

Experimental Performance Analysis of Solar Conduction Dryer (SCD) for Ginger drying

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Abstract

Lack of proper technology for farmers for quality product drying. This problem can be addressed by the development and promotion of the Solar Conduction Dryer. This research has focused in the experimentation analysis, comparison study of the Solar Conduction Dryer for ginger drying in Nepal.

Drying of ginger was carried out in a Solar Conduction Dryer (SCD). Drying temperature was achieved around 18-50°C for an ambient temperature in the range of 17-32°C. The 3 kg sample was dried upto 0.9 kg in 11 h drying time achieving overall efficiency of about 64.36% for 3-5 mm sample size, 50.97% for 9-11 mm sample size. Also drying time was effectively reduced and drying rate was faster when compared with the open sun drying for same sample sizes on identical conditions.

Keywords

Solar Conduction Dryer – Drying – Solar – Ginger

1. Introduction

1.1 Background

In developing countries, open sun drying is a popular, effective, and economical method used for drying and preservation of agricultural, food, and many other products. But the external drying parameters such as heat input, moisture contents, temperature, drying air flow rate etc. cannot be controlled and hence result into larger drying period or undesirable drying rate. The other drawbacks of open sun drying method include degradation of product quality by wind-blown, debris, rain, insects, and animals [1].

Solar dryer gives desirable product quality with minimal environmental impacts. It is an effective, cheap, and safe method of agricultural and food product drying. In solar drying of agricultural products, the moisture is removed by the solar heated air having temperature range of 50 to 60°C. Solar drying under controlled conditions of temperature and moisture removing rate ensures perfect drying and desirable product quality. The percentage of moisture content in different agricultural products is different and varies product to product. For drying different moisture content products, the drying systems are usually classified as low and

high temperature operated drying [2].

Ginger, Coffee, Cardamom are very sensible product. They catches odor very easily as well as it requires constant temperature and moisture removal rate while drying. The special necessities for the preparation and processing of those cash crops are not easily available to local farmers at affordable costs. So the farmers are liable to sell their fresh crops to factories. The production of the crops is higher than the capacity of the factories. Also the farmers living far from the factories are not able to bring fresh crops (raw crops for dried product) at right time. So they do not get proper price for their products. The traditional method of drying is very deplorable. Traditional method of drying may destroy the quality and flavor of the product. One of the requirements is the use of proper heat source. Directly combusted biomass is the main source of energy for the farmers which is not efficient and is also a source of pollution. On the other hand, in hilly region where the climatic condition is unsuitable for solar drying, biomass is the most suitable resource for the drying of ginger, cardamom, coffee, garlic and other herbal products. Nepalese ginger is superior in quality that is suitable for the production of dried ginger, or essential oils. But due to the lack of ginger processing

facilities within the country, the farmers have to sell their product in fresh or traditionally dried form which lacks quality.

Solar drying is often differentiated from “sun drying” by the use of equipment to collect the sun’s radiation in order to harness the radiative energy for drying applications. Sun drying is a common farming and agricultural process in many countries, particularly where the outdoor temperature reaches 30°C or higher. In many parts of South East Asia, spices and herbs are routinely dried. However, weather conditions often preclude the use of sun drying because of spoilage due to rehydration during unexpected rainy days. Furthermore, any direct exposure to the sun during high temperature days might cause case hardening, where a hard shell develops on the outside of the agricultural products, trapping moisture inside. Therefore, the employment of solar dryer traps on the freely available sun energy while ensuring good product quality via judicious control of the radiative heat. Solar energy has been used throughout the world to dry products. Such is the diversity of solar dryers that commonly solar-dried products include grains, fruits, meat, vegetables and fish [3].

Solar dryers are equipment, generally of small capacity and based rather on empirical and semi-empirical data than in theoretical designs. The majority of the numerous solar dryer designs, which are available, are used mainly for drying of various crops either for family use or for small-scale industrial production [4].

Fresh apples of 886.64 grams with moisture content of 86% were dried to moisture content of 8.12% (wet basis) within 9 hours 20 minutes at an average irradiance of 534.45 W/m². The overall dryer efficiency was estimated to be 17.89%. [5] The dryer performance under natural and forced convection with air mass flow rates 0.00653 kg/s and 0.019 kg/s respectively with air temperature reaching 45°C and 40°C. [6].

Various mathematical models have been studied by different researchers to compare the experimental results. [7] Thin layer modeling of potato, apple and pumpkin slices were studied on 13 different models.[8] [8] Borah, et.al, studied Solar Conduction Dryer while achieving 39 – 51°C and moisture content reduced to 6.36% (wb) and 5.5% for solid and sliced samples from 78.65%. The overall thermal efficiency of the dryer was

found to be 55% [9].

1.2 Solar Conduction Drier

The Solar conduction dryer is a solar powered food dehydrator developed by a group of innovators known as Science for Society (S4S). The device utilizes solar power in a conductive manner as well as convective way for drying.



Figure 1: Solar Conduction Drier

The structure of solar conductive dryer which comprises of four drying chambers constructed from hollow sections of stainless steel. The dryer has four drying trays, covering a surface area of 1.04 m² each. Transparent plastic (PC Multiwall Sheet) is used to cover the trays. The trays are coated with black color special food grade coating, where the products to be dried are placed. A low height air vent to create air current is provided at the middle of the dryer along horizontal direction which also separates the drying chambers in two parts. Each portion contains two drying trays. Atmospheric air enters from the front of the trays and it carries away the moisture of the sample through the chimney. Accesses to the trays are done by sliding the trays out in a designed channel for loading purpose.

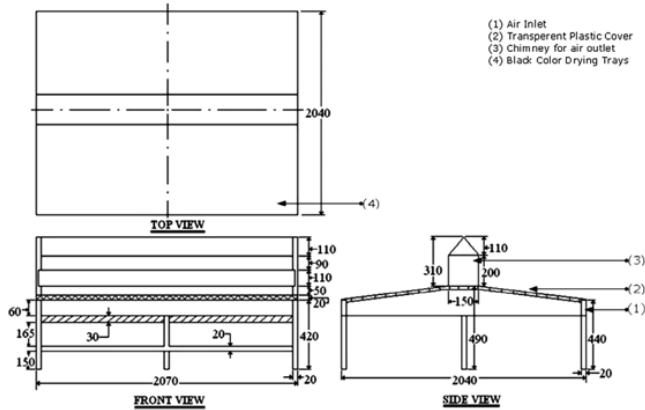


Figure 2: Engineering Drawing of Solar Conduction Dryer (All dim in mm)

2. Methods and Material

Temperature readings were taken at the interval of 1 hour for the ambient air, chamber inlet, inside and outlet. Temperature were recorded by using Mercury thermometer in the first two test. For accurate data, Temperature sensor LM 35 is planning to use. For this purpose Arduino UNO board and LM35 temperature sensor were required. Solar radiation was measured by using a pyranometer and with the reference of data provided by Department of Hydrology and Meteorology (DHM). For making the parameters precise as possible, 10 measured values were taken and the resulting value was calculated as an average of these values.

The dryer was tested on the roof of Pulchowk Campus. Intensive testing was done to test the performance of the dryer. The first experiment was performed in 2 September 2017 for assessing the temperature of filled and empty cabinet and other three consecutive experiments were performed on 16-18 October 2017.

2.1 Sample Preparation

The sample required for drying was collected from KalimatiTarkari Bazaar. The sample preparation protocol consisted of washing the ginger in water and removing the surface water. Prior to drying, the ginger and sorted out according to their cylindrical shape and size, then cut into pieces ranging from 3-5 mm, 6-8 mm, 9-11 mm and solid ginger. Sliced and solid ginger, each of 3 kg of sizes 3-5mm, 6-8 mm, 9-11 mm and solid ginger was also dried under open sun drying as control.

Temperature of air in the dryer and weight of the samples were also monitored at preset time interval.

2.2 Dryer Efficiency

The thermal efficiency of the dryer is defined as the ratio of energy used to evaporate the moisture from the product to the energy supplied to the drier. The overall thermal efficiency of the drier is therefore,

$$\eta = \frac{M \times h_{fg}}{I \times A \times T} \quad (1)$$

where, Where M is the mass of water evaporated (kg); h_{fg} is the latent heat of vaporization (MJ/kg); I is the total solar radiation on the dryer (MJ/m²); A is the solar collection area (m²) and t is the total time of drying

3. Result and Analysis

3.1 Dryer Efficiency

To measure the temperature of the cabinet under loaded and empty condition, one chamber was filled with sliced rhizomes and other was kept empty and temperature was monitored. When the solar radiation was as high as 1000 W/m², the temperature of the cabinet reached max of 80°C as the dryer was left in open environment prior to starting of data measurement at 1 pm. In the loaded condition, the temperature of the chamber was 45 degree Celsius which gradually decreased as the solar radiation decreased. The chamber temperature was around 30 degree Celsius at around 5 pm, when the solar radiation was as low as 70 W/m² and the ambient temperature 20°C signifying enough heat storage in chamber even after the solar radiation falls significantly. Figure 3 depicts the solar radiation and chamber temperature in both loaded and empty conditions.

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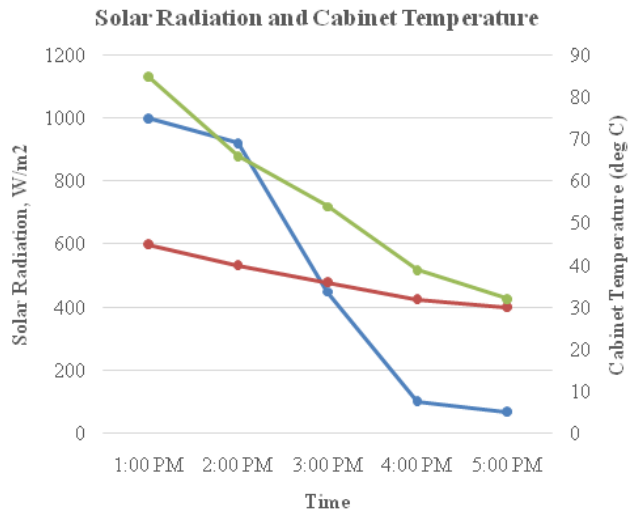


Figure 3: Solar Radiation and Temperature of Cabinet

The samples of sliced as well as solid ginger was then tested for three consecutive days. Each chamber was filled with 3 kg of the sliced/solid ginger of different sizes and the weight was measured in each hour interval to access the drying rate. The data were measured in 16-18 October, 2017 and the solar radiation of the three days is depicted in Figure 4.

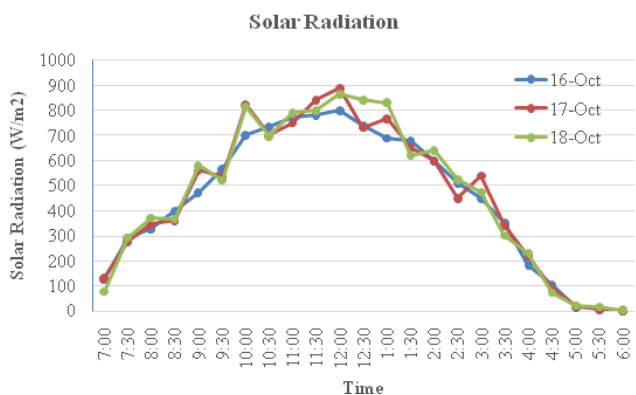


Figure 4: Solar radiation for the experiment days

The chamber temperature reached upto maximum temperature of about 50°C when the chamber was filled with higher sample sizes of 9-11 mm and solid ginger due to the fact that less surface area of chamber being covered and more of the surfaces being exposed to direct solar radiation. The cabinet maintained considerably higher temperature than that of ambient temperature thus being the main factor for effective drying and reduced drying time. Figure 5 shows the

different temperature of cabinets during the experiment.

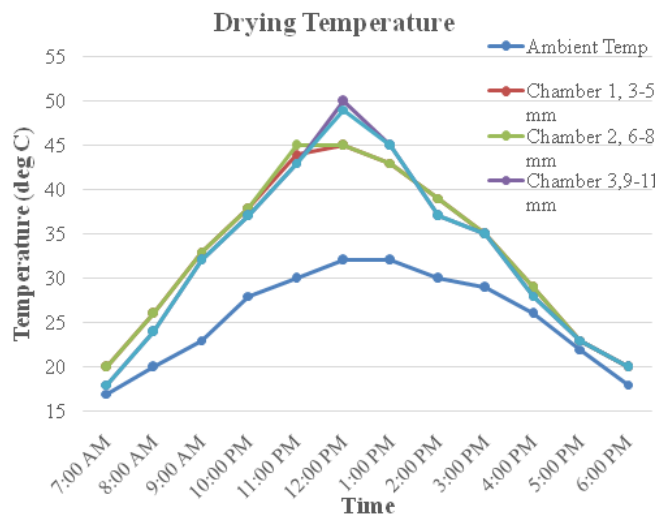


Figure 5: Temperature in different cabinet

The average reading of three experiment days has been presented in the figure below. The drying nature showed that the drying rate for the 3-5 mm sample was maximum due to more surface of rhizomes being exposed to direct solar radiation, followed by 6-8 mm sample and 9-11 mm sample. The rate of drying was least effective for the solid sample due to difficulty in releasing the moisture from the solid sample. During the 11 pm drying period, 3 kg of each sample reduced to 923 gm, 1060 gm, 1282 gm and 1737 gm for 3-5 mm, 6-8 mm, 9-11mm and solid sample respectively.

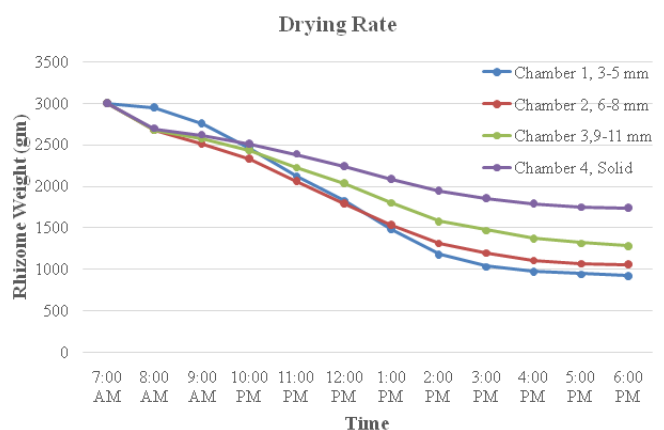


Figure 6: Temperature in different cabinet

On comparing the drying rate of 9-11 mm sample with open sun drying, the use of solar conduction dryer showed to be more effective than open sun drying. The

same sample reached 1282 gm in SCD and 1495 gm in open sun drying for same and identical drying conditions and period.

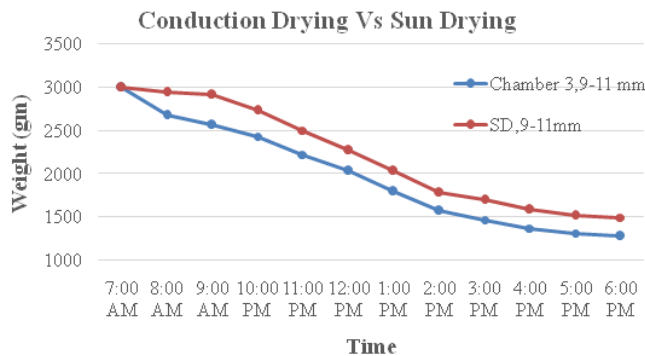


Figure 7: Solar Conduction Drying Vs Open Sun Drying

The efficiency of the solar conduction dryer for 3-5 mm, 6-8 mm, 9-11 mm and solid drying was found to be 64.36%, 58.86%, 50.97% and 32.84% respectively. The dryer was most efficient for the small sample size than as the size of the sample increased due to increase in surface area for moisture diffusivity. Borah et. al, 2015 on similar study found out that the overall thermal efficiency of sliced ginger of thickness 10-14 mm was 55% [9] which is in good agreement with the result obtained in experiment.

4. Conclusion

From the study, it could be inferred that solar conduction dryer can be effective alternative in drying of agricultural products and in reducing the drying time and increasing the productivity of the dried product. The efficiency of dryer reached optimum of 64.36% for 3-5 mm samples

50.97% for 9-11 mm samples. It has the potential to be applied to large scale drying in various agricultural crops in Nepal. Also it can retain the heat for longer period of time than other conventional dryers due to conduction of heat so drying process is continued for longer duration in effectively reducing overall drying duration.

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