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Fabrication of Hybrid Solar Dryer

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Abstract- The presents work is based on the working of dryers, the basic aim of this experiment is to design a dryer which meets the basic requirements of dryer which are improved by a modification in the design of indirect forced solar dryer. The concept behind the construction of a dryer is energy conservation and food preservation by the moisture removal process in solar dryer. In this experiment the dryer which is designed works by using solar energy as well as electrical energy that is why the name of the dryer is 'Hybrid Solar Dryer'. In this hybrid solar dryer a recirculating duct is added from the motor fan assembly to the drying chamber that the hot air which goes through the passage of air flow that is firstly hot air passes through the rectangular duct then in divergent duct and finally reaches in the drying chamber but in between them some amount of hot is wasted but by the recirculating duct this air is reutilized for heating the food product in drying chamber. After working on this dryer the drying time reduces, drying rate increases ,removal rate of moisture content increases in comparison to indirect solar dryer without air recirculation.

Index Terms- solar dryer, moisture content, drying rate, drying time.dew point

I. Introduction

Drying is a complicated process involving simultaneous heat and mass transfer. The required amount of energy to dry a particular product depends on many factors, such as initial moisture content, final moisture content, drying air temperature, relative humidity and velocity.

The dryers are broadly classified as:

(i) On the basis of their operating temperature ranges that is high temperature solar dryer and low temperature solar dryer :

1. Air movement mode
2. Insulation exposure
3. Air flow direction
4. Dryer arrangement
5. Solar contribution
6. Type of fruit to be dried

(ii) On the basis of air flow:

1. Direct Solar Drying
2. Indirect Solar Drying
3. Mixed Mode Solar Drying

II. WHY SOLAR DRYER

i. More than 20% of the total fruits and vegetables production is lost at various post harvest stages in India.

ii. To improve the shelf life of these food products, their moisture content should be reduced to an extent so that the microorganisms can't grow.

iii. It also saves shipping and transportation costs as volume and weight both decrease.

A. DRYING PRINCIPLE:

"In the process of drying heat is necessary to evaporate moisture from the substance to be dried, and a flow of air is needed to carry away the evaporated moisture."

There are two basic mechanisms involved in the drying process:

1. Migration of moisture from the interior of the substance to be dried.
2. Evaporation of moisture from the surface to the surrounding air.

The rate of drying is determined by observing following parameters:

i. Moisture content
ii. Temperature of the substance to be dried.
iii. Temperature, humidity and velocity of the air in contact with the substance to be dried.

B. PHYSICS OF DRYING:

Everybody knows what is drying, but not everybody understands the physical process of drying and the lack of understanding of this process could lead to the **destruction of entire crops** during the **drying, curing and storing** processes.

Drying an object (**onions, potatoes or other produce**) is a process where the following parameters play a determining role:

1. The air temperature,
2. The relative Humidity
3. The air pressure
4. The Dew Point
5. The temperature of the product to be dried.
6. The amount of air that passes through the product.

The first 4 parameters are strictly related through 'Laws of Physics'.

In all these processes the DEW POINT plays a determining role.

What is **Dew Point**?

"**Dew Point** is the temperature at which water vapour in a sample of air at constant barometric pressure condenses into liquid water at the same rate at which it evaporates."

These four parameters are represented relatively through "MOLLIER DIAGRAM**".**

C.Moisture Content: The moisture content of fresh foods ranges from 20% to 90%. Foods require different levels of dryness for safe storage. For example: the moisture content of rice must be reduced from 24% to 14% of the total weight. Therefore, drying 1,000 kg of rice requires the removal of 100 kg of water. Safe storage generally requires reducing the moisture content to below 20% for fruits, 10% for vegetables, and 10-15% for grains. If food is properly dried, no moisture will be visible when it is cut.

III. DESIGN, FABRICATION AND WORKING

A. DESIGN

(1) COMPONENTS AND SPECIFICATION

The design of this hybrid drier is divided into 3 sections:

Section-A: AIR REGULATION CHAMBER

This section consists of motor fan arrangement to regulate air flow and a tapered duct attached in front of it. The motor fan arrangement is mounted over a cuboid duct of length (0.5m), breadth (0.5m) & height (0.1m).

Figure 1: **Motor-fan arrangement with tapered duct.**

(A.1) MOTOR

Specification: 145 watt, 1440 rpm, 3 phase a.c motor.

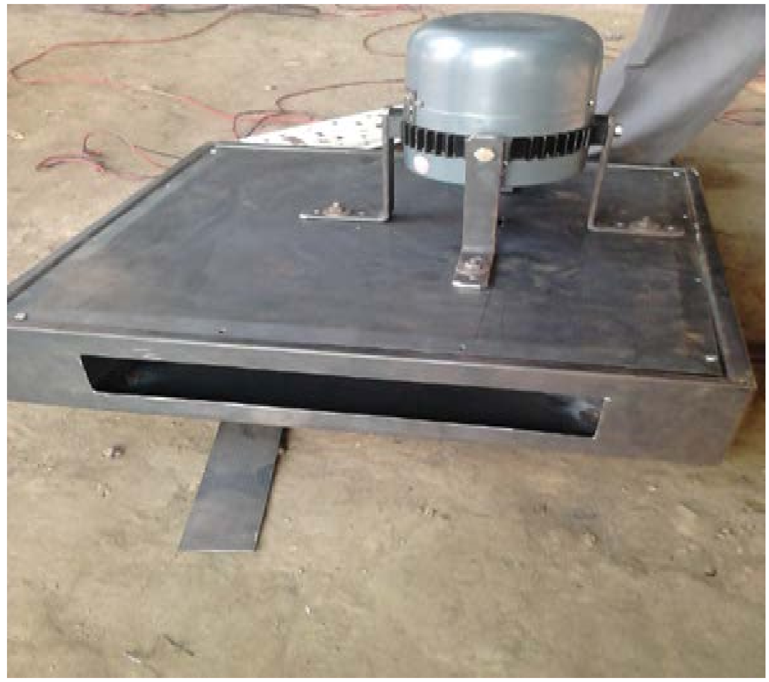

Figure 2: **Motor-fan arrangement**

(A.2) CENTRIFUGAL FAN

Specification: Dia (20cm), inward flow of air is axial, outward flow of air is radial.

Figure 3: **Centrifugal fan**

(A.3) INNER CIRCULAR DUCT

Specification: It directs the flow of air.

Figure 4: **Inner circular duct**

(A.4) TAPERED DUCT

Specification: length (1m), breadth (0.5m), height (0.1m & 0.05m).
Tapered duct increases the velocity of air.

Figure 5: **Tapered duct.**

SECTION-B: HEATING CHAMBER

Heating chamber consist of heating elements and solar collector plate.

Figure 6: **Heating chamber**

Specification: length (0.9m), breadth (0.5m) and height (11cm).

(B.1)HEATING ELEMENT

Figure 7: **Heating Elements**

Specification: load (4kW)

(B.2)SOLAR COLLECTOR PLATE

Fig 8: **Solar collector plate and heating elements.**

Specification: Toughened glass(4mm), (40 X 85)cm.

The glass can handle temperature upto 250 deg celcius.

SECTION-C: DRYING CHAMBER

The drying chamber consists of 3 horizontal trays, an outlet part for moisture removal and a hole at the bottom to avoid vacuum and a temperature sensor to measure the temperature of the hot air coming from heating chamber into the drying chamber.

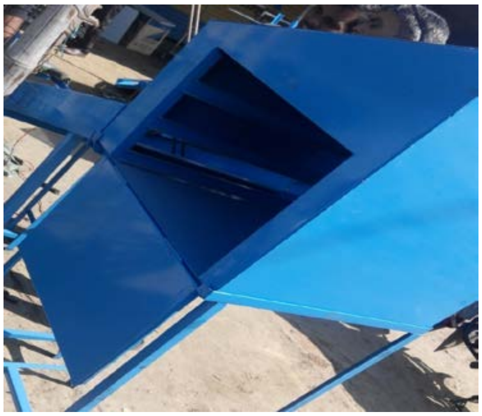

Figure 9: **Drying Chamber.**

(C.1) DRYING CHAMBER TRAYS

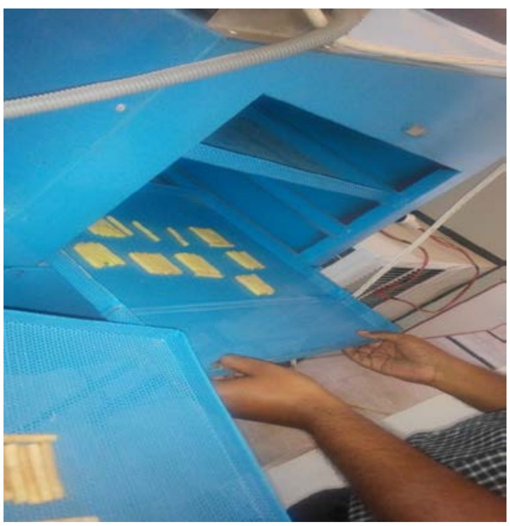

Figure 10: **Drying chamber trays**

Specification: (60 X 40) cm.
The distance between each tray is 10cm.

(C.2) OUTLET PORT

Figure 11: **Outlet port**

Specification: made of steel sheet. Height (4 inch) & dia (2.5cm).

(C.3) TEMPERATURE SENSOR

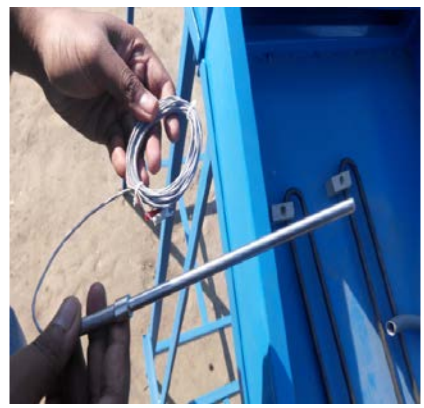

Figure 12: **Temperature sensor**

Function: To sense the temperature of the air entering the drying chamber.

(C.4) TEMPERATURE CONTROLLER BOX

The temperature control box is also mounted on the face of the drying chamber.

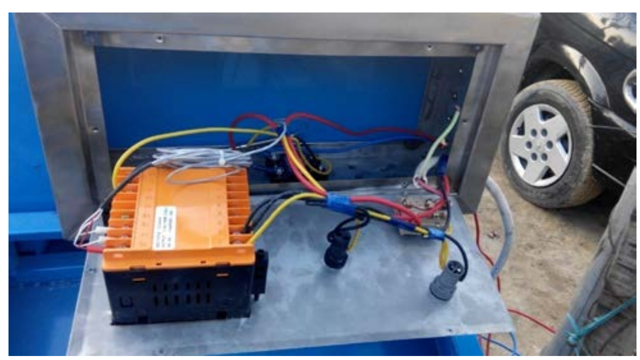

Figure 13: **Temperature Controller box set up.**

The components inside this box are:

Figure 14: **Temperature controller**

Specification: Temperature controller with adjustable temperature settings and display of (in process) temperature in the drying chamber. **Power consumption 6 VA max.**

- Row 2 temperature is the desired temperature to be set by the user.
- Row 1 temperature is the temperature of the hot air inside the drying chamber.

(b) Relay:

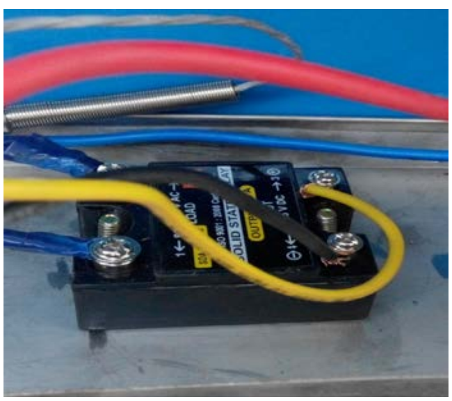

Figure 15: **The Relay**

Specification:
40amp relay is used to control and regulate the flow of current in heating coil and motor.
(c) Power Indicators:

Yellow indicator: It indicates the power supply to the device.
Green Indicator: It indicates, whether heating elements are on or off.

(d) Toggle Switch:
Used for switching the equipment on/off.

Figure 16: **Toggle Switch**

IV. MATERIALS USED IN THE FABRICATION

1. DUCTS:
   20 guage galvanised iron sheet.

2. RECIRCULATING DUCTS:
   24 guage steel sheet.

3. TREMPERATURE CONTROL BOX:
   22 guage steel sheet.

4. TRAYS:
   24 guage iron sheet.

5. STAND:
   Iron angles (2.5mm)

6. WIRES USED:
   (a) 2.5 mm Teflon high temperature wire inside the heating chamber.
   (b) 1.5 mm wires for motor – relay connection.
   (c) 2.5 mm wires for temperature controller-heating elements connections.

7. POWER PLUG USED:
   32 ampere used.
8. POWER CABLE:
   2.5 mm used.

V. WORKING AND APPLICATIONS

GENERAL WORKING:
1. AIR FLOW:

The air flow inside the dryer is maintained using the motor-fan arrangement. The intake of the air is axial and then it is thrown radially into the tapered duct where the velocity of the air is increased due to uniform decrement of the duct's height.

2. HEATING:

Heating of the air is achieved inside the heating chamber with the help of two heating elements and the sunlight falling on the collector plate (glass). Then this hot air goes inside the drying chamber.

3. DRYING:

The hot air at desired temperature enters the drying chamber and strikes the food item to be dried. Now, the drying phenomenon of the food item is described through a schematic diagram (shown on next page) :

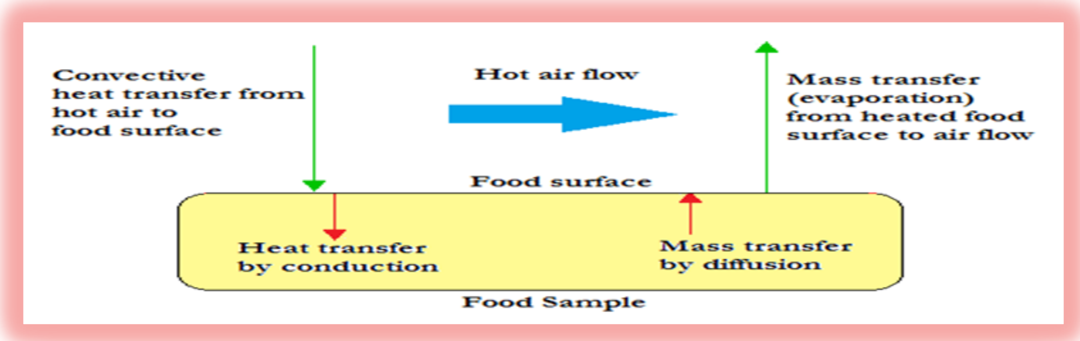

Figure25: Schematic Representation of the drying phenomenon.

4. MOISTURE REMOVAL:

The moisture is removed from the food item, through a outlet port at the top of the drying chamber.

5. HOT-AIR RECIRCULATION:

Now the hot air is recirculated into the motor fan arrangement, so as to maintain a constant temperature inside the drying chamber and the desired temperature is achieved in less time.

6. TEMPERATURE CONTROL:

The desired temperature can be set on the temperature controller which is connected to a temperature sensor (the sensor is placed inside the drying chamber). The controller takes the temperature input from the sensor and accordingly regulates current in the heating elements, and as the temperature exceeds the set temperature, the heating elements are automatically switched OFF, and further, as the temperature goes below the set temperature, the heating elements are again switched ON by the controller.

NOTE: To prevent vacuum formation inside the dryer, a small hole is given at the bottom of the drying chamber, adjacent to the opening of recirculation duct.

(E)Complete set up of hybrid solar dryer:

Figure :26 Front view of fabricated set up

VI. TYPES OF USAGE

"The dryer is named "HYBRID" as the heating of air inside the heating chamber can be achieved by using solar energy, electrical energy or both together."

1. OUTDOOR USAGE:

During the outdoor usage, the heating of air is achieved from the heat energy of sun rays falling on the solar collector plate, made of toughened glass. If the desired temperature cannot be achieved by the sole use of solar energy, then the heating elements can be switched ON, simultaneously to achieve a constant temperature inside the drying chamber.

2. INDOOR USAGE:

During indoor usage, the heating is achieved only by switching ON the heating elements.

VII. ADVANATAGES

- Higher drying temperatures which results in shorter drying times and the ability to dry to a lower final moisture content.
- Protection from contamination by dust and from rain showers.
- Total independence from weather conditions.
- Better control of the drying process.
- Food is not exposed to direct rays of sun, which reduces the loss of colour and vitamins.

VIII. LIMITATIONS

- Complex to construct at local workshops.

IX. TIPS FOR BETTER OPERATION

- The collector should face south in the northern hemisphere and the north in the southern hemisphere.
- The collector should be filed away from shadows of tress or buildings for outdoor experiment.

X. PRECAUTIONS

- The collector plate and the recirculating duct should not be touched because of their temperatures.
- The wiring inside the temperature control box should be checked from time to time.
- Gloves should be worn while taking out the trays from the drying chamber.

XI. GOALS ACHIEVED

The main goal of designing and fabrication of current dryer was to provide enhanced efficiency of drying and maintaining the food quality of the same time.

- The solar dryer is capable to achieve higher operating temperatures by directing spent air from drying chamber of higher temperatures than the inlet air and taking advantage of hot air to achieve. Still higher operating temperatures through recirculation of air, especially that outlet air is, which is minimally laden with moisture.

- Achieving temperatures in the range 35 deg Celsius to 90 deg Celsius inside the drying chamber.

- Utilizing the solar energy as well as using heating elements to heat up the air entering the heating chamber which further increases the usability of the dryer as completed indoor usage is also possible with it.

- Better temperature control is being stabilized inside the drying chamber by setting up a temperature control box mounted on the wall of the drying chamber and the use of temperatures sensor to accurately measure the temperature of hot air inside the drying chamber and feeding input to the control and thus allowing it. To control the current in the heating elements and the motor-fan assembly. Thus energy efficiency is achieved along with the SET temperature being maintained inside the drying chamber. Visual display of the current operating temperature and the SET temperature is also possible.

XII. FUTURE IMPROVMENTS

Although being an efficient dryer, there are always scope for further improvements and developments by bridging the communication gap between the solar researchers and food technologists. Food technologists are not aware of the capabilities of new breed of solar dryers while solar technologists are unaware of the technical requirements of different processes followed in food processing.

Any technical project is susceptible to various modifications and alternative forms. However some suggested future technical improvements are:

1. Addition of solar panels and creating an independent electricity supplying unit to run the dryer as a whole.
2. A solenoid-valve can be attached at both the ends of recirculation duct and being controlled by a programmable humidity controlled and a humidity sensor, a display panel being set behind the solar dryer, to display the inside the humidity. It will help in stopping the recirculation of air, when the amount of moisture in the air exceeds a certain value.
3. Introduction of silica gel sheets laminated between honey comb panels for further moisture removal inside the drying chamber.

XIII. CONCLUSION

Solar energy based technologies are currently playing an important role in food processing however they are limited micro to small scale processing. However, indirect solar drying gives no. of opportunity of using it on large scale and should be studied & in the goal of the future studies.

With changing lifestyle in India and elsewhere, there is a great demand for ready to eat (RET) foods that are also healthy and indirect solar food processing can be a major contributor to meet such demands.

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