Hindawi
Journal of Food Quality
Volume 2023, Article ID 9760148, 1 page
https://doi.org/10.1155/2023/9760148

Retraction

Retracted: Design and Fabrication of Solar Dryer System for Food Preservation of Vegetables or Fruit

Journal of Food Quality

Received 22 August 2023; Accepted 22 August 2023; Published 23 August 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] A. Kumar, K. U. Singh, M. K. Singh, A. K. S. Kushwaha, A. Kumar, and S. Mahato, "Design and Fabrication of Solar Dryer System for Food Preservation of Vegetables or Fruit," *Journal of Food Quality*, vol. 2022, Article ID 6564933, 14 pages, 2022.

Hindawi
Journal of Food Quality
Volume 2022, Article ID 6564933, 14 pages
https://doi.org/10.1155/2022/6564933

Research Article

Design and Fabrication of Solar Dryer System for Food Preservation of Vegetables or Fruit

Ankit Kumar,[1] **Kamred Udham Singh**,[2] **Mukesh Kumar Singh**,[3] **Alok Kumar Singh Kushwaha**,[4] **Abhishek Kumar**,[5] **and Shambhu Mahato**[6]

[1]*Department of Computer Engineering & Application, GLA University, Mathura, India*
[2]*Department of Computer Science and Information Engineering, National Cheng Kung University, 701, Tainan, Taiwan*
[3]*Institute of Business Management, GLA University, Mathura, India*
[4]*Department of Computer Science and Engineering, Guru Ghasidas Vishwavidyalaya, Bilaspur, India*
[5]*School of Computer Science and IT, JAIN (Deemed to be University), Bengaluru, India*
[6]*Department of Education, Janajyoti Multiple Campus, Lalbandi, Sarlahi, Nepal*

Correspondence should be addressed to Shambhu Mahato; shambhu.mahato@jjmc.edu.np

Received 3 February 2022; Revised 13 March 2022; Accepted 18 March 2022; Published 14 April 2022

Academic Editor: Rijwan Khan

Food preservation has been practised in many parts of the world for thousands of years, and it applies to a wide range of foods, including fruits, vegetables, cereals, and meat. Food preservation techniques are canning, freezing, pickling, curing (smoking or salting), and drying. Food spoilage caused by moisture is caused by the growth of mould, yeast, bacteria, and enzymes in the food. The drying process removes enough moisture from food to significantly reduce the humidity level's likelihood of these adverse outcomes. The material's content measures how much moisture is present in that substance. The moisture content of fresh food can range from 20 to 90 percent depending on the type of food consumed. There will be no signs of moisture in food that has been thoroughly dried before being chopped. We used the experimental analysis in this study to create a mathematical model that could be used to determine which parameter was most important in the design of a solar dryer. In the future, the model is expected to be a helpful design tool for estimating the short- and long-term performance of a solar dryer under load and overload scenarios. The simulation of a solar dryer system has been performed under conditions such as the gap between the glass and the absorber plate, and the impact of hole size. The optimal hole size and spacing between the glass and the absorber plate are determined.

1. Introduction

The sun is the primary source of solar energy on the planet. The sun powers the entire world. As a result, we should put that energy to good use. The sun is 1.495 1011 (metre) away from the Earth's surface, its diameter is 1.39 109 (metre), and it emits 1353 w/m^2 solar radiation on the Earth's surface perpendicular to the rays if there are no atmospheric disturbances such as cloud, dust, forest, and buildings. Approximately 165 trillion (kW) of solar energy is received by the Earth, with 30 percent of the total received energy reflecting space, and approximately 47 percent of energy is transformed to low-temperature heat energy, 23 percent of heat energy is used for evaporation, and 0.5 percent is consumed in kinetic energy of wind and waves [1].

This method uses solar radiation, which is both accessible and environmentally friendly and economically beneficial to the country. It is appropriate for drying at all levels, from minor to industrial. Solar radiation is one of the world's cheapest and most easily accessible energy sources. It is one of the most capable renewable energy sources due to its large quantity, nonpolluting nature, and infinite source as opposed to the costly and limited supply of fossil fuels—the concept of a solar dryer, in which solar radiation is used to dry. It reduces the use of fossil fuels, and the cost of solar dryers and equipment is meagre, and it produces no pollution, working on the greenhouse effect. Because there is no pollution, it is very environmentally friendly, providing a healthy environment with low-cost heating. Solar radiation air heating is a wellthought-out explanation of sun air heating, and it is a very efficient method of using solar dryers [2].

As the world's population grows, so does the demand for nontraditional fuel. They are drying fruits and vegetables such as fenugreek, mint, green, red chillies, and peas to fulfill the food demands of the world. Solar drying is a cheap and quick method of preserving fruits and vegetables. If we use sun radiation for drying, we will save a lot of conventional fuels. The main issue with solar energy for using solar drying is solar radiation. The sun's energy is one of the world's largest sources that can be accessed using current technology. As a result, we can use solar energy more efficiently while wasting less energy [3]. The solar collector is an essential dryer component; collectors absorb solar radiation, convert it into heat, and then transfer it into the air. Drying foodstuffs or leaves is an essential post-harvest activity in the life of a farmer or a herbal practitioner. The goal of drying is to keep foodstuffs from spoiling and keep them for a long time [4]. We dried food and vegetables at varying temperatures during the preservation process, as shown in Figure 1. As a result, different temperatures affect product quality, colour, potency, chemical composition, etc.

When that radiation enters the atmosphere, some of it is lost or absorbed by the ozone and other gases present, so on clear sunny days in summer, and the global radiation is measured at 800–1250 w/m^2.

1.1. Worldwide Radiation. The intensity of the radiation or the duration of the sunshine depends on the time of year, the natural weather conditions, and the altitude or geographical position. Global radiation falls to the ground in two forms: direct radiation and diffuse radiation. Direct radiation is the amount of radiation that falls directly on the ground, whereas diffuse radiation is the radiation that reflects off of other obstacles and equipment. Diffuse radiation is caused by the reflection or scattering of direct beam radiation from the sun when the radiation becomes scattered and no longer in the form of a beam. The amount of diffuse radiation depends on the weather and geographical location. Global radiation and diffuse radiation are primarily affected by weather conditions, dust, dirt, and other factors [5].

Evaporation necessitates the use of high-quality energy. A result, drying processes that require high temperature. Because most farmers are uneducated and thus unable to manufacture machines, solar dryers can be very inexpensive, but solar dryers are a very simple system. Almost all farmers can construct a solar dryer, and the materials used in its construction are inexpensive. Solar dryers are classified into natural convection solar dryers and forced convection solar dryers. Air flows naturally inside a natural convection solar dryer, whereas air flows inside a forced convection dryer via a fan. The air circulation inside the solar dryer will be uniform when drying fruits and vegetables in a forced convection solar dryer. We can, however, choose the design with the help of analysis fluent simulation. In addition, we can analyse the material of the solar dryer and the optimal thickness of the material used in its construction. Initially, the solar dryer was intended to dry vegetables and fruits. We ate dried mint, potato chips, fenugreek, and red chillies in Jaipur, among other things. Small farmers produce more than 80% of all food, so this low-cost, low-maintenance instrument, such as a solar dryer, is essential. Solar dryers are extremely beneficial equipment, especially for farmers and businesses. Various types of solar dryers (shown in Figure 2) have been constructed as an alternative to open-air drying. Although almost every country still uses open sun drying, it is ineffective compared with solar drying. It is necessary to dry a product before storing it for an extended period.

This experimentation is being done in Jaipur (Rajasthan). The fact that the sun rises 335–345 days a year is the most notable feature of the Rajasthan region. As a result, the efficiency of the solar dryer should be high, and it should outperform other states such as Jammu and Kashmir, Himachal Pradesh, and the United Kingdom.

Solar energy is used in almost every aspect of agriculture, including irrigation, agricultural equipment powering for agro-processing enterprises, and agricultural goods preservation, among other things. Food preservation is critical for reducing food waste. Governments have used dehydration, one of the most critical preservation strategies, to reduce these losses to an absolute minimum. Solar drying in a confined chamber is a resource-saving technique. Compared with the traditional drying method, which relies on nonrenewable fuels, this reduces postharvest losses and improves output quality. Because the solar dryer is a closed chamber, the food is protected from dust, rain, rodents, and other factors that could degrade the nutritious qualities of the product. There are two types of solar drying systems: those that use direct or indirect heating and those that use solar energy diversified. In general, this system is divided into two groups:

(a) Passive solar drying
(b) Active solar drying

Now, there are three main subcategories for every class. It is defined by the design and arrangement of the components and mode by which solar energy is utilised.

(a) Distributed-type solar dryer
(b) Integral-type solar dryer
(c) Mixed mode-type solar dryer

So, this study is concerned only with active-type solar dryers with natural and forced convection. The major disadvantage of this dryer is that we can utilise energy only from sun radiation.

By the experiment, of four dryers which one is more efficient has been noticed. The experimental results were used and subsequently validated with the simulation results.

1.2. Solar Drying Process. Sun drying is also known as air drying or solar air drying. The importance of air circulation within the dryer during the drying process cannot be

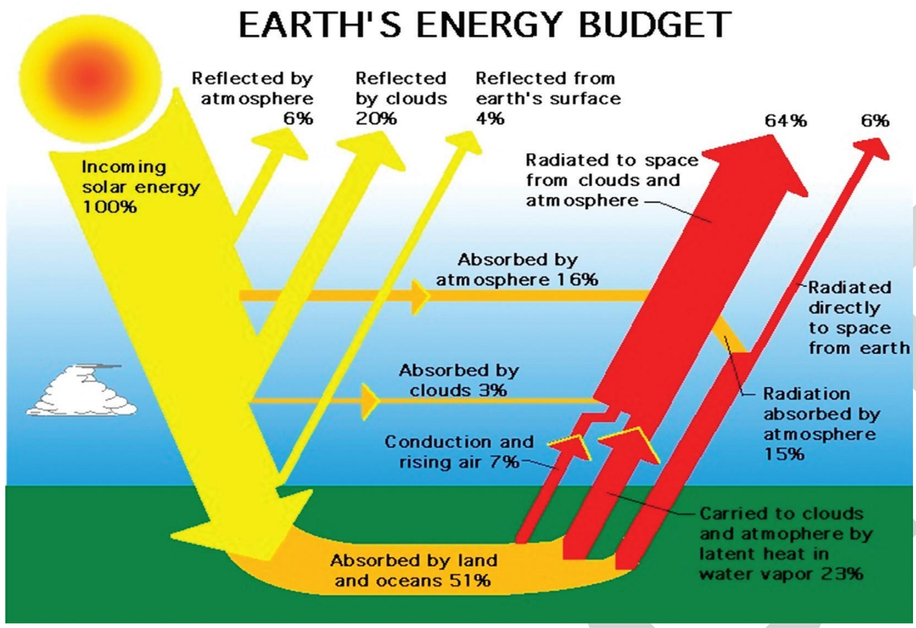

Figure 1: Model of economic energy (action energy) (https://ag.tennessee.edu/solar/Pages/What%20Is%20Solar%20Energy/Earth-Energy-Budget.aspx).

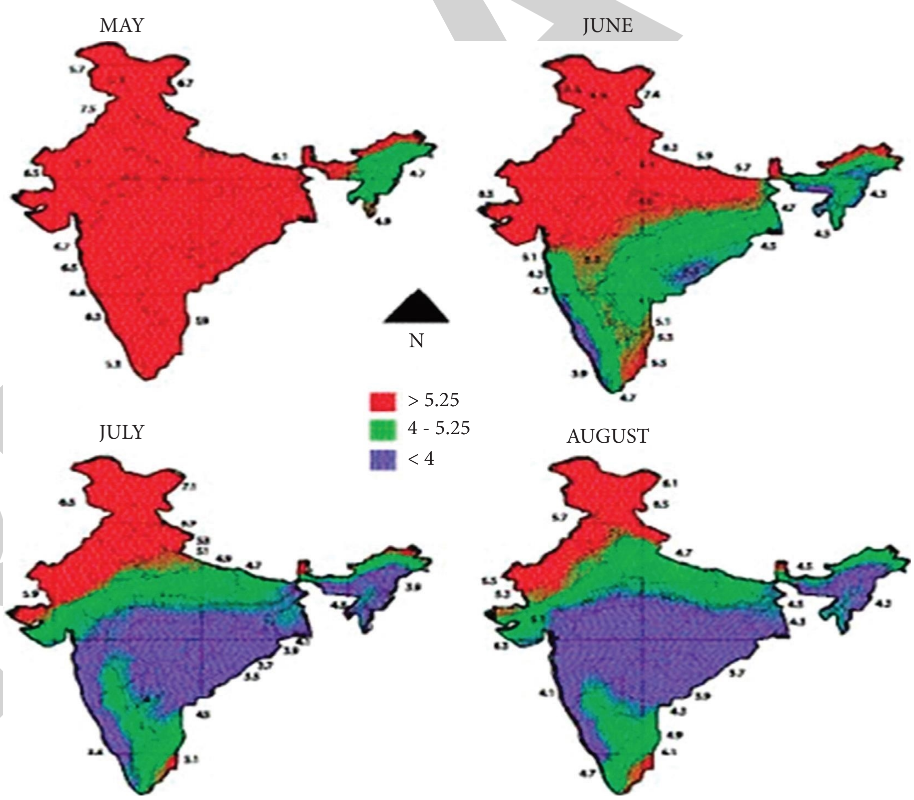

Figure 2: Month-wise intensity of solar radiation [2].

overstated. As a result, the efficiency of the solar dryer is heavily reliant on on-air circulation across the absorber plate within the dryer. Products drying inside the dryer may receive direct or indirect energy. Receiving energy causes the temperature to rise and the rate of moisture evaporation from the surface to increase. The drying rate is used to calculate the efficiency of the solar dryer. Other factors that influence the efficiency of the solar dryer include atmospheric temperature, humidity, and air movement inside the dryer. The drying process is heavily influenced by the shape and size of the product and the depth of the solar dryer as shown in Figure 3.

2. Literature Review

This section will look at paper-based solar energy collection systems. It has been stated that several schemes can be implemented to improve the thermal performance of solar dryers.

This device dries agricultural items using solar radiation. It is a strategy for reducing postharvest losses and poor quality associated with traditional solar drying [6–10]. Following numerous (attempts) tests, a successful design of solar dryer with natural convection was established, which can be used in active- and passive-type solar dryer applications. Several experiments have been carried out over the years [7]. In this system, the drying rate is entirely determined by mass transfer and heat transfer [8]. In indirect drying, heat is first applied to the absorber plate from the glass to cover it and then it is transferred to the absorber tray to evaporate any remaining moisture. Reference [9] has figured out that solar drying of agricultural goods using natural convection in a solar food drier is more efficient than open-air sun drying. Compared with traditional or open-air drying methods, it takes less time and achieves better drying results. It is dependent on two mechanisms: first, it removes moisture from the surface and prevents moisture from migrating from the interior of surface particles.

By [10], research on the testing procedures of box-type solar collectors for evaluating their energy performance had been published. The solar radiation intensity ratio between the absorber and the ambient air at the stagnation state has been determined as a test parameter based on outdoor experiments conducted under no-load or overload conditions. Following a thorough review of the literature, it was discovered that the thermal test process on a solar dryer with no-load condition and with load condition had two parameters that were superior in both cases. This method calculates the overall heat transfer coefficient (U.L.) and the drying efficiency (d). The maximum temperature of several solar dryer components, including the glass cover and absorber plates, and the air velocity present inside the dryer, determines the U.L. value [11].

According to [12], new agricultural product storage is a critical manufacturing component. A portion of the total production is lost during the various stages of the manufacturing process. As a result, asset preservation is the most effective method of mitigating such losses. Dehydration is one of the most common methods of preserving food and vegetables, mainly fruits. During operation, hybrid solar dryers use solar energy in addition to traditional energy sources such as electricity and other fossil fuels such as natural gas, oil, and coal. When nonirradiation situations occur more frequently, hybrid solar dryers are most commonly used, producing superior results at night. When a hybrid solar dryer's drying rate is compared to that of an essential solar dryer, the hybrid solar dryer outperforms the simple solar dryer because it can operate at night with the help of conventional fuels. Both types of energy are used in hybrid solar dryers (i.e., conventional and nonconventional). As a result, the hybrid sun dryer's total efficiency will be lower than that of the natural convection solar dryer [13].

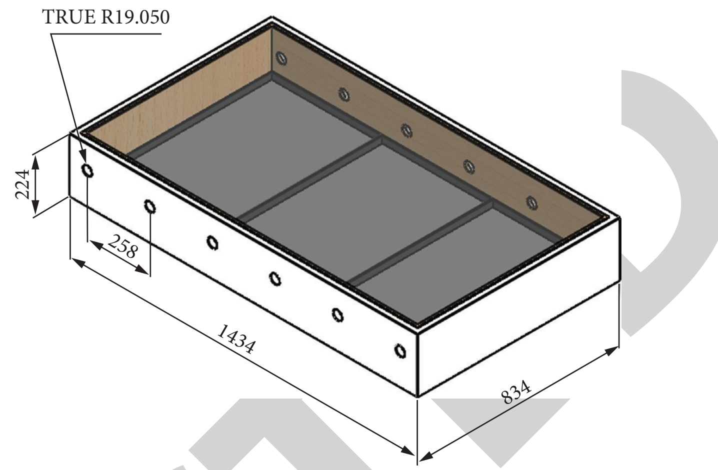

Figure 3: Solar dryer design for drying foods and vegetables.

Drying crops on the ground under the influence of the sun, wind, rain, insects, and dust, among other factors, is a traditional method of drying crops [14]. There are certain downsides to this method of open drying, including that it takes up a lot of room and takes a long time to dry. The sun, a source of radiation, is used to dry crops in many places worldwide. Heating applications use solar radiation, converted into useable thermal energy by the process (heat). In the home, solar energy is used for various tasks, including cooking, water heating, air conditioning and refrigeration, electricity generation, and cloth drying. Drying aids in reducing the water activity of the product to a level below which degradation does not occur for a brief period [15].

Natural sun drying is perhaps the oldest food preservation technique still in use today. However, it has several disadvantages, including the inability to manage the pace of drying, insect infestation, and microbiological contamination. Natural sun drying has many disadvantages, and replacing them with artificial or solar drying can considerably minimise these disadvantages and the losses produced by natural sun drying [16]. Even though sun drying is low-cost and needs minimal knowledge, it has many limitations, including moisture loss and a drying pace that is typically slow [17]. Direct drying from the sun impacts the crops' flavour, colour, and nutritional content, among other characteristics. A lack of control over the drying process and adverse weather conditions can cause crop loss.

Compared with traditional drying methods, a solar dryer keeps crops at a safe moisture level in situations where the crops must be protected from the elements. Solar dryers are handy for dehydrating agricultural goods. It evaporates water using energy and removes water vapour from the atmosphere via air movement. A significant amount of heat and control is required to achieve a high level of product quality. Weather variables such as ambient air temperature, relative humidity, solar radiation and wind speed, the amount of initial moisture content, and the type of dryer all impact the solar drying process [18]. Because there are so many variables, determining the drying efficiency of such a process is extremely difficult [18]. Natural convection dryers and forced circulation dryers are the two most common dryers found in most homes.

Natural convection dryers do not require a fan to circulate the air through the dryer. However, the drying capacity is limited because of the low airflow rate and the lengthy drying period. The usage of forced convection dryers should be considered for processing significant volumes of fresh food for the commercial market [19]. Studies have shown that using solar dryers to dry crops is more efficient and produces better outcomes than traditional drying crops in the open sun. Solar dryers are widely used in agriculture, including irrigation, powering agricultural equipment for agro-processing enterprises, and storing agricultural goods in storage facilities. Using solar dryers, which dry products at high temperatures while focusing on radiation [20], it is possible to get a longer shelf life.

Hot air is continually pushed over the food items in forced-type solar dryers. The food products are loaded and unloaded continuously or periodically. As a result, such dryers are more thermodynamically efficient, quicker, and may be used to dry large quantities of material [21]. When using hybrid dryers, the drying process is not as reliant on incident solar radiation since an auxiliary source of energy may be employed to ensure uniform drying conditions throughout the drying process. In a large-scale dryer, the cost, difficulty, and time required to monitor drying parameters at the drying chamber are prohibitively high since sensors and data loggers must be mounted in a plethora of locations. Because it can solve equations for the conservation of mass, momentum, and energy using numerical techniques [22], computational fluid dynamic (CFD) simulation is widely used in drying chambers to estimate temperature, velocity, and pressure profiles in the drying chamber.

To control the velocity, temperature, and pressure in a drying chamber using computational fluid dynamics (CFD), the airflow distribution in the drying chamber is predicted using CFD to achieve uniform drying. The material is dried with a system efficiency ranging from 15 percent to 18 percent for all test circumstances. Comparing the drying time to open-air drying, the drying time was reduced by approximately 20%, and the drying material on the trays was of higher quality. [23] The average drying efficiency was 69.6 percent at 29°C and 76.1 percent relative humidity with an average solar radiance of 750 W/m2. Under average ambient conditions of 29°C and 76.1 percent relative humidity with an average solar radiance of 750 W/m^2, the average drying efficiency was 69.6 percent [23].

The traditional method of drying chillies in Bangladesh is through sun exposure. Most farmers dry their chillies in the open sun on mats, cement floors, tin sheds, and earthen floors, among other things. We are unable to manage the drying pace, and as a result, we acquire a drying product with pretty bad quality. Drying time in open sun drying is likewise quite slow, taking roughly 7–16 days depending on the weather conditions [24]. Many problems arise with drying items (fruit and vegetables) while using the traditional drying technique, including dirt, dust, rains, birds, and other pet animals. As a result of these problems, 40–65 percent of the product amount is wasted [25].

Natural convection solar dryer is suitable at the household level for drying purposes. It can store 10–15 kg drying products, but there are limitations in natural convection solar dryer [26]:

(1) Availability of solar radiation intensity.

(2) Quantity of the raw product used for drying.

(i) The surface area of the absorber plate.

(ii) Latitude and longitude angles of the solar dryer.

(iii) Air circulation inside the drying chamber.

(iv) Heat transfer losses.

Tent-style solar drier with forced convection was built or created for drying red chillies at the Republic of Korea's Food Research Institute. The dryer had a 4.25 metre length and a two metre radius, with a drying surface of 22 m^2. It could dry 300 kg of fresh fruits and vegetables in 3 to 4 days, with a drying area of 22 m^2. The Sardar Patel Renewable Energy Research Institute in Gujarat, India, devised and built a direct sun dryer system with forced convection, which was then installed [27]. A solar dryer [28] was built by a Nigerian University in 1982; it comprises a flat plate collector that also serves as an absorber plate. The drier seen above was not used for drying crops. When the solar flux was at its highest, the temperature within the chamber was approximately 50 °C higher than the ambient temperature. It was discovered by Awachi (1982) that the effectiveness of the solar device was around 25% when it was used to dry products such as coconuts, maize, and fish for drying. In the wet state, the air temperature within the chamber was around 55–60°C, and in the dry condition, the temperature was approximately more than 55°C. The experiment was carried out by placing potato chips, tomato slices, and red chillies in the dryer and observing how long it took for the goods to dry, which was 2 or 3 days, respectively.

According to the findings of a group of women, 26–28 percent of the moisture in paddy (fruits and vegetables) may be eliminated for commercial purposes using a sun dryer. It was also identified that grains at a depth of 50–100 mm below the surface of the drying chamber might be dried to remove 15 percent of their moisture.

3. Materials and Methods

This section compares the thermal efficiency of natural convection and forced solar convection dryers, respectively. We will investigate the effect of airflow rate on the thermal efficiency of the solar dryer, which will help promote public awareness of the application, benefit, and necessity of solar drying, to prove solar dryer as a device for harnessing energy from the sun.

3.1. Construction of a Solar Dryer. Some construction material is used to construct a solar dryer. The plywood makes a wooden box. It is black painted inside to increase the heat absorptivity. The trays are held by the wooden box, as shown in Table 1. The wood itself is a bad conductor of heat; generally, we do not require insulation.

3.1.1. Glass. Glass is used as the cover of the solar dryer. It is placed at the above part of the solar dryer. The glass is transparent, allowing some percentage of solar radiation inside the drying chamber, and some reflected and some absorbed. Glass is used to capture the solar radiation shown in Figures 4 and 5inside the chamber; it decreases the value of irradiation which is given in Table 2.

3.1.2. Trays. The aluminium makes trays. Aluminium trays were also painted black to increase the absorptivity. Generally, aluminium has good thermal conductivity so these trays can heat quickly. These trays are placed inside the dryer, and all the drying products are spread over the trays used in Table 3. Some heddle is generated between the trays, and if the dryer is placed at an angle of 27, the product never slipped and is collected at the lower part of the dryers as shown in Figure 6.

3.1.3. Thermocol. It is used to insulate the solar dryer from outside. It reduced some heat loss. It is posted outside of the dryer and data used for it as shown in Figure 7 and Table 4.

1.5 inches holes are constructed in the wooden box for air circulation inside the drying chamber as shown in Figure 8.

Black paints are used in solar radiation collectors (trays) because bleach paints absorb more radiation than other colours, so black paints are used in solar dryers. Trays absorb more radiation and heat up quickly for drying the foods and vegetables.

4. Experimental Procedure

During February and March in 2021, four full-load trial runs were carried out on red chillies, fenugreek, potato chips, and mint, with the results being published. First and foremost, all the products were drained by pure water. Additionally, the goods were placed in the sun dryer on weighted trays and then spread out in a single layer. To evaluate the performance of the solar dryer in the different-2 designs and compare the performance of the solar dryer with the conventional sun drying, the drying process began at 9:00 a.m. and was completed by 3:00 p.m. The weight loss of the samples in the solar dryer and open sun drying samples was measured using a weight machine during the drying time at one-hour intervals during the drying period. At 3:00 p.m., as the experiment came close, the samples dried by the open sun were left in their solar dryers, while the samples dried by solar were left in the room at ambient settings. As is customary, the entire system was exposed to the sun the next morning at 9:00 a.m. After that, both the solar drying and open sun drying samples were treated to the same drying conditions in a dryer under the same conditions. It was necessary to use four thermocouples to measure thedifferent-different temperatures at different-different locations.

Additionally, the air temperature should be measured in the direction of the air movement. A pyranometer, also known as a solar metre, was used to measure the strength of sun radiation at two different positions: horizontal and at a 27-degree angle. Temperature and relative humidity were monitored using a digital humidity metre, and the air temperature was measured using a thermocouple placed 5 cm above the absorber plates. Using a vane-type anemometer, we measured the air velocity at both the intake and the output of the solar dryer as shown in Figure 9. Following the end of the drying process, all of the goods were gathered.

Around 2 kg red chillies' weight is reduced to .754 g, 2000 g fenugreek weight is reduced to 300 gm, and 2000 g mint weight is reduced to 230 gm as shown in Figure 10. All the four different-2 conditions of the dryer consumed different-2 time periods for complete drying. By the experiment, we found out the best design of the solar dryer and that best design was analysed using CFD. We tried many products during the experiment time, so we dried the fenugreek for the first time. First, we washed that coriander with the fresh water and then measured the weight by weighing the machine before spearing over the absorber plates (trays). The absorber plates (trays) are set in the solar dryer, and all the thermocouples are attached with all the absorber plates (trays). After setting up the entire thing correctly, the all-absorber plate's temperatures and air temperature and then outer temperature are noted with the help of the thermometer. The velocity at the inlet and outlet of the dryer is measured. The same procedure is followed after 1 hour for the next reading of the fenugreek. So finally, we showed that fenugreek took 2 days only for complete drying.

4.1. Observation and Data Collection. After installation, the solar dryer was left operating for several days under normal weather conditions. The LM-35 temperature sensor wires were positioned at a different point in the solar dryer. The solar dryer was tilted 27° angle and south faced. An experiment on the solar dryer was performed in the days of February-March 2021 in Jaipur, Rajasthan, India. The test was conducted between 09: 00 a.m. and 3:00 p.m. solar time.

Table 1: Wooden box size and material.

S. no.	Name	Size
1.	Area (m^2)	1.33
2.	Thickness (mm)	13
3.	Length (m)	1.35
4.	Thermal conductivity	0.23

Figure 4: Glass used in this system.

Figure 5: Stand used in the solar dryer.

Table 2: Class material size and material.

S. no.	Name	Size
1.	Thickness (mm)	4
2.	Length (m)	1.35
3.	Width (m)	0.75
4.	Density (kg/m^3)	2500
5.	Specific heat (J/kg K)	750
6.	Thermal conductivity (W/mK)	1.4
7.	Convective heat transfer coefficient (W/m^{2}K)	2.8

Table 3: Wooden tray size and material.

S. no.	Name	Size
1.	Area (m^2)	0.33
2.	Thickness (gauge)	30
3.	Density (kg/m^3)	2700
4.	Thermal conductivity (W/mK)	200
5.	Specific heat (J/kgK)	900
6.	Poisson ratio (N/A)	0.33
7.	Tensile strength (N/m^2)	68935600
8.	Yield strength (N/m^2)	27574200
9.	Shear modulus (N/m^2)	$2.7e^{01}$

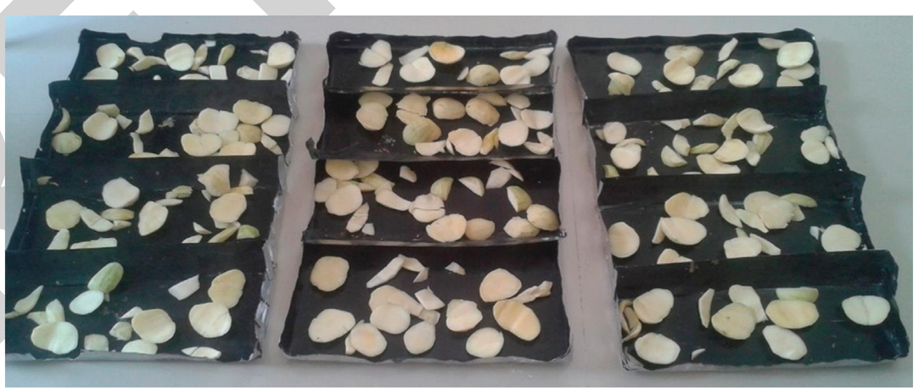

Figure 6: Potato chips in trays.

The reading was taken at the interval of every 1 hour as shown in Tables 5–9.

4.2. Result and Discussion. The uniform airflow is not possible with natural convection in the dryer. Because in natural convection, atmospheric air is generally more fluctuating, in forced convection, the air distribution uniform is possible because the fan of 20 watts gives the uniform flow in the solar dryer. So, simulation has been done on the whole solar dryer, not any part of the solar dryer. Therefore, the forced convection solar dryer study focuses on the results and conclusion of the whole solar dryer. The simulation was carried out with velocity and temperature profiles inside the

Figure 7: Solar dryer with thermocol insulation.

Table 4: Aluminium tray size and material.

S. no.	Material	Amount
1.	Density (g/cm^3)	0.96–1.6
2.	Melting point (°C)	240
3.	Thermal conductivity (W/mK)	0.33
4.	Refractive index (kHz)	1.6 dielectric const.
5.	Molecular formula	(C8H8)n

Figure 8: Paints used in the solar dryer.

Figure 9: Fenugreek in solar dryer.

Figure 10: Red chillies in the solar dryer.

solar dryer. The temperature fluctuates throughout the day, so the soar dryer temperature fluctuates, respectively, and air velocity profile also fluctuates throughout the day. Here, we have analysed the different-2 models with different-2 parameters as shown in Figure 11—study on the 19 cm gap between absorber plates and glass. We have the temperature contours and velocity path lines results generated by simulation and here validate the simulation results with the actual experimental results.

The above temperature shows the temperature contour on the absorber plates. The dryer area is 1.44 m^2, and the hole size is 1.5 inches as shown in Figure 12.

This contour shows the temperature profile on the glass. The yellow colour shows the temperature according to the diagram scale shown in Figure 13.

The morning time data table was generated by simulation (result finding on 19 cm gap). The contour diagram shows the velocity path lines and the temperature of these path lines as shown in Figure 14. Now, some data generated by simulation are put. The data will show what modification should be necessary for the solar dryer. The above data show the morning time contours: afternoon time contours and temperature profiles and simulation data (19 cm gap).

The contour shows the glass temperature in the afternoon time. We validate the experimental temperature with the simulation temperature, and we can obtain the temperature results at every point of the solar dryer as shown in Figure 15.

These contours show the velocity contour inside the solar dryer and the temperature variation inside the dryer.

Experiment timing was 9:00 a.m. to 3:00 p.m., so when the experiment goes to close, the temperature value is found more in June month, because in India in the June month solar radiation is found very high as shown in Figure 16.

This contour presented the evening temperature at mid of the solar dryer in Figure 17.

We have implemented and presented the results generated by the simulation using some experimental inputs. In North India, the experiment was done in May

Table 5: Observation of fenugreek in solar dryer.

Time of day	Weight (forced convection) (g)	Weight (natural convection) (g)	Temp. N.C. (°C)	Temp. F.C. (°C)	N.C plate (°C)	F.C. plate (°C)	Solar flux horizontal (W/m^2)	Solar flux at 27° (W/m^2)
09:00	1000	1000	37.3	35.6	42.2	40.2	680	556
10:00	920	895	39.1	38.2	45.3	44.2	863	773
11:00	900	870.5	40.7	39.1	48.2	46.4	1080	1951
12:00	740.3	720	45.8	40.4	65.1	47.1	1183	1025
01:00	690.2	669.4	43.9	45.9	67.7	55.2	1145	1025
02:00	577	490.3	43.3	42.8	61.1	53.2	1345	1030
03:00	478	433	45.5	45.4	59.9	53.7	1050	730

South facing at 27°C.

Table 6: Observation of fenugreek in the solar dryer in direct sunlight.

Time of day	Weight (F.C.) (g)	Weight (N.C.) (g)	Temp. F.C. (°C)	Temp. N.C. (°C)	Temp. F.C. plate (°C)	Temp. N.C. plate (°C)	Solar flux horizontal (W/m^2)	Solar flux at 27° (W/m^2)
09:00	280.3	243.6	33.8	38.1	46.4	53.3	450	493
10:00	267.6	174	34.2	41.4	50.3	56.2	460	480
11:00	254.3	165.4	34.6	39.4	51.3	59.2	466	546
12:00	202.4	145.3	35.2	39.9	52.2	60.7	502	565
01:00	190.5	120	38.2	37.3	49.2	61.9	550	445
02:00	165	108	37.2	41.4	44.9	54.3	420	347
03:00	161	102	35.4	38.1	41.7	49.9	417	322
AVG	217	151	35.5	39.3	48	56.5	466.4	376.1

Table 7: Observation of red chillies.

Time of day	Weight (F.C.) (g)	Weight (N.C.) (g)	Temp. F.C. (°C)	Temp. N.C. (°C)	Temp. F.C. plate (°C)	Temp. N.C. plate (°C)	Solar flux horizontal (W/m^2)	Solar flux at 27° (W/m^2)
09:00	1000	1000	30.4	33.3	33.1	36.5	702	734
10:00	989	977	37.1	35.3	33.8	37.5	754	934
11:00	970	895	38.4	44.9	48.9	62.4	888	1004
12:00	950	860	39.3	54.1	54.4	79.7	928	1086
01:00	915	810	39.8	56.3	60.3	80.3	954	1250
02:00	868	796	39.1	49.1	62.5	79.9	927	1154
03:00	805	730	38.6	45.5	64.4	67.4	905	1103

Table 8: Observation of red chillies in a solar dryer.

Time of day	Weight (F.C.) (g)	Weight (N.C.) (g)	Temp. F.C. (°C)	Temp. N.C. (°C)	Temp. F.C. plate (°C)	Temp. N.C. plate (°C)	Solar flux horizontal (W/m^2)	Solar flux at 27° (W/m^2)
09:00	805	730	39.5	40.5	36.6	37.6	775	796
10:00	776	711	43.4	44.5	44.5	42.4	743	776
11:00	686	676	39.3	46.1	49.8	56.9	904	1002
12:00	545	510	43.2	46.9	56.9	62.9	1032	1078
01:00	440	418	44.7	48.4	62.7	72.6	1085	1121
02:00	386	343	46.0	56.4	67.8	79.7	1276	1294
03:00	244	217	44.3	54.1	68.7	80.4	1165	1187

Table 9: Observation of coriander in a solar dryer.

Time of day	Weight (F.C.) (g)	Weight (N.C.) (g)	Temp. F.C. (°C)	Temp. N.C. (°C)	Temp. F.C. plate (°C)	Temp. N.C. plate (°C)	Solar flux horizontal (W/m^2)	Solar flux at 27° (W/m^2)
10:00	985	960	44.3	46.3	51.6	56.9	1183	1058
11:00	840	800	44.6	48	56.9	65.8	1236	1150
12:00	785	740	45.9	54.0	65.9	76.8	1265	1204
01:00	546	510	55	60.2	72.0	80.6	1260	1208
02:00	455	430	56.7	57.7	74.7	82.1	1264	1232
03:00	210	190	54.8	58.8	65.9	79.6	1227	1217

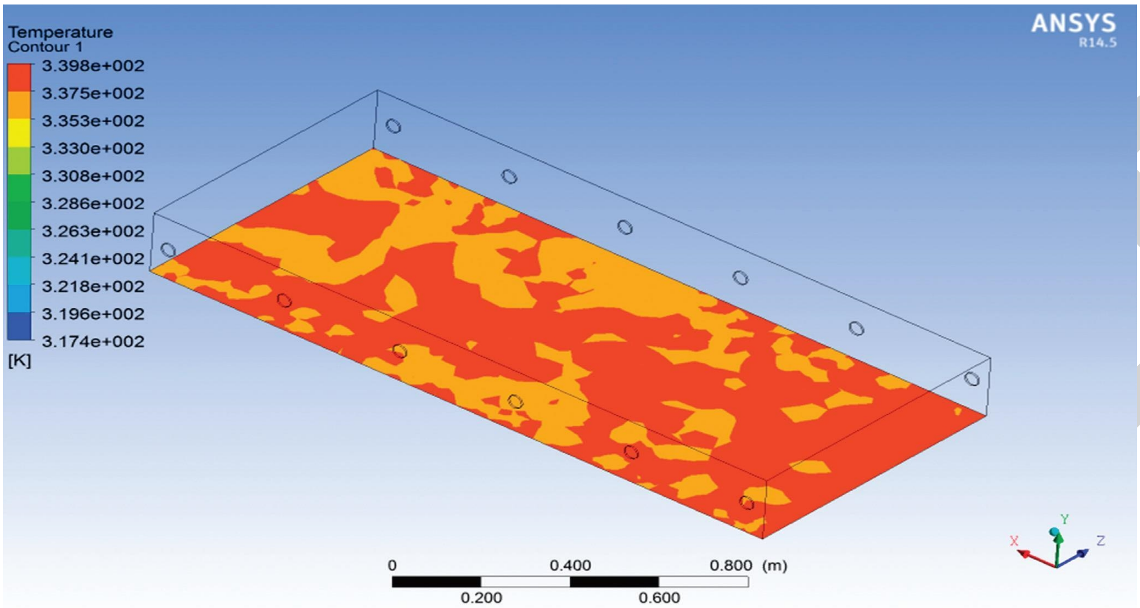

Figure 11: Effect of the temperature contour on the absorber plates.

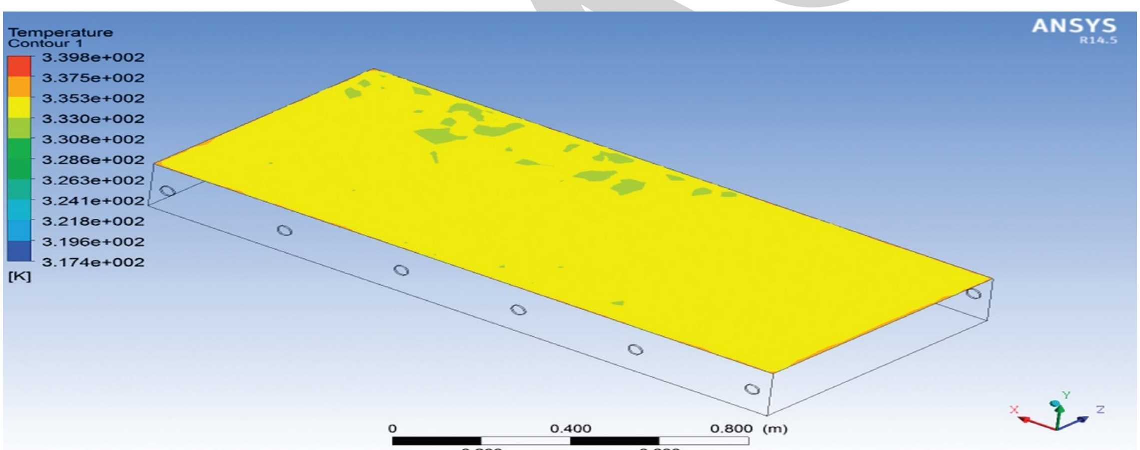

Figure 12: Temperature profile effect on the glass.

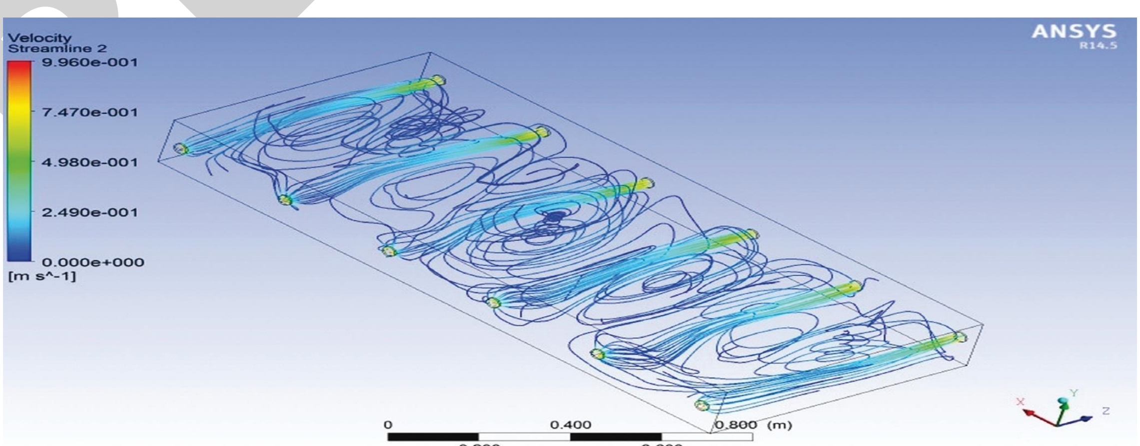

Figure 13: Velocity path lines and the temperature effect in the solar dryer.

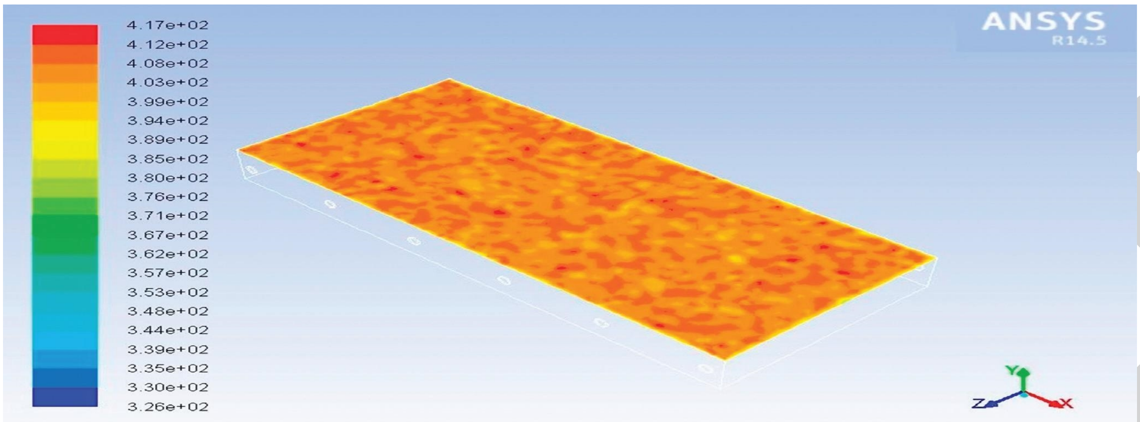

FIGURE 14: Effect of glass temperature at the afternoon time.

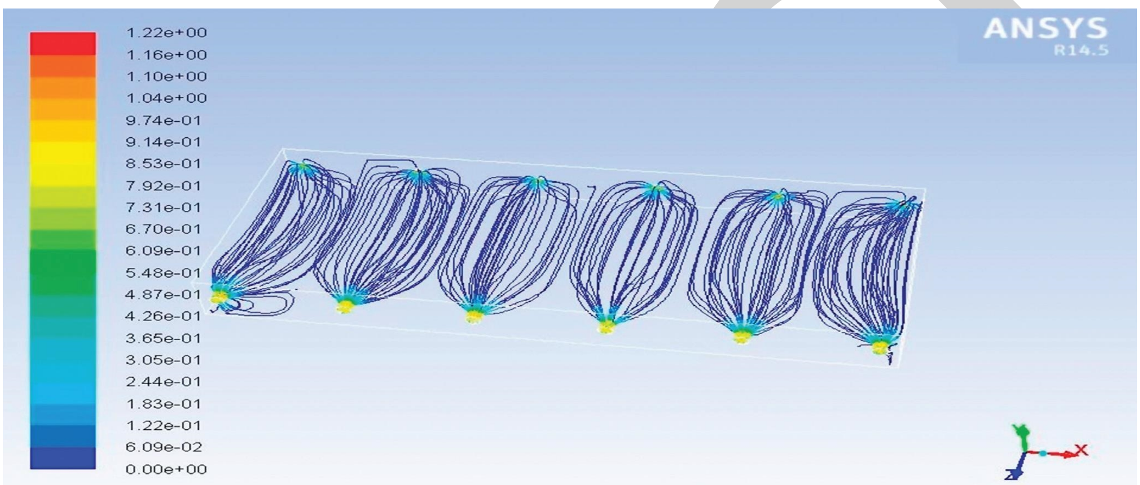

FIGURE 15: Velocity movement of contour inside the solar.

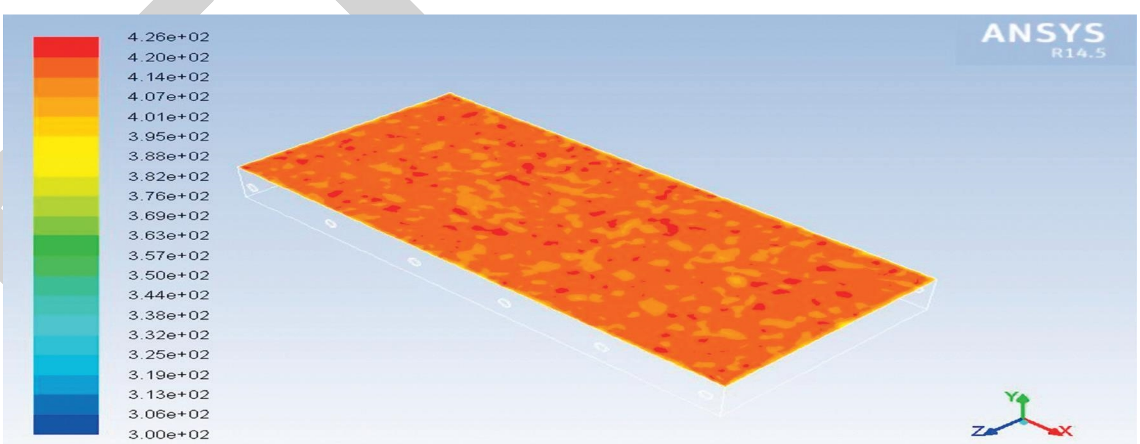

FIGURE 16: Contour presented the evening temperature at mid of the solar dryer.

and June in Rajasthan, Jaipur, the hottest place as shown in Figure 18. Approximately in the evening, time environment temperature is measured every day above 40°. The solar dryer gives output at 40° environment temperature above 70°. So, the efficiency of the solar dryer was found to be more than 15%. It is necessary for an efficient dryer. If the efficiency of the solar dryer is more than 15%, then it will be useable.

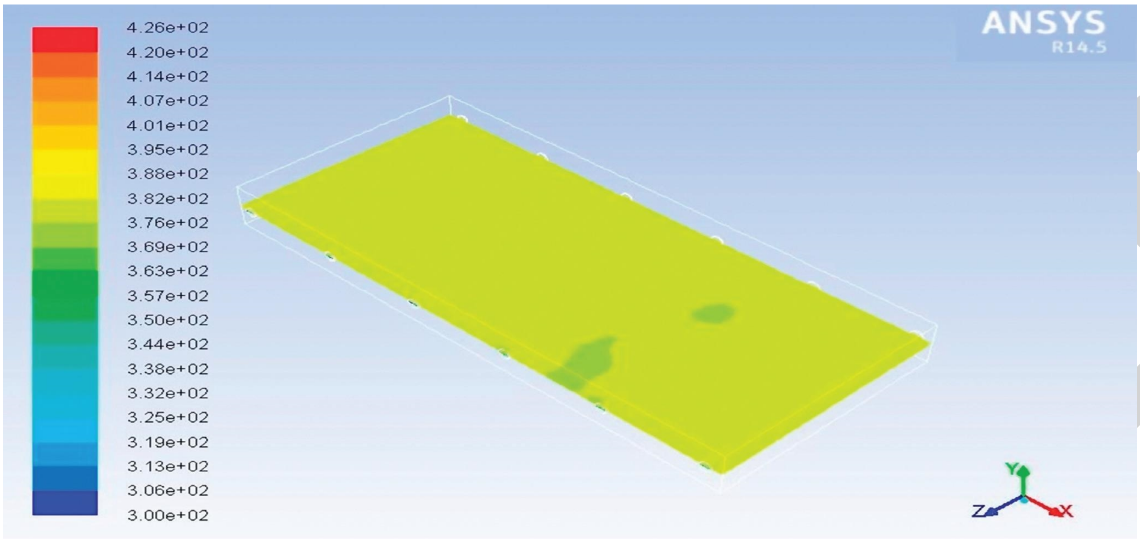

Figure 17: Red chillies in the solar dryer.

Figure 18: Effect of the solar dryer at the temperature of 40°C after 6 days.

5. Conclusion

Good airflow distribution can be improved by the drying efficiency of the solar dryer in forced convection with the help of a fan. So, the CFD simulation is a constructive tool to predict the air velocity, temperature, and pressure inside the chamber. CFD considers an essential part of the design purpose and analysis of the design because it can simulate the value of the temperature, velocity, density, and radiation inside and on the dryer. So here, the experimental outcomes are validated with the simulation results. The chamber's improper air distribution depends on the inlet and outlet hole size. So, hole size plays a vital role in the natural convection solar dryer. By the simulation, we find the optimum hole size in my design. The experiment has been successfully done so that some suggestions could be given on parameters according to the solar dryer.

(a) The temperature inside the drying chamber must be 55–60° with under load conditions, and 65–70° can be in an overload condition. Still, in an overload condition, the air velocity should be more than 2 m/s.

(b) The efficiency of natural convection solar dryer should be more than 15%.

(c) We can use the steel absorber plate in the summer season, but we have to use an aluminium absorber plate in the winter season.
(d) 1.5 inch holes are more effective in both types of solar dryers, forced convection and natural convection.
(e) The efficiency of the solar dryer is a function of airflow rate and increases with the increase in airflow rate.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Y. Abbaspour-Gilandeh, A. Jahanbakhshi, and M. Kaveh, "Prediction kinetic, energy and exergy of quince under hot air dryer using anns and anfis," *Food Sciences and Nutrition*, vol. 8, no. 1, pp. 594–611, 2020.
[2] S. A. Al Maiman, N. A. Albadr, I. A. Almusallam et al., "The potential of exploiting economical solar dryer in food preservation: storability, physicochemical properties, and antioxidant capacity of solar-dried tomato (solanum lycopersicum) fruits," *Foods*, vol. 10, no. 4, pp. 734–4, 2021.
[3] H.-R. Alizadeh, H. Mortezapour, H.-R. Akhavan, and M. Balvardi, "Performance of a liquid desiccant-assisted solar juice concentration system for barberry juice," *Solar Energy*, vol. 184, pp. 1–10, 2019.
[4] E. Ayua, V. Mugalavai, J. Simon, S. Weller, P. Obura, and N. Nyabinda, "Comparison of a mixed modes solar dryer to a direct mode solar dryer for African indigenous vegetable and chili processing," *Journal of Food Processing and Preservation*, vol. 41, no. 6, 6 pages, Article ID e13216, 2017.
[5] O. A. Babar, A. Tarafdar, S. Malakar, V. K. Arora, and P. K. Nema, "Design and performance evaluation of a passive Flat Plate collector solar dryer for agricultural products," *Journal of Food Process Engineering*, vol. 43, Article ID e13484, 10 pages, 2020.
[6] R. de Pinho Ferreira Guiné and M. J. Barroca, "Drying kinetics in solar drying," in *Solar Drying Technology*, O. Prakash and A. Kumar, Eds., pp. 317–355, 2017.
[7] R. P. F. Guine, M. F. S. Brito, and J. R. P. Ribeiro, "Evaluation of mass transfer properties in convective drying of kiwi and eggplant," *International Journal of Food Engineering*, vol. 13, Article ID 20160257, 7 pages, 2017.
[8] T. Hadibi, A. Boubekri, D. Mennouche, A. Benhamza, C. Besombes, and K. Allaf, "Solar-Geothermal drying/instant controlled pressure drop-swell drying of mechanically dewatered tomato paste," *Journal of Food Process Engineering*, vol. 44, Article ID e13811, 10 pages, 2021.
[9] T. Hadibi, A. Boubekri, D. Mennouche, A. Benhamza, and A. Kumar, "Economic analysis and drying kinetics of a geothermal-assisted solar dryer for tomato paste drying," *Journal of the Science of Food and Agriculture*, vol. 101, no. 15, pp. 6542–6551, 2021.
[10] A. Jahanbakhshi, R. Yeganeh, and M. Momeny, "Influence of ultrasound pre-treatment and temperature on the quality and thermodynamic properties in the drying process of nectarine slices in a hot air dryer," *Journal of Food Processing and Preservation*, vol. 44, Article ID e14818, 10 pages, 2020.
[11] S. Marulanda-Meza and J. C. Burbano-Jaramillo, "Energetic evaluation of a solar tunnel dryer for fruits," *Article. Uis Ingenierias*, vol. 20.
[12] H. O. Menges, A. Unver, M. M. Ozcan, C. Ertekin, and M. H. Sonmete, "The effects of drying parameters on drying characteristics, colorimetric differences, antioxidant capacity and total phenols of sliced kiwifruit," *Article. Erwerbs-Obstbau*, vol. 61, pp. 195–207, 2019.
[13] D. Mennouche, A. Boubekri, S. Chouicha, B. Bouchekima, and H. Bouguettaia, "Solar drying process to obtain high standard "deglet-nour" date fruit," *Journal of Food Process Engineering*, vol. 40, no. 5, 5 pages, Article ID e12546, 2017.
[14] E. Mujuka, J. Mburu, A. Ogutu, and J. Ambuko, "Returns to investment in postharvest loss reduction technologies among mango farmers in embu county, Kenya," *Food and Energy Security*, vol. 9, Article ID e195, 1 page, 2020.
[15] S. Nabnean, S. Thepa, S. Janjai, and B. K. Bala, "Drying kinetics and diffusivity of osmotically dehydrated cherry tomatoes," *Journal of Food Processing and Preservation*, vol. 41, no. 1, 1 page, Article ID e12735, 2017.
[16] N. N. Nagwekar, V. B. Tidke, and B. N. Thorat, "Seasonal nutritional food security to Indian women through community-level implementation of domestic solar conduction dryer," *Ecology of Food and Nutrition*, vol. 59, no. 5, pp. 525–551, 2020.
[17] G. Nikolaou, D. Neocleous, N. Katsoulas, and C. Kittas, "Effect of irrigation frequency on growth and production of a cucumber crop under soilless culture," *Emirates Journal of Food and Agriculture*, vol. 29, pp. 863–871, 2017.
[18] T. N. A. Othman, Z. A. M. Din, and S. M. M. Takriff, "Simulation on drying of sago bagasse in a fluidized bed dryer," *Journal of Engineering Science & Technology*, vol. 15, no. 4, pp. 2507–2521, 2020.
[19] R. Ouaabou, B. Nabil, M. Ouhammou et al., "Impact of solar drying process on drying kinetics, and on bioactive profile of Moroccan sweet cherry," *Renewable Energy*, vol. 151, pp. 908–918, 2020.
[20] S. N. Rokib, N. Yeasmen, M. H. R. Bhuiyan et al., "Hyphenated study on drying kinetics and ascorbic acid degradation of guava (psidium guajava L.) fruit," *Journal of Food Process Engineering*, vol. 44.
[21] F. Salehi, "Recent applications of heat pump dryer for drying of fruit crops: a review," *International Journal of Fruit Science*, vol. 21, no. 1, pp. 546–555, 2021.
[22] H. Samimi Akhijahani, A. Arabhosseini, and M. H. Kianmehr, "Comparative quality assessment of different drying procedures for plum fruits (prunus domestica L.)," *Czech Journal of Food Sciences*, vol. 35, no. 5, pp. 449–455, 2017.
[23] S. T. Sileshi, A. A. Hassen, and K. D. Adem, "Drying kinetics of dried injera (dirkosh) using a mixed-mode solar dryer," *Article. Cogent Engineering*, vol. 8, Article ID 1956870, 1 page, 2021.
[24] A. M. Silva, D. Pinto, I. Fernandes et al., "An insight into kiwiberry leaf valorization: phenolic composition, bioactivity and health benefits," *Molecules*, vol. 26, no. 8, 8 pages, Article ID 2314, 2021.
[25] N. H. A. Tajudin, S. M. Tasirin, W. L. Ang, M. I. Rosli, and L. C. Lim, "Comparison of drying kinetics and product quality

from convective heat pump and solar drying of roselle calyx," *Food and Bioproducts Processing*, vol. 118, pp. 40–49, 2019.

[26] M. C. Téllez, B. Castillo-Téllez, A. M. P. Gerardo, R. Marzoug, and D. C. M. Álvarez, "Design of an indirect dryer with coupling of solar collectors and its thermal characterization by drying the mint leaves (mentha spicate)," *European Journal of Sustainable Development*, vol. 10, no. 1, pp. 411–419, 2021.

[27] E. Uribe, A. Vega-Gálvez, V. Vásquez, R. Lemus-Mondaca, L. Callejas, and A. Pastén, "Hot-air drying characteristics and energetic requirement of the edible brown seaweedDurvillaea Antarctica," *Journal of Food Processing and Preservation*, vol. 41, no. 6, 6 pages, Article ID e13313, 2017.

[28] R. Wilkins, J. Brusey, and E. Gaura, "Modelling uncontrolled solar drying of mango waste," *Journal of Food Engineering*, vol. 237, pp. 44–51.