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Studies on Performance Improvement of Solar Dryer for Drying Agricultural Products

PRAGADEESH.G, JELIT SHARLIN.V, NITHISH KUMAR.S, RAJESH.S

Dr.E.GANAPATHY SUNDARAM M.E,Ph.D

Department of Mechanical Engineering, Velammal Engineering College, Chennai, India

ABSTRACT: The solar drying system utilizes solar energy to heat up air and to dry any food substance loaded, which is beneficial in reducing wastage of agricultural product and helps in preservation of agricultural product. Based on the limitations of the natural sun drying e.g. exposure to direct sunlight, liability to pests and rodents lack of proper monitoring, and the escalated cost of the mechanical dryer, a solar is therefore developed to cater for this limitation. This project presents the design and construction of a **developed solar dryer**.

A solar cabinet dryer with 1.25 m length, 1.50 m breadth and 1.09 m height with 1.61 m² bottom need required to fabricate. The heat is stored in phase changing material paraffin wax. The solar dryer type is a **mixed-mode solar dryer**. The solar dryer cabinet body is made up of **Mild Steel HR sheet** and a **reflective sheet** placed inside to avoid wastage of heat. A reflective northern wall is built to concentrate heat. The harvested products are placed on the trays and the **PCM** material is placed below it to store heat energy. The main objective of the project is to improve solar dryer performance and moisture content removal performance of harvested products.

INTRODUCTION

Due to the increasing global demand for energy, rising fossil fuel price, increasing concerns about global warming, and uncertainty about the costs and availability of fossil fuels in the future, use of solar energy will probably increase and can be economically acceptable in the future. Solar energy is the best source of free, available, and clean energy for the environment.

Nowadays, solar energy is used in the air or water heaters, air-conditioning systems, dryers and hydrogen and power generation systems, because it is the source of renewable and ecofriendly energies. Therefore, the use of solar energy is on the rise in most countries. One of the methods of using solar energy is drying food, agricultural crops, marine products and plants. In open sun drying of the food products, the product is exposed to the open sun and direct solar radiation. Due to direct solar radiation and other influential environmental factors, the quality of the product is minimized. Use of renewable energies indirectly can be an appropriate substitute for the open sun drying. Solar dryers are a substitute for traditional drying methods.

The first idea of the solar dryer to prevent the drying problem of products in open sun was developed by Everitt and Stanley (1976). They manufactured a box with a transparent cover. The main objective of this technology was to overcome the deficiencies of traditional drying methods. After decades, many well-known researchers developed solar drying technologies using natural and forced convection and auxiliary heat resources like electricity.

III.FABRICATION PROCESS

3.1 CAD DESIGNING :

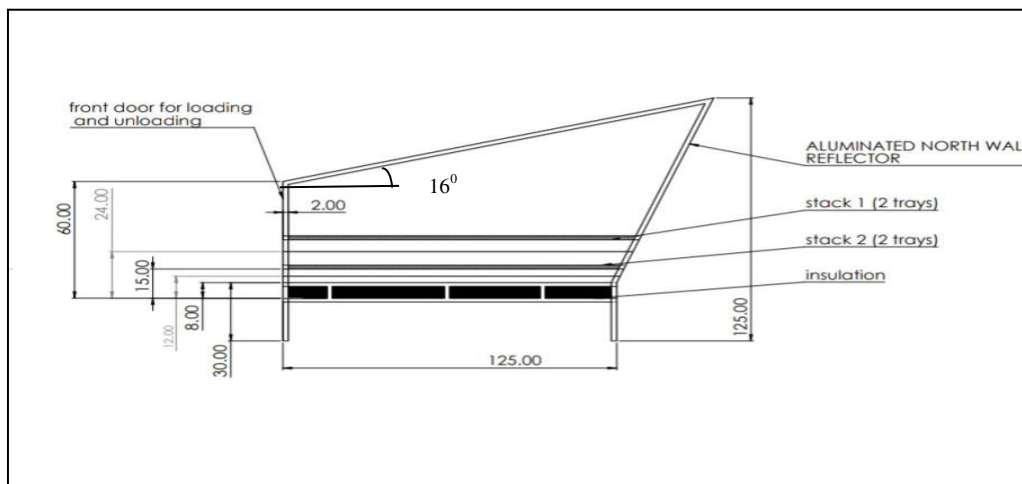
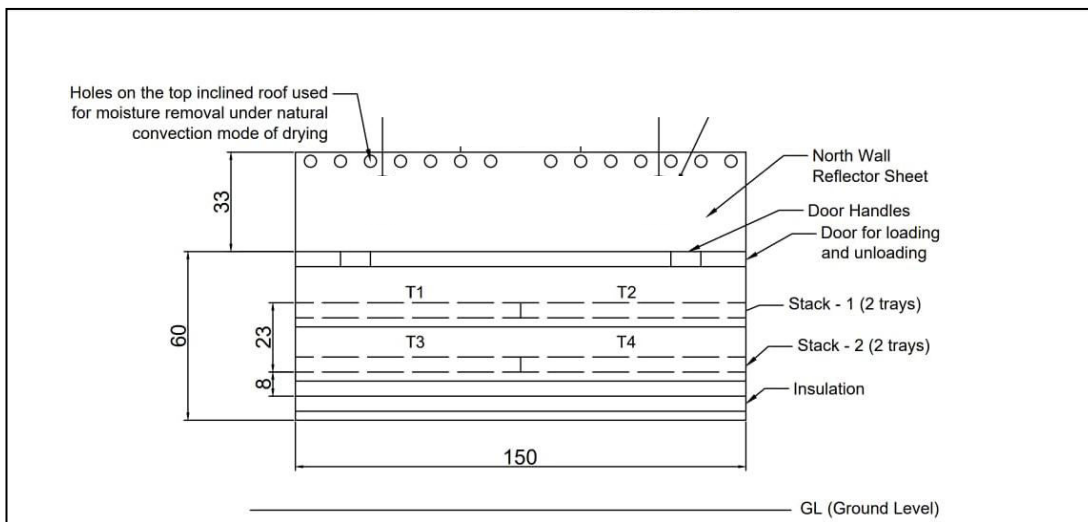


Figure 3.1 2D CAD model of solar dryer

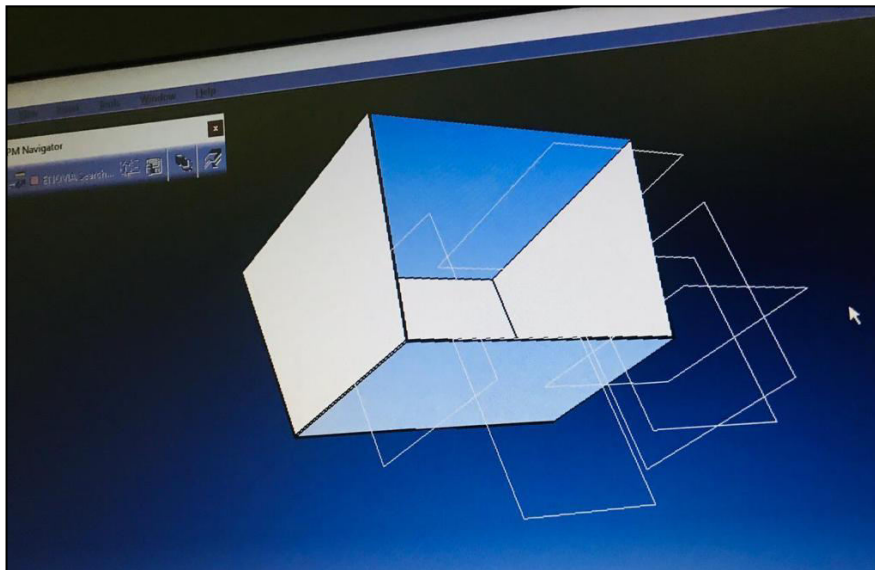
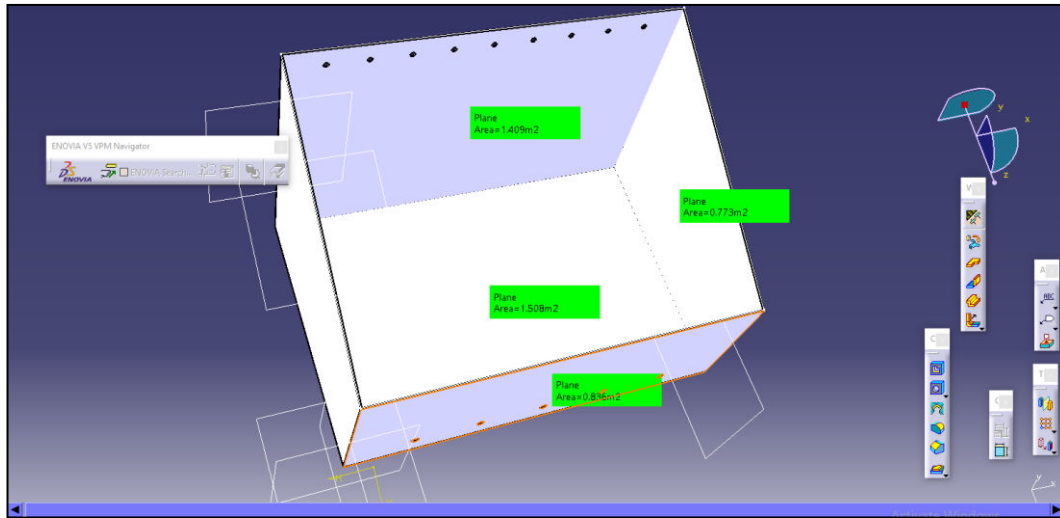


Figure 3.2 3D CAD model of solar dryer

Computer-aided design (CAD) is the use of computers (or workstations) to aid in the creation, modification, analysis, or optimization of a design.[1] CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. Designs made through CAD software are helpful in protecting products and inventions when used in patent applications.

CHAPTER 4 EXPERIMENTAL PROCEDURE

4.1 TESTING WITHOUT PCM

- A 300 grams green grapes are taken for drying.
- Thermocouple is placed to note the air temperature inside the cabin.
- The grapes are placed on the tray to start the drying process.
- The temperature reading should be taken for.
- The solar radiation should be checked by solar meter.



Figure 4.1 Image of grapes Drying



Figure : 4.2 Image of loading the tray

4.2 TESTING WITH PCM

- A 300 grams green grapes are taken for drying.
- Thermocouple is placed to note the air temperature inside the cabin.
- Phase changing material(1kg) is placed below the tray to store the heat energy.
- The grapes are placed on the tray to start the drying process.
- The temperature reading should be taken .

4.3 TESTING WITH PCM ADDED WITH $Al_2(SO_4)_3$ AND REFLECTIVE SHEET

- A 300 grams green grapes are taken for drying.
- Thermocouple is placed to note the air temperature inside the cabin.
- Phase changing material (1kg) is melted and added with 200 grams of $Al_2(SO_4)_3$. Then the mixture is placed under the tray.
- The aluminum reflective sheet is fixed on the northern wall.



Figure 4.3 Melting of PCM



Figure 4.4 Solar dryer with reflective sheet

- The grapes are placed on the tray to start the drying process.
- The temperature reading should be taken and solar radiation also checked throughout the process.
- Thermal images are taken to analyse the heat concentration factors and temperature at different spots.

V.RESULT AND DISCUSSIONS

5.1 TEST WITHOUT PCM

Initial grapes weight (W_i) =300 g

Final grapes weight (W_f) =122 g

Therefore,

$$\begin{aligned} \text{Reduction in moisture content} &= \frac{W_i - W_f}{W_i} \times 100 \\ &= \frac{300 - 122}{300} \times 100 \end{aligned}$$

Percentage of reduction in weight. = **59.33%**

The air temperature are noted at regular intervals using thermocouple,

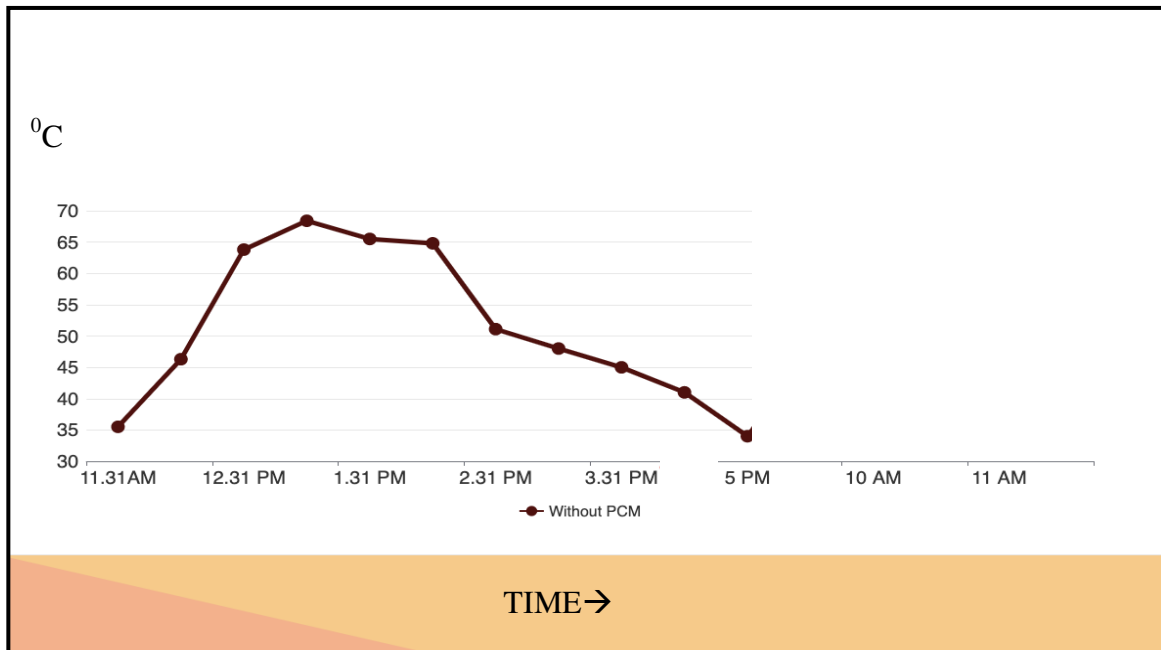


Figure 5.1 Graph of air temperature without PCM

5.2 TEST WITH PCM

Initial grapes weight (W_i) = 300 g

Final grapes weight (W_f) = 110 g

Therefore,

$$\begin{aligned} \text{Reduction in moisture content} &= \frac{W_i - W_f}{W_i} \times 100 \\ &= \frac{300 - 110}{300} \times 100 \end{aligned}$$

Percentage of reduction = 63.33%
n weight.

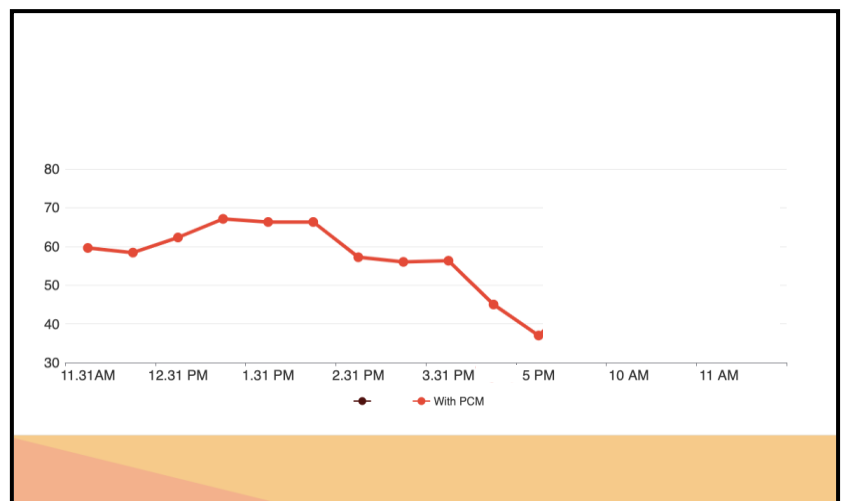


Figure 5.2 Graph of air temperature with PCM

5.3 TEST WITH PCM ADDED WITH Al₂(SO₄)₃ AND REFLECTIVE SHEET.

Initial grapes weight (W_i) =300 g

Final grapes weight (W_f) =93 g

Therefore,

$$\begin{aligned} \text{Reduction in moisture content} &= \frac{W_i - W_f}{W_i} \times 100 \\ &= \frac{300 - 93}{300} \times 100 \end{aligned}$$

Percentage of reduction in weight. =69%

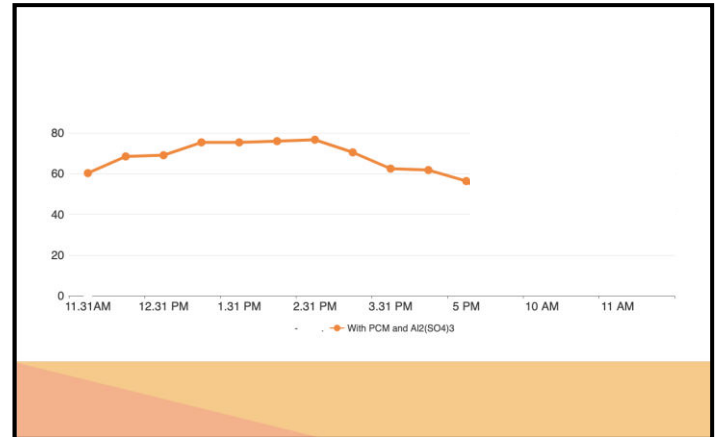


Figure 5.3 Graph of air temperature with PCM, Al₂(SO₄)₃ and Rf sheet

5.4 SOLAR METER READINGS

Average solar meter rating in W/m	
Day 1	998 W/m ²
Day 2	989 W/m ²
Day 3	995 W/m ²

Table 5.1 Solar meter reading

Figure 5.4 Solar meter reading



5.5 THERMAL IMAGE ANALYSIS

We took thermal images to study the heat concentration and to find temperatures at different surfaces. Thermal cameras usually detect radiation in the long-infrared range of the electromagnetic spectrum (roughly 9,000–14,000 nanometers or 9–14 μm) and produce images of that radiation, called **thermograms**. Since infrared radiation is emitted by all objects with a temperature above absolute zero according to the black



body radiation law, thermography makes it possible to see one's environment with or without visible illumination. The amount of radiation emitted by an object increases with temperature; therefore, thermography allows one to see variations in temperature. When viewed through a thermal imaging camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day or night. As a result, thermography is particularly useful to the military and other users of surveillance cameras.

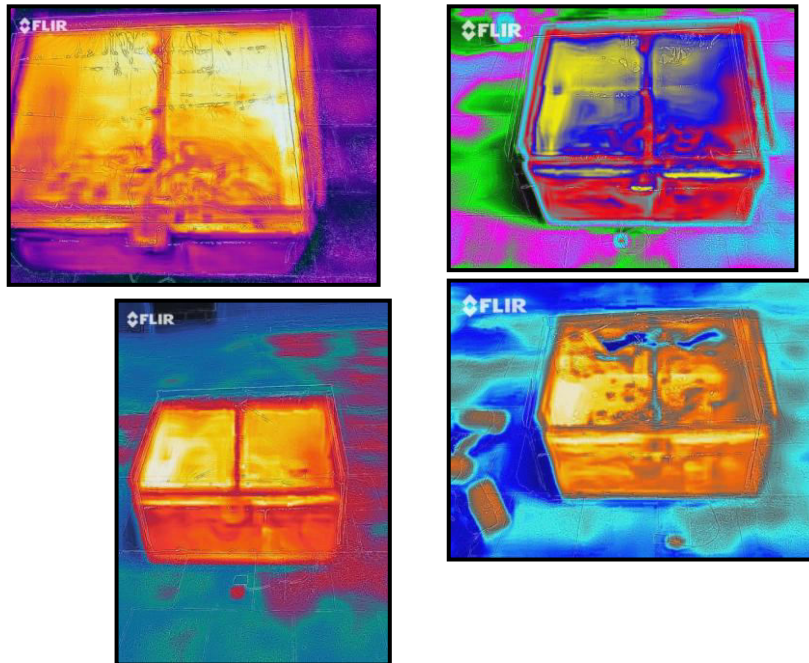


Figure 5.5 Thermograms of solar dryer

The uniformity in the solar dryer attained only after placing the aluminium reflective sheet. The reflective sheet reflects maximum sun rays back into the solar dryer cabin.



Figure 5.6 Spot temperature before Reflective sheet

Figure 5.6 Spot temperature after Reflective sheet



5.6 OVERALL OBSERVATION

TIME	TEMPERATURE (°C)		
	WITHOUT PCM	WITH PCM	PCM, Al ₂ (SO ₄) ₃ , REFLECTIVE SHEET
11.30 am	35.5	59.6	60.2
12.00 noon	46.3	58.4	68.4
12.30 pm	63.8	62.3	69
01.00 pm	68.4	67.1	75.3
01.30 pm	65.5	66.3	75.9
02.00 pm	64.8	66.3	76.6
02.30 pm	51.1	57.2	70.4
03.00 pm	48	56	62.4
03.30 pm	45	56.3	61.7
04.00 pm	41	45.3	56.3
05.00 pm	34	37	44.9
09.30 am	47.4	48	52.3
10.00 am	55.7	56	60.3
10.30 am	61.2	59	62.4
11.00 am	63.9	66	62.8
11.30 am	67.9	68	67.5

Table 5.2 OVERALL READING OF AIR TEMPERATURE

From the tabulation we can observe that the temperature improves from left to right, which means the effect of PCM in solar dryer had improved the temperature inside the solar dryer.

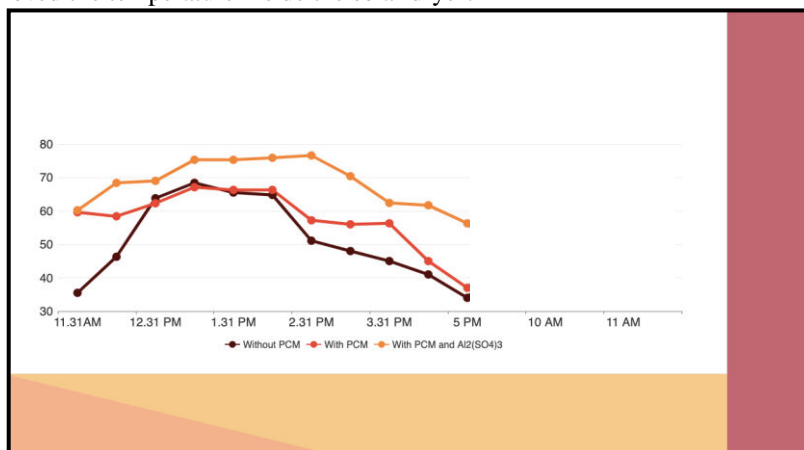


Fig 5.8 OVERALL AIR TEMPERATURE

VI.CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSIUON

- It is clear from the above test that the moisture content in the sample decreases maximum only when PCM ,Aluminum Sulphate and reflective sheet in placed.
- The maximum temperature is attained only at the last test with PCM ,Aluminum Sulphate and reflective sheet.
- The uniform temperature can be attained in solar dryer only after fixing reflective sheet on the northern wall.

6.2 FUTURE SCOPE

Still there are number of tests pending such as pasting Titanium Dioxide nanoparticle on reflective sheet and spreading polycarbonate powders on reflective sheet to study improvements in air temperature. The results of still now performed experiments are seems to be satisfying. After finding the air temperature using nanoparticle ,we intend to find the air temperature by placing solar heater as secondary source for heating agricultural products. Besides, higher ventilated frequency and higher drying temperatures give an increasing drying rate of the products. We also planned to repeat the experiment with other agricultural products to study its drying ability.

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