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A Glance on Solar Drying Technology: A Review

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Abstract **- Preservation of fruits, vegetables, and food are essential for keeping them for a long time without further deterioration in the quality of the product. In this review paper, the attention is given on different types of solar drying technologies. There are basically two types of solar drying methods viz, direct type and indirect type. In direct type solar radiations directly fall on the product which is in closed in cabinet and in case of indirect type drying of product can be done by natural or force method. Mixed mode solar drying method is combination of both direct and in direct type. Solar drying has been used to dry plants, seeds, fruits, meat, fish, wood, and other agricultural, forest products. In order to benefit from the free in recent years to develop solar drying mainly for preserving agricultural and forest products.**
Keywords: **Sun, Solar Dryer**

I. INTRODUCTION

Solar dryers used in agriculture for food and crop drying ,for industrial drying process, dryers can be proved to be most useful device from energy conservation point of view. It not only save energy but also save lot of time, occupying less area, improves quality of the product, makes the process more efficient and protects environment also. Solar dryers circumvent some of the major disadvantages of conventional drying. Solar drying can be used for the entire drying process or for supplementing artificial drying systems, thus reducing the total amount of fuel energy required.

A typical solar food dryer improves upon the traditional open-air sun system in five important ways:

It is faster. Foods can be dried in a shorter period of time. Solar food dryers enhance drying times in two ways. Firstly, the translucent, or transparent, glazing over the collection area traps heat inside the dryer, raising the temperature of the air. Secondly, the flexibility of enlarging the solar collection area allows for greater collection of the sun's energy.

It is more efficient. Since foodstuffs can be dried more quickly, less will be lost to spoilage immediately after harvest. This is especially true of products that require immediate drying of freshly harvested fruit with high moisture content.It is hygienic. Since foodstuffs are dried in a controlled environment, they are less likely to be contaminated by pests, and can be stored with less likelihood of the growth of toxic fungi. It is healthier. Drying foods at optimum temperatures and in a shorter amount of time enables them to retain most of their nutritional value such as vitamin C. It is cheap. Using freely available solar energy instead of conventional fuels to dry products.

A. Solar Dryers: Classification

Drying equipment may be classified in several ways. The two most useful classifications are based on the method of transferring heat to the wet solids or the handling characteristics and physical properties of the wet material. The first method of classification reveals differences in dryer design and operation, while the second method is most useful in the selection of a group of dryers for preliminary consideration in a given drying problem. A classification chart of drying equipment on the basis of heat transfer. This chart classifies dryers as direct or indirect, with subclasses of continuous or batch wise operation. Solar drying systems are classified primarily according to their heating modes and the manner in which solar heat is utilized. In broad terms they can be classified in to two major groups namely Passive solar energy drying systems (Conventionally termed natural circulation solar dryer systems) and Active solar energy drying systems (Most type of which are often termed as hybrid solar dryer) Solar drying methods are usually classified to four categories according to the mechanism by which the energy, used to remove moisture, is transferred to the product:

1. *Sun or Natural Dryers:* The material to be dried is placed directly under hostile climate conditions like solar radiation, ambient air temperature, relative humidity and wind speed to achieve drying.
2. *Direct Solar Dryers:* In these dryers, the material to be dried is placed in an enclosure, with transparent covers or side panels. Heat is generated by absorption of solar radiation on the product itself as well as the internal surfaces of the drying chamber. This heat evaporates the moisture from the drying product and promotes the natural circulation of drying air.
3. *Indirect Solar Dryers:* In these dryers, air is first heated in a solar air heater and then ducted to the drying chamber.
4. *Mixed-Type Solar Dryers:* The combined action of the solar radiation incident directly on the material to be

dried and the air pre-heated in the solar air heater furnishes the energy required for the drying process.

II. LITERATURE REVIEW

A. N.S. Rathore , N.L. Panwar[1]

Fig. 1 Tunnel type solar dryer

A walk-in type hemi cylindrical solar tunnel dryer has been built with heat protective north wall at College of Dairy and Food Science Technology, Udaipur, India for drying agricultural & horticulture product on large scale. In this paper attempt has been made to evaluate the performance of developed dryer to dry the seedless grapes (mutant: Sonaka). The study show that chemically untreated grapes took seven days to dry at 16% (wb) moisture content. The temperature gradient inside the tunnel dryer is about 10–28 ^{0}Cduring the clear day, which is quite sufficient to dry agricultural commodities.

B. R. VidyaSagar Raju1, R. Meenakshi Reddy, E. Siva Reddy [2]

Fig. 2 Box type solar dryer

A solar dryer is designed and constructed based on preliminary investigations of drying under controlled conditions (laboratory dryer). The constructed dryer is to be used to dry vegetables under controlled and protected conditions. The designed dryer with a collector area of 1m2 is expected to dry 20kg fresh vegetables from 89.6% to 13% wet basis in two days under ambient conditions during harvesting period from February to March. A prototype of the dryer with 1.03m2 solar collector area was constructed to be used in experimental drying tests. Along with this the water heating system is also employed to the dryer to recover the waste heat getting from the dryer. Hence the practical usage of dryer is greatly increased by employing the water heating system along with dryer.

C. Mr.Avesahemad Sayyadnaimutulla et al., [3]

Fig. 3 Indirect mode forced convection solar dryer

In this work mixed mode forced convection solar grape dryer with thermal energy storage has been developed and tested experimentally. The grapes with pretreatment have been dried with developed solar dryer. The designed dryer was integrated with a Phase Change Material to extend the use of dryer in the evening/night hours. The effect of air mass flow rate on moisture content, moisture ratio, drying rate, drying time and dryer efficiency has been evaluated for grapes. At the same time effect of thermal energy storage on drying time on grapes also evaluated with and without incorporation of thermal energy storage with variation in mass flow rate of air. The following conclusions have been arrived at, from the experimental investigation carried out in the present work on solar grape dryer.

Dried grape (Raisins) production is possible with developed solar dryer in much shorter time. An indirect type of solar dryer with forced air circulation can be used to produce superior quality raisins acceptable in the international market. The drying experiment conducted with grapes and it was found that the complete drying process could be attained with 30 hours, which is very less compared with open sun drying. Thermal energy storage must be implemented for drying purpose which reduces the drying time in terms of sunshine hours drastically.

D. G. B. Tchaya, M. Kamta, C. Kapseu [4]

This paper presents the design of a prototype of an indirect solar dryer with forced convection (The heat transfer fluid speed is between 1 and 1.4 m/s).It gives the possibility to obtain three different flux modes. A manual device mounted at the output of the collector permits to obtain the licking mode, the crossing mode or the mixed mode. The system has showed a change of more than 8 °C on different trays in crossing mode case, compared to the licking mode (which is closed to the natural drying), where this difference is almost zero. The entire equipment is built using local materials helps to achieve a temperature ranging from 40 ° C to 69 ° C in the drying chamber for each mode of airflow drying on each tray. In addition to the advantages provided by the indirect solar dryer, this method improves the performance of solar drying of crops.

Fig. 4 Indirect mode solar dryer

E. Ahmed Abed Gatea [5]

This research includes the design and manufacture of a solar dryer and its performance test on bean. Solar dryer consists of three parts; 1) the air heating section (solar collector), 2) two fins and 3) the drying chamber section with four trays. The drying test was conducted after setting the drying air speed at 1.5 m/s at the drying chamber. The drying process continued until the total beans weight was (100kg). The highest and the lowest solar collector efficiencies of 61.82 and 45.40% were obtained at 11.00 and 9.00 h, respectively. Higher moisture evaporating from the beans was achieved in the first tray, as moisture content was reduced from 60 to 8% during the 6 h compared with the other three trays. The study revealed the following conclusions:

1. The maximum drying temperature through the drying time was 61°C. 2.

F. S. Arun, S. Ayyappan, V.V. Sreenarayanan [6]

A natural convection solar tunnel greenhouse dryer was designed and developed for studying the drying characteristics of tomatoes. Three experimental runs with 30 kgs of tomatoes were carried out in the dryer during the month of June 2014. The performance of the dryer was studied (drying time and product quality) in comparison with open sun drying method. It was found that the solar tunnel greenhouse dryer took only 29 hours for reducing the moisture content of tomatoes from 90% (w.b.) to 9% (w.b.) whereas the open sun drying took 74 hours for the same. Also, the quality of dried tomatoes produced from solar tunnel dryer is much superior compared to that of open sun drying.

Fig. 5 Tunnel type solar dryer

G. Abhay B. Lingayat, Yogesh R. Suple [7]

Solar energy is a renewable energy source that can generate electricity, provide hot water, heat and cool a house and provide lighting for buildings. In response to increasing electrical energy costs, thermal storage technology has recently been developed. This paper presents an introduction to previous works on thermal energy storage using PCM and their applications. The choice of the substances used largely depends upon the temperature level of the application. Phase change material (PCM) are one of the latent heat materials having low temperature range and high energy density of melting– solidification compared to the sensible heat storage. Latent heat thermal energy storage (LHTES) with phase change materials (PCMs) deserves attention as it provides high energy density and small temperature change interval upon melting/solidifying. Phase change materials (PCMs) are becoming more and more attractive for space heating and cooling in buildings, solar applications, off-peak energy storage, and heat exchanger improvements. Latent heat thermal energy storage (LHTES) offers a huge opportunity to reduce fuel dependency and environmental impact created by fossil fuel consumption.

H. Avesahemad S.N. Husainy, et al., [8]

This paper presents an experimental effort on forced convection mixed mode solar dryer for turmeric at Miraj, India (16.83°N 74.63°E). To study the effect of drying time on mixed mode type forced convection on solar dryer, 15kg of good quality of boiled turmeric are loaded. It has been experimentally analyzed that drying time can be reduced up to 7 days as compared to a conventional method which requires 13 - 15 days. The experiment was conducted in February month in Miraj, Maharashtra having incident solar radiation and wind speed 5.12 W/m2/day and 5 km/hr respectively. The drying experiment conducted with turmeric and it was found that the complete drying process could be attained with 47 hours (considering sunshine hr.) The effect of different air mass flow rate on moisture content, moisture ratio, drying rate, drying time and dryer efficiency has been evaluated for turmeric.

Fig. 6 Mixed mode forced convection solar dryer

I. Blake Ringeisen , Diane M. Barrett et al., [9]

Fig. 7 Experimental Set up

The addition of the concave concentrator to one dryer reduced drying times by 21% on average as compared to the control dryer. This was accomplished by an increase in the internal dryer temperature and a lowering of the relative humidity, allowing for more favourable drying conditions. Although solar radiation incident on the tomatoes was also increased, it was unable to be accurately measured. The concentrating panels can be constructed by farmers with no technical construction skills, therefore can help increase dried fruit yield by increasing drying rate and decreasing spoilage. It was also shown that the use of a concentrator did not negatively affect tomato quality.

III. CONCLUSION

It has been established that solar drying of grapes is technically feasible and economically viable. It is observed that grapes dried in solar dryers take lesser time to reach the safe level of moisture content for storage when compared to open sun drying and the quality of raisins produced are far more superior. The chemical treatment of grapes prior to drying decreases drying time required to reach the safe moisture content for storage. Addition of certain variety of oils to the chemical solution used for treating grapes enhances the quality of raisins. An indirect type of solar dryer with forced air circulation can be used to produce superior quality raisins acceptable in the international market. Drying time can be further reduced using the same system with heat storage material. Economically sound farmers capable of moderate investments can choose solar dryers according to their individual requirements. The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. The introduction of heat storage material in the air heater enhances the rate of drying and reduces drying time. Thermal energy storage and chemical pre-treatment causes significant decrease in the drying time for all the investigated crops i.e.. Seedless grapes, grapes and apples. The dryer thermal efficiency was increased with the increasing of drying air temperature and air velocity. The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process.

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