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Enhancement and Optimization of Solar Dryer: A Review

Aditya Gaur
Department of Mechanical Engineering, NIT Hamirpur, Himachal Pradesh, India
E-mail: adityagaur0101@gmail.com

Abstract **- Infinite accessibility of solar energy and continuously reducing reserves of fossil fuel has led the humankind to use solar energy in efficient way for various requirements. One of the important requirements is drying, i.e. drying of various edible products, crops, etc. Research has been done on various ways to improve dryer efficiency, which includes depleting drying time, improving product quality coming out of dryer, minimizing energy loss, etc. This paper reviews the previous work done on optimization and enhancement of solar dryer. Techniques for optimizing solar dryer such as Artificial Neural Network, Genetic Algorithm, Response Surface Methodology, etc. have been studied whereas use of energy storage medium like Phase Change Material and other factors like geometrical parameter, solar dryer with thermal storage for enhancement of solar dryer has been reviewed.**
Keywords: **Solar Dryer, PCM, Thermal Storage, ANN, Response Surface Methodology**

I. INTRODUCTION

Fossil fuels are depleting at a lively rate which have been the most useful resource for the living of mankind. One of the important resources for the survival of humankind is solar energy. Solar energy is a copious source which is used for various processes as per the requirement.

Drying is one the requirement that uses solar energy. Fruits, vegetables and food are the most essential items for the survival of humankind and to preserve them for longer duration without getting their quality depleted is the necessity which could be achieved by the process known as Drying. To increase the time of storage and reduce the losses of agricultural products, drying is necessary and it not only limits to small scale natural sun drying but also to large scale industrial drying [1]. Classification of drying equipment is based on typically two ways. The first method is to transfer the heat to wet material and the second method is to classify the wet materials on basis of their characteristics and their physical properties [2]. Solar dryers are classified as

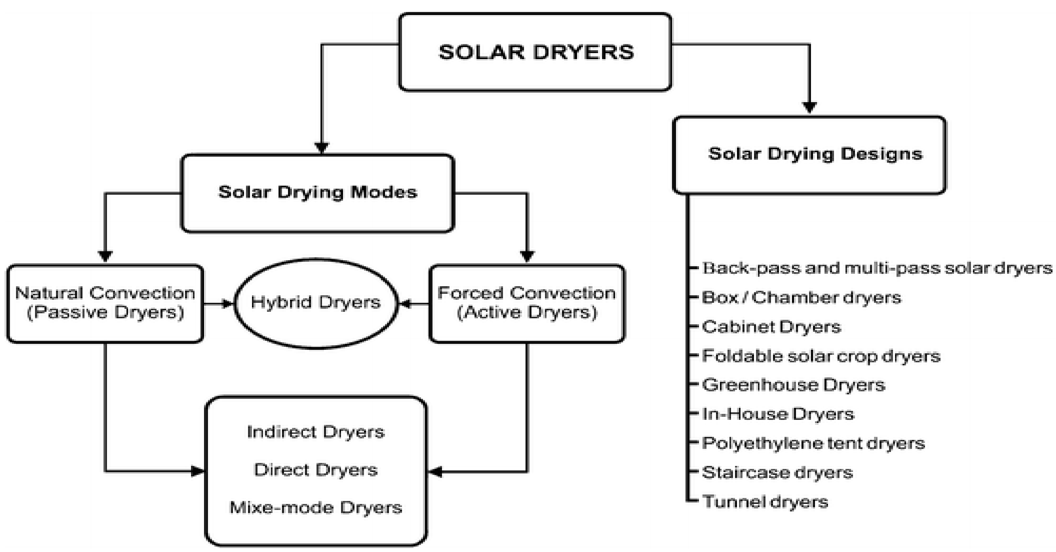

Fig. 1 Classification of Solar Dryers

II. OPTIMIZATION TECHNIQUES

A. Artificial Neural Network (ANN)

Optimization technique such as ANN help in vital modeling of drying characteristics because of ability of neural network to identify different products easily and viably due to its learning ability. A study done on drying of tomatoes using optimization technique ANN and it was found that drying actions can be explained more precisely through ANN. In this study multilayer perceptron network was used which helped in prediction as well as modeling [3]. For all the advantages of mathematical modeling perspective ,there are still some drawbacks that are hard to bridle, like we need to find out variables like kinetic coefficients and physicochemical characteristics and cost which gets included in determining these parameters decline the advantages of mathematical model and this all can be overcome by using ANN technique [4]. Tripathi and Kumar [5] prognosticated the temperature variation of food product by using the ANN technique in which the methodology was to optimize the dryer effectively. In this modeling solar radiation and ambient air temperature were the input parameters. In ANN modeling, it does not require the parameters of physical model, rather it learns from experimental data that after number of simulation optimizes the drying process [6].

B. Genetic Algorithm (GA)

Another technique which has been under focus in recent times for the optimization of solar dryer is Genetic Algorithm. To solve the problem of optimization parameter of drying a study [7] was done on mushroom drying technique in which control variables were setup and the results showed agreement to greater extent with experimental results. Open sun drying is most economic of all type of solar drying, since it is done on open ground so much dust gets into the edible product which is harmful for human health and so solar tunnel drying was introduced but it consumes so much time that it lead to decrease in efficiency of dryer and hence GA was used to optimize the solar dryer. A research done on drying chilies in solar tunnel dryer [8] using GA showed that overall performance of dryer can be increased by predicting maximum efficiency and reduced drying time. GA technique was used in simulation for drying corn malts which showed that moisture withdrawal rate was constant after some hours and grains could be stored for longer time without degrading their quality and results obtained were in agreement of optimization of drying process [9].

C. Response Surface Methodology (RSM)

Recent trends in research have shown that RSM is most studied optimization technique because of its positive outcomes which includes reducing time and minimization of number of trials.RSM uses independent variables like time and temperature for estimation. Ikrang and Umani [10] studied drying of catfish using optimization technique RSM in which they studied about contrasting effect of moisture level in catfish by commuting drying temperature and drying time taken and it was concluded that RSM helped in optimizing the parameters for the process of drying for various sizes of catfish. A study on drying of soybean seeds [11] was done using RSM to obtain results in high germination and field emergence using optimum union of starting moisture level, time of drying and velocity of air. Developing models for drying specifically where it involves both the transfer of mass and heat with optimum conditions was found to be difficult but in a study done on drying of coroba slices [12] RSM was implemented successfully in determining optimum zone for operating conditions which involved variation of moisture level in coroba slices.

III. ENHANCEMENT METHODS

A. Phase change Material (PCM) as Storage Medium in Solar Dryer

Solar dryer has its own shortcomings in which one of it is not maintaining constant temperature for drying process which lead to downfall of its efficiency. Hence to maintain moderate temperature throughout the drying process PCM is used as its storage medium which enhances the overall performance of solar dryer. Swami, Antee and Anil [13] performed an experiment using PCM for drying of fish and in this analysis PCM was used as storage medium inside drying chamber and it was concluded that overall drying time was reduced by 70% and only 40% of available heat was used for the process. In a study conducted on drying of medical herbs suggested that using solar dryer integrated with PCM ensured drying time could be extended beyond sunset hours which eliminated one of the main disadvantages of solar dryer [14]. PCM like paraffin wax are used to store surplus solar energy during peak hours of noon which could be used during night hours which will decrease the quantity of energy required for drying process [15].

B. Geometrical Parameters

Another challenge that is to be met for enhancing the performance of solar dryer is to provide steadiness in drying throughout the process and for this to summon design parameters are required to be detailed or precise. To provide better quality of product and steadiness in drying physical design of dryer is very important factor [16]. A comparison was done on solar dryer with reflector and solar dryer without reflector of almost same proportions and it was found that former one has 46% more energy for drying and 60% more drying capacity [17]. Another geometrical addition that could be made to enhance the performance of solar dryer is to add the concentrating solar panel. A mobile concentrating solar panel was attached to mixed mode solar dryer and in result it was found that overall effectiveness of dryer was increased by reducing the rate of drying [18].Kabeel and Abdelgaied [19] did an investigation by adding rotating desiccant wheel to solar drying units as an added geometrical parameter and results were exciting as drying air temperature uplifted from 65 to 82 degree C and humidity ratio had a fall from 15 g/kg of dry air to 8.8 g/kg of dry air.

C. Solar Dryer with Thermal Storage

Thermal storage is a recent advancement in field of research and to enhance the solar dryer one of the solution is to integrate it with thermal storage. In an experiment done on mixed mode solar dryer with thermal storage it was found that efficiency of moisture removal and overall effectiveness was 10% and 11% more respectively than solar dryer without thermal storage [20]. A dryer was tested on no load and with load condition while integrated with thermal storage and it was seen in the results that dryer was 2°C warmer due to thermal storage as well dryer was able to preserve more of the contents of product [21]. To continue the processing of solar dryer even during night time or after sunset hours thermal storage plays an important role as seen from a research done on mixed mode solar dryer with and without thermal storage and it was found that efficiency was uplifted by 13% due to use of thermal storage [22].

IV. CONCLUSION

Solar dryer is one of oldest invention but with time as every aspect, every technology gets renovated and modified so as solar dryer also needs to get optimized and enhanced. In this paper various optimization techniques and enhancement methods to increase the performance of dryer have been studied. This review paper interprets about efficiency, drying time and various other parameters that would lead to add the performance of solar dryer. Optimization techniques used in solar dryer like Artificial Neural Network , Genetic Algorithm and Response Surface Methodology have explained that these techniques are totally based on data and simulation results which are very precise and less time taking in evaluating the performance of solar dryer.

Enhancement methods used in solar dryer like use of thermal storage, use of PCM which is the future of solar energy have led in understanding that comparison done between solar dryer using enhancement methods and solar dryer which are not modified have vast differences between them with respect to parameters like rate of drying, use of solar dryer after sunset hours, overall efficiency. Using PCM as storage material concludes reduction in time interval between supply of energy and demand of energy which helps in energy preservation ultimately leading to improvement of drying systems.

REFERENCES

[1] M. A. Leon, S. Kumar, and S. C. Bhattacharya, "A comprehensive procedure for performance evaluation of solar food dryers," *Renewable and Sustainable Energy Reviews*, Vol. 6, No. 4, pp. 367-393, 2002.

[2] G. L. Visavale, "Principles, classification and selection of solar dryers," *Solar drying: Fundamentals, Applications and Innovations*, Ed. Hii, CL, Ong, SP, Jangam, SV and Mujumdar, AS, Published in Singapore, pp.1-50, 2012.

[3] K. Movagharnejad, and M. Nikzad, "Modeling of tomato drying using artificial neural network," *Computers and electronics in agriculture*, Vol. 59, No. 1-2, pp. 78-85, 2007.

[4] S. Janjai, K. Tohsing, N. Lamlert, T. Mundpookhier, W. Chanalert, and B. K. Bala, "Experimental performance and artificial neural network modeling of solar drying of litchi in the parabolic greenhouse dryer," *Journal of Renewable Energy and Smart Grid Technology*, Vol. 13, No. 1, 2018.

[5] P. P. Tripathy, and S. Kumar, "Neural network approach for food temperature prediction during solar drying," *International Journal of Thermal Sciences*, Vol. 48, No. 7, pp. 1452-1459, 2009.

[6] A. Khoshhal, A. A. Dakhel, A. Etemadi, and S. Zereshki, "Artificial neural network modeling of apple drying process," *Journal of food process engineering*, Vol. 33, pp. 298-313, 2010.

[7] M. M. Rahman, A. M. Billah, S. Mekhilef, and S. Rahman, "Application of Genetic Algorithm for optimization of solar powered drying," In *2014 IEEE Innovative Smart Grid Technologies-Asia (ISGT ASIA), IEEE*, pp. 647-651, May 2014.

[8] L. R. Dhumne, E. V. H. Bipte, and Y. M. Jibhkate, "Optimization of Solar Tunnel Dryer Using Genetic Algorithm," *International Research Journal of Engineering and Technology (IRJET)*, Vol. 3, pp. 1297-1300, 2016.

[9] J. C. Curvelo Santana, S. A. Araújo, A. F. H. Librantz, and E. B. Tambourgi, "Optimization of corn malt drying by use of a genetic algorithm," *Drying Technology*, Vol. 28, No. 11, pp. 1236-1244, 2010.

[10] E.G. Ikrang, and K. C. Umani, "Optimization of process conditions for drying of catfish (Clariasgariepinus) using response surface methodology (RSM)," *Food Science and Human Wellness*, Vol. 8, No. 1, pp. 46-52, 2019.

[11] S. A. ABBASI, F. Sharifzadeh, A. R. Tavakol, H. N. Majnoun, and H. R. Gazor, "Optimization of processing parameters of soybean seeds dried in a constant-bed dryer using response surface methodology," 2010.

[12] O. Corzo, N. Bracho, A. Vásquez, and A. Pereira, "Optimization of a thin layer drying process for coroba slices," *Journal of Food Engineering*, Vol. 85, No. 3, pp. 372-380, 2008.

[13] V. M. Swami, A. T. Autee, and T. R. Anil, "Experimental analysis of solar fish dryer using phase change material," *Journal of Energy Storage*, Vol. 20, pp. 310-315, 2018.

[14] A. K. Bhardwaj, R. Chauhan, R. Kumar, M. Sethi, and A. Rana, "Experimental investigation of an indirect solar dryer integrated with phase change material for drying valerianajatamansi (medicinal herb)," *Case studies in thermal engineering*, Vol. 10, pp. 302-314, 2017.

[15] L. M. Bal, P. Sudhakar, S. Satya, and S. N. Naik, "Solar dryer with latent heat storage systems for drying agricultural food products," In *Proceedings of the international conference on food security and environmental sustainability*, 2009.

[16] S. H. Abdulmalek, M. K. Assadi, H. H. Al-Kayiem, and A. A. Gitan, "A comparative analysis on the uniformity enhancement methods of solar thermal drying," *Energy*, Vol. 148, pp. 1103-1115, 2018.

[17] A. Aziz, S. Rehman, and S. Rehman, "Exergy Analysis of Solar Cabinet Dryer and Evaluate the Performance Enhancement of Solar Cabinet Dryer by Addition of Solar Reflectors," *International Journal of Renewable Energy Research (IJRER)*, Vol. 6, No. 4, pp. 1396-1402, 2016.

[18] J. Stiling, S. Li, P. Stroeve, J. Thompson, B. Mjawa, K. Kornbluth, and D.M. Barrett, "Performance evaluation of an enhanced fruit solar dryer using concentrating panels," *Energy for sustainable development*, Vol. 16, No. 2, pp. 224-230, 2012.

[19] A. E. Kabeel, and M. Abdelgaied, "Performance of novel solar dryer," *Process safety and environmental protection*, Vol. 102, pp. 183-189, 2016.

[20] E. Baniasadi, S. Ranjbar, and O. Boostanipour, "Experimental investigation of the performance of a mixed-mode solar dryer with thermal energy storage," *Renewable Energy*, Vol. 112, pp. 143-150, 2017.

[21] O. L. Lasisi, O. P. Fapetu, and A. O. Akinola, "Development of a solar dryer incorporated with a thermal storage mechanism," *Development*, 2020.

[22] S. Abubakar, S, Umaru, M. U. Kaisan, U. A. Umar, B. Ashok, and K. Nanthagopal, "Development and performance comparison of mixed-mode solar crop dryers with and without thermal storage," *Renewable energy*, Vol. 128, pp. 285-298, 2018.