dryers available for drying of agricultural commodity. They mainly include natural convection cabinet dryer and forced circulation solar dryer based on array of flat plate air heaters. In these types of dryer, drying is not continuous and during night time moisture is absorbed by the product. Due to this total fungal count and total microbes count increases. And also solar energy is intermittent in nature and time dependent energy source. To overcome this problem, electric heater can be used to make drying continuous and during night times or off sunshine hours electric heater can be used for the drying purpose. Thus keeping in view, the purpose of this project is to maintain a better quality of dried product and reduces the fungal and microbial growth.

2. Material and Methods

2.1 Raw Material

Fresh pineapple, about 90% mature were purchased from local market of Udaipur. The fruits almost had a similar ripening grade.

2.2 Sample Preparation

The pineapples were washed carefully in water to make them free from dust and foreign materials. The external surface of the skin of pineapple fruits was peeled manually by a knife. The fruit slices cut into uniform 0.5 to 1 cm thick slices. Vernier caliper was used for measuring the thickness (Rai *et al.*, 2007) [10].

2.3 Experimental Set-up

Solar dryer full load testing was performed to estimate the performance in actual loaded conditions. In this testing, the drying unit was loaded fully to its designed capacity. The initial weight and moisture content of the samples were recorded. At an interval of 30 min, each sample of 100 gm was weighted regularly. The temperature at different points of the drying chamber, wind velocity and solar radiation were measured. The final moisture content of the product was measured to estimate drying rate. Daily 9.00 am to 6.00 pm drying was conducted. Solar insolation was measured to calculate the performance. The taste, quality and shelf life of pineapple slices were increased due to spraying mixture of sugar powder and salt on it. In the solar hybrid dryer, the temperature was maintained in the chamber 50ºC using an electric heater with the help of thermostat. The drying experiment was conducted in the solar hybrid dryer and solar cabinet dryer. The performance of solar hybrid dryer was evaluated and compared with solar cabinet dryer. The parameters were considered in terms of temperature, solar radiation, moisture content, drying rate, qualities and economics. The layout of solar hybrid dryer as shown in Fig. 2.1.

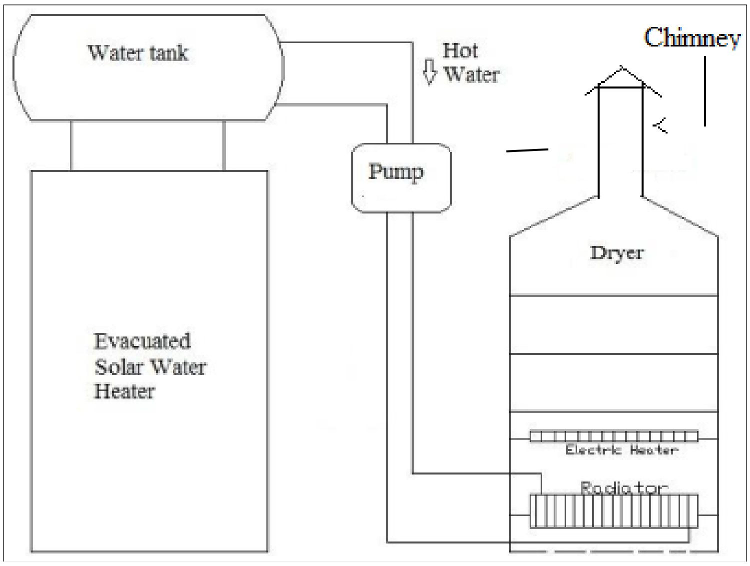

Fig 2.1: Layout of the solar hybrid dryer

2.4 Study of drying characteristics

2.1 Moisture content

The initial moisture content of fresh as well as dried pineapple samples was determined by using the oven method. The sample was kept in the oven for 24 hr at 60º C. After that the sample was cooled in desiccators and weighted using an electronic balance. The initial and final weight sample was used to estimate the moisture content of sample using the following formula

$$\text{Moisture content} = \frac{M1-M2}{M1} \times 100 \qquad \text{… (Eq.1)}$$

Where, M_1 = the weight of pineapple slices in gram before drying.

M_2 = the weight of pineapple slices in gram after drying.

2.2 Drying rate

Drying rate during drying experiments was estimated using the following equations.

$$R = \frac{\text{The initial mass of sample} - \text{Final mass of sample (kg)}}{\text{Time interval (min)} \times \text{dry matter(kg)}} \quad \text{... (Eq. 2)}$$

Where,
R = drying rate

2.5 Quality analysis
2.5.1 Colour
The calorimeter is the most commonly used method to evaluate the colour of products. To characterize the surface colour L, a, and b scale is used in hunter lab calorimeter. In this method L, a, b colour space is arranged in a cube form. Top to bottom line shows the L axis. The maximum for L is 100 which is perfect reflecting diffuser and minimum is zero which is black in colour. The axis a and b have no numeric limit. Positive 'a' indicate red colour. Negative 'a' indicate green. Positive 'b' indicate yellow and negative 'b' indicate blue.

2.5.2 Vitamin C/ Ascorbic acid
Oxidation of ascorbic acid was carried out by titrating colored dye 2, 6-dichlorophenolindophenol to the dehydroascorbic acid. The endpoint was easily determined by reducing dye to the pink coloured compound (Ranganna, 1986) [12].

2.5.3 Rehydration ratio
There a number of factors affecting rehydration, such as soaking period, the temperature of water and rehydration capacity of the product. The rehydration capacity of the dried product can be affected by the drying process.
For the determination of rehydration ratio, 10 g of dried pineapple slices were soaked with 100 ml of distilled water in a beaker. The test sample was taken out from the distilled water after 30 min and weighed (Ranganna, 1986) [12].

$$\text{Rehydration Ratio} = \frac{C}{D} \quad \text{...(Eq.3)}$$

$$\text{Coefficient of rehydration} = \frac{C \times (100 - A)}{\left(D - \frac{BD}{100}\right) \times 100} \quad \text{...(Eq.4)}$$

Where,
A = moisture content of samples before drying, IMC, (% wb)
B = moisture content of drying sample, (% wb)
C = drained weight of rehydrated sample, g
D = test weight of dehydrated samples, g

2.5.4 Microbiological examination
The pour plate technique is the most common method used to quantify microorganisms in food. Determination of direct microscopic counts is impossible, when the concentration is very high. Serial dilutions were made of a sample of bacteria and fungi, and that dilution was used to culture bacteria and fungi. The media was sterilized before inoculation by using Autoclave at 121˚C temperature and 15 psi pressure for 15 min. 1 mg of dried sample was added in 10 ml of distilled water and after that the sample was added to 9 mL, and it was mixed together (creating a 10^{-1} dilution). Then, 1 mL from previous solution was added to 9 mL distilled water in next test tube creating (a 10^{-2} dilution). That procedure was repeated for as many dilutions as needed. The distilled water was used to dilute the sample. Dilutions till 10^{-4} were made and used for pour plating to determine the total microbial count and total fungal count. For determining bacterial and fungal counts melted nutrient agar and potato dextrose media was used. For each dilution media plates were prepared by pour plate technique. 0.1 ml of the diluted bacteria and fungi sample from each tube was poured in empty plate and then media was poured on it. The plates were kept for 3 to 4 days at 28 to 30 °C in autoclave.

3. Result and Discussion
The experiment of solar hybrid dryer was done in terms of moisture content, drying rate, colour, and rehydration ratio.

3.1 Moisture content

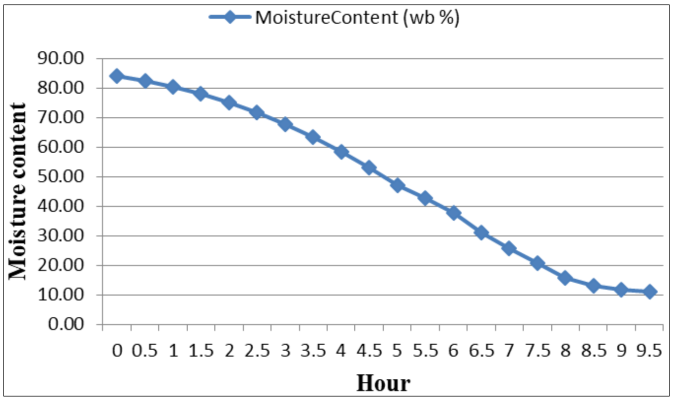

Fig 3.1: Variation in moisture content with respect to time

The change in the moisture content of the pineapple slices sample with drying time as shown in Fig. 3.1. In the solar hybrid dryer, the test was conducted for drying of 8 kg pineapple slices. In the solar hybrid dryer, test was conducted for drying of 8 kg pineapple slices. The final moisture content of the pineapple slices sample was reduced to 9.91% (wb) from its initial moisture content of 84% in 10 h (1 day) in the solar hybrid dryer. A similar result of moisture content was obtained by Daud (2017) [5]. They reported that initial moisture content of pineapple 85.12% (wb) to 12.23% (wb).

3.2 Drying rate

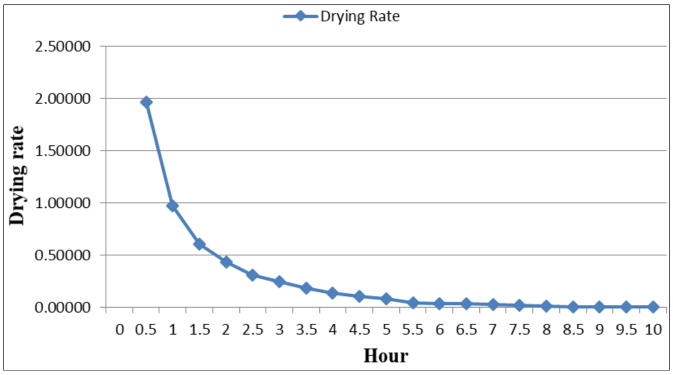

Fig 3.2: Variation in drying rate with respect to drying time

The changes in the drying rates with the drying time as shown in Fig. 3.2. It was observed that the drying rate of the pineapple slices dried in the solar hybrid dryer was more; it decreases continuously with the drying time. The drying rate of pineapple slices was faster during the first 6 h in the solar hybrid dryer, but afterward the drying rate became low due to low moisture content. The drying rate during the process varies from 1.9625 of water evaporated/g of dry matter to 0.0022 of water evaporated/g of dry matter in 10 h.

3.3 Colour
The colour of the dried pineapple slices was measured in terms of L-value (range 0 to 100). The L-value indicates the lightness/darkness of colour. The value near about zero means darker colour and near about 100 means more light colour. The L-value of fresh pineapple slices sample was recorded 72.81%. The L-value of pineapple slices dried in the solar hybrid dryer was recorded 79.85%. The higher colour variation in dried pineapple slices compared to the fresh sample mainly due to the effect of temperature. Similar results for the variation of values of parameter were found by Ramallo (2012) [11] and Corra (2011) [4].

3.4 Ascorbic acid
Ascorbic acid is a sign of vitamin C. During the drying process vitamin C lost due to the heat applied to the products. When fruits are cut to slices, due to their contact with air, vitamin C content is also lost. The vitamin C mostly affected by the size of the sample, amount of air during drying, water content, salt content, air temperature and air humidity. The ascorbic acid content present in the fresh pineapple slices was observed to be 32.4 mg/100 g. The sample dried in the solar hybrid dryer has 16.3 mg/100 g ascorbic acid content. The ascorbic acid is highly thermo-sensitive compound and hydrosoluble in nature. A similar result of ascorbic acid content was found by Rai (2007) [10].

3.5 Rehydration ratio
The quality of dried pineapple sample was determined by performing the re-hydration test. The dried pineapple sample was immersed in distilled water solution up to 20 min. The dried pineapple sample absorbed water during the experiment. To avoid any error, three replications were taken during the study. The rehydration ratio of dried pineapple sample was 2.17 and coefficient of rehydration was recorded 0.52. Similar results of the rehydration ratio were found by Krokida` and Philippopoulos (2005) [9] and Ramallo (2012) [11].

3.6 Microbiological examination
The total microbial count of the sample dried in the solar hybrid dryer was 0.1×10^3 CFU/g and the total fungal count was 1×10^4 CFU/g it is negligible. The total microbial count and the total fungal count were very less due to continuous drying in the solar hybrid dryer.

4. Conclusion
The final moisture content of the pineapple slices sample was reduced to 9.91% (wb) from its initial moisture content of 84% (wb) in 10 h (1 day) in the solar hybrid dryer the samples were kept for drying in solar cabinet dryer for 10 h a day. The dried products in solar hybrid dryer were contained negligible bacteria. The bacteria count for the solar hybrid dryer was 0.1×10^3 CFL/gm the dried products in solar hybrid dryer were contained a negligibal amount of fungi. The fungal count for the solar hybrid dryer was 1×10^4 CFL /gm. The solar hybrid dryer system was economically as well as technically feasible.

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