Forced Convection Solar Dryer For Multipurpose Drying Process

Rohan Mohod[1] , Harshal Dhage[2] , Dhanajay Atkari[3] , P.V.Mangalkar[4] , V.B.Vaiday[5]

[1,2,3] Student, [4,5] Assistant Professor, Department of Mechanical Engineering, KDK College of Engineering, Nagpur, India

Abstract

The solar drying system utilizes the solar energy to heat up a air and to dry any food substance which is loaded, which is not only beneficial but also it reduces wastage of agricultural products and helps in preservation of agricultural products, but it also makes transportation of such dried product easily and promotes the health and welfare of the people. This paper presents the design and construction of a solar dryer for drying a agriculture product. The dryer is composed of solar collector (air heater) with the trapezoidal collector and a solar drying chamber containing rack of four net trays both being assimilated together. The air allowed in through air inlet is heated up in the solar collector chamber and channelled through the drying chamber where it is utilized in drying (removing of the moisture content from the food substances or agricultural product which is loaded in it). The design was based on the geographical location which is Nagpur and meteorological data were obtained for proper design specification. Locally materials were used for the construction are iron bar and sheet, glass, CR metal sheet and net for the trays.

Keywords— *Solar dryer, drying chamber, solar collector, Absorber.*

I. INTRODUCTION

Drying is an excellent way to preserve foods. Drying was probably the first ever food preserving method used by mans. It involves the removal of moisture from agricultural product so as to provide a product that can be safely stored for longer period of time. “Sun drying” is the earliest method of drying farm produce ever known to man and it involves simply laying the agricultural products in the sun on mats, roofs or drying floors. This has several disadvantage since the farm produce are laid in the open sky and there is greater risk of spoilage due to adverse climatic situation like wind, rain, moist and dust, loss of product to insects, birds and rodents; totally dependent on good weather and very slow drying rate with danger of mould growth thereby causing deterioration and decomposition of the product. The process also requires large area of land takes time and highly labour intensive. In solar drying, solar dryers are specialized devices that control the drying process and protect agricultural product from damage by insect, dust and rain. In addition, it takes up less space, takes less time and relatively inexpensive compared to artificial mechanical drying. The solar dryer can be seen as one of the solutions to the world’s food and energy crises. With drying, most agricultural product can be preserved and this can be achieved more efficiently through the use of solar dryer.

In ancient times, the sun and wind would have naturally dried foods. Evidence shows that Middle East and oriental cultures actively dried foods as early as 12,000 B.C. in the hot sun. Later cultures left more evidence and each would have methods and materials to reflect their food supplies—fish, wild game, domestic animals, etc. Vegetables and fruits were also dried from the earliest times. The Romans were particularly fond of any dried fruit they could make. In the Middle Ages purposely built “still houses” were created to dry fruits, vegetables and herbs in areas that did not have enough strong sunlight for drying. A fire was used to create the heat needed to dry foods and in some cases smoking them as well. [1] The importance of food drying is likely to increase. The global population is predicted to exceed eight billion by the year 2025 (Cliquet and Thienpont, 1995). Food production must therefore be increased to meet the rising demand but this is unlikely to come from simply growing crops on previously uncultivated land (Dyson, 1996). One strategy to increase food supplies is to minimize crop wastage. In developing countries alone, the minimum estimates of post-harvest losses, including those from poor drying, vary between 10-20% (Pariser, 1987). A 1978 report by the National Research Council of the National Academy of Sciences in Washington, D.C., cited by Salunkhe and Kadam (1998), puts post-harvest losses as high as 30-40% in both industrialized and developing countries. In addition to foods for human consumption, many other products require Drying. These include organic crops like timber and rubber and inorganic materials like this has focused our attention on energy intensive processes like drying where fossil fuels can often be replaced by renewable and non-polluting sources of energy. All of the above arguments emphasize the importance of drying in people's lives. However, according to Mujumdar (1990), "drying is the most energy-consuming industrial process". It requires approximately 2.4 MJ to evaporate one liter of water. To dry one metric ton of most fruits in a conventional dehydrator to the safe moisture, content for long-term storage requires approximately 100 liters of oil. The shortage of energy is an issue in many countries, particularly those in the developing world. Even where conventional energy is plentiful, there is pressure to reduce the amount of fossil fuels used. Concern over global warming is universal and one metric ton of fruit in a conventional dehydrator produces approximately 300 kg of carbon dioxide. Technology the growers dry many crops at the point of production themselves so there is usually adequate land area available for the solar drying system. Solar energy is an obvious energy source for drying various products, particularly food crops. Many crops are harvested in the summer months and are usually dried at temperatures below 700C - a temperature which can be readily attained by solar [2] Some of the problems associated with open-air sun drying can be solved using a solar dryer, which comprises of collector, a drying chamber and sometimes a chimney. Solar drying may be classified into direct, indirect and mixed-modes. In direct solar dryers the air heater contains the grains and solar energy passes through a transparent cover and is absorbed by the grains. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the grain bed. In indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the grain bed, while in the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls or roof. In our project, the solar food air dryer consists of four main parts such as solar panel, cabinet and blower. The blower is used to passing the hot air forcedly to the drying cabinet.

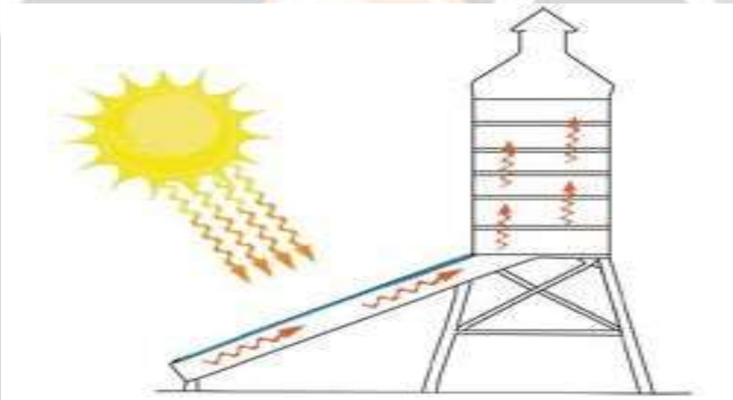


Fig: 1.1 Over view of solar dryer

II. LITERATURE REVIEW

The versi Both theoretical and experimental studies are reviewed. Numerous studies in the field of solar dryer have been reported. Different Solar dryer models and their study of drying time and moisture removal rate are reviewed.

Bukola O. Bolaji et al. [1] studied a rotary wind ventilator incorporated into the dryer, to increase the rate of air circulation through the dryer. Dryer consists of an absorber back plate insulated with foam material. Graph was plotted between time and temperature and time of drying and weight loss. The results obtained show that the temperatures inside the dryer and the air-heater were higher than the ambient temperature during most hours of the daylight. The drying of food items in the dryer was compared with open air-drying of similar items Comparatively, drying with the solar cabinet dryer showed better results than open air-drying. The results also revealed the dependence of the dryer performance on the proper air circulation through the system. The system efficiency increased as the air velocity through the system increased and 80% and 55% weight losses were obtained in the drying of pepper and yam chips, respectively, in the dryer. The average daylight efficiency of the system was 46.7%.Abdul Jabbar N et al. [2] investigated the benefit over natural drying by using solar drying with and without auxiliary heat for drying beans and peas under different airflow rates .The solar heat may be supplemented by auxiliary heat of different types to reduce further drying time. It is often desirable to vary airflow rate through the system during the different stages of drying .An experimental study is conducted to investigate the performance of a solar drying system and a system equipped with an auxiliary heater as a supplement to the solar heat. The performances of both are compared to that of natural drying. Beans and peas are dehydrated in a system that consists of two flat plate collectors, a blower, and a drying chamber. Tests with four different airflow rates, namely, 0.0383, 0.05104, 0.0638, and 0.07655m3/s are conducted. It was found that the drying time was reduced from 56 hours for natural drying to 12–14 hours for solar drying and to 8-9 hours for mixed (solar and auxiliary) drying. The efficiency of the mixed drying system was found to increase by 25% to 40% compared to the solely solar drying. A weak relation was observed between the variation of airflow rate and the decreasing rate of the moisture content of the dried material, especially for the mixed drying.BANOUT J et al.[3] designed a direct natural-circulation solar dryer,and compare its performance with the traditional open-to-sun drying. The design of the dryer was made to suit the local farmer needs, as a small-scale home drying unit with a capacity from 3 kg to 8 kg in relations to the product being dried. The purpose of this research was to study the performance of an integral-type natural-circulation solar-energy dryer for the drying of different crops under tropical conditions. It consist of a chimney for getting buoyancy. A K-type thermo-couple complete with digital relative humidity meter was used to measure the drying air temperature and drying air relative humidity inside the dryer. A pyranometer was used to measure the global solar radiation. The velocity of drying air was measured by an anemometer. The moisture contents of dried crops were measured at the starting and the end of each run of experiments.To evaluate drying performance of the solar dryer, the system drying efficiency was calculated. The performance of the integral natural circulation solar dryer is compared with that used in Pucallpa traditional open-to-sun drying. The mean solar radiation values over all the tests varied between 260 W/ m2 and 390 W/m2. Drying air temperatures were approximately over 39–70% higher than ambient air temperatures. The drying time required to reach 15% product moisture content in the integral natural circulation solar dryer varied between 7 and 24 hours. To achieve the same 15% product moisture by the traditional open-to-sun drying, from 25% to 85% longer drying time is required. In accordance with results of this research it is possible to conclude that using the integral natural-circulation solar dryer is a more appropriate technology to preserve agricultural products. Drying time is considerably reduced and the final product is acceptable in appearance and quality, because the dried crops are completely protected from rain, insects and dust. The solar dryer reported in this study was designed as a small-scale home drying unit adaptable to local farmers. A.O. Adelaja et al. [4] designed, constructed a forced convection solar dryer and tested for the purpose of drying yam in order to study the moisture removal pattern. In this paper the dryer comprises three main components namely the solar collector, the drying chamber and the pv- extractor assembly. Yam fillets weighing 0.52kg were dried in the dryer while an equal mass was dried in the open sun and the profiles obtained in both cases were compared. Quantity of heat used in evaporating moisture is found out. Efficiency of dryer and average drying rate is also found. The load test involved cutting 1.04kg of yam into slices of about 3mm, washed and weighed. This was divided into two parts, 0.52kg each. One part was spread into the first tray of the chamber which had earlier been checked for air tightness so as to avoid heat and moisture losses. The second part was spread in the open sun. An hourly measurement of the temperatures at specific locations and mass of the specimen was carried out between 10.00 and 17.00 hours each day for three days. Design parameters are Reynolds number, Nussult number, Coefficient of heat transfer, Heat removal factor, Total heat loss coefficient, Useful energy collected, mass flow rate, Collector efficiency. Evaluating the performance of the dryer; the collector and system efficiencies of 65.6% and 54.8% were obtained respectively. The moisture content removal of 75.0% was achieved as against 61.5% (control), indicating 13.5% difference, average drying rate of 0.0481kg/hr were recorded during solar drying of yam .The photovoltaic powered solar dryer designed, constructed and tested here can function on a continuous basis, that is, both during high intense sunshine and non-insolation hours especially during cloudy weather.

III. **PROVISION OF ARTIFICIAL ROUGHNESS**

Surface roughness often shortened to roughness, is a component of surface texture. Roughness plays an important role in determining how a real object will interact with its environment. In tribology, rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. All materials have normally harsh surfaces that can be either pictured through bare eyes or by putting it under the magnifying instrument. However, in a finished metallic surface, the mini size roughness components hardly influence the flow stream behavior thus the convective heat transfer process. It has been observed that the presence of artificial roughness components of ideal measurement can lead to a extensive changes in the air stream and heat transfer. The roughness of various shapes and size can be applied over surfaces that are exposed to air stream to restore the air stream design in the close-by area. The popular roughness geometries include grit, ribs, dimples, protrusions, wings, blockages and so forth.

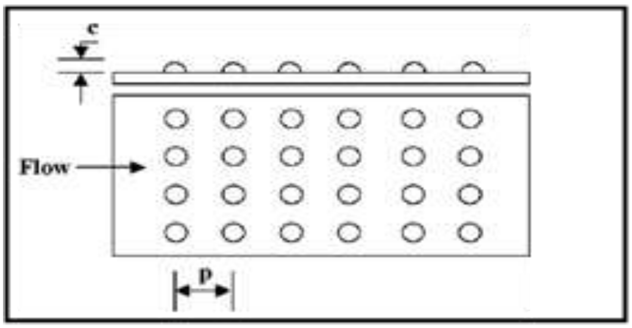


Fig.1.2: Diagram of dimples rough surface on absorber plate

Improvement in the performance of solar air heater can be done by enhancing the heat transfer, for this reason the concept of different artificial roughness elements study has been done in this paper. Energy for creating the turbulence has to come from the fan or blower and the excessive power is required to flow air through the duct. Therefore it is desirable that the turbulence must be created only by artificial roughness. A roughness element has been used to increase the heat transfer coefficient by creating turbulence in the flow. However it would also result in increase in friction losses and hence greater power required for pumping air through the duct. In order to keep the friction losses at a low level, the turbulence must be created only in the region very close to duct surface i.e. laminar sub layer. The purpose of the artificial roughness is to make the flow turbulent adjacent to the wall in sub layer region. Experiments were performed to collect the heat transfer and friction data for forced convection flow of air in solar air heater rectangular duct with one broad wall roughened by dimples geometry.

IV. TRAPEZOIDAL ABSORBER PLATE

Trapezoidal type groove is utilized in order to increase the rate of turbulence of air and it likewise expands the surface region of absorber which additionally builds the convective heat exchange amongst air and absorbing material. The collector works on natural convection so to quicken the speed of air and for uniform distribution exit area was in conical shape. Exit air temperature is more in trapezoidal plate absorber compared with flat plate collector because the reason the area presented to streaming air is more in case of trapezoidal absorber surface. As the heat transfer rate is increasing the thermal effectiveness of trapezoidal collector is higher. More heat transfer area is presented to air to carry more heat therefore thermal transfer rate is more in the case of trapezoidal absorber plate. It is trusted that the wall surface of trapezoidal corrugated absorber makes more turbulence; causes overwhelming blending of the air streaming over it, and also the heat transfer rate is higher.


Fig.1.3: Schematic figure of trapezoidal absorber plate

Nomenclatures	
A	Cross section area of the pipe connecting the drying chamber, m2
DR	Drying rate, kg of water/ kg of dry matter. h
hfg	Latent heat of vaporization of water, kJ/kg
k	Drying constant
Md	Final mass of the sample at any time , g
Me	Equilibrium moisture content, %
Mo	Mass of the sample at t=0, g
Mt	Initial mass of the sample at any time , g

Mwb	Moisture content (wet basis), %
ma	Mass flow rate of air, kg/s
mw	Moisture evaporated in time t, kg/s
Pd	Blower power, kWh
R	Calculated parameter
SMER	Specific moisture ratio, kg/kWh
Td	Drying air temperature, oC
TfHS,	Final temperature of heat storage materials
Ti	Temperature of at solar air heater inlet, oC
This	Initial temperature of heat storage materials, oC
To	Temperature of at solar air heater outlet, oC
Greek Symbols ηth	Drier thermal efficiency, %

V. EXPERIMENTAL PROCEDURE

Only good quality chilies were used in the experiments. About 40 kg of fresh chilies were dried as whole fruits, without any chemical pre-treatment, until the required final moisture content was attained. The fresh chilies were loaded over the trays of drier chamber having about 90% perforation. The initial moisture content was calculated by taking five different samples. Then the air blower was switched on and the air flow rate through the solar flat plate collector was adjusted to 0.025 kg/s. The velocity of air at inlet of the tray was measured with the help of vane type anemometer. Solar intensity was measured using solar intensity meter. During sunshine hours the air flow over the absorber plate gets heated and simultaneously the heat storage material (gravel) packed in the collector stores the heat energy. During off sunshine hours, the stored energy was used to heat the air. Temperatures at inlet and outlet of the solar collector and drying chamber were measured at every one-hour interval. The experiments with heat storage material were conducted for 8 h during potential sunshine hours and 4 h during lean or off sunshine hours. During idle conditions, the chilies were covered with polyethylene sheet to avoid deabsorption of moisture. All the experimental observations were made after the drier attains the steady state condition. The experiments were repeated thrice and an average value was considered. The drying characteristics of chilies such as moisture content, drying rate, specific moisture extraction rate and drier thermal efficiency were determined by using Eqs. (1) to (4), respectively.

VI. DESIGN CALCULATION

Determination of moisture content

The quantity of moisture present in a material can be represented on wet basis and expressed as percentage. About 10 g samples were taken and kept in a convective electrical oven, which was maintained at 105±1oC until constant weight has reached. The initial and final mass, Mt, and final mass, Md,of the samples were recorded with the help of electronic balance. The moisture content, Mwb, on wet basis was calculated by using Eq. (1). The procedure was repeated for every one hour interval till the end of drying.

$$M_{wb} = \frac{(M_t - M_d)}{M_t} \times 100$$

(1)

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[16]. The concept of thin layer drying was assumed for the experiments as reported by Eq. (2)

$$DR = \frac{dM}{dt} = -k(M_t - M_e)$$

(2)

Determination of specific moisture extraction rate

The specific moisture extraction rate, which is the energy required for removing one kg of water. SMER was calculated using Eq. (3) as reported by Shanmugam and Natarajan [11]

$$SMER = \frac{m_d}{P_d}$$

(3)

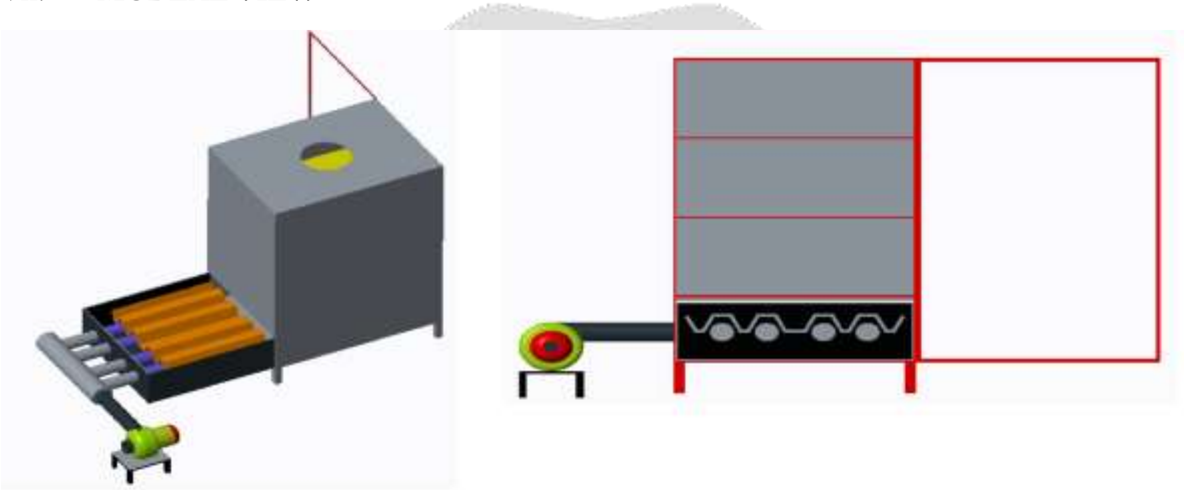
Determination of drier thermal efficiency

The thermal efficiency of the solar air heater was estimated using Eq. (4) as reported by Shanmugam and Natarajan [11]

$$\eta_{th} = \frac{m_w h_{fg}}{m_a c_{pa}\,(T_o - T_i) + P_d + m_a c_{pa}(T_{iHS} - T_{fHS})} \times 100$$

(4)

VII. MODEAL VIEW



VIII. CONCLUSION

Solar radiation can be highly effective and utilized for drying of agricultural product in our environment if proper design is carried out. This was demonstrated and the solar dryer designed and constructed expressed sufficient ability to dry agricultural produce most especially food items to an appreciably reduced moisture level. Locally available cheap materials were used in manufacturing of solar dryer making it available and affordable to all and especially for farmers. This will go a long way in reducing food wastage and at the same time food shortages, since it can be used extensively for majority of the agricultural food crops. Apart from this, solar energy is required for its operation which is readily available in the tropics, and it is also a clean type of energy. It protects the environment and consumes cost and time spent on open sun drying of agricultural produce since it dries food items faster. The food items are also well protected in the solar dryer than in the open sun, thus reducing the case of pest and insect attack and also contamination.

However, the performance of existing solar food dryers can still be improved upon especially in the aspect of reducing the drying time and probably storage of heat energy within the system. Also, meteorological data should be easily available to users of solar products to ensure maximum efficiency and effectiveness of the system. Such information will probably guide a local farmer on when to dry his agricultural product and when not to dry them.

REFERENCES

[1] Bukola O. Bolaji aΨ, Tajudeen M.A. Olayanjub and Taiwo O. Faladec, Performance Evaluation of a Solar Wind-Ventilated Cabinet Dryer ,The West Indian Journal of Engineering Vol.33, Nos.1/2, January 2011, pp.12-18.

[2] Abdul Jabbar N. Khalifa,1 Amer M. Al-Dabagh,2 andW.M. Al-Mehemdi2An Experimental Study of Vegetable Solar Drying Systems with and without Auxiliary Heat, International Scholarly Research Network ISRN Renewable Energy Volume 2012, Article ID 789324.

[3] Ehl P.1, Banout J.1*, Lojka B.2, Polesný Z.2, Lojková J.1, Post Harvest Processing Of Selected Tropical Crops Using a Natural Circulation Solar Dryer Agricultura Tropica Et Subtropica Vol. 43 (2) 2010.

[4] A.O. Adelaja, O.S. Asemota and I.K. Oshiafi, Experimental Determination of the Moisture Content Pattern in Yam During Drying, Journal of Applied Sciences Research, 6(8): 1171-1181, 2010.

[5] Salah A. Eltief*, M.H. Ruslan, B. Yatim,Drying chamber performance of V-grooveforced convective solar dryer,Journal of Desalination 209 (2007)151– 155.

[6] Sukhmeet Singh a,_, Parm Pal Singh b, S.S. Dhaliwal a,Multi-shelf portable solar dryer,Journal of Renewable Energy 29 (2004) 753–765.