MATHEMATICAL ANALYSIS OF FORCED CONVECTION CABINET SOLAR DRYER FOR DRYING OF COTTON

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Abstract

The main objective of this essay is to design and assess a cabinet solar drier that uses less energy for cooking purposes. Warm air flows through a pan while warm air from an absorber plate collects solar energy in the curing cupboard of the solar dryer. The cotton industry uses a lot of energy to maintain temperature and humidity throughout the drying process. The mathematical model based on the preliminary evaluation of the forced transmission of the cabinet photovoltaic dryer is evaluated in this paper. The models are evaluated using EMD and RMSE, and various measurements are observed. Based on the experimental results, it is indicated that the page framework is appropriate for the construction of a cabinet photovoltaic evaporator, and the air discharge speed is 0.15 kg/s.

Keywords: Solar air heater; Mathematical model; Drying chamber; Cotton;

1. Introduction

Cotton growing was done in Asian countries. The process was advanced with the assistance of technical growth fuelled by the industrialized progress in our country. An agricultural commodity requires warm air at around 45–60°C for effective dehumidification. The moisture removal of agrarian commodities could minimize or remove food consumption which enhances the efficiency of the cultivators [1]. Many investigations were scrutinized on regular convective stellar vaporization of agrarian commodities according to Borah, *et al*. [2], Exell and Kornsakoo[3], Zaman and Bala [4]. A minimal demoisturising duration of sixty hours might be needed to realize a balanced wateriness level of fourteen percent for cassava leaves and chips [5].

Our country has an excellent solar abundance. Many regions get average regular sunlight energy between 5–7 kWh m^{-2} [6]. Power existent parameters rely on the region and hence necessitate a thermal exchanger [7]. Analysis was done to assess the upgraded functionality and contrasted it with the framework devoid of regeneration. Arithmetic frameworks, as well as augmentation methods, were used on circuitous category devices to enhance their efficiency. The use of enhancement methods such as effective accumulator blueprints, thermal conservation modules, dehydrative substances, and air circulation allows the working circuitous category of sunlight dryers in the absence of sunlight [8]. The investigational analysis is said to be more efficient prior to and subsequent to noon [9]. An investigational analysis was done to assess the non-consistent irregular anhydrous driers which gave expected outcomes as a result of the enhanced synthetic constitution, excellent color superiority and tone, and highest rehydration[10]. Statistical parameters k and N used for compact-zone anhydrous formulations were variant representations of the particle dimensions as well as consistency characteristics[11].

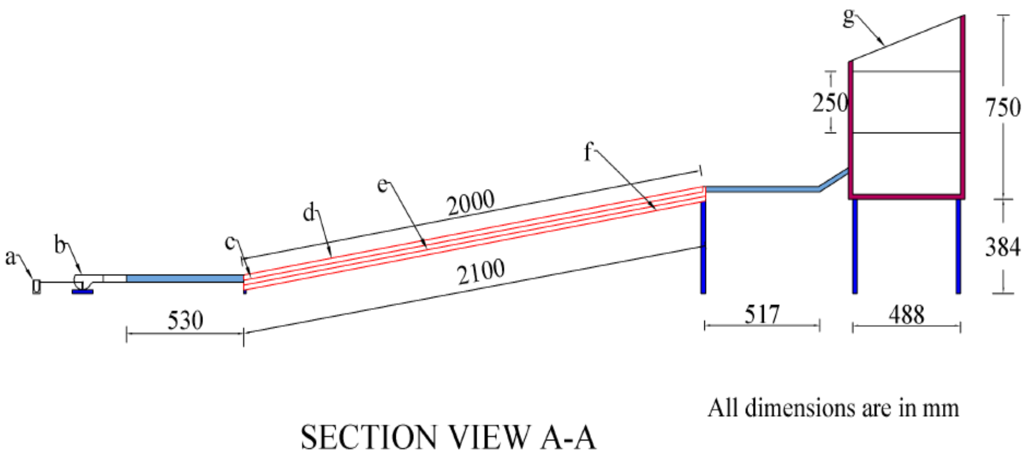
The current research aims to decrease the wetness content of crude elastomeric layers by smallholders to 2 to 3 percent until marketing to elastomeric layer companies as well as distributors[12]. According to Mahmoud and Abdellah [13], the accumulation solar dryer water-to-air thermal converter is made up of tubing in which air travels over the ducts while water subjected to heat in a solar collector travels through the pipes. Mahmudul and Timothy. [14] proposed a consistent and effective method for comparing the effectiveness of various furnace layouts. Nabnea et al. [15] discovered that the exploratory efficiency of innovative development of sunlight dryers for photovoltaic efficiencies ranged from 21% to 69%. Maneesh et al. [16] demonstrated that the solar air heater, as an augmentation to the earth-to-air heater, can outperform individual earth-to-air culvert thermal recyclers and is the ideal remedy for air conditioning during the cold period. Tahereh and Ranjbar [17] used RSM to analyze the influence of different measurements on the thermodynamic effectiveness & exergy of the DASC concentrator layout. Zhang et al. [18] discovered that the response surface methodology was very successful in enhancing SC-CO2 extraction variables for N Various considerations as well as threats are involved in the design, fabrication, application, and investigation phases of SDS, something that could influence the achievement or malfunction of associated initiatives [19]. [20] discovered that heat simulations for the PVT green-house evaporator were evolved by taking into account various variables such as plant, green-house, and photovoltaic atmospheric conditions, among others. Misha et al. [21] demonstrated that accessible sunlight curing takes approximately 30–40 h to reduce the item's dampness content from 69 percent to 29 percent. According to Kabeel and Mohamed [22], the benefits of utilizing a rotational dehumidification propeller in photovoltaic evaporative modules include enhanced evaporation rate owing to dry as well as warm air out of the rotational adsorbent roller and consistent curing throughout the day. Mahesh Kumar et al. [23]

analyzed the various categories of drying systems, such as direct solar dryers, inadvertent solar dryers, and blended solar dryers, as well as their assorted curing implementations. Franz and Oliver [24] deduced that because temperature detectors have bounded responsiveness, their position in the evaporator or tubing framework must be deliberately selected, especially when curing circumstances are supposed to occur quickly. According to Subbian et al. [25], the independent variables or responses were time, air temperature and solar radiation. ANOVA also showed that the lack of fit was not significant for all response surface models, at 95% confidence level. Olalusiet al. [26] created and assessed the effectiveness of a portable photovoltaic evaporator for sago bits. Pereaet al. [27] discovered that wood particles can be dried in 13 days under regular circumstances, with mean photovoltaic radioactivity of 13.74 MJ/m2 (autumn season). Han- Kun Zhu et al [28] explored the gelation temp of potato flour, which was enhanced from 63.73 to 69.47 °C as curing temperature enhanced, indicating that evaporative temperature can enhance the flour's thermodynamic consistency. Ssemwangaet al. [29] compared the evaporation effectiveness of ISD as well as SPE drying systems to that of the conventional OSD procedure. The results show that the ISD and SPE blowers performed more effectively than the conventional OSD procedure. Cresencio P. Genobiagon and Feliciano B. Alagao discovered that the evaporator effectiveness is lesser than the anticipated virtual evaporator effectiveness but appropriate provided the dryer's reduced development savers. Monica Patricia Camas-Nafate et al. [31] demonstrated that the photovoltaic detector attained drying productivity gains ranging from 22.8 to 37.9 percent by attaining humidity virtues underneath the 12.30 fixed level, which is regarded as diminished dampness cuisine by global norms. This research looks at the influence of using infrared energy on dehydration when solar energy is insufficient, as well as the effectiveness of SD and SDI by curing herbs as well as fruit cutlets [32]. The research explored experiments & quantitatively an innovative passageway type solar tunnel drying system for use in sewage sludge dehumidification [33]. The innovative outcomes demonstrate that utilizing Al yarn enhanced thermodynamic efficacy while reducing curing moments [34]. This research was crafted utilizing layer material but included no isolating and coating substance, resulting in a decrease in the cumulative expenses [35].

2. Experimental setup and procedure

The material substance utilized to build the cabinet solar dryer is readily available in the regional marketplace. The absorber plate (aluminum) is less expensive since any alloying substance must have excellent thermal conduction with sustaining flexural and compression toughness for improving environmental deterioration durability even when moisture changes. Fig. 1 reveals the schematic arrangement of a cabinet solar dryer. The second place is the absorber plate is aluminum. Aluminum has a thermodynamic conductance of 204 W/mK and a specific heat of 0.996 KJ/kgK. The absorber panel with shielding measures 2.00m 0.77m 0.001m. The thickness of the insulation material placed in the chamber was 50mm. Insulation materials used were sand, stone, thermocol, and saw dust. All framework elements were linked, as well as polymer tubing with a dimension of 50 mm, was utilized to convey them among the collector as well as the evaporation container. Fig. 2 shows the 2D views of a cabinet solar dryer.

Fig. 1. Cabinet solar drier experimental setup



a) Pitot tube b) Blower c) Sand and stones d) Absorber plate
e) Saw dust and thermocole f) Glass cover g) Glass cover
h) Top tray j) Bottom tray

Fig. 2 2D view of the cabinet solar drier

3. Experimental procedure

The following operations were carried out under various operational circumstances: An air blower with a power rating of 375 W provided airflow to the arrangement. The pace of the circulation was regulated by a mechanical regulator attached to the airflow ingestion. The drying cabinet absorbs sunlight radiation straightforwardly through the glass dome. The anemometer was used to measure the airflow. The colorimeters evaluated the periodic level of solar exposure on the collector. The wetness level of the cured substance was assessed by measuring the cotton-picked sample after 15 minutes to ascertain the mass decrease from which the wetness level may be calculated. The trials were carried out in the National Engineering College's resource facility at Kovilpatti. The following evaluation tools were utilized in this work: The temperature at any position was assessed using 9 standardized K category thermocouples attached to an electronic multimeter. The solarimeter evaluated the regular concentration of solar exposure on the collector. A probe was used to evaluate the flow of air in the conduit. A psychometric graph was utilized to estimate the relative moisture of air depending on wet and dry bulb temperatures. At 40% water content, the shells were scraped off the kernels and processed sans shells. The moisture content was measured by using equation (1).

4. Results and discussion

Figure 3 depicts the changes in peripheral air temperature and relative humidity, as well as sunlight exposure throughout the solar cabinet and external sun curing of cotton on an average March day in Kovilpatti. Throughout the curing trials, the situation was mostly sunny with no precipitation. External air temperature, relative humidity, and solar radiation ranged from 30 to 36^{o}C, 30% to 55%, and 195 to 1060W/m2, respectively.

The duration to achieve the ultimate moisture level of specimens for the solar cabinet was determined to be between 8.00 h, 12.00 h, and 14.00 h, whereas the dryness duration for the direct sunlight desiccation varied around 3.00 h, 1.30 h, and 2.45 h (Figs. 4-6). Cabinet solar dryers dried faster than exposed sun dryers. The dryer was designed to reduce the curing period of cotton samples based on meteorological circumstances. The dryer's increased temperature & reduced relative humidity readings may have contributed to the shorter drying time.

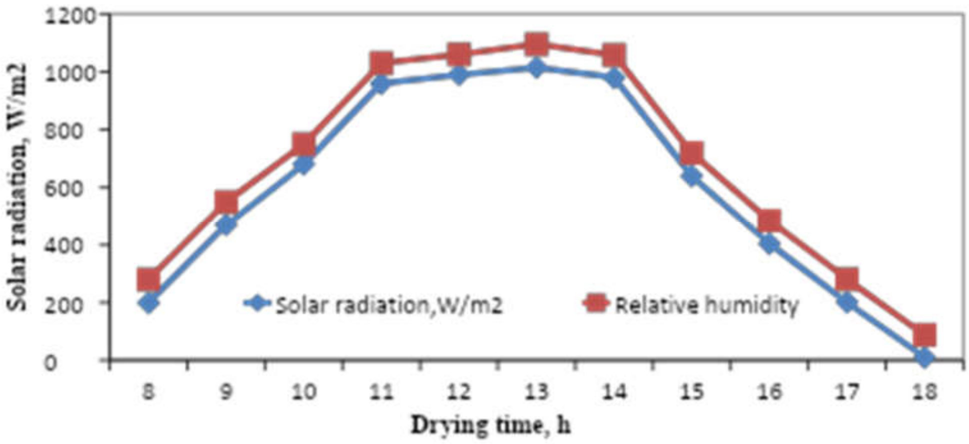


Fig. 3. Variation of solar intensity and ambient relative humidity

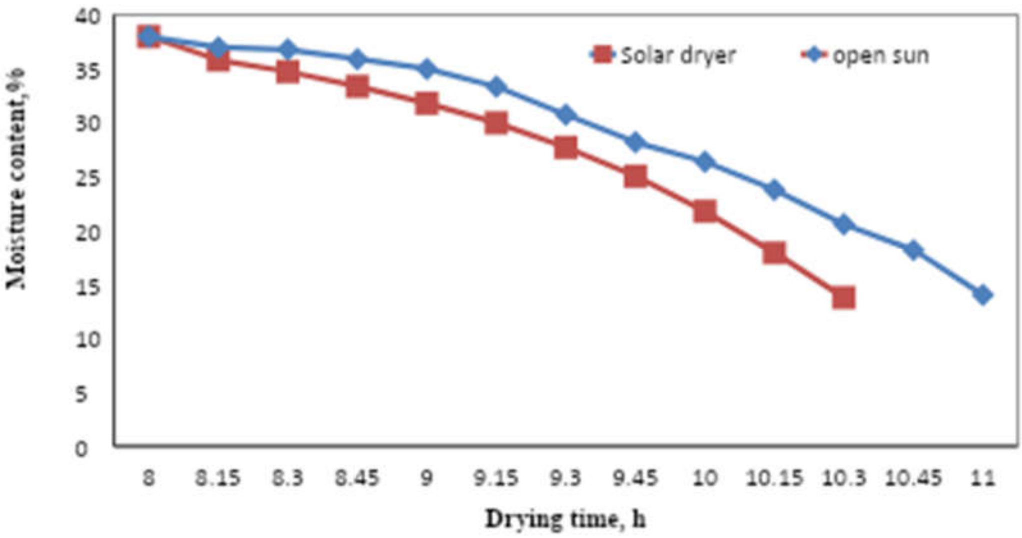


Fig. 4. Variation of the moisture content mass flow rate 0.15 kg/s (8 am -11am)

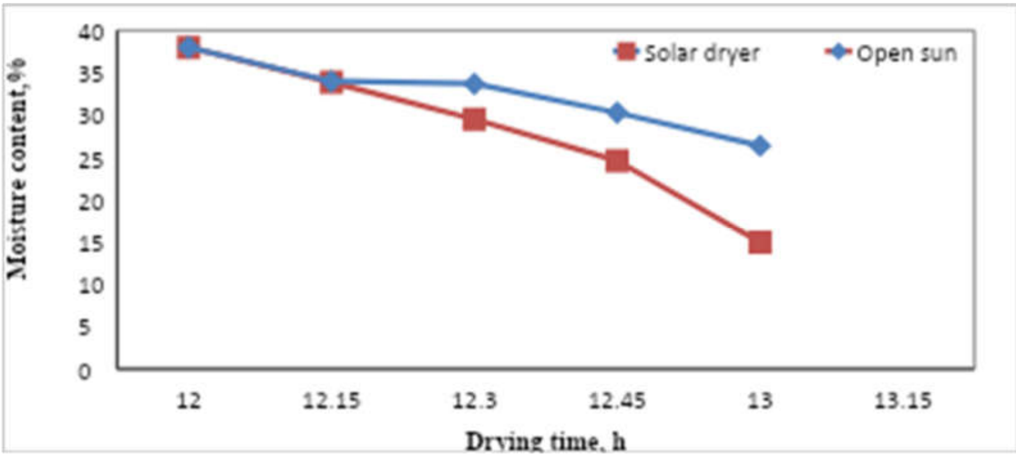


Fig. 5. Variation of the moisture content mass flow rate 0.15 kg/s (12pm -13.30pm)

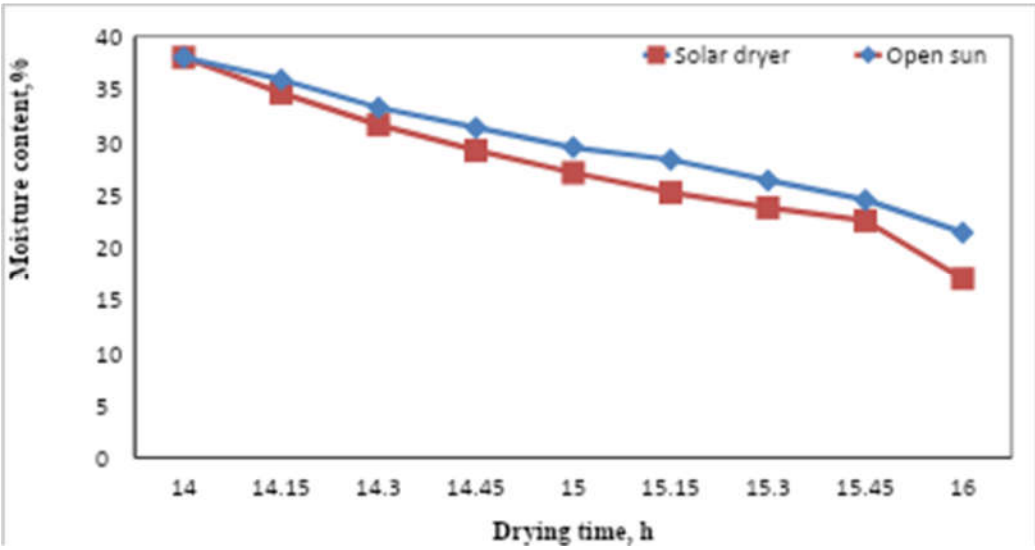


Fig. 6. Variation of the moisture content mass flow rate 0.15 kg/s (14pm -16.30pm)

4. 1. Thermal Efficiency of the Dryer for Cotton

The dryer's thermodynamic effectiveness was estimated using equation (2). The heating effectiveness of the cabinet solar dryer varies when curing cotton at a mass flow rate of 0.15 kg/s, ranging from 0 to 98 percent from 8 am to 10.30 am 0 to 99 percent from 12 pm to 1.30 pm, and 0 to 50 percent from 2 pm to 4.30 pm. Figures 7-9 show an evaluation of the dryer's thermodynamic effectiveness throughout cotton processing at a mass flow rate of 0.15 kg/s. It was discovered that the photovoltaic dryer had an increased performance for processing cotton with this mass flow rate between 12 pm and 1.30 pm

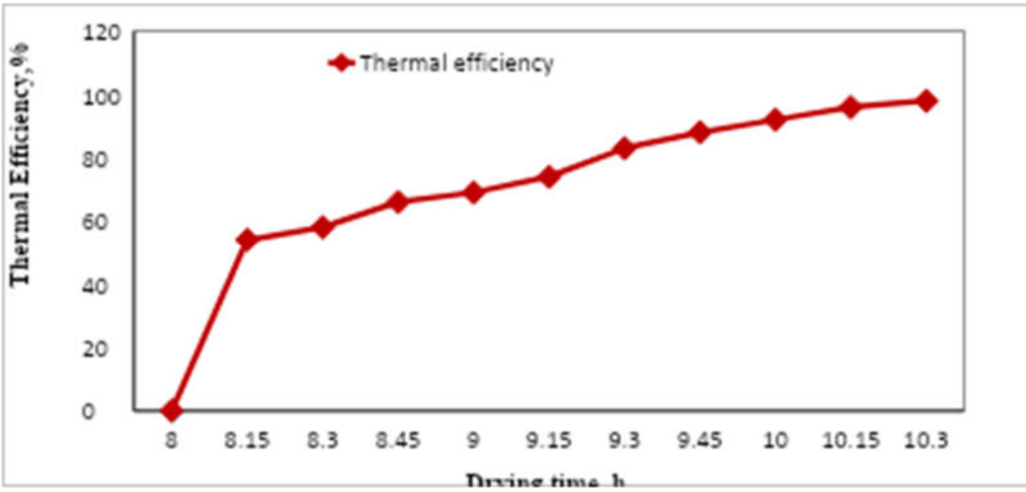


Fig. 7. Thermal efficiency of the dryer during drying of cotton with a mass flow rate of 0.15 kg/s (8am -10.30am)

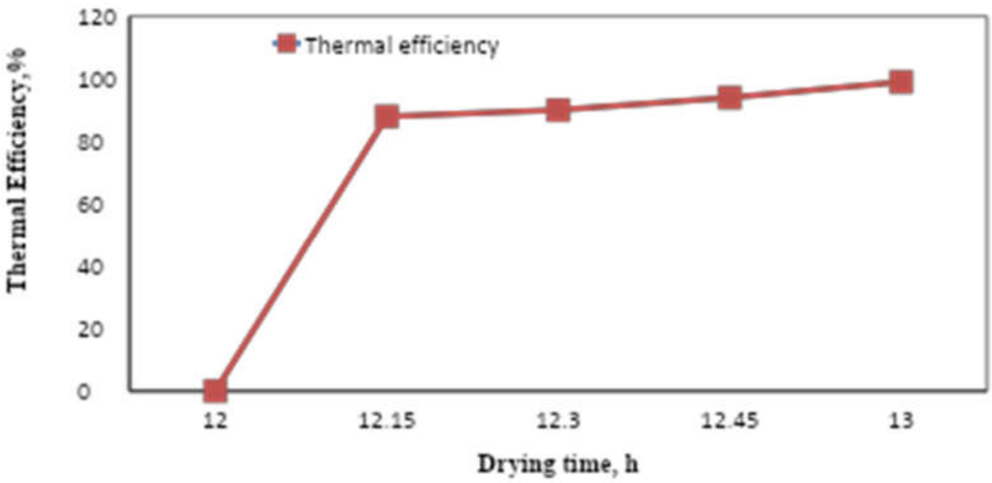


Fig. 8. Thermal efficiency of the dryer during drying of cotton with a mass flow rate of 0.15 kg/s (12pm-13pm)

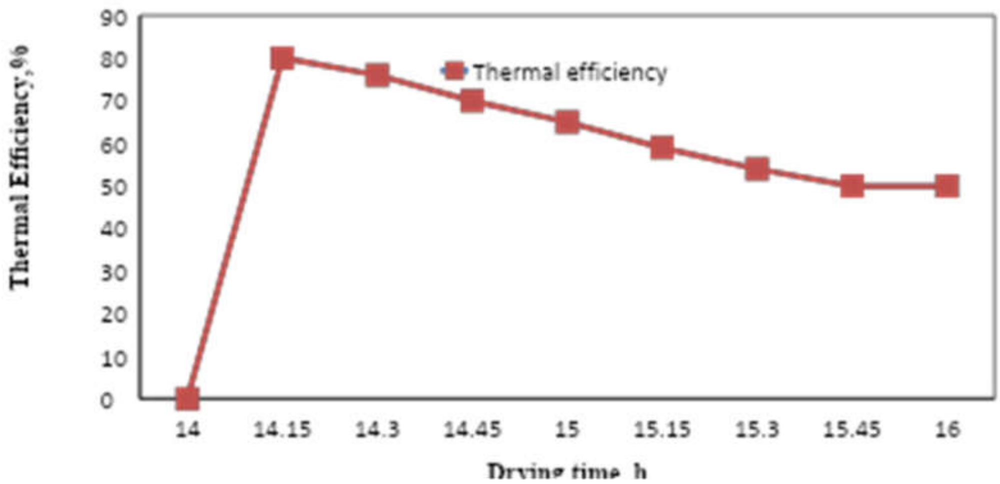


Fig. 9. Thermal efficiency of the dryer during drying of cotton with mass flow rate of 0.15 kg/s (14pm -16pm)

4. 2. Fitting of the drying curves for cotton

Table 1 shows the predicted characteristics and comparative data for four cabinet sun-drying models for actual trials. All options except the Wang & Singh model showed an appropriate match to the empirical findings, with an R2 value of 0.96611, suggesting a satisfactory fit.

According to the aforementioned findings, all model results are determined to be less when contrasted with Wang & Singh models, and the Wang & Singh model is appropriate for evaluating the coefficient of R2 values.

Table 1 Statistical results of different models for mass flow rate 0.15 kg/s for cotton.

Model Name	Constant	R^2	E_{MD}	E_{RMS}	χ^2
Newton (36)	K = 0.39625	0.92500	8.33098	0.057530	0.004137
Page (37)	K= 0.40514 m= 1.1072	0.94889	7.09777	0.047493	0.003759
Henderson & Pabis (38)	a= 1.00592 k= 0.41180	0.96093	4.9014	0.041521	0.002873
Wang & Singh (39)	a= 24.0594 b= -35.7435	0.96611	5.3853	0.03867	0.002492

From the above results, it is observed that all model values are found to be less as compared with Wang & Singh models and the Wang & Singh model is suitable for the determination of grater in the coefficient of R^2 values for the case of lower airflow rate model.

5. Conclusion

The concept of a cabinet solar dryer for foodstuff conservation and power conservation is shown in this work. It includes research analysis, problem remedy methodology, conceptual evaluation, and response surface methodology for solar air heaters, as well as the device's financial, fabrication, and empirical assessment. Analytical results revealed that the device attained 52°C at the output of the solar air heater around midday. The drying rate rises in proportion to the tiny quantity of mass flow rate. Subsistence farmers might benefit more from a cabinet solar drier for curing farming goods. The Wang and Singh model is appropriate for a cabinet solar dryer to dry cotton.

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