Performance Analysis of Mixed Mode Solar Dryer for Tobacco Leaves

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Reg # 00000275280

Session 2018-22

Supervised by

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Syed Ali Wahaj Abdi

Abstract:

It is well recognized that mishandling organic products results in a large loss. For tobacco leaves, drying is the most effective and ideal preservation method before storage in order to reduce the growth of mould and mycotoxin. The problem of two separate temperature ranges for drying makes it very challenging to dry tobacco leaves and stems. A mixed mode, active type, affordable, and environmentally friendly solar dryer is proposed in the current study work to dry tobacco leaves. The dryer consists of an exhaust fan with a regulator to create the necessary airflow in the system, a solar collector/absorber integrated with a single drying chamber divided into two halves, and solar panels. The suggested design can maintain two distinct temperature ranges for tobacco leaves in a single cabinet with almost perfect uniformity. For tobacco leaves, the drying temperatures for the leaves and stems are 333 K and 348 K, individually. The objective of the ongoing review is to look at the exhibition of a clever blended mode sun based bureau dryer for drying tobacco. Tobacco leaves and stems can be dried separately in portions that are close to the appropriate temperature range thanks to the cabinet dryer's proposed architecture. Utilizing a verified numerical model with varied operational settings, the performance is assessed. The outcomes show improved execution records and a more equivalent circulation of temperature, tension, and speed. The drying chamber can keep a temperature somewhere in the range of 298 and 344 K, and the sun powered safeguard can reach up to 330 K. It has also been examined how air admission and outlet sizes, delta speed, gulf temperature variety, examinations of the left and right sides of the sun powered bureau dryer, and the proportion of outlet to channel width influence the sun oriented bureau dryer's typical temperature. By and large, the outcomes demonstrate the way that the proposed plan setup can keep the temperature even in various pieces of the single bureau dryer, which is a decent sign for keeping the nature of the dried tobacco leaves and stems at a standard level.

Keywords: Solar dryer, Tobacco leaves, CFD analysis, Laminar flow, Mixed mode type solar dryer

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List of Abbreviations

T_{amb}	Ambient Temperature	m_w	Mass of water vapor (kg)
m_i	Initial moisture content in product (%)	m_f	Final moisture content in product (%)
E_p	Energy required to evaporate water vapor (joule)	L_v	Latent heat of vaporization of water (kJ/kg)
E_a	Energy gain from air (joule)	I_c	Solar intensity (W/m^2)
A_C	Area of collector (m^2)	η_c	Efficiency of collector (%)
T_i	Inlet air temperature (K)	T_O	Outlet air temperature (K)
T_a	Ambient air temperature (K)	m_a	Mass flow rate of air (kg/sec)
Cp_a	Specific heat of air (kJ/kgK)	ΔT	Temperature difference (K)
Pa	Density of air (kg/m$_3$)	Va	Volume flow rate of air (m$_3$/sec)
v_a	Velocity of air (m/sec)	A	Area of inlet air section (m^2)
t_d	Drying time (hour)	M_{dr}	Average drying rate (kg/hour)
η	Efficiency	m_p	Mass of product (kg)
I	Transmissivity	α	Absorptivity
Q_U	Heat gain (W)	Q_L	Heat loss by convection (W)

K	Thermal conductivity of insulation (W/mK)	T_d	Thickness of base insulator (mm)
F_R	Heat removal factor (0.1)	f_v	water vapour transfer coefficient, kg/s m^2 Pa
T_a	temperature of air, °C	A	water surface area, m2
T_s	water temperature, wet bulb, °C	P_s	water vapour pressure at ts , kg / m^2 or Pa
h_{fg}	latent heat of vaporization, kJ/kg	P_a	water vapour pressure in the air, kg / m^2 or Pa
D	is the moisture transfer coefficient of both liquid and vapour, m^2/hr	k_f	thermal conductance of air film, W/ m^2K
k	is the energy transfer coefficient	ρ	the density of air (kg/m^3)
m	refers to transfer due to a moisture gradient	I_c	the insolation on the collector
th	refers to transfer due to a temperature gradient	ΔT	the temperature elevation
MR	moisture ratio	C_p	the specific heat capacity of air at constant pressure (J/kg K)
M	the moisture content (g water/g dry matter) at any time *t*;	V	the volumetric flow rate (m^3 /s)
M_o	initial moisture content (g water/g dry matter) at time t = 0;	A	the effective area of the collector facing the sun (m^2)
M_e	material equilibrium moisture content (g water/g dry matter).	M_w	weight of moisture evaporated, kg
$MR_{exp,i}$	the i_{th} experimentally observed moisture ratio values	L	Latent heat of evaporation of water (at temperature of dryer), kJ/kg
$MR_{pre,i}$	the i_{th} predicted moisture ratio values	t	drying time
N	the total number of observations, and	M_i	mass of sample before drying

M_d	mass of sample after drying	W_w	initial total weight;
t	drying period	M_i	initial moisture content on wet basis;
n	the number of constants in the model	M_f	the final moisture content on wet basis
w	weight of wet material	M	is the average moisture content (dry basis) at any time,
d	weight of dry material	Me	is the equilibrium moisture content (dry basis), decimal
M_w	amount of moisture removed;	k	is the drying constant, hr^{-1}
t	is the drying time, hr	a	an indication of shape, gas absorption coefficient
M_t	is the average moisture content (dry basis), decimal at any time	k	the drying constant3.
n	Page parameter (dimensionless).		

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CHAPTER 1
Introduction

1 Introduction

1.1 Background

The tobacco plant is native to both North and South America. Tobacco leaves are related to peppers, a lethal plant, a toxic nightshade, and tobacco leaves. Considering how tiny the seeds of these leaves are, a 1-ounce sample has 300,000 seeds. People tend to agree that American Indians used tobacco mostly when it was first grown, around 6000 B.C. They use tobacco for both spiritual and health reasons. Additionally, it was used as a remedy, such as a pain reliever and a dressing for wounds. The tobacco could also be chewed for dental purposes to ease toothache pain [1].

The tobacco industry runs a huge business. It has spread over the globe, and the tobacco business, worth many billions of dollars, is impacted by every facet of it, from leaf farming to product manufacturing. According to numbers from the six biggest companies in the sector, global sales are estimated to be $342 billion, profits to be $44.1 billion, and annual production to be 6 trillion cigarettes[2].

The newly formed global corporation's supply chain for tobacco is its core. The market for tobacco products is still expanding favorably despite the health dangers they pose. Many personnel from many industries are involved, including sales companies, nearby leaf producers, and cigarette makers. Production standards for the goods are quickly improving to meet higher quality and more ecologically friendly requirements[3]. Figure 1 shows the three stages of tobacco production. Farmers are in charge of agriculture and curing, and they are required to produce tobacco leaves of the highest quality. The smoked product is put together during the manufacturing process in accordance with consumer expectations.

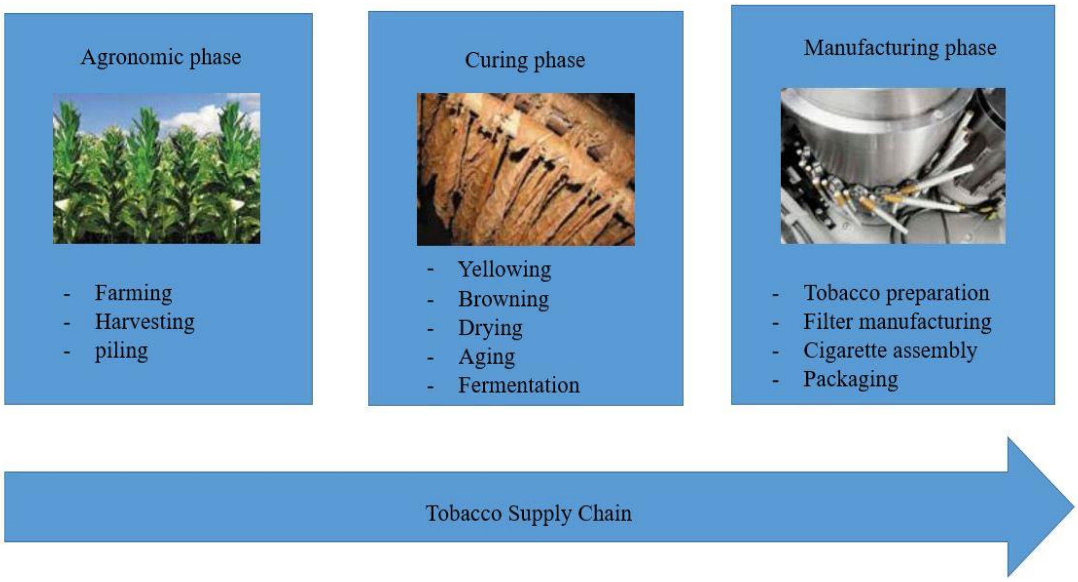


Figure 1-1. Schematic diagram of tobacco supply chain

The type of tobacco leaves used and the producer's level of technology determine how the product differs.

1.2 Tobacco flue- curing process

For pipe assuage tobacco, the reestablishing framework is isolated into different stages that are accumulated into three critical full-scale stages: yellowing, leaf-drying, and stem-drying. Concerning preventing yellowing, it's trying to sort out a congruity between keeping a high relative soddenness of some sort and taking out however much moistness as could be expected without over-drying. On the one hand, the objective is to prevent over-drying while simultaneously allowing for the completion of physiological and biological processes taking place on leaves. At the conclusion of this phase, the moisture content has decreased by 50% from its initial 90% (in mass) water content. The going with leaf and stem drying can achieve the ideal dampness content on tobacco leaves and stems by slowly raising the restoring horse shelter air temperature. When the temperature in the relieving stable is around 75 °C, the typical method for completing the process of restoring is to have something like 10% water in the wood. The cured tobacco leaves are then delivered to manufacturing facilities for the finishing touches of production, including the manufacture of tobacco and filters, the assembly of cigarettes (and other products), packaging, storage, and distribution[4].

1.3 Reference flue- curing cycle

Cluster handling for relieving tobacco requires close to seven days. The regular temperature and moistness pattern for conventional ready tobacco during the relieving time frame is displayed in Figure 2. Regardless of the way that each stage endures about 48 hours, the genuine time required may vary. The yellowing stage regularly endures 72 hours, making the total cycle precisely one day Temperatures of 60 °C close to the completion of the leaf-drying stage and 75 °C close to the completion of the stem-drying stage are possible. During the yellowing stage, the commonplace temperature increment is between 0.3 °C/h and 0.4 °C/h.

As a matter of fact shown, the reference working with cycle is an overall helper, and the specific arrangement followed may change depending upon the turn of events and status of the tobacco, the environment during the creating and harvesting seasons, wind flow, and various variables. Tobacco assembled from grouped fields on a comparative farm could fix distinctively when presented to a comparable reestablishing environment[5].

1.4 Drying

Using solar, electric, or fossil fuel energy effectively to dry agricultural products will help to significantly reduce post-harvest losses. Despite the fact that drying has been a common occurrence since the dawn of time, technological research on the subject only started in the middle of the twentieth century. For agricultural products to be preserved, drying is essential [6].

The world's largest source of energy is becoming solar energy. If there were no atmospheric layer, the sun, which is 1.39x109 m in diameter and is 1.495x1011 m from the planet, would radiate 1353 (W/m2) of energy onto a surface perpendicular to its rays. 170 trillion (KW) solar watts are received by the entire planet. Yet again under 0.5% of this energy is used in major areas of strength for the of the breeze, waves, and plant photosynthesis, while 30% is reflected into space, 47% is changed over totally to low temperature heat energy, 23% is used for the biosphere's dispersing and speeding up cycle, and 30% is used for this energy [7].

The most generally involved innovation for drying farming items is sunlight-based energy. The drying system is vital to the food business since edibles contain water as free particles that can take part in substance or microbial responses or capability as impetuses to hurry the decay of the item. In this way, decreasing or, in any event, disposing of the water in food items can make them last significantly longer [8].

One of the oldest, simplest, and most widely used drying techniques among rural farmers is the traditional open-air solar method. The interaction requires a little beginning speculation, a sizable drying region, and takes time and is often unhygienic. Mechanized dryers, which are by and by liked to the conventional external sun drying system, dry things all the more rapidly yet are energy-requested to run since they utilize a great deal of petroleum derivatives or power. Studies have shown that while the underlying expense of sunlight based dryers is exorbitant, the lifetime cost of drying is just 33% of the expense of dryers that utilize customary fills, making sun-oriented drying a predominant drying strategy [9].

The majority of farmers in the majority of developing countries cannot afford the high expenses associated with utilizing fossil fuels to dry their crops[10]. The method of solar drying employs unrestricted, free energy without harming the environment, lowering CO2 emissions and stopping other byproducts of burning fossil fuels from falling as acid rain. Because there is at least seven (7) hours of sunlight every day in the tropics, solar energy can be used to dry agricultural products[11]. A daily solar radiation dose of 7.4 to 7.6 KWh/m2 is received by Ethiopia. The majority of Ethiopia receives this copious solar energy, which is on the order of 7-8 KWh/m2, daily for over 6–8 hours. The two kinds of sun drying frameworks are both dynamic and detached sun oriented energy drying frameworks. Immediate, backhanded, and blended mode sun based dryers are the three sub-classifications into which sun oriented dryers are additionally separated. A different gatherer warms the approaching wind stream in a blended mode sun powered dryer before direct daylight warms the wind stream and the item. Natural convection sun dryers of various sorts have been compared, and it has been found that the mixed-mode variety has the fastest drying time [12].

1.5 Types of solar dryer

As indicated by the strategy for drying, like direct sun-powered drying, circuitous sun-based drying, and blended mode sun-powered drying, sun-oriented dryers can be named either normal-flow or constrained-course dryers. They are additionally partitioned into lots in light of how the drying segment is constructed. The characterization of sun-oriented dryers and their drying modes are displayed in Fig. 2. **[13].**

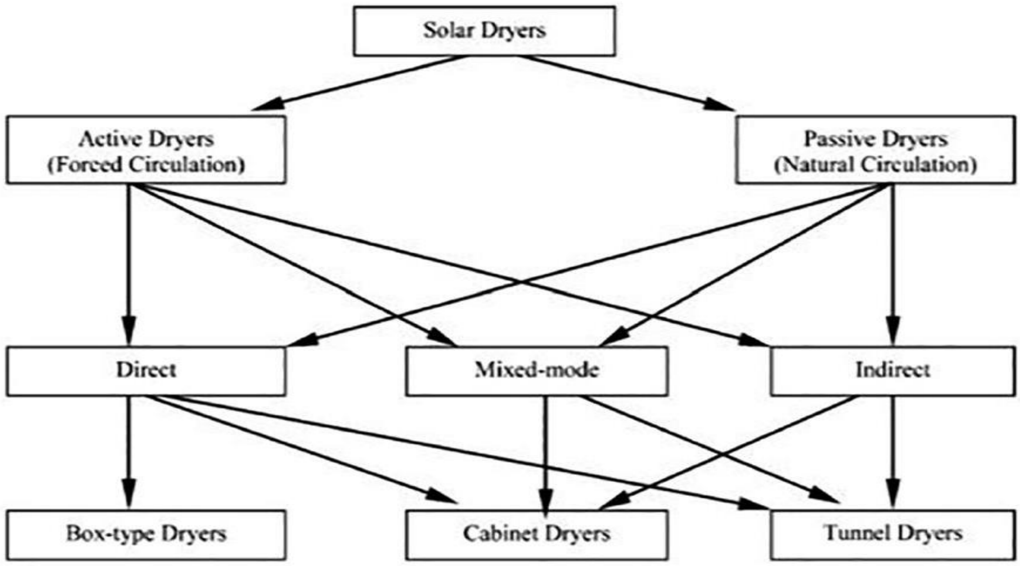


Figure 1-2. Classification of solar dryers[14]

1.5.1 Natural convection solar dryers (passive dryers)

1.5.2 The normal convection sun based dryer works on the possibility that after the air inside is warmed by sun powered energy, the overall stickiness of the air will diminish and ascend through the drying system. This air will haul dampness out of the item and set it back up high around it**[15].**

1.5.3 Forced convection dryer (active dryers)

1.5.4 The air in the sun dryer is warmed by sun powered energy, which makes the overall dampness lessening and ascend through the drying system. This is the manner by which the constrained convection sun oriented dryer works. With the assistance of an exhaust fan, this air will rush out of the item and dispose of any dampness **[16].**

1.5.5 Open sun drying (OSD)

The simplest strategy for drying farming items, for example, natural products, vegetables, food grains, fish, spices, milk items, and so on, is open sun drying. In this technique, the substance is fanned out daintily on the ground, left in the sun, and dried to a protected degree of dampness.

1.5.6 Indirect Solar Dryer (ISD)

This approach does not expose the crop to the sun directly, as the name would imply. A surface that is typically referred to as the collector absorbs solar light and transforms it into heat. This surface is ignored to warm the air that will be utilized to dry the food, which is hence used to dry the food thing inside the drier. The capacity to oversee temperatures is the essential advantage of backhanded drying. In contrast with direct sun dryers, the sizes can go from kilos to metric tons, however they are more costly and challenging to assemble.

Direct Solar Dryer (DSD)

What is to be dried is acquainted straightforwardly with sun-filled radiation through an unmistakable material that covers the arrangement. The power conveyed by the sun-based energy is utilized to dry the yields or food things and, also, heat up the normal factors. The principal inconvenience of utilizing the immediate mode is that the intensity that will be consumed by the thing can't be controlled. The item is accessible in many sizes, going from kilograms to metric tons. The straightforwardness of the item and its reasonableness are its USPs.

1.5.7 Mixed Mode Dryer (MMD)

The material to be dried and the air that has already been heated in the solar collector work together to make the heat that is needed for the drying process [17].

1.6 Applications of solar driers

Solar dryers can considerably increase the amount of food that is available in developing nations by reducing post-harvest losses. Estimates of these losses are typically in the range of 40%, but they might reach about 80% in really unfavorable circumstances. A lot of these losses are caused by cereal grains, pulses, tubers, meat, fish, and other foods that are dried too quickly or in the wrong way. The decrease of these misfortunes and waste is critical, especially when there is an ensuing bungle among market interest during the slow time of year for gathering. Because of this growing business sector potential, tobacco must be accessible in a more viable structure, which has sparked innovation for its conservation and handling, especially in a dry structure.

In this review, the presentation of a blended mode sun powered bureau dryer was inspected corresponding to the shift point, cut thickness, tobacco leaf assortment, and method of approaching wind stream rate.

The best-fitting drying kinetics model and CFD simulation were chosen as part of the research. Cut new tobacco leaves were used as the unrefined substance to evaluate the viability of a blended mode sun based bureau dryer. [18].

1.7 Problem Statement

The issue of two different drying temperature ranges makes drying of tobacco leaves and stem very difficult to achieve.

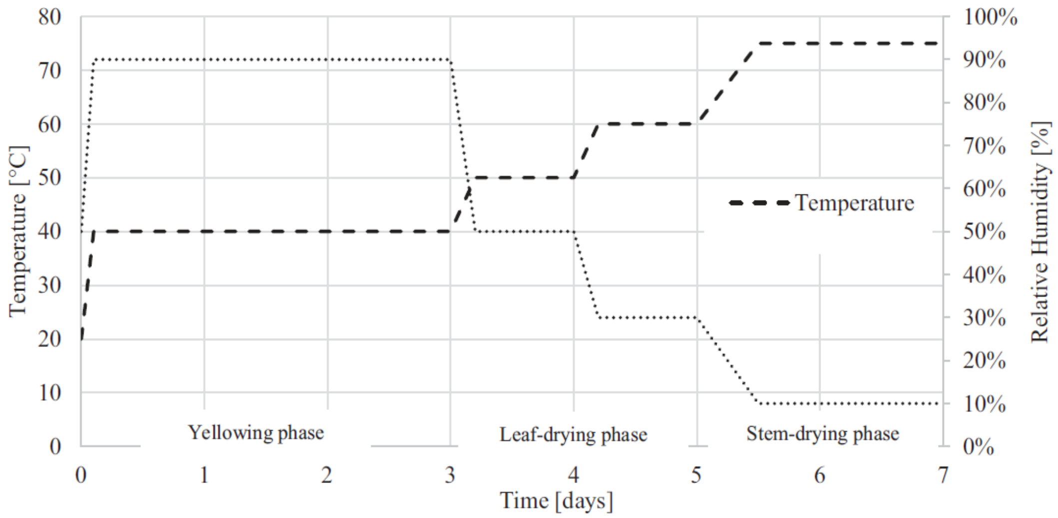


Figure 1-3. Six-day restoring cycle for typical ready tobacco, adjusted for Italy from David Reed [6]

The objective of the ongoing review is to inspect the presentation of an original blended mode sun-oriented bureau dryer for drying tobacco. With the proposed design of the bureau dryer, tobacco leaves and stems can be dried independently in parts that are near the right temperature range.

1.8 Scope and Limitation

According to the assessment of the literature, not many studies have been done to look into this novel form of mixed-mode solar dryer. This study focused on the following issues:

- To develop a solar air dryer capable of drying tobacco stems and leaves in the same cabinet.
- Design an experiment to validate a numerical model
- Perform parametric analysis using a validated numerical model.

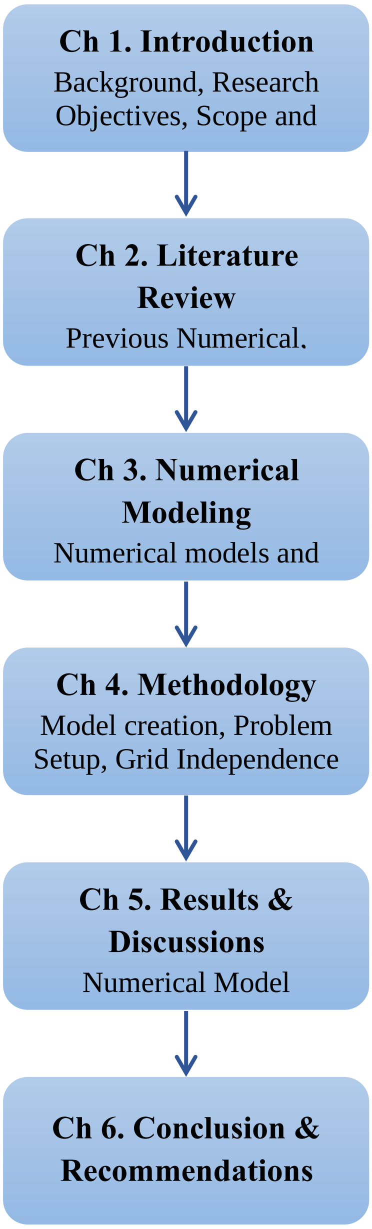
1.8.1 Scope

The issue of two separate temperature ranges for drying makes it extremely difficult to dry tobacco leaves and stems. The objective of the ongoing review is to inspect the presentation of an original blended mode sun oriented bureau dryer for drying tobacco. With the proposed plan for the bureau dryer, tobacco leaves and stems can be dried independently in parts that are near the right temperature range.

1.8.2 Restrictions

In order to conduct the study, numerical modeling is used; as a result, assumptions are made in order to model the issue. Due to limited computational resources, turbulence modeling—which has good accuracy and is currently used most frequently—is used in ANSYS simulations. However, LES and DNS provide a solution with a high degree of precision. Due to the availability of sunshine, the study is only carried out under daytime conditions for the design conditions. The primary focus of the research is simulations at design conditions.

1.9 Organization of thesis



Summary

The history of the solar cabinet dryer and the reasons for switching to renewable energy are discussed in this chapter. The solar cabinet dryer's benefits and drawbacks are described in the background. The solar cabinet dryer's operating concept is explained, and the necessary components are thoroughly covered. This chapter discusses the study's scope and constraints. The chapter includes a presentation of the study's goals.

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CHAPTER 2

LITERATURE REVIEW

2 Literature Review

2.1 Introduction

Agricultural items must be dried in order to be preserved. Moisture is taken out of the items through the drying process. Temperature and humidity must be kept under control for drying to happen quickly and safely, which improves the quality of the product [1].

2.2 Tobacco Leaves

Help long conceive a technique for easing tobacco leaves utilizing the sun. An assortment of 38.5 m2 level plate daylight based air radiators, a 6 m3 rock-bed unit, and a cut back (1:4 scale) tobacco reestablishing horse cover with a 1 tons new leaf stacking limit made up the preliminary model structure. To create forced convection all through the structure, one 1.5 kW and one 0.75 kW blower were utilized. Direct utilization of LPG as a fuel for supplemental warming was made. It was found that a common fuel investment fund of 28% was practical. The typical warm proficiency, which is not entirely set in stone, is 40.5%. The rock-bed thermal storage unit's overall effectiveness remained debatable [2].

The tobacco leaf is extremely sensitive to variations in the technological parameters throughout the dehydration process [3]. It is difficult to pinpoint how the tobacco leaf interacts with its surroundings. So, a way was found to figure out the most important thermo physical and transport properties of the leaf. This was especially true for the binding and diffusion energies of water in tobacco or other agricultural products, such as how the surface temperature changes and how much heat moves through the leaf [4].

The basic features of dried tobacco leaves may be determined using a variety of applicable theoretical and experimental methods, so we had a number of appropriate systems to use during our research[5]. One effective technique used a numerical method to statistically manage the drying of the essential tobacco leaf components [6]. A computer programme might track the ongoing changes in the surface temperature and dryness of the entire leaf. This tool worked well for using our measurements to estimate the model's parameters [7].

2.3 Other type of solar dryer

The farming food to be dried is kept inside a design with clear covers and side boards in a direct sun powered dryer. The harvest and its fenced in area get hotter in light of the fact that the yield assimilates sun powered energy, which warms up within surfaces of the drying chamber [8]. Such dryers are fitting for where direct light can be gotten for longer periods during the day [9]. Direct sun-based dryers can be named association dryers and tent dryers using regular convection with solidified drying and finder chamber [10]. Figure 2.1 shows the trial of the department dryer. It is usually delivered in a wooden box that is secured at the bottom and sides. The material to be dried is kept on a penetrated plate. Air coming from the lower a piece of the division goes through the openings and leaves through the upper ventilation openings, keeping a brand name air course [11]. To avoid the effect of covering by the sides, the length of the division dryer should be more essential than its width on various events. The roof should be slanted to avoid the party of water during fierce periods. Versatile power dryers can be made using wood or metal; regardless, for fixed structures, stone, block, mud, or concrete could be used. For the best inside temperatures, the base and sides of the division should be protected with a layer of something like 50 mm of sawdust, dried grass or leaves, coconut fiber, bagasse, or wood shavings. Plastic cross regions or work can be used to encourage the drying plate [10].

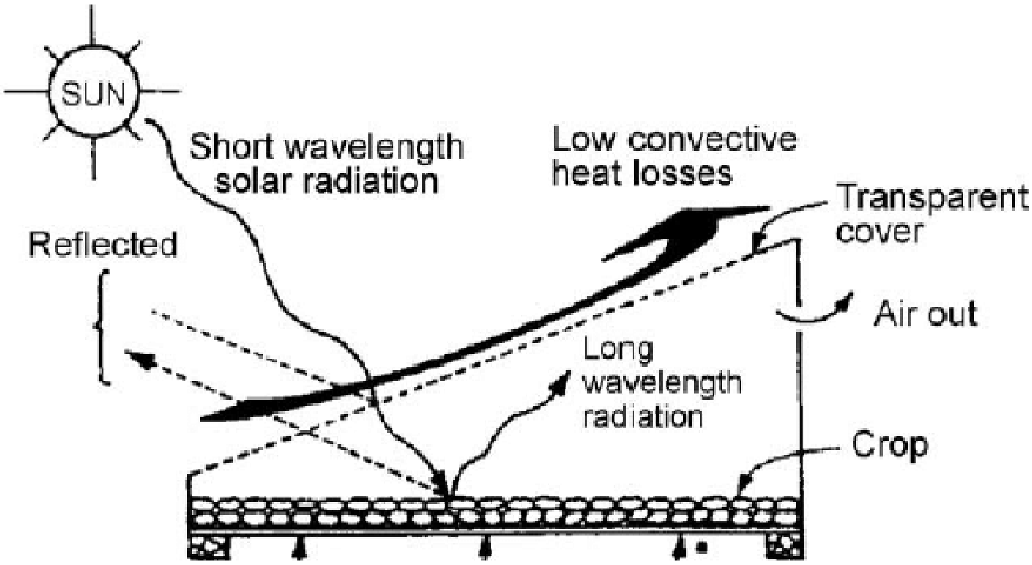

Figure 2-1. Sketch of direct mode solar dryer [8]

Raju [12] planned and built a cabinet-style direct solar dryer. In two days, it dried a batch of 20 kg of fresh veggies, including tomatoes and chilies. The dryer was innate in India, and exploratory drying tests were run on a dryer model with a daylight based finder area of 1.03 m2. The sides of this dryer, which measures 100x103x76 cm3, are made of stirred steel, while the base is made of wood. A piece of glass was utilized as the cover, and a 5 cm air opening was placed in it. The ideal temperature for the sunlight based controlled dryer was supposed to be 60 °C with an inlet air temperature of 30 °C or the surrounding temperature. At the end of the main day of using this drier to dry 3000 grammes of potatoes, the outcome weighed 1180 grammes rather than 1550 grammes while drying a similar amount in the open sun. On the subsequent day, the potato's last weight diminished to 550 grammes while utilizing the dryer, compared with 920 grammes with outdoors drying. In roundabout sun-oriented dryers, the air entering the drying bureau where the harvests are set is warmed by utilizing a sun-based gatherer. Convective intensity moves between the wet yield and the hot flying corps, the hot air through the drying bed to dispose of the water [13].

Svenneling [14] created and evaluated an indirect solar dryer for drying pineapples. 1.05 m2 is the size of the solar collector, and there is a 0.2 m gap between it and the air duct. Metal sheet was used to construct a 0.1 m diameter, 1.2 m long chimney that connects to the drying chamber. When pineapple slices were dried in a lab for five hours at 70 °C, the case hardening process occurred. However, it took the pineapple slices dried at 50oC for roughly 23.43 hours to obtain 10% moisture content. The chunks were now pale and light yellow and were ready to be consumed. Insufficient oven ventilation was blamed for the extended drying time in the experiment. The drying chamber and collector attained temperatures of roughly 50°C and 60°C, respectively, when the solar dryer was operating at the test site. In no less than 16 hours of daylight, the moisture content dropped from 90% on a wet premise to generally 10%. Moreover, it was found that the base level, which is nearer to the gatherer, had a quicker drying rate than the higher level. Moringa is dried in a roundabout, constrained traditional sun-crop dyer that has been planned and assembled. The drying load for the dryer is a social event of 2 kg moringa leaves that had a key wetness content of 80% and anticipated that 1.556 kg of water should be discarded to be dried to the ideal sponginess content of 10%. A drying season of 24-30 hours is normal for the organized test locale (Kumasi; 6.7oN, 1.6oW), with a conventional normal sun power of 320 W/m2 and integrating territories of 25°C and 77% relative dampness. As per the plan, 0.62 m2 of sunlight-based assembling region is expected to accomplish the expected dry productivity of 25%. The dryer was produced using parts that were effectively open nearby. In an alternate report, a sun-powered drier with roundabout constrained convection and coordinated heat capacity was made, tried, and readied for drying bean stew. The dryer's capacity to store heat makes it conceivable to keep a steady inward air temperature. The utilization of intense center amassed material additionally becomes the drying time by something like 4 hours of the day. They arrived at the assurance that an obliged convection sunlight based fueled dryer ends up being better for making incredible dried chilies [15].

Figure 2-2. Indirect forced convention solar dryer [12]

The drying cabinet is the most crucial part of the dryer. The use of computational fluid dynamics (CFD) algorithms in this situation is a practical method of evaluating the airflow parameters. This technique aids in determining which design modifications are most essential to improve performance. This approach was employed in numerous investigations[16-18].

A relative report between blended mode sunlight based dryer in with and without nuclear power stockpiling materials has been performed by Lakshmi et al [19]. Amanlou Y. et al. I examined a brand-new drying cabinet design. They discovered that raising the input size raises the drying air temperature as a result. The speed transport is furthermore advanced by developing the disparity point, and moving the air gives to highlight the middle outcomes in more uniform speed dispersing at the plate zones. The air distribution along the edges of the dryer chamber would be less whether the air outlet was cleared out of the game plan [20].

M. Suhaimi Using the CFD approach, et al. developed a two-dimensional simulation of a tray dryer system. They found that where the trays are placed affects how the air flows, and that adding a baffle makes sure that each tray gets the same amount of airflow and dries faster [21] .

Execution of a sun based dryer with reinforcement incinerator was assessed by Barki [22] in Makurdi, Nigeria . The level plate authority, drying chamber, and incinerator were the mixture sun based dryer's three essential parts. The 0.82m2 solar collector is made of thick clear glass and is supported by a hardwood frame. The absorber plate is 0.14m deep. The drying chamber is related with an incinerator with the accompanying aspects: 49 cm x 124 cm x 40 cm, which can be utilized as an extra force source. The biomass drank in the incinerator was charcoal, and the force was moved by using water that was permitted to stream by gravity. A heap test was conducted utilizing ground cassava with an underlying dampness level of 69.8%. In contrast with the combined sun powered incinerator dryer, which required 16 hours to dry out the ground cassava test to a dampness level of 47.48%, the sun-based dryer alone required 12 hours to lessen the dampness content to 47.19%. Both the open sun drying (control) and the incinerator dryer required 20 hours to obtain their respective moisture content levels of 47.99% and 47.01%. He assessed the effectiveness of the solar and solar incinerator dryers using open sun drying as a control. This recommends that analyses directed at different periods be utilized to think about the presentation of the sun-oriented dryer and the joined sun-based incinerator dryer.

While testing the sun-powered dryer alone versus the sun-based incinerator dryer, the encompassing temperature and dampness will vary; it could be more radiant or overcast. A more precise examination might have been conducted on the off chance that a subsequent comparable plan that took into consideration synchronous testing had been made.

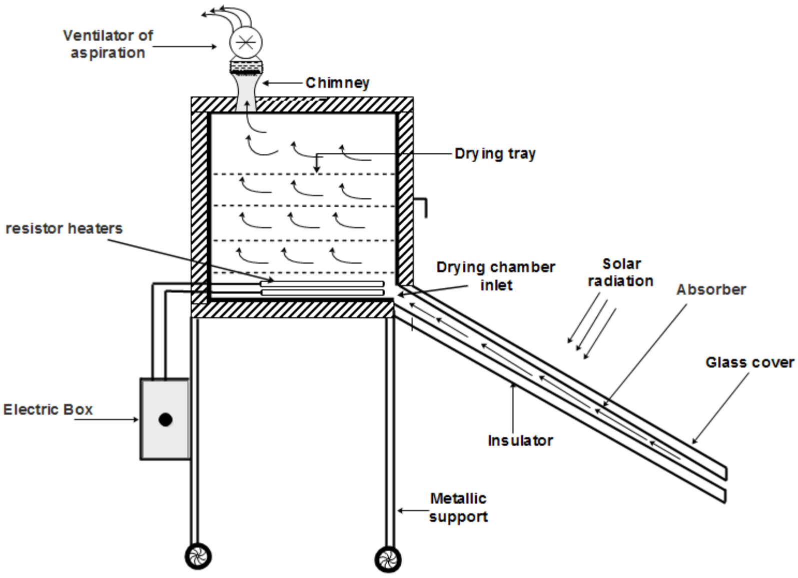

Figure 2-3. Sketch of hybrid type solar dryer [19]

The viability of the gatherer essentially affects the presentation of the sun-drying framework. Along these lines, many tests have been completed to work on the presentation of the sun-oriented dryer Belhamri[23] explored a straightforward, affordable, and efficient solar batch dryer for agricultural products. A heater is utilized when the sunshine is scarce. The dried item was chosen in light of the onion's fast degeneration trademark. The outcomes showed that drying relies on the outside layer of the locater, the temperature of the air, and the properties of the thing.

Muller et al. [24] dryer with a finder area of 16.8 m2 was organized and implied solicitation to dry 195.2 kg of new mango (100 kg of cut mango) from 81.4% to 10% wet reason in 2 days under encompassing circumstances during the gathering season from April to June.

Ismail et al. [25] In light of primer exploration for mango cut drying under controlled conditions, planned and fabricated a sunlight based drier. During the harvesting season from April to June, the proposed drier with a finder area of 16.8 m2 was expected to dry 195.2 kg of new mango (100 kg of cut mango) from a 81.4% moistness level to 10% on a wet reason in 2 days.

Mujumdar et al. [26] examined the new drying techniques and a selection of current advancements relevant to postharvest processing. They included heat siphon-helped drying with multimode and time-fluctuating intensity sources of info, low and climatic strain superheated steam drying, changed climate drying, sporadic bundle drying, osmotic pretreatments, microwave-vacuum drying, etc; which were all associated with their survey. Sarsavadia [27] sunlight based helped constrained convection drier was made to research the effect of wind current rate (2.43, 5.25, and 8.09 kg/min), air temperature (55°C, 65°C, 75°C), and part of reused air (up to 90%).

A novel form of effective solar dryer with a setup to collect the most solar radiation via the absorber plate was created by Sreekumar et al [28]

Abene et al. [29] Ramana Murthy [30] investigated different solar dryer applications for small-scale food product drying.

Exploratory assessment on the impact of various working elements on drying potential and drying time was driven by Karim et al.[31] focused on likely the effect of different working elements on drying potential and drying time. A propagation and smoothing out approach was used by Smitabhindu et al. to decrease the drying cost per dried banana unit.[32]

2.4 Mixed mode solar dryer

Mixed mode the sun dryer is a half breed of the immediate and roundabout assortments. The sun's immediate beams and the utilization of warm air assist the item with drying [33]. Air is warmed in a gatherer prior to being conveyed to the drying chamber, which has a glass cover over the top. which is prepared to do straightforwardly engrossing sun powered energy. As opposed to coordinate sunlight based drying, the drying rate is expanded as such[34].

A mixed mode sun powered dryer was worked by Olalusi and Bolaji for food safeguarding. After 12 o'clock for about 3 hours, it was found that the drying chamber's inside temperature came to 74%. The drying rate was 0.62 kg/h, and the framework effectiveness was 57.5%.[35]. Tripathy and Kumar provide details about the dryer that has a series-connected flat plate collector. They utilized this dryer to dry potato slices with a 0.05-meter diameter and a 0.01-meter thickness. [36].

Immediate and circuitous sort sun oriented dryers' basic characteristics are joined in blended mode sun powered dryers[37]. Two strategies are utilized to get the intensity expected to dry the produce: direct sun powered protection on the produce and pre-warmed air from the sun based authority [38].

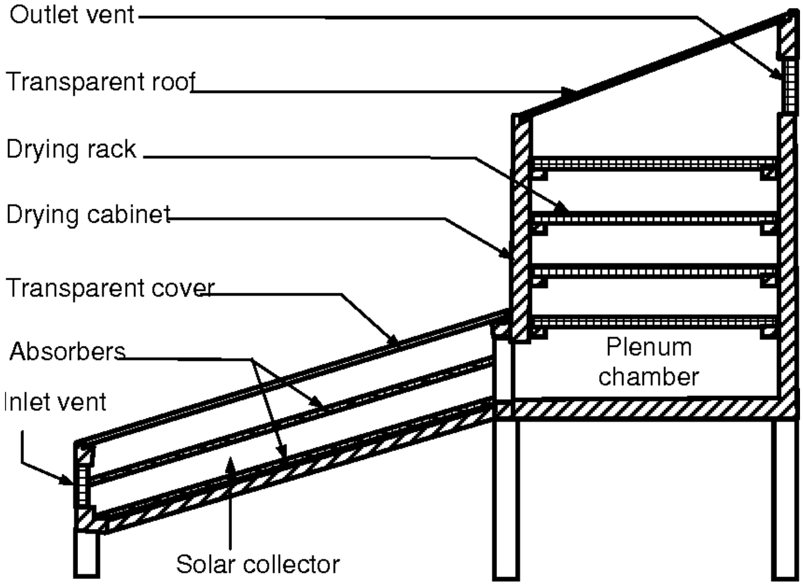

Figure 2-4. Sketch of mixed mode type solar dryer[39]

A cheap mixed-type solar cabinet dryer was created by Basumatary. The drying chamber is made of wood, with a metal interior coating and a translucent plastic paper exterior [40].Although non-corrosive stainless steel can be used to make the drying trays, the authors chose to utilize bamboo nets due to their reduced cost. The solar collector is built of non-corrosive galvanized iron (GI) sheet that has been painted a deep black color and is covered with either clear glass or plastic paper. The upper tray's average measured temperature during the experiment, which was conducted on a bright, sunny day, was 63°C, whereas the surrounding air's temperature was 31°C. Another dryer that they created connected three solar collectors to the drying chamber. The dryer temperature in this instance is 2°C higher than it was for the dryer with just one collector [38]. Stew dried persistently for 7 hours on a brilliant day, eliminating 48.72% of the dampness from the upper plate and 33.03% from the lower plate. At the point when it was sun dried in a similar climate, just around 15.38% of the dampness content was taken out from the bean stew. The mixed-mode solar dryer was built with the purpose of drying low-moisture food items including cauliflower, turmeric, and pepper. This might restrict farmers that grow crops with high moisture content, like fruits, from using the drier. Additionally, only a full sunny day was used by the writers to report on this dryer's performance. Its assessment on days with less sunshine or clouds was excluded. [41].

Forson created and distributed a blended mode normal convection sun dryer, with Kumasi, Ghana, filling in as the test site for their trial. An air-warmer (essential gatherer), a drying chamber, and a still up in the air to be the dryer's three essential parts. The drying chamber's top cover and sidewalls are straightforward so they can go about as auxiliary gatherers.[42] . The dryer was used to dry cassava and the drying limit was outlined to be 12.3% with a drying time of 35.5 hours. With 162 kg of test load, a 28.2oC mean wrapping temperature and a beginning sogginess content of 66%, the last suppleness content of the dried thing was assessed to be 17.3% while the temperature of the warmed air in the air more steamy rose by around 10.9oC.Forson's examination report gave a definite methodology on the best way to plan a solar-powered dryer. Fundamental plan ideas and dependable guidelines were likewise illustrated in the paper. In like manner, their plan for a sun-based dryer required 42.4 m2 of sun-powered gatherer for the normal drying effectiveness.

Bolaji et al. [43] fostered a basic and economical blended mode dryer from privately obtained materials. Bukola et al. [44] We tentatively settled the mixed mode sun oriented controlled dryer's show assessment for food security. In the early evening, the temperature inside the vanishing authority rose by 74% for very nearly 3 hours. The system's efficiency was 57.5%, and the drying rate was 0.62 kg/h.

Kumar et al. [45] Using a brand name convection mixed mode sun dryer, tests were done on potato chambers and cuts with a general thickness of 0.01 m and a close to length and width of 0.05 m. This was finished to figure out the convective power move coefficient.

Research Gap

Broad work has been finished in the writing using trial and mathematical methods. The proposed authority drier arrangement, which engages the drying of tobacco leaves and stems specifically separates close to the reasonable temperature range, has, in any case, got decently little thought. To the best of the creator's information, no work has been finished in which both the stem and the leaves were dried in a similar bureau.

Summary

The characteristics, qualities, and basic operation of the solar cabinet dryer—whose mechanical and methodological feasibility has previously been established—are reviewed in this chapter for maximum efficiency. This technique has shown to be highly straightforward and practical because it just requires daytime operation yet has a higher impact on all other technologies. Discussions include exploratory investigations, experiments, and prototype simulations. The solar cabinet drier has been demonstrated and validated as a promising technique for usage in the future. The study's need for more research is emphasized.

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Chapter 3

Methodology

3 Material and Methods

The main goal of this chapter is to mathematically state and explain the governing equations employed in this numerical analysis. The benefits and drawbacks of various computational fluid dynamics are discussed. The turbulence model's governing equations are described. Mathematical discussion and explanation of the radiation model used to simulate solar radiation. A grid independence analysis is done to look into how the sensitivity of the mesh affects the solution. The mesh that performs the best and is closest to the experimental data is chosen. The study's presumptions are described. The issue setting's solver configuration is described in full.

3.1. Setup of the experiment

Prompt and underhanded sun dryers fall under the grouping of "sun-based drying. In direct sun-based dryers, the tobacco leaves are set inside an air heater alongside sun radiation that enters through a sensible cover and is then consumed by the tobacco leaves. Fundamentally, radiation to the top layers and coming about conduction into the grain bed produce the power expected for drying. In any case, in backhanded dryers, sun-controlled energy is trapped in a substitute sun-based locater (air radiator), and the warmed air then, at that point, moves through the grain bed. Be that as it may, in a blended mode dryer, warmed air from a substitute sun-arranged locater flows through a grain bed while the drying office straightforwardly holds sun-arranged energy through the reasonable walls or roof. The objective of this work is to make a "Mixed mode" sun-coordinated dryer in which the tobacco leaves are dried simultaneously by both warm air from the sun-enabled dryer and direct radiation investigating the reasonable walls and top of the division. The parts expected to manufacture the mixed mode daylight based dryer are efficient and expeditiously open in the neighborhood market. The sun-based gatherer (air warmer), drying bureau, and drying plate are displayed as the dryer's essential parts in the graph beneath.

Figure 3-1. Cross - Sectional View of the mixed mode solar cabinet dryer

3.1.1 System Components

The solar dryer is comprised of a drying bureau, drying plate, and a sun based gatherer (an air heater): Collector

3.1.1.1 (Air Heater)

The solar air heater's heat absorber (inner box) was built from well-seasoned wood and painted black. The translucent cover that encloses the air flow channel makes up the solar collector assembly (glazing). Since the mesh and back plate retain the sun based energy that comes in through the unmistakable cover, a shield network screen set somewhere close to the glass cover and the defend warms the air capably.

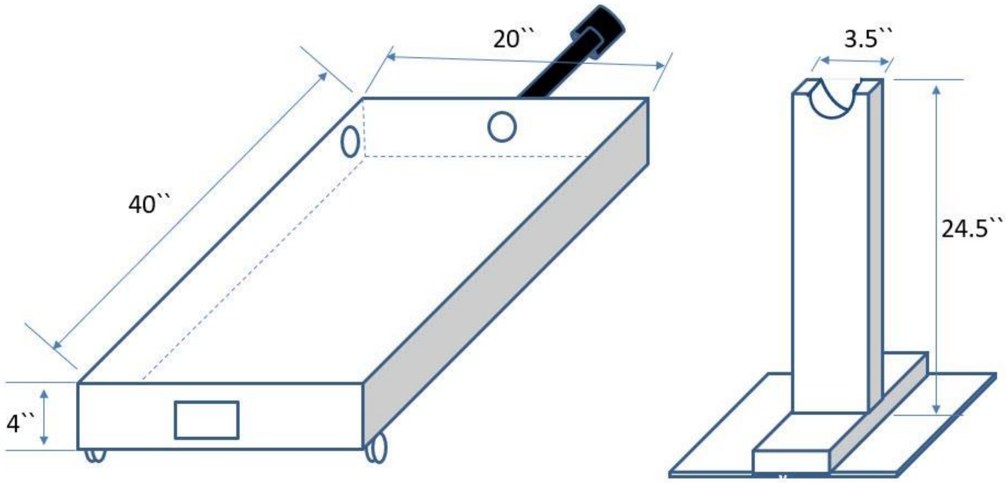

Figure 3-2. Dimension of Solar Air Heater

Figure 3-3. Front and side of solar air heater

3.1.1.2 The Drying Cabinet

Termite and atmospheric attacks could not harm the well-seasoned woods used to construct the drying cabinet and the dryer's structural frame. To work with and deal with the convection stream of air through the dryer, an outcome vent was added to the front and upper completion of the department. There was moreover an entry doorway to the drying chamber at the front of the authority. Transparent acrylic sheets 4 mm thick are used to cover the cabinet's roof and front side walls, providing additional heating.

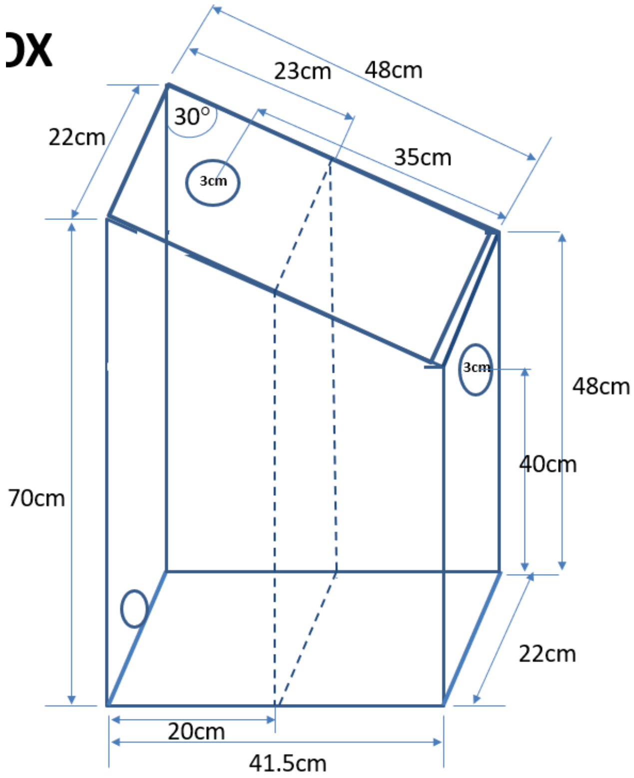

Figure 3-4. Dimension of Dryer Cabinet

Figure 3-5. Cabinet Dryer

3.1.1.3 Drying Trays

The drying plates, which are housed inside the drying chamber, are made of a two-layer fine chicken wire network with a genuinely open desire to allow drying air to go through the food things.

3.1.2 The Sun powered Gatherer's direction

The level-plate sun-oriented gatherer is constantly disposed and situated to exploit as much sun-based radiation as could be expected during the planned use season. Due south in the northern half of the globe and due north on the southern side of the equator are the best fixed directions. Along these lines, the sun-oriented gatherer in this piece is pointed south and slanted 30 degrees from the east. This inclination likewise works with simple water overflow and further develops the wind stream.

3.1.3 Resources needed to develop a solar dryer:

The components that go into making the solar dryer are things we use every day. And they are conveniently located near our area.

1) Plywood

2) Hammer

3) Nail and Glue

4) Wired Mess

5) Acrylic sheet

6) Thermocouple

7) Black Paint

3.1.4 Instruments and equipment

The following devices and tools were utilized to do this study:

- **Anemometer:** The channel air speed of the gatherer and fan was estimated utilizing a Computerized Cup Anemometer (PYLE®) with an exactness of 0.1 m/s.
- **Data Logger:**Temperature and relative dampness were estimated utilizing information lumberjacks (HOBO® temp/RH lumberjack, Onset®, and ACR temperature lumberjack) at every plate and different areas in the authority

3.1.5 A description of the experiment

Because of a tension slope, natural air enters the bureau through the air input stream. For a blended mode solar powered bureau dryer, the calculated straightforward plastic sheet and the highest point of the straightforward plastic sheet permit sun beams to enter the bureau. Exactly when they get to the sun-situated finder, which fills in as a circumlocutory force source, they are changed into heat energy, which raises the temperature inside. As opposed to a prompt energy source, where sunshine directly warms the tobacco leaves, heat energy is transported to the plate dwelling the leaves. The tobacco leaves vanish ensuing to emanating water exhaust when they are warmed. Hot, sodden air gradually ascends to the highest point of the drying chamber (stack) and leaves the dryer through the air outlet at the top.

3.2 Numerical modeling

The density model, turbulence model, and radiation model were discussed together with an overview of the governing equations of the numerical model. The CFD pretreatment and processing procedures are also covered in this chapter. The creation of geometry and numerical modelling is covered in detail. First, the geometry is made. Utilizing Solid Works, the redesigned cabinet profile was produced. The ICEM CFD generates the geometry and mesh. The ICEM CFD generates the quadrilateral mesh. For the boundary conditions, the boundary conditions are defined. Material choices are made for the components, such as the ground, glass roof, and chimney.

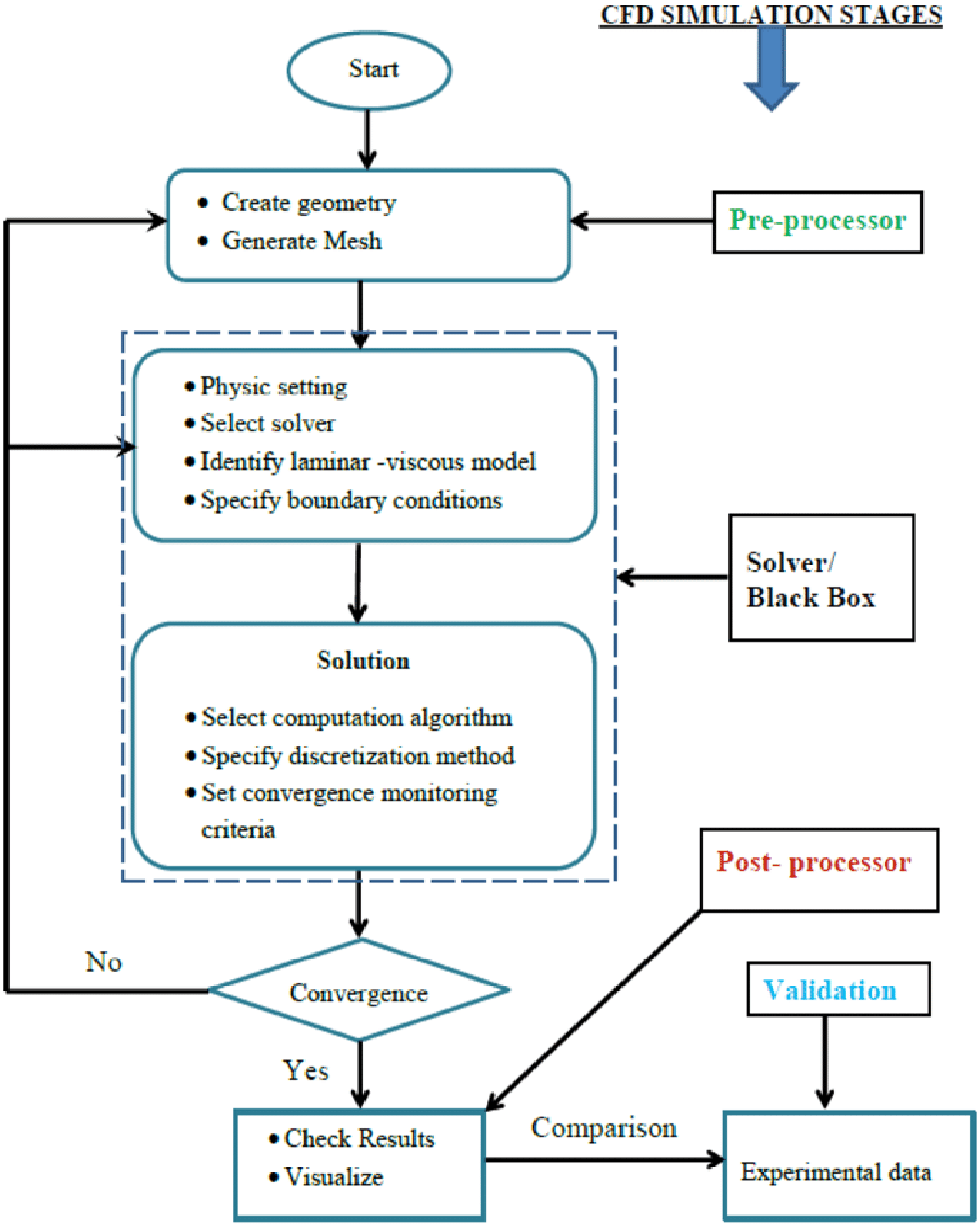

Figure 3-6. Flow chart of methodology for numerical modeling [1]

3.1.6 Design of Solar Dryer

Fig. 1 portrays the numerical methodology of the sun-organized power dryer. A blower and a flatbed vanishing chamber make up the sun-controlled office drying system. The drying room is 1.5 meters long and 1.0 meters wide. With a 0.12m opening between each plate, there are fifteen on the left side and eleven on the right. The drying structure is a compelled convection mixed mode type, and the dryer's place of propensity was changed as per 30o with its face southward. A blower is associated with the power source to draw in air. The sunlight based bureau dryer is intended to hold 50 kg of equally scattered tobacco leaves that have been partitioned into eight plate. One part of the bureau dryer will be utilized for stems, and the other area will be utilized for leaves. Interestingly, with leaves, the stem requires a higher temperature to dry. At the point when the essential temperature is reached, the dried leaves will be taken out, and the drier will then, at that point, be warmed to the important stem temperature.

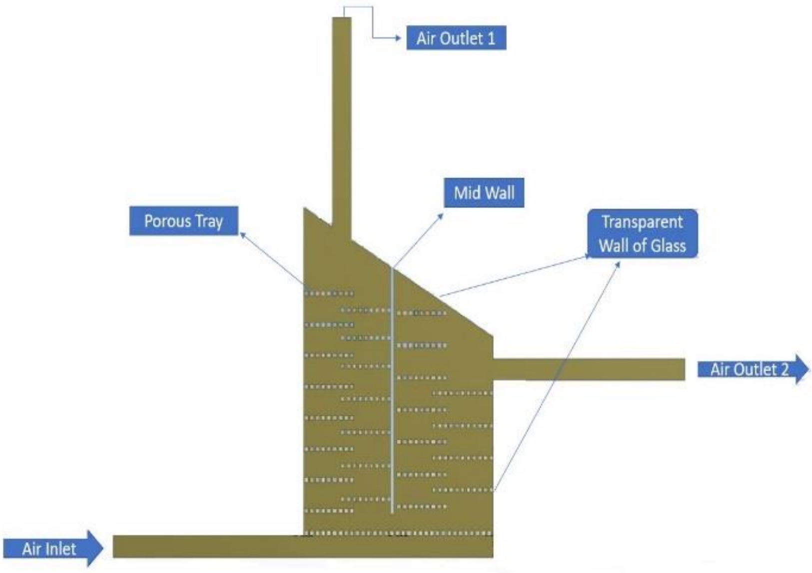

Figure 3-7. Schematic sketch of the solar cabinet dryer

3.1.7 Design considerations for solar dryer

- **Temperature-**Tobacco leaves should be dried in any event of 40 °C and a most outrageous temperature of 75 °C; in this manner, 45 °C and higher is seen as typical.
- The productivity of a sunlight based dryer is alluded to as the proportion of a gadget's usable result to its feedback.
- Dryer plate made of aluminum can be used to course air inside the drying chamber. The gives to be placed on the plate are safeguarded from direct sunlight by the dryer chamber's arrangement, which uses wooden wall sides and a glass top that is skewed.

3.1.8 Meshing

Meshing is used to analyze the temperature variation in the dryer's interior. ANSYS 19.1 software is used to create the hexahedral mesh for the domain in order to get correct results (Figure 2). Six mesh layers make up the boundary layer. To account for temperature change at the dryer's edges, the cabinet is composed of 5 mm of material with a 1.2 growth factor.

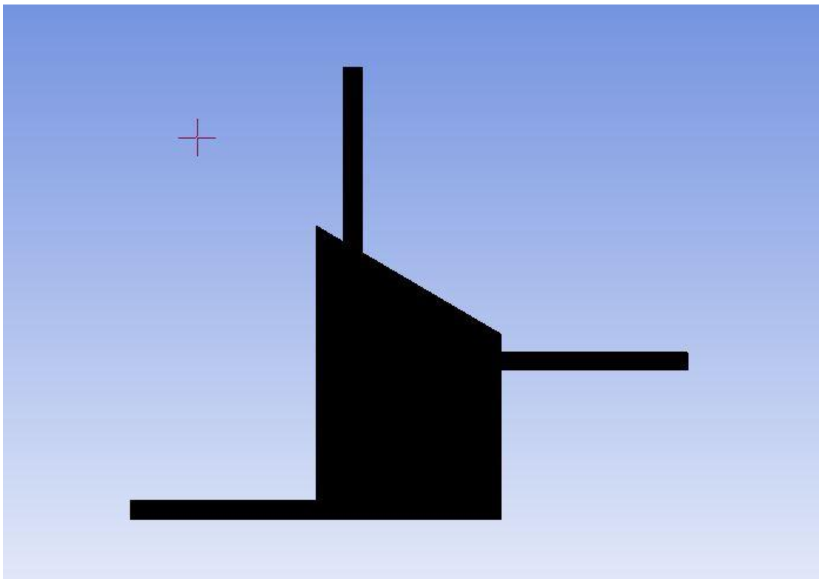

Figure 3-8. Full View

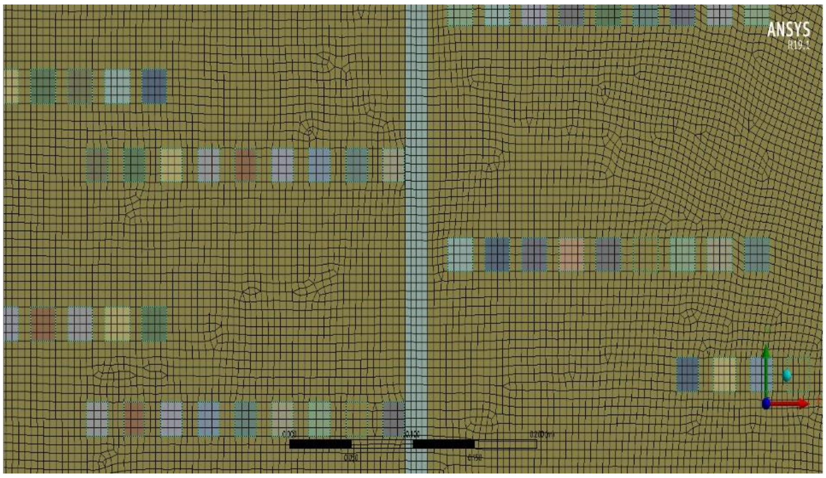

Figure 3-9. Magnifier view of dryer

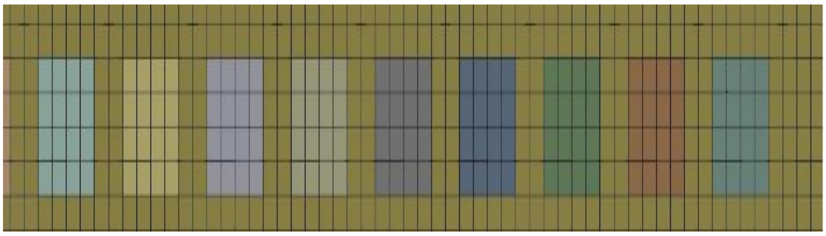

Figure 3-10. Meshing of trays in cabinet

3.1.9 Materials for solar dryer

Table 3-1. Material used to construct solar cabinet dryer

Sr. #	Components	Material	Explanation
1.	Casing (Housing)	Wood	Wood is chosen for the system's casing (housing) because it is a strong insulator and is generally less expensive than metals. Heat transfer is reduced due to the material's lower thermal conductivity than other materials. [2]
2.	Curved part of Drying Chamber	Glass	The drying chamber's cover. It permits sun powered radiation to enter the framework yet keeps heat energy from leaving. It transmits light more effectively than other materials. [2]
4.	Trays	Aluminum	The aluminum mesh used to build the tray is lightweight and durable. Aluminum weighs incredibly little. It is hardly corrosive. Moreover, it has a high unambiguous intensity and great warm conductivity. It is likewise sensibly evaluated and open. Aluminum serves as the tray's foundational material. This means the tray is already optimized.[3]

Table 3-2. Thermophysical properties of the materials [4]

Material	Density, ρ (Kg/m^3)	Thermal Conductivity (w/m-k)	Specific heat Cp (j/kg-k)
Wood	700	0.173	2310
Glass	2500	0.8	840
Aluminum	2719	202.4	871
Air	1.225	0.0242	1006.43

3.1.10 Design Calculation

3.1.11 Mass of water to be dissipated from the tobacco item is assessed utilizing the connection **[5]**

$$m_w = m_p\left(\frac{m_i - m_f}{100 - m_f}\right) \qquad (1)$$

Where

m_p= Mass of product (kg)

m_i= Initial moisture content in product (%)

m_f = Final moisture content in product (%)

Energy required for evaporating water from tobacco leave is,

$$E_p = m_w \times L_v \qquad (2)$$

Where Lv = Latent heat of vaporization of water (kJ/kg)

Energy gained by air from radiation,

$$E_a = I_c A_c \eta_c \qquad (3)$$

Where I_c= Solar intensity (W/m^2)

A_c= Area of collector (m^2)

η_C = Efficiency of collector (%)

Total Energy required for evaporating = Energy gain by air x time

$$E_p = E_a \times t_d \qquad (4)$$

Where t_d is Drying time (hour)

Heat gain by air

$$E_a = I_c A_c \eta_c = m_a C_{P_a} \Delta T \quad (5)$$

Where m_a is Mass flow rate of air (kg/sec)

Cp_a = Specific heat of air (kJ/kgK)

ΔT = Temperature difference (K)

Calculating mass flow rate of air

$$m_a = \frac{I_c A_c \eta_c}{C_{P_a} \Delta T} \quad (6)$$

Now calculating velocity of air required Va,

$$m_a = p_a V_a \quad (7)$$

But,

$$V_a = A \times v_a \quad (8)$$

$$V_a = \frac{m_a}{P_a} \quad (9)$$

Where is v_a is Velocity of air (m/sec)

Calculating air velocity

$$v_a = \frac{V_a}{A} \quad (10)$$

$$A = h \times w \quad (11)$$

Average drying rate

$$M_{dr} = \frac{m_w}{t_d} \quad (12)$$

3.1.12 Performance Parameters

Evaluation of thermal performance in drying applications is thought to be a way to figure out how well (or badly) a dryer works in a certain situation[6]. The following expression is used to calculate the system's performance and drying characteristics:

The moisture content(Mc) is conveyed as a degree of sogginess present in the thing. Utilizing the going with verbalization, the fast clamminess content at some irregular time on a wet not set in stone [7].

$$M_c(wet) = (\frac{M_i - M_d}{M_i}) \times 100 \quad (13)$$

where M_i, is the underlying mass of the example in kg and Md is the last mass of the example in kg.

Drying rate (Rd) is shaped by a reduction of the water focus during the time stretch between two resulting estimations separated when span

[8]

$$R_d = (\frac{M_i - M_d}{t}) \quad (14)$$

where ‘t’ is the time of drying in sec.

Efficiency of drying (ŋd) is a check for a drying framework's general viability (as for the drying chamber). The drying proficiency at some random time was determined as follows: where E is the energy expected to eliminate dampness from the item and E is the energy provided to the sun oriented dryer [9] . Accepting that the intensity from the dryer is utilized to raise the temperature of the item and that there is little intensity misfortune to the encompassing air,

$$ŋ_d = (\frac{W_w L + m_p c_p \Delta T}{A I_t t_h}) \quad (15)$$

Dormant intensity of vaporization is generally communicated as an element of temperature. Thus, the dormant intensity of vaporization (J/kg) in this study was determined at the drying air temperature as per ASAE standard of dampness content assurance of 1992 as keeps [10]

$$L = 2502535.259 - 2385.76424(T_d - 273.16) \quad (16)$$

where ηd is drying efficiency (%), th is desired time period (7200 sec) in this study, ‘A’ is the surface area of air heater (m2), Ww is water evaporated during a time period (kg), mp is mass of cassava samples at a time period (kg), Cp is specific heat of cassava [11], ΔT is temperature contrast between air temperature inside the drying chamber and surrounding air temperature (°C), It is absolute sun oriented power on level surface (W/m2) and Td is drying air temperature, (°K)

3.1.13 Administering Conditions

The mass, force, and energy preservation conditions act as the establishment for the mathematical model.

Laminar behavior is also being considered. Here is a summary of the general transport equations that describe how the proposed dryer system acts in terms of temperature and speed [12], [13]:

Continuity equation- The continuity equation is given by:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho\mu) = 0 \tag{17}$$

Where μ and ρ are velocity and density of air respectively.

Navier-Stokes equation- The Navier Stokes equation is given by [13]

$$\frac{\partial(\rho\mu)}{\partial t} + \nabla.(\rho\mu\mu) = -\nabla \mathrm{P} + \nabla\tau + \rho \mathrm{g} + S_m \tag{18}$$

Where τ and Sm and are Reynolds shear stress and momentum source term respectively.

Energy equation- The energy equation is given by:

$$\frac{\partial(\rho E)}{\partial t} + \nabla.\left(\mu(\rho E + P)\right) = \nabla.(-q + \tau\mu) + S_h \tag{19}$$

Where, S_h , q and E are heat source term, heat transition vector and all out energy separately. The all out energy (E) is the amount of interior energy and motor energy which is given by

$$E = h - \frac{P}{\rho} + \frac{\mu^2}{2} \tag{20}$$

where, h is the sensible enthalpy of air.

3.1.13 Boundary Condition

The mass, force, and energy protection conditions are utilized to fabricate the two-stage Schumann model conditions that act as the establishment for the transient mathematical model. The delta temperature climbs throughout the drying activity as surrounding air is constantly taken care of into the drying chamber from the admission segment. The suggested dryer section has a two-dimensional geometric configuration with dimensions of 1.57m in height and 0.99m in width. The predominant meshing grid is quadrilateral, and the discretization size for the cells is approximately 5 mm. The spatial discretization is done utilizing the Most Un-Square Cell based technique with second request upwind plans. The mathematical model is executed by forming transport conditions in familiar utilizing the COUPLED plan. A second-request understanding plot is utilized for the transient definition of fleeting terms. When the residuals for the energy equilibrium factor and the stream factor get close to values of less than 10-6 and 10-3, the numerical model's solution is deemed to have converged. The equations are discretized in a time-implicit and totally conservative manner.

3.1.14 Initial and boundary conditions

Appropriate start and limit conditions were utilized to address the administering numerical conditions. Before the drying process begins, it is assumed that the fluid domain inside the cabinet is at a temperature of 298 K.

Table 3-3. Boundary condition of the solar dryer

Initial condition	The liquid in the sun powered bureau dryer is at first expected to be stale and at a uniform surrounding temperature. At t=0, $Ta_{,c}$ = 298K
Boundary conditions	Walls: the slanted wall and right-side mass of the sun based bureau dryer is of made of glass and fixed on account of the blended mode dryer type. $T_{inclined\ wall} = T_{right\ side\ wall} = 330K$ For the remaining walls, no slip wall condition was used. $\Delta Q_{wall} = 0$
outlet	An outlet pressure is fixed. $P_{outlet} = 10^5 Pa$

3.2 Mesh independency

Ensuring that the discoveries are free of the matrix size is critical to affirming the laid out mathematical model's precision. In the work that is still going on, a network freedom test is done to make sure that the results don't depend on mesh size. In the current investigation, eight alternative grid sizes are evaluated. During the drying process, Fig. 5 illustrates the variation in cabinet temperature with respect to time for various grid sizes. If the grid size of 0.009m is employed, the temperature in the solar cabinet varies greatly. However, it is evident from the results that utilizing a more precise grid size than 0.007 m will not further increase the accuracy of the computation. Thusly, the cross section size of 0.005 m is picked for extra evaluation of the proposed authority plan and is portrayed in the accompanying fragment to safeguard assessment accuracy and reduce computational time.

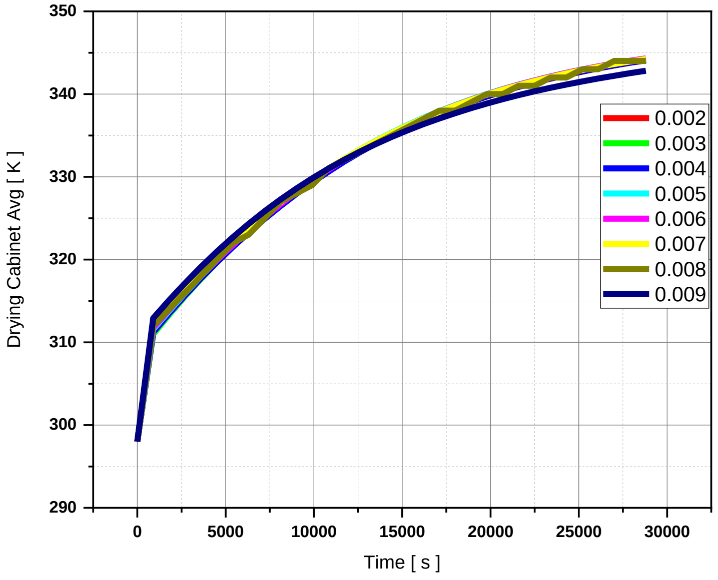

Figure 3-11. Graph Between Time and Temperature with Mesh size variation

Summary

The primary objective of this part is to numerically state and make sense of the overseeing conditions utilized in this mathematical examination. The advantages and downsides of different computational liquid elements are discussed. The review utilizes a functional mathematical methodology. Numerical conversation is utilized to show the administering conditions for mass, force, and energy protection. By standing out the disturbance model from different models, it is examined with regards to why it is proper for the review. The choppiness model's administering conditions are portrayed. Numerical conversation and clarification of the radiation model used to mimic solar powered radiation. The thickness model, disturbance model, and radiation model were examined along with an outline of the administering conditions of the mathematical model. The CFD pretreatment and processing procedures are also covered in this chapter. The creation of geometry and numerical modeling is covered in detail. First, the geometry is made. Utilizing Solid Works, the redesigned cabinet profile was produced. The ICEM CFD generates the geometry and mesh. The ICEM CFD generates the quadrilateral mesh. For the boundary conditions, the boundary conditions are defined. Material choices are made for the components, such as the ground, glass roof, and chimney. A grid independence analysis is done to look into how the sensitivity of the mesh affects the solution. The mesh that performs the best and is closest to the experimental data is chosen. The study's presumptions are described. The issue setting's solver configuration is described in full. This chapter explains how the numerical problem was set up with solver settings and how the new cabinet profile was made.

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Chapter 4

Results and Discussions

4 Results and Discussion

Transient recreations are utilized to address the overseeing conditions and their connected limits and starting circumstances for the proposed bureau plan for drying tobacco leaves. This segment presents a parametric responsiveness investigation of the proposed blended mode sun-based dryer cabinet by varying the cabinet's inlet and outlet sizes, velocity, temperature, left and right dryer portions, and outlet-to-inlet diameter ratio. The results show that the proposed new type of cabinet can be improved by making the most of the described influencing parameters.

4.1 Validation

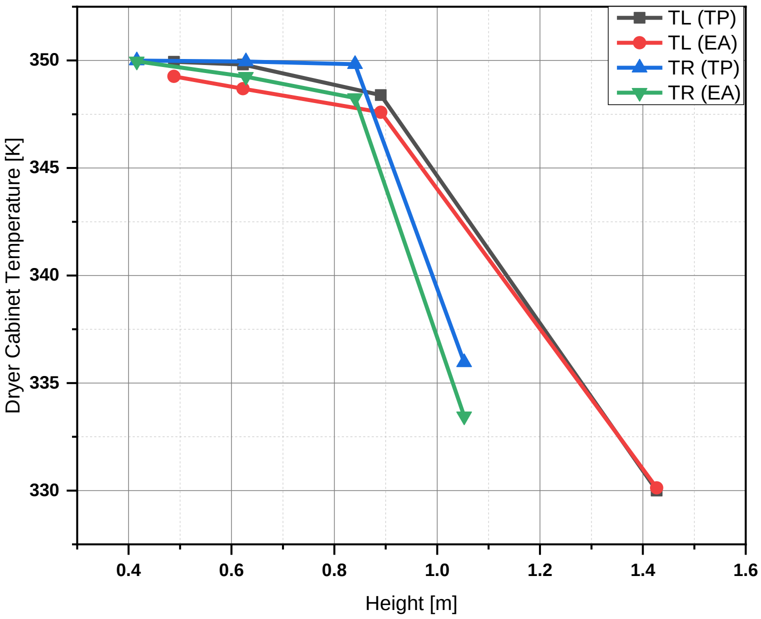


Figure 4-1. Graph between drying temperature cabinet vs Height

TL: Left side cabinet temperature

TR: Right side cabinet temperature

EA: Experimental Analysis

TP: Numerical Analysis

4.2 Thermal performance analysis using experimental results analysis

The no heap test, which assessed the dryer's temperature with next to no drying materials present, filled in as the exhibition assessment. Every five minutes, the temperature values at the drying chamber, the collector output, and the ambient temperature were recorded. We figured out how the collector and drying chamber's temperatures were spread out by setting up the data loggers to record the temperatures at certain points every 5 minutes. The dump test made it conceivable to realize the most extreme passable temperature climb in the drying chamber in comparison with the pertinent surrounding environment. During this test, temperature and sunlight-based radiation were estimated to ascertain the proficiency of the authority. Each test was run from 9:00 AM to 5:00 PM local time.

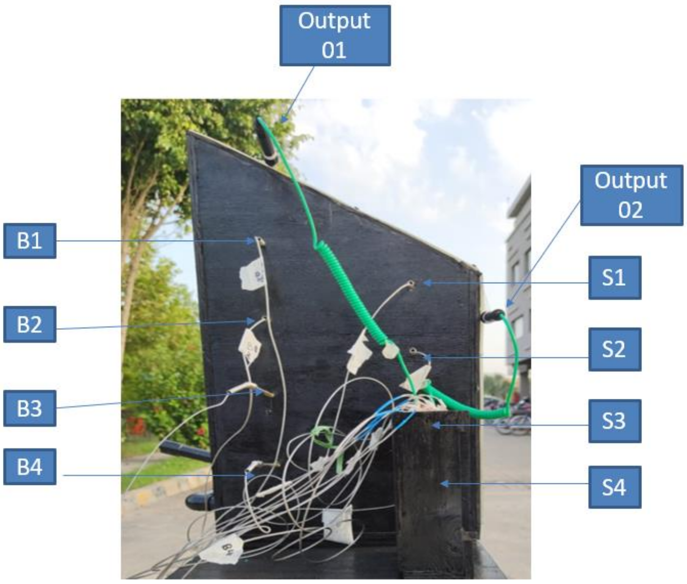


Figure 4-2. Thermo couple attached with the cabinet dryer

4.2.1 Experiment 01

Figure 25 shows that the temperature rises during the morning, peaks at midday when the sun is at its highest level of insulation, and then begins to fall again after two o'clock local time. S1, S2, S3, and S4 were determined to have the highest temperatures because they get heat from both direct and indirect sources. On the trays, the temperature rose by a maximum of roughly 55 OC. This suggests that the dryer's temperature rose to a maximum of roughly 70 OC. Since it receives hot air first, the bottom tray (B4) recorded the second peak temperature. 50 OC was about right. The drying chamber's temperature is raised by 21.9993% by the solar dryer. At 1:00 PM local time, the highest reading temperature was recorded for all trays. This is undoubtedly caused by the sun's solar radiation strength at the time the recording was made. Because they affect how well the heated air can absorb moisture and move in and out of the dryer, these temperature differences show how well the heated air in the drying chamber can dry things.

The higher trays (B1 & S1) experienced the greatest average temperature rise, which was found to be 30 OC. This suggests that the dryer's temperature rose by a maximum of roughly 70 °C when compared to the surrounding air. The solar dryer raises the temperature inside the drying chamber by 20.4829%. This is because it gets heat from both direct sources (the top plastic sheet) and indirect sources (the collector).

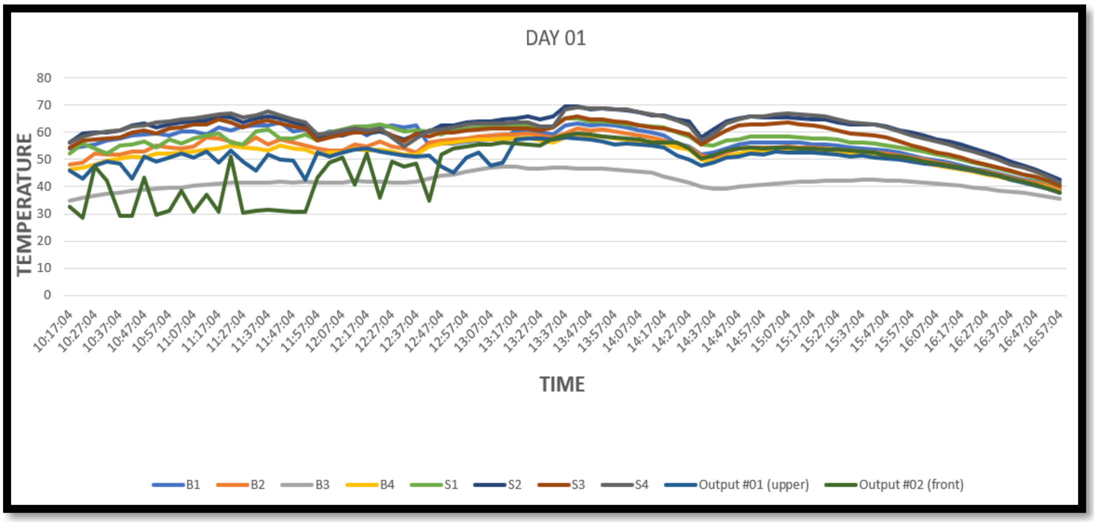


Figure 4-3. Data collected on Day 01

4.2.2 Experiment 02

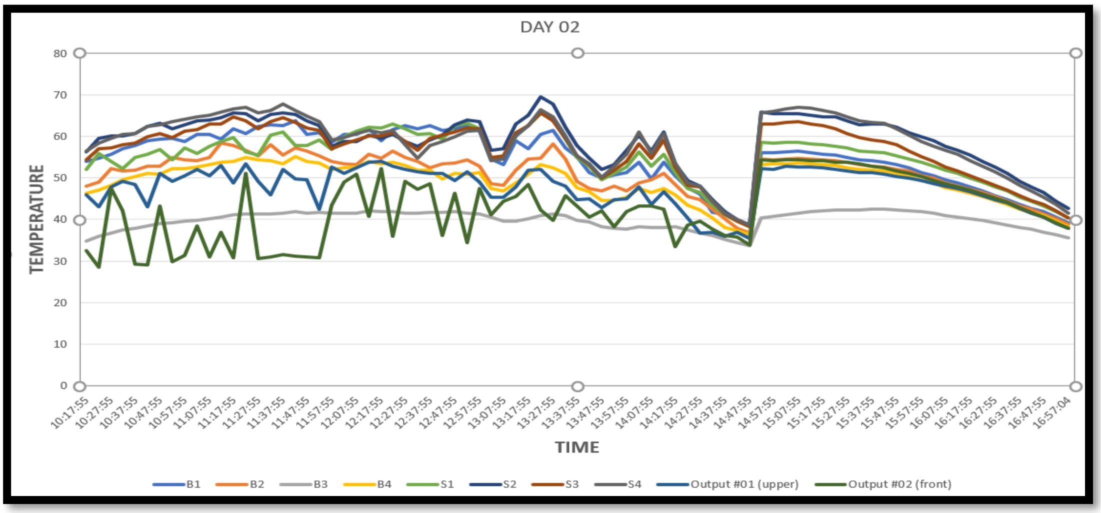


Figure 4-4. Data collected on Day 02

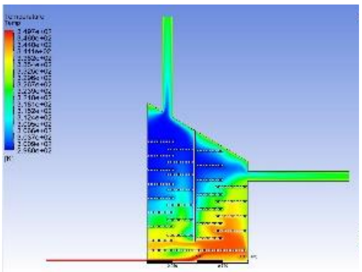
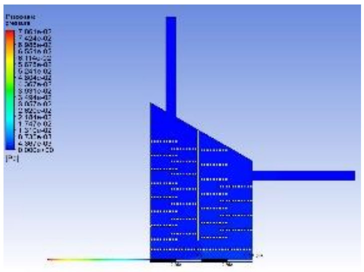
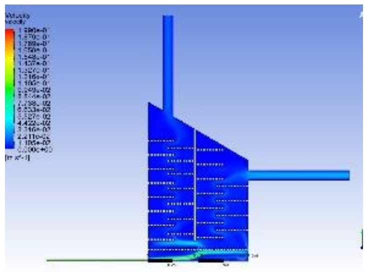
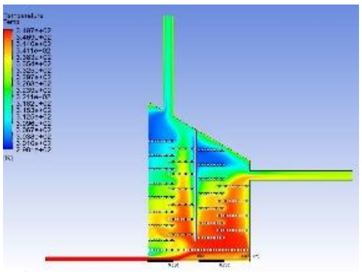
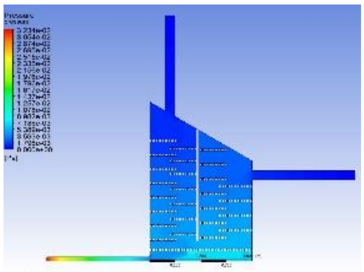
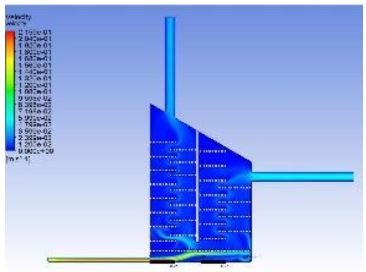
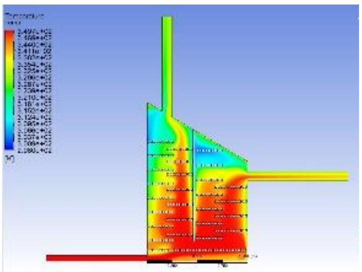
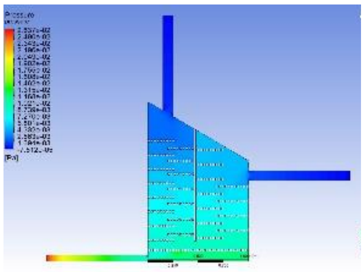
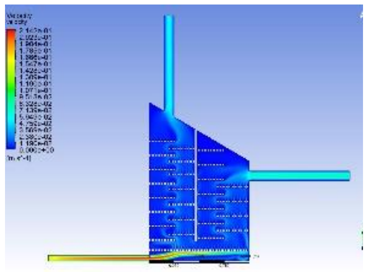
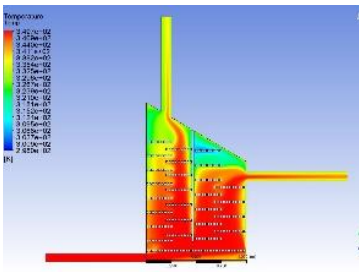
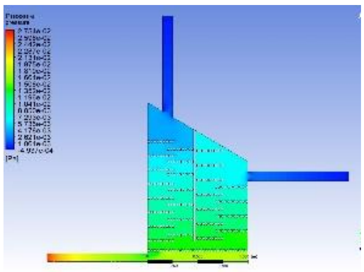
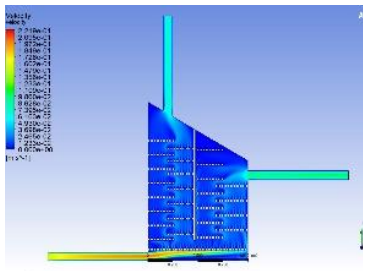
4.3 Thermal performance analysis using numerical results

The analysis of thermal performance is carried out using a reliable numerical model. The impact of input and exit size variations in velocity and temperature is investigated. Below is a discussion of the dryer's left and right-side performance analyses.

4.3.1 Effect of inlet feature size variation of solar cabinet dryer

This segment centers around the sun based bureau dryer's channel size alteration and analyzes the effect on temperature, tension, and speed. The assessment of the outcomes shows that as the measurement of the liquid section point of the bureau increments, temperature do as well, tension, and speed. There are more surface particles operating to conduct heat on an object with a larger surface area. Along these lines, these amounts increment as the surface region does in light of the fact that the pace of intensity move is straightforwardly corresponding to the surface region through which the intensity is being moved. In table No. 4, the temperature, pressure, and speed curves show how the diameter of the solar cabinet changed after eight hours.

Table 4-1. Contours of temperature, pressure and velocity with entry size variation

Sr.	Size (m)	Temperature	Pressure	Velocity
1	0.02			
2	0.04			
3	0.06			
4	0.08			

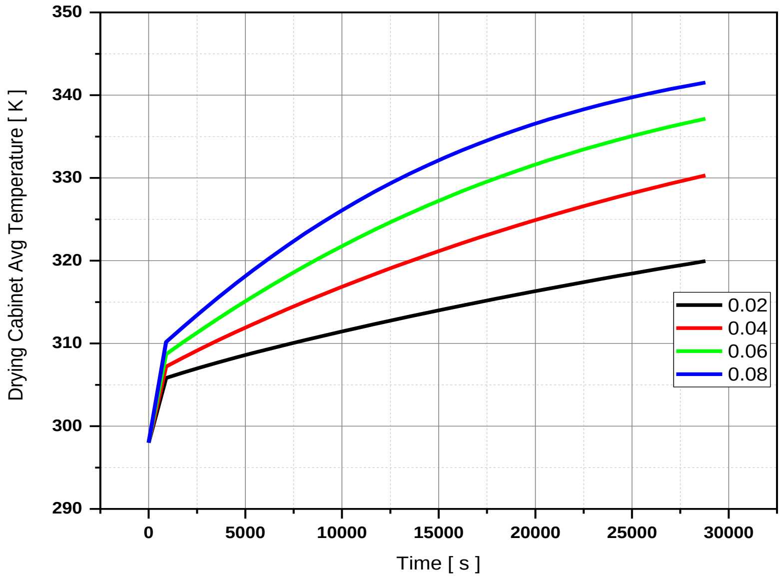


Figure 4-5. Graph between time and temperature with inlet size variation

The graph among time and temperature with differing section highlights is displayed in Fig. 5. With an expansion in surface region, the normal drying temperature climbs. The temperature of tobacco leaves often climbed initially, reaching its peak at noon, and then declined. In contrast, it is evident that the inlet sizes affect the maximum crop temperature that may be obtained. The maximum temperature for crops at 0.02, 0.04, 0.06, and 0.08 m is 320, 331, 338, and 342 K, respectively. So, when the size of the entrance goes from 0.02 m to 0.08 m, the maximum temperature of the crops goes up by about 6.875%.

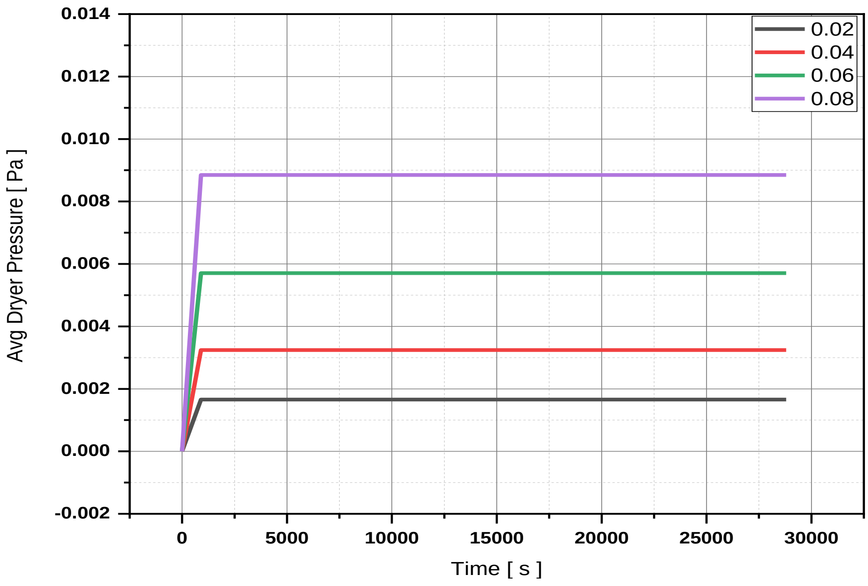


Figure 4-6. Graph between time and Pressure with inlet size variation

The graph above shows that as the size of the bureau section expands, the typical strain ascends from 0.001 to 0.009 Dad. The typical motor energy and the speed of the gas particles striking the bureau walls both climb as the temperature increases.As the temperature rises, the pressure must rise as well, since pressure is the force the particles per unit of area exert on the container. Temperature and pressure are inversely related.

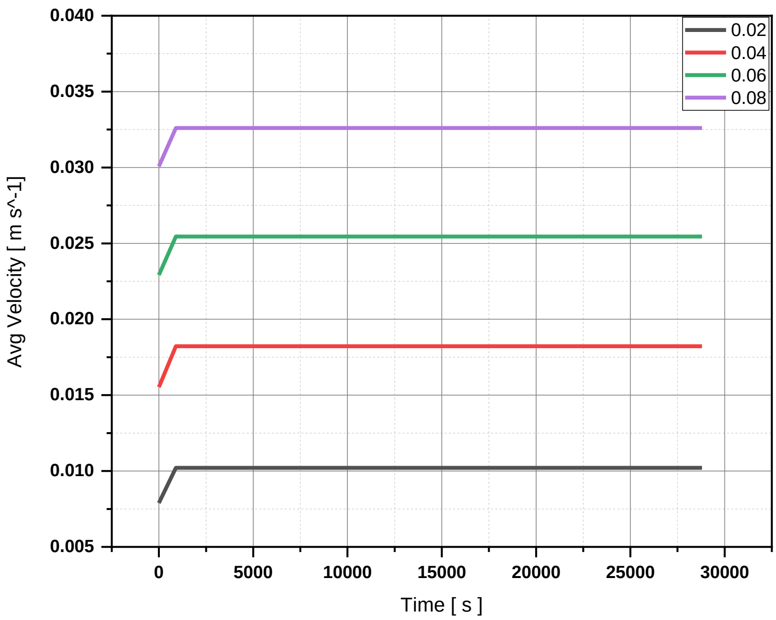


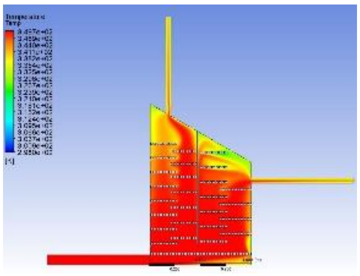
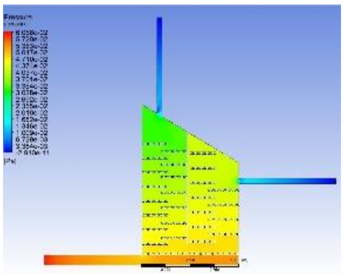
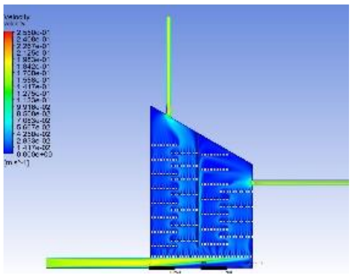
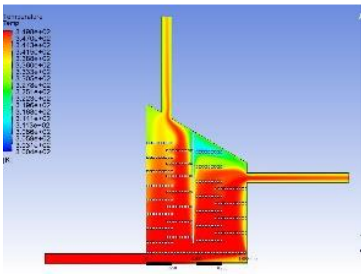
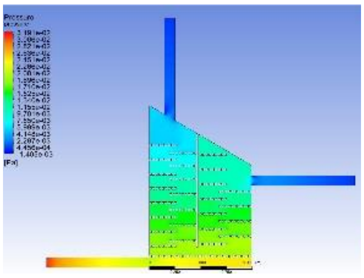
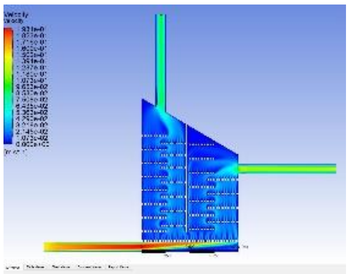
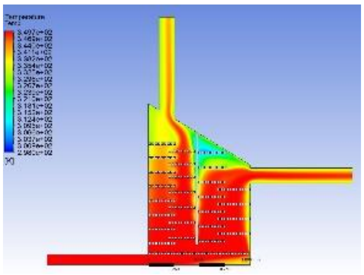
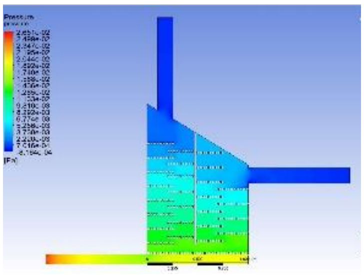
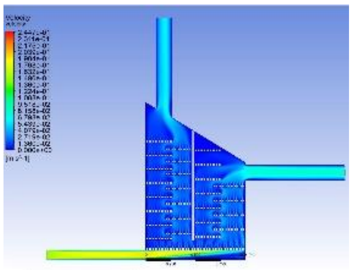
Figure 4-7. Graph between time and Velocity with inlet size variation

It means quite a bit to give the wind current speed inside the sun powered dryer for the four sizes to fathom the temperature conduct of yields with delta size (Fig. 7). The average velocity at various inlet sizes can be compared, and the results demonstrate that there is a proportionate relationship between the two. The air flow velocity increases as the input size increases. An intake size of 0.08 m results in a maximum flow rate of approximately 0.033 m/s. For intake sizes of 0.02, 0.04, and 0.06 m, respectively, this value changed to 0.010, 0.017, and 0.026 m/s. The increase in air flow is what causes the temperature to rise as the input size is increased, as shown in Fig. 5. The dryer's inlet size appears to be a deciding factor in controlling the drying process (flow rate and crop temperature). A channel thickness of 0.08 m would be ideal to get a greatest harvest temperature with a sensible measure of info wind current, and we would accomplish more prominent proficiency with this model.

4.3.2 Effect of exit feature size variation of solar cabinet dryer

This section focuses on the solar cabinet dryer's exit size variation and examines the impact on temperature, pressure, and velocity. The temperature, pressure, and velocity will gradually decrease as the diameter of the cabinet's departure point is increased. In table No. 5, you can see how the diameter of the solar cabinet's exit changes after eight hours in terms of temperature, pressure, and speed.

Table 4-2. Contours of temperature, pressure and velocity with exit size variation

Sr.	Size (m)	Temperature	Pressure	Velocity
1	0.05			
2	0.1			
3	0.15			

The solar dryer will function as a diffuser when the cabinet's outlet size is increased. The dryer will operate as a nozzle if the outlet size is tiny (0.05 m), which results in high temperature, pressure, and velocity at this point.

The graphs below show what happens to temperature, pressure, and speed when the solar cabinet dryer's outlet is changed.

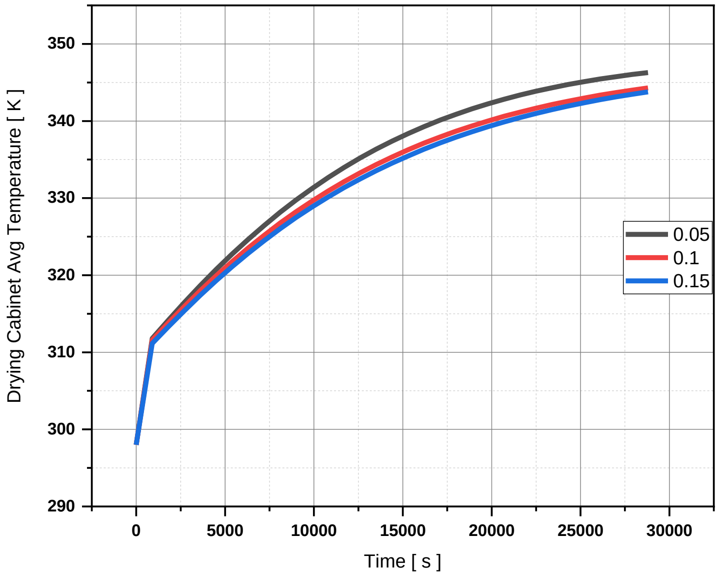


Figure 4-8. Graph between time and temperature with outlet size variation

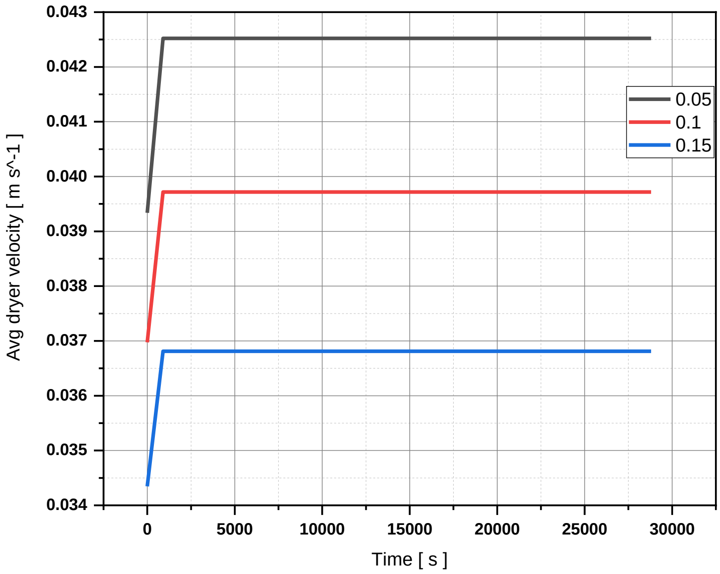


Figure 4-9. Graph between time and velocity with outlet size variation

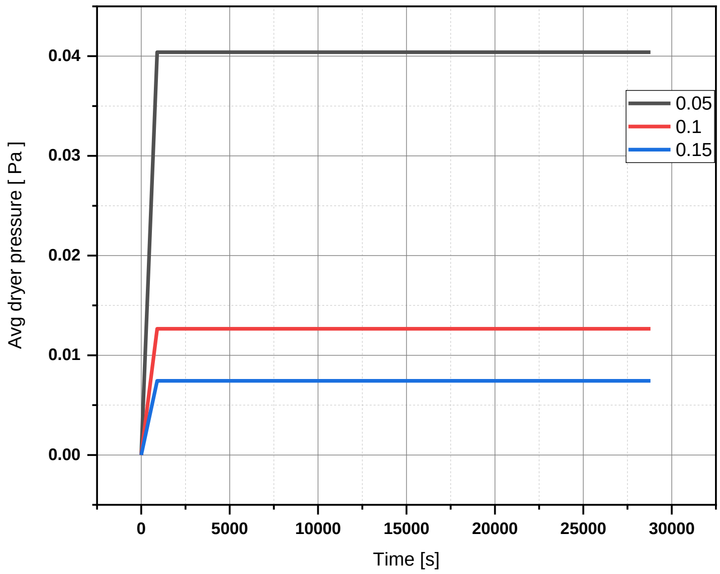


Figure 4-10. Graph between time and Pressure with outlet size variation

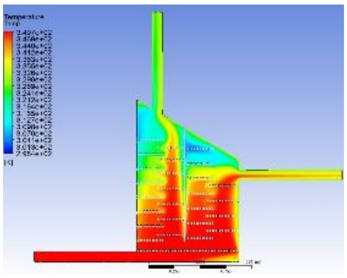
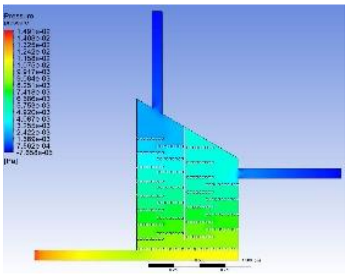
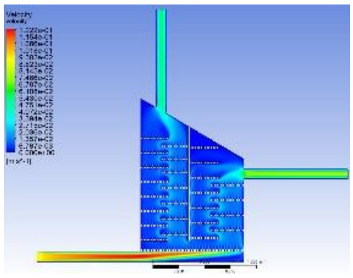
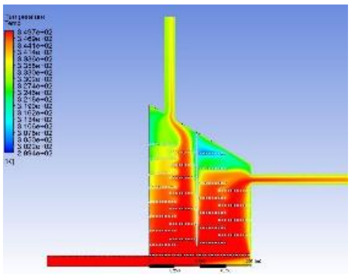
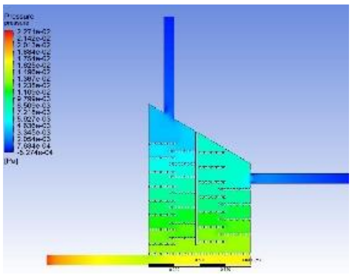
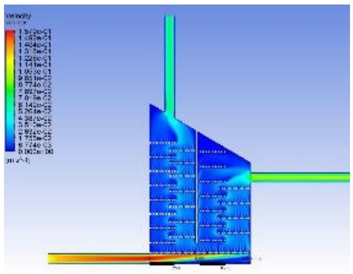
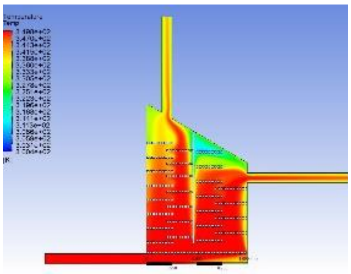
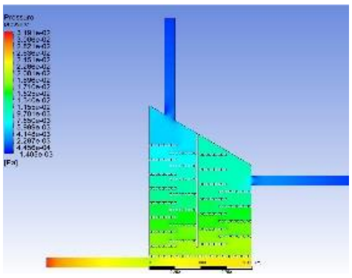
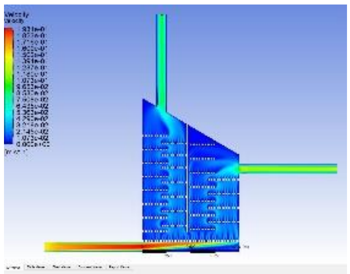
The solar dryer will function as a diffuser when the output size is 0.15 m, lowering the velocity, temperature, and pressure. In this method, a dryer outlet in a cabinet that is smaller will yield better results. We are obtaining the necessary temperature earlier than necessary to dry the crops effectively.

4.3.3 Effect of Velocity Variation at dryer entry

This part shows the solar-powered bureau dryer's speed variety and investigates the effect on temperature and tension. The temperature and tension will ascend after some time as the wind's current speed is expanded at the dryer's entrance point. Dynamic energy is moved between particles when intensity is delivered. Assuming that the speed is higher, the active energy will likewise be higher, expanding the intensity. Temperature increases as speed climbs since temperature is a proportion of intensity. The forms of temperature, tension, and speed as for the speed variety in the quality of the sun-oriented bureau dryer after eight hours are displayed in table No. 6.

Table 4-3. Contours of temperature, pressure and velocity with velocity variation

Sr.	Velocity (m/s)	Temperature	Pressure	Velocity

1	0.09			
2	0.12			
3	0.15			

The air velocity of the sun oriented bureau drier is straightforwardly corresponding to the temperature and strain. The reenactment results referenced above show that as air speed is expanded, dryer bureau strain and temperature additionally increase.

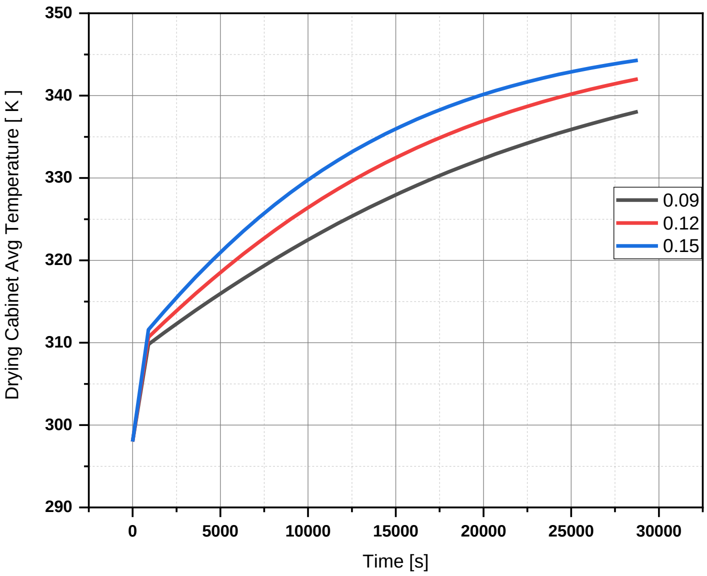


Figure 4-11. Graph between time and Temperature with velocity variation

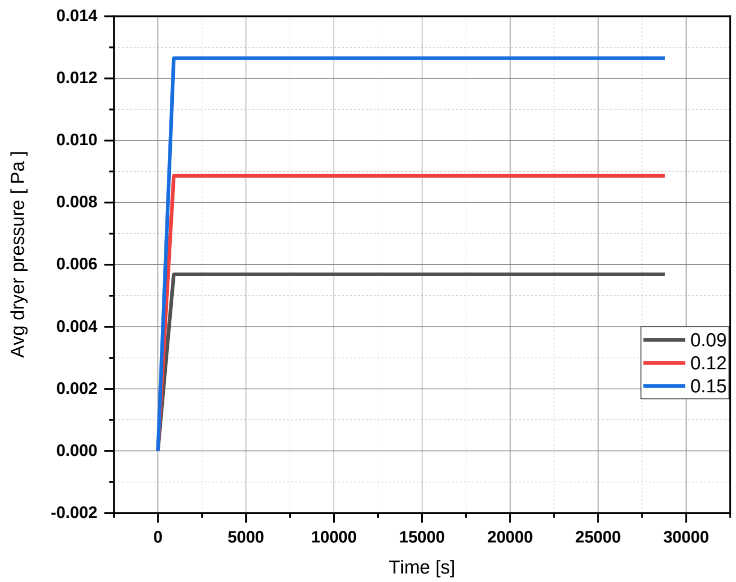


Figure 4-12. Graph between time and Pressure with velocity variation

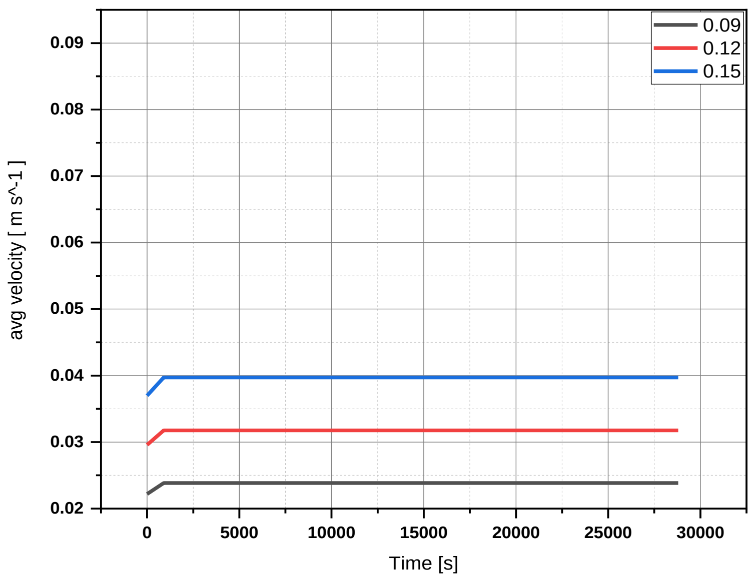


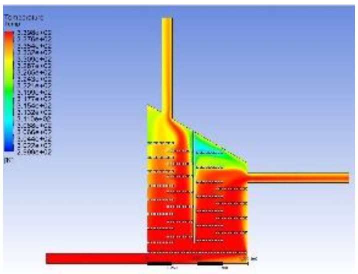
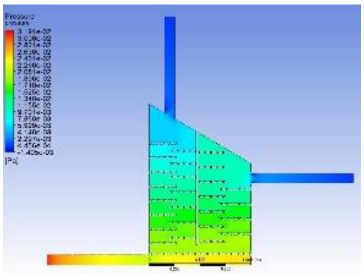
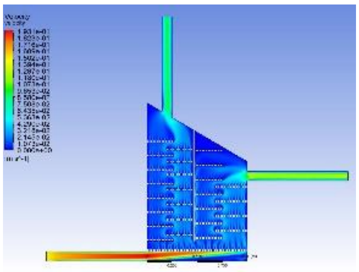
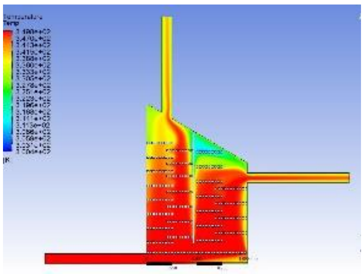
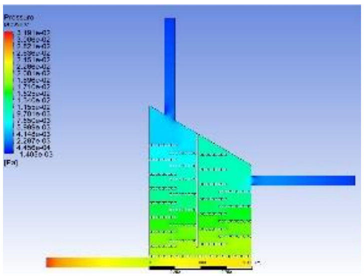
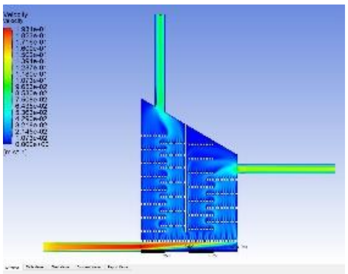
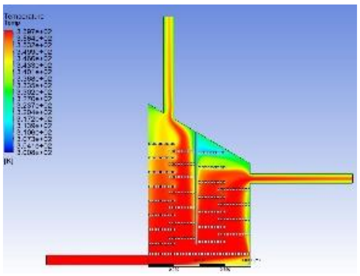
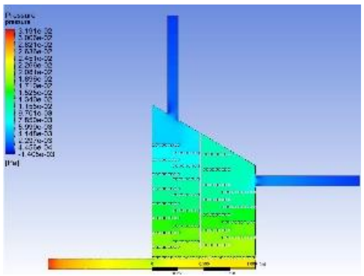
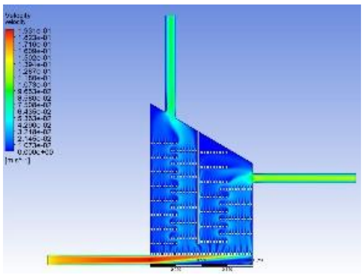
Figure 4-13. Graph between time and velocity with velocity variation

To accomplish the important drying temperature and boost viability, we should utilize a wind current speed of 0.15 m/s. This will guarantee careful and convenient drying of the leaves.

4.3.4 Effect of Temperature Variation

In this section, we examined the solar cabinet dryer's temperature variation and examined its impact on velocity and pressure. As indicated by the product study, the speed and tension will stay steady concerning time in the event that we raise the wind current temperature at the dryer's entrance point. The types of temperature, strain, and speed concerning the speed assortment in the attitude of the sun fueled agency dryer following eight hours are shown in table No. 7.

Table 4-4. Contours of temperature, pressure and velocity with temperature variation

Sr.	Temperature (K)	**Temperature**	**Pressure**	**Velocity**
1	340			
2.	350			
3.	360			

The rate of evaporation affects the temperature. Higher air temperatures and velocity result in a faster rate of evaporation. The expansion of air molecules occurs as the temperature rises. It increases the air's ability to absorb water vapor. At higher temperatures, though, the gradient essentially starts to disappear. It means that, with constant speed and a high temperature, the evaporation rate tends to be saturated. The rate of evaporation increases as temperatures and velocities rise. At high temperatures, the impact of temperature is less noticeable. At first, the rate of evaporation is high, but it tends to slow down as the process goes on.

The graphs below show how the pressure, temperature, and speed change over time.

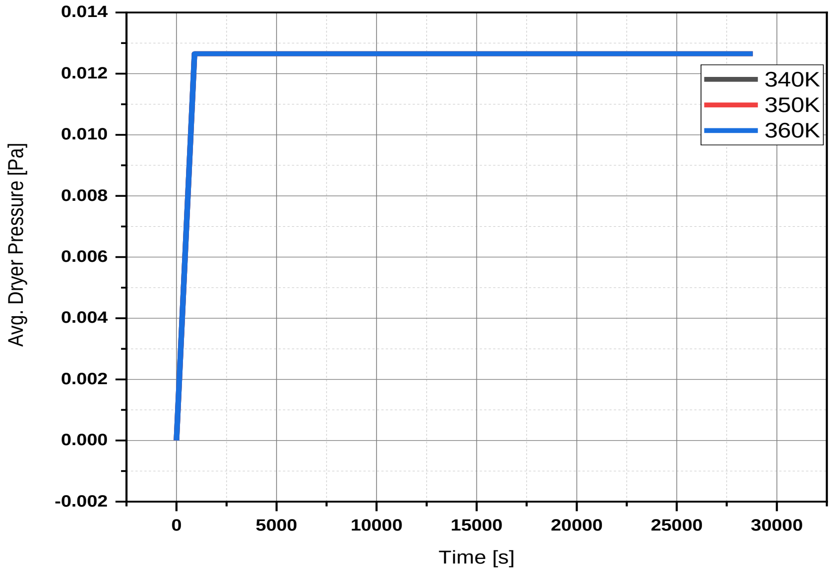


Figure 4-14. Graph between time and Pressure with Temperature variation

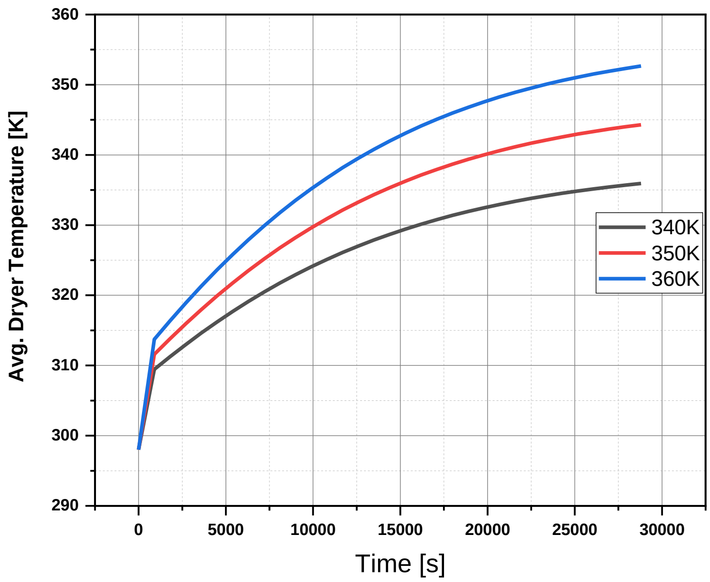


Figure 4-15. Graph between Time and Temperature with Temperature variation

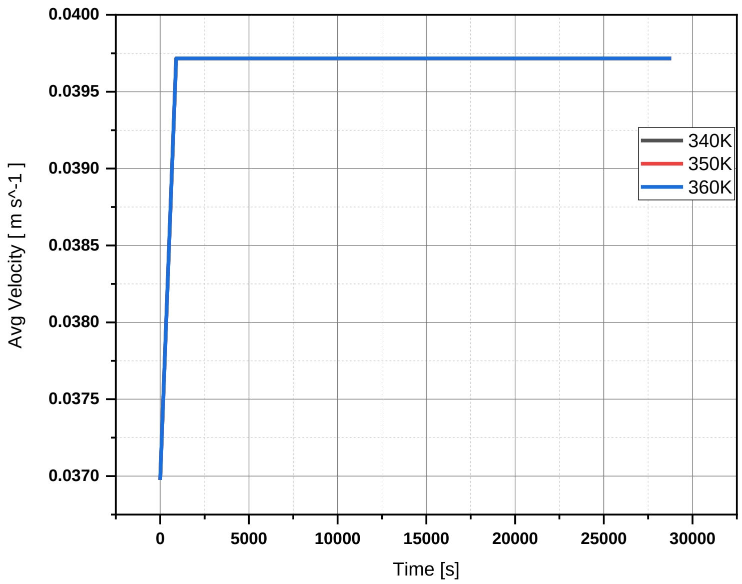


Figure 4-16. Graph between Time and Velocity with Temperature variation

4.3.5 Performance analysis of left and right sections of the dryer

By looking at the effect on the normal drying air temperature as a piece of time and spatial direction, the left and right bundles of the sunlight based division dryer are explored in this section. The discoveries show that while the left half of the dryer warms up more leisurely over the long run, it at last arrives at a higher temperature than the right side. In our case, one side of the dryer needs to be heated more than the other because we will put steam on one side and leaves on the other, and stems require more heat to dry than leaves do.

If we set the temperature to the same on both sides, the products won't reach the necessary temperature or they may become overheated. This result shows that the stem ought to be put as an afterthought that is more warmed (the left side), and the leaves ought to be put on the dryer right side. The two items will be dried suitably and appropriately as such.

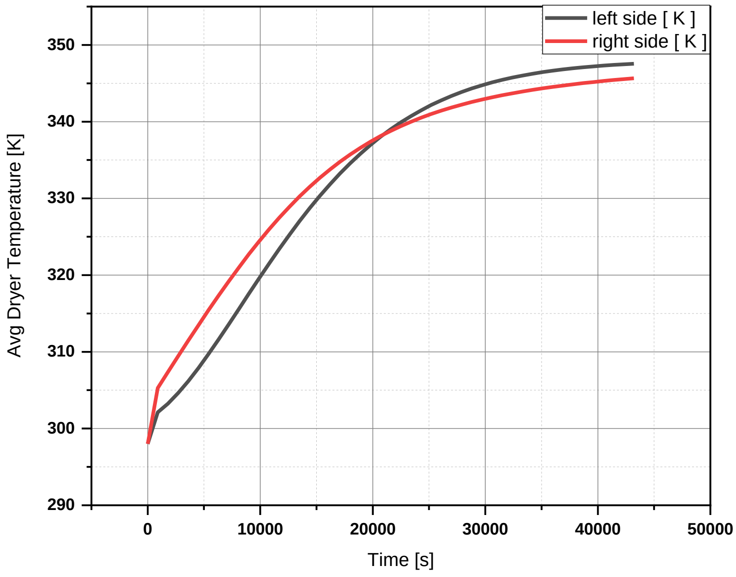


Figure 4-17. Graph between Time and Dryer Temperature showing temperature variation in left and right portion of the dryer

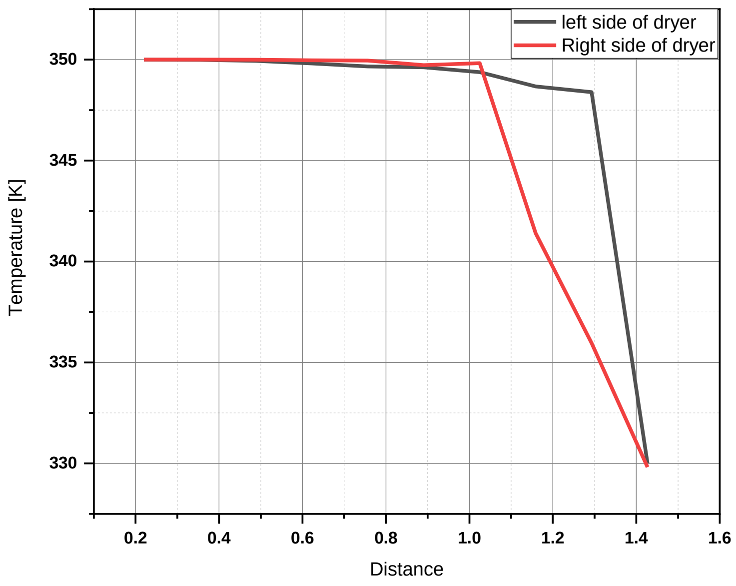


Figure 4-18. Graph among Distance and Dryer Temperature showing temperature variety in left and right piece of the dryer

Table 4-5. Ratio between outlet over inlet diameter of the solar dryer with respect to temperature

Sr.	Inlet diameter of dryer (D1)	Outlet diameter of the dryer (D2)	D2/D1	Temperature
1.	0.02	0.1	5	313.6969
2.	0.04	0.1	2.5	320.6673
3.	0.06	0.1	1.67	326.6383
4.	0.08	0.1	1.25	331.4978
5.	0.1	0.1	1	335.3441
6.	0.1	0.05	0.5	337.3962
7.	0.1	0.15	1.5	334.5474

The effect of the diameter ratios between the cabinet's outflow and intake on the average temperature after four hours is shown in Table 4.5. The findings demonstrate that when the ratio rises, the average temperature falls, and this pattern demonstrates a uniform distribution of temperatures between the two distinct parts of the solar dryer.

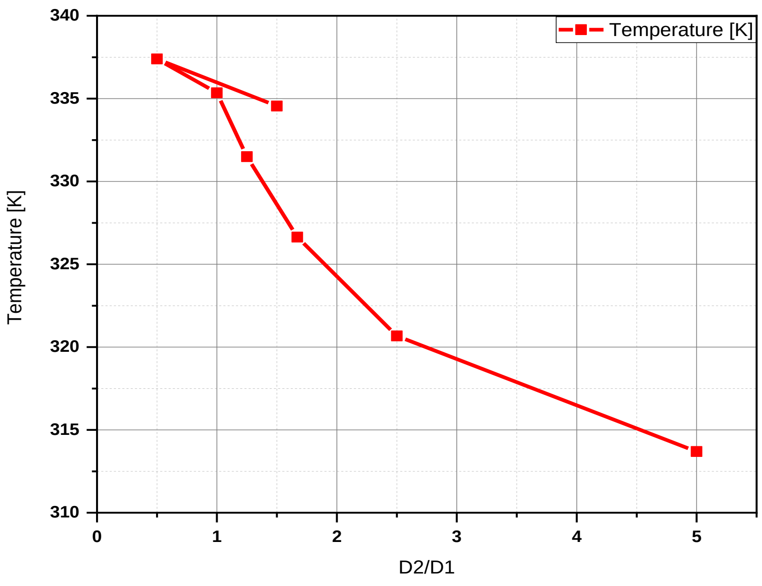


Figure 4-19. Graph between the ratio D2/D1 with the temperature

Summary

The outcomes are entirely depicted in this part. Using exploratory information from the model under planned conditions, the mathematical model is approved. The objective of the ongoing review is to look at the exhibition of a cleverly blended mode of sun-oriented bureau dryer for drying tobacco. Tobacco leaves and stems can be dried independently in segments that are near the fitting temperature range thanks to the bureau dryer's proposed design. Using a checked mathematical model with different functional settings, the exhibition is surveyed. The outcomes exhibit improved execution files and a more equivalent circulation of temperature, strain, and speed. The drying chamber can keep a temperature somewhere in the range of 298 and 344 K, and the sun-powered safeguard can arrive at up to 330 K. It has likewise been examined how air admission and outlet sizes, gulf speed, delta temperature variety, correlations of the left and right sides of the sun-oriented bureau dryer, and the proportion of outlet to channel width influence the sun-powered bureau dryer's typical temperature. By and large, the outcomes demonstrate the way that the recommended plan design can keep the temperature even in various pieces of the single bureau dryer, which is a decent sign for keeping the nature of the dried tobacco leaves and stems at a standard level.

Chapter 5

Conclusions and Recommendation

5 Conclusions and Recommendation

5.1 Conclusions

Another hybrid mode sun-oriented dryer design is introduced. Moreover, utilizing mathematical recreations, a complete parametric exhibition investigation of the proposed sun-based dryer is introduced. The mass, force, and energy conditions used in the two-layered computational area set up the mathematical model for what happens next. The following succinct summary of the major findings from the study is provided:

1. 1. The proposed plan design has a decent possibility keeping the standard nature of the dried tobacco leaves and stems since it can keep the necessary reliable temperature dissemination in various pieces of the single bureau drier.
2. The temperature, tension, and speed will ascend after some time as the bureau's entrance point width increments. Thus, when the size of the entry goes from 0.02 m to 0.08 m, the greatest temperature of the yields goes up by around 6.875%.
3. The temperature, pressure, and velocity will decrease over time as the diameter of the cabinet's exit point increases, which will slow air extraction by around 14%.
4. To get the required drying temperature and best effectiveness, we should use a wind current speed of 0.15 m/s at the dryer's entry point in light of the fact that as the wind current speed expands, the temperature and tension moreover ascend over the long haul. The yield will dry appropriately and in the required measure of time whenever done along these lines.
5. The velocity and pressure will remain constant with regard to time by raising the air flow temperature at the dryer's entrance. At high temperatures, the impact of temperature is less noticeable. The evaporation rate is considerable at the beginning of the process but tends to decrease as it goes along.
6. The left 50% of the dryer heats up consistently over an extended time, yet come what may, the left side shows up at a higher temperature than the right

side. This outcome shows the way that we can arrange the stem as an idea in retrospect that is more warmed (the left side) and the leaves on the dryer right side. The two things will be dried fittingly and properly thusly.

7. When the ratio of the solar dryer's output to its inlet diameter is compared to the temperature, the results are very accurate.

5.2 Suggestions for the Future

Through the studies listed below, more research should be done on the subject to learn more about performance.

- A photovoltaic module can run the solar dryer independently of the power grid. The operation of the solar dryers powered by photovoltaic needs to be adjusted.
- Energy collection is increased when a system is oriented so that the surface normal in the center always corresponds with the solar beam. This is only conceivable if the system rotates continually in accordance with the sun's position or when tracking is done in conjunction with solar movement.

Appendix

Performance Analysis of Mixed Mode Solar Dryer for Tobacco Leaves

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Abstract:

Tobacco leaf drying is a critical and reasonable security structure before the end with respect to tobacco accommodates limit shape and mycotoxin improvement. The drying temperatures of leaves and stems of tobacco are 333 K and 348 K, solely. The consistent audit takes a gander at the presentation of another kind of blended mode light based division dryer to dry tobacco. The proposed development of power dryer licenses the drying of tobacco leaves and stems in discrete parts close to the ideal temperature ranges. Mathematical redirections of questionable laminar breeze streams and power going through a two-layered model are done for a typical day of August in the climatic locale of Islamabad (Pakistan). Moreover, the impacts of air limiting rate and assessment of the left and right drying area of the sun-controlled power dryer have been separated. All around, results show the way that the proposed procedure can remain mindful of the normal uniform temperature spreading in the bound locale of the single affiliation dryer and accordingly offers promising outcomes to keep the standard thought of the dried tobacco leaves and stems. light based dryer; tobacco leaves; CFD assessment; laminar stream; blended mode type sun-coordinated dryer.

Journal: Engineering proceedings

Current status: **Accepted**

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