Improving the efficiency of solar drying unit with PCM (Paraffin wax)

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Abstract. The renewable energy source like solar is been used in this projects to produce more efficiency in a solar dryer. It is one the most reliable energy source and that does not pollute the environment and green house free emission. In this project work we use sunlight to dry the crops and to preserve the dry fruits we are using sunlight. The motivation of the work is to use a solar dryer with phase change material. With the help of PCM we can able to increase the efficiency of solar dryer because of increasing the contact area of the crops with PCM during off sunlight. In this project work we use indirect solar radiation principle because PCM will absorb the solar radiation and that will be emitted during the night time. A absorber plate is used to absorb the solar radiation. Once after receiving the radiation from the sun that is been transferred to the chamber where the crops are been provided. In that chamber we will be having the PCM box that will be in solid state and once after receiving the solar radiation phase change will be taking place from solid to liquid phase. Once the sun starts to set off the solar radiation will not be available so during that time PCM is used to transfer the heat. The moisture present in the crop is been removed with the help of the heated air. With the help of the above information the crop drying process is been evaluated with the help of calculation.

Keywords: Air heater, Chamber, Paraffin wax, solar absorber plate

1. Introduction

Solar dryer are used to dry the fruits and vegetables. The need of drying of the crops or vegetable is to preserve them from decaying. The agriculture products are tough to manufacture and the spoiling of those products are biggest sin so we use solar dryer to reduce the wastage of agriculture products [1]. The drying of the crops helps us to transport the food product or crop from one place to another since there is no moisture content is available on that product [2]. The absorber plate contains glass plate and that is used to collect the air from the atmosphere and that will sent into the chamber were the fruits and vegetable are arranged in a tray arrangement. In the olden day the crops are been dried by spreading the moisture content crop in the land surface and that is been exposed to the sunlight.
and over a period of time the crops moisture content is been removed because of radiation and as a output we will get dry crops [3]. The main disadvantage of this kind old method is that in off shine
days we cannot able to do this so we switch to some thermal devices. The thermal device which we
are using in this experiment is Solar Dryer [4]. That too the solar dryer used in this process is
integrated with a phase change material is been used to improve the efficiency if the solar dryer.
While drying the food the ultimate goal is to remove the moisture content present on the fruits [5].
The flavor of the food product and smell need not to be changed. The major components used in
the experimental setup are Solar absorber plate, Chamber, Trays, PCM box and Tunnel. When we
speak about the heat transfer we will be consider conduction, convection and radiation. Conduction
is a mode of heat transfer taking place between solid to solid medium. Convection is a mode of heat
transfer that will be taking place between solid to fluid medium. Radiation is a mode of heat transfer
that will be taking place without any contact through electromagnetic waves. In our experiment we
will be having all the three mode of heat transfer taking place. We can dry the crops with the help of
boiler setup also but the fuel used for that will be coal one of the fossil fuel and the coast of coal is
high when compared with solar energy. The solar energy utilization in India has been around 10% -
25% alone. But if we switch to solar energy then the emission of polluting gaseous will be reduced
and green house gaseous also reduced that will help in the environmental growth that will lead to a
eco-friendly environment [6]. The proper drying means removing the moisture content from the
food product may vary from 5% to 25% depending on the type of the food. Success rate depends on:

- Required amount of heat is supplied to remove moisture.
- Hot dry air to absorb moisture content.
- Circulation of air to vary the moisture.

Phase change material- PCM
PCM stands for phase change material. The property of the phase change material is that it can change its phase from solid to liquid or vice-versa with libration of heat. In technical wording we can
call that heat as latent heat. Latent heat is nothing but the change of phase is been taking place at a
constant temperature [7].The phase change material is salt hyfrates, paraffins, non-praffins and
organic materials. As already spoken the phase change material will have the tendency to change its
phase from solid to liquid or liquid to solid [8]. The melting point of phase change material is more
because of that we have used the PCM in our experiment to improve the efficiency of the solar dryer
equipment.

Properties required for the selection of PCM
The PCM used in our experiment is prarffin wax since it is solid in state and has the melting point
range of around 40 – 45 degree celcius. The PCM is not harmful and it does not disturb the efficiency
of the solar dryer [9]. And it should have less toxic, harmless, less flammability; density should be
high and stability.

2. SOLAR DRYER

Solar dryers can be proved to be most useful device from energy conservation point of view [10]. It
not only save energy but also save lot of time, occupying less area, improves quality of the product,
makes the process more efficient and protects environment also. Solar drying can be used for the
entire drying process or for supplementing artificial drying systems thus reducing the total amount
of fuel energy required.

Solar dryer is a thermal device used for
1. Drying of Agriculture crop.
2. Food processing industry.
3. Dairy products like milk power.
4. Removing moisture content in wood and timber.
5. Textile industries.

3. STORAGE SYSTEM FOR THERMAL ENERGY
Heat is stored in the PCM and when that heat is needed is been liberated in enormous amount is released. The PCM storage box is collecting all the heat and that is given to the crops when it is needed [11]. PCM is in solid form and it is used to store the energy and that act as a thermal storage device in this experiment. Therefore, PCMs are used in the solar dryer to sent the heat during the required time. PCM is used to store latent heat and that will be transferring heat without change in temperature with change in its phase.

4. EXPERIMENTAL SETUP
The solar absorber plate is there to absorb the solar radiation and the air from the atmosphere is absorbed by natural convection mode and the air been heated up the heated air is been sent to the chamber. In that chamber different rack are provided to keep the fruits or vegetables that to be dried. In addition to that we have box made up of steel which contains PCM. The PCM which we used in the chamber is paraffin wax. The PCM is Phase Change Material which will be in a solid state and once the solar radiation is incident or heated air is sent to that box the phase change will be taking place like solid will be converted to liquid and the liquid will be having a high temperature. That temperature is been used by the crops to dry down the fruits or crops with the help of PCM. The chamber is been isolated with a steel to avoid the heat loss by PCM and also absorber plate heat. In normal dryer that use solar radiation to dry down the crops and that can be used only during day time but during night time the solar dryer has very very less efficiency. But in our experiment we have used the solar dryer with PCM setup so the efficiency of our experiment during the night time also increase because of PCM.

![Fig. 4.1 Layout of project design](image-url)
The solar absorber plate is inclined at an angle of 45 degree to absorb maximum solar radiation and the during the day time. The inclination of the absorber plate can be varied with respect to the location so the experimental setup is been fabricated accordingly. From that absorber plate the hot air is been sent to the camber where the drying of crops or fruits will be taking place and also some heat is been utilized by the PCM box to have a phase change and to store the thermal energy and act as a thermal energy storage device. The properties of paraffin wax are white, tasteless and solid in their physical state. Since the paraffin wax can have of temperature range of 40 to 68 degree Celsius. The application of PCM are used in laboratory and medical sectors

5. SPECIFICATIONS

5.1 DRYING CHAMBER
Dryer size is 90cm x 55cm x 55cm was made with the plywood, consisting of 4 trays.
Dryer capacity is 4kg. Hollow transparent polycarbonate sheet is used to cover the upper most drying chamber.

SOLAR ABSORBER PLATE
To measure the amount of heat required for the removal of moisture:

Material to be dried = Green chilli, Grapes, Kiwi, Pine apple

Moisture content = 80%, 78.2%, 80%, 87%

Moisture content = 20%

The equation for removing moisture content,
\[ M_m = m \times \frac{(\text{weight\%} - \text{dryness \%})}{(100\% - \text{percentage of dryness})} \] (1)

For green chilli
\[ M_m = 1 \times \frac{(0.8 - 0.2)}{1 - 0.2} \]
= 0.75 Kg

For grapes
\[ M_m = 1 \times \frac{(0.782 - 0.2)}{1 - 0.2} \]
= 0.72 Kg

For kiwi
\[ M_m = 1 \times \frac{(0.8 - 0.2)}{1 - 0.2} \]
= 0.75 Kg

For chilli
\[ M_m = 1 \times \frac{(0.87 - 0.2)}{1 - 0.2} \]
= 0.83 Kg

Total moisture content to be removed = 0.75 + 0.72 + 0.75 + 0.83
= 3.05 kg
We have to remove 3.05 kg of water from 4 kg raw material in order to get the required value added product. Amount of heat required to remove moisture content is given by equation 2,

\[ Q_R = M_m \times h_{lg} + M_m \times h_f \]  

(2)

Where,

\( h_{lg} \) = Latent heat of evaporation of water. From steam tables, at 100\(^0\)C,

\[ h_{lg} = 2256.4 \text{ KJ/Kg} \]

\( h_f \) = Enthalpy of water.

From steam tables, at 100\(^0\)C, \( h_f = 419.17 \text{ KJ/Kg} \)

\[ Q_R = (3.05 \times 2256.4) + (3.05 \times 419.17) \]

\[ = 8160.48 \text{ KJ} \]

\[ = 8160.48 / (60 \times 60 \times 12) \]

\[ = 188.9 \text{ W} \]

To find out area of flat plate collector:

The useful amount of heat delivered by a flat plate is given by equation 3,

\[ Q_u = A_c \{It \cdot (\tau \cdot \alpha) - U_L \cdot (T_p - T_a) \} \cdot F_R \]  

(3)

\[ Q_u = A_c \{420 \times 0.88 \times 0.9 - 5 \times (45-20) \} \times 0.9 \]

\[ = A_c \times 186.9 \text{ W} \]

Considering the design purpose,

\[ Q_R = Q_u \]

To calculate the surface area we have used the above equations,

\[ A_c = \]

\[ = 173.4/186.9 \]

\[ = 0.93 \text{ m}^2 \]

**TRAYS**

Drying chamber consists of 4 trays of 70 cm x 50 cm x 50 cm sizes, which can hold 5 kg of drying products. The materials used for trays are aluminum mesh.
**PCM CHAMBER**

In order to reduce heat losses the PCM storage unit is fixed at the inner bottom of the drying compartment. No insulation is made for the PCM chamber. The quantity of PCM required is calculated as:

\[
\text{PCM required} = \frac{8160.48}{220} = 37.09\text{Kg}
\]

For extension of working of dryer to one more hour amount of PCM required = 37.09/12 (12 hours)

=2.8 Kg

We select 3 Kg of paraffinwax

**6. EXPERIMENTAL SETUP**

The evaluation of the experiment is carried out in an open ground. The solar dryer unit is been exposed to the sunlight and the angle is maintained accordingly to receive maximum radiation from the sun as shown in the fig 6.1. The Atmospheric condition temperature is maintained at the range of 30-35 degree celsius. The performance of the dryer is evaluated with help of fruits like kiwi, pineapple, green chilli and grapes which are been harvested from the agriculture lands. The proportion taken is 1kg each and net capacity of the chamber is 20kg. The moisture content present in the green chilli, grapes, kiwi, pineapple are 80%, 78.2%, 80%, 87% respectively. Each product are arranged in a different segment to avoid the mixture of moisture content present on the fruits. The experimental work is carried out in Coimbatore location and during the time period of 10.00am to 5.00pm. The outcome during this timing is reached around 20% of moisture is been removed. The temperature inside the chamber is measured with the help of K-type thermocouple.

![Fig 6.1. Absorber plate](image1)
![Fig 6.2. Drying chamber](image2)
7. RESULT AND DISCUSSION
The experimental work is carried out with solar dryer as a thermal device with two stages one is without PCM and with PCM. The result inferred from the graph and value evaluated we came to know that the efficiency of Solar dryer unit has been achieved in the presence of PCM and it can be further increased with Nano PCM also. Considering the various climate conditions it is wise use our solar dryer unit integrated with PCM. With paraffin wax we could able to achieve around few hours of extension of solar radiation. Since solar is one of the renewable sources of energy and utilization of that energy is in our hands. Thermal energy storage is achieved with the help of PCM (Paraffin Wax).

![Temperature Graph](image)

8. CONCLUSION
The proposed work have achieved the maximum solar radiation with PCM and the heat of air is been taken place by means of convective mode of heat transfer. The fabricated mode has proven that the removal of moisture by means of solar dryer unit is done with the help of PCM. The whole experimental work is been carried out with green chilli, grapes, kiwi, pineapple and finally we got the output as dry fruits without any moisture content which can be persevered and used for a long period of time. The cost estimation for this setup is around Rs 10,000. In future the research work can be carried with Nano PCM and the efficiency will be much better when compared to the PCM. The basic rule behind this is when the surface area increases the heat transfer rate increases eventually. The conclusion of the research work is that by using PCM in the solar Dryer we can has more efficiency.

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