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Applications of software in solar drying systems: A review

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ABSTRACT

This review paper is focused on the application of software in solar drying systems. The application of software is very important to develop and analyze the mathematical models and predicting the performance of different kinds of solar drying systems. It is also useful for predicting the crop temperature, moisture content and drying rate, drying kinetics, and color of the crop. Computational fluid dynamics can be used for the analysis and investigation of air flow and temperature distribution pattern through appropriate simulation with the help ANSYS and FLUENT. MATLAB and FORTRAN are very useful tools to develop mathematical models for prediction the crop temperature, air temperature, the moisture evaporated. It is also very useful for training and testing of various models. For statistical data analysis, statistical software SPSS, Sigma Plot V and Statistica. All recent employed software and their utility in solar drying systems are emphasized in this communication. This comprehensive review of the various software applications in different solar drying systems is useful for academician, scientist and researchers.

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1. Introduction

Application of solar energy has been old since the existence of human being on the earth. At present, the way of life of the people is dependent on the production and utilization of energy; as a result, the demand and supplying of energy is increasing in human societies. Presently, 77% of the world's total energy is supplied by fossil fuels, which release polluting and greenhouse gases, by degrading ozone layer excessively threatens environment and contributes to more global warming. Therefore, in order to maintain an environment, considering alternate energy sources has become an essential mission [1]. Every day earth receives thousands of times more energy from the sun than it consumed from all other resources. Solar energy has plenty of potential to fulfill our energy demand. Solar drying is one among the applications of utilization of solar energy. Solar drying is one of the oldest methods of preservation of crops and it is utilized everywhere [2]. Solar drying is a dual process of heat transfer to the product from the heat source and mass transfer in the form of moisture, from the product to its surface and from the surface to the surrounding air [37].

Solar dryers are available in the variety of design and size based on drying capacity. To test a dryer, it is essential to evaluate its complete and relative performance with the other dryers. The test results give the related information to the researchers, manufacturers and end users [3]. The application of software is very important to develop and analyze the mathematical models and predicting the performance of different kind of solar drying systems. The design of solar drying can be optimized with the help of software and it saves time which consumed during experiments. It is also useful for predicting the crop temperature, moisture content and drying rate, drying kinetics, texture and color of the crop. Computational fluid dynamics (CFD) can be used for the analysis and investigation of air flow, air flow rate inside the solar dryer, temperature distribution pattern and humidity, through appropriate simulation of energy and momentum equations and heat and mass transfer in both gaseous and solid phases [4]. MATLAB is very useful tool for developing mathematical models to predict the crop temperature, air temperature, the moisture evaporated and for predicting the thermal performance of the solar dryer. It is also very supportive of training and testing of various models [5]. Statistical software SPSS is an important tool for statistical data analysis of any solar dryer. It computes the coefficient of determination (R^2), reduced chi-square, and the percentage of root mean square error (RMSE) which can be used for selecting the best-fit equation to describe the drying process. Another software Statistica can also be used for statistical analysis. Sigma Plot V software is used for data fitting [6]. TRNSYS software is applied for modeling and describes the drying behavior [7].

The aim of this review article is to provide the information of the existing software applied in solar drying, simulation procedures and optimization techniques to the researchers. At present there is not a single available source which provides such type of information to the researchers and scientists working in solar drying. The selection of a dryer for a particular crop drying is a main challenge. This communication introduces a comprehensive review based on the application of different kinds of analysis and performance evaluation software for different solar drying systems.

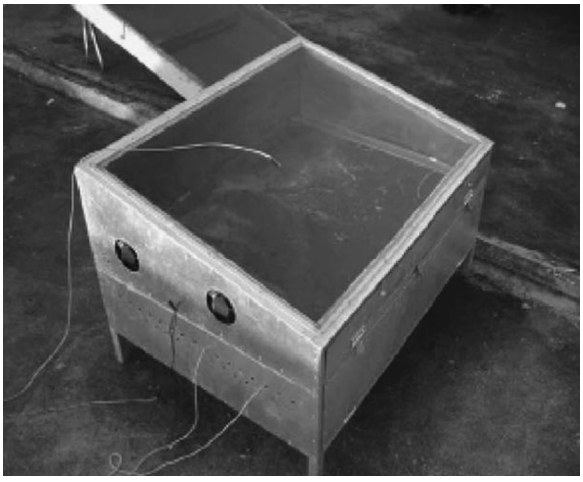

Fig. 1. Direct solar dryer [8].

2. Simulation methodologies of different solar dryers

Solar dryers are classified broadly into four categories such as direct, indirect, mixed mode solar dryer and hybrid solar dryer. Simulation methodologies of these dryers with the help of different softwares have been discussed as:

2.1. Direct solar dryer

In the direct solar drying systems, crop is exposed to sunlight directly such that it can be dehydrating. With this type of drying system a black painted heat absorbing surface is provided that can collect the sunlight and converts it into heat; the crop to be dried is placed directly on this surface. These dryers may have glass lid covers and vents to in order to increase efficiency [8]. The cabinet solar dryer is a kind of direct solar dryer which is shown in Fig. 1.

2.1.1. CFD simulation

Mathioulakis et al. constructed an industrial batch-type, tray dryer for the drying of fruits. CFD FLUENT software was used to simulate the air movement inside the drying chamber. Three boundary conditions were assumed for simulation. In the first condition, fixed-mass-inflow boundary condition was assumed at the inlet (25 m s^{-1} velocity and 4.0% turbulence intensity). In the second condition, no-resistance boundary condition was imposed where as mass is allowed to leave the solution domain at the outlet. In third condition, a wall shear stress condition was assumed on surfaces bounding domain. The variation in the dryness in several trays was observed. The non-uniformity was also traced to in certain areas of the chamber. In this article CFD FLUENT software was used to predict the air velocities in the drying chamber and optimizing the drying condition and