

DESIGN AND FABRICATION OF PORTABLE GREENHOUSE SOLAR DRYER

Submitted in partial fulfillment of the requirements for the award of Bachelor of
Engineering degree in Mechanical Engineering

By

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SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of PRAVEEN KUMAR N (Reg.No.. 39150100) and SHRI VISHNUPATHY G (Reg.No.. 39150121) who carried out the Project entitled "**Design and Fabrication of Portable Greenhouse Solar dryer**" under our supervision from December 2022 to April 2023.

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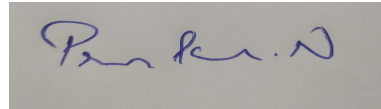
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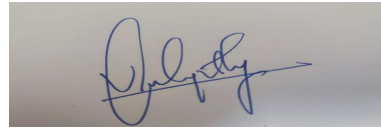
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DECLARATION

We, PRAVEEN KUMAR N (Reg.No.. 39150100) and SHRI VISHNUPATHY G (Reg.No.. 39150121) hereby declare that the Project Report entitled “**DESIGN AND FABRICATION OF PORTABLE GREENHOUSE SOLAR DRYER**” done by us under the guidance of **Dr.M.PURUSOTHAMAN, M.E., PhD.**, Associate Professor in Department of Mechanical Engineering is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering in Mechanical Engineering.



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ABSTRACT

Fruits, Vegetables are nutritious and good in minerals, vitamins and fibers. Most of the fresh fruits and vegetables contain minimum 70% of moisture content which causes the formation of bacteria, fungus, virus to affect and cause the items to rot. But dried fruits contain only less than 20% of moisture content. So drying the fruits and vegetables helps to preserve the items for longer use without causing them to rot. Dried fruits have a great source of antioxidants and help in health benefits like improving blood flows, reducing the effects of many diseases. Compared to fresh fruits, dried fruits are good in nutrition and less weight for packaging and transportation usage. For drying materials, various types of Solar dryers are used. Natural or open sun drying methods comparatively consume more than 12 hours to dry a material. whereas Direct and Indirect Drying methods would enhance the efficiency and dry the products more quicker than open drying. For the consideration of quality drying and to increase the efficiency, various modifications of solar dryers are designed and fabricated. In this report, we discussed the new design of portable Greenhouse Solar Dryer, most appropriate developments in the drying of food items, required PCM, Performance and environmental analysis of solar dryer and also reported the various design of the solar drying technique.

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LIST OF SYMBOLS AND ABBREVIATIONS

SD	Solar Dryer
WB	Wet Basis
DB	Dry Basis
DPSD	Double Pass Solar Dryer
CD	Cabinet Dryer
CFD	Computational Fluid Dynamics
GHSD	Greenhouse Solar Dryer
OSD	Open Solar Dryer
PPEGHSD	Parabolic Polyethylene Greenhouse Solar Dryer

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CHAPTER-1

INTRODUCTION

Drying materials, particularly fruits and vegetables, is done by means of solar dryers, which harness solar energy. Solar dryers use the sun's heat to decrease the moisture content of the various food items and respected materials. In order to enhance the agricultural products shelf lives, dryers have been created and are now being employed and also some of the advantages of using SD are higher product quality is obtained, lowers losses and improves product market prices, products are protected from dust, flies, and rain, reduces environmental effects and prevents the need for fuel and it is more affordable and effective. The majority of these methods either rely on pricey energy sources like electricity or combine solar energy with another type of energy. Because the concluded designs and Drying techniques are sometimes inappropriate or the affordable cost has remained out of reach, the majority of projects of this kind have not been adopted by small scale farmers and also some of the disadvantages of using SD are, the quality of the products cannot be reached in some situations and sufficient use of Solar energy is necessary. This study's goal is to elaborate the new feature of proposed portable greenhouse solar dryer and outline some of the fundamental SD types with a motive of providing a better solution on their effectiveness in the drying and how well they work to dry agricultural products.

1.1 TYPES OF SOLAR DRYER

The modes of SD are classified into three types namely sun or natural dryer, Direct solar dryer and Indirect solar dryer.

1.1.1 Sun or Natural drying

Natural dryer is the oldest and most straightforward drying method. The majority of agricultural products, including grains, spices, fruits and vegetables are still dried in the natural solar energy. However, there are numerous disadvantages

to drying these products in the open air, such as trash, rain, blowing wind, bug infestation and human contamination.



Figure 1.1: Natural drying

In tropical and subtropical regions, the most popular drying technique entails laying the crop out in thin layers on trays, covering the mats with shade, and exposing the goods to sun and wind. The categories for solar drying techniques are generated depending on the processing stage, the drying location, or anxiety about solar radiation. Environmental factors like sun radiation, breeze and other ambient circumstances might affect open-air drying. Due to the numerous drawbacks of sun drying, it has been replaced by mechanical dryers to force dry air through the agricultural goods by using electricity and fossil fuels to heat the drying air. However, the usefulness of utilizing solar power for reaching high temperatures in a solar drying system without reducing the capacity and reliability. For huge quantities of materials produced by big businesses, the open drying technique is not appropriate. In addition to the negative effects of increased labor costs, increased space requirements, and poorer quality of items, it also entails a time-consuming procedure prior to the Products might be stocked-ready. Drying in the open sun takes a very long time and can cause extremely large losses. The Products are exposed to dry by solar energy. The quality of drying frequently falls short of international standards.

1.1.2 Direct solar drying



Figure 1.2: Direct drying

In Direct solar dryer, the transparent sheet or mostly glass is used to cover the food items and or required materials and also it is used to higher the temperature inside the dryer than the ambient temperature when solar energy passes through the sheet or glass. So the thermal efficiency should be increased. A direct-kind sun dryer is typically utilized in zones that acquire direct daylight throughout the day for a longer period. Here, the pressed wood with the thickness of 1 cm is used to make out the drying cupboards and also the glass wool is harnessed to insulate at the inside and bottom wall of the cupboard. A thick sheet of inclined glass front wall is covered to allow the sun rays to pass through. The similar principle is proposed for an opaque mode of drying by using opaque and insulated sheets as a blanket. The dryer has exhaust holes to suckout the humidity of air with the help of an exhaust fan. The lowest element of the front wall is made in this type of manner so that it is able to redirect the warm air using the centrifugal blower from the sun collector into the chamber. Inside the glass cover, the moisture content reduces its permeability.

1.1.3 Indirect solar drying

In this type of solar dryer, the principle used is similar to the direct solar dryer. Instead of heating the materials to be dried directly, Indirect solar dryers heat the air entering the device from the outside.

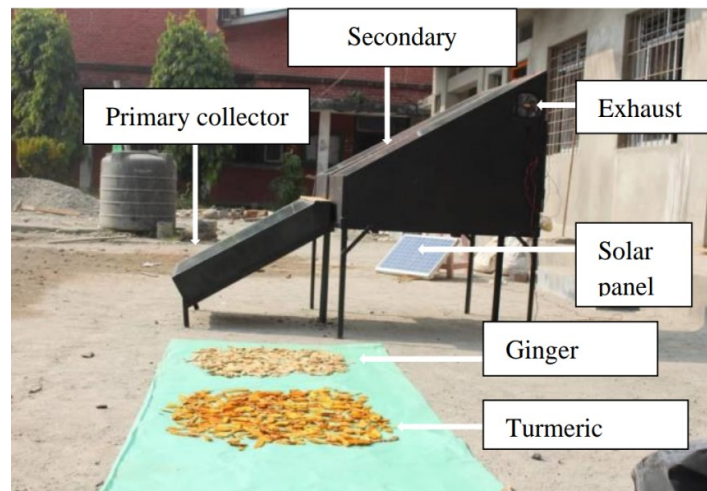


Figure 1.3: Indirect drying

Then the warm air is circulated over the materials carrying humid air with it and passes to the ambient by the chimney. The Solar dryer finally gives the required solution. Due to its affordable price it is an appropriate drying technique for the small scale farmer's applications. This solar dryer is made with thermally insulated pipes connected and hinged with a flat plate collector and a drying chamber. Under detrimental climate situations, the performance of the dryer nevertheless gives high-satisfactory quality products. The temperature of the drying chamber and the sample thickness are the two primary variables to take into account in this type of drying procedure.

1.2 MODES OF SOLAR DRYER

The modes of heat transfer employed in SD systems are: Forced and Natural convection.

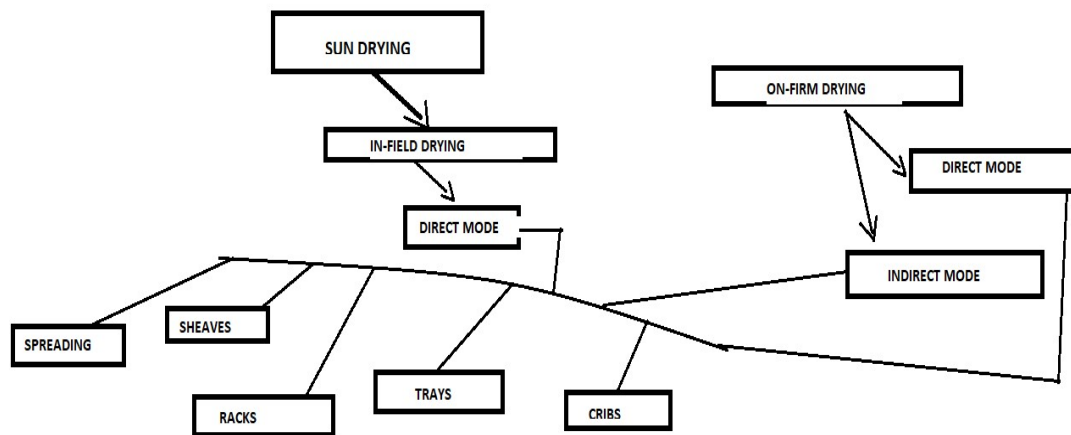


Figure 1.4: Classification of solar dryers

1.2.1 Forced convection

In Forced convection mode of a solar dryer, air is forcefully passed over the solar panel and products keeping trays by use of external devices like fans or blowers. It is commonly called an active dryer.

1.2.2 Natural convection

In the natural convection mode of solar drying, solar power is passed over the transparent blanket materials and warms the air inside the dryer without any external devices. It is commonly called a passive dryer.

1.3 PHASE CHANGE MATERIALS FOR STORING HEAT IN SOLAR DRYER

Solar dryers work well during the day time, and lose the working efficiency after sunshine. To control and store the latent heat from solar energy by use of

PCM that helps as a storage medium which supplies sun energy when SD requires [17]. The Solar dryer is more efficient when the collector is filled with paraffin wax to maintain the warm condition throughout the chamber after sunlight loss and which is also used as a thermal storing material [27]. Nowadays, PCMs have researched and put more attention on storing techniques. Many projects are being conducted on the development of thermal factors of PCMs in many kinds of methods. Presented studies on Nano-particles PCMs to increase the thermal storing ability [26]. Paraffin wax or other composites are used as PCMs in Greenhouse drying which increases the heat transfer rate efficiently [21]. Water and Waste oil of engines is used as a storage medium to collect the heat energy from sunlight was successfully demonstrated and noted the flow rate 0.035 lit/sec, 0.045 lit/sec and 0.065 lit/sec [6].

1.4 PERFORMANCE ANALYSIS OF SOLAR DRYER

To reduce the moisture content in a food item and preserve it for a longer period, the SD can be used. By the Application of North Wall insulation, the temperature inside the dryer is more than the atmospheric temperature so the food humidity level is gradually reduced from the initial level and so the drying time consumption is decreased. The drying temperature of food items reaches around 61°C and reduces the moisture level of 60% initially to 32% at the end of the drying. Compared to other drying techniques, insulated parabolic drying gives more effectiveness than span drying [19]. Covering the dryer by using polycarbonate roof sheet which warms the inner region of the Forced GHSD with a highest temperature and mass flow rate of 71°C and 0.025kg/s and which the temperature is 40% more than a passive mode drying. Simulated and analyzed a GHSD of natural and forced convection with different shapes of roof structures in CFD Software [24]. Observed the temperature difference between these roofs are nearly 8°C to 10°C . The designed model reaches an average temperature of about 65°C , 61°C and 64°C respectively. Conclude that the Trapezoidal shaped GHSD reaches maximum temperature than the GHSD of Hemispherical and Triangular shaped. But compared to the PPEGHSD, PPEGHSD gives a higher nutrient

element than the OSD method. To dry green peas OSD took 32 hrs. to dry and for the same quantity of green peas dried in PPEGHSD only took 20 hrs. to dry. Moisture level reduces from 76% initially to 9% at the end of drying .

1.5 ENVIRONMENTAL ANALYSIS OF SOLAR DRYER

By concentrating on the quantity of (CO₂) emission caused by the combustion at an auxiliary system heating, an environmental analysis is carried out from the method of solar dryer and the result of adding a solar collector to the drying system reduces the amount of energy which is consumed by an auxiliary system of heating and also to reduce the emission of CO₂ by roughly 34% yearly . Comparing GHSD to forced convection SD, the emission of CO₂ is reduced than (electrical one). The mixed mode SD using phase change material of paraffin wax (thermal storing material) was compared with normal conventional SD and analyzed the environmental and economical performance that the energy payback time period in the proposed method is comparatively lower than the normal solar dryer and Similar method without PCM. Utilizing PV modules and aluminum casing for the construction of GHSD reduces the consumption of embodiment energy. In particular, the PV modules chosen (low embodied energy density material) are crucial for lowering CO₂ emissions, shortening payback times, and mitigating effects .

1.6 BENEFITS OF DRIED FRUITS

Nuts and dried fruits are widely consumed by all types of people around the world. They are preferred by students and athletes for their nutritional value. A good number of calories also make up for their moment Energy from protein, multivitamins and other micronutrients. Pregnant and nursing mothers often enjoy the contoured structure, crunchy texture with overwhelming taste and amazing health benefits during pregnancy period. Nuts and dried fruits can be easily and quickly digested by soaking them in water in the early morning or at other times, or

by taking them immediately within 2-3 hours without causing indigestion. It comes in raw or roasted form and is used in a variety of dishes, including dessert preparations to add flavor and nutritional value. Due to their so many essential biochemical compounds, nuts and dried fruits have health benefits for the human body, including the heart, brain, skin, hair, cholesterol, muscles, and bones. and always a powerful antioxidant [29].

Fruits and vegetables become dehydrated when the water has been removed from them, which results in dry fruit. Two methods to get rid of the water include solar drying and using specialist dehydrators and dryers. This method produces a fruit that is smaller but yet full of essential nutrients. Fruit that has been dried is rich in vital nutrients and has a better bioavailability. Dry fruits have a lot of medicinal potential because they include a huge number of nutrients that are present in many fruits and vegetables [15].

1.7 DIFFERENT DESIGNS OF SOLAR DRYER

Various designs of solar dryer are compared and noted the overall efficiency of the same as shown in Table 1.1.

Table 1.1: Performance comparison of different designs of SD

Name of the Dryers	Energy	Overall Efficiency	References
Normal Cabinet Dryer	Natural convection Direct SD	20%	Diemuodeke E et al.,2011
Wind ventilated solar cabinet dryer	Natural convection Indirect SD	46.7%(with Rotary wind ventilator),31.2%(without Rotary wind ventilated)	Bukola O. Bolaji et al.,2011

Efficiency enhancement in mixed mode solar dryer	Natural convection Indirect SD	57.5%	Bukola O. Bolaji & Ayoola P.olalusi.,2008
Gravel Integrated to Forced Convection Solar Dryer	Forced convection Indirect SD	21%	M. Mohanraj & P. Chandrasekar.,2009
Semi continuous Solar Dryer	Forced convection Indirect SD	18.23%	A.Zomorodian et al.,2007
Multicollector passive mode Solar Dryer	Natural convection Indirect SD	12.3%	F.K. Forson et al.,2007
Industrial dryer for fruits and vegetables	Forced convection Indirect SD	82%(Average Thermal efficiency)	J.C. Ehiem et al.,2009
Hemi cylindrical solar dryers	Natural convection Indirect SD	30%	N.S. Rathore & N.L. Panwar.,2010
Active mode Solar Dryer for drying groundnuts	Forced convection Indirect SD	39.2%	Subramaniyan C et al.,2021

A mixed-mode ginger and turmeric solar dryer	Forced convection mixed SD	31.36%	Manoj Gyawali et al.,2021
Passive mode greenhouse solar dryers for lima beans	Natural convection direct SD	12.03%	Purusothaman Mani & Valarmathi Thirumalai Natesan.,2021
Active mode greenhouse solar dryers for lima beans	Forced convection direct SD	14.7%	Purusothaman Mani & Valarmathi Thirumalai Natesan.,2021

CHAPTER-2

LITERATURE SURVEY

Different designs of SD are modified and developed to enhance the overall performances for users benefits are discussed below.

2.1 NATURAL CONVECTION CABINET DRIER

Developed a Direct design and Fabricated Natural convection solar dryer for drying tapioca in the countryside area as shown in Fig.2.1. A Solar

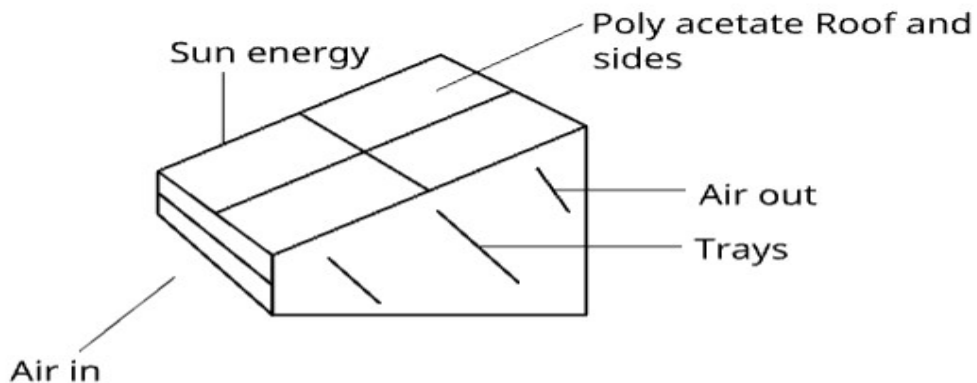


Figure 2.1: Direct solar drying (Cabinet Dryer)

collector area of 7.56 m^2 is needed to dry a 100 kg of tapioca in 20 hours (Drying time is 2 days). Beginning and End of the working period 79% and 10% of moisture content was considered on a WB. Mean atmospheric Conditions are air temperature of 32°C , relative humidity of 72% and solar radiation of $13 \text{ MJ/m}^2/\text{day}$ in horizontal area and also the climatic conditions were considered in Wari (lat. $5^\circ 30'$, length. $5^\circ 41'$), Nigeria with a minimum collected area of 1.08 m^2 was manufactured [9].

2.2 WIND VENTILATION SOLAR CABINET DRYER

Designed and researched wind Ventilated solar closet dryers in Nigeria at 7.5° latitude N shown in Fig.2.2. They Compared the cabinet drying method with a normal outdoor dryer, which resulted in cabinet drying giving a better solution than normal drying.

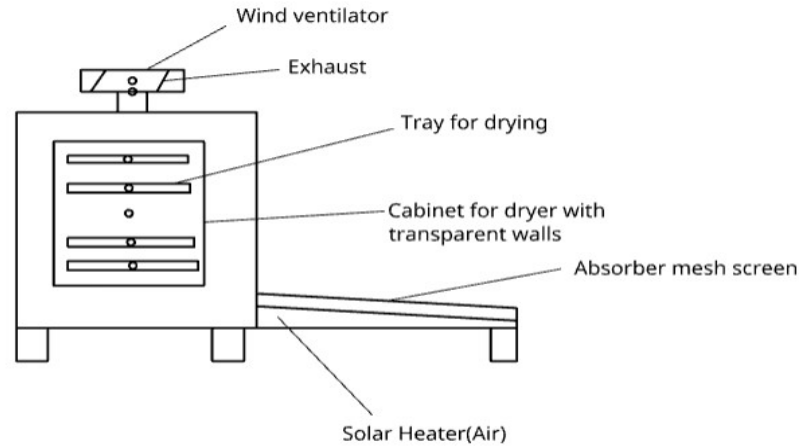


Figure 2.2: Solar wind ventilated cabinet drier

Average airspeed over the test period the maximum speed obtained through the solar dryer is 1.62 m/s, the mean efficiency of the solar system is 46.7%. The highest temperature detected in the dryer is 64°C of dry air. Average temperature of the dry air in the drying cabinet was above ambient temperature in the range of 5°C in the early morning to 31°C during the day. By using this method of drying, pepper and yam chips lose their maximum weight of 80% and 55% by drying [8].

2.3 EFFICIENCY ENHANCEMENT IN MIXED MODE SOLAR DRYER

Built a cheap, straightforward mode of mixed solar dryer with regionally specific materials as shown in Fig.2.3. For a period of time right after 12:00, the drying cabinet's temperature rise by up to 24°C (74%) (noon).

They observed the drying rate of 0.62 kg h⁻¹, collector efficiency of 57.5% and the decreased percentage of humidity rate is 85.4% on a DB respectively. The appropriate humidity level and quite quickest drying solution is achieved by use of this mode of solar dryer. The dried product is of exceptional grade [7].

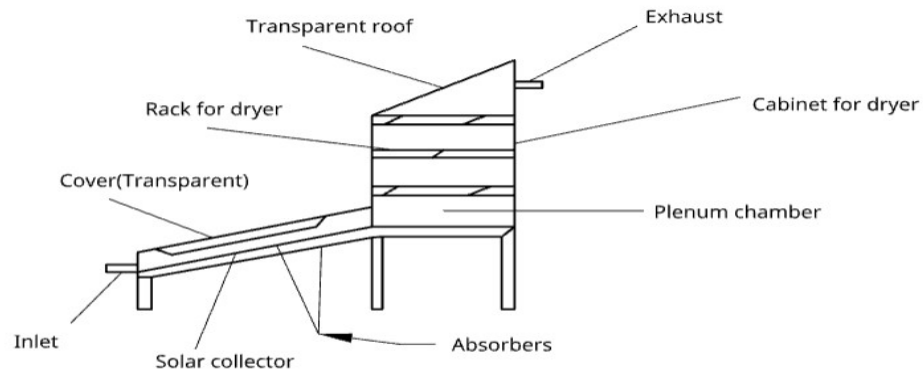


Figure 2.3: Mixed-Mode solar dryer

2.4 GRAVEL INTEGRATED FORCED CONVECTION SOLAR DRYER

A design, construction, and performance study of an indirect active mode solar dryer integrated with Gravel for heat storage is shown in Fig.2.4 to dry the chillies.

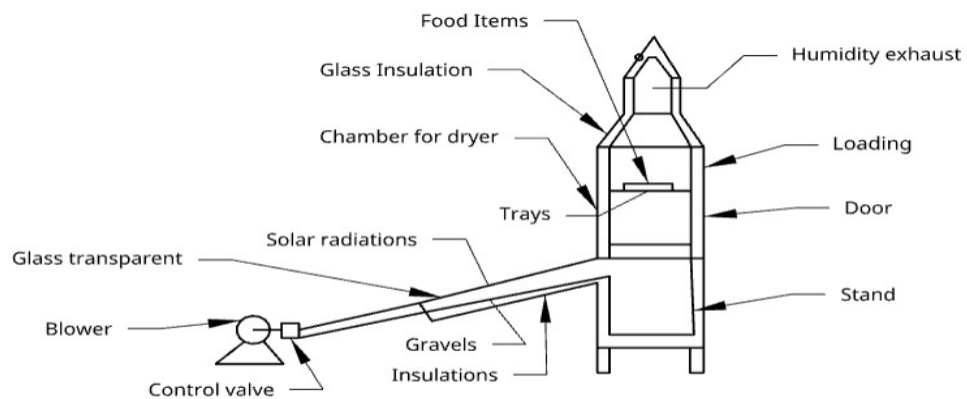


Figure 2.4: Active mode Solar Dryer

The dryer's ability to store heat makes it possible to keep the air at constant temperature inside the dryer. Additionally, the drying time was increased by the use of gravel heat storage material by around 4 hrs. every day. The chili was dried initially with a moisture content of 72.8% and ended with a moisture content of 9.2% to 9.7% on a WB respectively in the bottom and top trays. They came to the conclusion that a solar dryer mode of forced convection is more suited for small farmers or domestic users for high-quality dried chili production. They also observed a specific moisture extraction rate of 0.87 kg/kW h and the thermal efficiency of 21% [18].

2.5 NEW DESIGNED SOLAR DRYER FOR COCOA BEANS

Developed and designed an intermittent Solar dryer as a thermal energy storage method for drying cocoa beans as shown in Fig.2.5. The combination of direct radiation and convective heating is the mechanism to control

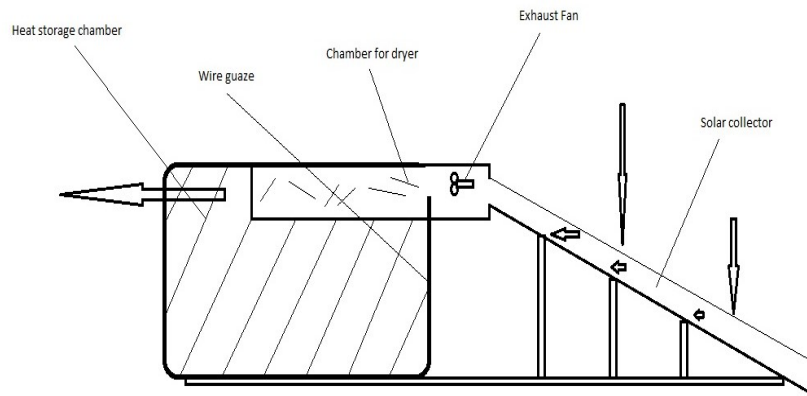


Figure 2.5: Schematic illustration view of solar dryer

the warm airflow throughout the beans. The solar collector area is basically an open-top crate with 10mm thickness to 1100×1000×200mm plywood. Experimental model of dehydrated cocoa by 72 hours with a bean moisture content (WB) of initially 53.4% to finally 3.6% timed intermittent process of drying to atmospheric temperature and relative humidity in the range of 25-30°C and 58% to 98% respectively. Natural convection drying achieved equilibrium moisture

content of 3.56% (WB). Forced convection drying achieved moisture content of 9.09% and 7.11% on a WB with an airflow rate of 1.02 m³/min and 1.32 m³/min [1].

2.6 SOLAR DRYER WITH V-GROOVE COLLECTOR

Designed and created a solar Dryer for drying a maize with a V-groove collector of 2.04 m², a chamber for drying and a blower as shown in Fig.2.6.

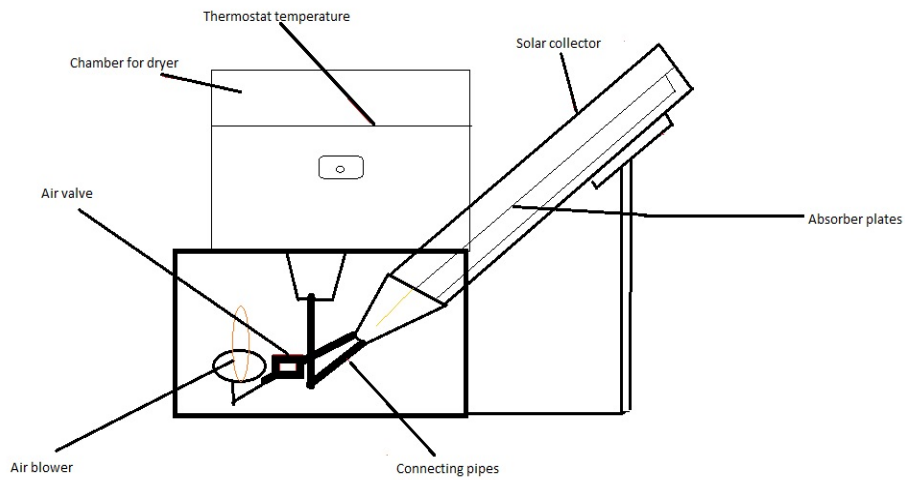


Figure 2.6: Section of solar maize dryer

They determined the Heat losses and the thermal energy from the solar collector by the three inclined angles of 30°, 45°, and 60°. The test period's results showed that the highest energy obtained peaked at 11 o'clock at noon and then progressively decreased because this was when solar radiation was at its highest. Other significant findings include the theoretical thermal energy and experimentally verified that increase in heat gain is caused by enhancing the intensity of radiation. The peak efficiency was observed at 11 am and then slowly decreased. The energy obtained at a tilt angle of 45⁰ is comparatively more than the energy obtained at an angle of 30⁰ and 60⁰ [3].

2.7 NEW DESIGNED SOLAR DRYER FOR CEREALS (RICE)

Proposed an optimization and evaluation of a semi continuous SD for cereals, rice etc .The attempted solar energy dryer was a cross stream and a dynamic blended mode type with an innovative and productive technique helped by a semi-consistent releasing framework. The Drying rig was planned and created which comprises six common sun based air warmers, with an assist of electric heating channel, an electrical rotational releasing valve drying chamber and air dispersing framework. The region of every authority is 2 m^2 (overall 12 m^2) and they introduced a method of light edged 45° towards the S. The analyses were tested on radiant periods between 11 am - 2 pm (The Solar radiation of normal occurrence in Sep.2001 is 865 W/m^2 , almost consistent relative stickiness and normal encompassing temperature of air is 25°C). The motive in this exploration was to assess the impact of mass air flow rate and release timespan, dryer harvesting pace of drying. Along these lines, they also observed a mass air flow rate of $0.0048 \text{ kg/m}^2/\text{s}$, $0.0066 \text{ kg/m}^2/\text{s}$ and $0.011 \text{ kg/m}^2/\text{s}$ and the progressive release of rotational valves are also observed in the time period between 15 to 30 min. Drying air temperature of 55°C was kept up with all through the trials. The greatest effectiveness of the gatherers was 37.13%. The greatest limit of the dryer was around 132 kg harsh rice with 27% beginning down to 13% last dampness content in three hours drying time. The greatest generally drying framework effectiveness was 21.24% on $0.011 \text{ kg/m}^2/\text{s}$ and stretch release season of 15 min, though the most extreme drying limit was on $0.011 \text{ kg/m}^2/\text{s}$ with 30 min stretch release time with generally total drying framework efficiency of 18.23% [2].

2.8 MULTI COLLECTOR PASSIVE MODE SOLAR DRYER

Designed a Multi collector passive mode SD for cassava and other crops drying. A 160 kg mass weight cassava batch with moisture content of 67% on a WB (Initially) is used as a dry load. Minimum 100 kg of water content to be removed to get a required moisture content of 17% on a WB. The Fundamentals of dryer design on expected the test location (Kumasi; latitude 6.71° N , longitude 1.61° W) provides a desired solar radiation of 400 W/m^2 , ambient conditions of 25°C , relative humidity of 77.8%, and a drying time of 30-36 hours. They

concluded that a solar collector area of minimum of 42.4m^2 was needed to obtain the expected performance and required drying efficiency of 12.5% depending on the design. At average ambient temperature and relative humidity of 28.2°C and 72.1% achieved an irradiance of solar power of 340.4 W/m^2 . They also achieved 35.5 hours of drying time and 12.3% of drying efficiency when tested at the maximum designed load. This proved that the design of the multi collector dryer procedure is sufficient [11].

2.9 A FRUITS AND VEGETABLES DRYER

Designed and developed an industrial dryer for fruits and vegetable to reduce the loss of vegetables and further develop storage conditions. The vegetable drying season was developed by a drum dryer with an average drying limit of 258.6 kg of tomatoes per piece and 84% thermal efficiency and a drying speed of 40 g/hr. ,35% of relative humidity and a drying temperature of drying the materials is 50°C . and is intended for modern customer. The average thermal efficiency of the dryer is 82% with a normal limit of 258.6 kg/batch. The speed of the device at normal drying is 40g/hr. The size, wind speed and time for drying significantly affects the gram weight of the tomato pieces to be dried. For all tomatoes and wind flow levels, tomato weight decreases with increasing drying time. In addition, gram weight decreased for all sizes at all levels of drying time as airflow increased [13].

2.10 NATURAL CONVECTION CABINET DRYER

To dry mango slices, a natural convection sun dryer (Cabinet Type) as shown in Fig.2.7. They came to the conclusion that, under ambient conditions, the collected area of 16.8 m^2 for the designed cabinet dryer is sufficient to dry a fresh mangoes of 195.2 kg (100 kg of mango slices) and the humidity content decreased from 81.4% to 10% on a WB during the drying period from April to June. A Solar Dryer was designed and built with a respected collection area of 1.03 m^2 [10].

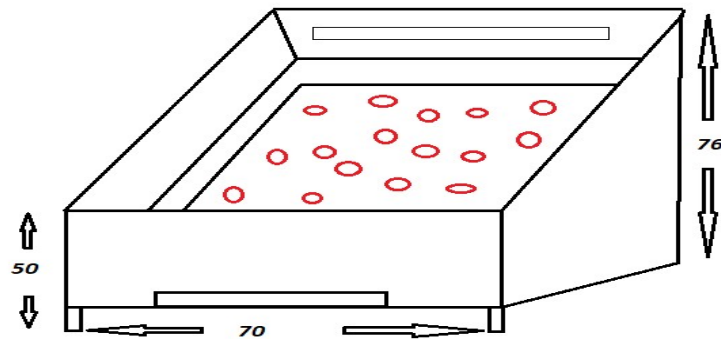


Figure 2.7: Isometric view of constructed solar Dryer

2.11 NEW DESIGNED TUNNEL DRYER FOR HOT CHILIES

In Bangladesh's tropical climate, Developed and created a mixed active mode type solar tunnel dryer for red chilies and green chilies. The SD includes a construction materials such as dryer with air inlet, exhaust fan, solar module, Solar collecting material, Metal frame for side fitting and Wooden support for the collector, net in plastic, a frame structure to support the plastic cover, a frame structure to support the dryer, a rolling bar, and a drying tunnel outlet. Red chili's moisture content was reduced throughout the drying period from 2.85 kg/kg to 0.05 kg/kg on a DB in 20 hours using a tunnel solar dryer, while upgraded and traditional sun drying methods required 32 hours to achieve the same results [16].

2.12 HEMI CYLINDRICAL SOLAR DRYER

Presented research on hemi cylindrical solar dryers. The dryer was created for industrial-scale drying of grapes. The maximum temperature permitted during the drying process was 65°C, with 2.3 MJ/m² of mean solar radiation and ten hours per day for 320 kg of grapes to dry. For 1.012 kJ/kg/⁰C air Specific heat, the moisture content was decreased throughout the drying period from 85% to 16% with a 30% dryer efficiency tunnel dryer in a week [22].

2.13 DOUBLE PASS SOLAR DRYER FOR RED CHILIES

Developed a two-stage solar dryer (DPSD) for drying red chili peppers in central Vietnam and compared it with an enclosure dryer (CD) and conventional open sun drying. They found that the mean temperatures for drying are 60°C, 52°C, and 35.8°C, and the noted relative humidity levels were 34% for DPSD, 45% for CD, and 62% for outdoor solar drying. The moisture content of fresh red pepper was almost the same in all drying experiments ranging from 9.18 kg/kg, 9.17 kg/kg and 9.30 kg/kg (DB) for DPSD, CD and outdoor solar drying. The final moisture content for DPSD was 0.05 kg/kg after 23 hours. 09 kg/kg after 29 hours for CD and 0.18 kg/kg after 36 hours for outdoor sun drying (except overnight). dried red chili. DPSD gave the quickest drying time to reach the required moisture content of pepper of 10% on a WB, which corresponds to the maximum drying rate compared to other techniques. Although the cost for construction of DPSD was comparatively more than that of CD, the overall drying efficiency of DPSD was more than twice that of CD. Therefore, the dual-circulation solar dryer was found to be drying of red chili pepper is technically and economically suitable under the special conditions of Central Vietnam [13].

2.14 NEW DESIGNED HYBRID SOLAR DRYER FOR BANANAS

Designed and constructed a solar dryer of hybrid mode energy and a heat exchanger. By reusing the drying air up to 65% within the SD and expelling a little portion of it external, the efficiency of the dryer was increased. It can rise in the summertime in central Europe. In this condition Air temperatures from 30 to 40°C reaches more than the ambient temperature. The SD capability to dry about After 8 hours on a sunny day, Bananas of 30 kg attained the moisture content level of 82% initially to 18% on a WB. At the time of drying it decreased the Moisture content level of 62% on a WB during drying in the open sun [5].

2.15 NEW DESIGNED THREE PASSIVE SOLAR DRYER

Researched and designed three passive solar dryers as shown in Fig.2.8. This investigation into the kinetics of drying and the quality of dried orange slices in three indirect SD with active mode type, to compare the thermal performance of SD, a data acquisition system is used to track the evolution of climatic variables. The researched results obtained during this study show that it absolutely was possible to attain within the three models of dryers, the required climate for drying food while preserving its nutritional quality. The beginning weight for the orange slices have been decreased from 1005 grams to 273 grams all the existing notes of drying modes. According to the various designs and operation modes, the three passive mode dryer gives better thermal performance. They also observed that while in the third SD (Dryer 3) the inside temperature was 40°C , in dryer 1 the inside temperature was 34°C , and in dryer 2 it was 28°C respectively,

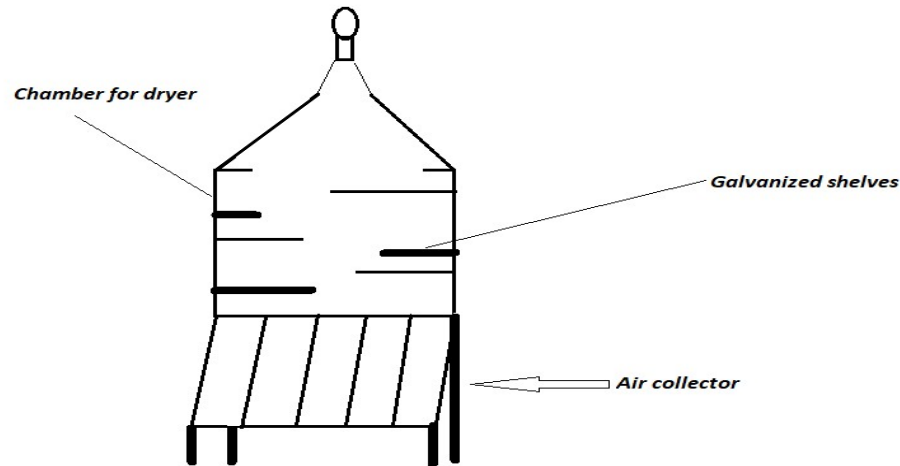


Figure 2.8: Three Passive solar dryer

according to the tested measurements for a few days in the month April to May, the dryer2 does not exceed 19.5°C of average temperature. While the outside relative humidity, the atmosphere changes between [60%, 85%]. It is noted that the relative humidity into dryers is for Dryer 3, Dryer 1 and Dryer 2 values range between [5%, 35%], [5%, 70%] and [32%, 75%] respectively [12].

2.16 CYLINDRICALLY SECTIONED SOLAR DRYER

A cylindrical section SD system was designed as shown in Fig.2.9 and a performance analysis was created. The system consists of a collector with a 1.10 m length and 1.10 m width plate of flat surface. A cylindrical sectioned drying chamber with an exhaust fan was built and designed for crop beans of 70 kg to dehydrate. The collector of solar air is examined with a total of three flows of air to note the drying performance. At 11:00am the SD reached its highest temperature of 71.4°C. A lowest temperature of 40°C was attained with an air flow rate of 0.0675 kg/s at a radiation intensity of 460 W/m² and an airflow rate of 0.0401 kg/s at a radiation intensity of 750 W/m². The solar air collector's average thermal efficiency ranges from 18.63% at the minimum air flow rate of 0.0405 kg/s to a maximum value of 25.64% at an air flow rate of 0.0675 kg/s. The beans had a 70% beginning moisture content and a 14% end moisture content at a flow rate of

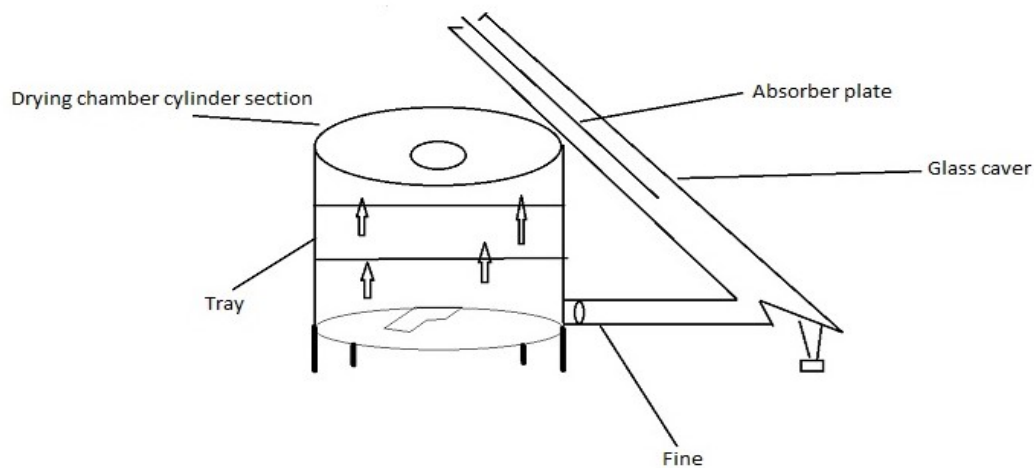


Figure 2.9: SD system, a cylindrical section

0.0405 kg/s, 18% DB at a flow rate of 0.0540 kg/s, and 20% DB at a flow rate of 0.0765 kg/s [4].

2.17 PARABOLIC COLLECTOR SD INTEGRATED WITH HEAT STORAGE SYSTEM

Proposed a new method of drying products and introduced a solar dish parabolic concentrator for preserving food items. To Fabricate the model, materials

include square sheets and pipes SS sheets and pipes, aluminum and iron materials and transparent sheets or glass. This method is a type of conversion of energy from solar radiation to thermal energy. Using this system, various applications are carried out such as drying fruits and vegetables, generating heat energy and water warming. A nitrate salt was integrated as a thermal storage system in this SD which was designed and researched for drying red peppers of 1 kg at a drying temperature between 19.6°C and 62.4°C . Parabolic SD system gives more efficient and better performance of drying and reduces humidity content from initially 86% to 10% (finally noted) for 1 kg of red pepper in 24 hours when compared with Natural sun drying for 36 hours. They obtained the highest temperature by using heat storage material of nitrate salt from 87.8°C to 125°C and the mean temperature at ambient condition from 19.3°C to 37.4°C . They also found that Although without proper sunlight, this kind of SD preserves a warmth throughout the dryer for maximum 4 hours by the help of nitrate salt thermal storage technique [30].

2.18 FORCED CONVECTION SD FOR DRYING GROUNDNUTS

Designed and analyzed an Active mode SD for drying groundnuts . The factor affecting storing products for longer days is the humidity content in food items which leads to bacteria, fungus formations. They developed a quality of the products to prevent these kinds of issues. In Groundnuts, the humidity content was observed between 10% and 15% on a WB. The prototype of the solar dryer which is very helpful to reduce the moisture content to store the groundnuts for longer days. Analyzed and noted the performance of the forced convection SD with regards to various designs and other parameters like temperature inlet and outlet of the drying chamber, flow rate of air, removal of moisture rate. The area of the Solar drying system is about 2 m^2 with fabricated materials including an absorber copper plate coated with black paint to increase the heat absorbing rate. The Groundnut initially contains a humidity content of 25% to 30% on a WB. Then after the process of drying the groundnuts over the proposed SD method, the humidity content is gradually decreased to 10%. Finally stated that the efficiency of 39.2%

is obtained for the mass flow rate of 0.022 kg/s . And also mentioned that mass flow rate of air increases above 0.022kg/s which makes impacts in drying overall efficiency and mean temperature for collector is step by step reducing and when mass flow rate of air decreases lower than 0.022kg/s , the efficiency of the dryer still decreases [28].

2.19 NEW DESIGNED MIXED MODE SOLAR DRYER FOR DRYING GINGER AND TURMERIC

Designed and Fabricated a new model of drying for ginger and turmeric products. In this type of mixed mode SD, the process of drying is very comfortable to handle, assemble and disassemble procedures are simple. Also Done chemical processes and performance analysis of the SD. In Nepal, The production of turmeric and ginger are popular and high but they are dried by the method of natural Solar drying. so the quality of the products is poor. Factors considered for the designs are solar irradiation, well warm sunshine, location at latitude, cheap materials, humidity content and capacity of drying products. To predict the temperature inside the dryer and behavior of airflow was CFD analyzed by using ANSYS software. From the CFD analysis result, the mean temperature from lower to upper trays increases and reaches peak temperature at noon. Compared to the natural solar drying using turmeric and ginger, this kind of SD took almost only 14 hours of sunlight to reach the humidity content initially from 88% to 11% as a final result. Before comparing the dryer, the properties of Oleoresin and essential oils were tested by using Steam distillation and Soxhlet methods. Recorded the highest collector rate and efficiency of the dryer at 45.32% and 31.36% respectively. Compared to various drying methods, for drying ginger and turmeric, this kind of Mixed mode of SD is more appropriate in reducing moisture content and enhancing quality products [20].

2.20 NEW DESIGNED INDIRECT TYPE SD TO DECREASE PRODUCTS WASTAGE

Proposed a newly designed Indirect solar dryer to reduce the product waste of agriculture and also to enhance the storage conditions. By using this kind of drying, it receives sun shines and dries the food products by reducing agricultural wastes and preserving the products' longer days. Also helps in extension of shelf life in agriculture. The dryer dimension was designed with a construction volume of 40*50*40 cm by using local materials like wood, transparent polyurethane sheets or glass, Metal sheet of aluminum and heat conducting metals for trays. The average temperature obtained from the dryer was 75⁰C which is greater than the ambient temperature of 30.5⁰C. The moisture content was reduced by 199.9 grams of vegetables by using this drying method. If the weather was friendly for the dryer possibly it reduces more moisture content and decreases the weight of the vegetables maximum 300 grams effectively [23].

2.21 GREENHOUSE SOLAR ACTIVE AND PASSIVE MODE DRYER FOR DRYING LIMA BEANS

Fabricated and investigated experimentally about active and passive modes of drying Greenhouse SD. Designed and researched the thermal performance of span and parabolic roof kind of GHSD under the passive and active mode of drying as shown in Fig.2.10. Dryer model is fabricated and covered with a polyethylene sheet to enhance the solar energy effects.



Figure 2.10: Experimental setup of span and parabolic Drying GHSD

They noted the humidity content of the lima beans decreased from 75% on a WB (before drying) to 11% on a WB (after drying) and Approximately lost its weight

from 2500 grams to 900 grams. For the same performance, the weight reduced by natural Convection took 36 hr and by Forced convection 32 hr and by OSD 40 hr. By use of this kind, the maximum efficiency obtained on an active mode of drying was 14.7% in a parabolic dryer and minimum efficiency obtained on a passive mode of drying was 12.03% in a span dryer. Finally, they conclude that the GHSD of forced convection parabolic drying gives much better results than other kinds of drying and noted that parabolic forced dryer gives 16.39 kcal/100g more drying energy than OSD.

CHAPTER-3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 AIM

To Design and Fabricate the Portable GreenHouse Solar Dryer for Domestic usage.

3.2 OBJECTIVE

- This attempt aimed to improve the efficiency and utilize the thermal energy to dehydrate the food product by conduction and convection processes.
- Helps the users to keep the Solar Dryer wherever they need the application by means of portable folding mechanism.
- To maintain sustainable and required temperature inside the dryer throughout the work.

3.3 SCOPE OF THE PROJECT

The attempted invention was passive mode direct solar dryer which couldn't using any external devices. The invention developed the unique feature of drying technique by expanding a polyethylene sheet covered like a dome shaped structure with the help of stretcher and ribs by pulling the rope connected on the runner and it would mounted on the aluminum square plate drilled hole on all the corners to fix the solar dryer which protect from wind breeze and wind storms. The proposed design was attempted mainly because to overcome the issues from the existing solar dryers such as improving the overall efficiency, comfortably keep the solar dryer wherever users need the applications by means of portable folding mechanism.

CHAPTER-4

MATERIALS AND METHODS

4.1 MATERIALS AND PROCESSES

Consideration of the materials used for to fabricate the Portable GHSD are good in thermal conductivity, Light weight and should be ductile with appropriate dimensions.

The following materials obey the conditions above and so the fabrication done by use of the materials.

4.1.1 Polyethylene transparent plastic sheet



Figure 4.1: 200 micron Polyethylene sheet

- Polyethylene sheet is a type of plastic sheet which is good in impact resistance and flexible according to its thickness as shown in Fig.4.1.
- Due to its lightweight transportation is easier and easy to lifting. For portable GHSD 200 micron polyethylene sheet was used because of its advantages mentioned and also for its good heat absorbing property.
- The 200 micron polyethylene sheet for a solar dryer is a thin, transparent and durable material that has excellent light transmission properties.
- It can withstand the heat from the sunlight and allow the products to dry without any electricity or any flammable gas.

4.1.2 Aluminum Plate



Figure 4.2: Aluminum Plate

- Aluminum plate has major advantages in industrial usage of many cases due its light weight, corrosion free, good in electrical and thermal conductivity, ductile metal and also good in reflectivity as shown in Fig. 4.2.
- The proposed portable GHSD need a food keeping material which is very good in thermal conductivity and light weight with corrosion resistance property.
- So the food item plate is made from the aluminum plate material because of its light weight and good in thermal conductivity.
- The 2.5mm AL 6061 plate was used due its better thermal absorbing property and drilled holes at all the four corner edge for the portable GHSD footer to be mount.

4.1.3 PVP Pipe and Thin Steel Rods [2.5mm]



**75mm steel rod
(Ribs)**



**25mm steel rod
(Stretchers)**



Figure 4.3: PVC Pipe (Chimney)

- Steel rods are made of mostly ferrous and iron based alloys as shown in Fig. 4.3. This type of steel rods are mostly used in industrial usage for fabricating frame structure, automobile industries and furniture items etc.,
- Here the chosen steel rod was high strength and flexible in using. So the steel rods used in making stretchers and ribs gives better result according to our desire.
- Because of its properties It was used for to make a stretchers and ribs and the connections of the polyethylene sheet hinged with aluminum plate and the PVC acts as a chimney to exhaust the warm humid Air.

4.1.4 Nylon Rod

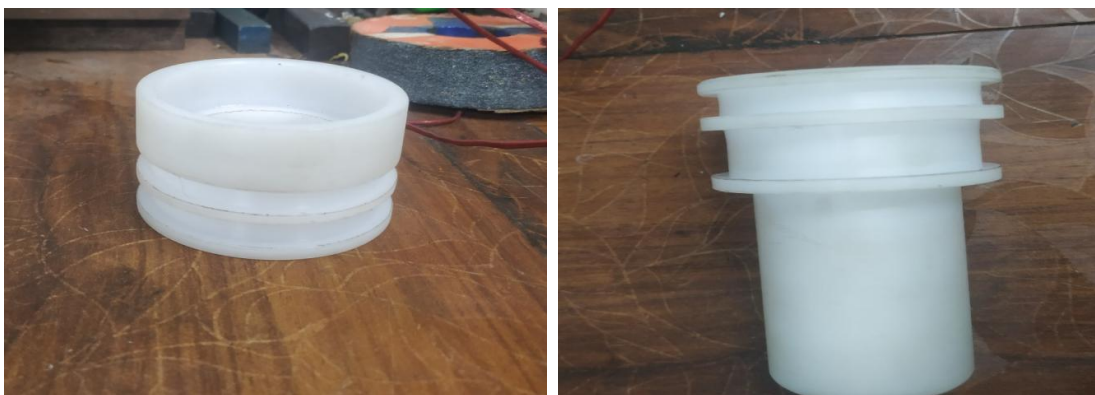


Figure 4.4: Notch and Runner

- Nylon rods are made from plastic materials as shown in Fig. 4.4. Nowadays nylon rods are commonly used in industrial areas in many cases.
- It was highly durable, has high tensile, compressive strength, effective in wear resistance and mainly more advantage in machining as easier.
- So the Nylon rod material has been chosen to make a Runner and a notch for the solar dryer.
- Because of the light weight, It was easy to pull up the runner for extending the stretchers which push up against the ribs.

4.2 METHODOLOGY

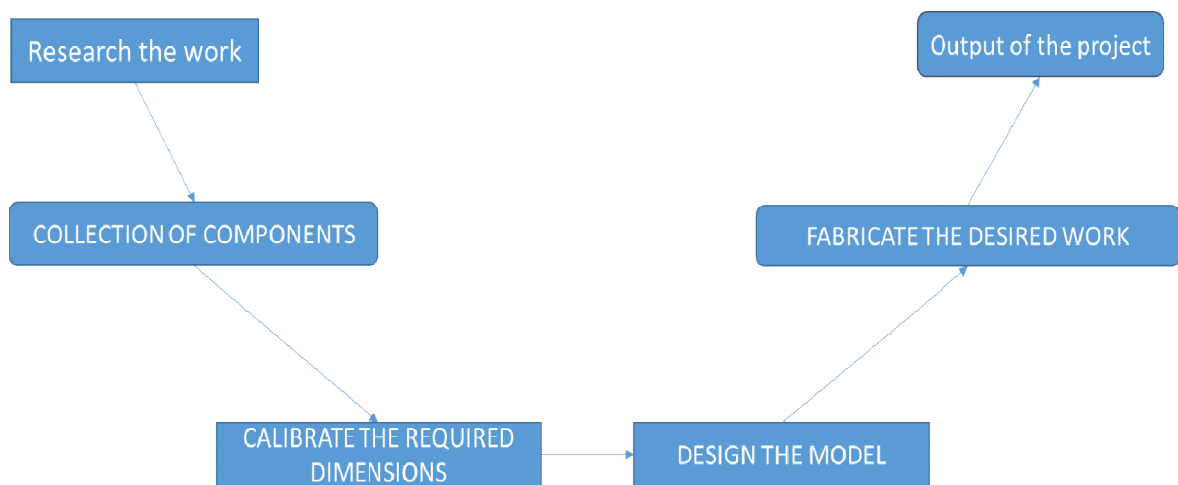


Figure 4.5: WORKFLOW OF PORTABLE GREENHOUSE SOLAR DRYER

4.2.1 Calibration of Portable Greenhouse solar dryer

The fabrication was done in appropriate dimension with suitable materials used as shown in Fig. 4.6 and Fig. 4.7. Area of the proposed solar dryer when expanded is 1m^2 and the Aluminum plate with area of 1.1025 m^2 . The inside dryer volume when SD expanded is 1.18m^2 .

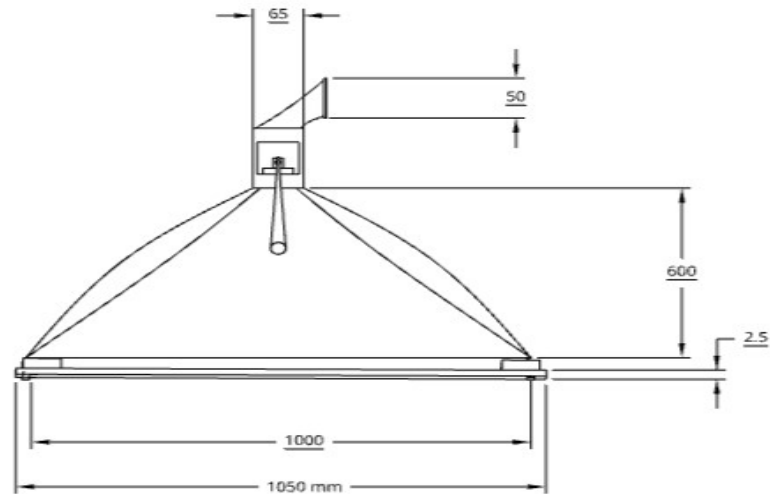


Figure 4.6: Dimension of the Portable GHSD

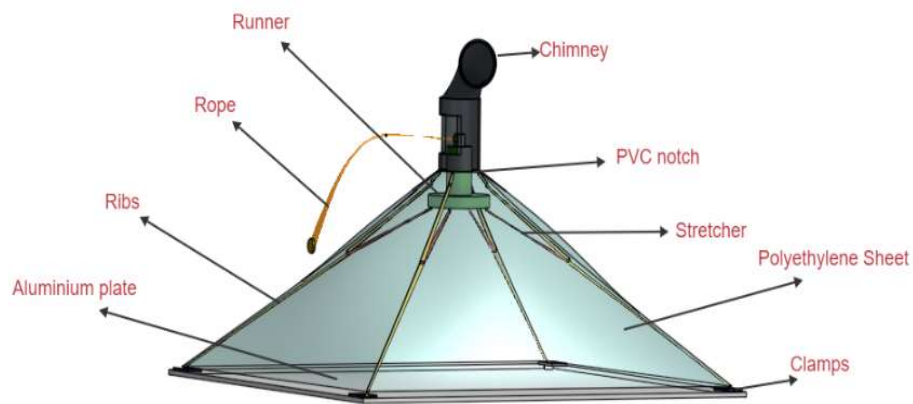


Figure 4.7: Perspective view of Portable GHSD

- 1) From the above reports, we understood that SD refers to a technique that utilizes incident solar radiation to convert it into thermal energy required for drying purposes. Most solar dryers use solar air heaters and the heated air is then passed through the drying chamber to be dried. This air transfers its energy to the materials causing evaporation of moisture of the materials.

- 2) From the use of this principle, Our attempt is to design and fabricate the portable and foldable GHSD for small scale farmers and domestic purposes.
- 3) Many kinds of advanced solar dryers type have been designed and fabricated to enhance the efficiency and make comfortable benefits for small scale farmers. But these kinds of solar dryers would occupy more space and some dryers are permanently mounted.
- 4) In order to overcome these kinds issues, The proposed design helps the users to place the solar dryer wherever they need the application and it is easy to fold and comfortable to keep it in a respected place.
- 5) The working principle of this solar dryer is when the rope (Connected with runner) pulls up which leads to moves up the runner for extending the stretchers, that push up against the ribs.
- 6) This creates a force that fully extends the polyethylene sheet for warm up the air inside the dryer. After fully extended the tapered runner locks into the top notch.
- 7) The top placed inclined black stainless steel PVC pipe acts as a chimney which exhaust the warm air to maintain constant temperature inside the dryer throughout the work.
- 8) A food items are placed inside the dryer on the plate and the plate is made up of Aluminum metal which conduct high temperature to increase the thermal efficiency.
- 9) The clamps are fixed at all the four corners of the aluminum plate to hold the portable Greenhouse Solar Dryer and which prevents from the wind breeze and wind storm.

4.2.2 The Different views of Portable Greenhouse Solar dryer (Design)

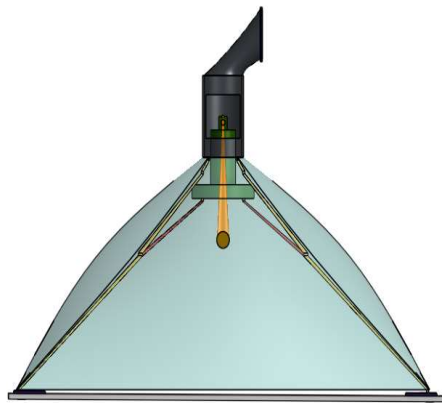


Figure 4.8: FRONT VIEW

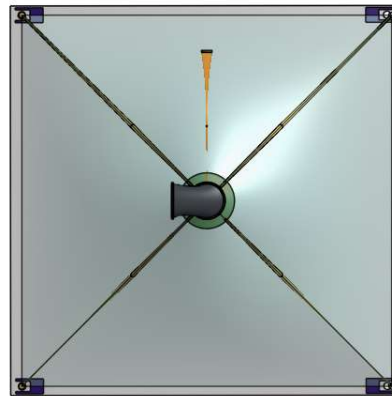


Figure 4.9: TOP VIEW

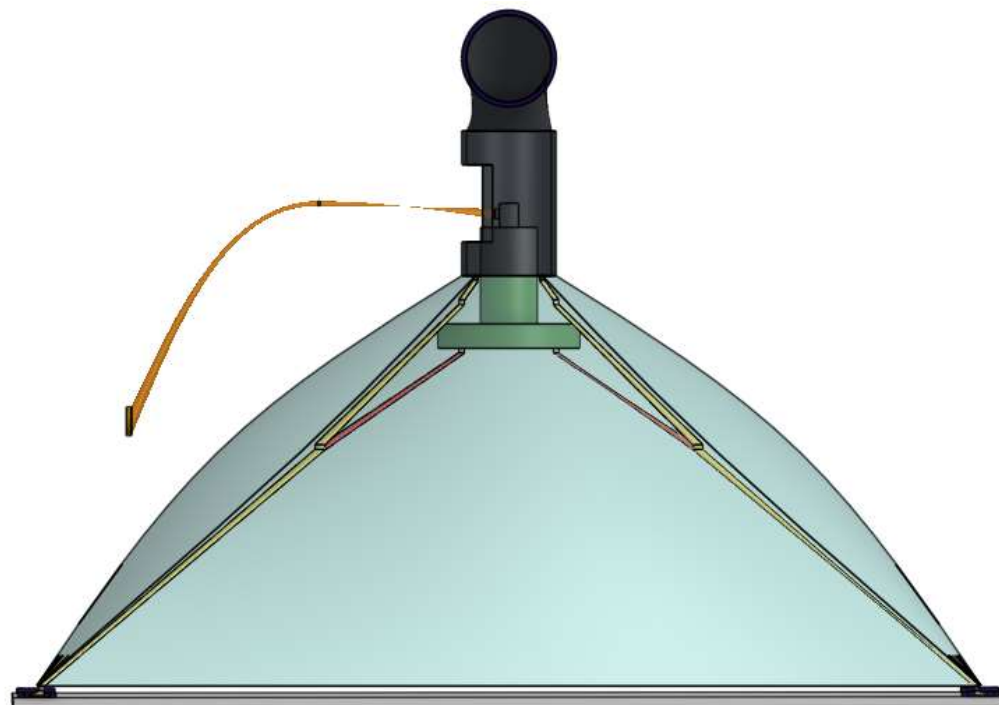


Figure 4.10: SIDE VIEW

4.2.3 Fabricated the proposed Portable GHSD



Figure 4.11: Assembled Front view of Portable GHSD (Drying performance Tested with red chilli



Figure 4.12: Assembled side view of Portable GHSD (Drying performance Tested with red chilli

CHAPTER 5

RESULT AND DISCUSSION

5.1 THERMAL ANALYSIS OF PORTABLE GREENHOUSE SOLAR DRYER

The attained temperature and the air velocity have the most effects on the drying process. Drying is a procedure that removes moisture from a product and transfers heat from the source to the products enclosed space. In solar drying, Solar energy provides the majority of the drying heat, active or passive mode drying can be used to circulates air into the dryer.

By using ANSYS Workbench analysis software, Researched and noted the total heat flux, temperature achieved and Directional heat flux at 200 micron polyethylene sheet and Aluminum plate by steady state thermal analysis.

5.1.1 Thermal Analysis on 200 micron Polyethylene sheet

Thermal analysis simulation is applied on Portable GHSD 200 micron Polyethylene sheet.

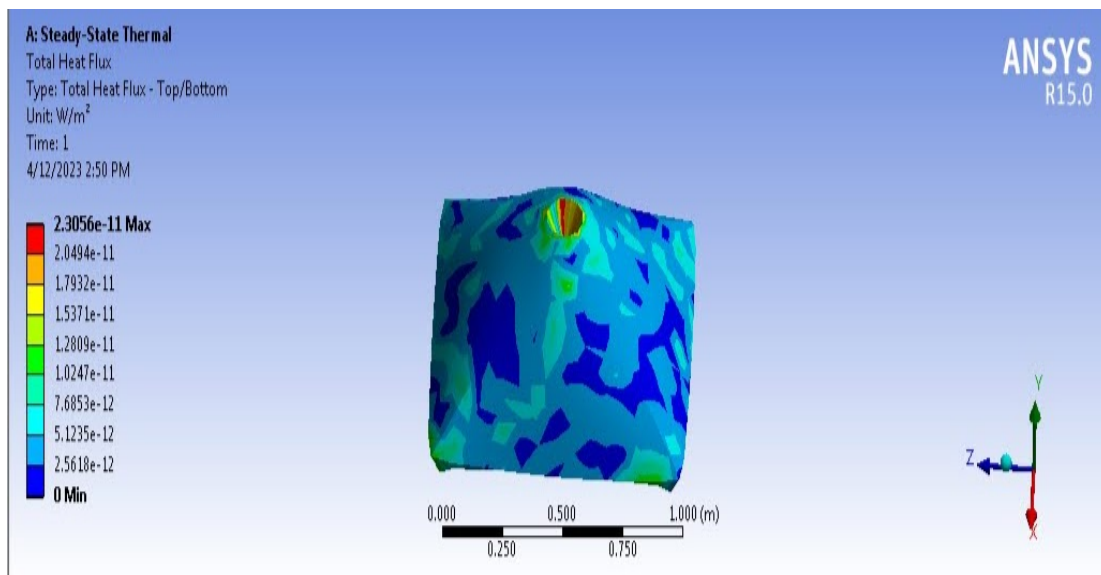


Figure 5.1: Total Heat Flux measurement on polyethylene sheet

- Heat Flux is nothing but the amount of heat energy transferred through the layer of the materials per unit cross sectional area as per time taken.
- The polyethylene sheet thickness have been varied and assumed that the ambient temperature as 30⁰C.
- At the rate of 30⁰C (atmosphere temperature), Achieved maximum heat flux of 2.3 W/m² by less than 1min of time for thin layer of the sheet .
- From the thickness of sheet, solar energy and total heat flux obtained, it is clearly observed that the proposed Greenhouse solar dryer performs better on sunny region than open sun drying with affordable price.
- The comparison of results obtained in heat flux respect to the time is shown in Fig.5.1.

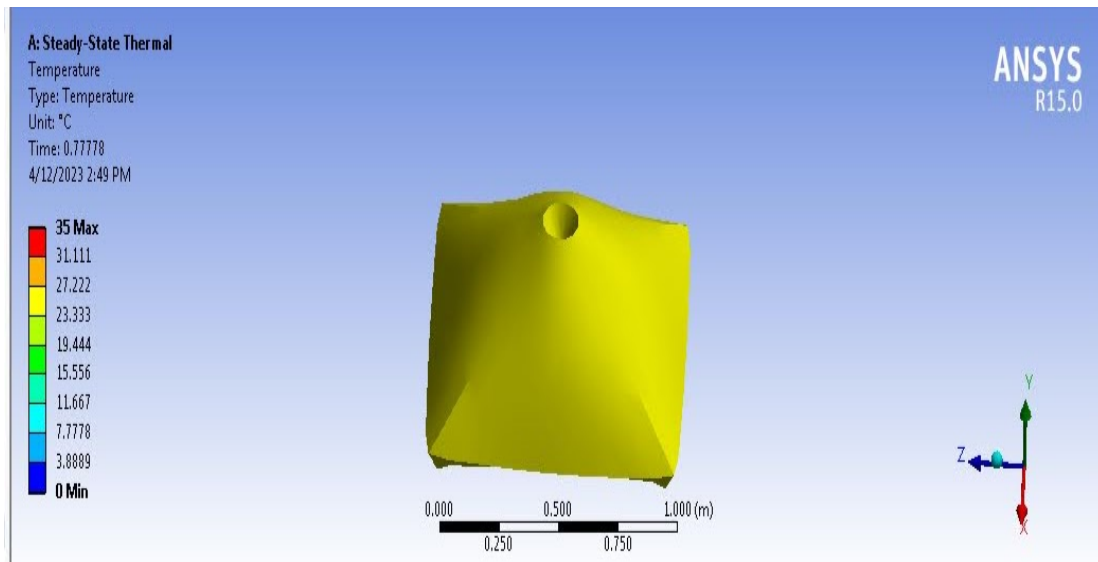


Figure 5.2: Temperature measurement on polyethylene sheet

- Temperature is the measure of the average energy motion of the molecule of the substance.
- The polyethylene sheet thickness have been varied and assumed that the ambient temperature as 30⁰C.
- At the rate of 30⁰C (atmosphere temperature), Achieved maximum temperature around the layer of the sheet of 35⁰C by less than 30 min.

- Because of the property of thin polyethylene sheet, the solar energy absorbed and make radiation scattered inside the dryer and makes temperature rise.
- The comparison of results obtained in temperature respect to the time is shown in Fig.5.2.

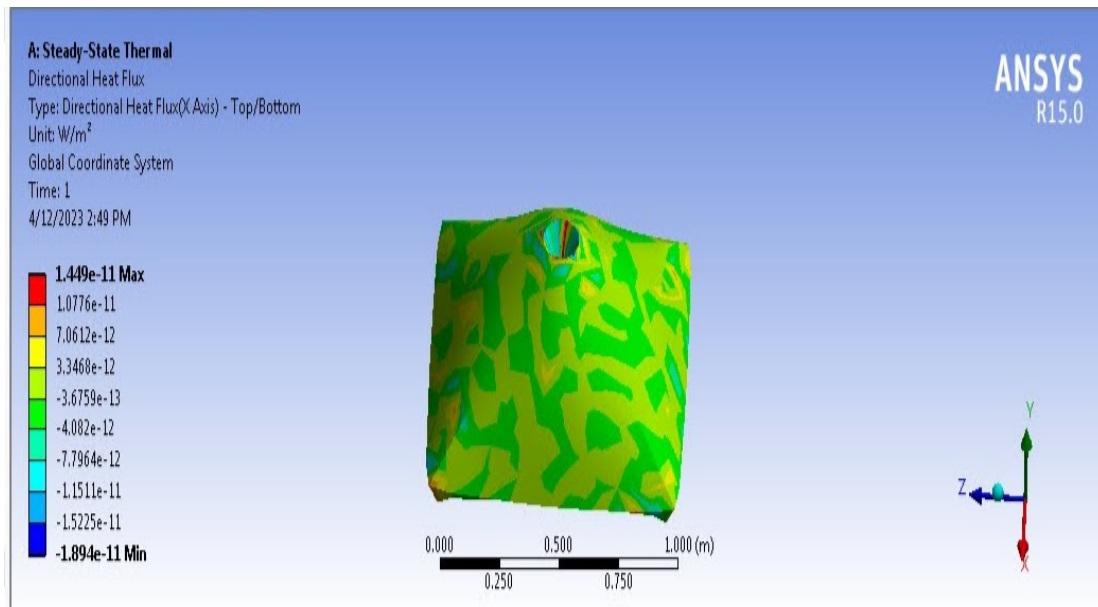


Figure 5.3: Directional Heat flux measurement on polyethylene sheet

- Directional heat flux is a measure of energy obtained per unit area as per unit time which determines the temperature variation of the objects.
- The polyethylene sheet thickness have been varied and assumed that the ambient temperature as 30⁰C.
- At the rate of 30⁰C (atmosphere temperature), Achieved directional Heat flux around the layer of the sheet of 1.5 W/m² by less than 30 min.
- From the thickness of sheet, solar energy and directional heat flux obtained, it is clearly observed that the proposed Greenhouse solar dryer performs better on sunny region than open sun drying with affordable price.
- The comparison of results obtained in heat flux respect to the time is shown in Fig.5.3.

5.1.2 Thermal Analysis on Aluminum plate

Thermal analysis simulation is applied on Portable GHSD 200 micron Polyethylene sheet.

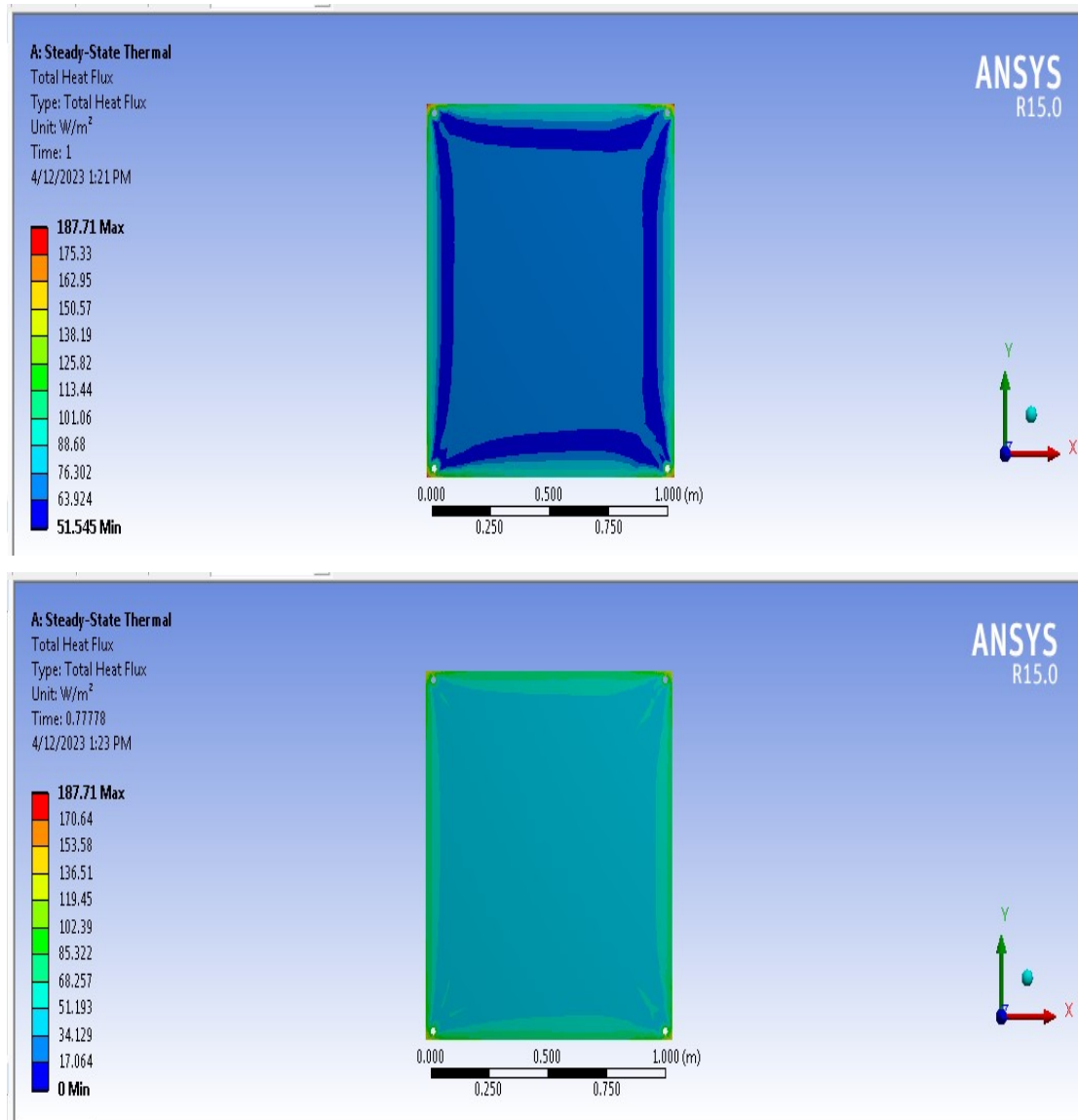


Figure 5.4: Heat Flux measurement on Aluminum plate

- Heat Flux is nothing but the amount of heat energy transferred through the layer of the materials per unit cross sectional area as per time taken.

- The Aluminum plate thickness have been varied and assumed that the ambient temperature as 30⁰C.
- At the rate of 30⁰C (atmosphere temperature), Achieved maximum heat flux of 187.71 W/m² by less than 1min of time for 2.5mm thickness of plate.
- From the thickness of plate, solar energy and total heat flux obtained, it is clearly observed that the proposed Greenhouse solar dryer performs better on sunny region than open sun drying with affordable price.
- The comparison of results obtained in heat flux respect to the time is shown in Fig.5.4.

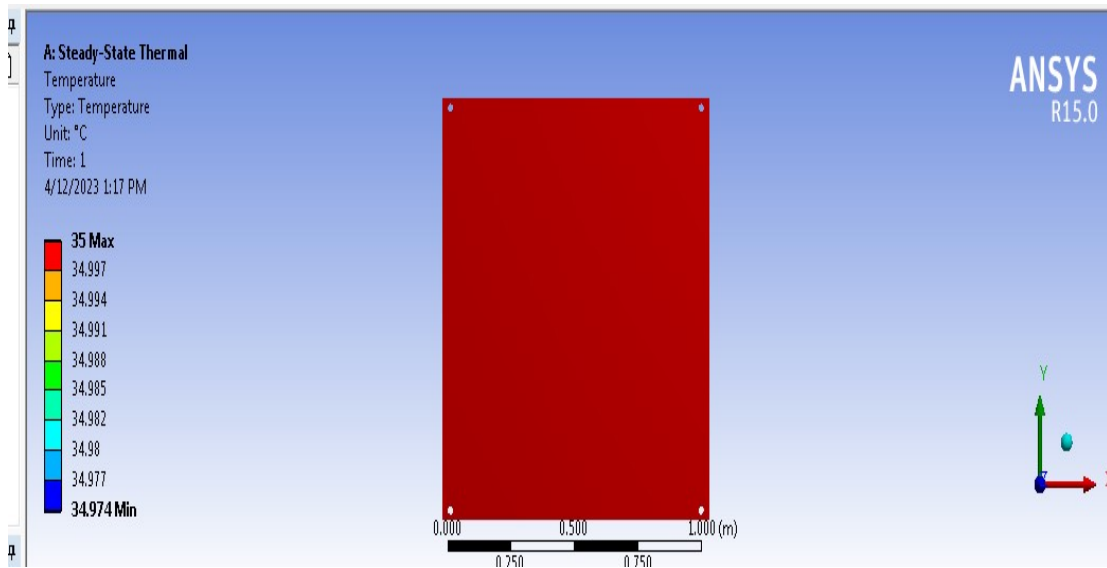


Figure 5.5: Temperature measurement on Aluminum plate

- Temperature is the measure of the average energy motion of the molecule of the substance.
- The Aluminum plate thickness have been varied and assumed that the ambient temperature as 30⁰C.
- At the rate of 30⁰C (atmosphere temperature), Achieved maximum temperature on aluminum plate of 35⁰C by less than 30 min.
- Because of the property of aluminum plate, the solar energy absorbed and conduct high amount of heat on the plate and makes temperature rise.

- So, it helps increase in thermal efficiency.
- The comparison of results obtained in temperature respect to the time is shown in Fig.5.5.

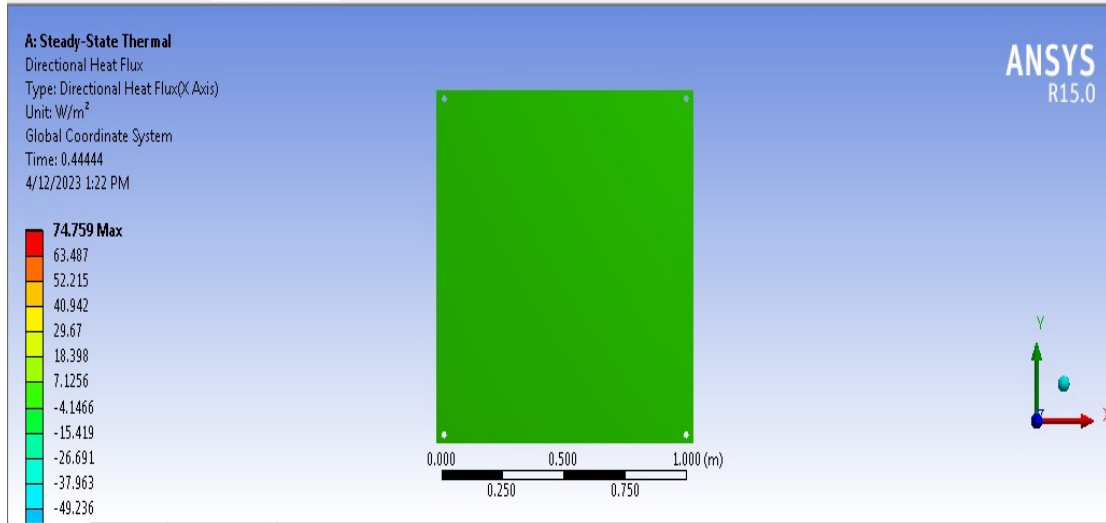


Figure 5.6: Directional Heat flux measurement on Aluminum plate

- Directional heat flux is a measure of energy obtained per unit area as per unit time which determines the temperature variation of the objects.
- The Aluminum plate thickness have been varied and assumed that the ambient temperature as 30⁰C.
- At the rate of 30⁰C (atmosphere temperature), Achieved directional Heat flux around the layer of the sheet of 74.759 W/m² by less than 30 min.
- From the thickness plate, solar energy and directional heat flux obtained, it is clearly observed that the proposed Greenhouse solar dryer performs better on sunny region than open sun drying with affordable price.
- The comparison of results obtained in heat flux respect to the time is shown in Fig.5.6.

CHAPTER-6

CONCLUSION

The various methods of solar dryers are designed and developed to enhance the overall efficiency of drying a food items and make comfortable usage for small scale farmers. The following conclusions are observed from the literature,

- ❖ Cabinet type indirect SD reaching a Maximum temperature of 64°C from a temperature range of 50°C to 30°C during a day time. So the food items dried and lost weight nearly 80% to 50%.
- ❖ Using Gravel for a SD as a thermal storing material keeps temperature constant inside the dryer even in dull sunshine regions and helps in reducing a 80% of moisture content from fresh items.
- ❖ SD with V- Groove collector achieves the maximum temperature and efficiency at 11 o'clock (noon) and then gradually decreases . The peakest efficiency was reached when the groove was at an angle of 45° rather than 30° and 60° .
- ❖ The maximum drying efficiency of 12.3% was reached in the multicollector passive mode solar dryer more than the normal dryer.
- ❖ Drying in an active mode SD reaches thermal efficiency of 39.2% at a mass flow rate of 0.022 kg/s. Changing in mass flow rate impacts in efficiency decreases.
- ❖ GHSD of span dryer and parabolic dryer gives different results in drying efficiency. GHSD of parabolic drying gives better thermal performance than span drying and OSD with a thermal efficiency of 14.7%(maximum).

But these kinds of SD are occupy more space and permanently mounted. In order to overcome these kinds issues and to control the external energy source, comfortable handling and makes affordable price, the portable GHSD was made. So from this research work, it is clearly observed that using a new feature of

proposed portable GHSD makes more benefits for the uses under affordable price and the improvement in the quality of the products produced from this solar dryer could able to achieve higher prices in the market.

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CHAPTER-1

INTRODUCTION

Drying materials, particularly fruits and vegetables, is done by means of solar dryers, which harness solar energy. Solar dryers use the sun's heat to decrease the moisture content of the various food items and respected materials. In order to enhance the agricultural products shelf lives, dryers have been created and are now being employed and also some of the advantages of using SD are higher product quality is obtained, lowers losses and improves product market prices, products are protected from dust, flies, and rain, reduces environmental effects and prevents the need for fuel and it is more affordable and effective. The majority of these methods either rely on pricey energy sources like electricity or combine solar energy with another type of energy. Because the concluded designs and Drying techniques are sometimes inappropriate or the affordable cost has remained out of reach, the majority of projects of this kind have not been adopted by small scale farmers and also some of the disadvantages of using SD are, the quality of the products cannot be reached in some situations and sufficient use of Solar energy is necessary. This study's goal is to elaborate the new feature of proposed portable greenhouse solar dryer and outline some of the fundamental SD types with a motive of providing a better solution on their effectiveness in the drying and how well they work to dry agricultural products.

1.1 TYPES OF SOLAR DRYER

The modes of SD are classified into three types namely sun or natural dryer, Direct solar dryer and Indirect solar dryer.

1.1.1 Sun or Natural drying

Natural dryer is the oldest and most straightforward drying method. The majority of agricultural products, including grains, spices, fruits and vegetables are still dried in the natural solar energy. However, there are numerous disadvantages to drying

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