www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(12): 3436-3440

www.thepharmajournal.com
Received: 08-09-2023
Accepted: 16-11-2023

P Vijayakumary
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

SA Ramjani
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

J Gitanjali
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

R Parimala Devi
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

K Chandrakumar
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

D Ramesh
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding Author:
P Vijayakumary
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Development of evacuated tube collector solar drier for drying grapes

P Vijayakumary, SA Ramjani, J Gitanjali, R Parimala Devi, K Chandrakumar and D Ramesh

Abstract
Drying plays an important role in processing and preservation of agricultural produce. Drying avoids the growth of microorganisms thereby retains the quality and enhance the shelf life of the products. In this research work an evacuated tube collector (ETC) solar dryer is designed and developed for drying seedless grapes. The collector and dryer are designed based on the sample size, i.e. 5 kg of the grapes and on the criteria of collector surface to volume of dryer ratio. Performance analysis of this system is done on analytical and experimental basis. During the experiment, temperatures of hot and cold air at various places, ambient relative humidity and humidity variation in drying chamber, wind velocity and mass of the grapes are measured throughout the tests on an hourly basis. Average thermal efficiency of the air heating system was found to be 31 percent. The desired moisture content of 20% from an initial moisture content of 80% of grapes was reached within 7 days when dried using evacuated tube solar air collector compared to 20-22 days in open sun drying method.

Keywords: Collector, moisture content, efficiency, dryer

Introduction

The environmental pollution and energy crises are very serious issues of the world environment and sustainable environment. The application of solar energy for heating, electricity production, drying the crops etc. becomes important. During the last two decades, many researchers have developed efficient solar collectors. However, most of the designs were demonstrated to improve the structure of solar collector, latest coating techniques for the absorber or reducing the losses of the absorber or collector. Solar drying for the various foods and agricultural products has been demonstrated by many researchers. This is a cost effective and economical alternative to the conventional drying procedures. Drying of agricultural products by solar energy plays an important role in processing and preservation of agricultural products. If drying is not completed fast enough, growth of microorganisms result which leads to the deterioration of the quality of the products. Proper utilization of solar energy for drying can easily be possible by choosing a proper solar dryer. Solar energy is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

ETC solar driers are a type of solar thermal technology designed to capture and concentrate solar energy. They consist of rows of evacuated glass tubes, each containing an absorber plate and a heat pipe. Evacuated tubes are made with a double layer of glass fused together at one or both ends with a vacuum between the layers, with the absorber and heat pipe contained at normal atmospheric pressure. These tubes are usually oriented in a way that maximizes exposure to sunlight. As sunlight penetrates the glass tubes, it is absorbed by the absorber plate and transferred to a heat pipe, which carries the heat to a specific location, such as a drying chamber. They work exceptionally well on cloudy/overcast days.

India has achieved the highest productivity of 20 t/ha in the production of table grapes. Presently in India about 78 percent of grape is used for table purpose, nearly 17-20 percent is dried for raisin production, while 1.5 percent is used for juice and only 0.5 percent is used in manufacturing wine.

Though this fruit is processed to the largest extent relative to other fruits in the country the processing of this fruit in our country is very less as compared to the traditional grape growing countries in the world where more than 80 percent of the produce is processed in the form of wine, raisin and juice. Presently the fresh grape industry in the country is facing problems in marketing of the produce in both domestic and international market and in such situation the maximum benefits from grape cultivation can be derived by establishing the processing industries for production of value-added products like good quality raisin which has market potential for domestic as well as international market. Raisin is prepared from the sound dried grapes of the varieties conforming to the characteristics of *Vitis vinifera L*. processed in an appropriate manner into a form of marketable raisin with or without coating with suitable optional ingredients. In open sun drying, the source of energy is the ambient temperature and natural wind for moisture removal which is disproportionate and unpredicted.

In this research work an evacuated tube collector (ETC) solar dryer is designed and developed to study analytically and experimentally the performance of solar collector and dryer for drying Sonaka seedless grapes in Coimbatore, India.

Materials and Methods

Based on the literature and the field result evacuated tube collector (ETC) solar dryer is designed and developed.

Design of the ETC solar air heating system

The collector and dryer are designed based on the sample size, i.e. 5 kg of the grapes and on the criteria of collector surface to volume of dryer ratio and fabricated.

Assumptions

Quantity of product to be dried = 5 kg
Initial moisture content of grapes =80% (w.b)
Final moisture content of raisin = 20% (w.b)
Drying period = 5days
Temp of drying = 50-55 °C
Ambient temp = 30-40 °C

Calculations

Initial moisture content (m_1) = 80%
Final moisture content (m_2) = 20%
Amount of moisture present = 5x0.8 = 4kg
Mass of bone-dry weight (m) = 5-4 = 1kg
Quantity of water to be removed (m_w) = 4kg

Volume of air required

$$V = (m\, L\, R_a\, T_a)/(C_p\, P\, (T_o-T_a))$$

Where,
m=mass of water to be removed, kg
L=Latent heat of water, kJ/kg
R_a=Gas constant, kJ/Kg K
T_a=Ambient temperature, K
C_p=Specific heat of air, kJ/Kg K
P = Pressure, N/m^2
V = (4x2260x287x38)/(1.005x101325x (55-38))
=56.95 m^3 of air

Assuming the total drying period as 5 days & sunshine hours as 6 hours
Drying period:5 days=5x6x60 =1800min.
Rate of air required=56.95/1800=0.032m^3/min
Assuming volume of the absorber as 0.125m^3
Volume = $\pi r^2 h$=0.0125m^3
h =1.8m
Radius r = 0.047m
Number of tubes = 0.125/ 0.0125=10

Various experimental tests are carried out to check the performance of the solar collector and the behaviour of the grape drying. The air velocity is measured from 9.0m/s to 9.3 m/s. Based on the discharge the instantaneous mass flow rate is calculated. The temperature of air at the inlet and outlet of the dryer and heat gained by the air is calculated. The performance evaluation of evacuated tube hot air generation system (Fig.1) was carried out without load and with load conditions.

Performance evaluation of solar air heating system

Performance evaluation of evacuated tube solar collector for hot air generation was carried out under no load and load conditions and also compared with the conventional method.

Fig 1: Performance evaluation of evacuated tube hot air generation system

The measurements of temperature, RH, solar intensity, air flow, drying time was taken to have comparative study of the various methods of drying. The quality of the finished product was evaluated in terms of cooler, moisture loss.

No load conditions

The experiment was carried out without product in order to derive the temperature profile inside the dryer. The drying parameters such as ambient temperature, relative humidity, solar radiation and wind velocity also measured using automatic weather station. Hot air outlet from solar compound parabolic collector is measured by K-type thermocouple with the time span of half an hour from 10am to 6pm. Hot air velocity also measured at the point of hot air entry to the drying chamber with the help of hot wire anemometer.

Load conditions
The experiment was carried out with product in view to obtain the temperature profile at different locations. The same measurement followed in no load condition was observed under load condition.

Measurement of inlet and outlet air temperature
The temperature of the air at the inlet and outlet of the air heater were measured with the help of K-type thermocouple with digital display. The temperature was recorded at every half an hour interval.

Measurement of drying air velocity
The velocity of hot air flowing in the dryer was measured by means of an electronic hot wire anemometer (AM-4204). The velocity was measured at one time in the beginning of the trials.

Measurement of solar radiation, wind velocity and other weather parameters
The weather parameters such as ambient temperature and ambient RH, wind velocity, wind direction, solar radiation and rainfall details were measured using an automatic weather station. The weather station (model: Vantage Pro, Make: Davis) includes two components: the Integrated Sensor Suite (ISS) and the console. The ISS contains the sensor interface module (SIM), rain collector, an anemometer, and a passive radiation shield. The console provides the user interface, data display, and calculations.
The drying time required for drying grapes from initial moisture content to the final safe storage moisture content inside the dryer was critically observed. The recorded data during load test was analysed to study drying curves.
The drying efficiency is defined ratio of the energy required to evaporate the moisture to the energy supplied to the dryer. The hourly and overall drying efficiency were determined for sample using following equation.

$$\eta = q/ (I_b r_b + I_d r_d)$$

Where, q= Heat required for drying, KJ; I_b= Incident beam radiation, W/m^2; r_b= Tilt factor for beam radiation; I_d= Incident diffuse radiation, W/m^2; r_d= Tilt factor for diffuse radiation
The cost economics was worked out to know whether the technology is economically viable or not. Therefore, an attempt was made to determine economics of the drying system. Different economic indicators were used for economic analysis of developed system under this study.

1. Benefit cost ratio (B/C ratio)
2. Payback period

Benefit cost ratio is the ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. The formal selection criterion for the benefit-cost ratio for measure of project worth was to accept projects for a benefit-cost ratio of 1 or greater. In practice, it is probably more common not to compute the benefit-cost ratio using gross cost and gross benefit, but rather to compare the present worth of the net benefit with the present worth of the investment cost plus the operation and maintenance cost. The ratio is computed by taking the present worth of the gross benefit less associated cost and then comparing it with the present worth of the project cost. The associated cost is the value of goods and services over and above those included in project costs needed to make the immediate products or services of the project available for use or sale. Project economic cost is the sum of installation costs, operation and maintenance cost and replacement costs.
The payback period is the length of time from the beginning of the project until the net value of the incremental production stream reaches the total amount of the capital investment. It shows the length of time between cumulative net cash outflow recovered in the form of yearly net cash inflows. The payback period of the project is estimated by using Investment and savings. The cost of the integrated system was determined by summing the cost of different components fabricated and assembled. The cost of compound parabolic air heating system was worked out by considering fixed cost, variable cost, repair and maintenance, annual usage etc.

Results and Discussion
Based on the literature and the field result solar collector and dryer is designed and developed. Various experimental tests are carried out to check the performance of the solar collector and the behaviour of the grape drying. The air velocity is measured from 9.0m/s to 9.3 m/s. Based on the discharge the instantaneous mass flow rate is calculated. The temperature of air at the inlet and outlet of the dryer and heat gained by the air is calculated. During the test time solar radiation varies from 800-1100W/m^2 with an average radiation of 900W/m^2. The maximum ambient temperature during the test time ranges from 35.8 to 38.3 ºC and the minimum average temperature range is 27.3 to 29.9 ºC. Whereas maximum collector output temperature reached to 60 ºC to a mass flow rate of air 0.032m^3 with average collector outlet temperature of 50 ºC. It is observed that more amount of heat is gained as solar radiation is more between 12pm to 2 pm. The maximum heat gained by the working fluid is observed up to 485 J/s. Average thermal efficiency of the air heating system was found to be 31 percent, which is comparatively higher than the other system like natural convection flat plate solar collector. It is observed that more the solar radiation, heat gain by the working fluid increases. The average heat required to dry the grapes are 234 W and the average heat gained by the air is 269 W.

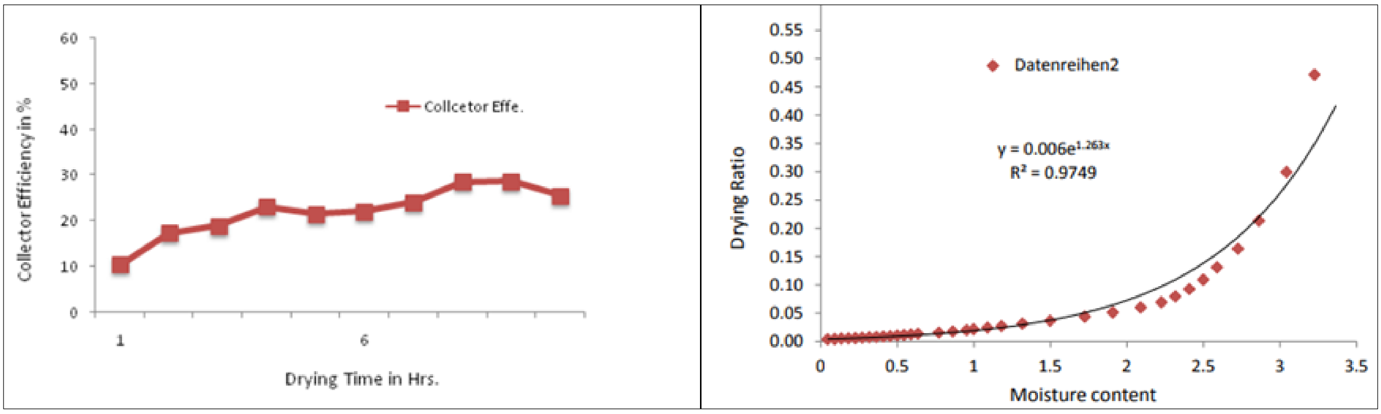

Fig 2: Drying Time Moisture content

The drying rate was rapid during the initial period, but it became very slow at the last stages (falling period) during the drying process. As seen from the below graph, there was no constant drying rate period, and the entire drying process occurred during a falling rate period. On the basis of economic analysis it is revealed that drying of grapes was economical in ETC with payback period of 11 months.

Conclusion

The solar drying of grapes using Evacuated Tube Collector (ETC) solar driers is a sustainable and efficient method for preserving grapes, transforming them into raisins. This research article explores the principles, benefits, and challenges of solar drying grapes with ETC solar driers. It delves into the technical aspects of the process, energy efficiency, and its potential impact on agricultural practices and food preservation. The no load testing of the evacuated tube solar collector revealed that uniform temperature distribution was obtained which is suitable for grape drying. Average thermal efficiency of the air heating system was found to be 31 percent. The desired moisture content of 20% from an initial moisture content of 80% of grapes was reached within 7 days when dried using evacuated tube solar air collector compared to 20-22 days in open sun drying method. It was revealed from the studies that the variation of moisture content during drying period followed falling rate and the system utilized solar energy efficiently for drying of grapes. On the basis of economic analysis, it is revealed that drying of grapes was economical in ETC with payback period of 11 months. Solar drying of grapes using ETC solar driers is an eco-friendly method. It significantly reduces greenhouse gas emissions by eliminating the need for fossil fuels or electricity. This has a positive impact on reducing the carbon footprint associated with grape drying and food preservation. Further research and development in this area can lead to broader adoption and a more sustainable future for the food industry.

Acknowledgements

The author would like to thank the Tamil Nadu Agricultural University and Department of Renewable Energy Engineering, Agricultural Engineering College and Research Institute, TNAU, Coimbatore for facilitating to do the research.

References

1. Ashisk, Kaushik S. Thermal performance of one-ended evacuated tubes solar air collector. Energy Technology. 2014;21:1699-1706.
2. Avadhesh, Kiran Naik. Performance Assessment of a Counter Flow Cooling Tower – Unique Approach. Energy Procedia. 2017;109:243-252.
3. Bajpai VK, Yadav. Experimental study on Evacuated tube solar collector for heating of air in India. International Journal of Mechanical and Mechatronics Engineering. 2011;5(7):112.
4. Hayek M, Jhonny Assaf, William. Experimental Investigation of the Performance of Evacuated-Tube Solar Collectors under Eastern Mediterranean Climatic Conditions. Energy Procedia. 2011;6:618–888.
5. Kabeel AE, Omara ZM. Development of the thermal performance of the glass evacuated solar collectors. International Journal of Ambient Energy. 2017;38(1):85-93.
6. Kumar R, Adhikari RS, Garg HP. Thermal performance of a solar pressure cooker based on evacuated tube solar collector. Applied Thermal Engineering. 2013;21:1600-1706.
7. Liang. Study of the energy balance for the glass evacuated tube solar collector with U-tube. Applied Thermal Engineering. 2010;1:25.
8. Michael. Experimental investigation of the overall performance of solar collectors. International Journal of Engineering and Technology. 2014. ISSN: 0975-4025.
9. Morrison GL, Budihardjo I, Behnia M. Measurement and simulation of flow rate in a water heater in-glass evacuated tube solar collectors. Applied Thermal Engineering. 2005;27:257-267.
10. Neeraj, Yadav. Experimental analysis of thermal performance of evacuated tube solar air collector with phase change material for sunshine and off-sunshine hours. International Journal of Ambient Energy. 2015;2:1012-1202.
11. Nitin Panwar. Design and Performance Analysis of One Ended Evacuated tubes at Different Air Flow Rates. International Journal for Scientific Research & Development. 2015. ISSN: 2321-0613.
12. Rajagopal. Design and development of Evacuated Tube Solar System with Forced Air Circulation. International Journal of Engineering and Technology. 2014. ISSN: 0945-4332.
13. Sanjeev, Ashish Kumar. Thermal performances of an evacuated tubes solar air collector in Indian Climate conditions. International Journal of Ambient Energy.

2014;37(2):1-10.
14. Sundari UAR, P. Neelamegam, C.V. Subramanian. Performance Evaluation of a Forced Convection Solar Drier with Evacuated Tube Collector for Drying Amla. International Journal of Engineering and Technology. 2013. ISSN: 0975-4024.
15. Yadav, Neeraj. Experimental analysis of thermal performance of evacuated tube solar air collector with phase change material for sunshine and off-sunshine hours. International Journal of Ambient Energy. 2015;2:1012-1202.