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Development of Solar Dryer for Selected Agricultural Products

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Abstract

This study was undertaken for design, development and testing of solar dryer for selected agricultural products. Testing of solar dryer was done for potato, red chilli and mango. The developed machine was fabricated at the workshop of private fabricator, and tested at SVCAET campus, Raipur, Chhattisgarh. The developed solar dryer consists of solar collector, cabinet dryer, Chimney glass, tray, DC motor, battery and speed controller.

The frame of the machine is made up of GI pipe of size 40 X 40 mm. The dimension of solar collector is 55 X 102 cm^2. The dimension of cabinet area is 76 X 56 X 56 cm^3. The size of 18 gauge sheet is used to cover the machine. Angle iron and 22 gauge perforated sheet having 90% perforations and hole diameter of 5mm is used to fabricate the tray. The fan is attached at one side of the collector to suck atmosphere air into the dryer where the collector heat up the air. Then the air moves to drying cabinet where the product are placed for drying then the air takes the moisture from the product and exhale out from the hole of the chimney.

Firstly the initial moisture content of the sample was obtained. The initial moisture content of potato and red chilli was 86.13%, and 77.94% respectively. To evaluate the performance of dryer two tests were carried out i.e. no load test and full load test.

The full load test was carried out with open sun drying method for comparison with it. The final moisture of the product were 4.48% and 6.79% respectively for Potato and Red chilli. The time required for drying was found less as compared to open sun drying for all three products. Quality of dried product was also better with dryer as compared to the open sun drying.

The developed equipment is rigid, reliable and work satisfactory for the given product. The cost of the developed machine is Rs. 18,130.

Key Words: **Solar dryer, full load test, Final moisture content, potato, red chilli.**

INTRODUCTION

Most of the agricultural products require some type of preservation to increase their shelf life and keeping quality of products, since the production usually exceeds market demand at the harvest season and it will be helpful during the off season as it fetches more price or when the production level is low. Due to lack of post harvest management unfortunately about 25-30% of horticultural produce, 10-25% vegetables and 20-30% fruits get wasted which result in huge loss of crores of rupees (www.phytojournal.com). Postproduction management system is necessary with the increasing production rate and to reduce losses. Drying is the primary requirement of crop's postproduction system.

Thermal drying is the most common method used for drying the industrial and agricultural products. Drying inhibit the growth of bacteria, yeasts and mold through the removal of water. During this process, airflow is required to remove vapor away from the product. Fossil fuel and electricity is previously the main energy source for thermal dryer

either for the heat source or to induce the airflow which make it expensive. The current global trend to reduce the greenhouse gas emissions resulting in the need to minimize the utilization of fossil fuels. This leads to extensive research on renewable energy applications including solar drying. Compare to open sun drying, solar dryers put the product being dried in closed space which gives better and hygienic results. With the rising costs of conventional fuels and increasing awareness about the dangers of pollution in the environment, solar dryers are becoming an economically and technically viable option in many industrial and agricultural applications as it is operated by solar energy which is in abundant in nature.

Solar dryer may also be classified into direct, indirect and mixed modes. In direct solar dryers the cabinet /chamber contains the materials and solar energy passes through a chamber and is absorbed by the materials. Essentially, the heat required for drying is provided by radiation by the sun to the upper layers and conduction occur into the material bed. In indirect dryers, solar energy is collected in a separate solar collector or and the heated air then passes through the chamber or material bed, while in the mixed-mode type of dryer, it follows the both direct and indirect type dryer procedure simultaneously, the heated air from a separate solar collector is passed through a chamber and at that instant, the drying cabinet or chamber absorbs solar energy directly through the transparent walls or roof.

The performance of solar dryers is significantly dependent on the weather conditions and pre-treatment given to the product, as pre-treatment reduces the drying time and increase the drying rate. Various pretreatment given to product are blanching, dipped in chemical solution, freezing etc.

Keeping in view, the project entitled “Development of Solar Dryer for Selected Agricultural Products” was under taken with the following objectives.

Objectives

- Development of solar dryer for selected agricultural products.
- Performance evaluation of solar dryer.
- Cost economics of developed solar dryer.

REVIEW OF LITERATURE

Fudholi Ahmad et al.(2013) studies the performance of solar drying in theMalaysian red chili (*Capsicum annuum* L.). the initial moisture content of red chilli is obtained with the help of oven maintaining the temperature 120ºC. It was found that the initial moisture chilies was 80.2 (wb) and the moisture content was reduced from 80.2% (wb) to 10% (wb) in 33 h. The drying process was conducted during the day, and it was compared with 65 h of open sun drying. Solar drying yielded a 49% saving in drying time compared with open sun drying. The average solar radiation of 420 W/m2 and air flow rate of 0.07 kg/s. The specific moisture extraction rate (SMER) of 0.19 kg/kWh was obtained.

Dongardive Snehal (2016)developed a forced convection solar dryer. The frame size of drying chamber was(1.5 x 1) $m^2$and front side size was (1.5 x1.2) m^2.it is also provided with provision for inclination of 45º, 35º, 25º C, which is madeup of M.S. angle, G.I. sheet and glazing. It was observed that the maximum temperature attained inside the drying chamber was recorded as 66.9^{0}C at 45^0, 70.2^{0}C at 35^0 and 71.4^{0}C at inclination of 25^0. Moisture content of Fenugreek leaves reduced to 5.18 % from 777.14 % (d.b.) inside the dryer at an inclination angle 45.Time required for drying the sample was 10 h.

Goyal R.K *et.al*(2006) studies the thin layer drying of raw mango slices. The sample were dried at the temperature of 55º C, 60ºC, 65ºC with different pretreatment given to the sample the initial moisture content of the sample was evaluated by hot air oven. The samples were blanched in hot water blanching in 50º C for 2 min and blanching with 1% of potassium metabisulphate solution.

MATERIALS AND METHODS

The dryer was fabricated as per the conceptual design at the workshop of private fabricator and was tested at Swami Vivekanand College of Agricultural Engineering and Technology and Research station. The methodology followed during the course of this research work is discussed in brief under this chapter. The following methodology was adopted.

Solar Dryer Design Consideration

The following points were considered for the design of solar dryer:

- The amount of moisture to be removed from the product.
- Daily sunshine hours for determination of total drying time.
- The quantity of air for drying.
- Daily solar radiation energy received by the dryer.
- Wind speed for calculating the size of air vent.

Table 1: General description of developed solar dryer

Sr. No	Description	Specification
1	Volume of cabinet(m^3)	0.238
2	Area of collector plate(m^2)	0.571
3	Tray area(m^2)	0.24
4	Total tray area(m^2)	0.96
5	Total length(m)	1.68
6	Total height(m)	1.64
7	Weight of solar dryer (kg)	75.4

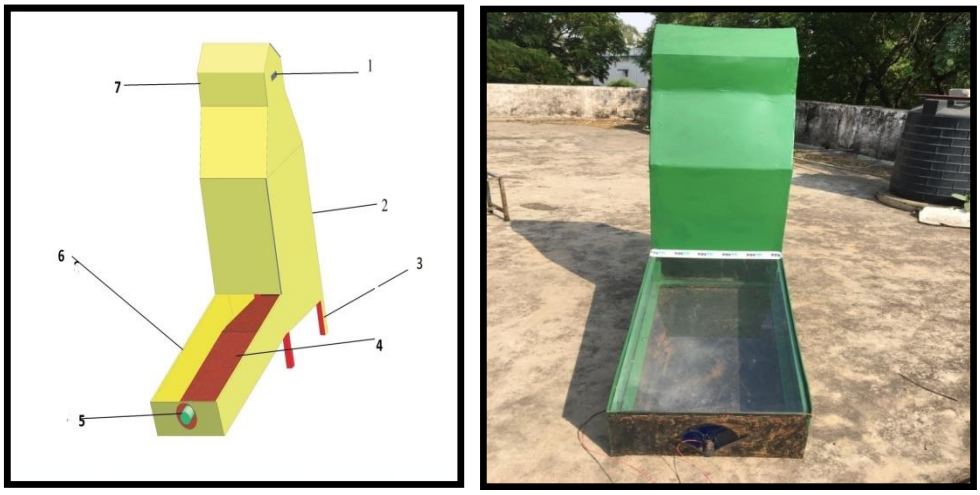

Fig.1: Isometric view of developed solar dryer

1. Chimney hole.
2. Drying cabinet.
3. Dryer stand .
4. Collector bottom plate.
5. D.C Motor.
6. Solar collector.
7. Chimney.

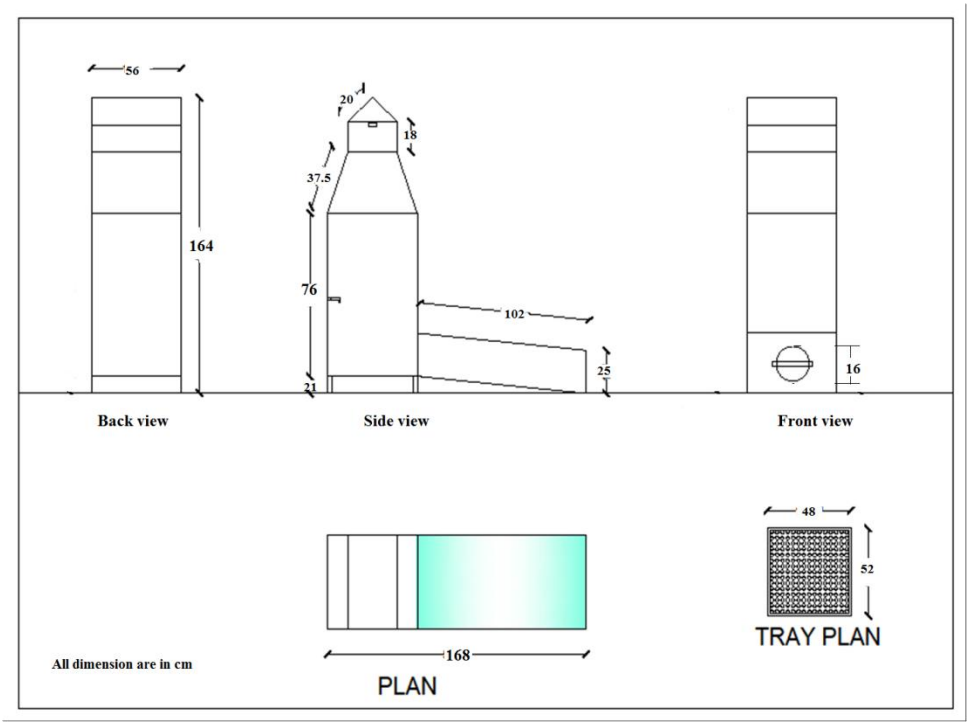

Fig.2: Isometric view of developed solar dryer

Formula used

Mass of water to be removed from the product

$$M_w = \frac{Mp(mi-mf)}{(100-mf)}$$

M_w = amount of moisture to be removed from the product, kg.

Mp = initial mass of the product to be dried, kg

m_i ,m_f= initial and final moisture content of the product% wb

Determination of moisture content

$$mc\ (w.b) = \frac{w_1 - w_2}{w_1} \times 100$$

mc= moisture content of product% (wb).

w_1,w_2 = initial and final weight of the product, kg.

Experimental procedure

The samples were prepared and dried until the required final moisture content was attained. The fresh samples were placed over the perforated trays of drying chamber having about 90% perforation. The initial moisture content of the product was determined by taking three samples in the oven. The moisture content is noted every hour and the required temperature is maintained in the oven.

During the drying experiment moisture content was observed at hourly basis during the day time. The standard procedure (Narnaware Sunil 2007) was used for determination of moisture content.

The fan is operated with the help of battery for reducing the relative humidity and temperature inside the solar dryer. Various parameters were observed during the experiment. The inside and outside temperature of solar dryer were noted drying the experiment. Solar dryer was tested for its performance in drying of products such as potato, red chilli, and mango. The test was conducted in day time from 10 am to 5:00 pm.

The full load test was carried out to evaluate the performance of the developed solar dryer. The dryer contains four trays in the drying chamber. The samples were placed in the trays for the drying experiment and some samples are placed in the open air on the plastic sheet for sun drying so that comparison can be done.

The inside temperature of solar dryer was measured with thermometer. The dry and wet bulb temperature was measured with the sling psychrometer. The product was weight with the help of weighing balance & the oven was used to find out the initial moisture content of the products. The performance of drying unit was evaluated in terms of moisture content, variation of drying rate etc. for this calculation reduction in weight of the sample was recorded.

The performance of developed solar dryer was carried out by conducting load test and loaded test in comparison with sun drying.

3.6.1 No load testing

The no load test was carried to know the maximum temperature attained and temperature profile inside the dryer. During the test hourly data is recorded.

3.6.2 Full load testing

The full load test was carried to evaluate the performance of the developed solar dryer. Different sample with known moisture content were loaded on trays of solar dryer. Different parameters were recorded at hourly basis. Initial

moisture content of sample was measured by oven drying method. Drying of the sample is carried till the weight of the product remains constant.

RESULT AND DISCUSSIONS

A natural convective solar dryer was designed and developed for drying of selected agricultural product. The developed solar dryer was combined with fan and battery which make it possible to work as a forced convection solar dryer. The dryer was tested at SVCAET campus Raipur, Chhattisgarh.

Performance evaluation of developed solar dryer for potato chips drying

The average moisture removed from the product was observed to be 0.414 kg from the whole sample of 0.507 kg. The moisture content removed was calculated as 81.65% (wb). The heat energy required to evaporate the water is about 2125.32kJ.The drying rate for Potato was 0.0233 kg/h where as the mass flow rate of air is about 5.2 kg/h. The volumetric air flow rate was found to be 4.81 m^3/s. The dryer was compared with sun drying in which the moisture removed from the product was about 78.91% (wb) and it took more time then the dryer and in sun drying spoilage of product was maximum. The dryer took 5hour to dry the potato and the open sun drying took about 6 hours. As there is slightly difference in drying time between the solar and sun drying but the solar drying maintains the quality and quantity of product. The products obtained in sun drying gets deteriorate and the quantity also gets affected. The capacity of the dryer for the potato is about 2.5 kg.

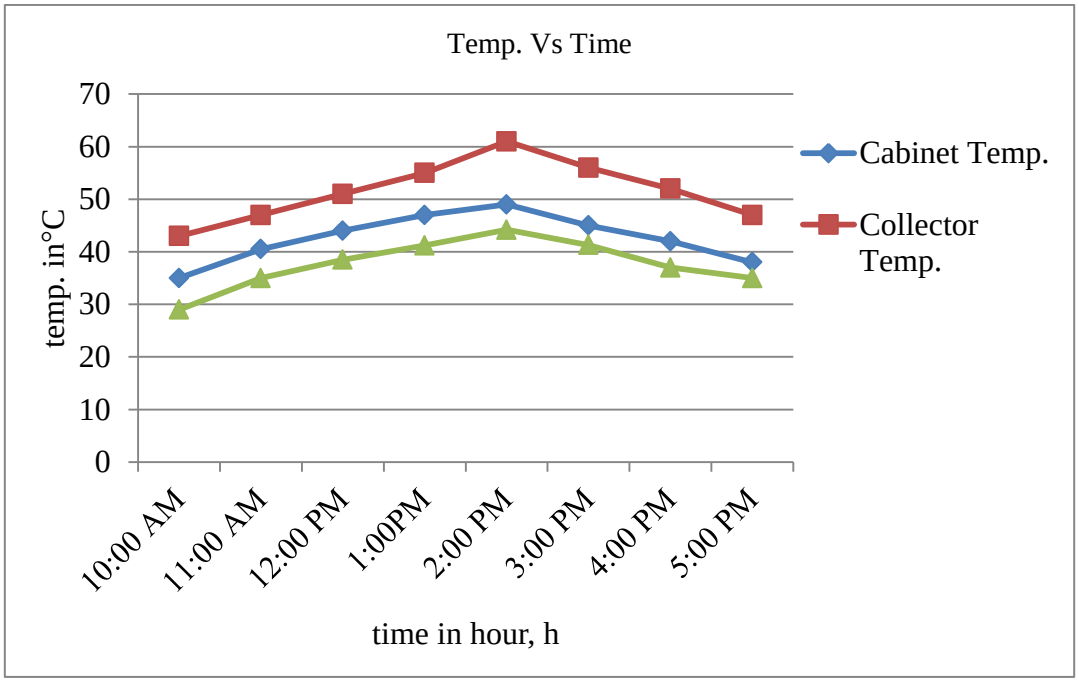

Fig.3: Variation of temperature in solar dryer with respect to time while drying potatoes.

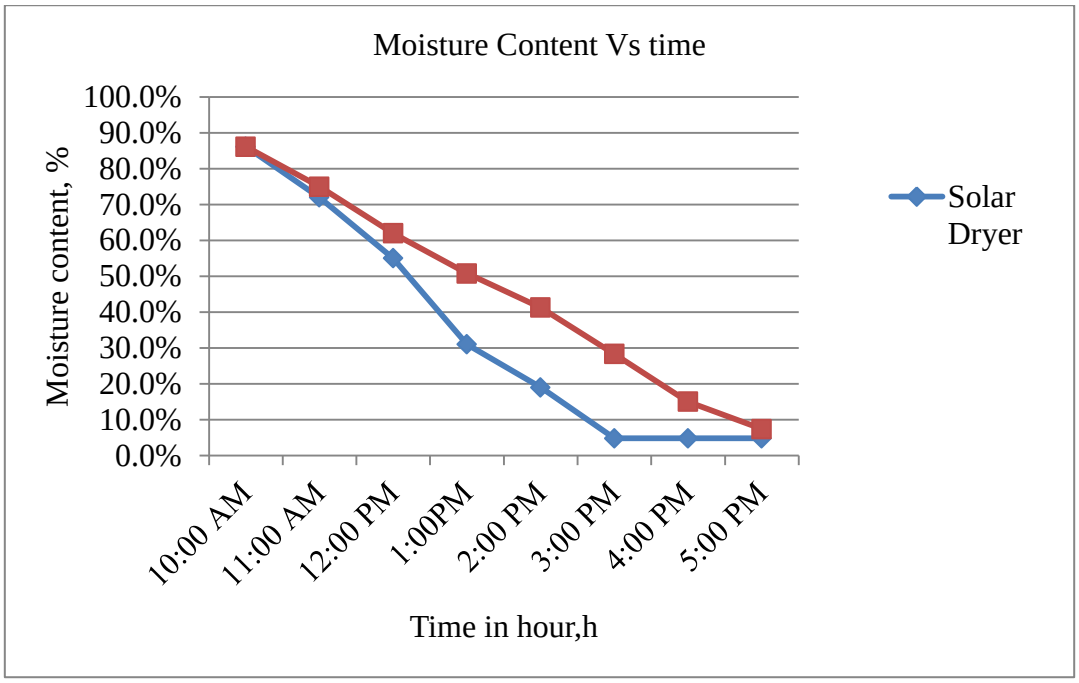

Fig.4: Moisture content removed with respect to time while drying potatoes.

Performance evaluation of developed solar dryer for red chili drying

The performance of the solar dryer was evaluated by loading red chilli in the dryer. The maximum temperature attained in the cabinet, collector and the ambient temperatures was. 49°C, 60°C and 42°C respectively. The test is carried out in the month of May. Where the average solar radiation is about 6.65 kwh/m^2/day. The average temperatures attempted in whole testing in collector & cabinet are 58°C, 48°C.

The testing of solar dryer was carried out by placing blanched sample in the dryer cabinet. It was found that the water removed from the sample was about 0.372 kg from the whole sample of 0.520 kg. The final moisture content of red chilliwas found to be 6.41% (wb) with the help of above data, other necessary data was calculated and then the heat energy required to evaporate the water was found. It was found as 3301.60 kJ. The drying rate was calculated as 0.0866 kg/h. The value of maximum flow rate of air was 32.07 kg/h and the volumetric air flow rate is about 26.69 m^3/s. The capacity of dryer for red chilli is about 2.5 kg. The solar dryer was compared with open sun drying which takes more time for drying. As the solar drying takes 17hours and the sun drying takes 22 hours to dry the product. The average moisture removed in sun drying is about 68.54% (wb). Sun drying also affects the product and reduced the quality as the foreign materials mixed with it from the air. The cost of drying of per kg of chilli is 24.92/-Rs.

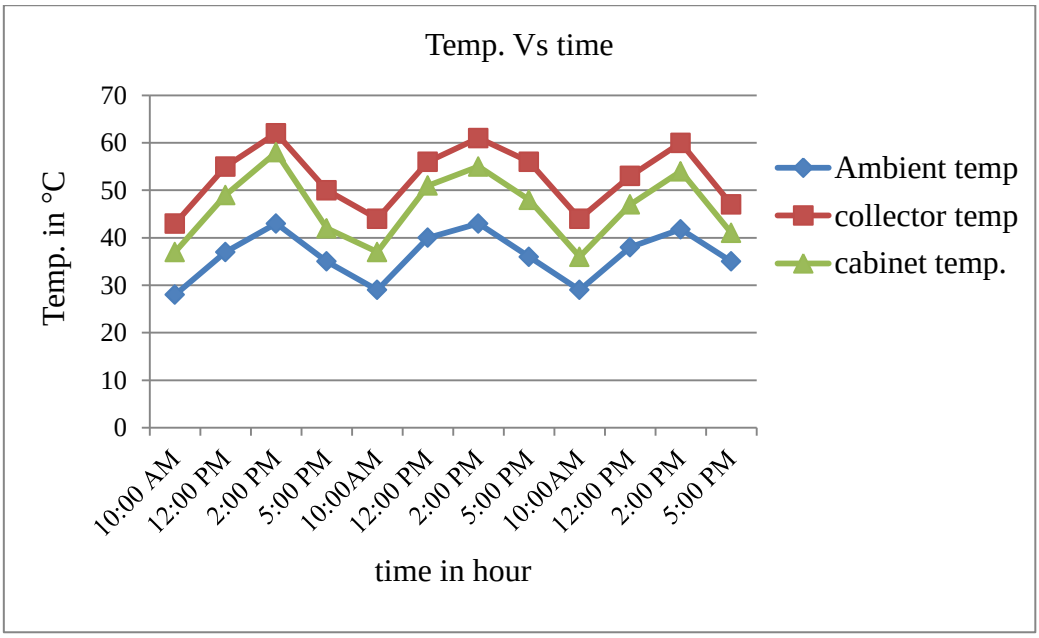

Fig.5: Variation of temperature in solar dryer with respect to time while drying red chili

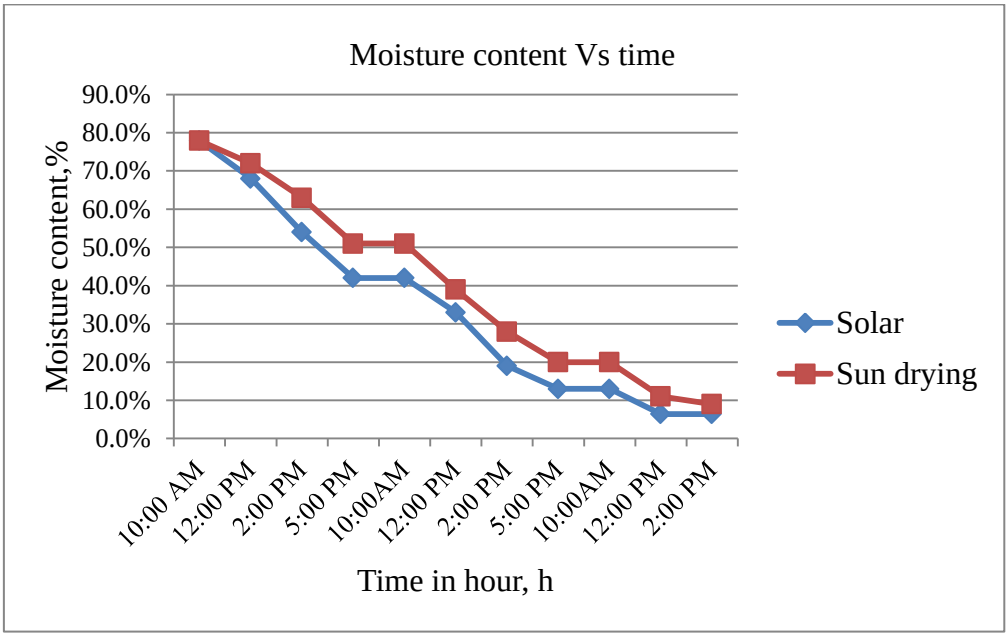

Fig.6: Moisture removed comparison of solar and sun drying.

Findings

The developed machine was evaluated and following findings were noted:-

1. Firstly the initial moisture content of the product was found with the help of hot air oven method. The different temperature is maintained for different product for e.g. Potato 70°C Red chilli- 120°C, Until the constant weight was obtained.
2. The initial moisture content of Potato, red chilli were 86.13%, 77.94%.

3. The highest temperature attained in the solar collector solar dryer cabinet and ambient temperature are 63°C, 58°C, 43°C.
4. The sample was loaded at 10 am and unloaded at 5 pm.
5. The samples were dried in the solar dryer until the final moisture content is obtained. After drying the final moisture content of the product Potato, red chilli are 4.48% and 6.41%.
6. The solar dryer is compared with open drying system. It take less time than the open sun drying & it reduces more moisture up to safe level then the sun drying system.
7. The heat energy required for the sample Potato and red chilli was 2125.32 kJ and 3301.60 kJ..
8. Average drying rate of the product are 0.0233 kg/h and 0.0866 kg/h..

CONCLUSIONS

1. The developed solar dryer was rigid & reliable and easy to use.
2. The performance of solar dryer was found satisfactory. The dryer was also compared with open sun drying method. It resulted in less time as compared to open drying system and also maintained the quality of the product.
3. The cost of drying of per kg of Potato and red chilli was found Rs 8.76, Rs and 24.92 respectively.

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Fig 7 Products before drying

Fig8 Products after drying