A Review Investigation on the Thermal Performance of the Solar Dryer System Integrated with Latent Storage Material

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Abstract— The quality of drying capacity of the solar dryer is chiefly depends on the external environmental conditions as an result the quality of dried product is decreases. So to improve the quality of dried product in the dryer reduce fluctuation of the temperature, reduce loss of energy is to be necessary. This is possible by employing the thermal energy storage material in the dryer. This paper is primarily focused on the arrangement of the latent heat storage material integrated with solar dyer. Which reduces fluctuation of temperature, reduce the loss of energy also increase the working hours of solar dryer even during off sunshine hours.
Key words: Solar Dryer, Latent Heat Storage Material, Phase Change Material (PCM)

I. INTRODUCTION

The [1] applications of the solar thermal energy is increases rapidly due to the global acceptance that it is very helpful for saving energy in the agricultural dryer applications. For the preservations of the crops like grains, vegetables, fruits, medicinal plants, etc. the drying is one of best method. The traditional method of drying is an open drying .Although it is economical process but it has many limitations like uncertainty in atmosphere, insect infection, interference of human and animals due to which the quality of the crops get decreases. To overcome these problems solar dryer is an effective tool. However the solar dryer is opertable only during sunshine hours. So by implementing the thermal energy storage material the solar dryer is operatable even during off sunshine hours.

The objective of present work is to present Phase change material (PCM) based solar dryer.

A. *Classification of Thermal energy storage [9]:*

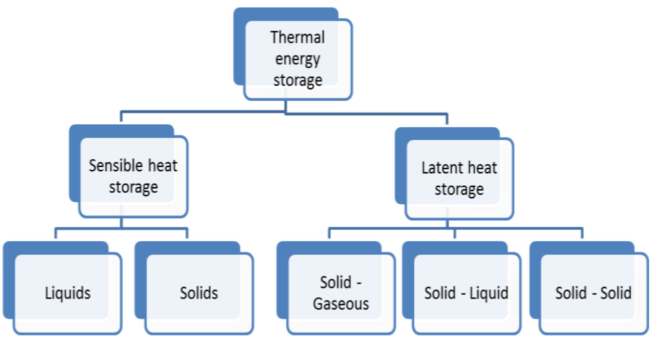

Fig. 1: Classification

1) *Sensible Heat Storage [13]:*

In this type of thermal energy storage system the energy is stored by changing the temperature of storage like water, air, bricks, etc.

2) *Latent Heat Storage [13]:*

In this storage system the heat transfer occurs when the substance like salts of Nitrates, Paraffin wax,etc. stores energy at high temperature by changing the phase i.e. from solid to liquid or vice versa and release the stored energy at low temperature by changing phase i.e. from liquid to solid or vice versa.

B. *Classification of Solar Dryer [10]:*

Solar dryers are available in the market in wide range of size and design as per the requirements of the crops. Primarily the solar dryer is classified as per the requirement of the temperature i.e. high temperature solar dryer and low temperature solar dryer.

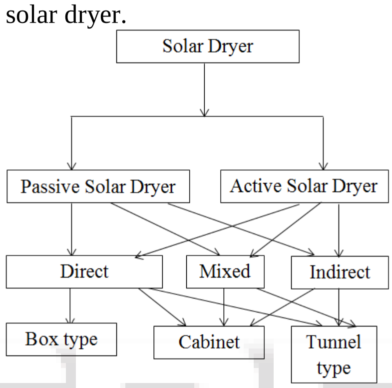

Fig. 2: Classification

C. *Classification of Solar Dryer [11]*

1) *Direct Solar Dryer:*

In this type of solar dryer the solar radiations are directly absorbs by the product which is to be dried in the cabinet by the mechanism of direct convection. Due to extra solar radiation the quality of the product gets decreases. In this type of arrangement the solar radiation is passed through the transparent glass or the plastic (which is mounted on the dryer cabinet) into the cabinet.

2) *Indirect Solar Dryer [11]:*

In this type of dryer the solar radiation is used to heat the air by the means of some external device and this heated air is blown into the cabinet. Hence this mode is called as force convection. The air vents are available at top portion of the cabinet for removing the moisture. The quality of drying achieved through this dryer is better than the direct drying.

D. *Criteria for the Selection of Solar Dryer: [11]*

- Amount of Movement of air to be moved.
- Arrangement of the dryer
- Type of solar contribution
- Type of Insulation to exposure
- Direction of flow of air
- Type of crop to be dried.

1) *Various PCM used by Investigator:*

S.Esukkimath, Abdel Hakim Hassbou et al [1] carried experimentation on the latent heat storage material coupled with solar dryer system. In that experiment they focused on HS58, and inorganic Salt base PCM which was in the ball sized shape. The constant mass flow rate of PCM as

200KG/hr was provided for getting the uniform rate of charging and discharging. From their experimentation they were concluded that As the mass flow rate increases the efficiency of the collector also get increases since heat loss get reduces at high mass flow rate also the coefficient of the heat transfer get increase.

Fig. 3: Experimental Setup of S.Esukkimathu[1]

S.M Shalby, M.A. Bek [2] carried an experiment on the Novel indirect solar dryer which is integrated with phase change material as an storage for energy for drying Ocimum Basilicum and Thevetia. The experiment is carried into the two phases one phase is without using PCM and other is with PCM under no load condition. The wide range of mass flow rate of PCM was supplied i.e. from 0.0664 kg/sec to 0.218 kg/sec. From their experimentation they were concluded that by the use of PCM the temperature is higher than 2.5-7.5℃ for 5 hours after sunset. After completion of experimentation they found that after using PCM the temperature of air higher than 2.5 – 7.5℃ after sunset for 5 hours. They achieve final moisture content in 12-18 hours in the case of implementing PCM.

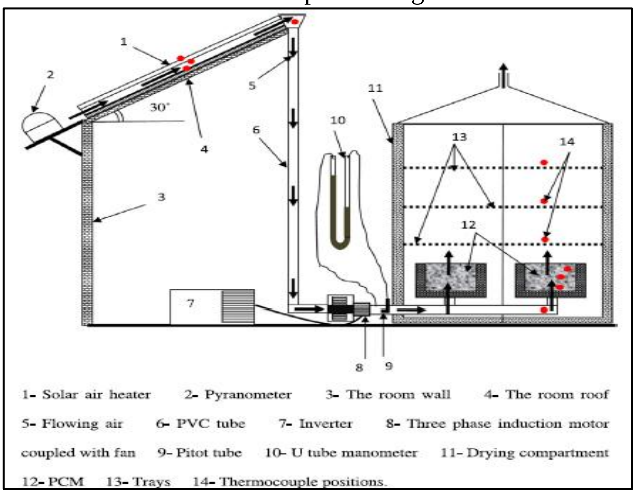

Fig. 4: S.M. Shalby, M.A. Bek Experimentation arrangement[2]

C.V. Papade, M.A. Boda [3] conduct the experimentation on the solar dryer integrate with the latent heat storage material for drying 5 Kg of grapes. They were assume that the average solar radiation as 450W/m^2.The grapes were took contains 80% moisture and ambient temperature was 30℃. The amount of air required to remove the moisture was 0.7864 m/sec. The convergent divergent section was considered by the use of CFD software. Result were obtained from experimentation as the final moisture content in the grapes was 18%.Total time required for drying was 7.58 hours at the rate of drying 0.66kg/hr. The latent heat storing material is very useful since it stores maximum amount of energy. Finally they were concluded that PCM is very convenient

Vikas shringi, Surendra Kothari et al [4] carried an experimentation to dried the garlic cloves at an Initial moisture content of 55.5%. They develop the drying chamber which acts as an dehumidifier having dimensions 1.2m*0.6m*0.5m.The drying cabinet contains seven trays out of those which three are for heat storage material and remaining three for drying product . The PCM works under three steps viz. charging, storing and discharge of the energy. The charging of PCM is done by copper coil. Dehumidifier blower is situated at the top for removing air from the cabinet. The whole experimentation was carried in the Month of June 2013.The dryer was facing south to extract maximum solar radiations. After the completion of the experimentation they were concluded that the moisture content in the garlic clove is reduced to the 6.5% and it requires 8 hours. The calculations for the moisture content are done by wet basis.

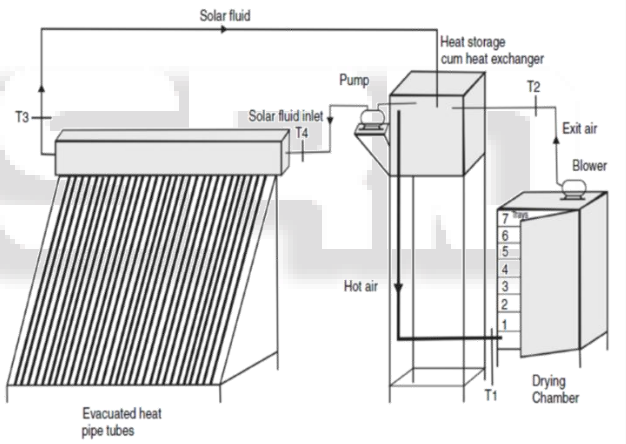

Fig. 5: Experimental setup Vikas shringi, Surendra Kothari et al [4]

M.Joseph Stalin, P.Barath [5] Carried an experimentation on the solar dryer integrated with phase change material for drying 25 Kg of crop. The PCM taken in ball in shape with cylindrical hole at centre. The initial moisture content was 50%. The dimensions of drying Chamber was 3m*1.28m*015m. The PCM material that taken having the melting point was 30℃.The size of PCM ball was 10cmwith 3cm hole at centre. After the experimentation they found that the mass of evaporation of water was 7.14kg and final moisture content was 30%. The time taken for drying was 3hours.So the PCM is very effective for improving performance of the Solar dryer.

S.M. Shalby, M.A. Bek [6] carried an experimentation for drying the Nerium Oleander in the indirect type of the solar dryer which is coupled with PCM as an latent heat storage material . In this experiment they use 12 kg paraffin wax as PCM .After their experimentation they observed that the maximum temperature was 50℃. And final moisture content achieve after 14 hours. Due to use of PCM the efficiency of the system get improves.

Dilip jain, Pratibha Tewari [7] developed state of the art solar dryer with PCM thermal storage medium for maintaining continuous flow of energy. They carried an experimentation on herbs for maintaining colour flavour. Dryer was designed with collector area $15m^2$ .The dryer contains six drying trays of dimensions 0.5m*0.75m. Which is Above PCM. The capacity of each tray was 10-12 kg. The maximum temperature observed at outlet was 50℃. The stored energy in PCM helps to maintain the constant temperature between the ranges of 40-45℃. Hence the extend the period of drying up to night. The overall thermal efficiency was 28.2%.

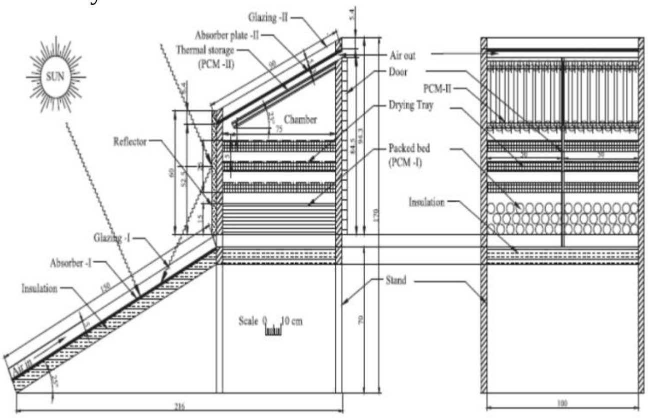

Fig. 6: Experimental setup Dilip jain ,Pratibha Tewari [7]

S.M. Shalaby , M.A. Bek etal [8] presents review on PCM as an energy storage material in solar dryer. In that they were concentrated on the PCM as an energy storage material, since PCM has higher thermal storage density as compared to the sensible heat storage material. By the use of PCM the reduction occurs in the loss of heat as well as in mismatch between the demand and supply of energy by improving the efficiency of energy. They also concentrated on the methods h improving thermal conductivity of paraffin waxes to be used as energy storage medium. From their review they concluded that drying of medicinal plant is proposed to be a new trend by using PCM as energy storage material in solar dryer.

II. Conclusion

It can be concluded from the present review that the solar dryer integrated with latent heat storage material improves the efficiency of the solar dryer and make it operative even during off sunshine hours i.e. even during night time. As we know the solar dryer is beneficial over the sun drying but the efficiency of solar dryer get decreases due to uncertainty in the weather. Hence for improving the efficiency The latent heat storage material is an effective tool for it.

References

[1] S. Esakkimuthu[a], Abdel Hakim Hassabou[b], C. Palaniappan[c], Markus Spinnler[b] ,Jurgen Blumenberg[b], R. Velraj[d*] “Experimental investigation on phase change material based thermal storage system for solar air heating applications” . International journal of Solar Energy 88 (2013) 144–153.

[2] S.M. Shalaby[*] , M.A. Bek “Experimental investigation of a novel indirect solar dryer implementing PCM as energy storage medium” . International journal of Energy Conversion and Management 83 (2014) 1–8.

[3] C.V.Papade[1] M.A.Boda[2] “Design & Development of Indirect Type Solar Dryer with Energy Storing Material”. An International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Volume 1 Issue 12 (December 2014)

[4] Vikas Shringi • Surendra Kothari • N. L. Panwar “Experimental investigation of drying of garlic clove in solar dryer using phase change material as energy storage”. Article in journal of thermal analysis and calorimetry · october 2014.

[5] M. Joseph Stalin & P. Barath “Effective utilization of solar energy in air dryer”. An International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN 2249-6890 Vol. 3, Issue 1, Mar 2013, 133-142

[6] S. M. Shalaby and M. A. Bek “Drying Nerium Oleander in an Indirect Solar Dryer Using Phase Change Material as an Energy Storage Medium”. International journal of Clean Energy Technologies, Vol. 3, No. 3, May 2015.

[7] Dilip jain ,Pratibha Tewari “Performance indirect through pass natural convective solar crop dryer with phase change material storage”. International journal of Renewable energy 80(2015)244-250.

[8] S.M. Shalaby[a,n], M.A. Bek[a], A.A. El-Sebaii[b] “Solar dryers with PCM as energy storage medium: A review”. International journal of Renewable and Sustainable Energy Reviews 33 (2014) 110–116

[9] Atul Sharma (a) , V.VTyagi (b)., C.R. Chen (a) , D. Buddh (b) “ international Review on thermal energy storage with phase change Materials and applications” . Journal of Renewable and Sustainable Energy Reviews 13 (2009) 318–345.

[10] 1UmeshToshniwal and 2 S.R Karale “A review paper on Solar Dryer” An International Journal of Engineering Research and Applications (JERA) ISSN: 2248-9622 Vol. 3, Issue 2, March -April 2013, pp.896-902.

[11] Pranav C. Phadke[1], Pramod V .Walke[2] and Vilayatrai M. Kriplani[2] “A review on indirect solar dryers”. ARPN Journal of Engineering and Applied Sciences.

[12] A.A. El-Sebaii[a,*], S.M. Shalaby[b] “Solar drying of agricultural products: A review” international journal of Renewable and Sustainable Energy Reviews, 16 (2012) 37– 43.

[13] A Textbook of Thermal energy storage by Ibrahim Dincer, Marc A. Rosen Wiley publication.

