

PERFORMANCES OF DIFFERENT GREENHOUSE SOLAR DRYER FOR DRYING OF GINGER

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

By

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**DEPARTMENT OF MECHANICAL ENGINEERING
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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

APRIL - 2023



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **PANNEERSELVAM. K (39150096)**, and **MADHAN KUMAR. A (39150077)**, who have done the Project entitled **"PERFORMANCES OF DIFFERENT GREENHOUSE SOLAR DRYER FOR DRYING OF GINGER "** Under our supervision from DECEMBER 2022 to APRIL 2023.

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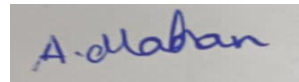
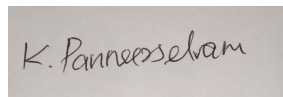
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DECLARATION

We, **PANNEERSELVAM.K (Reg.No. 39150096)** and **MADHANKUMAR.A (Reg.No.39150077)** hereby declare that the Project Report entitled “**PERFORMANCES OF DIFFERENT GREENHOUSE SOLAR DRYER FOR DRYING OF GINGER** ” done by me under the guidance of **Dr. M. PURUSOTHAMAN, M.E., Ph.D.**, Associate Professor in Department of Mechanical Engineering is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering in Mechanical Engineering.

DATE: 26.04.2023

PLACE: CHENNAI



SIGNATURE OF THE CANDIDATES

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ABSTRACT

Agriculture products can be preserved for long-term use by drying, a dehydration process. Open sun drying, which involves simply laying the products on the ground, a road, mats, a roof, etc., is the most often used and least expensive technique. However, there are certain drawbacks to open-air drying, including the need for favourable weather, dust contamination, significant animal and bird consumption, long drying time, and damage from severe winds and rain. Solar dryers with controlled environments have been created to get around these problems and properly dry agricultural products. The right drying process and input parameters must be chosen if you want to produce food of high quality while using less energy. Research on various sun dryers for drying agricultural products has recently been conducted globally by researchers. Natural or open-air sun dryer, greenhouse SD, solar bubble dryer, modified greenhouse dryer with thermal energy storage, rack-type greenhouse effect dryer, solar biomass dryer, solar conduction dryer, mixed mode forced convection dryer with thermal energy storage system, and active indirect solar dryer are a few examples of the various dryers. In this research performance of GHSD and GHSBD investigated under the sunlight. The performance of these dehydrators found by drying ginger. The MC content of ginger was reduced 95 % (w.b) to 20 % (w.b). GHSD took 7 days to dry the ginger whereas GHSBD took 9 days. By open sun drying method ginger could dry in 12 days. Nutrition retainment was more in greenhouse solar dryer.

CONTENTS

CHAPTER NO	TITLE	PAGE NO
	ABSTRACT	v
	LIST OF FIGURES	viii
	LIST OF ABBREVIATION	ix
1	INTRODUCTION	1
	1.1 Types of solar dryers	1
	1.1.1 Open sun drying or Natural drying	1
	1.1.2 Direct solar dryer	2
	1.1.3 Indirect solar dryer	2
	1.2 Modes of solar dryer	3
	1.2.1 Forced convection	3
	1.2.2 Natural convection	3
2	LITERATURE SURVEY	4
	2.1 Open sun dryer	4
	2.2 Hot air dryer	5
	2.3 Mixed mode forced convection solar dryer	6
	2.4 Greenhouse solar dryer	6
	2.5 Mixed mode forced convection solar tunnel dryer	10
	2.6 Mixed mode forced convection solar dryer with thermal energy storage system	11
	2.7 Indirect forced convection solar dryer	13
	2.8 Active indirect solar dryer	14
	2.9 Solar bubble dryer	16
	2.10 Solar conduction dryer	16
	2.11 Solar biomass dryer	17
	2.12 North wall insulated greenhouse dryer	19
	2.13 PCM equipped greenhouse solar dryer	19
3	AIM, SCOPE, MATERIAL AND METHODOLOGY	21
	3.1 Aim	21
	3.2 Scope	21

	3.3 Materials	21
	3.3.1 Polyethylene sheet	21
	3.3.2 Solar panel	21
	3.3.3 Battery	21
	3.3.4 Exhaust fan	22
	3.3.5 Ginger (for drying)	22
	3.4 Methodology	22
	3.5 Instruments used	23
4	EXPERIMENTATION	26
	4.1 Fabrication of GHSD	26
	4.2 Fabrication of GHSBD	27
	4.3 Working of GHSD and GHSBD	28
	4.4 Experimental work	28
5	RESULT AND DISCUSSION	30
	5.1 Temperature comparison of dryers	30
	5.2 Humidity comparison of dryers	32
	5.3 Solar intensity of dryers	34
	5.4 Mass and moisture comparison of dryers	35
	5.5 Nutrition and energy	37
6	CONCLUSION	39
	REFERENCES	40
	APPENDIX I	47
	APPENDIX II	48
	APPENDIX III	49

LIST OF FIGURES

FIGURE NO	TITLE	PAGE NO
2.1	Open sun dryer	4
2.2	Mixed mode forced convection solar dryer	6
2.3	Greenhouse solar dryer	7
2.4	Mixed mode forced convection solar tunnel dryer	11
	Mixed mode forced convection solar dryer with thermal	
2.5	energy storage system	12
2.6	Indirect forced convection solar dryer	14
2.7	Active indirect solar dryer	15
2.8	Solar bubble dryer	16
2.9	Solar conduction dryer	17
2.10	Solar biomass dryer	18
3.1	Anemometer	23
3.2	Solar power meter	23
3.3	Thermo-hygro meter	24
3.4	Infrared thermometer	24
3.5	Weighting machine	25
4.1	Greenhouse solar dryer	26
4.2	Greenhouse solar bubble dryer	27
4.3	Open sun drying	29
5.1	Average inside temperature of GHSD and GHSBD	30
5.2	Average outside temperature of dryers	31
5.3	Outside humidity trend on day 1	32
5.4	Inside humidity trend on day 1 for GHSD and GHSBD	33
5.5	Solar intensity trend on day 1 for GHSD and GHSBD	34
5.6	Moisture content of ginger on dryers	35
5.7	Crop mass of ginger on dryers	36
5.8	Nutrition on dried ginger	37
5.9	Energy of dried ginger on dryers	38

LIST OF ABBREVIATIONS

SD	Solar Dryer
OSD	Open Sun Dryer
HAD	Hot Air Dryer
IRD	Infra Red Dryer
MC	Moisture Content
WB	Wet Basis
DB	Dry Basis
PCM	Phase Change Material
NWIGHD	North Wall Insulated Green House Dryer
SBD	Solar Bubble Dryer
SS	Stainless Steel
PPEGHSD	Parabolic Polyethylene Greenhouse Solar Dryer
GHSD	Green House Solar Dryer
GHSBD	Green House Solar Bubble Dryer

CHAPTER-1

INTRODUCTION

The dehydration process is called drying, which removes moisture from food goods with the help of heat energy. Hot air or solar energy are two possible sources of heat. The food products are preserved for later use through the drying process. Bacterial and yeast growth are stopped by drying. Drying can be accomplished utilizing the open-air sun and greenhouse methods. Open-air drying takes longer than drying in a greenhouse, and as a result the items that are produced will be of worse quality because of dust contamination, weather-related damage, and air moisture. Additionally, food products are lost as a result of birds, animals and insects. The calibre of goods produced through greenhouse drying because the process is carried out in a secure setting, it is superior. This enclosed space was created using unique cover materials, such as polycarbonate and polyethylene, etc. Dryers for greenhouses are distinguished based on the roof structure, such as dome-shaped dryers and even span roofs depending the form of energy transmission, such as passive and active. The primary goal of this investigation is to offer a thorough analysis of the literature on recent developments in the drying of agricultural food products.

1.1 TYPES OF SOLAR DRYERS

The types of SD are actually classified into three types three types. Those open sun drying (OSD) or natural drying, direct solar dryer and indirect solar dryers.

1.1.1 Open Sun Drying (OSD) or Natural drying

The oldest and simplest drying method is the natural drier. Most agricultural goods are still dried using solar energy in its natural form. However, drying these things outdoors has a number of drawbacks, including bug infestation, litter, rain, wind, and human contamination.

The most common drying method in tropical and subtropical areas is spreading the crop out on trays in thin layers, covering the mats with shade, and exposing the products to the sun and wind. The processing step, the dehydration location, or solar radiation anxiety are used to create classifications for solar drying procedures. Open-air drying may be impacted by environmental elements like sunlight, breezes, and other ambient conditions. Due to the multiple problems of sun drying, it has been substituted with mechanical dryers that use electricity and petroleum-based fuels to heat the drying air in order to force dry air through the agricultural commodities. But there is value in using solar energy to raise the temperature in a solar drying system without compromising its capacity and dependability. The open drying method is inappropriate for the massive amounts of materials produced by large corporations. Along with the negative consequences of higher labour costs, greater space requirements, and lower-quality products, it also requires a lengthy process before the Products are ready to be stocked. Drying outdoors in the sun takes a very long time and can result in enormous losses.

1.1.2 Direct solar dryer

In a direct solar dryer, the food products and/or necessary materials are covered with a transparent sheet, usually glass, which raises the temperature inside the dryer above the surrounding environment when solar energy flows through the sheet or glass. Therefore, thermal efficiency needs to be improved. A direct-type sun drier is often used in areas that receive direct sunlight all day long for an extended length of time. Here, drying cabinets are constructed out of pressed wood that is 1 cm thick, and the inside and bottom walls of the cabinets are insulated with glass wool. To allow the sun's rays to enter, the front wall is covered with a thick sheet of slanted glass.

1.1.3 Indirect solar dryer

This sort of solar dryer operates on a similar concept as a direct solar drier. Indirect solar dryers heat the air entering the device from the outside, as opposed to directly heating the things to be dried.

The humid air is then carried by the warm air as it travels through the materials and into the ambient air by the chimney. Finally, the Solar dryer provides the needed answer. It is an ideal drying process for small-scale farmers' applications because of its reasonable cost. Thermally insulated pipes that are joined and connected with a flat plate collector and a chamber for drying make up this solar dryer. Even under unfavourable weather conditions, the dryer's performance produces goods of high-satisfactory quality.

1.2 MODES OF DRYER

The modes of heat transfer employed in SD systems are natural convection and forced convection

1.2.1 Forced convection

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

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.

CHAPTER-2

LITERATURE SURVEY

Solar dryers are classified as indirect or convection type, direct absorption and the both joined together. In this paper, various types of solar dryers are discussed.

2.1. OPEN SUN DRYER

The easiest method of drying agro-products such as food grains, herbs, vegetables, fruits, mil products, fish etc. This involves spreading the agro-products in a thin sheet on the floor and exposing to direct sunlight to dry it to a safe moisture level through Open sun dryer (OSD) as shown in Fig .2.1.



Figure 2.1: Open Sun Drying[39]

2.2 HOT AIR DRYER

One popular drying technique is hot air drying, during which the food products to be dehydrated is involved to a burst of hot air. In terms of model fitting, colour, minerals, drying time, thermal stability, and microstructure for turmeric samples with a 9 mm thickness, OSD samples took less time than hot air dried (HAD) samples. OSD is a proposed method that could yield turmeric of higher quality than HAD [42].

A solar air heater that was designed shown great efficiency that is suitable with more complicated designs that are discussed. Additionally, combining a greenhouse dryer and a tube shape solar air heater resulted in a 30% reduction in dehydrating time. By analysing the temperature differential data, it can be seen that this straightforward and affordable design may achieve great performance without the inclusion of extraneous and costly components. This design appears to have promise for producing hot air sustainably. In addition to being used for dehydrating purposes, this straightforward construction can also be used as an alternate system for hot air supply. It should be noted that recyclable substances can be used in manufacturing. It should be noted that recyclable substances can be used in the production of tube shape solar air heaters. Sheet metal was used as the heating material in both. The temperature in the drying cabin peaked on the first day of the testing at 51.25°C. The temperature within the dehydrating cabin reached a maximum of 49.95°C on the second day of the testing. 18.9% was observed as the maximum usual thermal efficiency for the ETSC assisted drying method. On the 1st and 2nd days of the experiment, respectively, 14.35°C and 13.95°C, were measured as the temperature difference between the drying procedures. In an evacuated tube solar collector aided drying system, a 30% time savings was noted. A constructed model of the drier was used to determine the 385.1 kJ of heat energy needed to dry the mushrooms [3].

2.3 MIXED MODE FORCED CONVECTION SOLAR DRYER

These dryers generate the necessary heat for drying process by combining the effects of solar radiation impacting on the material to be dried with air heated by a solar collector. Mixed mode forced convection solar dryers as shown in Fig .2.2. In a drying research with turmeric, it was discovered that turmeric could be dried completely in just 47 hours (taking sunlight hours into account), which is far less time than OSD. With a mixed mode forced convection sun drier, dried turmeric may be produced in a lot less time. To manufacture superior grade turmeric that is suitable on the international market, an indirect form of sun dryer with induced air movement might be employed [4].

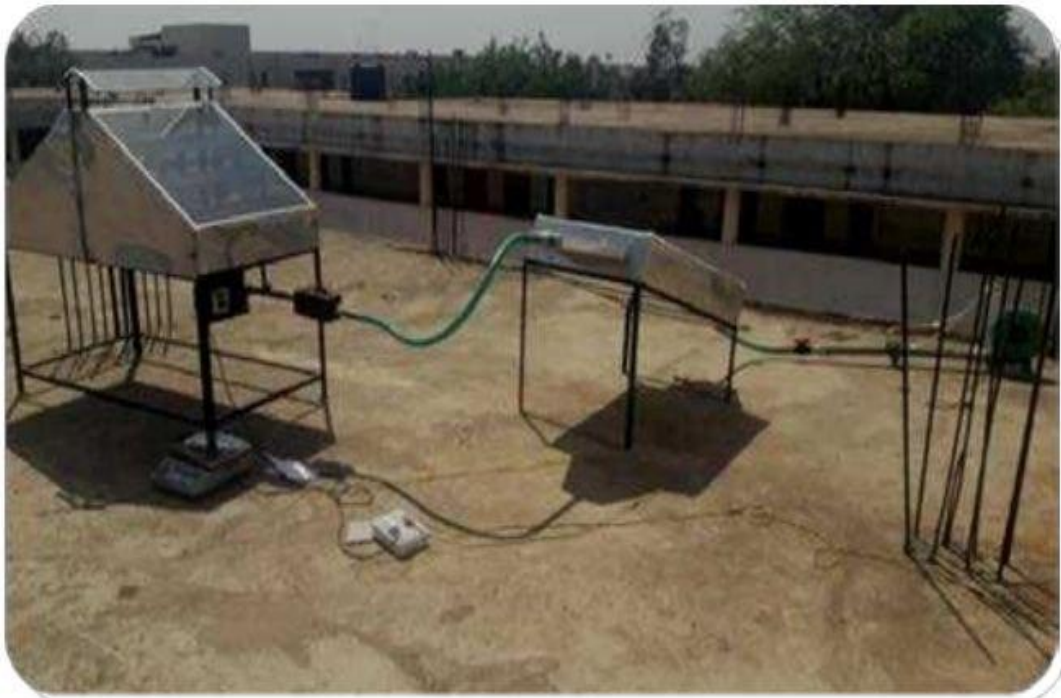


Figure 2.2: Mixed mode forced convection solar dryer[4]

2.4 GREENHOUSE SOLAR DRYER

The term greenhouse dryer refers to a greenhouse structure used for drying. Crops are dried inside greenhouses using sun thermal energy. Where moisture is eliminated by forced convection or natural convection and the product is positioned in

boxes to receive solar radiation through the plastic sheet. Greenhouse solar dryer shown in Fig.2.3. The product temperatures are higher than they drying air temperatures outside and in greenhouses. The temperatures of the products are higher than those of the drying air both outdoors and within greenhouses. Low relative humidity is better for drying since it increases the air's ability to evaporate. The air inside the greenhouse and the dryer compared to the air outside the open sun, the dryer had higher relative humidity during the night [1].

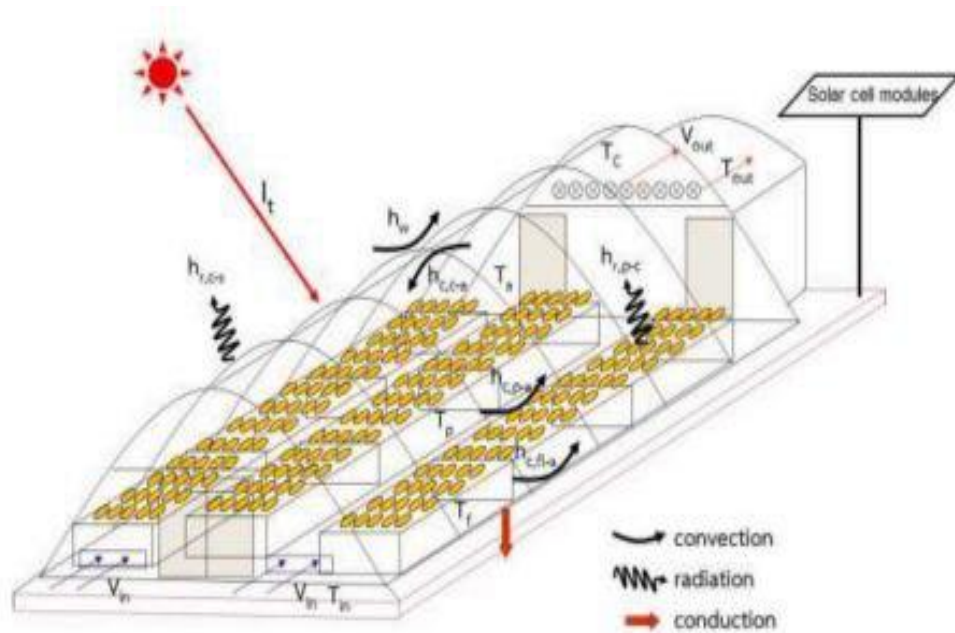


Figure 2.3: Greenhouse solar dryer[26]

To assess the drying effectiveness and energy efficiency of the large-scale green-house solar dryer with and without phase change material thermal storage technology, chilli was dehydrated on-site. Chilli was dehydrated to a MC of 10.0% (WB) from an earlier MC of about 74.7% (WB) over the course of 2.5 days using a PCM thermal storage system, while chilli was dehydrated to the same MC 10.0% (WB) from an earlier MC of about 74.7% (WB) over the course of 3.5 days without a phase change material thermal storage system, taking 11 days. It is obvious that the greenhouse solar dryer significantly reduces the drying time. The dryer with phase change material thermal storage system has higher average energy efficiency than

the dryer without phase change material thermal storage system. To analyse the efficiency of the direct type SD in both forced and natural convection conditions, potatoes and bananas were dried in it. Both within and outside the chamber, the temperature and humidity range were recorded. Although the drier was effective at drying, controlling the rate of drying did not work to produce the expected level of food nutrients. It was discovered that forced convection was more efficient than natural convection. However, the change in drying rate did not allow for the regulation of fan speed [25].

A mixed mode greenhouse solar dryer was built and put through its paces. The current drying technology reduces the dehydrating time of red pepper by seven hours in actuality. Under the experimental circumstances used, the red pepper's drying curves displayed a lengthy falling-rate dehydrating period rather than a constant-rate dehydrating period. Although the Pabis and Modified Henderson model performs better than the other models, all of the drying models taken into consideration in this study may accurately depict the drying behaviour of pepper. At 0.047 kg/s air mass flow rate throughout the two drying days, solar collector efficiencies of 30% and 88%, respectively, were observed as high as possible and as low as possible. The economic evaluation was conducted using the payback period criterion, which changes from product to product. In the newly created hybrid active greenhouse SD, which also serves as a drying bed, a heat exchanger is housed within the dryer. The copper tubes of the heat exchanger, which delivers its heat to the room air and the crop surface in touch with it, receive hot water from evacuated tube solar collector. The constructed drier for three crops is subjected to an experiment to determine its economic viability and environmental acceptability. The ginger, tomato and bottle gourd are the three high moisture crops that were chosen for the study. When the outside temperature is 31°C, the dryer's maximum internal temperature is 46.9°C. The created dryer shortens the time it takes for ginger, tomatoes, and bottle gourds to dry of 34.09%, 47.36 and 61.90% [14].

During the three stages of a built facility's life cycle—construction, operation, and disposal—a significant amount of energy is used. Operational energy and embodied energy (EE) are two categories for the total energy usage. The entire energy used during the stages of raw material acquisition, transportation, production, building, use (maintenance and restoration), and discharge is known as embodied energy. The energy needed to supply during its process or usage periods is known as the operational energy [47]. Richu Zachariah carried out a study of the economic and environmental impacts of mixed mode SD using PCM of paraffin wax (thermal storing material) and normal conventional SD. The results showed that the proposed method's energy payback time is significantly shorter than that of the conventional solar dryer and similar methods without PCM [40]. Bilal Lamrani and colleagues looked into a hybrid SD design that was suggested for the wood industry. An environmental analysis of the solar dryer method was conducted by focusing on the amount of (CO_2) emission produced by combustion at an auxiliary system of heat generation. They came to the conclusion that adding a solar collector to the solar dryer decrease the amount of energy that is absorbed by an auxiliary system of heating and also to decrease the CO_2 emissions about 34% every year. Using PV modules and Aluminium casing materials for construction of GHSD which impacts in reducing the consumption of embodiment energy and specifically, the chosen PV modules (low embodied energy density material) plays a main role in reducing the CO_2 emission, payback time and mitigation [7]. Hisham Elhage et al investigated and reviewed a paper about environmental assessment on indirect cabinet SD. The emission of CO_2 is decreased while using GHSD when compared to forced convection SD [13].

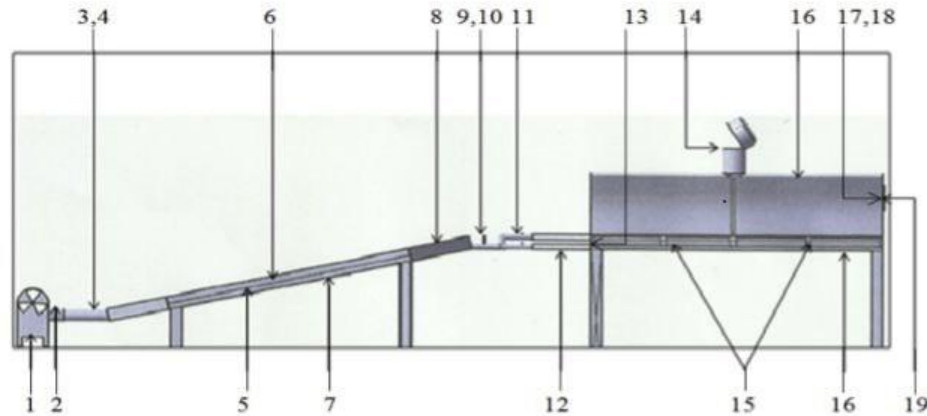
Coconuts were dried using a solar-biomass hybrid system in the summertime from an initial MC of roughly 53% to a final MC of 7% in 54 hours as opposed to 153 hours using OSD, saving 64% of dehydrating time. In the winter, drying in the drier took 74 hours and drying outside in the sun required 247 hours. The dryer's typical thermal efficiency ranged from 24% in the summer to 21% in the winter. When compared to other drying systems, the annual CO_2 emission was determined to be

fairly low at 1518 kg, hence this dryer has a smaller environmental impact. The dryer has greater potential for carbon reduction as evidenced by the net CO₂ mitigation figure of 678 tonnes. So, when drying the coconuts, the dryer aids in maintaining a clean environment [5].

It was discovered that the floor was covered in black PVC sheet dried more quickly. It offered a greater greenhouse room temperature and a lower relative humidity in the greenhouse room. This allows for the correct crop to be chosen and dried in the drier. Loss through the north wall of the dryer was examined by applying a mirror to the wall. Additionally, this made drying conditions optimal. Due to the proposed dryer's low embodied energy of 480.2776 kWh, it was determined that it was energy-efficient. Total uncertainty was little (0.0891) and low [28].

2.5 MIXED MODE FORCED CONVECTION SOLAR TUNNEL DRYER

Agricultural products are dried using wind and solar power in solar tunnel dryers so they may be properly stored, processed and exported. Inside of the tunnel, the crop is arranged in an equal layer on tables or drying trays. Mixed mode forced convection solar tunnel dryer shown in Fig.2.4. A mixed mode forced convection solar tunnel drier was developed to study the exergy analysis and kinetics of turmeric. The results showed that the drying air's temperature at the solar tunnel dryer's input varied between 42.2 and 82.8 C, while the drying air's temperature at the dryer's exit varied between 40 and 71.8 C. The dryer's average energy efficiency was discovered to be 49.12%. The dryer used an average of the available energy, demonstrating the solar tunnel's enormous potential for performance enhancement [15].



1.Blower. 2.Airflow regulating valve. 3.Solar collector inlet. 4,9,13,18. Thermocouples. 5.Aluminium sheet. 6.Transparent glass. 7,16.Insulator. 8.Pyranometer. 10. Anemometer section. 11.Airflow valve. 12.Solar dryer inlet. 14.Chimney. 15.Drying trays. 16.Transparent polycarbonate sheet. 17.Hygrometer. 19.Solar dryer exhaust.

Figure 2.4: Mixed mode Forced Convection Solar tunnel dryer[15]

2.6 MIXED MODE FORCED CONVECTION SOLAR DRYER WITH THERMAL ENERGY STORAGE SYSTEM

This is a mixed mode forced convection solar dryer with thermal energy solar system. Solar thermal storage (STS) is the collection of energy by a specific solar plant to be used at a later time. Mixed mode forced convection solar dryer with thermal energy storage system shown in Fig.2.5. A performance evaluation of a mixed mode SD with thermal energy storage has been carried out in order to dry 15kg of black turmeric. It was noticed that sunlight dried samples are fit for two term model and sun dried samples are for page model. The time taken by mixed-mode solar dryer was 60.7% less than OSD. The overall effectiveness of the solar dryer was found to be 12.0% [22].

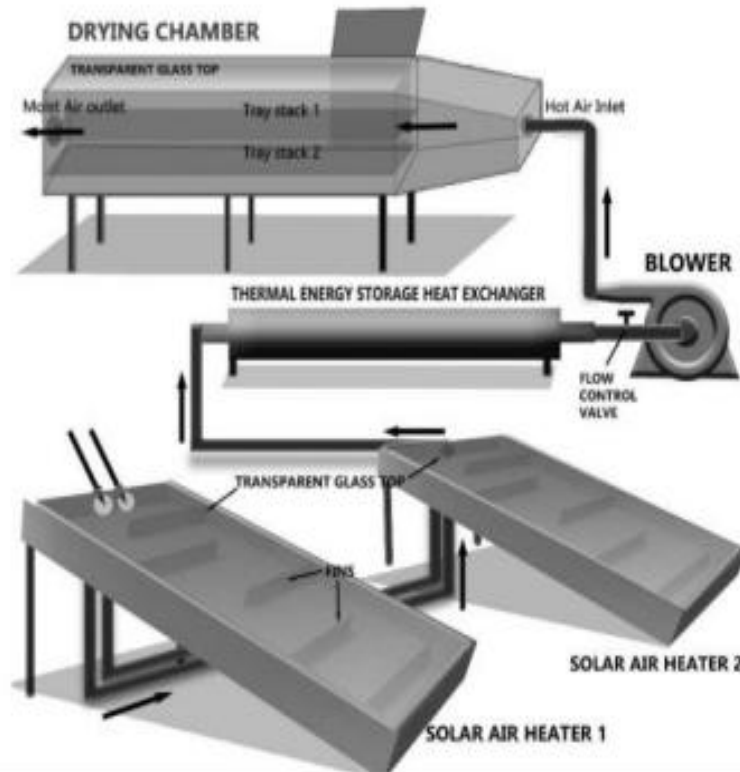


Figure 2.5: Mixed mode forced convection solar dryer with thermal energy storage system[22]

This study builds and tests a mixed-mode forced draught solar dryer with energy storage for drying fruits and vegetables. The dehydrating rates of specimens placed on various areas of 2 parallel trays are compared in a number of experiments, and the effectiveness of using PCM for thermal energy storage is also assessed. The only factor affecting the dehydrating rate of the apricot specimen on various areas of the top and lower trays was the incident sun irradiation during the day. Drying time is reduced by roughly 50% when an energy storage unit made of paraffin material is used. Prior to midday, the dryer's peak drying rate of 2.1 g/hr and its highest temperature of before midday, the dryer dries at a rate of 2.1 g per hour, and in the noon, when the energy storage system is in use, it reaches a maximum temperature of roughly 65 degrees Celsius. The energy storage system improved the solar dryer's overall thermal efficiency as well as its pick-up efficiency. Three different roof shapes of dryers for free and forced convection are used to examine the greenhouse solar dryer simulation. The temperature value for both forced and free convection is

fluctuating during all analyses. All three dryers have temperature ranges between 8°C - 10°C. Passive convection produces higher temperatures than natural convection. As a result, it can be said that trapezoidal greenhouse solar dryers are capable of reaching higher temperatures than hemispherical and triangular dryers [9].

Madhankumar et al have researched Indirect Solar Dryer with 3 various types and analyzed CO₂ emissions, carbon credit and mitigation and found that ISD with thermal energy storage unit having fins with PCM had better efficiency than others [23].

2.7 INDIRECT FORCED CONVECTION SOLAR DRYER

Indirect solar dryers, instead of heating the material to be dried directly, the black surface warms the entering air. Following passage over the material to be dried, this hot air frequently escapes through a chimney and rises upward, carrying any moisture that was released from the material with it. Indirect forced convection solar dryer shown in Fig.2.6. For drying slices of bitter gourd, a low-cost indirect forced convection solar drier with a porous bed that stores sensible heat has been created and researched. A solar collector with a surface area of 2 m² makes up the experimental setup. According to the findings, the bitter gourd's mass was reduced in the solar drying system from 4000 grams to 723 grams in 7 hours at an air mass flow rate of 0.0636 kg/s[48].

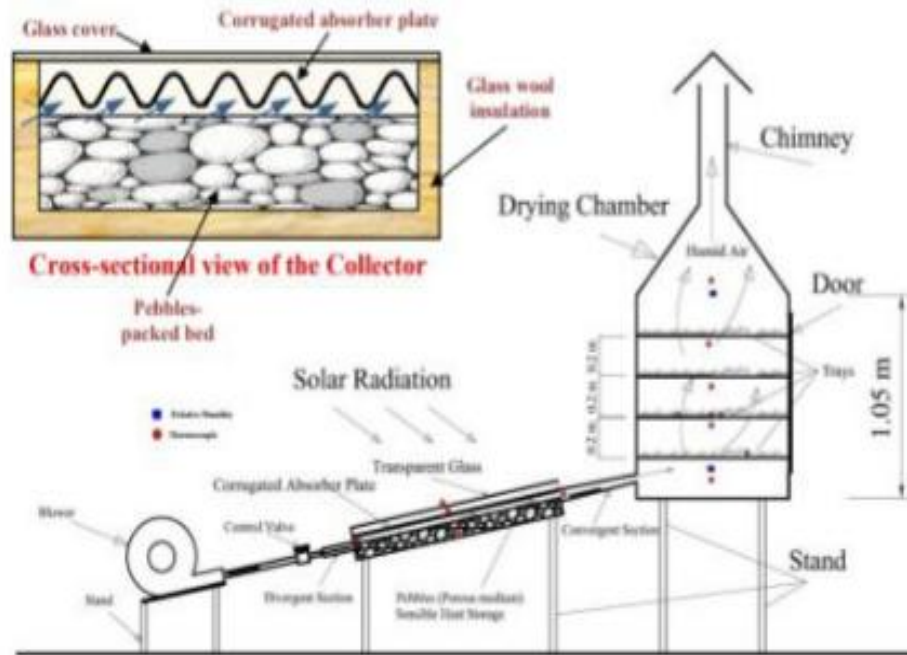


Figure 2.6: Indirect forced convection solar dryer[48]

2.8 ACTIVE INDIRECT SOLAR DRYER

Compared to OSD, this active indirect solar dryer has greater loading per unit aperture area. In comparison to an OSD, this active indirect solar dryer has an overall average thermal efficiency of 34.1% when drying fenugreek leaves and 23.6% when drying turmeric. For turmeric and fenugreek leaves the average steady state thermal efficiency is 44.9% and, respectively. In comparison to OSD, active indirect solar drying produces dried goods of higher quality [45]. Active indirect solar dryer shown in Fig.2.7.

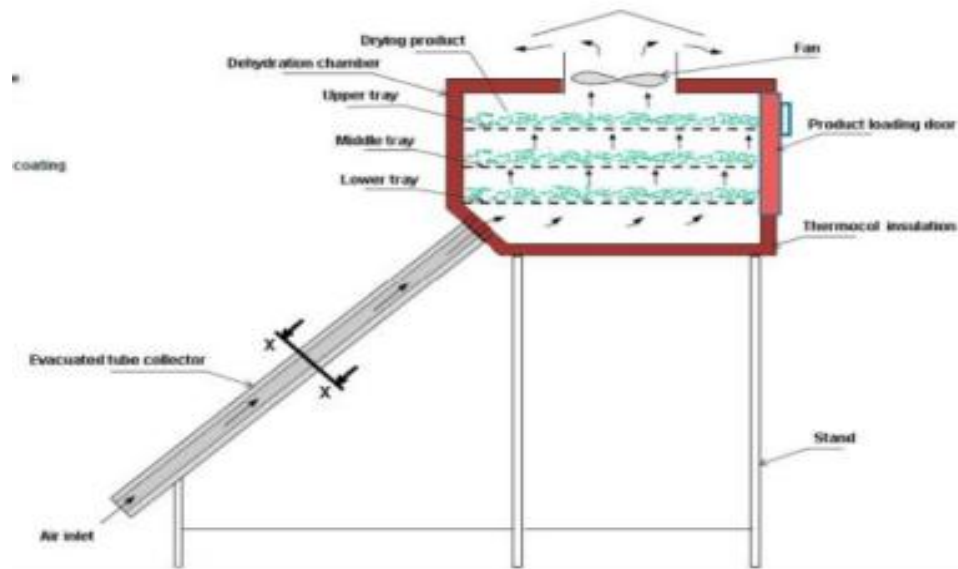


Figure 2.7: Active indirect solar dryer[45]

In order to dry the banana slices, NIT Warangal created an indirect type solar dryer. Studies have shown that indirect sunlight drying, which shortens the drying time, is more efficient than OSD. It has been noted that the dehydrated product is free of pollution and dust. Banana mass is decreased from 2 to 0.5628 kg. For trays 4, 3, 2, 1, and OSD, the MC of bananas decreased respectively from an average initial value of 356% (DB) to final values of 31.1582% ,21.1592%, 19.4736%, 16.3292% and 42.3748% (DB). The average heating efficacy of the collector was 31.50%, and the average dehydrating efficacy was 22.38%. Solar dryer decreased drying time while providing a high-quality product, so it is better than OSD. The indirect solar drier and water storage tank were integrated to keep the temperature of the grapes greater than the surrounding air during periods of low sunlight. In comparison to an OSD, the indirect SD's storage technology has shortened the time it takes for grapes to dry. The internal drying chamber climate is directly influenced by the storage system. Grapes dried using indirect solar energy had an effective moisture diffusivity of $4.08 \text{ m}^2/\text{s}$ and $2.34 \text{ m}^2/\text{s}$, respectively [2].

2.9 SOLAR BUBBLE DRYER (SBD)

The Solar Bubble Dryer's elevated drying racks allowed 270 kg of maize to be dried from 18.2% to 12.6% in under six hours as opposed to eleven hours for the same amount of food goods to be dried on the SBD's tarpaulin to reach a moisture content of 12.5%. (w.w.b). The elevated drying rack system produced average moisture extraction and drying rates of 2.88 kg/h and 0.93%/h as opposed to 1.60 kg/h and 0.52%/h while drying on the SBD's tarpaulin. The Solar bubble dryer reported an average temperature of 44.6 °C, which was 9 °C higher than the surrounding air. The SBD collector's thermal efficiency was found to be 36.2%.SBD [21] shown in Fig.2.8.



Figure 2.8: Solar bubble dryer[21]

2.10 SOLAR CONDUCTION DRYER

A solar powered agro-products dryer called as a solar conduction dryer uses natural conduction as its primary mechanism of heat transmission and secondary means of convection and radiation to lower the moisture content of agro-products. Solar conduction drier shown in Fig.2.9. Using a solar conduction dryer, turmeric was dried (SCD). For an ambient temperature of 25–28 °C, a dehydrating air temperature of about 39–51 °C was reached. In twelve hours of effective dehydrating time, the moisture content decreased from 78.65% (WB) to 5.50 % (WB) and 6.36 % (WB), respectively, for sliced and solid samples [8].



Figure 2.9: Solar conduction dryer[8]

2.11 SOLAR BIOMASS DRYER

A dryer using direct natural convection for biomass was developed. The system is able to provide a continuous and sufficient flow of hot air that is between 55 and 60 degrees Celsius. In a well-developed technique, turmeric was successfully dehydrated. When it comes to physical characteristics like colour, texture, and other visual cues, dried turmeric obtained under solar biomass (hybrid) drying by two various methods, namely slicing and boiling water, were of a similar quality. The quantitative research revealed that solar biomass dryer produced better-quality output in just 1.5 days as opposed to the usual drying method, which involved drying the rhizomes under open sun for 11 days. The final efficiency for the entire unit was 28.57% and Solar biomass drier as shown in Fig.2.10 [15].

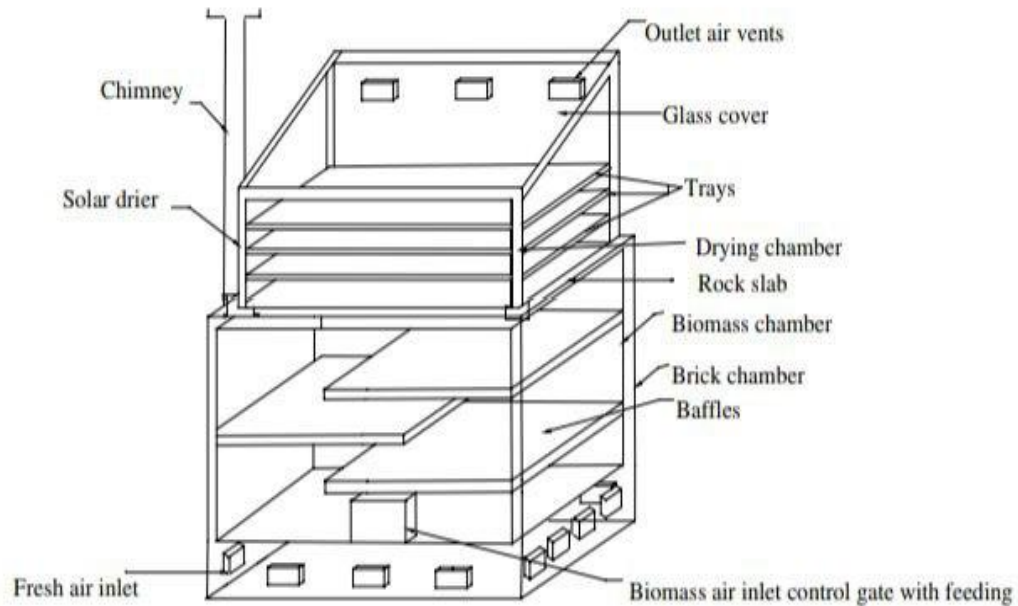


Figure 2.10: Solar biomass dryer[15]

In the case of drying cucumbers, natural convection in a double slope dryer was 11.96% more efficient than an open sun drying method. When compared to the OSD method, the solar dryer dried the materials substantially faster. The solar dryer's output was discovered to be more sanitary. It can be inferred that the radiation levels, the mass flow rate of drying air and air temperature all have a significant impact on the drying time. Additionally, it is established that the natural convection solar dryer has a higher drying rate than the open-air sun drying method. On the Chulalongkorn University campus in Nan (northern Thailand), the parabolic greenhouse solar drier was tested throughout the wet season. The findings of the studies demonstrate that, despite a primarily cloudy sky, light rain, and periodic, the conditions within the dryer including relative humidity and temperature were ideal for drying cayenne chilies. The specimens had to spend more than one day being dried to a safe MC (about 10% WB), thus it was necessary to take them out of the dryer at the day end and keep them in a dry enclosure during night to prevent moisture absorption throughout the night. The cayenne pepper specimens could be dried more quickly than using a solar dryer because to the tray dryer's more consistent drying air temperature [41].

2.12 NORTH WALL INSULATED GREENHOUSE DRYER

This study has demonstrated that tomato waste is effectively treated by direct solar drying. It enables volume reduction, which has a direct impact on transportation and storage expenses. hygiene: bacteria are destroyed by drying at a temperature between 40 °C and 58 °C for 5 hours; Stabilization: The dry tomato waste is stabilised by the decrease in water content which prevents any biological activity; The reduction of odours released: Unlike fresh tomatoes, dry tomato waste does not cause odour issues. This experimental effort has evaluated the performance of two distinct NWIGHD operating in natural convection mode with no load. Results show that, when compared to prior established greenhouse dryers, NWIGHD with solar collector was found to be the high effective for dehydrating. During the experiment, it results in a greenhouse with a higher interior room temperature of 65.2 °C and a lower interior room relative humidity of 4.4%, which is an ideal drying environment for the majority of fruits and vegetables. The use of reflectors helped to maximize the use of solar radiation by reducing radiation losses through the north wall. In an experimental investigation, several elements are being employed as north wall insulating layers in the dryers, and the outcomes of OSD, without insulation, and with insulation are being compared. When compared against all other possibilities, a parabolic roof with insulation performs better at drying grapes. The grape that has been dried using an insulated parabolic roof drier has a lower moisture content than grapes dried using any other method, allowing for longer storage. When compared to other dryers and open-air sun drying, the quality produced by a parabolic drier with insulation is superior [34].

2.13 PCM EQUIPPED GREENHOUSE SOLAR DRYER

In order to find the thermal performance of several sensible heat storage materials (rock-bed, sand, and concrete), experiments were performed in a natural convection solar greenhouse drier. The ideal thickness for both rock-beds and sand

was determined to be 4" since it offers a better drying environment both night and day. For heat storage medium concrete was used. The dryer lowered the MC of coconuts from 52 (weight per pound) to 7% (weight per pound) in 78 hours, saving 55 percent of the time required for open-air sun drying to achieve the same result. When compared to OSD, the rock-bed dehydrated in only 53 hours while the sand dried in 66 hours, saving 62% of time. The efficiency of the dryer was found to be 11.65, 11 and 9 % using rock-bed, sand and concrete respectively.. After sunset, the air temperature within the dryer with phase change material was 7°C hotter on average than the air temperatures outside and in the greenhouse SD without phase change material. When compared to the greenhouse SD without phase change material and open daylight after sunset, the relative humidity of the air within the PCM-equipped greenhouse was 18.6% lower [38]. The drying behaviour of red pepper was modelled using ten thin layers drying equations. The Midilli-Kucuk model was shown to be the most effective thin layer dehydrating model for greenhouses SD with thermal storage, according to the data. The solar greenhouse drier without thermal storage and the OSD were both best described by the two-term model. Red pepper was discovered to be more suitable for solar greenhouses operating in natural convection mode at night. A promising solution to shorten drying time for a product of the highest quality is the thermal storage unit, which can make drying continuous [48].

CHAPTER 3

AIM, SCOPE, MATERIAL AND METHODOLOGY

3.1 AIM

The aim of this project is to find the performance of three different solar dryers for drying of ginger.

3.2 SCOPE

Scope of this project is to compare the performances of greenhouse solar dryer, greenhouse solar bubble dryer and open sun drying. For that we are going to fabricate the greenhouse solar dryer and greenhouse solar bubble dryer and find its performance by means of quality, time and nutrition.

3.3 MATERIALS

3.3.1 Polyethylene sheet

Polyethylene has a more ductility, less strength, rigidity and hardness. And polyethylene looks like normal plastic cover which feels waxy when touches. For fabrication of GHSD and GHSBD we have used polyethylene 200 micron sheet with multi layers.

3.3.2 Solar panel

Solar panel which is also photovoltaic panels works by capturing sunlight and converts it into electric energy which is used here to charge the battery. For our dryers we have used 25W solar panels.

3.3.3 Battery

Battery is used to give power to the exhaust fan to run. When battery is drained it is recharged by electricity that produced from solar panels. We have used 12V battery for the dryers.

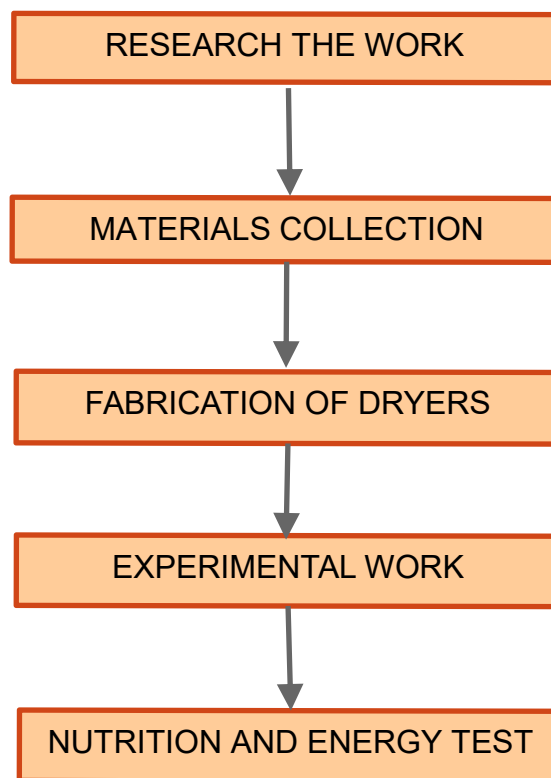
3.3.4 Exhaust fan

Exhaust fan used to remove the air from the inside of greenhouse solar dryer. Whereas it is used to circulate the air inside greenhouse solar bubble dryer. For our dryers we have used 12V exhaust fan.

3.3.5 Ginger (for drying)

For finding the performances of GHSD and GHSBD we have dried the ginger in both dryers and also dried the ginger in open sun drying method.

3.4 METHODOLOGY



3.5 INSTRUMENTS USED



Figure 3.1: Anemometer

This anemometer is used for measuring the air velocity that enters and comes out from the GHSD and GBHSD. We need to place this anemometer near the inlet and outlet of the dryer. The air rotates the small fan in the anemometer which used to find the wind speed. Wind speed is measured in m/s unit.



Figure 3.2: Solar power meter

Solar power meter is used to find the solar intensity of the dryer. Solar intensity means amount of solar radiation entering through the transparent sheet. To find solar intensity we have to keep this meter at 0° angle towards the transparent sheet. Solar intensity is measured in w/m^2 .



Figure 3.3: Thermo-hygro meter

It is used to measure the temperature and humidity. Humidity means amount of water vapour present in the air. To measure the humidity we need to keep that pin in the place to be measured. And also it can be used to measure the temperature of the particular place. Humidity is measured in %.



Figure 3.4: Infrared thermometer

Infrared thermometer as the name suggest this is used to measured the temperature of the place. It has infrared light that can be used to spot specific point and the display shows the temperature of that specific point. Temperature is measured in °C.



Figure 3.5 Weighting machine

Weighting machine used to measure the weight of the ginger. It is a digital weighting machine that displays the weight on the display. This machine can be used to measure 1g to 10000g. Weight is measured in grams.

CHAPTER 4

EXPERIMENTATION

4.1 FABRICATION OF GHSD

Greenhouse solar dryer was fabricated with parabolic shaped roof. And the dimensions of the dryer is 1.5 x 1 x 1.02. Height of the dryer from the bottom is 1.02 m. And we have used 200 micron multi layered polyethylene sheet which has less strength, rigidity and hardness. And plywood which is made of thin layers or plies that are fixed together with the help of glue. 12V exhaust fan equipped to remove the air from the inside of dryer. And there is a hole for natural air to go inside the dryer. This 12V exhaust fan is worked with the power of 12V battery. The battery is charged by solar panels which produces electricity from solar radiations in Fig.4.1.



Figure 4.1: Greenhouse solar dryer

4.2 FABRICATION OF GSBD

Greenhouse solar bubble dryer is fabricated similar to GHSD but in this dimensions of the dryer is 2 x 0.40 m. When air is circulated inside the shape of polyethylene become is bubble on the top which is 0.60 m from the ground surface. 12V exhaust fan is equipped but here it is used to circulate the air inside the dryer. This exhaust fan is powered by 12V battery. The battery is charged by 25W solar panels.



Figure 4.2: Greenhouse solar bubble dryer

4.3 WORKING OF GSD and GSBD

The GHSD and GHSBD uses solar energy from the sun in 2 ways. At first the dryer which is used polyethylene as roof works as solar collecting materials to convert the solar radiation to heat, due to that temperature of the air gets increased. Second, the GHSD and GSBD is attached with photovoltaic or solar system that includes solar panels for generating electricity. The electricity produced from solar panels is connected with battery and charges the battery. Exhaust fan is connected to battery and attached in dryers. In GHSD exhaust fan is used to remove air from the inside of dryer. Whereas in GHSBD it is used to circulate the air to the inside of dryer. There is a hole to circulate air inside the dryer of GHSD.

4.4 EXPERIMENTAL WORK

We have dried 3 kg of ginger in all three drying methods simultaneously. We have started our drying process at 9 o'clock in the morning. Before starting our dehydrating process we have washed the ginger to remove the sand. And kept them to dry in fresh air without any sunlight. And before keeping the ginger in dryer we have weighed the ginger to confirm its quantity. After weighing the ginger we have kept those ginger in both the dryers. And also under the open sun in polyethylene sheet.



Figure 4.3: Open Sun Drying

After the drying process starts we have taken notes of different parameter. Those are roof temperature of the both the dryers, inside and outside temperature of the dryers, inside and outside humidity of the dryers, solar intensity, Inlet and outlet velocity of the dryers and weight of the ginger. These parameters taken for every 2 hours from morning 9'o clock to evening 5'o clock. Drying process taken place only under the sunlight.

CHAPTER 5

RESULTS AND DISCUSSION

After drying the ginger in all the dryers performance of the dryer have found. And temperature, humidity, solar intensity, moisture content and crop mass of the ginger all shown as graph and explained.

5.1 TEMPERATURE COMPARISON OF DRYERS

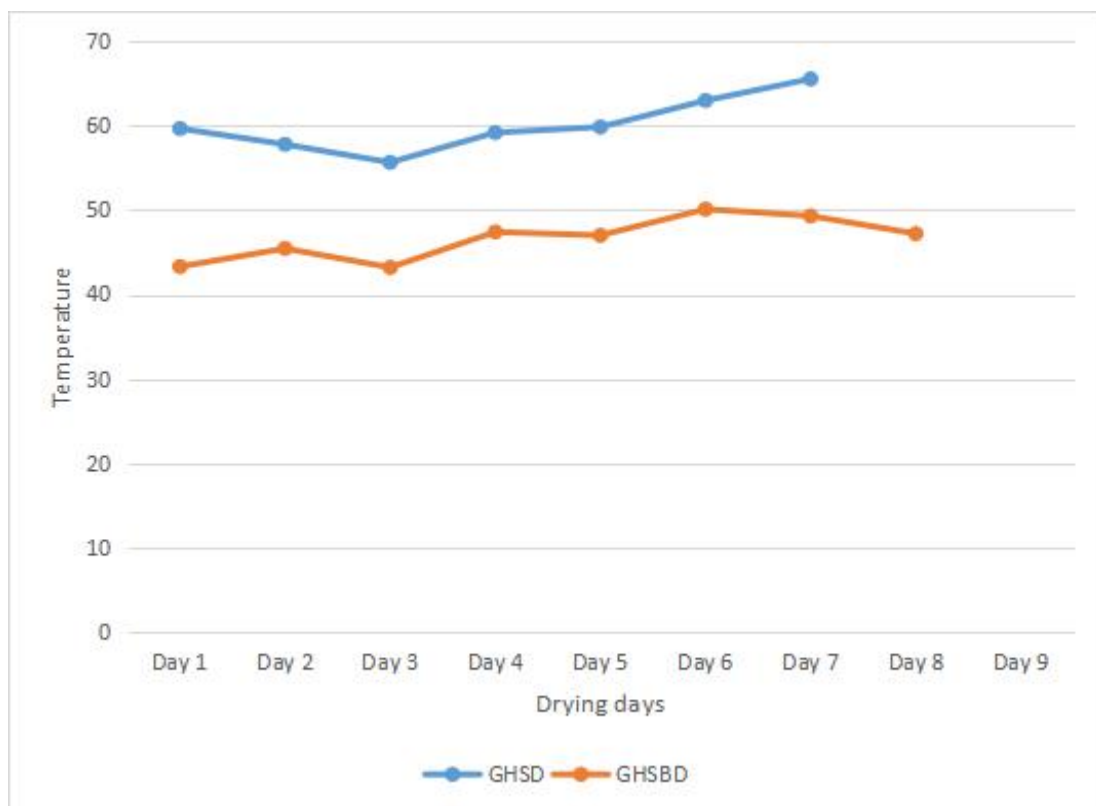


Figure 5.1: Average inside temperature of GHSD and GHSBD

Fig.5.1 represents the average inside temperature of GHSD and GHSBD while the ginger drying. Temperature value taken for every 2 hours from 9 am to 5 pm. The average of that is shown above as graph. Average Inside temperature of GHSD at 9 am is 50°C everyday and 37°C in GHSBD. The highest temperature is mostly noted at 11 am and 1 pm that is around 73 °C to 75°C for greenhouse solar dryer.

Compared to GHSD temperature in GHSBD is low. In GHSBD highest temperature is noted as around 52°C to 55°C. Due to this temperature difference between these dryers GHSD been found efficient than GHSBD. And also we have noted the temperature of roof on both the dryers. At 9 am temperature is around 42°C and 38°C in GHSD and GHSBD respectively. In GHSD 50°C - 55°C is noted as highest around 11 am to 3 pm. Whereas 45°C to 48°C is the highest temperature noted in GHSBD. But the temperature value is less on the end of the day that is at 5 pm.

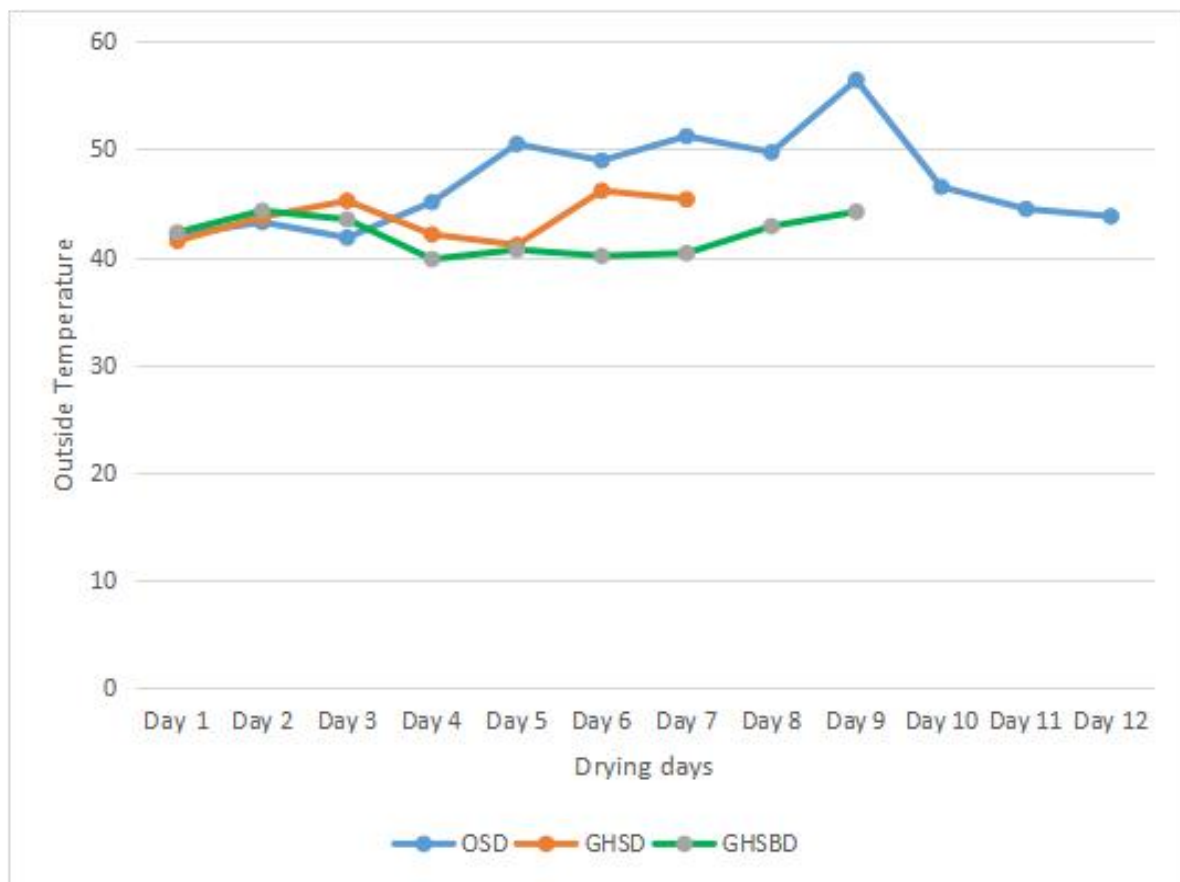


Figure 5.2: Average outside temperature of dryers

Fig.5.2 represents the outside temperature variations of three different dryers. For open sun drying the temperature value is taken at the polyethylene sheet. For GHSD and GHSBD the temperature is taken as side of the dryer. Because on the

roof we have already taken the temperature value as one of the parameter. Open sun drying temperature is slightly better than other 2 dryers because for outside temperature we have considered side of the dryer only. But in OSD the whole ground surface covered by polyethylene is outside so its value is more than other 2 dryers. At 9 am temperature is around 40°C - 42 °C , 39 °C and 40° C respectively on OSD,GHSD and GHSBD.

5.2 HUMIDITY COMPARISON OF DRYERS

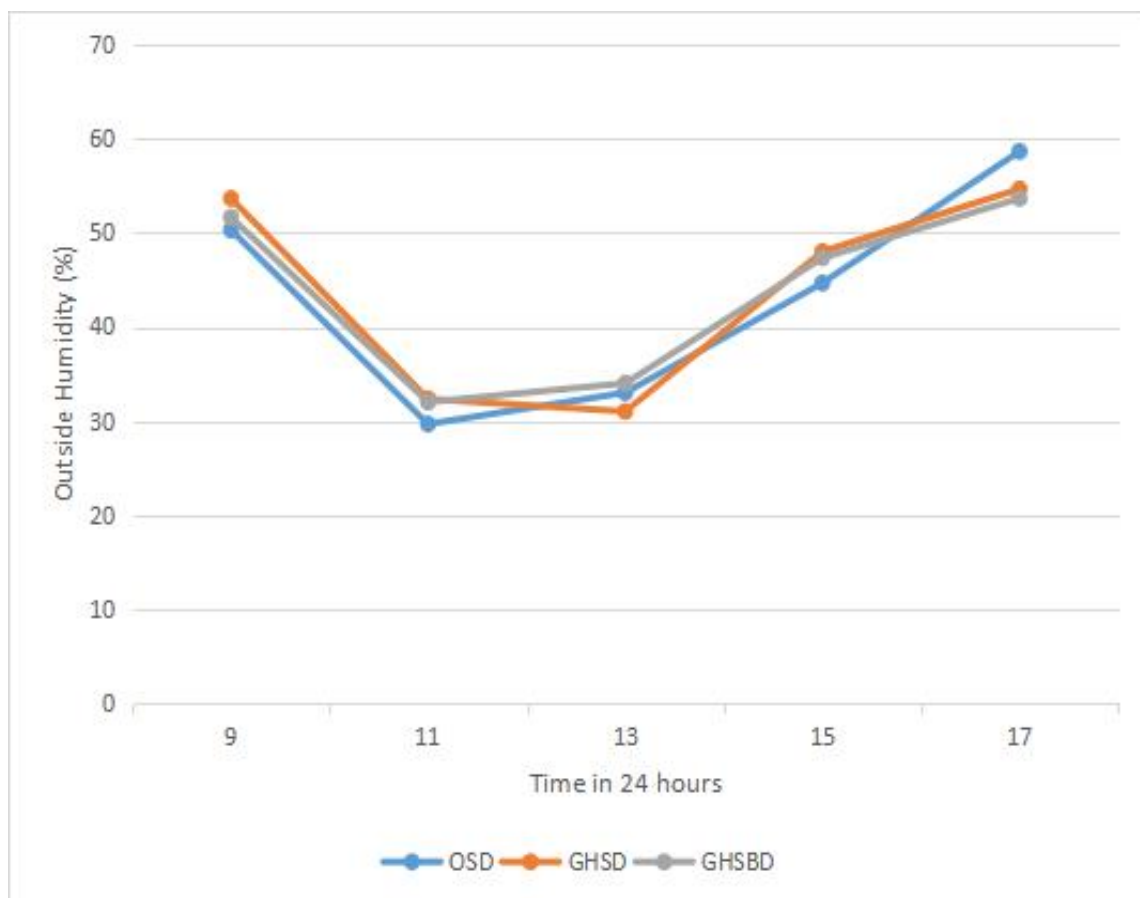


Figure 5.3: Outside Humidity trend on Day 1

Fig.5.3 represents the outside humidity of all three dryers on day 1. we have used humidity/clock to measure the humidity present on the dryers. Humidity means amount of water vapour present in the air. Humidity level is mostly equal on all three dryers at 9'o clock around 52% - 54%. At 11 and 13 hours humidity level is lowest

compared to other timings. Whereas at 17 hours the humidity present in the air more than 55%.

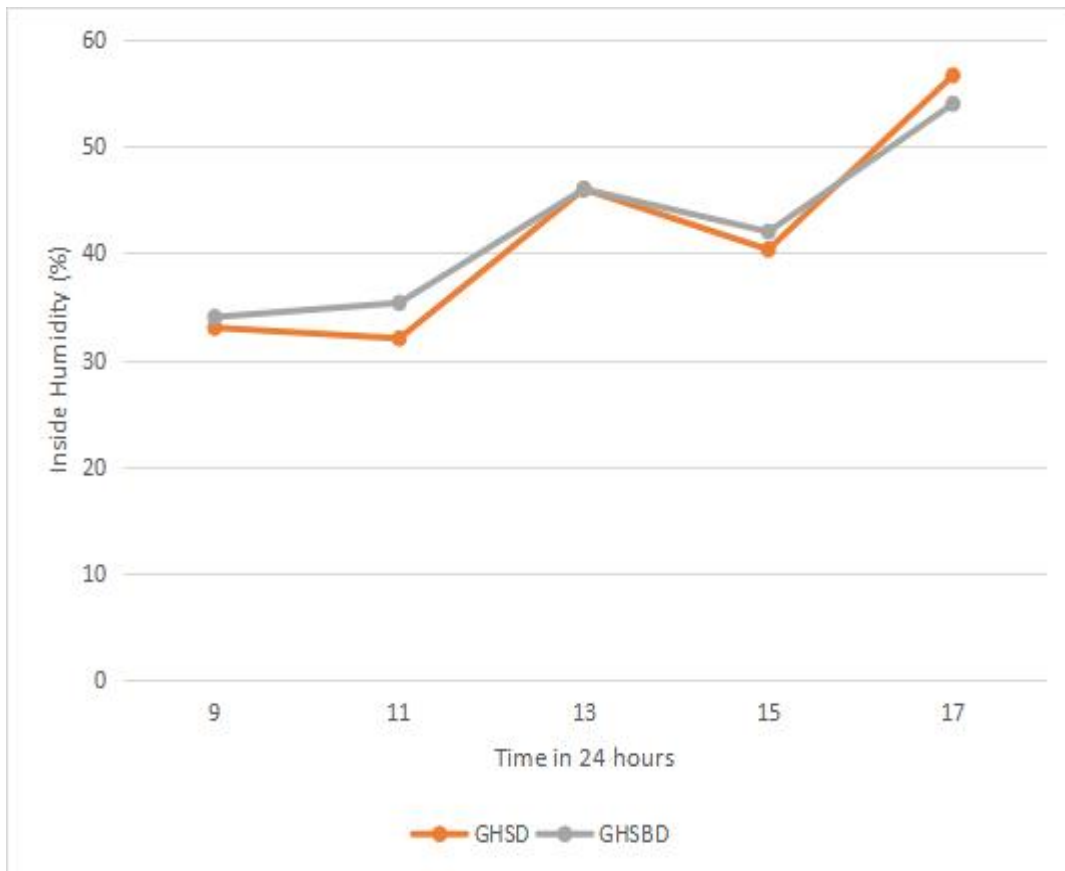


Figure 5.4: Inside humidity trend on Day 1 for GHSD and GHSBD

Fig.5.4 represents the inside humidity trend on Day 1 for GHSD and GHSBD. It is similar to outside humidity graph but whereas it represents only 2 dryers. Inside humidity also means the same that shows the amount of water vapour present in the air. On day 1 at 9 hours the humidity level is around 34% on both the dryers. It is slightly different to outside humidity because at 13 hours it is more than the morning humidity value. But as we have seen other parameters the humidity value at 17 hours is highest on the day.

5.3 SOLAR INTENSITY OF DRYERS

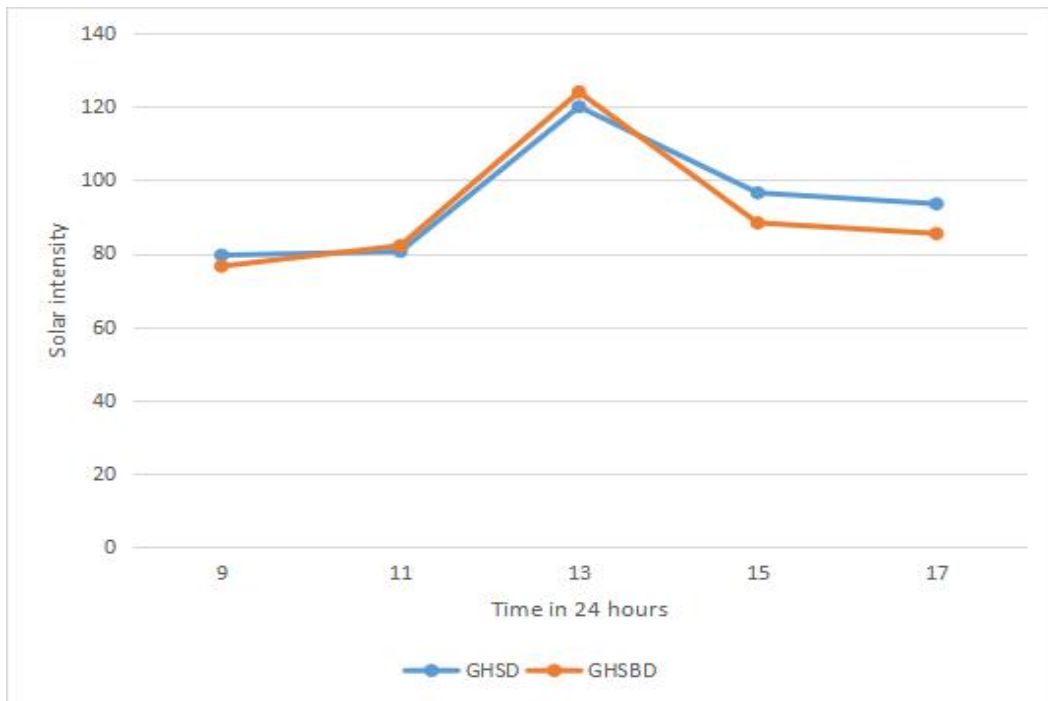


Figure 5.5: Solar intensity trend on day 1 for GHSD and GHSBD

Fig.5.5 shows the solar intensity on day 1 for greenhouse solar dryers and greenhouse solar bubble dryer. Solar intensity means amount of solar radiation falling on the dryers. Solar intensity gets increases by the time sun is at the top. That is around 12 and after solar intensity is at his high. After 13 hours its getting decreased. And also we have measured the inlet and outlet velocity of GHSD and GHSBD. Average amount of air flowing inside the GHSD is 1.4 to 2 m/s it whereas airflow in GHSBD is around 4 to 6 m/s. We have equipped exhaust fan to remove the air from GHSD. Outlet velocity of greenhouse solar dryer is around 6 - 7 m/s.

5.4 MASS AND MOISTURE COMPARISON OF DRYERS

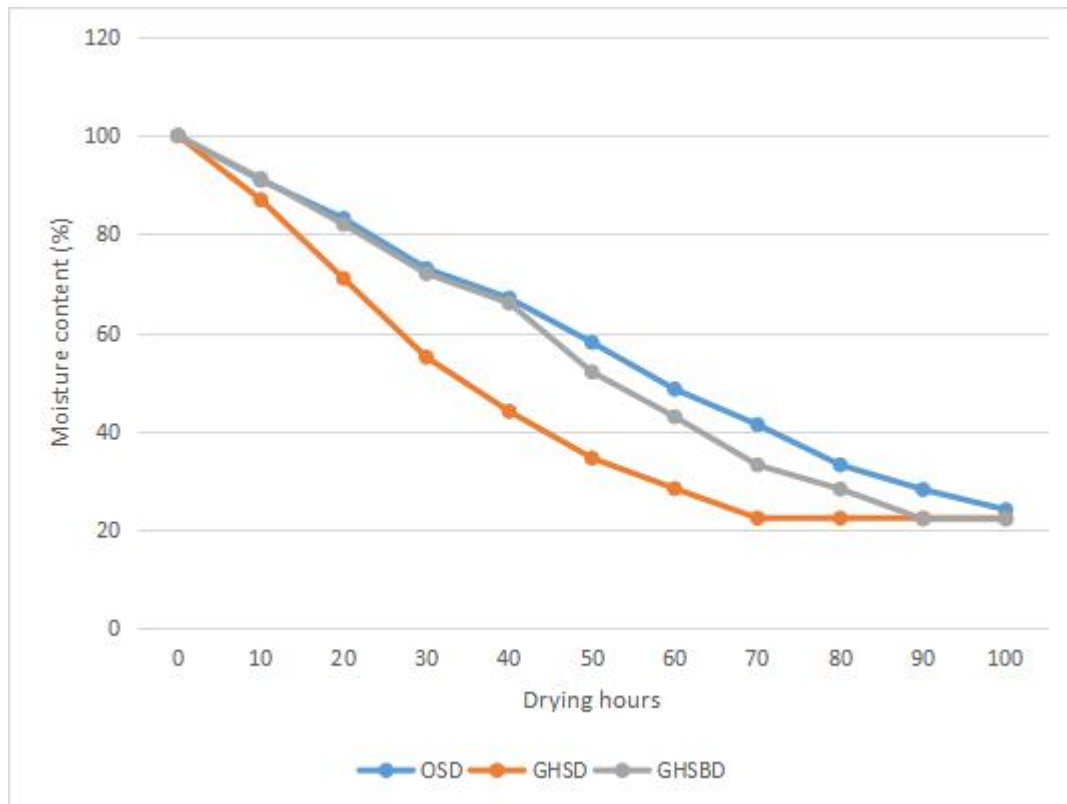


Figure 5.6: Moisture content of ginger on dryers

Fig.5.6 represents moisture content decreasing on all three dryers for ginger. On day 1 where fresh ginger had full moisture content get decreased for each and every hour. As the above graph shows moisture content in ginger is decreased quickly in GHSD. Whereas GHSBD takes extra hours to dry the ginger. Open sun drying takes more time to decrease the moisture content in ginger. As similar to the above graph, Fig.5.7 shows the drying time taken for ginger to dried fully. We have considered the ginger as fully dried by the weight value taken at 15 and 17 hours comes closer to each other value. By the below graph we can clearly see GHSD took only 7 days to dry the ginger while GHSBD took 9 days. Open sun drying took the most days that is 12 days to dry the ginger.

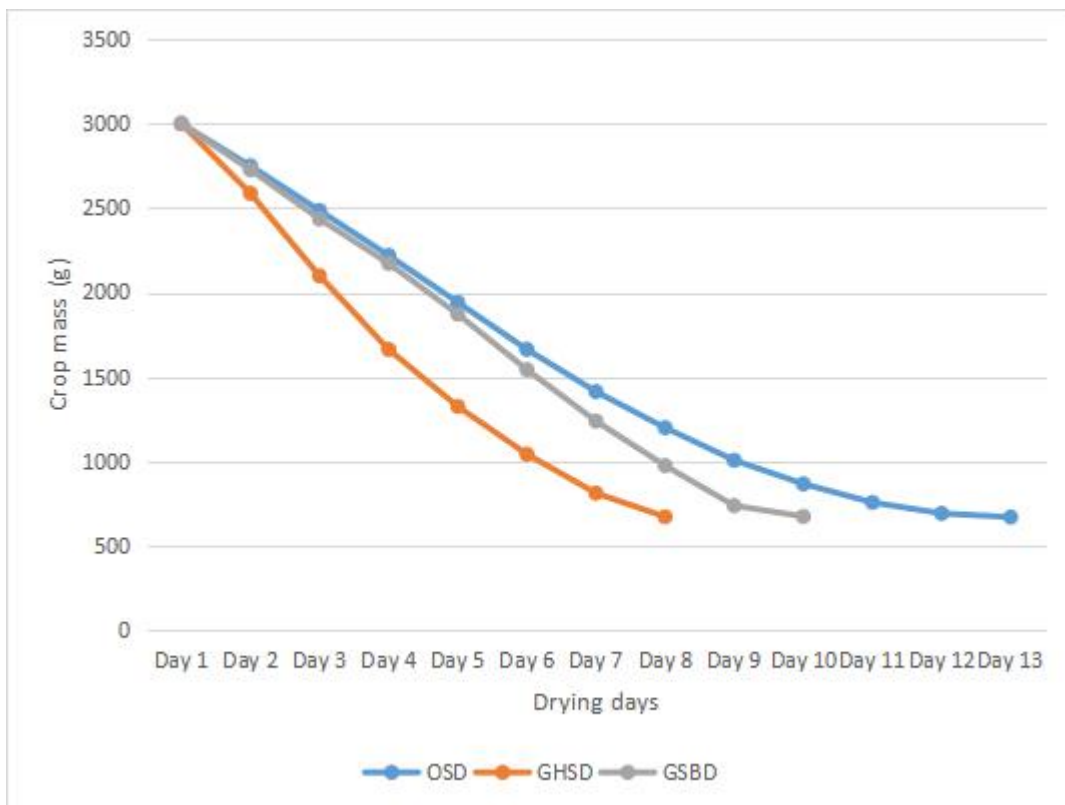


Figure 5.7: Crop mass of ginger on dryers

5.5 NUTRITION AND ENERGY

After the complete drying of ginger in all dryers we have kept that dried ginger in closed container. And given the 100g sample to the lab for the nutrition and energy test.

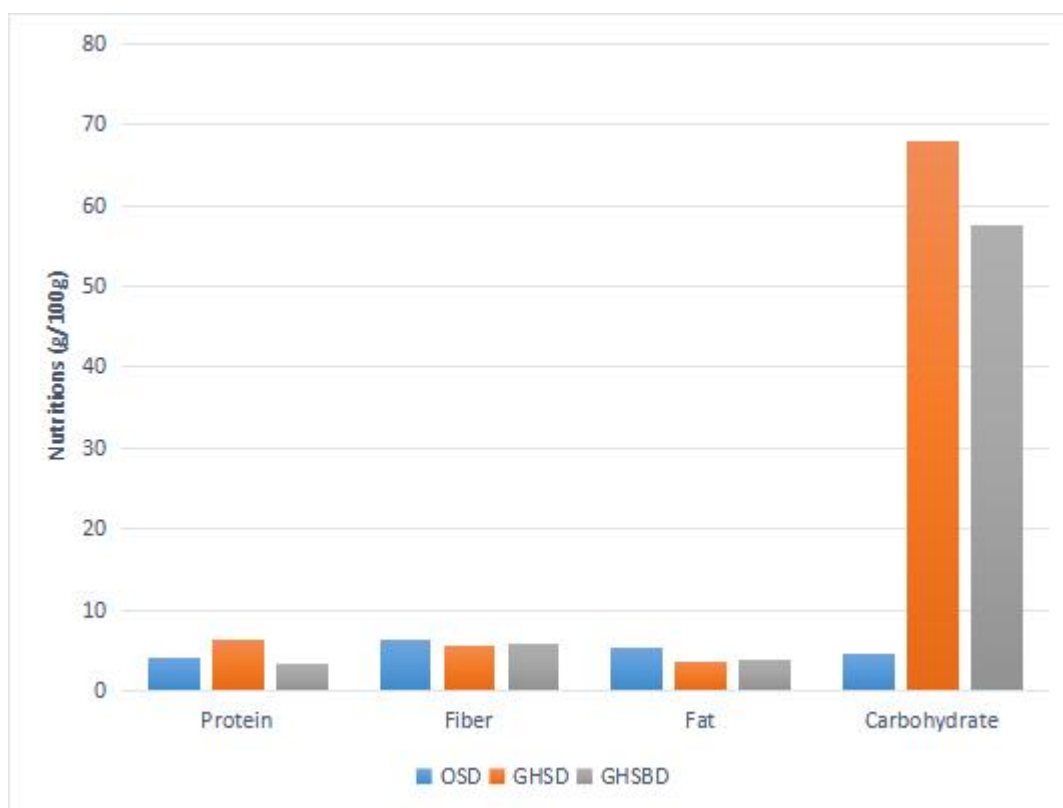


Figure 5.8: Nutrition on dried ginger

Fig 5.8 represents the nutrition present in the dried ginger on all three dryers. Carbohydrate, protein is high in GHSD and equal amount of fiber. Whereas GHSBD has slightly less amount of carbohydrate and protein. OSD has very low amount of carbohydrate and slightly high amount of fiber. In GHSD fat level is lower than other 2 dryers. OSD has more fiber and more fat in its dried ginger sample. Energy value is shown in Fig. 5.2. GHSD has the more energy value of 330.33 kcal/100g. Whereas GHSBD has 277.16 kcal/100g amount of energy value. Open sun drying value is slightly shorter than GHSBD that is 271.86 kcal/100g.

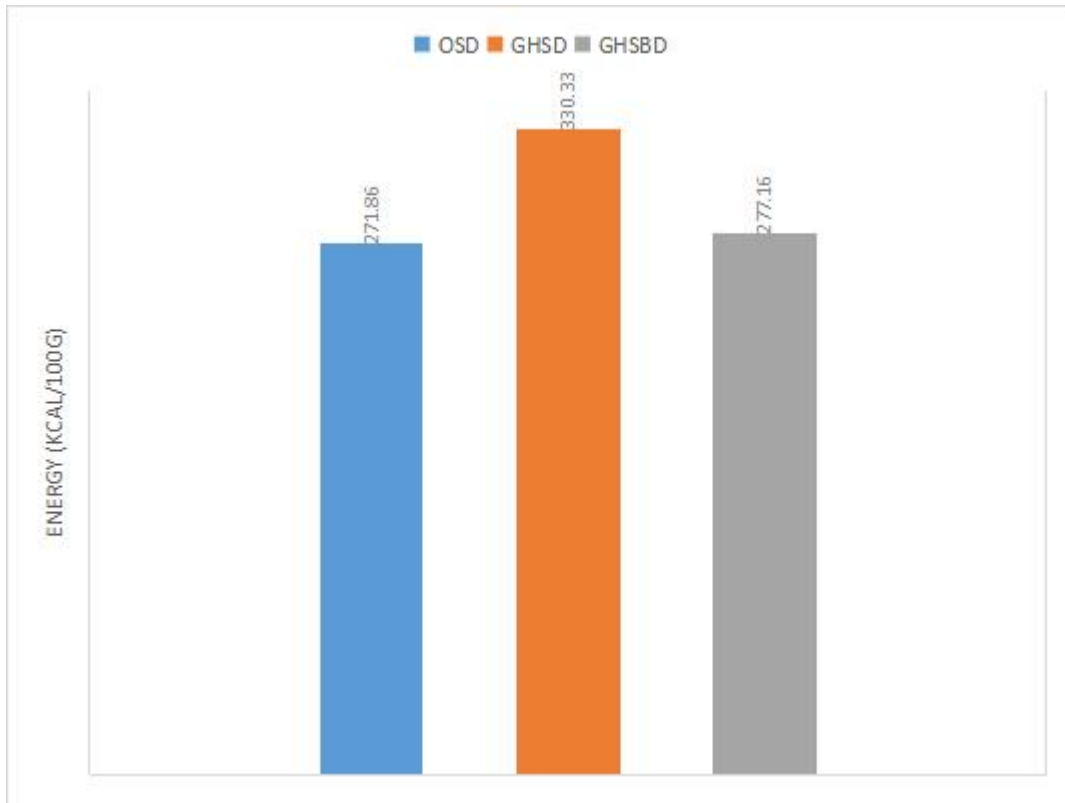


Figure 5.9: Energy of dried ginger for all dryers

Greenhouses dryer has been found to significantly improve agricultural product quality and speed up the dehydrating process. Therefore, to get around the drawbacks of the conventional OSD approach, a more advanced method called greenhouse drying should be used. Ginger drying is experimentally dehydrated using a greenhouse SD with parabolic shape roof and greenhouse solar bubble dryer in comparison to OSD. Ginger' weight is decreased from 3000 to 670 grams in 7 days (70 hours) by GHSD, 9 days (90 hours) by GHSBD, and 12 days (120 hours) by OSD. As we can see GHSD took 2 and 5 days less than GHSBD and OSD respectively. GHSBD took 3 days less than OSD to dehydrate the ginger. Due to the exhaust fan present in GHSD significantly improves the drying speed compared to GHSBD. And also black colour painted plywood increase the heat absorption more where it results in fast drying of ginger. Compared to GHSD, GHSBD has slightly less inside temperature which become as it drawback for its drying speed.

CHAPTER-6

CONCLUSION

In this study, the most recent developments in agricultural food product drying, including new techniques and products, have been revealed. And the comparison of greenhouse solar, greenhouse solar bubble dryer and open sun drying is discussed. The greenhouse dehydrating process is effective and reliant. Because the product was dried in closed atmosphere. It prevents the product without getting any dust or insects interruption. Ginger' weight is decreased from 3000 to 670 grams in 7 days (70 hours) by GHSD, 9 days (90 hours) by GHSBD, and 12 days (120 hours) by OSD. As we can see GHSD took 2 and 5 days less than GHSBD and OSD respectively. GHSBD took 3 days less than OSD to dehydrate the ginger. GHSD is more efficient than greenhouse solar bubble dryer because of its large drying area and exhaust fan present in the dryer. But both the greenhouses dryers are better than open sun drying without any doubt. By the means of nutrition GHSD has good performance. And energy value of the GHSD is significantly high. Energy value of OSD and GHSBD is nearly equal to each other. By drying time taken, nutrition and energy value based GHSD is more efficient than other 2 dryers.

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APPENDIX I



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ALPL - 553

TEST REPORT

SAMPLE NO. : ALPL/FD/2023-04/441-02	REPORT NO.: ALPL/FD/2023-04/441-02
Job Order No. :441	DATE : 15.04.2023

Sample Described by the Customer : **SOLAR DRYER** Sample Received on : 10.04.2023

Name & Address of the Customer : **Mr.Panneerselvam.k & Mr.A.Madhan kumar.** Analysis Commenced on : 10.04.2023

Analysis Completed on : 15.04.2023

Customer Reference : *

Sample Drawn By : Customer

Quantity of the Sample Received : 200g X 1 No

Sample Condition When Received : Good, received in a plastic Container.

Discipline : Chemical Testing

Group : Food & Agricultural Products

S.NO	PARAMETERS	TEST METHOD	UNIT	RESULT
1	Protein	IS : 7219 : 1973	g/100g	6.4
2	Crude Fiber	AOAC 20th Edn 2016: 920.102	g/100g	5.6
3	Fat	AOAC 20th Edn 2016 Chapter 32 922.06	g/100g	3.65
4	Energy	ALPL/FD/SOP/067	Kcal/100g	330.33
5	Carbohydrate	ALPL/FD/SOP/065	g/100g	67.97

Report Prepared By: AD

..... End of Report.....

For Azodi Labs Pvt Ltd.,
G.Prabakaran
 Quality Manager

APPENDIX II

PERFORMANCES OF DIFFERENT GREENHOUSE SOLAR DRYER FOR DRYING OF GINGER

by madhanlal m

Submission date: 17-Apr-2023 11:15PM (UTC-0500)

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APPENDIX III

PERFORMANCES OF DIFFERENT GREENHOUSE SOLAR DRYER FOR DRYING OF GINGER

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