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Performance Evaluation of Natural Circulation Solar dryer for Dehydration of Cauliflower

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Abstract: *A study on performance evaluation of natural circulation solar dryer (NCSD) for dehydration of cauliflower was carried out. The dryer can be used for drying various agricultural products like fruits and vegetables. During the study, cauliflower was successfully dried from moisture content of 90% to 10% on wet basis in 54 hours in natural circulation solar dryer. The performance of natural circulation solar dryer was also compared with electric tray dryer and solar tunnel dryer (STD). It was found that drying time in STD was minimum (46 hrs) as compared to electric tray dryer (48 hrs) and natural circulation solar dryer (54 hrs) for same commodity and reduction of moisture. The quality of cauliflower dried in natural circulation solar dryer and solar tunnel dryer was good in comparison to electric tray dryer.*

Keywords: *Cauliflower, Drying, Natural circulation solar dryer, Moisture content, Solar radiation*

I. Introduction

Cauliflower (cabbage flower) is one of familiar vegetables packed with essential nutrients. Its compact flower heads contain numerous health benefiting phtyo-nutrients such as vitamins, sulforaphane etc. and plant sterols such as indole-3-carbinol that help in preventing overweight, diabetes and also offers protection against prostate, ovarian and cervical cancers. Also, Di-indolyl-methane (DIM), a lipid soluble compound present abundantly in Brassica group of vegetables, including cauliflower, has found to be effective as immune modulator, anti-bacterial and anti-viral agent (www.nutrition-and-you.com). It is a rich source of proteins, carbohydrates, vitamins and minerals and also a very important vegetable having maximum availability in tropical climate from November to February which causes glut in the market and consequently vegetable growers do not get remunerative prices [1]. Cauliflower is produced on an area of 0.348 million hectare with the total production of 6.57 million tones with the productivity of 18.9 t/ha (Indian Horticulture Database 2010). Fresh cauliflower can be stored for 2–4 weeks at storage temperature of 0°C and relative humidity (RH) of 95–98% and post harvest losses are estimated as 49% in India [2]. Large quantities of vegetables perish during glut season due to poor post harvest management and inadequate processing facilities. The suitable preservation procedures would be helpful in harnessing the useful characteristics of vegetables during off-season. Among the numerous methods of preservation, drying is one of the oldest methods of food preservation [3]. Drying not only reduces the bulkiness of the fresh product but also facilitates easy transport because of the reduction in weight and volume but also ensures enhanced availability of the product throughout the year at affordable prices [4]. The preservation of cauliflower in dried form would not only provide nutritional benefits to a vast section of the society but would also provide a low cost product with extended shelf life without significantly varying its nutritional quality. The surplus production during the peak season can be preserved through drying which can be suitably utilized during the offseason for the manufacture of cauliflower based curry, preparation of cauliflower pickle, rehydrated vegetable mix, soups, canned products, extruded products etc.

Drying is one of the most frequently used operations for preservation of agricultural products. It is essentially a technique for preservation of food materials by reducing the activity of water to a level for enhancing length of desired self-life. In several cases, the drying process is connected to some physical and chemical processes inducing proper internal biochemical and/or microbiological changes, which should take place simultaneously to ensure the characteristic quality features of the product like colour, smell, taste, consistence and shape [5]. Drying or dehydration is one of the most energy intensive processes in the food industry and it is practiced to maintain the quality of product during storage as well on rehydration [6]. The food industry can save money by employing energy efficient methods. One percent increase in energy efficiency may result in an increase of 10.0% profits. Seasonal and perishable nature of fruits and vegetables make it almost mandatory to preserve them for long-term storage without further deterioration in their quality. Several studies reveal that the structure of dried foods depends on the drying methods and conditions such as temperature, relative humidity, air flow rate and initial physico-chemical characteristics of the product [7] [8]. The quality of end product in terms of sensory and other physic-chemical factors are significantly influenced by drying conditions [9] [10] . Open sun drying, convective mechanical drying or microwave drying are mostly employed drying techniques for mass product drying in many rural as well as urban areas. These methods suffer from one or the other limitations like quality losses in terms of colour, flavour (taste and aroma), and texture along with

poor dehydration characteristics, uncontrolled heating, time consuming, susceptible to contamination and also costlier and energy intensive.

Thus, solar dryers which are quite efficient in drying of agricultural products are more effective than sun drying and have lower operating costs than mechanized dryers. Solar dryers using natural convection or forced circulation have been investigated in the past to overcome these problems. For commercial applications, the ability of the dryer to process continuously throughout the day is very important to dry the products to its safe storage level and to maintain the quality. Therefore drying of cauliflower using solar dryer would be a promising area of research. Thus, the present study was undertaken to study the performance evaluation of Natural circulation Solar Dryer and also compare the performance of Natural Circulation Solar Dryer with Electric Tray Dryer and Solar Tunnel Dryer for drying of Cauliflower.

II. Material and Methods

The experiment was conducted at Renewable Energy Lab. of Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, CCS Haryana Agricultural University, Hisar Fresh and good quality cauliflower of average size was procured from the local vegetable market, Hisar. Glass-in-mercury thermometers were used to measure the ambient and dryer temperature. Solar Insolation meter (Suryamapi) was used to measure the solar insolation (W/m^2). This instrument had a photo-voltaic cell which directly converted solar radiation into electric current. The instrument was calibrated to give readings of solar intensity in the range of 1200 W/m^2. Hygrometer, weighing balance and suryamapi equipments were used during collection of the data.

2.1 Sample preparation

Cauliflower was thoroughly washed in simple water. After washing, cauliflower was chopped into small pieces (1cm x 1cm). After cutting, the cauliflower buds were properly blanched in hot water mixed with 2 teaspoon of salt for 3 min. The blanched cauliflower was then kept under a fan for 30 minutes for the removal of excess water present in the cauliflower.

2.2 Drying

Two kg of cauliflower was kept in Natural Circulation Solar Dryer, Solar Tunnel Dryer and Electric Tray Dryer for drying purpose. Initial moisture content of the samples was determined using oven drying method. The subsequent moisture during the drying period was calculated by weight reduction method after a regular interval of time.

2.3 Natural Circulation Solar Dryer

The produce was placed on trays inside an opaque drying chamber to which was attached an air type solar collector. The sun rays did not fall directly on the material to be dried, instead the air heated in solar collector was ducted to the drying chamber for dehydration. Air circulation in these types of dryers is by natural convection. These dryers result in higher temperature than the cabinet dryers or sun drying, and could produce better quality product.

2.4 Solar Tunnel Dryer

It was a natural convection type dryer useful for bulk drying of agricultural & industrial products at moderate air temperature, consisted of a hemi-cylindrical metallic frame (3.75m x 5m) covered with UV stabilized transparent polythene sheet of 200 micron thickness. There were three chimneys on the top and an exhaust fan on one side of the tunnel to remove the moist air. It had an insulated wall on north side. The product was spread on the trays which were kept on the movable trolleys.

2.5 Electric Tray Dryer

It was a cabinet dryer with temperature and air control knobs. The cauliflower pieces were spread in single layer on aluminum trays and were kept in electric tray dryer. The drying was carried out at a temperature of 50 +/– 2º C. During drying, the samples were turned regularly at an interval of two hours for uniform drying.

2.6 Parameters recorded during the experiment

Drying parameters (temperature, °C and relative humidity, %) and solar radiation (W/m2) ware determined by using the thermo hygrometer and suryamapi (solar radiation meter) respectively.

2.7 Moisture content

Moisture content of the samples was determined as per the standard method described by [11].

III. Results and Discussion

This study was undertaken to evaluate the performance of Natural Circulation Solar Dryer based on drying efficiency that depends on the duration of drying which depends on ambient conditions and temperature attained in the dryer.

3.1 Performance Evaluation of Natural Circulation Solar Dryer

The performance of Natural circulation solar dryer was evaluated for drying of cauliflower. 2 kg of cauliflower with initial moisture content of 90% (w.b.) was taken for study. The experiment was conducted for consecutive days in the month of April. The dryer took 54hrs in reducing the moisture content from 900 % (d.b.) to 20 % (d.b.). **V**ariation of moisture content of the sample, solar insolation, ambient and dryer temperature with time are presented as Fig 1, 2 and 3. It can be seen from fig. 1 that maximum temperature attained inside the dryer was around 45°C while minimum temperature inside dryer was 27°C on the typical day of April against the maximum and minimum ambient temperature of 37°C and 23°C respectively. It was also observed that the maximum solar insolation during the period of study was around 720 W/m^2. Fig. 2 shows that the moisture content initially reduced steeply during the day time and slowed down in the night time which was obvious. Then moisture content decreased with a constant slope and became stable at moisture content of 20% (d.b.). Fig. 3 demonstrates that the temperature inside the dryer is always 10 to 30 °C higher than the ambient temperature. The maximum temperature inside the dryer was ^{o}C. Ambient temperature during period ranged between 23-37^{o}C and dryer temperature ranged between 28-45^{o}C.

3.2 Comparative Performance of Different Dryers

The comparative study of natural circulation solar dryer, solar tunnel dryer and electric tray dryer were carried out. Two kg samples of cauliflower placed in each dryer and it was dried from an initial moisture content of 90% to 10 on wet basis. The drying time taken by electric dryer was 48 hr at 50°C followed by 46 hr at the temperature inside the dryer varied between 28°C to 51°C and solar insolation varied between 400 W/m2 to 720W/m2 (solar tunnel dryer) and 54 hr at the 36 °C from moisture content 90% to 11% on wet basis (Natural circulation solar dryer). Fig. 4 shoes that the Electric tray dryer the cauliflower dried at same rate and become constant but on the other hand in Solar tunnel dryer and Natural circulation solar dryer drying was fast in the day time and slowed down during the night time. The moisture content of cauliflower initially 90% and dried up to 10 % (wet basis) in all the dryers in different period of time

IV. Conclusion

The performance evaluation of natural circulation solar dryer for the drying of cauliflower and compared with different dryers as electric and solar tunnel were carried out and found that the dryer can be used for drying various agricultural products like fruits and vegetables. During the study, cauliflower was successfully dried from moisture content of 90% to 10% on wet basis in 54 hours in natural circulation solar dryer. The drying time in solar tunnel dryer was minimum (46 hrs) as compared to electric tray dryer (48 hrs) and natural circulation solar dryer (54 hrs) for same commodity and reduction of moisture. The quality of cauliflower dried in natural circulation solar dryer and solar tunnel dryer found better and also retained maximum consumer acceptability scores as comparison to electric tray dryer.

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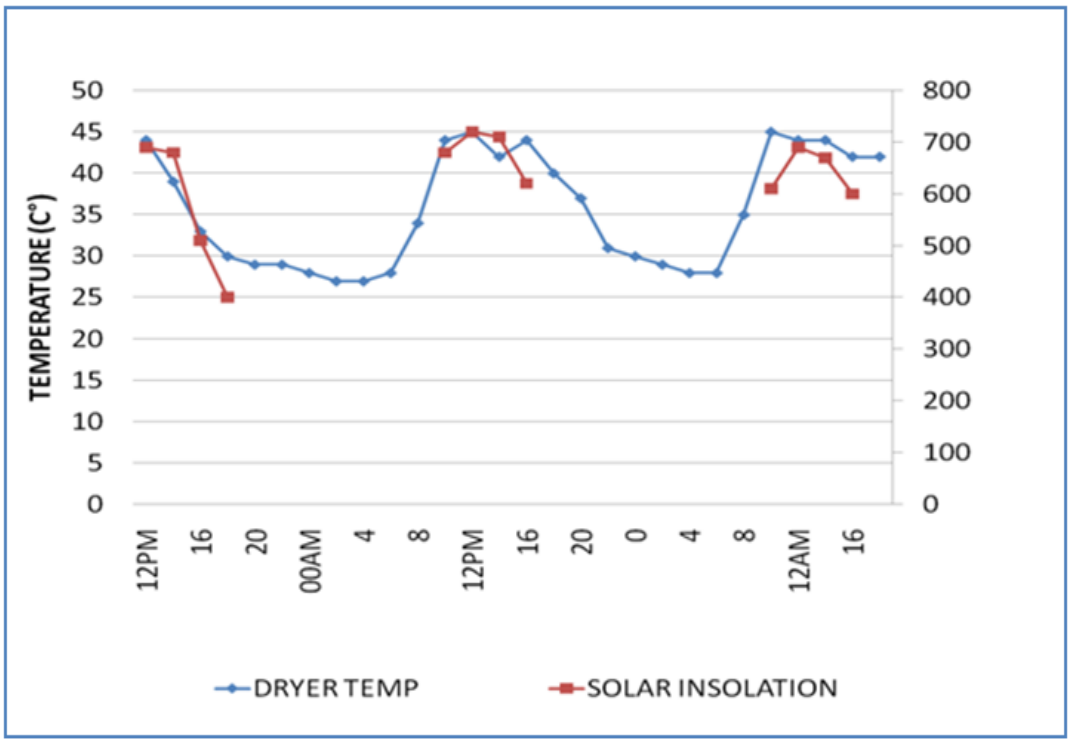

Fig.1: Variation of solar insolation and dryer temperature with time

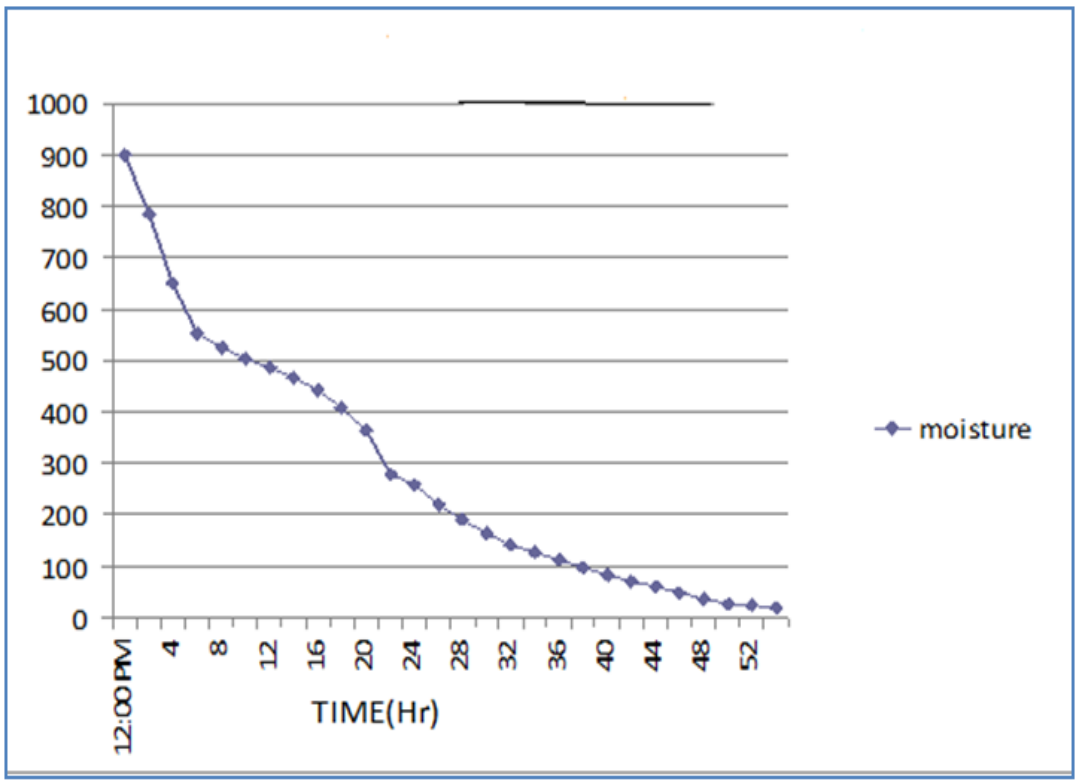

Fig 2: Variation of moisture content with time in Natural Circulation Solar Dryer

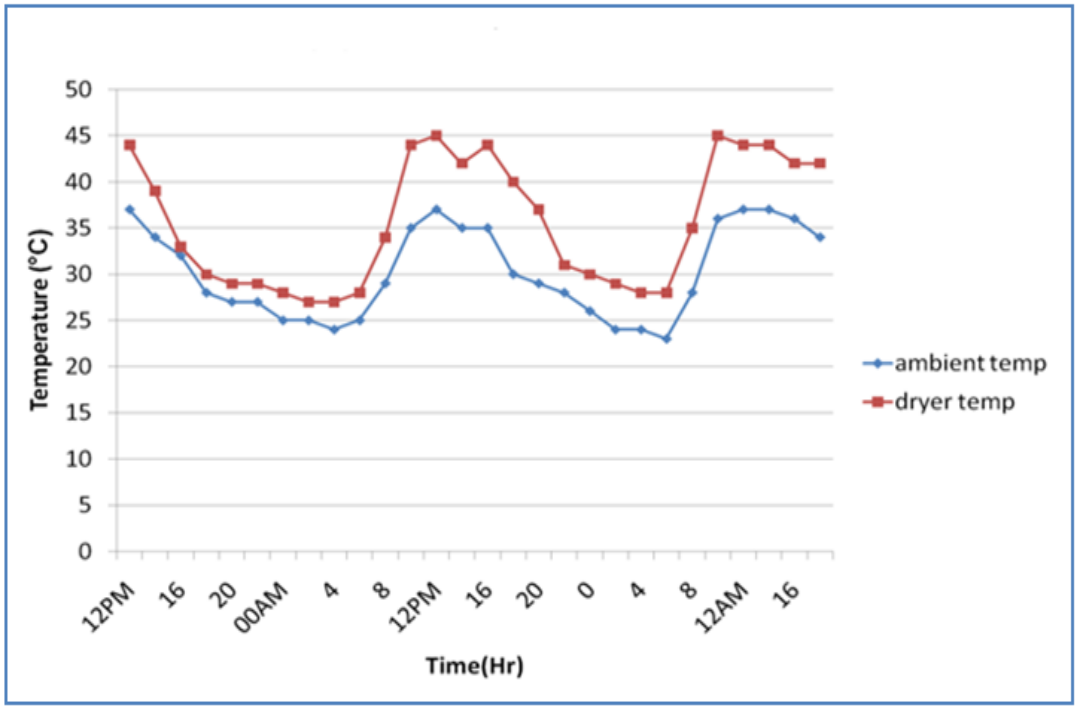

Fig. 3: Variation of ambient temperature and dryer temperature with time

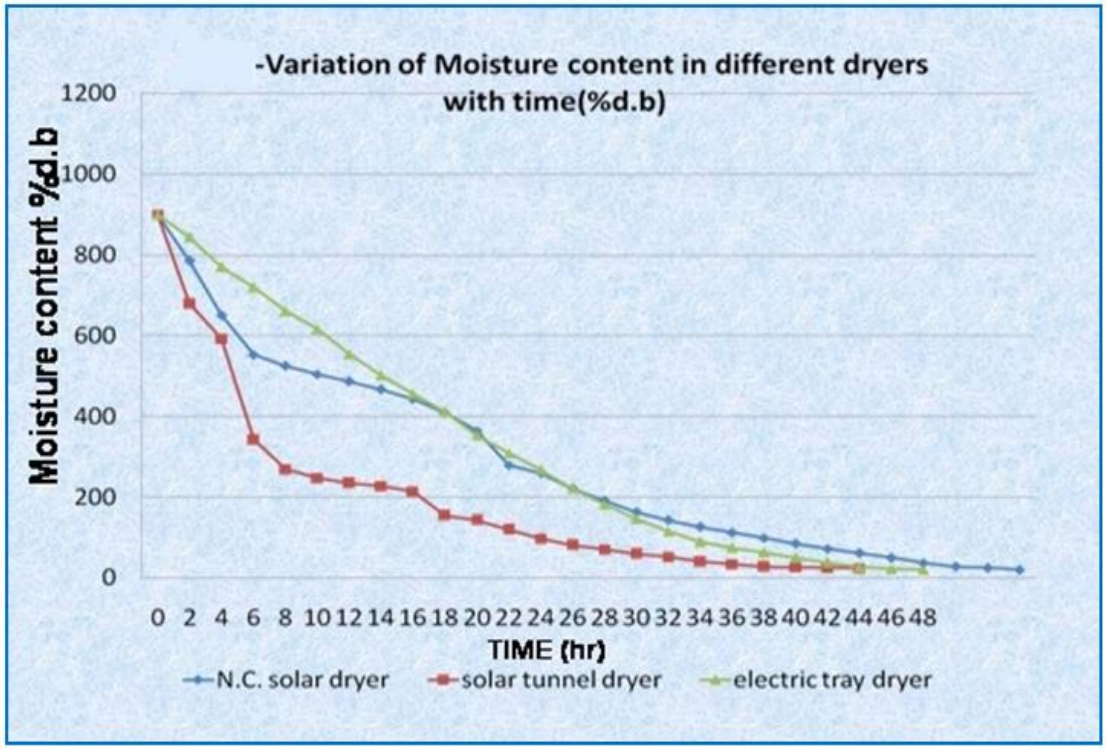

Fig.4 The variation of moisture content in different dryers with time