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A Fuzzy Logic-Based Temperature Prediction Model for Indirect Solar Dryers Using Mamdani Inference Under Natural Convection Conditions †

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Abstract

The drying process in indirect solar dryers is strongly influenced by rapidly changing ambient conditions, resulting in highly nonlinear and dynamic system behavior. Accurate modeling is therefore essential for performance evaluation, process optimization, and reliable prediction of the drying chamber temperature, which plays a key role in ensuring efficient moisture removal while preserving the nutritional and sensory quality of dried products. In this study, a fuzzy logic–based modeling approach using the Mamdani inference system is developed to predict the drying chamber temperature over a wide range of operating conditions. Experimental measurements were carried out with solar radiation varying from 400 to 950 W/m^2 and ambient temperature ranging from 20 to 50 °C, covering both static and dynamic system responses. The fuzzy model employs solar radiation and ambient temperature as input variables, represented by five and three triangular membership functions, respectively, while the drying chamber temperature is defined as the output variable using five triangular membership functions (T1–T5). The Mamdani inference system consists of 15 "if–then" rules, and centroid defuzzification is applied to obtain crisp output values. Model validation across the investigated operating range demonstrates a strong agreement between predicted and experimental temperatures. For example, at a solar radiation of 700 W/m^2 and an ambient temperature of 46 °C, the predicted chamber temperature is 50.9 °C compared to a measured value of 51.0 °C, while at 750 W/m^2 and 50 °C, the predicted temperature of 52.0 °C closely matches the experimental value of 51.8 °C. Statistical evaluation yields RMSE = 0.38 °C, MAE = 0.29 °C, and R^2 = 0.997, demonstrating effective temperature tracking capability within the tested operating range. These results show that the Mamdani fuzzy logic approach can effectively represent the thermal behavior of an indirect solar dryer within the tested operating range. The proposed model also provides a promising basis for the future development of real-time intelligent control strategies aimed at improving energy efficiency and product quality.

Keywords: solar drying; fuzzy modeling; Mamdani inference system; temperature prediction; nonlinear dynamics; intelligent control; renewable energy; natural convection dryer

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1. Introduction

Fruits, vegetables, and medicinal plants are important components of the human diet due to their high nutritional value. Most of these products contain approximately 90% water, which makes them highly perishable and difficult to store for extended periods. Drying technologies are therefore widely used to ensure long-term preservation. By reducing moisture content, drying extends product shelf life and helps retain beneficial nutritional properties. As a result, drying plays an important role in food safety and product quality improvement [1–3].

More than 80% of dried food products in developing countries are produced by small-scale farmers. These producers typically require low-cost agricultural equipment that operates with minimal maintenance and relies on independent energy sources. Since drying high-moisture products requires considerable energy input, the use of readily available and low-cost energy sources represents an economically viable solution. This approach not only reduces energy consumption but also improves overall production efficiency [4].

Direct sun drying is one of the most commonly used drying methods in developing countries. Farmers apply this technique by exposing agricultural products to sunlight and natural airflow. Its low cost and simplicity make it particularly attractive for field applications, including mobile drying systems. However, the method is highly dependent on weather conditions, which often results in uneven drying. In addition, products are exposed to dust, rain, insects, and microorganisms, leading to quality deterioration and process inefficiency [5,6].

Despite these limitations, direct sun drying remains widely practiced because of its affordability and simplicity. Nevertheless, improving drying quality and efficiency is essential to ensure food safety and extend product shelf life. This requires the development of improved drying technologies, including enhancements in mechanical design and energy utilization.

Drying occurs through heat and mass transfer between the product and heated air. Indirect solar dryers improve this process by separating the solar energy collection stage from the drying chamber. This configuration helps preserve the color and nutritional composition of dried products while protecting them from external contaminants such as dust and insects. Consequently, indirect solar drying systems play a key role in enhancing drying efficiency and product quality.

The development of energy-efficient solar drying technologies is closely aligned with the United Nations Sustainable Development Goals (SDGs). In particular, this research supports SDG 2 (Zero Hunger), SDG 7 (Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production), highlighting its global relevance and practical importance.

Due to continuous fluctuations in solar radiation and ambient conditions, the temperature inside the drying chamber varies throughout the drying process. Chamber temperature is a critical parameter because it directly affects the drying rate and product quality. Process modeling enables the prediction of drying temperature and the evaluation of key hydrothermal parameters, including solar irradiance, ambient temperature, and airflow. To accurately characterize solar dryer performance, experiments can be conducted under both loaded and unloaded conditions. Modeling the dryer without product load provides valuable insight into its inherent thermal behavior.

Extensive research has been conducted on modeling and control of solar drying systems. Mohammadi et al. proposed adaptive and intelligent modeling approaches for semi-solar greenhouse environments [7]. Hamdi et al. developed a mathematical model of a greenhouse grape-drying system and performed simulations using TRNSYS 18 software [8]. Zoukit et al. applied fuzzy logic–based modeling to medicinal plant drying in an indirect

hybrid solar–electric dryer, demonstrating that improved control significantly enhances drying efficiency and product preservation [9].

Prakash and Kumar developed an Adaptive Neuro-Fuzzy Inference Systems (ANFIS) model to estimate greenhouse air temperature and humidity evaporation and to predict thermal efficiency based on solar radiation and ambient temperature [10]. Vafamand et al. proposed a Takagi–Sugeno fuzzy model with online parameter estimation for nonlinear systems [11]. Arslankaya investigated process modeling using ANFIS and artificial neural networks for prediction and control applications [12]. In addition, Prakash et al. applied neural networks to predict dried product mass using solar irradiance, ambient temperature, and relative humidity as input parameters [13].

Among Uzbek researchers, Yusupbekov et al. have extensively studied intelligent control and fuzzy decision-making systems [14]. Gulyamov and Mukhamediyeva proposed nature-inspired optimization approaches for drying processes. Eshbobayev et al. applied fuzzy inference systems to wastewater treatment control [15], while Sultonova et al. demonstrated that fuzzy logic effectively improves drying process performance by accounting for system complexity and uncertainty [16,17].

In our previous studies, the drying of apricot products—turshak, bargak (qaysa), and kuraga—was analyzed using a solar dryer. The influence of airflow and temperature on drying time was investigated, and comparative evaluations were performed between open sun drying and indirect natural-convection solar drying in terms of drying duration, moisture content, and color changes [18].

However, there is still a lack of sufficient research on applying fuzzy logic methods to the modeling and control of agricultural product drying processes. In particular, no Mamdani-algorithm-based temperature prediction model has been developed for indirect solar dryers during the drying of agricultural products (such as apricots). This reveals the need for deeper investigation in this field and the introduction of new scientific approaches.

In this context, the present study develops a Mamdani fuzzy logic–based temperature prediction model specifically designed for an indirect natural-convection solar dryer operating under unloaded conditions. Unlike previous studies that primarily employed ANFIS, Artificial Neural Networks (ANN), or Takagi–Sugeno fuzzy models, this work constructs a Mamdani inference structure directly from experimentally identified operating points. A set of 15 nonlinear fuzzy rules is formulated based on measured hydrothermal parameters. The resulting fuzzy surface captures the coupled influence of solar irradiance and ambient temperature, providing a realistic nonlinear representation of the dryer's thermal behavior. The proposed framework addresses an important research gap and establishes a foundation for future integration with intelligent control strategies.

2. Materials and Methods

Uzbekistan receives high solar radiation due to its southern geographical location. During the summer season, sunshine duration exceeds 2900 h in Tashkent and 3100 h in Karshi. Because the climate is predominantly clear with few cloudy days, solar energy is especially abundant during the agricultural season from May to October. With more than 320 sunny days per year and annual solar radiation ranging between 1400 and 1800 kWh/m^2, Uzbekistan has strong potential for effective use of solar technologies. The natural-convection indirect solar dryer used in this study consists of a solar air-heating collector with a transparent glass cover (surface area 1.71 m^2, dimensions 1.9 × 0.9 × 0.2 m) and a drying chamber made of 2 mm steel (0.7 × 0.9 × 0.5 m), fully insulated with 6 mm wooden panels to maintain optimal drying conditions. The system is designed to dry 5 kg of apricots per day. Solar radiation passes through the glass cover and heats the air beneath it, which then naturally flows into the drying chamber; the collector is installed at a 30° tilt

facing south to ensure maximum solar exposure. The air temperature and relative humidity inside the system were measured using a DHT-22 Temperature-Humidity Sensor (Aosong Electronics Co., Ltd., Guangzhou, China), which records maximum and minimum values and displays them on a large LCD screen. The schematic representation of the indirect solar dryer is shown in Figure 1 and is inserted below [4].

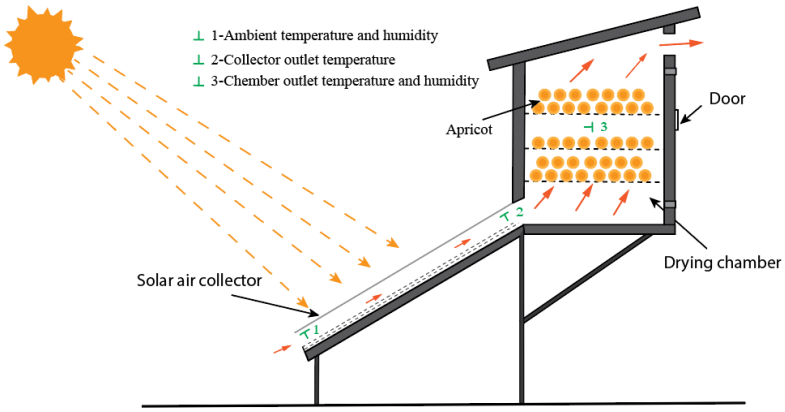


Figure 1. Cross-sectional schematic of the natural-convection indirect solar dryer illustrating solar-energy absorption in the collector, heated-air flow into the drying chamber, and the corresponding thermal zones influencing the drying process.

2.1. Thermal Analysis of the Solar Dryer

The thermal behavior of an indirect natural-convection solar dryer is governed by the interaction between solar energy input, heat transfer processes, and ambient environmental conditions. The system mainly consists of a solar air-heating collector and a drying chamber, where heated air flows naturally due to buoyancy forces. To describe the physical behavior of the dryer, a simplified thermal analysis based on energy balance principles can be considered.

For the solar collector, the energy balance can be expressed as:

$$Q_{solar} = Q_{useful} + Q_{los}$$

where Q_{solar} is the absorbed solar energy, Q_{useful} represents the useful heat transferred to the air, and Q_{los} denotes heat losses to the surroundings through convection and radiation. The absorbed solar energy depends on solar irradiance, collector area, and optical properties, while heat losses are influenced by ambient temperature and wind conditions. Similarly, the energy balance of the drying chamber can be written as:

$$m_{air} \cdot c_p \cdot (T_{out} - T_{in}) = Q_{in} - Q_{los,ch}$$

where m_{air} is the air mass flow rate induced by natural convection, c_p is the specific heat of air, T_{in} and T_{out} are the inlet and outlet air temperatures of the drying chamber, Q_{in} is the heat supplied from the collector, and $Q_{los,ch}$ represents heat losses from the chamber walls.

Although these equations provide a physical description of the drying process, accurate analytical modeling is challenging under real outdoor conditions. Solar radiation, ambient temperature, and airflow rate vary continuously and are difficult to measure or estimate precisely. In addition, heat transfer coefficients and natural convection flow rates are highly nonlinear and dependent on instantaneous weather conditions. As a result, purely analytical models often require simplifying assumptions that limit their accuracy in practical applications.

To overcome these limitations, a data-driven modeling approach based on fuzzy logic is adopted in this study. The fuzzy inference system allows the nonlinear relationship

between solar radiation, ambient temperature, and drying chamber temperature to be captured directly from experimental observations without requiring precise knowledge of all physical parameters. Therefore, the fuzzy model complements the thermal analysis by providing a flexible and robust framework for temperature prediction under variable climatic conditions.

2.2. Mamdani Fuzzy Logic Modeling

As discussed in the thermal analysis, the temperature behavior of an indirect natural-convection solar dryer is governed by multiple interacting parameters, including solar radiation and ambient temperature. Under real outdoor operating conditions, these parameters vary continuously and exhibit nonlinear relationships that are difficult to capture accurately using purely analytical models. To address these challenges, a fuzzy logic–based modeling approach is adopted in this study.

A Mamdani-type fuzzy inference system was selected due to its ability to represent nonlinear systems using linguistic rules derived from experimental observations and expert knowledge. Unlike analytical models, the Mamdani approach does not require precise estimation of heat transfer coefficients or airflow rates, making it suitable for systems operating under uncertain and variable climatic conditions.

In the proposed model, solar radiation and ambient temperature are defined as the input variables, while the drying chamber temperature is considered as the output variable. Solar radiation is described using five triangular membership functions, namely very low, low, medium, high, and very high. Ambient temperature is represented by three triangular membership functions, defined as cold, warm, and hot. The output variable, drying chamber temperature, is modeled using five triangular membership functions labeled T1 to T5, corresponding to increasing temperature levels.

Based on experimental observations obtained under unloaded operating conditions, a set of 15 fuzzy "if–then" rules was formulated to describe the relationship between the input and output variables. These rules reflect the combined influence of solar radiation and ambient temperature on the drying chamber temperature and were constructed to ensure smooth transitions between operating regimes.

The Mamdani inference mechanism was employed to evaluate the fuzzy rules, and the centroid defuzzification method was used to convert the fuzzy output into a crisp temperature value. This modeling framework allows the nonlinear thermal behavior of the solar dryer to be captured effectively without relying on simplified physical assumptions. The developed fuzzy model provides a flexible and robust basis for temperature prediction and serves as a foundation for further performance evaluation and intelligent control design.

2.3. Experimental Procedure and Data Collection

To characterize the thermal behavior of the indirect natural-convection solar dryer, a series of experimental measurements were conducted under unloaded operating conditions. The unloaded configuration was selected to eliminate the influence of product moisture evaporation and to capture the inherent thermal response of the dryer to environmental inputs. This approach allows a clearer assessment of the relationship between solar radiation, ambient conditions, and drying chamber temperature.

The experimental setup was installed outdoors in an open area, free from shading by buildings or vegetation, to ensure uninterrupted solar exposure. Measurements were carried out during daytime operation between 10:00 and 17:00, when solar radiation levels are relatively stable and representative of effective drying conditions. Solar radiation, ambient temperature, ambient relative humidity, and drying chamber temperature were recorded at hourly intervals.

Ambient temperature and relative humidity were measured using a calibrated DHT-22 temperature—humidity sensor, while solar radiation data were obtained using a pyranometer positioned in the plane of the solar collector. The drying chamber temperature was measured at three different locations inside the chamber to account for possible spatial temperature variations. The observed temperature differences between measurement points were minimal, with a maximum deviation of 1.4 °C. Therefore, the average chamber temperature was used in subsequent modeling and analysis.

The collected experimental data define the operating range used to develop the fuzzy inference model. These measurements were employed to determine the boundaries of the membership functions and to formulate the fuzzy rule base. A summary of the experimental conditions and corresponding drying chamber temperatures is presented in Table 1.

Table 1. Variation in drying chamber temperature under different levels of solar radiation and ambient temperature.

Time	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Solar radiation	538	620	673	700	705	683	646	584
Ambient temperature	39.4	42.2	44.3	45.7	41.1	39.2	40	41.6
Ambient humidity	22	20	18	17	17	16	16	17
Drying chamber temperature	42.9	45.8	48.5	50.4	51	48.8	47.6	46.9

The experimental dataset presented in Table 1 represents the range of environmental conditions used for model development. These data served as the basis for defining fuzzy membership functions and constructing the Mamdani rule base described in the following subsection. Although the dataset reflects a limited number of operating points, it captures the essential nonlinear dependence of the drying chamber temperature on solar radiation and ambient temperature under natural convection conditions.

2.4. Model Training and Validation Strategy

To evaluate the predictive capability and generalization performance of the proposed Mamdani fuzzy inference model, a structured validation strategy was adopted. The available experimental dataset was divided into two subsets corresponding to model development (training) and model evaluation (testing). Specifically, 70% of the collected data were used for model training, including the definition of membership functions and construction of the fuzzy rule base, while the remaining 30% of the data were reserved exclusively for testing purposes.

The training dataset was employed to identify representative operating points and to establish the fuzzy "if–then" rules linking solar radiation and ambient temperature to the drying chamber temperature. The testing dataset was not involved in the rule formulation process and was used only to assess the model's prediction accuracy under previously unseen operating conditions. This separation ensures that the reported performance metrics reflect the model's ability to generalize beyond the data used for model construction.

Model performance was quantitatively evaluated using standard statistical indicators, including the root mean square error (RMSE), mean absolute error (MAE), and the coefficient of determination (R^2). These metrics provide complementary information regarding prediction accuracy, average deviation, and goodness of fit between predicted and experimental values. The validation results are presented and discussed in the following Section 3.

3. Results and Discussion

3.1. Fuzzy Model Output and Static Temperature Prediction

The Mamdani fuzzy inference model was implemented in MATLAB R2014a using the defined input–output variables and rule base. For each operating condition, the model generated a predicted drying chamber temperature based on the corresponding solar radiation and ambient temperature inputs. Figure 2 illustrates the structure of the fuzzy inference system, including the input variables, output variable, and inference mechanism.

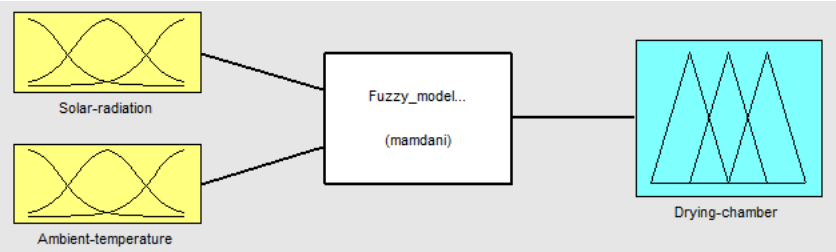


Figure 2. Structure of the Mamdani fuzzy inference model in MATLAB, showing the input variables (solar radiation and ambient temperature) and the output variable (drying chamber temperature).

The Mamdani fuzzy inference system rule evaluation and activation for selected input values are illustrated in Figure 3a. The static relationship between environmental inputs and drying chamber temperature is visualized using a three-dimensional surface plot, as shown in Figure 3b. Figure 3b clearly demonstrates that increases in both solar radiation and ambient temperature lead to higher drying chamber temperatures. This nonlinear behavior is consistent with the physical thermal analysis presented in Section 2.1 and reflects the combined influence of radiative heat input and ambient conditions on natural convection heat transfer.

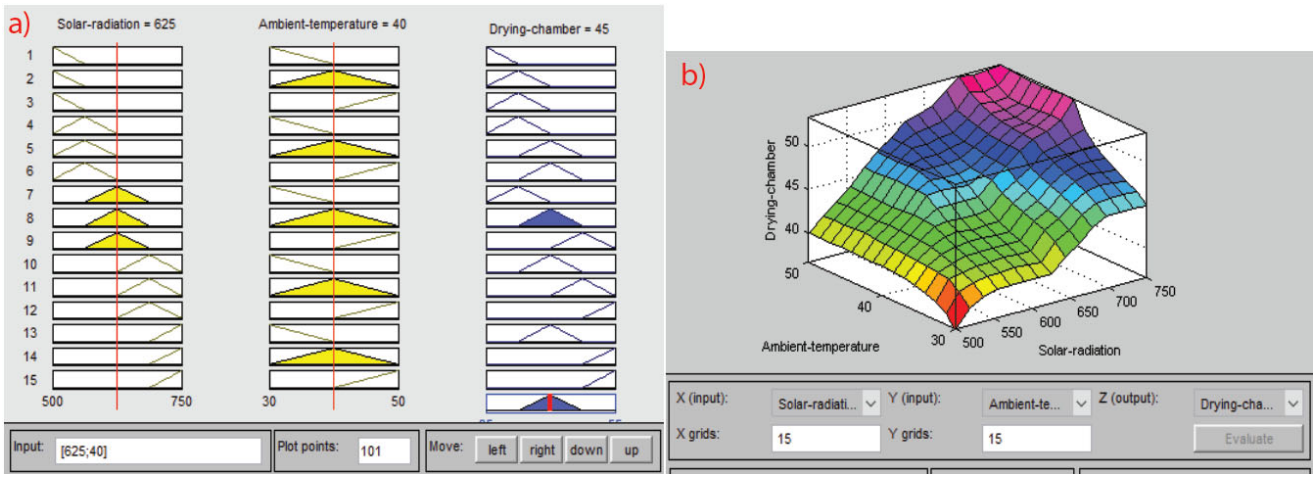


Figure 3. Visualization of the Mamdani fuzzy inference system: (**a**) rule evaluation and activation for selected input values, and (**b**) 3D surface plot showing the predicted drying chamber temperature as a function of solar radiation and ambient temperature.

The predicted temperature values obtained from the fuzzy model were compared with experimental measurements. Representative results are summarized in Table 2, showing close agreement between predicted and measured drying chamber temperatures across the investigated operating range.

Table 2. Predicted drying chamber temperature values obtained using the Mamdani model.

Solar radiation		538	620	673	700	705	683	646	584
Ambient temperature		39.4	42.2	44.3	45.7	41.1	39.2	40	41.6
Drying chamber temperature	Experimental results	42.5	45.8	48.5	50.4	51	48.8	47.6	46.9
	Mamdani model predictions	42.9	46.3	49	50.8	50.7	48.7	47.1	46.7

3.2. Dynamic Validation Using Experimental Time-Series Data

To evaluate the model's ability to track temporal variations in drying chamber temperature, the fuzzy model predictions were compared against experimental measurements over a full daytime operating period. Figure 4 presents a time-series comparison between experimental temperature data and fuzzy model predictions from 10:00 to 17:00.

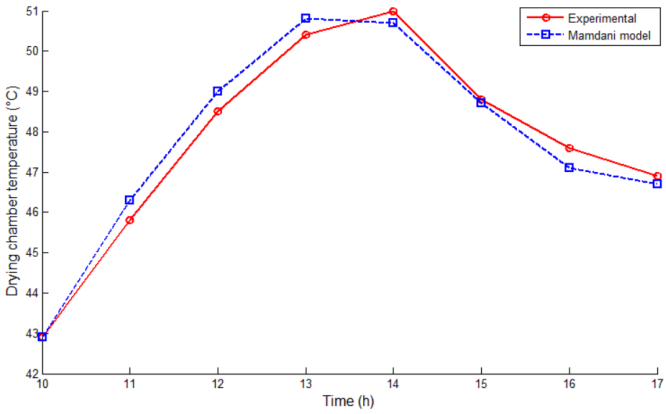


Figure 4. Time-series comparison of experimental and Mamdani fuzzy model–predicted drying chamber temperatures over a full daytime operating period (10:00–17:00) under natural-convection conditions.

The results indicate that the proposed fuzzy model accurately follows the temporal trend of the drying chamber temperature under varying solar radiation and ambient temperature conditions. Minor deviations observed during rapid changes in environmental inputs can be attributed to the inherent inertia of the thermal system and natural convection airflow. Nevertheless, the model maintains stable and consistent tracking performance throughout the operating period, demonstrating its suitability for dynamic temperature prediction.

3.3. Quantitative Performance Evaluation and Discussion

The predictive performance of the fuzzy model was quantitatively assessed using the testing dataset described in Section 2.4. The resulting performance metrics yielded RMSE = 0.38 °C, MAE = 0.29 °C, and R^2 = 0.997, indicating a high level of agreement between predicted and experimental values.

The low RMSE and MAE values confirm that the average prediction error remains within an acceptable range for practical drying applications, while the high coefficient of determination reflects the model's strong capability to capture the nonlinear thermal behavior of the solar dryer. These results validate the effectiveness of the Mamdani fuzzy inference approach for temperature prediction under variable outdoor conditions.

Compared to purely analytical thermal models, the fuzzy approach demonstrates improved robustness in handling uncertainty and environmental variability without requiring precise estimation of heat transfer coefficients or airflow rates. This characteristic is particularly advantageous for natural-convection solar dryers operating under real climatic conditions, where system parameters are difficult to measure accurately.

3.4. Limitations of the Study

Despite the encouraging prediction results obtained in this study, several limitations should be acknowledged.

First, the fuzzy logic model was developed and validated using experimental data collected during a single representative daytime operation under natural convection conditions. Although this dataset captures the essential nonlinear thermal behavior of the solar dryer, it does not fully represent long-term climatic variability.

Second, due to the limited number of experimental data points (approximately 8–10 measurements), the adopted Train/Test split should be interpreted with caution. The reported statistical indicators (RMSE, MAE, and R^2) primarily reflect the model's fitting and tracking capability within the observed operating range rather than a rigorous assessment of generalization performance.

These limitations indicate the need for extended experimental campaigns to strengthen the statistical robustness of the proposed model.

4. Conclusions

In this study, a prototype of a natural-convection solar dryer was modeled, and its static and dynamic characteristics were analyzed. The results showed that the system is highly sensitive to variations in solar radiation and ambient temperature. To address the associated uncertainties, a Mamdani fuzzy logic–based model was implemented, enabling accurate prediction of the dryer's thermal behavior under changing weather conditions.

The Mamdani model successfully predicted a drying chamber temperature of 50.9 °C under conditions of 700 W/m^2 solar radiation and an ambient temperature of 46 °C, which closely matched the corresponding experimental measurement. The model further indicated that when solar radiation increased to approximately 750 W/m^2 and ambient temperature approached 50 °C, the chamber temperature rose to about 52 °C. According to the obtained results, the model achieved a root mean square error (RMSE) of 0.38 °C, a mean absolute error (MAE) of 0.29 °C, and a coefficient of determination of $R^2 = 0.997$, confirming its high predictive accuracy. In addition, the Mamdani inference approach proved effective for rapid simulation of the drying process, identification of suitable drying conditions, and potential reduction in energy consumption. Overall, the proposed Mamdani fuzzy model provides a practical framework for temperature prediction in indirect solar dryers and offers a solid basis for the future development of intelligent control strategies. Although the present study is based on a limited experimental dataset obtained during a representative operating day, the proposed modeling framework is generic and can be readily extended to multi-day datasets covering diverse weather conditions, which will be addressed in future work. Future work will focus on collecting multi-day experimental datasets across different seasons and climatic conditions. This extended dataset will enable rigorous statistical validation, improved assessment of model generalization capability, and the development of adaptive fuzzy-based control strategies for real-time solar dryer operation.

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References

1. Madhankumar, S.; Viswanathan, K.; Taipabu, M.I.; Wu, W. A Review on the Latest Developments in Solar Dryer Technologies for Food Drying Process. *Sustain. Energy Technol. Assess.* **2023**, *58*, 103298. [CrossRef]
2. Ghani, N.M.A.; Othman, A.; Hashim, A.A.A.; Nasir, A.N.K. Comparative Analysis of PID and Fuzzy Logic Controllers for Position Control in Double-Link Robotic Manipulators. *JISC* **2023**, *2*, 183–196. [CrossRef]
3. Deng, Z.; Li, M.; Xing, T.; Zhang, J.; Wang, Y.; Zhang, Y. A Literature Research on the Drying Quality of Agricultural Products with Using Solar Drying Technologies. *Sol. Energy* **2021**, *229*, 69–83. [CrossRef]
4. Rejabov, S.; Usmonov, B.; Usmanov, K.; Artikov, A. Experimental Comparison of Open Sun and Indirect Convection Solar Drying Methods for Apricots in Uzbekistan. In *Proceedings of the 3rd International Electronic Conference on Processes*; MDPI: Basel, Switzerland, 2024; p. 26.
5. Feng, G. *Analysis and Synthesis of Fuzzy Control Systems: A Model-Based Approach*; CRC Press: Boca Raton, FL, USA, 2018.
6. Janjai, S.; Bala, B.K. Solar Drying Technology. *Food Eng. Rev.* **2012**, *4*, 16–54. [CrossRef]
7. Mohammadi, B.; Ranjbar, S.F.; Ajabshirchi, Y. Application of Dynamic Model to Predict Some inside Environment Variables in a Semi-Solar Greenhouse. *Inf. Process. Agric.* **2018**, *5*, 279–288. [CrossRef]
8. Hamdi, I.; Kooli, S.; Elkhadraoui, A.; Azaizia, Z.; Abdelhamid, F.; Guizani, A. Experimental Study and Numerical Modeling for Drying Grapes under Solar Greenhouse. *Renew. Energy* **2018**, *127*, 936–946. [CrossRef]
9. Zoukit, A.; El Ferouali, H.; Salhi, I.; Doubabi, S.; Abdenouri, N. Design of Mamdani Type Fuzzy Controller for a Hybrid Solar-Electric Dryer: Case Study of Clay Drying. In *Proceedings of the 2019 6th International Conference on Control, Decision and Information Technologies (CoDIT)*; IEEE: Paris, France, 2019; pp. 1332–1337.
10. Prakash, O.; Kumar, A.; Kaviti, A.K.; Kumar, P.V. Prediction of the Rate of Moisture Evaporation from Jaggery in Greenhouse Drying Using the Fuzzy Logic. *Heat Trans. Res.* **2015**, *46*, 923–935. [CrossRef]
11. Vafamand, N.; Arefi, M.M.; Khayatian, A. Nonlinear System Identification Based on Takagi-Sugeno Fuzzy Modeling and Unscented Kalman Filter. *ISA Trans.* **2018**, *74*, 134–143. [CrossRef] [PubMed]
12. Arslankaya, S. Comparison of Performances of Fuzzy Logic and Adaptive Neuro-Fuzzy Inference System (ANFIS) for Estimating Employee Labor Loss. *J. Eng. Res.* **2023**, *11*, 469–477. [CrossRef]
13. Prakash, O.; Kumar, A. ANFIS Modelling of a Natural Convection Greenhouse Drying System for Jaggery: An Experimental Validation. *Int. J. Sustain. Energy* **2014**, *33*, 316–335. [CrossRef]
14. Yusupbekov, N.R.; Adilov, F.T.; Aytbaev, J.A. Fuzzy Models and Optimization by Distillation Units in the Aspen Hysys Software Environment. *Chem. Technol. Control Manag.* **2024**, *2024*, 30–34. [CrossRef]
15. Eshbobaev, J.; Norkobilov, A.; Usmanov, K.; Khamidov, B.; Kodirov, O.; Avezov, T. Control of Wastewater Treatment Processes Using a Fuzzy Logic Approach. *Eng. Proc.* **2024**, *67*, 39. [CrossRef]
16. Sultanova, S.; Usmanov, K.; Ungbayeva, D.; Tadjibayeva, D. Development of Adaptive Neural-Fuzzy Models for Predicting Solar Dryer Performance. *Univers. Tech. Sci.* **2024**, *2*, 5–9. [CrossRef]
17. Yakubova, N.; Usmanov, K.; Turakulov, Z.; Eshbobaev, J. Application of Quantum Computing Algorithms in the Synthesis of Control Systems for Dynamic Objects. *Eng. Proc.* **2025**, *87*, 68. [CrossRef]
18. Usmanov, K.; Islamova, F.; Rejabov, S.; Jabborov, A. Modeling the Drying of Medicinal Plants in a Cabinet Solar Dryer. *Univers.:Tech. Sci.* **2024**, *2*, 32–35. [CrossRef]

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