

Performance Improvement of Solar Dryer



Engineering

KEYWORDS :

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ABSTRACT

Renewable energy sources are the best ways to meet the increasing demands of the world's energy and solar drying is one of the renewable energy sources. Solar drying is efficient method for drying food products and vegetables. Drying preserves foods by removing extra moisture from the food to prevent decay and spoilage. Computational Fluid Dynamics (CFD) is a simulation tool, which uses the powerful computer and applied mathematics to model flow simulations for the prediction of heat, mass and the momentum transfer and optimal design in industrial processes. The aim of this paper is to make optimum design of solar dryer with the help of CFD analysis using ANSYS software by varying different parameters such as the angle of solar plate, outlet pipe diameter, inlet area of dryer and reflector plate.

1. INTRODUCTION

The drying operation comprises the evaporation of the water and an extraction phase of water evaporating from the system. During evaporation there is a need for high energy. Therefore, drying operations are those in which high energy is used. Solar dryers can be cost effective because relatively unskilled village artisans can construct, operate and maintain the dryers at minimum cost and that cheap and locally available materials can be used for the construction. Natural convection and forced convection are the two main types of solar dryer. In natural convection air flows inside the dryer naturally where in forced convection fan is used to flow the air inside the dryer. However, choosing the geometry of the dryer and the materials for construction requires the use of physical and biological sciences through computer simulations [2].

Simulation enables the researcher to evaluate the performance of the solar dryer before actual production of the prototype and experimentation is done. If simulation is combined with optimization, the researcher is able to design a cost effective solar dryer, that is, a solar dryer with minimum cost and maximum drying rate within given constraints [2].

2. SOLAR DRYING PROCESS

Sun-drying and solar drying are also called as sun/air drying and solar/air drying. Their efficiency is mainly determined by their provisions for moving air across the surfaces of the produce. The produce being dried may receive energy by direct absorption of solar radiation, by transfer from the air surrounding it, and by transfer from the surface on which it lies. The energy received may raise the temperature of the produce as well as causing the evaporation of moisture from its surfaces. For most produce the drying rate in the early stage of drying is determined by the rate of evaporation of moisture from its surfaces. It depends largely on the temperature and humidity of the surrounding air which are interrelated and on the speed of air movement. Drying rate depends on the shape and size of the produce's constituent unite and on the depth to which they are packed.



Figure-1 The cross flow, active mixed mode type solar dryer with its attachments.[9]

1. Storage bin
2. Main drying chamber
3. Electro-mechanical rotary valve
4. Discharging chute
5. Air discharging slots
6. Control switch
7. Plenum chamber
8. Auto-mechanism for rotary

The figure shows the active mixed mode type solar dryer. The upper storage bin was made of press wood with capacity of 300 kg, of rough rice. An adjustable window was installed underneath for controlling the paddy discharging to the dryer bin. The drying process was performed in the drying chamber. Since the dryer was a mixed mode type, the upper part of this chamber was covered with a sheet of glass through which the solar radiation can pass. The full capacity of the chamber was about 130 kg of rough rice.

A galvanized screen was incorporated below the chamber to let the hot air in as well as to support the product. Several air discharging slots (13 × 2 cm) were made on two sides of the drying chamber, (Figure1). The thickness of drying chamber was 10 cm. An electro-mechanical rotary valve was designed, fabricated and installed between the drying chamber and the discharging chute. This valve was activated automatically by a timer which was adjustable from 10 s to 2 h interval time. The rotary valve rotates only one revolution when it is activated by the timer and discharge about 9–10 kg, of the dried product to discharging chute. Therefore the discharging system works semi-continuously according to timer order. The discharging chute was covered by perforated plates to let the hot and dried product be cooled. Freshly harvested rough rice (30% to 27% db average initial moisture content) was selected to be dried with the solar dryer. Solar air heaters and dryer were mounted on proper portable stands and were tilted 45° towards the south.[9]

3. PERFORMANCE OF THE DRYER

The performance of the dryer was investigated by means of full-scale tests of the dryer. The instruments and the method used for the experiments are as follows. [6]

3.1 INSTRUMENTS:

To investigate effects of environmental and operating parameters on the performance of the dryer, various measuring devices were employed. Two pyranometers (Kipps and Zonen, model CM3 and CM5) were placed on the solar collectors to measure solar radiation, one on the north-facing side and the other on the south-facing side of the roof.

Relative humidities of ambient air and drying air were periodically measured with a hygrometer (Defensor, model MS1). Voltage signals from the pyranometers and thermocouples were recorded every 10 min by a 20-channel data logger (Yokogawa, model DC100). For relative humidity, it was manually read and recorded at 3-h intervals.

The air speeds in the solar collectors and the air ducts were also manually read and recorded 2–3 times during the drying experiments. Samples of products in the dryer were weighed at 3-h intervals using a digital balance (Satorius, model E2000 D).

3.2 MATERIALS:

Materials used for drying tests were rosella flowers and lemon-grasses. In general, dried rosella flowers are used to make rosella juice by boiling them with water. It is a medicinal plant whose constituents are believed to help reduce high blood pressure.

For the drying testes, 200 kg of fresh rosella flowers with an initial moisture content of about 90% (wb) was used for each drying test. Before drying, their seeds were manually taken out.

3.3 METHOD:

Four drying tests were carried out for rosella flowers in November–December 2002. For lemon-grasses, three tests were undertaken in February 2003. For all tests, the dryer was manually loaded with the products to be dried in the morning and the fan was started at about 8 a.m. and it was stopped at 5 p.m. [6]

4. LITERATURE REVIEW

I.N. Simate (2003) presented a comparison of optimized mixed-mode and indirect-mode natural convection solar dryers for maize. The mixed-mode and indirect-mode solar drying simulation models were validated against results from a laboratory solar dryer with experiments carried out under a solar simulator at the University of Newcastle upon Tyne, UK. The solar drying simulations were combined with the cost of the dryer materials and a search technique that finds the dryer dimensions at the minimum drying cost. The moisture content distribution of the dry grain in the mixed-mode dryer is more uniform due to additional drying from direct radiation at the top of the grain bed. [2]

S. Janjai, P. Tung (2005), developed a solar dryer for drying herbs and spices using hot air from roof integrated solar collectors. The dryer was used to dry rosella flower and lemon-grasses. With this dryer, 200 kg of rosella flowers and lemon-grasses can be dried within 4 and 3 days, respectively Hot air is supplied to the dryer from fiberglass-covered solar collectors, which also function as the roof of a farmhouse. They noted that the solar air heater had an average daily efficiency of 35%. However, the solar collectors have to be cleaned from time to time to eliminate the deposits of dusts. [6]

P. Gbaha, et al. (2006), designed a direct type natural convection dryer. It was constructed in local materials (wood, blades of glass, metals) then tested experimentally in foodstuffs drying (cassava, bananas, mango). The drying process allowed reducing the moisture content of cassava and sweet banana approximately to 80% in 19 and 22 h, respectively to reach the safety threshold value of 13%. This value permits the conservation of these products about one year without deterioration. [8]

F. Bentayeb, et al. (2007), presented a numerical simulation of the functioning of a wood solar dryer in atmospheric conditions of Moroccan climate. A comparison of the numerical results with experimental measurements carried out on wood solar dryer showed a good agreement. Results showed that drying period is closely linked to glass partitions and timber thickness. The type of ventilation has no effect on the drying period (initial timber humidity lower than 40%). [10]

P.P. Tripathy, Subodh Kumar (2009), studied the application of artificial neural network (ANN) or prediction of temperature variation of food product during solar drying was investigated. The important climatic variables namely, solar radiation intensity and ambient air temperature are considered as the input parameters for ANN modeling. The ANN model proposed in the present study is simple to understand and can easily implemented with the help of simple Matlab program by readers. [12]

Chr. Lamnatou et al. (2012) proposed Experimental investigation and thermodynamic performance analysis of a solar dryer using an evacuated-tube air collector. They developed novel solar

dryer by using the evacuated tube collector. The collector was initially tested and its potential for agricultural products drying was evaluated before its incorporation into the drying system. A performance analysis of the dryer was also conducted based on several efficiency factors, such as energy utilization ratio, pick-up efficiency, energetic and exergetic efficiencies which were determined. Furthermore, the optimal collector surface area was calculated based on the criterion of minimum entropy generation. Apart from the scientific benefits, the proposed system has also industrial benefits since this configuration can be adopted in the frame of large-scale, industrial dryers. [13]

Shobhana Singh, Subodh Kumar, 2011, presented paper on the testing methods for thermal performance based rating of various solar dryer designs. a modest attempt was made to develop a test method based on steady state heat balance concept of solar dryer. The study also reveals that for a given absorbed energy, the forced air convection in contrast to natural convection causes higher values in NLPI The dimensionless parameter referred as no-load performance index, NLPI was identified for performance evaluation of a given dryer. Comparative study of NLPI results for different dryer designs indicates the maximum NLPI of mixed mode dryer. [14]

Cristiana Brasil Maia, et al. (2012), constructed a hybrid solar dryer and experimentally tested. The dryer was tested without the trays and without any load. Steady-state temperatures and mass flow rate were measured in order to provide experimental data to validate a numerical model. The numerical simulation of the airflow inside this hybrid solar-electrical dryer was performed with the ANSYS-CFX 11 code. Experimental data was used for the boundary conditions and numerical validation. The numerical results were in agreement with experimental results, inside the uncertainty range of the temperature sensors. [15]

5. CFD ANALYSIS OF SOLAR DRYER

Based on the experimental data, the CFD analysis of the solar dryer will be done after preparing the mathematical model in PRO-E software.

The CFD Analysis helps to predict the efficiency of the dryer without making any change in the prototype. The CFD Analysis is to be done in the ANSYS CFX module but before that the mathematical modelling should be prepared in the PRO-E software.

The heat transfer in the model of solar dryer can be found out by the k-ε model which introduces two basic equations.

The continuity equation

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho U) = 0$$

And the momentum equation

$$\frac{\partial (\rho U)}{\partial t} + \nabla \cdot (\rho U \otimes U) - \nabla \cdot (\mu \text{eff} \nabla U) = \rho F + \nabla \cdot (\rho \text{eff} \nabla U) T + B$$

6. CONCLUSION

From the above literature survey it may be concluded that to design the natural convection solar dryer, thermal analysis is not sufficient. CFD analysis is necessary as it involves all the parameters including temperature, velocity, mass flow rate etc. The CFD analysis gives the exact solution which enables the researcher to analyse the optimum design and the overall performance of the natural convection solar dryer. The optimum design can be introduce with CFD analysis by varying the different parameter like solar collector, inclination angle, and outlet pipe diameter.

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