DESIGN AND DEVELOPMENT OF SOLAR AIR DRYERS FOR RAISIN

Asane Pravin A[1]., Kulkarni Rushikesh U[2]., Ubale Govind B[3].,Bhosale Sunil D[4]., Prof. Amol Kalhapure[5].
[1]UG Student, Mechanical Engineering, GHRCOEM, Maharashtra, India
[2]UG Student, Mechanical Engineering, GHRCOEM, Maharashtra, India
[3]UG Student, Mechanical Engineering, GHRCOEM, Maharashtra, India
[4]UG Student, Mechanical Engineering, GHRCOEM, Maharashtra, India
[5]Assistant Professor, Mechanical Engineering, GHRCOEM, Maharashtra, India

Abstract: Grape is one of the world's largest fruit crops. The world production of grapes is presently 65,486 million tones out of which India accounts for 1.2 million tones, drying the grape produces raisins. Traditionally, drying has been accomplished under the sun drying this method is economical and simple but it has drawbacks like, no control of over the rate of drying, non-uniform drying, chances of deterioration due to exposure of products against rain, dust, storm, inject and human and animal interference. Solar energy is renewable sources those are available abundantly. So the objective of project to modify, design and development a solar air dryer. Solar air dryer gives advantages over the traditional open sun drying method in terms of drying rate, less risk of spoilage and average efficiency of dryer is increase.

Key Words: Solar air dryer, Performance parameter, Forced Convection, Absorber material

1. INTRODUCTION

In India, open sun drying is the most commonly used method to dry the agricultural materials like grains, fruits and vegetables. In open sun drying, the crop is spread in a thin layer on the ground and exposed directly to solar radiation and other ambient conditions. The rate of drying depends on various parameters such as solar radiation, ambient temperature, wind velocity, relative humidity, and initial moisture content, type of crops, crop absorptivity and mass of product per unit exposed area. This form of drying has many drawbacks such as degradation by wind-blown, debris, rain, and insect infestation, human and animal interference that will result in contamination of the product. Drying rate will reduce due to intermittent sunshine, interruption and wetting by rain.

Fruits and vegetables constitute a major part of the food crops in developing countries. Drying is one of the methods used to preserve fruits. Many varieties of fruits are seasonal and most of them are consumed in their dryer form to a large extent. This has been made possible by the process of drying. Grape is one of the world's largest fruit crops. The world production of grapes is presently 65,486 million tones out of which India accounts for 1.2 million tones. Drying the grape produces raisins. This project presents the background and possibilities of solar air drying, focusing on the technical needs of small farmers in the developing world. The theory section discusses the solar energy available in India and it also contains alternatives renewable resources. The literature section contains the work of some of the scientist in the same field and contains the different designs of solar air dryer. The background section explains the moisture content of foods, how moisture is removed and the energy require for drying process.

Design selected is a single circulating type, in which the exhaust air from the dryer box is drawn to surrounding. The collector box inlet is gradually increasing and outlet is gradually decreasing for uniform transfer of air through collector plate which is connected at inlet of dryer box and at inlet to blower. After the modification, performance test will be conducted to find the average dryer efficiency, extraction rate, reduction in the weight content, drying time. Solar air drying methods are usually classified to four categories according to the mechanism by which the energy, used to remove moisture, is transferred to the product.

2. THEORY

2.1 Principle of Fruit Dehydration

The outer layers and surface of grape berries have physical and chemical mechanisms to resist water loss nature's way of keeping the berry hydrated and turgid. The principal barrier is the berry cuticle, which includes the outer layer of epicuticular wax or bloom. This wax consists of partially overlapping flat plate lets that are irregular or lace like in texture. Their orderly spacing and arrangement and the chemical characteristics of the wax provide water repellence and vapor loss resistance.

2.2. Raisins

In indirect type of solar air dryer solar radiation absorb by using absorber sheet, hence air which is flow through pipe convert into steam. By using blower this steam pass into cabinet with high pressure. Grapes are spreads on to tray in drying cabinet. The temperatures of grapes rise, resulting in evaporation of moisture. After sometime remaining moisture remove from grapes. Temperature at this point is very high therefore moisture removing rate is high, hence grapes are easily converting into raisins by dehydration.

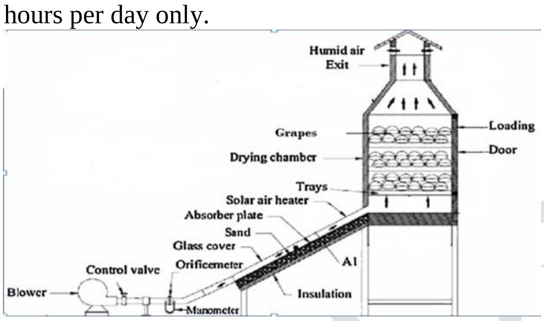
Raisins are basically dry grapes and they are known as Kishmish, Bedana, Manuka or dry fruit. Raisins are popular in India since long. Apart from regular use in many preparations, a small quantity is also used in some herbal medicine preparations. Grapes from Nasik and Sangli districts of Maharashtra are famous all over the country. Grapes are perishable but raisins have a fairly long shelf life. These two centers of Maharashtra supply bulk quantities to western, central and north Indian states. Raisins are made primarily by sun drying several different types of grapes. They are small and sweetly flavored with a wrinkled texture. The technique for making raisins has been known since ancient times and evidence of their production.

3. EXPERIMENTAL SETUP

3.1 Indirect Solar Air Dryer

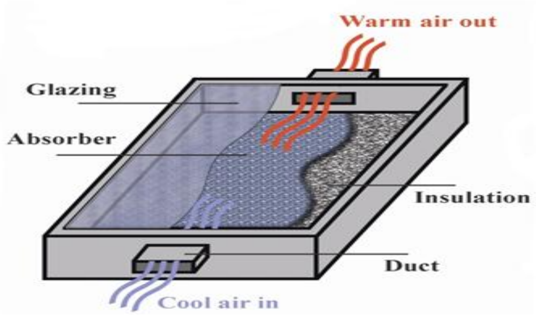
A schematic diagram of the forced convection solar air dryer and its pictorial view in the solar air dryer consists of flat plate solar air heater connected with drying chamber. The solar air heater consist absorber plate coated with black paint to absorb the incident solar radiation. The absorber plate is placed directly behind the transparent cover (glass) with a layer of air separating it from the cover. The air to be heated passes between the transparent cover (glass) and the absorber plate. To increase the temperature of air by green-house effect, a glass cover of 5 mm thickness was placed. The gap between the glass and the absorber surface was maintained at 25 mm for air circulation. One side of the collector was connected to the blower with the help of reducer and the other side was attached with dryer cabin. The 100-mm gap between the absorber and insulation was filled with sand mixed with aluminum scraps to store the heat during sunshine hours and to obtain hot air during off sunshine hours. The dryer is capable of holding about 50 kg of grapes per batch. The solar air heater was tilted to an angle about 30° with respect to horizontal.

The system is oriented to face south to maximize the solar radiation incident on the solar collector. On the basis of measurements, Pollachi (latitude of 10.39°N, longitude of 77.03°E), where the experiment was conducted had about 11 hours 30 min of sunshine, but potential sunshine duration was about 8 hours per day only.



3.2 Collector (Air Heater)

The heat absorber (inner box) of the solar air heater was constructed using aluminum plate, painted black, is mounted in an outer box built from well-seasoned Odum and plywood. The space between the inner box and outer box is filled with foam material of about 40 mm thickness. The solar collector assembly consists of air flow channel enclosed by transparent cover (glazing). The Glazing is a single layer of 5 mm thick transparent glass sheet; it has a surface area of 2000 mm by 400 mm. One end of the solar collector is fitted with fan and blower to provide the forced convection, the other end opens to the drying chamber.



3.3 The Drying Cabinet

The drying cabinet together with the structural frame of the dryer was built from well-seasoned Odum and plywood which could withstand termite and atmospheric attacks. An outlet channel was fitted with chimney. Access door to the drying chamber was also provided at the side of the cabinet.

3.4 Drying Trays

The drying trays are contained inside the drying chamber and were constructed from a double layer of fine chicken wire mesh with a fairly open structure to allow drying air to pass through it.

4. SELECTION OF COLLECTOR MATERIAL

Aluminum has some special properties that make it a useful mirror in various applications of solar cells, lasers and astronomer's instruments. For example, aluminum can be deformed easily to have the best shape of reflectors and achieve the highest concentrating efficiency. Unlike glass mirrors, aluminum reflectors can't broken easily, which is a favorite property for outdoor applications. Aluminum mirrors not only have better surface reflectivity than glass mirrors, they are much lighter. Compared to glass mirrors that have average weight of $11kg/m^2$, aluminum reflectors have only weight of 7 kg/m^2.

Due to mechanical properties of aluminum and its low cost compared with silvered glass mirrors, aluminized reflectors found applicability to high temperature solar concentrating technologies. Rolled aluminum also can be suitable for certain solar energy applications since it is cheaper than other reflector materials and can be cost-effective material in this application. Thermal evaporation is one of the most practical methods to prepare aluminum reflector in order to use in concentrated solar power systems. Ling et al. studied performances of aluminum reflectors produced by thermal evaporation method on different substrates include galvanized iron, acrylonitrile butadiene styrene (ABS) and aluminum alloy. Experimental results clarified that reflection of thermally evaporated aluminum on ABS is comparable with that of silver mirror of ultra-white glass. It was also found that smoothness and roughness of the substrate have important effects on optical properties of the aluminum reflectors.

Absorber Material	Absorptivity	Availability
Black paint	0.98	Easy
Graphite Powder	0.64	Easy
Copper Powder	0.84	Easy

5. DESIGN CALCULATIONS

Nomenclature

mw	Mass of water vapor (kg)
mp	Mass of product (kg)
mi	Initial moisture content in product (%)
mf	Final moisture content in product (%)
Ep	Energy required to evaporate water vapor (joule)
Lv	Latent heat of vaporization of water (kJ/kg)
Ea	Energy gain from air (joule)
Ic	Solar intensity (W/m2)
Ac	Area of collector (m2)
η	Efficiency of collector (%)
td	Drying time (hour)
Mdr	Average drying rate (kg/hour)

Ti	Inlet air temperature (K)
T0	Outlet air temperature (K)
Ta	Ambient air temperature (K)
ma	Mass flow rate of air (kg/sec)
Cpa	Specific heat of air (kJ/kgK)
ΔT	Temperature difference (K)
ρa	Density of air (kg/m3)
Va	Volume flow rate of air (m3/sec)
A	Area of inlet air section (m2)
T	Transmissivity
α	Absorptivity
Qu	Heat gain (W)
QL	Heat loss by convection (W)
K	Thermal conductivity of insulation (W/mK)
tb	Thickness of base insulator (mm)
FR	Heat removal factor (0.1)

Mass of water to be evaporate from product,

$mw = mp [(mi - mf) / (100 - mf)]$ (1)

Energy required for evaporating water from product,

$EP = mw \times Lv$ (2)

Energy gain by air from Radiation,

$Ea = Ic\ Ac\ \eta c$ (3)

Heat gain by air,

$Ea = Ic\ Ac\ \eta c = ma\ Cpa\ \Delta T$ (4)

Calculating mass flow rate of air,

$ma = Ic\ Ac\ \eta c / Cpa\ \Delta T$ (5)

Now calculating velocity of air required,

$ma = Va\ \rho a$ (6)

But, $Va = A \times va$

$Va = ma / \rho a$

Calculating air velocity,

$va = Va / A$

$A = h \times w$

Average drying rate,

$Mdr = mw / td$ (7)

6. ADVANTAGES

- Low investments, as compared to mechanical dryers.
- Minimize the problems associated with open sun drying.
- A variety of solar natural dryers are available worldwide.
- Better Quality of Products are obtained
- It Reduces Losses and Better market price to the products.
- Products are protected against flies, rain and dust; product can be left in the dryer overnight during rain, since dryers are waterproof.
- Prevent fuel dependence and Reduces the environmental impact
- It is more efficient and cheap

7. LIMITATIONS

- Due to its small capacity it is useful to small scale applications only.
- Discoloration of crop due to direct exposure to solar radiation in case of dried solar air dryer.
- Moisture condensation inside glass covers reducing its transitivity.
- Sometimes the insufficient rise in crop temperature affecting moisture removes.
- Limited use of selective coatings on the absorber plate.

8. CONCLUSION

The solar air dryer is beneficial than the sun drying techniques because of,

- A variety of solar natural dryers are available worldwide.
- Solar energy is renewable source.
- Products are protected against flies, rain and dust,
- Product can be left in the dryer overnight during rain, since dryers are waterproof.

The aluminum absorber sheets and blower will give superior results and more efficiency than the natural or direct solar air dryer.

REFERENCES

[1] M. Mohanraj , P. Chandrasekar, " Performance of a force convection solar drier integrated with gravel as heat storage material for chilli drying," Journal of Engineering Science and Technology,2009, 4(4). pp. 305-314.

[2] Ong K.S, Results of investigation into forced convection and natural solar heater and dryers.Reg J Energy Heat and Mass Transfer, 1982, 4 (1),pp. 29-45.

[3] Hegazy, A.A,Optimum channel geometry for solar air heaters of conventional design and constant flow operation. Energy Conversion andManagement, 1999, 40 (7), pp. 754-774.

[4] Shariah, Adnan, Al-Akhras, M-Ali, and Al-Omari, I.A, Optimizing the tilt angle of solar collectors. Renewable Energy, 2002,26 (4), pp. 587–598.

[5] Shanmugam, V, and Natarajan, E,Experimental study of regenerative desiccant integrated solar dryer with and without reflective mirror. Applied Thermal Engineering,2007,27(8-9), pp. 1543-1551.

[6] Satish R. Desai,V.Vijaykumar, and Anatachar M, " Performance evaluation of farm solar dryer for chilli drying," Karnataka Journal of Agricultural Science, 2009 22(3-5), pp. 896-902.

[7] M. S. Dulawat, and N. S. Rathore, "Forced convection type solar tunnel dryer for industrial applications," AgricEngInt: CIGR Journal, 2012.

[8] Ms. Vaishnavi Bharat Chougule , A.G.P.I.T.,. Mr. Abijit Ashok Bhairappa , A.G.P.I.T., " Design and fabrication of a solar drying system for food preservation ," International journal of innovation in engineering, research and technology [ijiert], national conference on innovative trends in engineering & technology-2016 Conference proceedings issn no - 2394-3696.