Solar Air Heating using Evacuated Tube Collector for Agro Processing

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Abstract— In conventional method of food processing, hot air (Thermal energy) is being used to dry the food products such as grapes, fish, ginger, banana, etc. by using fuels like diesel, fire-wood, kerosene, electricity. High moisture content is one of the reasons for food spoilage during storage and preservation. The conventional methods of heating though are popular but have some problems. Solar air heating system maximum use of air heating potential of sunlight. Special solar heat absorber is used for food processing applications by absorbing the heat and using for hot air generation. Solar collector like parabolic dish, solar shuffler system can be used. The trials carried out with parabolic systems show not only fuel saving but also great value addition because of better quality of product in terms of colour, aroma and taste.
Key words: Closed Loop Evacuated Tube Collector

I. INTRODUCTION

In conventional method hot air (thermal energy) is being used to dry the food products such as grapes, fish, banana etc. by using fuels like kerosene, fire- wood, diesel, electricity. Present energy scenario indicates these sources are costly and depleting day by day. They also pollute the environment and responsible for hazards like global warming. The renewable energy bridges the gap between mounting energy demand and diminishing supply of conventional sources of energy. Need of cleaner environment and the increase in demand of more healthy and hygienic food-products encourages the use of renewable energy in agro-industrial production process. Solar energy, the mother of renewable energy sources, is an inexhaustible, clean, cheap source of energy. Lying between 80 to 360 norths's, India has 2500 to 3200hours of sunshine per year providing 5.4 to 5.8Kw of power per m^2 per day @1kJ/sec/m^2. Utilizing small portion of this immense resource would save our fossil fuels and forest without sacrificing our energy consumption. Solar hot air generation systems are more reliable, durable and cost effective energy production methods for agricultural and industry process. It is more efficient, easily adaptable from existing fuel-driven systems, environmentally friendly and hygienic.

II. WORKING PRINCIPLE

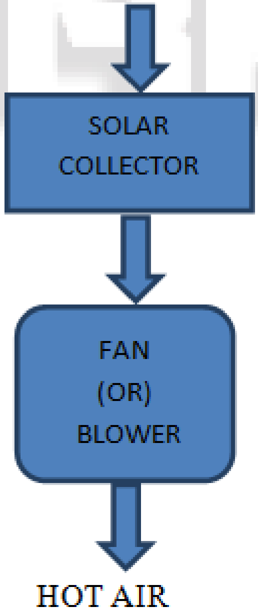
The basic principle of solar dryer is to make use of solar energy to heat the air which is used to dry the products. When air is heated, its relative humidity decreases and it is able to hold more moisture. Warm, dry air flowing through the dryer carries away the moisture that evaporates from the surface of the food. Drying plays a major role in which the free water molecules are removed leaving the essential bound water molecules. The ancient method used to preserve food is natural sun drying. But Natural sun drying has many disadvantages such as uncontrolled drying, contamination by birds, insects and dust, climate adversities etc. The quality of the product is found to be less and cannot be exported. It also requires more labour and the process is found to be slow. The main objective of the present work was to improve the quality of pine apple produced in solar dryer. But it has been reported that the efficiency of evacuated tube collector is very high as compared to the efficiency of flat plate collectors (FPC). The Pine apple contains 80% of water, when heated up-to 70C° moisture content reduces to 10%

A. *Disadvantage of Natural sun drying*

1) Contamination by birds.
2) Uncontrolled drying.
3) Insect and dust.
4) Required more labours.

B. *Advantages of Solar drying*

1) Makes product more uniform, healthy, and hygienic
2) Preserves colour, texture and natural appearance and Retains nutrients like beta carotene
3) Gives long life to products
4) Maintains moisture level at optimum level
5) Can be easily adopted into fossil fuel systems
6) The system Functions consistently and efficiently for 15-20years.
7) COLD AIR



C. *Applications*

1) This system can be used for processing of grain and other food products like spices, tealeaves, fish, dehydrating fruits& vegetables.
2) This system can also be used in industry for producing paper& board, supplying hot air toboilers, space heating at hill stations, processing leather& hides, etc.
3) Same system can be used for heating the thermal liquid which can be used as heat source.

III. MATERIALS & MEASURING INSTRUMENTS

1) solar collectors
2) axial fan (or) blower
3) drying chamber
4) Temperature sensor
5) Radiation meter
6) Pyranometer
7) Anemometer

IV. MEASURING INSTRUMENTS & DEVICES

A digital anemometer (or) volume flow meter is used to measure ambient temperature and Air velocity. Radiation meter (or) Pyranometer is used to measure direct (or) Beam radiation and diffuse radiation. The samples are weighed in hourly basis using a digital electronic balance with an accuracy of one milligram. PT-100 sensor is using measure the dryer temperature.

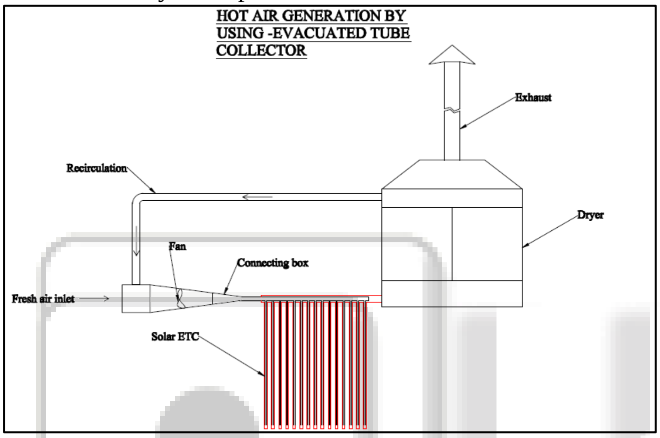


Fig. 1:

V. EXPERIMENTAL SETUP

The indirect type forced convection solar dryer is mainly constructed with four essential features namely, the blower, the evacuated tube collector, the drying chamber and the chimney. Fig.1 shows the section of the solar dryer. The drying chamber is made of stainless steel sheets of thickness 27.5mm and insulated on all sides with rock wool slab thickness of 75mm to prevent a loss of heat. it consists of two perforated trays as top and bottom tray to place the product to dried. It consists of 15 evacuated tube collectors with a copper header for transfer of heat cold air enter the inner copper tube and hot air from outer tube. The collector is placed along North – south direction. Facing south so as to track maximum solar radiation during the day time. The evacuated tube collector is used as air heater which connected to the drying collector with the help of EPDM (Ethylene Propylene Diene Monomer) rubber hose. The hot air from the drying collector outlet is connected to the inlet of drying chamber. The blower is attached at the inlet of the drying collector for conducting the experiment of forced convection. sliced Pineapple's are uniformly spread in the trays and are kept inside the chamber for solar drying. in the designed solar dryer. air is blown into the evacuated tube collector with the help of the external device blower. The solar radiation falling on the collector, the collector gets heated up and transfer heat to the air flowing through the drying collector. This hot air enters the inlet of the drying chamber where pineapple is loaded in two trays. The moving hot air evaporates the water contents (moisture) of the pineapple under the basic mechanism of removal of moisture from the surface of the product to the surrounding followed by the removal of moisture from inside the product to the surface.

VI. EXPERIMENTAL PROCEDURE

The velocity of the air at the tray was adjusted by using a damper. During the experiments temperatures at various locations in the solar collector and the drier chamber, ambient dry and wet bulb temperatures were measured at hourly intervals. The relative humidity of air was calculated from measured wet and dry bulb temperatures using a psychometric chart. Experiments were only conducted during day light hours. The readings are taken on hurly basis from morning 9.00 AM to evening 4.00PM

A. *Analytical calculation*

1) *Determination of moisture Loss*

moisture loss of drying product copra every hou using the below fromula

$$ML=M_t-M_d \quad (1)$$

The initial Mt and Md final mass of the samples were recorded with the help of electronic balance.

2) *Determination of Moisture content*

The quality of moisture present in materials can be represented on wet basis and expressed as percentage. The moisture content M_{wb} on wet basis was calculated by using 2 equations the procedure was repeated for every one hour interval till the end of drying.

$$M_{wb}=(M_t-M_d)/M_t*100 \quad (2)$$

3) *Determination of Drying Rate*

The drying rate. DR. should be proportional to the difference in moisture content between material to be dried and the equilibrium moisture content.

$$DR=dM/Dt \quad (3)$$

dM-Mass loss of the crop
dt = Drying time.

4) *Determine energy of the system.*

$$Q=\dot{M}\, C_P\, \Delta T \quad (4)$$

$\Delta T=(T_1-T_2)$
T_1= Inlet Temperature
T_2= Out let Temperature
Q=Energy- kcal
$\dot{M}$=Mass (m^3/h)
C_P= specific heat(j/Kg/k)
ΔT= change in Temperature- ^{0}C

5) *Determine the efficieny of the system.*

$$Q = \frac{\dot{M}\, C_P\, \Delta T}{I_T A\, T} \quad (5)$$

$\Delta T=(T_1-T_2)$
T_1= Inlet Temperature
T_2= Out let Temperature
Q=Energy- kcal
$\dot{M}$=Mass
C_P= specific heat
ΔT= change in Temperature- ^{0}C
I_T= solar Radiation (w/m^2)

A = Area of the collectors (m^2)
T =Time period (seconds)

VII. RESULT & DISCUSSION

Temperature variations of the designed solar dryer circulation for one da on hourly basis from 9.00am to 4.00pm during the experimentation for circulation are shown in Fig: 2. the maximum Temperature 88^0C was observed and average temperature recorded at the outlet of the drying collector was 70^0C. It is observed that the temperature inside the drying chamber is higher during the mid – noon time.

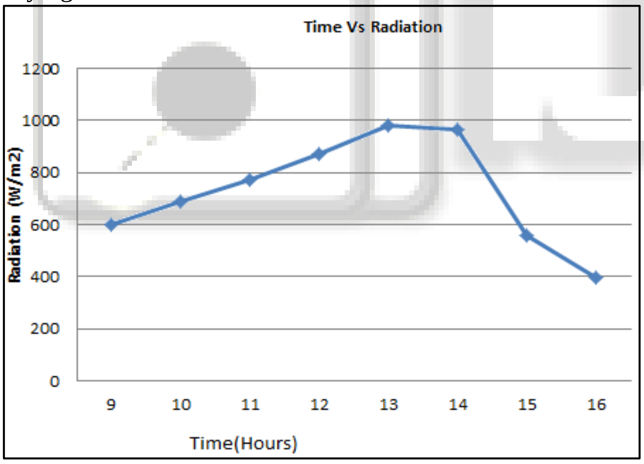
The variation of air temperature at outlet of collector with respect to drying time on hourly intervals for one day with forced convection is shown in FIg:3.The minimum and maximum temperature was recorded minimum 53^0C and maximum 88^0Crespectively. The temperature variation is due to the change in solar radiation intensity which is measured by using the instrument radiation meter.

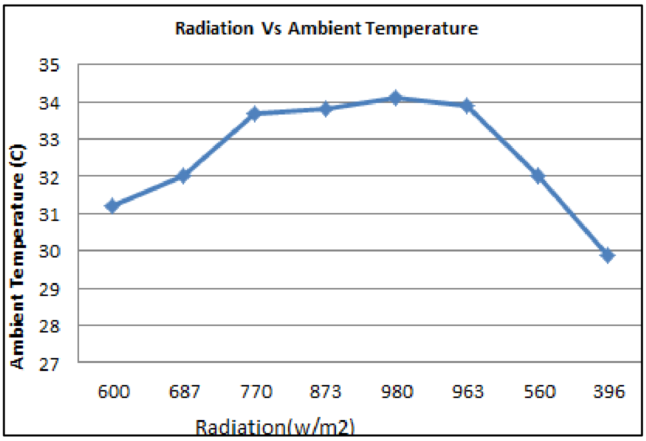
A. Before Drying

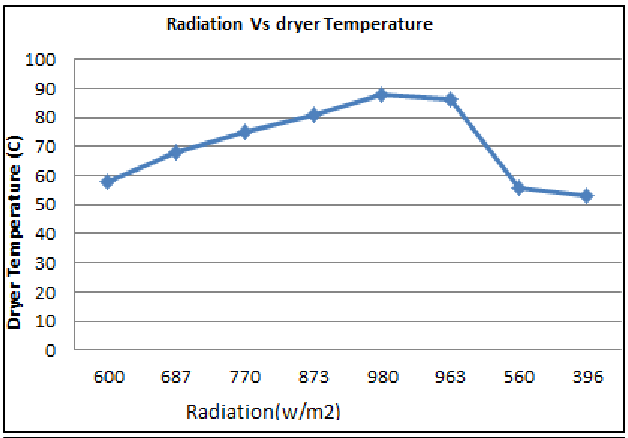
Initial weight of Pine apple 1kg (1000gms)
Initial temperature pine apple 28^0C

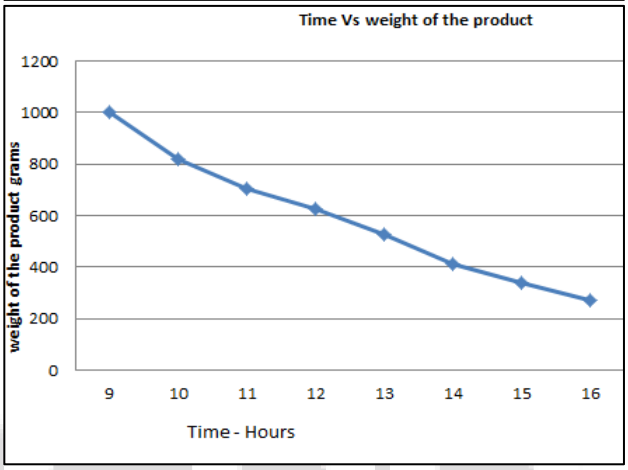
B. After Drying

Final weight of Pine apple approximately 270gms
Expected reduction in moisture content 74%
Drying time 8hrs









VIII. CONCLUSION

In this experimental study, the drying of pineapple was investigated under the two different modes as natural and forced convection. The indirect type forced convection solar dryer with evacuated tube collectors generates air temperature higher inside the chamber and enhance drying rate thereby reducing the drying time required to dry a convection to reach desired moisture content is less than the time required in natural convection. As the solar dryer using evacuated tube collector can perform better even during cloudy days and winter season. The designed indirect type solar dryer utilized the more solar thermal energy as a result obtained as reducing the time required to dry the pineapple and also improves the quality of the drying product.

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