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A COMPARATIVE INVESTIGATION ON THE EQUALITY DEVELOPMENT APPROACHES OF SOLAR THERMAL DRYING PERFORMANCE RESPONSE ON AGRICULTURAL PRODUCTS: A REVIEW

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ABSTRACT

Solar energy is an important source ofsustainable renewable energy. It attracts many researchers across the world. Since it is used in modern ages and has been extended to a remarkable advantage.It is typical to dry the agriculture product with low energy consumption, since it eliminates the moisture content from the various agricultural products by means of different systems. To protect the environment- it is necessary to adopt green energy for drying the agriculture products.Farmers and labourers face a lot of complications during drying tasks due to various weather uncertainties and natural conditions, product wastage, taste and colour etc. The solar energy can be used for drying of agriculture products. For this purpose we can use solar dryers. For this drying operation, two parameters are very important i.e. uniformity and quality. Instead of temperature, velocity and humidity are also desired parameters in the air quality for drying. Accordingly, unevenness or improper drying rate of agricultural products may be improved by the use of integrated solar dryers having thermal energy storage systems, dehumidification systems or design of dryers. The present paper reviews the contributions of various researchers in the area of solar drying systems such as hybrid dryers, desiccant systems with solar energy, solar dryers which are capable of drying in off sunshine hours. Some recent advancement in this area is the use of phase change and desiccant material. Approaching this paper may encourage increase in the use of solar drying energy efficient techniquesin agriculture product by saving cost and time.

Keywords:*solar energy, dryers, solar dryer performance, desiccant, low temperature drying, PCM.*

I. INTRODUCTION

The agricultural products in developing countries are saved by means of food preservation and storage in different seasons. Absence of appropriate technology, low marketing networks, inappropriate transportation, high loss in post-harvesting processes etc., causes loss of food 10 to 40% [1]. There are various types of losses of food in post- harvest handling like decomposition, infective contamination, birds and insects, etc. These kinds of losses are essential issues in agricultural products. Another cause of deterioration is the amount of moisture present in the product. While harvesting, food products contain high moisture contentthis develops fungi and bacteria. To protect and increase the durability of agriculture products, moisture removal is required up to a definite level. To increase the life of the food, it is required to remove the moisture from food at certain limits. [2].

Drying is the conventional method forfood preservation. It is an energetic concentrated action in many industries like paper making industry, food processing unit, textile industry etc. In several countries, the natural drying process is used in farms. By this it produced more than 75% dehydrated food product. [3]. Numerous disadvantages in open air natural sun drying like high crop losses, fungal attacks, dirt, airstream, animals, insect's rodents, large area requirements and the weather uncertainties .To overcome these problems many solar dryers are available to dry products instead of natural drying. In agriculture drying purposes, the availability of solar energy is totally free which meets the energy demands throughout the year.

By using new techniques like low energy dehumidification systems, we can save more energy throughout the year. Previously many researchers worked on drying agricultural products, to improve its performance and decrease the energy consumption level. The present paper reviews the work done by various researchers and to present the relevant techniques on the equality or air properties. These techniques contain in general solar dryers, thermal energy storage material, effect of dehumidifier design, Performance Augmentation Techniques for Solar Dryer and drying compartment design.

II. DEVELOPMENT OF DRYERS

A number of researchers have put in efforts in developing dryers using conventional or unconventional methods and materials. An account of these dryers with their performance parameters and other design aspects in detailed below.

Bolaji et al. [4] tested the performance of dryers operated by solar energy. The dryer consists of a drying chamber, absorber plate and insulation using foam etc. Inside the drying chamber the temperature was more than 60ºC. It was recommended that the overall system efficiency increased as the velocity of air increased throughout the experiment.

Gateaet al. [5] experimentally investigated solar dryer for maize and compared three tilt angles (30ºC, 45ºC, 60ºC). It was found that, maximum energy collection was with the tilt angle 45ºC.

Forsonet al. [6] designed and fabricated a mixed mode solar dryer based on solar radiation and drying chamber design parameter for drying cassava, crops, beans etc. The system was analysed for different solar radiation intensity, air temperature and relative humidity. It was found that the drying efficiency was 12.3% at solar radiation 340.4W/m^2 and drying time was 35.5h.

Banout et al. [7] Compared the performance of double pass solar drier and cabinet drier. In his experiment work, red chilli was selected to dry at different moisture level contents. The result showed that, double pass solar drier was hypothetically appropriate for drying red chilli.

Hossainet al. [8] designed and fabricated amixed mode tunnel drier based on forced convection method compared its overall performance with open sun drying. In his experiment, he selected hot red and green chillies to dry some extent. It was found that solar tunnel dryers have higher moisture removal rate and reduce drying time as compared to convection sun drying methods.

Mustayenet al. [9]studied different types of dryers or drying methods for drying agricultural products like banana, cassava, rice etc. They also recommended which type of drying technology is better for the farmers in rural areas at low cost.

Ekechukweet al. [10] studied and categorised different types of dryer i.e. active, passive, direct, indirect and mixed mode dryer.

Agrawalet al. [11] studied different types of drying techniques for drying agricultural products like crop, grain, maize, beans etc. It was found that mixed mode and forced circulation mode gives better drying performance and reduced drying time as compared to natural, direct and indirect mode of drying.

Hegdeet al. [12] in his experimental setup used a cost economic dryer to dry banana slices and analysis was done for its various properties. The experimental setup was based on the change in the air flow directions from top to bottom and vice- versa at different flow rates.

The literature shows that the development of a dryer is unique in all respects of its capacity and performance characteristics. Dryers have been compared for quality and different energy and air inputs.

III. DRYERS BASED ON THERMAL ENERGY STORAGE/ HYGROSCOPIC MATERIAL.

For drying a product, hot air is passed through a material made up of desiccant to eliminate the moisture from the hot air. This hot low humidity air dries the product efficiently. For an efficient dryer heating medium and desiccant material play an important role**.**

Thoruwa et al. [13] fabricated a dryer with a combination of two desiccant material i.e. Bentonite and clay to dry fresh maize. The whole experiment was performed whole day i.e. day and night time. It was found from the number of experiments that 90kg of fresh maize dried within 24h and reduced moisture content from 38% to 15% (d_{wb}). Also result showed that, the performance of drying time was increased by using desiccant material.

Thoruwa et al. [14] evaluate the performance of desiccant dehumidifiers which are regenerated through solar in terms of relative humidity, mass of the desiccant material, air flow rate and time etc. A unit was established to validate the feasibility of the system. It was suggested that the occurrence of solar energy in the collector can upgrade the overall performance of the system.

Thoruwa et al. [15] established an experimental setup which is based on combination of solid clay- $CaCl_2$ desiccant. The system is low cost and operated at night time, which continues the drying process. The analysis was done under the same solar drying system, moisture sorption and desorption performance can be calculated for the desiccant.

Madhlopa et al. [16] designed and fabricated solar dryer system by the combination of collector storage and biomass backup heaters. The researcher selected a group of pineapples for drying purposes. The system was operated in three modes i.e. solar, biomass, combination of solar biomass. It was found that continuous drying was achieved in the solar biomass system.

Dina et al. [17] developed a dryer with a combination of thermal storage material for drying cocoa beans. Comparison was done with three different methods of drying. It was found that the temperature inside the dryer was more than 50ºC. The specific energy consumption of solar dryer with absorber is lower than other two materials i.e. 13.29 MJ/Kg.

Misha et al. [18] fabricated a desiccant based dryer for drying palm fronds and calculated the performance of dryer in terms of drying time and drying rate. They suggested that asolar dryer using desiccant gives better drying rate and reduces the drying time as compared to open sun drying methods.

Shanmugamet al. [19] investigated the drying rate and temperature variations in desiccant based solar dryers. The experiment was conducted for different air flow rates. It was reported that the higher flow rate has no benefits for drying whereas flow rate below .01Kg/m^2s gives higher temperature, which is not suitable for drying green peas. From air flow rate .01, .02, .03 gives better drying rate and temperature variation. In his experiment work, desiccant gives an additional advantage for drying purpose also improves the quality of the product.

Hodali et al. [20] use a solar drying system combined with silica gel with adsorption unit. In his mechanism the parameter of adsorption used was simulated to find out the result for apricot drying. The experiment was performed to achieve an advantage of 5h reduction in drying time.

Leon et al. [21] designed forced convection dryer setup to dry chilli at air having temperature of 60ºC and flow rate of 90m^3/h. In his experiment, hot air is delivered to the drying chamber at a temperature more than 60ºC during the drying period.

Researchers with their different designs and use of desiccant materials have established better performance of the dryers for a product.

IV. DRYER BASED ON THE EFFECT OF DEHUMIDIFIER DESIGN

Researchers have also studied the effect of dehumidifier design on the drying rate and performance of the dryer.

Kabeelet al. [22] presented the performance of desiccant wheels in solar drying units. In their work the drying air temperature reached more than 75ºC. It was found that the performance of a solar drying unit with a desiccant wheel was more appropriate towards drying.

Chramsa-ard et al. [23]experimentally investigated the performance of two kinds of systems with dehumidification and without dehumidification for drying 8kg chilli. The result demonstrated decreased drying time by 20.83% when the dehumidification system was incorporated.

V. PERFORMANCE AUGMENTATION TECHNIQUES FOR SOLAR DRYER AND DRYING COMPARTMENT DESIGN

The drying performance can be enhanced by using performance augmentation techniques and better drying compartment designs. Solar heaters, desiccant wheel, heat exchangers are some of the performance augmentation techniques.

Jain et al. [24] in his experimental setup, the investigation was done for a duct type drying system having solar heater for drying. Various parameters were studied for better performance of the system.

Jain et al.[25] fabricated a multi tray dryer and studied different key parameters such as drying time, moisture content and radiation intensity. The dryer consists of four trays in which hot air is passed from bottom to top of the drying chamber.

Velmuruganet al. [26]presented the moisture content parameter of a drying chamber based on a flat plate solar collector for drying grapes. It was found that the moisture content was reduced from 80% to 10.6% in 22.6h.

Chan et al. [27]constructed and experimentally investigated recirculation type dryer.It was found that the moisture contentof rough rice was reducing from 28.4% to 14.3%(w.b). During the whole experiment, the temperature inside the drying chamber was 50ºC.

Sarsilmazet al. [28]has designed and developed cylindrical type drying chambers for preserving reliable drying conditions to dry apricots. It was recommended that the revolution of the drying chamber provides a better drying rate and reduced drying time.

VI. SUMMARY AND CONCLUSION

This paper presents a comprehensive evaluation and performance of different types of solar dryer.Through various findings, it is found that the use of solar dryers on drying various types of agricultural products will help in reducing the consumption of electrical and fossil fuels. In this way the ecological issue reduces and gives proper drying. Solar dryer is much more beneficial than sun drying methods. It involves preliminary expenditure, seems better looking, better tasting, and provides nutritious food. Also increase the market value of food. It is more efficient, safer, and faster than traditional sun drying methods. It also promotes the profitable acceptance of small solar crop dryers because it reduces post-harvest losses, prevents cereal grains from deteriorating, and maintainsnutritional value. The use of Phase change material or desiccant in solar dryers allows continuous drying of agricultural food products, and using this system makes food safe to some extent. The work done by various researchers has been reviewed properly like the use of desiccant systems in the dehumidification process, design of the drying chamber and solar thermal dryer.

1. Solar radiation intensity and ambient temperature are the main two factors that enhance the achievement of solar drying structure.
2. Desiccant system describes as a sensible and latent heat storage material providing constant and steady drying without sunshine hours.

3. Some significant constraints in the dehumidification process include type of desiccant material, wheel design and method of regeneration.
4. Merging of solar concentration devices leads to increase in the desiccant regeneration capacity.
5. Making a dehumidifier is very simple; it gives us a major effect on drying and also affects the grain storage process.
6. Physical design of the solar dryer plays a very important role for its drying uniformity and product quality.
7. The thermal enforcement of the dryer is improved by enhancement in the geometry of flat plate solar collectors and using reflective mirrors.
8. The arrangement of both desiccant and solar dryer together gets superior drying air and upgraded drying performance. By using this system, the electrical energy consumption is low because the availability of solar energy is free from sun radiation.
9. The desiccant dryer with solar which has a lot of drying chambers has a separate scenario, which improves the drying capacity and quality of the product.
10. The time of loading and unloading depends mainly on the design of the dryer that directly leads to expense of labour cost.

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