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Design Modification and Fabrication of An Active Solar Dryer

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Abstract: This study presents the design modification and performance evaluation of an active solar dryer. The Modified Active Solar Dryer (MASD) is equipped with a non-concentrating flat plate thermal collector and drying chamber to dry various agricultural products. The drying chamber contains trays inside it. These are used to completely circulate airflow inside it. The drying Chamber has a cross-section Area of 0.30m × 0.45m and a height of 0.45m. The Flat plate collector has 0.91 m length, 0.45 m width, 0.12 m depth, and 0.049 m^3 volume. This study performed experimental work and evaluated performance by drying the chili in a Simplified Active Solar Dryer and Modified Active Solar dryer from 8 am to5 pm with average solar irradiance of 883.25W/m^2. The temperature has been recorded at six different points. The difference in temperatures between the dryer input and the surrounding air has been observed continuously. Temperatures at the Thermal Collector and Drying Chamber are the main prime mover of solar drying, so our main concern was on these two temperatures. The temperature achieved by SASD in the thermal collector is in the range of 55 ~ 60˚C meanwhile in the MASD temperature range is 65 ~ 70˚C. In SASD chili was dried in five days meanwhile in Modified Active Solar Dryer it took four days. The moisture content of the chili was reduced to 10% and it took 45hour for SASD and 34 hours for MASD. It is concluded that Modified Active Solar Dryer took 34% less time than the Simplified Active Solar Dryer.

Index Terms: Modified Active Solar Dryer (MASD), Fabrications, Solar Dryer, Temperature, Thermal Collector

1. Introduction

1.1. Background

Drying is an essential process for the preservation of agricultural products. Food products, especially fruits and vegetables require hot air in the temperature range of 45~ 70˚C for safe drying. Agricultural food products can dry quickly to a safe moisture content and assure superior quality of products by solar drying under controlled temperature and humidity.

For thousands of years, people have dried fruits and vegetables in the open sun by spreading out the product in a suitable area and allowing it to dry. It is a highly economical method of drying. While the product is soaked, a person must keep chasing away animals and remove it when the weather turns too windy, dusty, or rainy.

In most South Asian countries, agriculture represents the biggest part of the economy. Agriculture contributes 24% of the GDP of Pakistan [1]. In Pakistan, 35% to 40%people work in agriculture. Despite these significant numbers, the population's needs are not being met by the food supply system. I.e tomatoes are imported from neighboring countries to fulfill needs. One of the main reasons for this shortfall is that a substantial number of crops are spoiled in the post-harvest period.

As science brings new technologies, population growth increases day by day, and demands for nutritious food, affordable natural food has led to the development of the Modified Solar Dryer. Solar drying requires technology and costs to dry fruits and vegetables. To dry the food properly in a solar dryer, a great amount of dry air circulates through the thermal collector to the drying chamber. Modified Active Solar Dryer allows products to dry overnight and in heavy rain. Dried food has enough nutrients, minerals, fibers, and vitamins. Modified Active Solar Dryer improves the position of farmers because farmers sell their agricultural products at very low cost during the harvest seasons as they can't preserve or store their products in large quantities [2].

This study intends to solve these issues by designing and fabricating the model of MASD using Solid Works. [3] Also analyses and compares the performance of Simplified Active Solar Dryer and Modified Active Solar Dryer.

1.2. Solar Energy Potential in Pakistan

Energy is an essential input for the economic growth of any country (Agriculture and industries). Pakistan is blessed with rich solar resources. Pakistan is the luckiest country since it has an average sunlight 12 hours every day. Pakistan receives the mean value of sunlight 19MJ/m2 per day over 95% of the country's total areas. [4]

1.3. Solar Thermal Collector

The primary component of a solar heating system is a Thermal collector, which captures solar energy converts it into heat energy, and transfers it to fluid passing through it. Solar collectors extract heat energy from radiation using radiation and convection processes. The components of a solar thermal collector are a metal plate called an absorber, a transparent cover, and insulation materials. Types of Solar Thermal collectors are:

Non-concentrating or Flat plate type solar thermal collector (Collector Area = absorber area). Concentrating or Focusing type STC. Concentrating Collectors have an area greater than the absorber area and higher temperature can be obtained. It focuses the sun's beams on the pipe through which the fluid is passing. Compared to non-concentrating thermal collectors concentrating thermal collectors have higher efficiency.

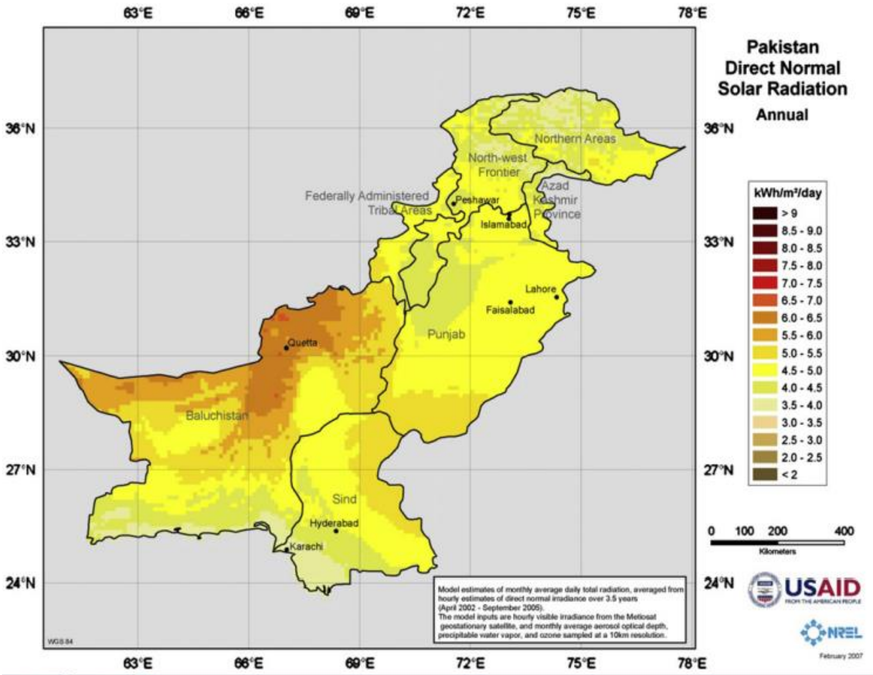


Fig. 1. Solar energy map of Pakistan with direct normal solar radiation [5]

1.3.1. Flat plate solar thermal Collector

The earliest generation of home hot water heating collectors used flat-plate collectors. A flat plate collector (FPC) comprises an insulated, weatherproof box with a glass and absorber plate with pipes to convey the heat transfer circulating fluid. When solar energy strikes a blackened absorber surface, after passing through a transparent cover. A large portion of this energy is absorbed by the plate and then transferred to the transport medium in the fluid tubes.

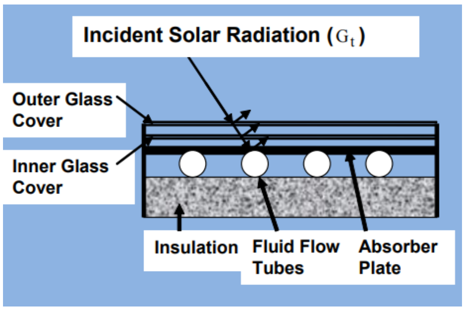


Fig. 2. Flat plate thermal collector [6]

1.3.2. Evacuated tube Solar Thermal Collector

Evacuated tube collectors (ETC) are composed of parallel rows of clear glass tubes, each housing an absorber tube. Although evacuated tubes are sensitive to breakage, they have several important benefits. Even in low temperatures and cloudy environments, efficiency is maintained at a high level. Because of its circular shape, it absorbs solar radiation the whole day.

1.3.3. Parabolic trough Concentrator

The parabolic trough (PTC) is a type of concentrating solar thermal collector. It focuses the sun's beams on the pipe through which the fluid is passing. It has a set of concave mirrors that focus sunlight on it. It can produce a temperature of 150 to 200˚C and is used to produce steam and for space heating.

1.3.4. Parabolic Dish Concentrator

Parabolic dish solar concentrators (PDC) are two-axis solar tracking devices that focus the sun's rays on a heat engine in the dish's center or concentrate them on a thermal

The receiver is at the dish collector's focal point as the dish is swiveled to follow the sun.

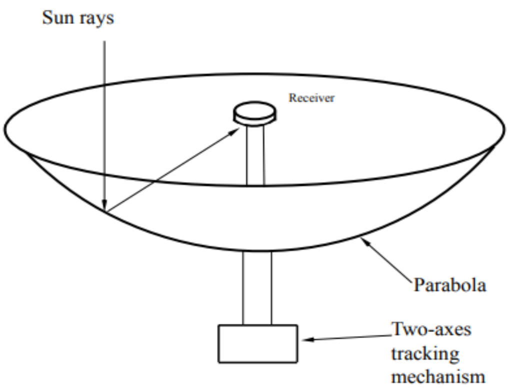


Fig. 3. Parabolic dish solar concentrators [6]

Table 1. Comparison of solar collectors

Motion	Type of collector	Concentration ratio	The temperature	Temperature in (℃)
Stationary	Flat plate collector (FPC)	1	Flat	33-80
	Evacuated tube collector (ETC)	1	Flat	50-210
	Compound parabolic collector (CPC)	1-5	Tubular	60-250
Tracking on a single-axis	Parabolic trough collector (PTC)	10-40	Tabular	50-300
	Parabolic dish reflector (PDR)	100-100	Point	100-510
Tracking along two axes	Heliostat field collector (HFC)	100-1500	Point	200-2000

1.4. Solar Dryer

Solar dryers are used to remove moisture from agricultural products including fruits, vegetables, and crops.

The basic principle of the solar dryer is that air is heated in the thermal collector through solar radiation and passed over to the agricultural products that must be dried.

The heating process could include:

- by directly subjecting the item to sunlight radiation
- the air being heated and passing through the product.

In MASD can dry fruits, vegetables, spices, food items, green leaves, seawater foods, etc. Solar dryers can be classified into two types based on their heating modes.

1.4.1. Passive solar dryer

The Passive solar dryer is also known as a natural circulation system or natural ventilation solar dryer. In this dryer there is no external source to push the air in the dryer, meanwhile, it is naturally circulated to the absorber and then to the dryer chamber.

1.4.2. Active solar dryer

An active solar dryer is also known as a forced convection dryer.

In this dryer, the air is pushed into the thermal collector with the help of blowers and fans. Active solar dryer temperatures are in a wide range and do not depend on weather conditions. Compared to natural circulation type, Active solar dryers are more efficient.

1.5. Problem statement

Various factors such as temperature, humidity, and moisture content affect open sun drying. Further problems affiliated with open sun drying are varying sunlight, rainy season, unhygienic conditions, and non-homogenous drying of products. There are numerous flaws and faults in open sun drying and dryer without control of temperature.

No uniform heat distribution inside the drying chamber due to improper subcomponent arrangements and lack of solar radiation absorption throughout the whole day. Due to the low temperature in the simple solar dryer, the product takes a lot of time to dry. Modifications in the thermal collector can alter the overall results of the dryer and can improve the quality of agricultural products, and the efficiency of the dryer.

*1.6. Aim and **Objectives***

This study aims to design modification and fabricate the active solar drier by providing the product with more heat than is naturally accessible, raising the moisture vapor pressure, and lowering the relative humidity. This project is to introduce a low-cost, temperature-controlled solar dryer to raise the temperature and dry agriculture products. The objectives of this study are:

To design a modified active solar dryer. To fabricate the modified active solar dryer. To evaluate the performance of the modified active solar dryer and compare it with the SASD.

2. Literature Review

This chapter consists of a review of previous studies made on agriculture drying-based solar energy to enhance the performance and effects of different factors. The literature provides the different methods of drying and gives the important equations used to find out the required factors for the performance.

2.1. Scanlin D [7] has reviewed that food drying was a great technique to keep the food fresh, and solar food dryers were suitable for food preservation technology. Authors concluded that every year, millions of dollars worth of gross were lost through spoilage. Because there is no preservation of agricultural products rural farmers sell their harvested products at low rates.

2.2. C L Hii et al [8] have shown that sun drying is economical but the product through it is poor quality. Because of the involvement of dust, insects, birds, and rain. Also, there is a loss of vitamins and unacceptable color changes due to the direct strike of ultraviolet sun rays. They show that solar dyer is the best device to protect foods from these.

2.3. Abro A [9] has developed an Active dryer in the laboratory EE Department SAU, Tandojam. Evaluated the performance of Active Home Use Dryer and dried commonly available vegetables such as bitter guard spinach, also suggested that Active Home Use Dryer can also be used commercially.

2.4. Mohanraj M and Chandrasekhar [10] concluded that the action drying system i.e. forced convection drying is highly efficient than natural convection solar dryers and drying faster than forced convection dryers and it has a better quality.

2.5. Hedge V N [11] developed a top-flow and bottom-flow solar dryer, in a drying chamber using skewers and conventional trays. Vinay evaluated the performance of the banana. The drying rate is increased by using skewers instead of conventional trays.
2.6. Kumar R et al [12] developed two different dryers namely a Cabinet dryer and a Hot air oven drying to dry the chili. They show that it took about one hour less time at 70˚C as compared to 50, and 60˚C to dry the sample completely. They also concluded that Hot air oven drying took more time to dry the sample as compared to tray drying, which means that more moisture transfer took place in the case of tray drying than hot air oven drying.
2.7. The EI Paso Solar Energy Association [13] claims that the necessity for solar drying is driven by the fact that in some areas of the world, during the summer season, fruits are in great amounts or abundance. But there is no easy or cost-effective way to store them, most of it is spoiled. And during the winter season, there is no agricultural cultivation, causing hunger. They concluded that solar food drying may be employed in most locations where the food chain is influenced by a variety of factors, particularly the amount of sunlight and relative humidity. Additionally, they offer some instructions for drying food.
2.8. Bhandari et al [14] explained the comparative performance analysis of three different types of FPTC, FPTC with single glazing. FPTC with double glazing, Double-glazing solar air heating.

A MATLAB code was generated to analyze by considering the effect of mass flow rates, inlet temperature, and intensity of solar radiation.

2.9. For all three types of FPTC, it was concluded that for the same mass flow rate. Double-pass finned FPTSC has the highest thermal performance in terms of efficiency factor F as compared to double-glazing FPTSC and single-glazed FPTSC
2.10. Wissam et al [15] evaluated exegetic performance and the experimental evaluation of energy efficiency and exergy loss of several absorber plates. They compare the exergy performance of conventional solar dryers i.e. flat plate collectors with three different absorber plates equipped with different fins arrangements with variable mass flow rates. They conclude that the largest exergy loss is at solar noon of the traditional type of absorber is a flat plate. This is due to the exergy calculations for this kind only using a small portion of the solar energy collected by the absorber plate. And exergy efficiency of the incline staggered tabulator is higher around 77% than in-line and staggered tabulators.
2.11. Said M et al [16] performed the 4E analysis of solar PV panels and PV thermal collectors. The study analyzed that solar thermal dryers are equipped with PV panels to enhance energy efficiency, and profitability, and determine viability and cost-effectiveness on a big scale using economic, and environmental. It was concluded that the drying time of infrared and heat pump solar dryers is short while construction and energy costs are relatively high. Compared to non-concentrating solar dryers, concentrating solar dryers have high energy efficiency and short drying times. Discussed that drying is the best way to preserve food and that solar dryers are a suitable food preservation technique for sustainable development.
2.12. Kumar L et al [17] analyzed and compared the real-time performance of flat plate collectors with photovoltaic thermal in series and photovoltaic thermal with heat pipe evacuated tube collector. Cascade Solar assessed process heating can relatively improve the performance of the Process heating system by up to 85.59%. It was concluded that these technologies can be assessed in process heating in different industries.

After a detailed literature review, it has been found that a modified active solar dryer is the most suitable or finest type of drying system, which can be designed and fabricated for the conventional dryer to improve its overall efficiency and performance. Although enough research work has been done on this technology, it requires massive attention and research to improve previous work.

According to this literature review, which is mentioned above, we have concluded that most agricultural commodities can be dried using a modified version of the conventional sun drying approach. In comparison to open drying, solar dryer maintains solar dryers retain greater air temperatures and much lower relative humidity, which enables them to achieve improved drying rates.

3. Design and Fabrication of MASD

3.1 Introduction

This chapter presents the methodology for design modification and fabrication of an active solar dryer. Five steps have been used to complete the design and fabrication. In the first step, review of the literature to clear the concept of the solar dryer and their evolution from already existing work to the present. The problem statement and set of objectives have been achieved and defined. As a part of the second step, the dryer has been designed using CAD models for each component in SolidWorks, whose dimensions were taken from the information found in earlier related studies. In the third step purchase the required parts and fabricate using the designed model the simplified active solar dryer and modified active solar dryer at the Mechanical workshop MUET Jamshoro. In the fourth step analyzed the performance of the Simplified active solar dryer and modified active solar dryer and compared the results of each dryer to check the performance and efficiency.

A project report with a set of Conclusions, Recommendations, and future work has been written in the final step as a concluding document.

3.2 Design of Modified Active Solar Dryer

The objective of the thesis is to design MASD using SolidWorks software 2017. Each component of the solar dryer is designed and given below.

3.2.1 Design model of the drying chamber

The drying chamber is a rectangular type of structure closed box consisting of horizontal trays heating the air present in the thermal collector passed into the drying chamber and drying the agriculture products is shown in Fig 4. The 3-D design of the drying chamber is shown in Fig 5.

The dimensions of the drying chamber are:
Length of drying chamber = 45 centimeters
Width of drying chamber = 30 centimeters
Height of drying chamber = 45 centimeters

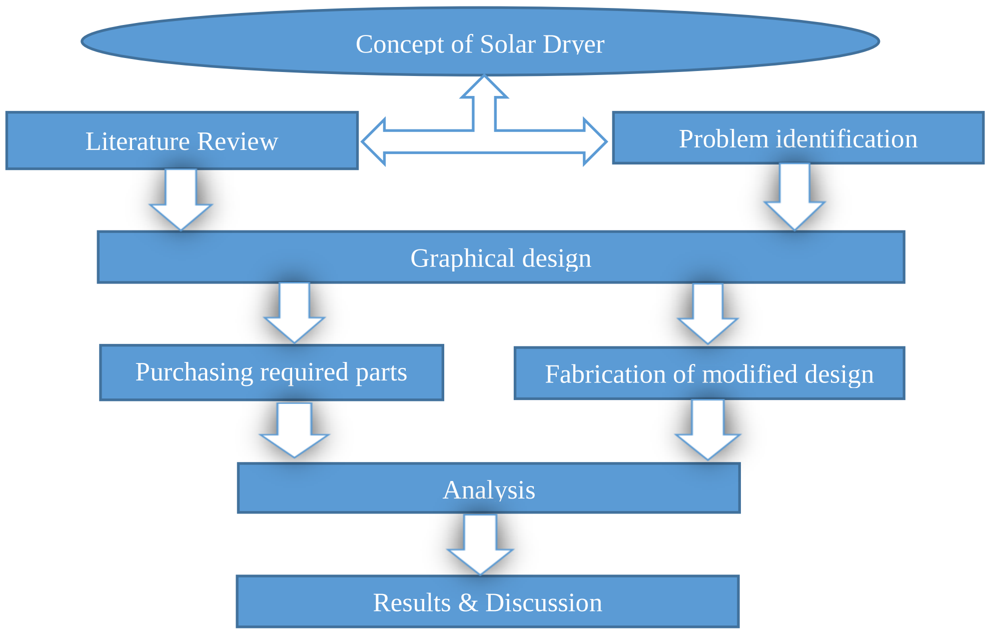


Fig. 4. Flow diagram of the methodology

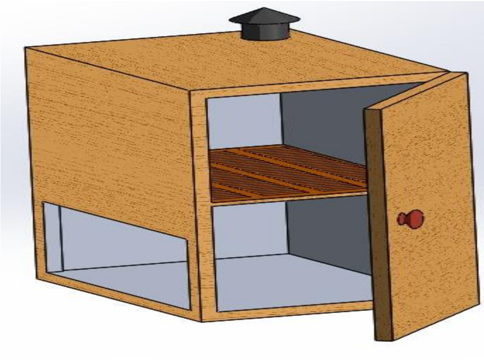


Fig. 5. 3-D Design model of the drying chamber

3.2.2 Design model of Flat plate thermal collector

The thermal collector is a heat exchanger device that converts solar energy into heat energy. Fins are attached to the absorber plate to increase the contact area. To maintain the consistency of heat use insulation. When solar radiation strikes an absorber attached to the fins is heated. The airflow along the fins is heated, and the heated air is used for drying. The 3-D dimensioned model of the thermal collector is designed on solid work and is shown in Fig 6.

The dimensions of the thermal collector are:

Length of Thermal collector = 91.44 centimeters

Width of Thermal collector = 45.72 centimeters

Height of Thermal collector = 12.7 centimeters

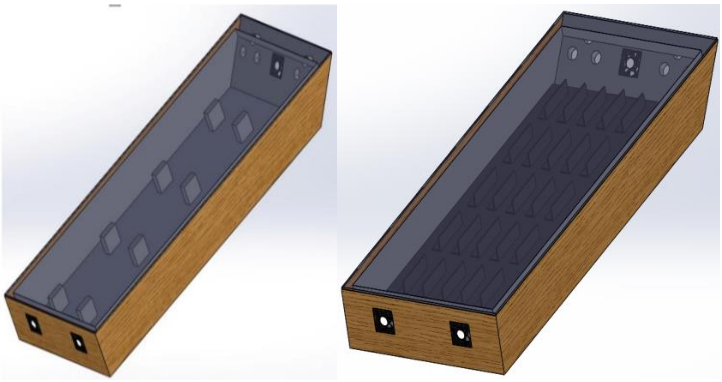


Fig. 6. 3-D design model of thermal collector

3.2.3 Design model of the Absorber plate

The basic function of the absorber plate is to collect the heat energy from solar radiation. On the surface of the absorber plate extended L-type fins are mounted to increase the rate of heat transfer to the air. The three-dimensional model of the Absorber plate and L-type fins designed in solid works is shown in Fig 7.

Dimensions of the Absorber plate are:

Area of Fins = 4 x 6 square inches

Area of Absorber plate = 30 x 15 square inches

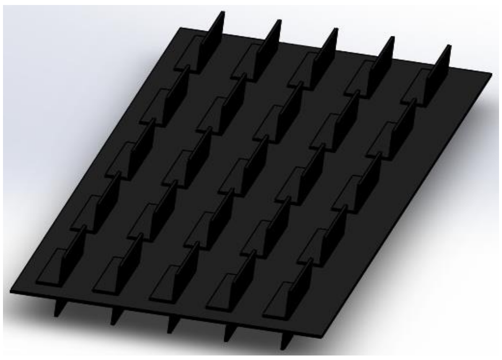


Fig. 7. 3-D design model of Absorber plate

3.2.4 Design model of DC fan

The DC fans of 12 Volt consist of an electric motor having 12V voltage and 0.12A current. DC fans are used to push the air in the thermal collector. The dimensions designed model of the DC fan is shown in Fig 8.

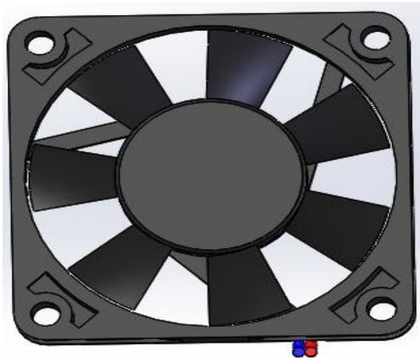


Fig. 8. 3-D design model of DC fan

3.2.5 Design model of solar dryer stand

The Solar dryer stand, or foundation is welded by arc welding that supports other components. The 3-D dimensioned model of solar dryer stand is designed on SolidWorks as shown in Fig 9.

The dimensions of the solar dryer are:

Length of frame = 47 centimeter

Width of frame = 32 centimeters

Height of frame = 40 centimeters

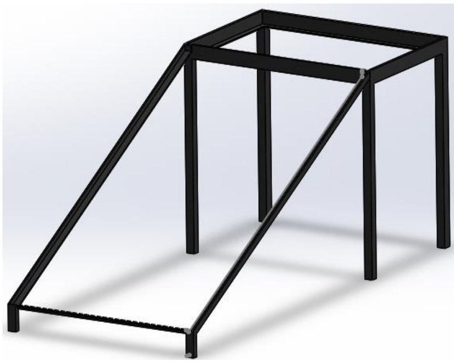


Fig. 9. 3-D design model of solar dryer stand

3.3 Fabrication of Modified Active Solar Dryer

The raw material is transferred into the finished product in this project. The fabrications of each part are fabricated first by referring to their respective design and then assembled into a single final body. During project fabrication, the following procedure is followed.

- Material Selection
- Fabrication

3.3.1 Fabrication of drying chamber

The solar dryer chamber is the main part of the dryer and is a box-type construction, where the products are placed and get dried. It consists of two trays having tiny holes for the passage of the rising warm air from the thermal collector. The fabricated drying chamber is shown in Figure 10.

Fig. 10. Fabricated drying chamber

3.3.2 Fabrication of Thermal Collector

The thermal collector is fabricated to warm out the air circulating toward the drying chamber. The thermal collector is made of wood and an L-type aluminum fins sheet is inserted in the modified active solar dryer. The fabricated flat plate thermal collector is shown in Figure 11.

Fig. 11. Fabricated Flat plate thermal collector

3.3.3 Transparent Glass

Transparent material glass is placed inclined on the thermal collector such that proper transfer of solar radiation. Glass is composed of sand, soda, ash, and limestone.

Transparent glass is shown in Figure 12. Dimensions of transparent Glass are:

Width of Glass = 12 inches

Length of Glass = 36 inches

Thickness of Glass = 0.4 inch

Fig. 12. Normal Glass

A list of different types of Glass is given below.

Table 2. Different types of Glasses.

S.NO	Name
1	Tempered glass
2	Acrylic glass
3	Float Glass
4	Toughened Glass
5	Mirrored Glass.
6	Laminated glass

3.3.4 Absorber plate

Absorber plates are fabricated to collect the heat energy of solar radiation into the air through the method of the convention. We attach the five L-type aluminum fins to the absorber plate by the arrangement of rows and columns as shown in Figure 13.

Fig. 13. Fabricated Absorber plate

3.3.5 Solar dryer stand

The solar dryer stand holds the drying chamber and inclines the thermal collector at an angle of 25 The solar dryer stand is made of mild steel with six legs on which all other components are mounted, and it is fabricated to support the thermal collector and drying chamber during the drying the agriculture products.

The fabricated solar dryer stands as shown in Fig 14.

Fig. 14. Fabricated Solar dryer stand

3.4 Experimental procedure and Energy analysis of Modified active solar dryer

3.4.1 Experimental procedure of Modified active solar dryer

In the Modified Active Solar dryer daily tests have been done every day from 8:00 am to 5:00 pm. A thermocouple is used during the experiment to detect the air temperature at the input and output of the solar thermal collector and the drying chamber.

Solar irradiation on the surface of the collector is obtained by a pyrometer. The pyrometer and all the thermocouples are connected to a data logger to save data at regular times. In the MSD two DC fans are used to push air inside the thermal collector. The air is heated by the action of convection heat transfer between the fins. This heated air is then directed to the drying chamber.

3.4.2 Energy analysis of the Modified active solar dryer

Heat and mass transfer are combined in the modified active solar dryer method to get rid of any moisture that might be in the product. As a heat exchanger, the solar thermal collector converts solar energy into heat energy and then transmits that heat to the working fluid air.

Energy analysis is performed to quantify the energy required to dry chili in the designed solar drying chamber.

Energy analysis is performed to calculate the energy needed to dry the chili in the constructed solar drier using solar energy Based on the mass balance for hot air in a steady state that is present in Equation 1

$$the \sum \dot{m}_{ai} = \sum \dot{m}_{ao} \tag{1}$$

Moisture content while drying in 2.

$$\sum(\dot{m}_{wi} + m_{mp}) = \dot{m}_{wo} \tag{2}$$

For energy conversion in 3.

$$\dot{Q} - \dot{E}u = \sum \dot{m}_{ao}\left(h_{ao} + \frac{{v_{ao}}^2}{2}\right) - \sum \dot{m}_{ai}\left(h_{ai} + \frac{{v_{ai}}^2}{2}\right) \tag{3}$$

The useful heat energy in STC in 4

$$\dot{Q}_u = m_{ai} Cp_{ai} (\dot{T}_{ai} - T_{amb}) \tag{4}$$

The heat use in the Chamber in 5

$$\dot{Q}_d = m_{ai}(h_{hi} - h_{do}) \tag{5}$$

Moisture Ratio in Dryer

The moisture ratio in the drying chamber is calculated as in Equation 6

$$MR = \frac{M - M_d}{M_d} \tag{6}$$

The efficiency of flat plate collector

Collector efficiency defined in Eq. 7

$$\eta_{collector} = \frac{\dot{m} . C_p . (T_{out\ collector} - T_{in\ collector})}{A_{collector} . G_T} \tag{7}$$

4. Results and Discussion

4.1. Final Assembly of Simple Active Solar Dryer

The three-dimensional model of Simplified Active Solar Dryer using SolidWorks 2017 software is designed as shown in Fig 15 (a).

A simplified active solar dryer consists of the following components, which are assembled to form the complete design.

Thermal collector, drying chamber, DC fans, solar dryer stand, Normal Glass of 4mm thickness. Simple Active Solar Dryer is without aluminum fins sheet. The drying chamber and thermal collector are insulated with aluminum foil. The fabricated final assembly of the Simple active solar dryer is shown in Figure 15 (b).

(a) (b)

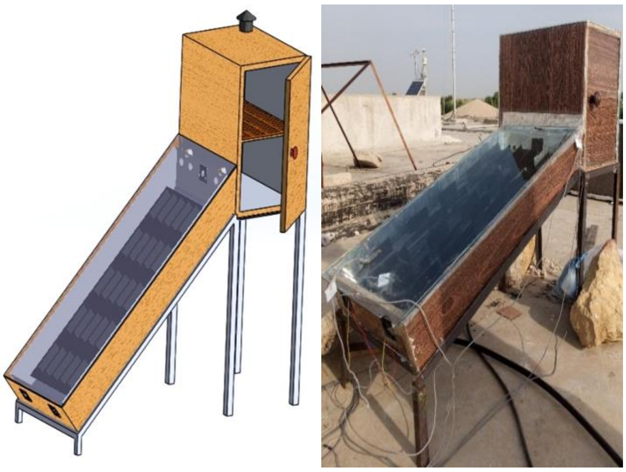
Fig 15. (a) 3-D Design model of Simplified Active Solar Dryer (b) Fabricated Simplified Active solar dryer

4.2. Final assembly of Modified Active Solar Dryer

The three-dimensional model of the Modified Active Solar Dryer using SolidWorks 2017 software is designed as shown in Fig 16 (a).

The modification is done by adding L-type Fins in a thermal collector painted with black color, due to its great absorption property. The thermal collector is provided with two DC fans at the inlet fitted in holes 3x3cm for fresh air and one at the exit to push the hot air toward the drying chamber. The thermal collector and drying chamber are made up of wood sheets. And insulate it with aluminum foil. The drying chamber is connected with a thermal collector tilted at 25˚ at the ground to utilize or capture maximum sun irradiance. The drying chamber has two trays between the top and bottom surfaces on which the chili has dried.

The final fabricated assembly of the Modified active solar dryer is shown in Fig 16 (b).



(a) (b)

Fig. 16. (a) 3-D Design model of Modified Active Solar Dryer (b) Fabricated Modified Active solar dryer

4.3. Performance evaluation of SASD & MASD

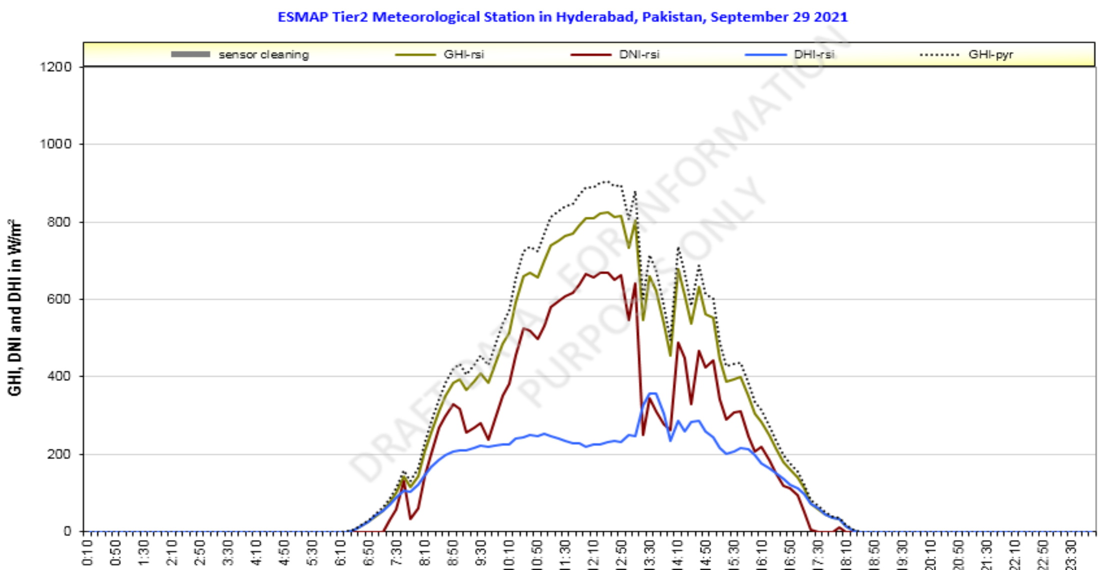
4.3.1 Solar Irradiance on Dryer

It is shown in the figures that meteorological reports give us global solar irradiance on the earth starts from 6 am and increases to 889W/m2 at 12:50 pm on average and then decreases continuously as the sun sets.

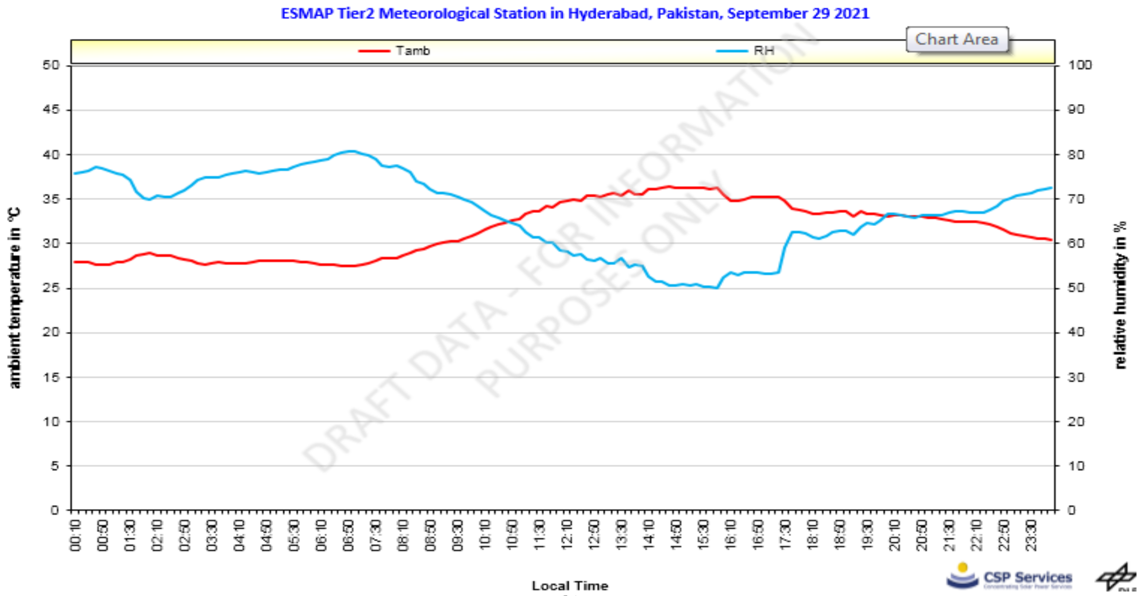
Indirect global solar irradiance is in the range of 800~900 W/m2 (black dotted line) shown in the figure 17. Direct Solar Irradiance is shown in the blue line. It is very low as the Sun radiation is reflected and diffused by hindrances.

4.3.2 Temperature and relative humidity

The graph shows the relationship between temperature and humidity. With the increase in temperature, humidity decreases. In the morning's temperature is low and the humidity is relatively high. These coincide at the times of 10 a.m. and 8 p.m. Here meteorological reports of Hyderabad show that humidity is 40% at midnight and 26% at noon.



(a)



(b)

Fig. 17. (a): Solar Irradiance on Dryer, (b): Temperature and Relative humidity

4.3.3 1st day of drying

The first day of our analysis started on the 11th of September 2022 by drying chili in SASD and MASD Dryers.

500g Chilies have been kept in a drying chamber. On that day highest ambient temperature was 54.83˚C and the highest Drying temperature was 59˚C in SASD and 69 ˚C in MASD. Hourly reading has been collected which is shown in Table 4. The results of the 1nd day are shown in figure 18.

Table 3. Results of Simplified and Modified Active Solar Dryer - 1st day

Time	SASD		MASD	
	T1	T3	T1	T3
8:00	37.31	48	37.31	44.44
9:00	38.67	52	38.67	44.29
10:00	47.45	57	47.45	54.58
11:00	51.99	51.2	51.99	61.76
12:00	53.08	55.25	53.08	68.34
13:00	54	58.9	54	69
14:00	54.83	59	54.83	65.8
15:00	49.9	57.98	49.9	62.5
16:00	43.35	56.82	43.35	60.83
17:00	41.5	50.95	41.5	59
18:00	40.1	43	40.1	58

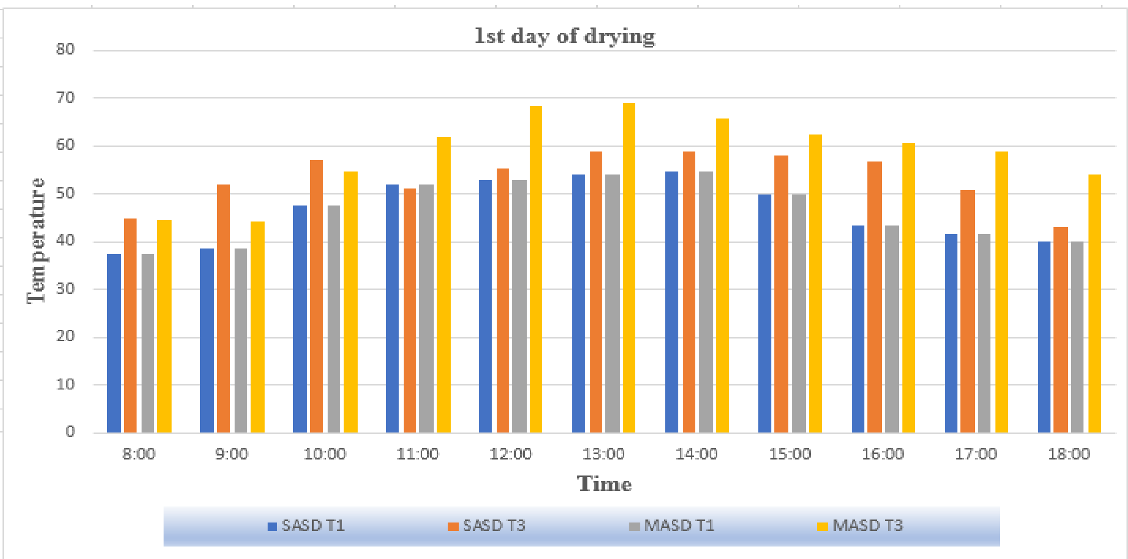


Fig. 18. Results of Simplified and Modified Active Solar Dryer - 1st day

4.3.4 2nd day of drying

The results of the SASD and the MASD are tabulated in Table 4. It is observed in the graph that SASD has a maximum temperature of 59˚C and MASD has achieved a maximum temperature of 69 ˚C. Both have a maximum temperature of 1:20 pm. This was the last day of drying for MASD. The chili has achieved a minimum (10%) moisture content in MASD meanwhile the SASD product had a 42% moisture content

The results of the 2nd day are shown in figure 19.

Table 4. Results of Simplified and Modified Active Solar Dryer – 2nd day

Time	SASD		MASD	
	T1	T3	T1	T3
8:00	37	48	37	50
9:00	40	52	40	60
10:00	41	57	41	62
11:00	41.5	58	41.5	66
12:00	43	59	43	68
13:00	44	59	44	69
14:00	43	59	43	69
15:00	42.5	59	42.5	68
16:00	41	58	41	67
17:00	39.5	56	39.5	65
18:00	37.5	50	37.5	62

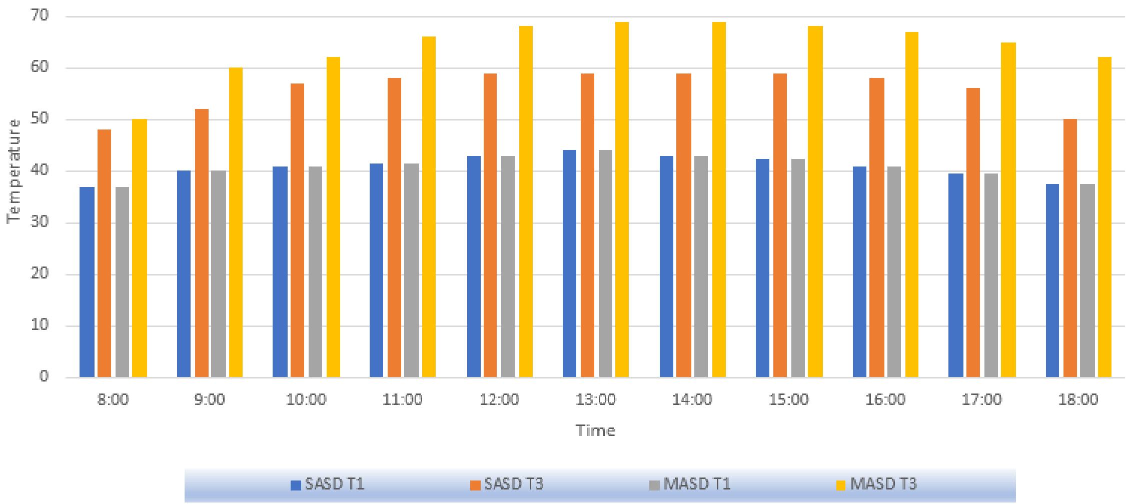


Fig. 19. Results of Simplified and Modified Active Solar Dryer – 2nd day

4.3.5 3rd day of drying

It was the last day for drying chili in SASD. Chilies were dried from 9 September 2022 to 15 September 2022 and on the 5th day of drying in SASD chili was completely dried. It took a total of 45 hours to dry to the minimum moisture ratio of 10%. The highest ambient temperature on the fifth day was T1 = 51.03˚C and the highest collector temperature recorded was 58.23˚C. Hourly reading which has been collected is shown in Fig 20.

Table 5. Results of Simplified Active Solar Dryer – 3rd day

Time	T1	T3
8:00	37	41
9:00	40.83	44.02
10:00	46.37	48
11:00	47.35	53.31
12:00	51.03	54.88
13:00	49	56.43
14:00	48.11	57.75
15:00	47.56	58.23
16:00	43.4	54.82
17:00	41.36	47.95
18:00	37.98	40.51

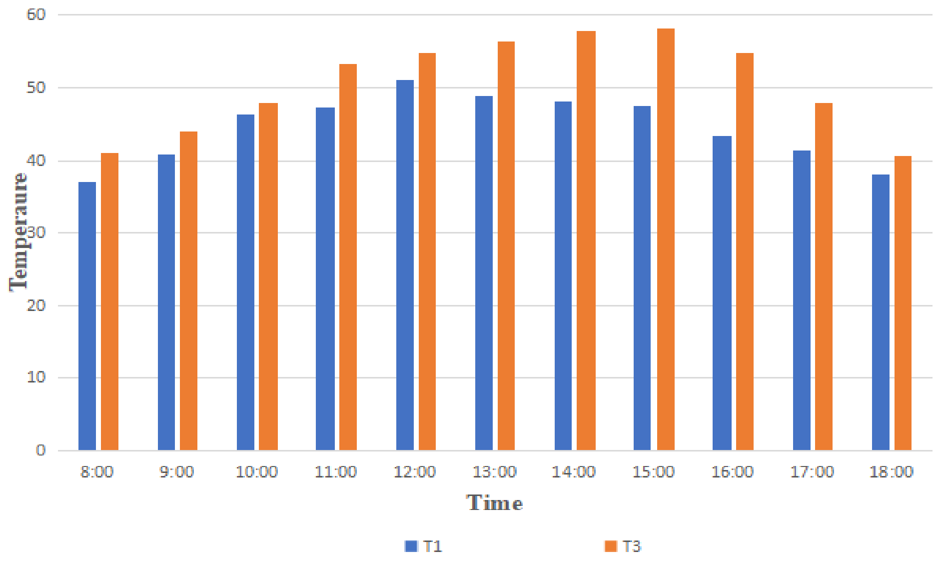


Fig. 20. Results of SASD – 3rd day

4.4 *Bill of quantities*

The cost of Modified Active Solar Dryer to fabricate is Rs.12000 PKR as shown in Table 6. It shows that locally available material can be used to fabricate the Modified active Solar Dryer at a reasonable cost.

Table 6. Material needed for fabrication of MASD

S.NO	Name	Quantity	Unit rate	Budget (Rs) PKR
1.	Wood sheet (4 x 8 inches)	1	2500	2500
2	Black Spray 0.5letter	1	250	500
3.	Inlet DC Fan	2	250	500
4.	Outlet DC Fan	1	250	250
5.	Aluminum foil (2x4 cm)	3	400	1200
6.	Aluminum sheet (4 feet)	2	300	600
7.	Hygrometer Humidity meter	1	500	500
8.	Temperature sensor	6	50	300
9.	Voltage Regulator	2	250	500
10.	Stitch solution	1	80	80
12.	Angle for stand (Mild steel)	1	3000	3000
13.	PV panel 80 watt	1	720	720
14.	Glue	2	50	100
15.	Wood Screw (Stainless Steel)	100	3	300
16.	Normal Glass (1.5x3 feet)	1	900	900
17	Nails (kg)	1	50	50
	Total			12000

5. Conclusion

In this study, the solar dryers have been designed, fabricated and performance of Modified Active Solar Dryer has been compared with Simplified Active Solar Dryer. Both equipped with Flat plate thermal collector. In Simplified Active Solar Dryer we dried the chili completely in five days at a lower temperature. Meanwhile, in the Modified Active Solar Dryer more temperature is obtained, and drying time was reduced.

The conclusion of the MASD is:

The SASD dried the chilies under the temperature of 60˚C for three days. The MASD dried the chili within 2 days at a temperature of 69˚C.MASD products have been dried well and food can be stored for a longer time. The moisture in chili is completely removed after 34 hour in MASD. By increasing the inlet temperature of the drying chamber humidity in the chili was removed quickly, and the results show an effective drying and better quality.

Observation from the experiments indicated that MASD is an effective method for drying agriculture products because it has a higher Drying temperature and takes less time to dry products.

The performance of MASD equipped with a flat plate collector is more if there is sufficient solar energy supplied. Also, MASD took less time to dry the vegetables.

6. Declaration

6.1 Recommendations

The following recommendations are made based on this experiment:

The temperature of the Modified Active Solar Dryer can be increased by changing the size of the thermal collector and drying chamber according to need. In thermal collector instead of L-shape fins use diamond shape extended fins for more effective heat transfer. For getting better heat ratios in thermal collector tempered glass may be used instead of normal glass. Solar drying shall be experienced in all months of the calendar of the year including cloudy days to understand the time versus drying ratio. Many crops were ruined by the recent flood in Sindh province; if farmers had access to this dryer, they could harvest their crops, dry them, and store them for a longer period. It recommended to the Sindh government that MASD can be distributed to the formers directly or through NGOs. MASD can be utilized by farmers because of very convenient and cost-effective. It's also recommended that other species of chilies should be tested and observe the behavior of different varieties of chilies in Sindh province.

6.2 Future work

Future work in any running scientific project is always needed, as the population grows it feels the deficiency for its foods. The suggestions for future work are shown below. This lab-scale experimental research work can be extended for projects on a scale-up level. It will be advantageous for the Modified Active Solar dryer to have an energy storage system so that the product continues to dry even when there is no sunlight

Photovoltaic panels with a dryer system will increase electrical and thermal efficiency. A proper solar dryer mechanism can be designed and built to dry and store the agricultural products cultivated by farmers for a long time. The government should subsidies NGOs and commercial institutions so they can move forward with creative initiatives to promote the MASD to formers.

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