DESIGN AND DEVELOPMENT OF SOLAR DRYER

T. Somasekhar[1], B. Guruprasad[2], M.V. Kishore[3]

[1]Assistant Professor Research Scholar, Mechanical Engineering Department & Annamalai University Annamalai Nagar
[2] Assistant Professor Mechanical Engineering Department & Faculty of Engineering & Technology, Annamalai University, Annamalai Nagar
[3] Professor, Mechanical Engineering Department Matrusri Engineering College, Hyderabad

---***---

Abstract - The design and construction of a solar dryer, the dryer is composed of solar panel, aircollector and heater, and a solar drying chamber. The air allowed in through air inlet is heated up in the aircollector and channeled through aluminum pipe to the drying chamber where it is utilized in removing the moisture content from the food substances loaded. The dimensions of the dryer are 94cm x 45cm x 101cm/ 20cm (length x width x height). Locally available materials were used for the construction, chiefly comprising of plywood, toughened glass. The optimum temperature of the dryer was 60.5ºC with a corresponding ambient temperature of 34.50ºC. The mass of water removal of 199.9g and 153.6g in tomato and grapes respectively using the solar dryer was achieved as against 156.8g and 125.3g in tomato and grape respectively using the sun drying method and indicating 43.1g and 28.3g difference respectively,for ten slices of tomatoes and grapes dried over a particular day. The rapid rate of drying in the dryer revealsits ability to dry food items reasonably rapidly to a safe moisture.

Key Words: Solar Dryer, moisture, weight of material,

1.INTRODUCTION

Preservation of fruits and vegetables is essential for keeping them for a long time without further deterioration in the quality. Several process technologies have been employed on an industrial scale topreserve food products; the major ones are canning, freezing, and dehydration. Among these, drying is especially suited for developing countries with poorly established low-temperature and thermal processing facilities. It offers a highly effective and practical means of preservation to reducepostharvest losses and offset the shortages in supply.

Drying is a simple process of moisture removal from a product in order to reach the desired moisture content and is an energy intensive operation. The prime objective of drying apart from extended storage life can also be quality enhancement, ease of handling, further processing and sanitation and is probably the oldest method of food preservation practiced by humankind. It brings about substantial reduction in weight and volume, minimizing packing, storage, and transportation costs and enables storability of the product under ambient temperatures. These features are especially important for developing countries, in military feeding and space food formulations.

Drying in earlier times was done primarily in the sun, now many types of sophisticated equipment and methods are used to dehydrate foods. During the past few decades, considerable efforts have been made to understand some of the chemical and biochemical changes that occur during dehydration and to develop methods for preventing undesirable quality losses.

2. DESIGN APPROACH

The drying of a product is a complex heat and mass transfer process which depends on external variables such as temperature, humidity and velocity of the air stream and internal variables which depend on parameters like surface characteristics (rough or smooth surface), chemical composition (sugars, starches, etc.), physical structure (porosity, density, etc.), and size and shape of products. Therate of moisture movement from the product inside to the air outside differs from one product to another and depends very much on whether the material is hygroscopic or non-hygroscopic. Non-hygroscopic materials can be dried to zero moisture level while the hygroscopic materials like most of the food products will always have residual moisture content. This moisture, in hygroscopic material, may be bound moisture which remained in the material due to closed capillaries or due to surface forces and unbound moisture which remained in the material due to the surface tension of water.

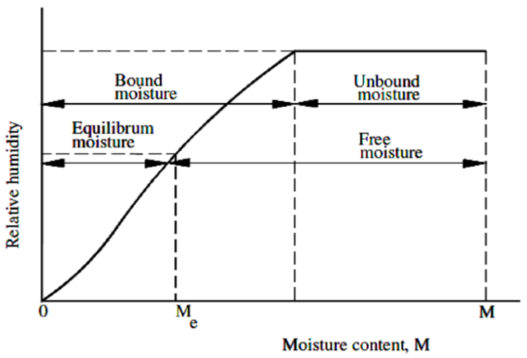

Fig:2.1 Moisture in the Drying Material

When the hygroscopic material is exposed to air, it will absorb either moisture or desorbs moisture depending on the relative humidity of the air. The equilibrium moisture content (EMC = Me) will soon reach when the vapour pressure of water in the material becomes equal to the partial pressure of water in the surrounding air [14]. The equilibrium moisture content in drying is therefore important since this is the minimum moisture to which the material can be dried under a given set of drying conditions. A series of drying characteristic curves can be plotted.

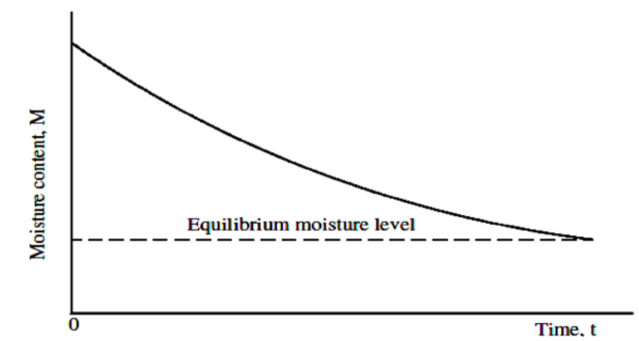

Fig:2.2 Rate of Moisture Loss

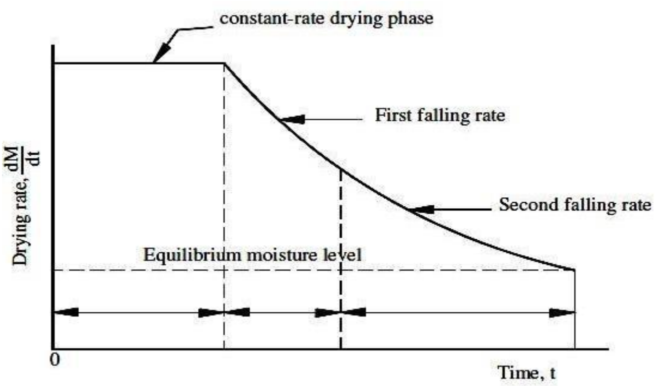

Fig: 2.3 dM/dt versus moisture content M

As is seen from Figure 2.3 for both non-hygroscopic and hygroscopic materials, there is a constant drying rate terminating at the critical moisture content followed by falling drying rate. The constant drying rate for both non-hygroscopic and hygroscopic materials is the same while the period of falling rate is little different. For no hygroscopic materials, in the period of falling rate, the drying rate goes on decreasing till the moisture content become zero. While in the hygroscopic materials, the period offalling rate is similar until the unbound moisture content is completely removed, then the drying rate further decreases and some bound moisture is removed and continues till the vapour pressure of the material becomes equal to the vapour pressure of the drying air. When this equilibrium reaches then the drying rate becomes zero.

The period of constant drying for most of the organic materials like fruits, vegetables, timber, etc. is short and it is the falling rate period in which is of more interest and which depends on the rate at which the moisture is removed. In the falling rate regime moisture is migrated by diffusion and in the products with high moisture content, the diffusion of moisture is comparatively slower due to turgid cells and filled interstices. In most agricultural products, there is sugar and minerals of water in the liquid phase which also migrates to the surfaces, increase the viscosity hence reduce the surface vapour pressure and hence reduce the moisture evaporation rate.

Types of Solar Dryers:

Solar-energy drying systems are classified primarily according to their heating modes and the manner in which the solar heat is utilized. In broad terms; they can be classified into two major groups, namely

- Direct (integral) type solar dryers.
- Indirect (distributed) type solar dryers.
- Direct solar dryers have the material to be dried placed in an enclosure, with a transparent cover on it. Heat is generated by absorption of solar radiation on the product itself as well ason the internal surfaces of the drying chamber. In indirect solar dryers, solar radiation is not directly incident on the material to be dried. Air is heated in a solar collector and then ducted to the drying chamber to dry the product. Specialized dryers are normally designed with a specific product in mind and may include hybrid systems where other forms of energy are also used. Although indirect dryers are less compact when compared to direct solar dryers, they are generally more efficient. Hybrid solar systems allow for faster rate of drying by using other sources of heat energy to supplement solar heat.
- The three modes of drying are: (i) open sun, (ii) direct and (iii) indirect in the presence of solar energy. The working principle of these modes mainly depends upon the method of solar-energy collection and its conversion to useful thermal energy.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 07 | July - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

(i) Open sun drying (OSD)

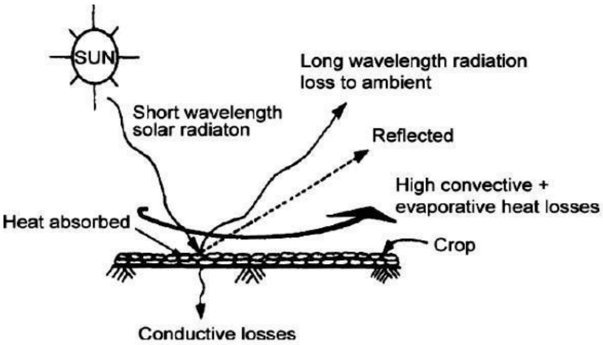

Fig:2.4 Open Sun Drying

solar energy falls on the uneven product surface. A part of this energy is reflected back and the remaining part is absorbed by the surface. The absorbed radiation is converted into thermal energy and the temperature of product stars increasing. This results in long wavelength radiation loss from the surface of product to ambient air through moist air. In addition to long wave length radiation lossthere is convective heat loss too due to the blowing wind through moist air over the material surface. Evaporation of moisture takes place in the form of evaporative losses and so the material is dried.

Further apart of absorbed thermal energy is conducted into the interior of the product. This causes a rise in temperature and formation of water vapor inside the material and then diffuses towards the surface of the and finally losses thermal energy in the end then diffuses towards the surface of the and finally losses the thermal energy in the form of evaporation. In the initial stages, the moisture removal is rapid since the excess moisture on the surface of the product presents a wet surface to thedrying air. Subsequently, drying depends upon the rate at which the moisture within the product moves to the surface by a diffusion process depending upon the type of the product.

(ii) Direct type solar drying (DSD)

Direct solar drying is also called natural convection cabinet dryer. Direct solar dryers use only the natural movement of heated air. A part of incidence solar radiation on the glass cover is reflected back to atmosphere and remaining is transmitted inside cabin dryer. A direct solar dryer is one in which the material is directly exposed to the sun‘s rays. This dryer comprises of a drying chamber that is covered by a transparent cover made of glass or plastic. The drying chamber is usually a shallow, insulated box with air-holes in it to allow air to enter and exit the box. The product samples are placed on a perforated tray that allows the air to flow through it and the material. Fig. 2.6 shows aschematic of a simple direct dryer [15]. Solar radiation passes through the transparent cover and is converted to low-grade heat when it strikes an opaque wall. This low-grade heat is then trapped inside the box by what is known as the greenhouse effect.‘‘Simply stated, the short wavelength solar radiation can penetrate the transparent cover. Once converted to low-grade heat, the energy radiates

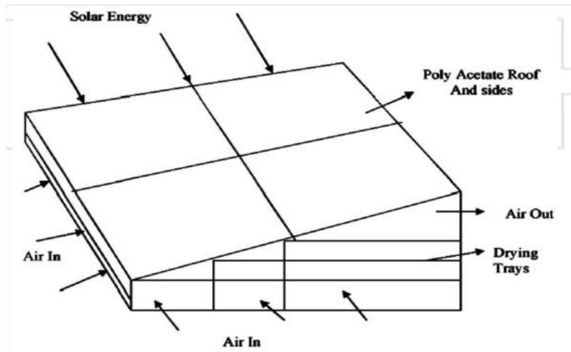

Fig:2.5 Direct Type Solar Drying

(iii) Indirect type solar drying (ISD)

This type is not directly exposed to solar radiation to minimize discolorations and cracking. The drying chamber is used for keeping the in wire mesh tray. A downward facing absorber is fixed below the drying chamber at a sufficient distance from the bottom of the drying chamber. A cylindrical reflector is placed under the absorber fitted with the glass cover on its aperture to minimize convective heat losses from the absorber. The absorber can be selectively coated. The inclination of the glass cover is taken as 45º from horizontal to receive maximum radiation. The areaof absorber and glass cover are taken equal to the area of bottom of drying chamber. Solar radiation after passing through the glass cover is reflected by cylindrical reflector toward an absorber. After absorber, a part of this is lost to ambient through a glass cover and remaining is transferred to the flowing air above it by convection. The flowing air is thus heated and passes through the placed in the drying chamber. The exhaust air and moisture is removed through a vent provided at the top of drying chamber

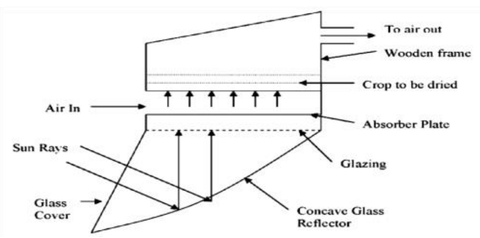

Fig: 2.6 Indirect Type Solar Drying

3. SOLAR DRYER COMPONENTS:

The solar dryer consists of the solar collector (air heater), the drying cabinet and drying trays:

3.1 Collector (Air Heater):

The heat absorber of the solar air heater was constructed using well-seasoned plywoods painted black. The solar collector assembly consists of air flow channel enclosed by ttoughened glass. An absorber mesh screen midway between the glass and the absorber back plate provides effective air heating because solar radiation that passes through the toughened glass is then absorbed by both the mesh and back-plate.

3.2 The Drying Cabinet:

The drying cabinet together with the structural frame of the dryer was built from well seasoned plywoods which could withstand termite and atmospheric attacks. An outlet vent was provided toward the upper end at the back of the cabinet to facilitate and control the convection flow of air through the dryer. Access door to the drying chamber was also provided at the back of the cabinet. The roof and the two opposite side walls of the cabinet are covered with transparent glass sheets of 4 mm thick, which provided additional heating.

4. THE ORIENTATION OF THE SOLAR COLLECTOR:

The flat-plate solar collector is always tilted and oriented in such a way that it receives maximum solar radiation during the desired season of used. The best stationary orientation is due south in the northern hemisphere and due north in southern hemisphere. Therefore, solar collector in this work is oriented facing south and tilted at approximately 45 to the horizontal.

5. MATHEMATICAL MODELS AND FORMULATIONS:

5.1 Operation of the Dryer

The dryer is a active system in the sense that it has moving parts. It is energized by the sun‘s rays entering through the collector glazing. The trapping of the rays is enhanced by the inside surfaces of the collector that were painted black and the trapped energy heats the air inside the collector. The greenhouse effect achieved within the collector drives the air current through the drying chamber. If the vents are open, the hot air rises and escapes through the upper vent in the drying chamber while cooler air at ambient temperature enters through the lower vent in the collector.

5.2 Drying mechanism

In the process of drying, heat is necessary to evaporate moisture from the material and a flow of air helps in carrying away the evaporated moisture. There are two basic mechanisms involved in the drying process:

- The migration of moisture from the interior of an individual material to the surface.
- The evaporation of moisture from the surface to the surrounding air.

  The drying product is a complex heat and mass transfer process which depends on external variables such as temperature, humidity and velocity of the air stream and internal variables which depend on parameters like surface characteristics (rough or smooth surface), chemical composition (sugars, starches, etc.), physical structure (porosity, density, etc.), and size and shape of product.

Experimental Setup:

The solar dryer consisting of collector, absorber, and drying chamber were constructed using the materials that are easily obtainable from the local market. To begin, the air collector was made using plywood with the dimensions 70 cm in length, 41 cm in breadth and 14 cm in depth. The thickness of the plywood is 2 cm. The collector consistsof two 4-inch holes through the wood on either side of the collector. The side along the breadthof the collector is drilled with four holes for the purpose of acting as an inlet to air.

An inner frame is also made using wood with the dimensions 51 cm in length, 36 cm in breadthand thickness of 4 cm which is hollow rectangle in shape. The air inlet at the bottom of the collector is covered with mesh so as to stop dust particles and insects from getting into the collector. The inner frame is also covered with a mesh on both the sides. A toughened glass was also used to cover the air collector.

Both the collector and inner frame are then sprayed with black paint as to increasing its capability of absorbing the solar radiation.

An aluminium pipe is fixed into the upper four-inch hole of the collector. And then a 12v DC fan is also screwed to the collector to direct the hot air flow into the aluminum pipe which in turn is attached to the drying chamber.

A 12v DC solar panel was connected to a solar charge controller which was connected to a 12vbattery. The battery is then connected to the fan screwed the collector with a regulator providedto control the fan speed.

Lastly a Drying chamber was made using plywood to house the food produce (vegetables andfruits) with a 4-inch holes drilled to attach the aluminium pipe from the air collector.

An iron stand set up was also welded to house the entire solar air dryer.

The Air Collector

Fig: Air Collector with black paint

Design Implementation:

Ambient temperature was recorded during the course of experiments with the help of digital sensor. This project presents the design, construction and performance of a mixed-mode solar dryer for food preservation. The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

6. OBSERVATIONS

It is observed that the hot air from the dryer has temperature between 48 C and 58 C. The dryertakes around 2 hours to reach this temperature.

As observed the time taken for dehydrating the food produce through sun dried methods takesup to 4 days to 7 days.

Using the Solar air dryer, the time can be reduced massively. The time taken to dry the producecan be brought to as low 2-3 hours.

7. CONCLUSIONS:

From the test carried out, the following conclusions were made. The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of food produce. The product inside the dryer requires less attentions, like attack of the product by rainor pest (both human and animals), compared with those in the open sun drying. Although the dryer was used to dry grapes, it can be used to dry other crops like tomato, green chillis, applesetc. There is ease in monitoring when compared to the natural sun drying technique. The capitalcost involved in the construction of a solar dryer is also reasonable since it initial cost is low and is powered by solar energy. Also, from the test carried out, the simple and inexpensive solar dryer was designed and constructed using locally sourced materials. In this experiment we find that how much moisture removed from the sample which is present in solar dryer and the sample which is present in ordinary air and we compare both of them by mathematical calculation. In this paper we took tomato, some of the tomato we put inside the dryer and somein the ordinary air and then compare their moisture removed with respect to time andtemperature. We find that temperature inside the dryer is two times outside the temperature. As per our experiment the maximum peak temperature inside the drying chamber is 60°C during mid-day(3pm) and in an average approximately 54°C-56°C in a full sunny day (10:00AM to 03:00PM). In 6 hours, continuous drying in one full sunny day under the same climatic condition and in same time the solar dryer removed a maximum of 30- 40% moisture content from drying chamber for drying of low moisture content food products. experimental observation shows that the solar dryer can be used as an alternative in case of food preservationand the efficiency is also acceptable the people can make it in their homes, especially in the developing countries where the energy demand is skyrocketing. It can be handy in times of recession. The food stuffs can be stored in this dryer and used for days without wasting it.

REFERENCES

[1] W. An, J.Wu, T. Zhu, and Q. Zhu, “Experimental investigation of a concentrating PV/T collector with Cu9S5 nanofluid spectral splitting filter,” Applied Energy, vol. 184, pp. 197–206, 2016.

[2] M. Faizal, R. Saidur, S. Mekhilef, and M. A. Alim, “Energy, economic and environmental analysis of metal oxides nanofluid for flat-plate solar collector,” Energy Conversion and Management, vol. 76, pp. 162–168, 2013.

[3] G. L.Morrison and J. E. Braun, “Systemmodeling and operation characteristics of thermosyphon solar water heaters,” Solar Energy, vol. 34, no. 4-5, pp. 389–405, 2011.

[4] Sunil K, Amrutkar Satyshree G and Patil KN (2012) Solar flat plate collector analysis. IOSR Journal of Engineering 2(2): 207–2013.

[5] Sunil U, Salim A, Prafulla S, et al. (2015) Process of improving efficiency of solar water heater. International Journal for Scientific Research and Development 3(5): 908– 910.

[6] Yousefi T, Veysi F, Shojaeizadeh E, Zinadini S. An experimental investigation on the effect of Al2O3–H2O nanofluid on the efficiency of flat-plate solar collectors. Renewable Energy 2012;39(1):293-298.

[7] Das SK, Putta N, Thiesen P, Roetzel W. Temperature dependence of thermal conductivity enhancement for nanofluids. . J. Heat Transfer . 2003;125:567–74.

[8] S. M. S. Murshed, K. C. Leong, and C. Yang, “Enhanced thermal conductivity of TiO 2—water based nanofluids,” International Journal ofThermal Sciences, vol. 44, no. 4, pp. 367–373, 2005. [9] Adil A. , Gupta, S. , Ghosh , P. Numerical prediction of heat transfer characteristics of nanofluids in a minichannel flow. Journal of Energy 2014 ; Article ID 307520 : 1-7.

[10] Gupta H., Agrawal G. , Mathur J. An overview of nanofluids: a new media towards green environment . International Journal of Environmental Sciences 2012 ; 3 : 433- 440.

[11] Jaisankar S. , Ananth J. , Thulasi S. , Jayasuthakar S. , Sheeba K. A comprehensive review on solar water heaters . Renewable and Sustainable Energy Reviews 2011 ; 15 : 3045-3050.

[12] Delhi International Renewable Energy Conference, Ministry of New and Renewable Energy, Government of India, Viewed on December 16 2010.

[13] Naveen Kishore P (2022) “Design and Fabrication of Multipurpose Agriculture Machine” International Journal of Innovative Research in Technology, Vol 9 Issue 4 pp. 118-122.

[14] Abdulkadir, B.H., and Muhammadu, M. (2012) "Design, construction and Performance Evaluation of a Solar Water Pump". IOSR Journal of Engineering, Vol.2 (4) pp. 711-718.

[15] A. Kalyan Charan, R. Uday Kumar, B. Balunaik, "Evaluation of Thermal Properties by Incorporating Perforations of Various Shapes in Fins Made with Aluminium", Science Direct: Materials today Proceedings Elsevier Ltd, Volume 46, June 2021, pp. 609-614.

[16] Kalogirou, S., (2007) "Solar Energy for Domestic Heating and Cooling and Hot Water Production". International Journal of Energy, Environment and Economics, Vol. 14 (3), pp. 289-339

[17] Somasekhar T (2022) "Design and Development of Solar Water Heater to Enhance Thermal Efficiency" International Journal for Research in Applied Science & Engineering Technology, Vol 10 Issue VIII pp. 446-453.

[18] T Somasekhar, P. Naveen Kishore, "Thermo Acoustic Refrigeration", IOSR Journal of Mechanical and Civil Engineering, pp 58-63.