International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Thermal analysis of Solar dryer

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Accepted 15 June 2016, Available online 20 June 2016, **Special Issue-5 (June 2016)**

Abstract

The increased consumption of energy, resulting in soaring prices of fossil fuels and ecological imbalance, has increased the interest in utilization of solar dryers. Experiments performed in many countries have clearly shown that solar dryers can be effectively used for drying agricultural crops. It is a matter of adopting it and designing the right type of solar dryer. This research work is an attempt to work out the development and thermal analysis of dryer for effective and economical method of drying of grapes to produce quality raisins.

Keywords: *Solar dryer, Raisin, Solar air heater, Steam generator.*

1. Introduction

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In India though solar energy is abundantly available, there is less attention towards its effective utilization. Though the technology is present which depends on it, the efficiency of such systems is less one. There should be improvements in available techniques and there should be research to develop the new one. Solar drying is old and ancient technique in which up gradation is always going on. Solar drying is cost effective and represents an effective alternative to traditional and mechanical drying systems, especially in locations with good sunshine during the harvest season.

The interior temperature of grapes, which are exposed to solar radiation, is generally found to be 4-8°C above the ambient air temperature, whereas for grapes in shade, the internal temperature was reported to be a few degrees below the ambient. The solar energy absorbed the fruit in the morning and evening is subsequently utilized for water vaporization during the shaded mid-day period, as well as after sunset. The drying time in this method is usually high. The ancient methods like open drying in sun with or without cover, were found to be unsatisfactory because of mass losses and low quality of the raisins produced due to their exposure to rain, dust and insects. Further, direct exposure to solar radiation results in undesirable colour changes. Uncontrolled conditions may also result in microbial attack, spoiling the entire stock in the process.

Because of the ever present possibility of rainfall occurring during the drying period of the grapes, the artificial (mechanical) drying process, which is rapid and controlled, is attractive to grape growers, but a large number of small farmers engaged in growing grapes have not been able to use this because of the large initial investment and additional running energy cost. The energy cost was comparatively high for this application, even prior to the energy crisis.

Moreover, the increasing rate of fuel consumption in agriculture has made it necessary, not only to save energy by intensifying the drying process, improving designs etc., but also by using renewable energy sources for the drying process The main advantage of a flat plate collector is that it utilizes both beam and diffuse components of solar radiation [3]. Efficiency of flat plate collector depends on the temperature of the plate, ambient temperature, solar isolation, top loss coefficient; emissivity of plate, transmittance of cover sheet, number of glass covers etc. The efficiency improvement for flat-plate solar collector can reduce its size and obtain higher temperature fluid at outlet for wider application. In response to these demands, different highly-effective techniques have been used in the past to enhance the thermal performance of solar collectors including the methods of reducing the heat loss from the top surface or increasing the energy gain inside the solar converter.

2. Literature Review

Experiments carried out in various countries have clearly shown that solar dryers can be effectively used for drying agricultural product. It is a question of adopting it and designing the appropriate type of solar dryer.

2.1Conventional Solar Drying

Historically the production of raisins from grapes by open sun drying can be traced back to 1490 BC in

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Greece. Hence, grape drying utilizing solar energy is an age old traditional method. Some of the traditional methods followed.

2.2Present Theories and Practices

Pangavhane *et al*. have studied that mechanical drying of agricultural products is an energy consuming operation in the post-harvesting technology. Greater emphasis is paid to using solar energy sources due to the high prices and shortages of fossil fuels. For these purposes, a new natural convection solar dryer consisting of a solar air heater and a drying chamber was developed. This system can be used for drying numerous agricultural products like fruits and vegetables. In this study, grapes were successfully dried in the developed solar dryer.

D. R. Pangavhane and R. L. Sawhney has proved solar drying of grapes is technically and economically feasible. To improve the acceptability of solar dryer among the farmers, it necessary to develop a large scale dryer, which is economically attractive. During the night period a system having thermal backup storage is to be developed.

Teslime Mahmutoglu *et al*. have proved that treatment with K_2CO_3 (4%) -ethyl oleate (2%) or with K_2CO_3 (5%) -olive oil (1.5%) solutions accelerated the drying rates to some extent. Solar drying reduced drying times of grapes to about half of that of sun drying on concrete ground.

J. C. Ehiem *et al*. have designed an industrial fruit and vegetable dryer and developed to reduce vegetable wastage and improve their storage conditions. It is divided into three units: drying chamber, blower and heat exchanger. The performance test and evaluation were conducted in a total number of 756 observations using tomatoes. The size (small, medium and large), air flow rate and drying time have a highly significant effect on gram weight of the tomato slices being dried. For all the tomato sizes and at all air flow rate levels, gram weight of the tomato decreased with increase in drying time. Also for all the sizes at all drying time levels, gram weight decreased with an increase in air flow rate.

EL- Amin Omda Mohamed Akoy et. al.have proposed preliminary investigations under controlled conditions of drying experiments, a natural convection solar dryer was designed and constructed to dry mango slices. This paper describes the design considerations followed and presents the findings of calculations of design parameters. A minimum of 16.8 m^2 solar collector area is required to dry a batch of 100kg sliced mango (195.2kg fresh mangos at 51.22% pulp) in 20hours (two days drying period). The initial and final moisture content considered were 81.4% and 10% wet basis, respectively. The average ambient conditions are 30ºC air temperature and 15% relative humidity with daily global solar radiation incident on a horizontal surface of about 20MJ/m^2/day. The weather conditions considered are of Khartoum, Sudan. A prototype of the dryer is so designed and constructed that has a maximum collector area of 1.03 m^2. This prototype dryer will be used for experimental drying tests under various loading conditions.

2.3Different Designs of Drying Chamber from Literature Survey

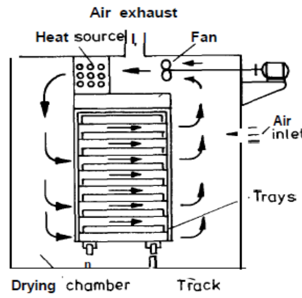

Fig:2.1 Tunnel drying cabinet

2.3.1 Tunnel drying cabinet

This design, the drying material is spread over trays, & these trays are kept in the tunnel where a constant temperature is maintained with the help of heat source. Air circulation is maintained with the help of a fan.

Drawbacks: In this type of dryer, mostly the same air is circulated through a cabinet. Hence at initially, the drying rate is better. But, when the air becomes moist due to evaporation, automatically drying rate is going to decrease. Therefore we cannot consider this design for our project

2.3.2Drying chamber design by C. Pardhi & Bhagoria

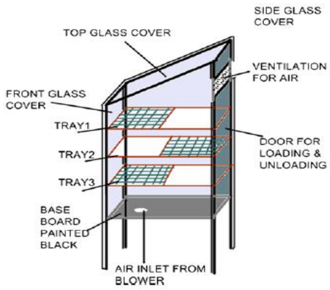

Fig:2.2 Drying chamber design by C. Pardhi & Bhagoria

In this dryer the grapes are spread over three trays in equal amount. Hot air enters from the bottom and comes out from the top opening.

Drawbacks: In this design, the moisture removal rate is high for tray no. 3 and further that a rate is in decreasing order. For tray no. 1 moisture removal rate is poor. Hence due the differences in moisture removal rate here we get three different types of raisins which are not acceptable. The raisins of tray no. 1 is having higher moisture as compared to the raisins of tray no. 3, hence we cannot consider the design for our project.

3. Design and Development of Experimental Setup

The schematic of dryer is shown in Figure 3.1. In this system, air is heated in the solar air and with the help of a fan this air is circulated in drying chamber. The electric air heater provided in the heating chamber is working at night only. During day time, air is heated in the solar air heater.

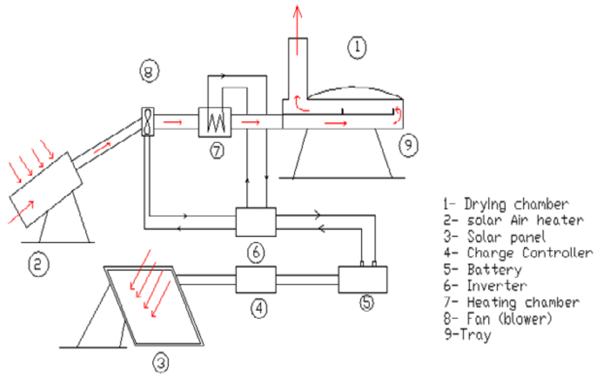

Fig 3.1 Schematic of dryer

Solar air heater :The solar air heater is shown in Figure 4.4. During day, after heating the air in solar air heater, it is circulated in the drying chamber.

Heating arrangement :Heating arrangement is one in which air is forced on the surface of air heater with help of a fan.

Drying Chamber :Drying chamber is having the dimensions of 2m×1m×0.4m which is made-up of waterproof plywood

Solar air heater :Finned type electric air heater is used to maintain the temperature of drying chamber within the range of 55^0 - 60^0 C, at night only.Solar air heater is having box shape, with the dimensions of 1.5m ×1m × 0.15m made-up of Mild steel sheet, 1.5mm thick.

4. Test Methodology

Different testing are carried as follows

1) Weather Condition calcultions
2) Heat load calculations
3) Calculations of evaporation rate
4) Assumptions related to grapes geometry
5) Quantity of air required
6) Volume of air
7) Fan selection
8) Heater selection
9) Solar air heater area design
10) Amount of moisture removal

5. Testing, Calculations & Results

5.1 Testing of Dryer

5.1.1 **Trial No. 1**

Place: - Heat Transfer Lab Terrace

Date: 28/2/16 to 8/3/16

Atmospheric conditions:

DBT= 30^0 C, WBT = 21^0 C, Relative humidity = 41 %

Procedure:

i. Washing of 5 Kg grapes by washing powder solution (conc.0.1%).
ii. Preparation of dipping solution (conc. 1%)
Dipping oil = Khandelwal Cold Dip- Active
iii. Separation of grapes in small bunches.
iv. Dipping process (dipping time = 4 mins.)
v. Keeping bunches on one tray of dryer.
vi. Keeping tray in atmosphere for 5 mins.
vii. Drying in drying chamber.

Observations:

1. Use of solar energy = 114 hours
2. Use of heater energy = 154 hours
3. Colour of raisins = dark red shade
4. Reduction in weight:
Initial wt. of grapes= 4800gms.
Wt. of raisins produced= 1440gms

$$\text{wt. reduction} = \frac{\text{initial wt.of grapes} - \text{final wt.of raisins}}{\text{initial wt.of grapes}} \quad (5.1)$$

$$= \frac{4800-1440}{4800} = 70\%$$

Calculations:

1. Use of Heater energy and cost estimation:
Number of hours per day the heater used = 14 hrs. (7pm to 9am)
Number of days used the heater = 11
Wattage of heater = 250W
Power of heater = no. of hrs/day × no. of days × wattage of heater
= 14 × 11× 250= 38500 W-hrs.= 38.5 KW-hrs.
Cost per unit = 7 Rs.
Total cost of heater = 38.5 × 7
=269.5 Rs.
2. Use of Fan and cost estimation:
Number of hours per day the fan used = 24
Number of days used = 12
Wattage of Fan = 18 W
Power of fan = no. of hrs/day × no. of days × wattage of fan
=268×18=4824 W-hrs.=4.824 KW-hrs.
Cost of fan = 4.824 × 7 Rs./unit
=33.76 Rs.
3. Manufacturing cost of raisins :
Total cost for 1440 gm. Raisins = 269.5 + 33.76
= 303.26 Rs.

Hence cost for 1 Kg. of raisins = 210.6 Rs.

Remarks:

- Drying period is 12 days (268 hrs.) which is less than the traditional method (15-20 days).
- Evaporation rate is increased.
- Increase in evaporation rate is mainly due to –
  1. Puncturing of grape berry skin by dipping solution.
  2. Rise in temperature of drying chamber.

Photograph of sample:

Fig 5.1: Photograph of sample of 1st trial

Trial No. 2

Date: 14/3/16 to 18/3/16

Atmospheric conditions:

DBT = 35^0 C, WBT = 25^0 C, Relative humidity = 42 %

Procedure:

i. Washing of 0.5 Kg grapes by washing powder solution (conc.0.1%).
ii. Separation of berries from bunch.
iii. Manual cracking of berries with blade.
iv. Drying in chamber

Observations:

1. Use of Solar energy = 44 hours
2. Use of heater energy = 56 hours
3. Colour of raisins = mixing of dark and fair red shade.
4. Reduction in weight:
   Initial wt. of grapes= 495 gms.
   Wt. of raisins produced= 154 gms.

$$\text{wt. reduction} = \frac{\text{initial wt. of grapes} - \text{final wt. of raisins}}{\text{initial wt. of grapes}}$$

$$= \frac{495-154}{495} = 69\%$$

Calculations:

1. Use of Heater and cost estimation:
   Number of hours per day the heater used = 14 hrs. (7pm to 9am)
   Number of days used the heater = 4
   Wattage of heater = 250W
   Power of heater = no. of hrs/day × no. of days × wattage of heater
   = 14 × 4 × 250= 14000 W-hrs.= 14 KW-hrs.
   Cost per unit = 7 Rs.
   Total cost of heater = 14 × 7=98 Rs.

2. Use of Fan and cost estimation:
   Number of hours per day the fan used = 24
   Number of days used = 5
   Wattage of Fan = 18 W
   Power of fan = no. of hrs/day × no. of days × wattage of fan
   =24×5×18=2160 W-hrs.=2.16 KW-hrs.
   Cost of fan = 2.16 × 7 Rs./unit=15.12 Rs.
3. Manufacturing cost of raisins :
   Total cost for 154 gm. Raisins = 98 + 15= 113 Rs.
   Cost for 1Kg. of raisins = 0.154/113=733.76 Rs.

Remarks:

- Drying period is 5 days (100 hrs.) only which is tremendously less than the traditional method (15-20 days).
- Evaporation rate is increased due to-
  1. Puncturing of grape berry skin due cuts
  2. Increase in temperature of drying chamber i.e. 53^0 C.

Photograph of sample:

Fig 5.2 : Photograph of sample of 2nd trial

Trial No. 3

Date: 15/4/16 to 17/4/16

Atmospheric conditions:

DBT = 40^0 C, WBT = 28^0 C, Relative humidity = 38 %
Procedure:

i. Washing of 0.36 Kg grapes by washing powder solution (conc.0.1%).
ii. Separation of grapes berries from bunches.
iii. Steaming in super heater (temp. =175^0 C & time = 10 min.)
iv. Drying in drying chamber.

Observations:

1. Use of Solar energy = 20 hours

2. Use of heater energy = 28 hours
3. Colour of raisins = dark red shade.
4. Reduction in weight:
   Initial wt. of grapes= 360gms.
   Wt. of raisins produced= 120gms

$$\text{wt. reduction} = \frac{\text{initial wt. of grapes} - \text{final wt. of raisins}}{\text{initial wt. of grapes}}$$

$$= \frac{360-120}{360} = 67\%$$

Calculations:

1. Use of Heater and cost estimation:
   Number of hours per day the heater used = 14 hrs. (7pm to 9am)
   Number of days used the heater = 2
   Wattage of heater = 250W
   Power of heater = no. of hrs/day × no. of days × wattage of heater
   = 14 × 2 × 250=7000 W-hrs.= 7 KW-hrs.
   Cost per unit = 7 Rs.
   Total cost of heater = 7 × 7= 49 Rs.
2. Use of Fan and cost estimation:
   Number of hours per day the fan used = 24
   Number of days used = 2
   Wattage of Fan = 18 W
   Power of fan = no. of hrs/day × no. of days × wattage of fan
   =48×18=864 W-hrs.=0.864 KW-hrs.
   Cost of fan = 0.864 × 7 Rs./unit= 6.05 Rs.
3. Manufacturing cost of raisins :
   Total cost for 120 gm. Raisins = 49+6.05
   = 55.05 Rs.
   Hence cost for 1Kg. of raisins = 55.05/0.12
   = 458.75 Rs.

Remarks:

- Drying period was only 2 days (48 hrs.) only which is less than the traditional method (15-20 days).
- Evaporation rate is increased due to-
  1. Puncturing of grape berry skin by superheated steam
  2. Increase in temperature of drying chamber i.e. 57^0 C.
- But there was a dark red shade of raisins shown in Figure 5.9 may be due to the higher temperature of superheated steam which was used for pre-treatment.

Photograph of sample:

Fig 5.3 :Photograph of sample for 3rd trial

6. Result and Discussion

1) Achieved chemical free process where steam was used for pre-treatments of grapes.
2) Superheated steam has an effect on grape berry skin to accelerate the evaporation rate.
3) Drying period decreases up to 7 days for 10 Kg of lot size which is less than traditional method.(15-20 days)
4) During the initial use of steam for pre-treatment, partially condensation is occurring which results into increase in drying period. Condensation is mainly due to the contact between superheated steam and the grapes which are at room temperature while starting the steaming.
5) While walking with large scale, the operating cost so also the material cost (grapes) can be reduced drastically. Making the operating cost altering, the total manufacturing cost of raisins will be low and affordable.
6) While concentrating on the drying chamber & utilization of solar energy, we have not paid attention in purchase of grapes. If the grapes for raisins manufacturing are purchased with some criteria given, the quality of raisins can still be improved satisfactorily

Conclusion

Solar dryer is the method which provide remarkable advantages such as Chemical free process, Reduction in drying period, Improvement in colour, Cost Effective method which can be implemented practically with ease and compatibility. The goal of research to implement research work and apparatus practically to perform its function cn be absolutely work out in the farm areas effectively.

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