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Development of Vacuum Solar Grape Dryer

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ABSTRACT: In this work a performance evaluation of a vacuum solar dryer is done and its different characteristics are analyzed. In this system a drying chamber is developed where drying will be done and vacuum is created inside the drying chamber by using a vacuum pump. A indirect heating of drying chamber will be done by using solar water heater and circulating that hot water into the drying chamber. The experimentation is carried out for the 250 gram sample of the grapes; all the characteristics of the solar dryer are monitored in the drying process of the grapes. Experimentation also conducted for varying vacuum pressure of the drying chamber and all the characteristics of process are monitored. After the results are obtained, all the available data studied and analyzed and conclusions are made. From this work it is found out that vacuum solar dryer delivers good quality of product at the end of drying process. It is also find out that the vacuum pressure in the drying chamber does have effect on the performance of dryer. In vacuum solar dryer, higher vacuum pressure result into the reduction in dying time. As vacuum pressure increases, drying period required for production of raisons decreases. It is observed that the For vacuum pressure of 55 mm of Hg the drying period required for production of raisins is 91 hours.

KEYWORDS - Solar drying, Vacuum solar dryers, solar energy.

I. INTRODUCTION

In many nations across the globe, the application of solar thermal systems in the agricultural area to conserve vegetables, fruits, coffee & other crops is very common. Drying fruits under the direct sun light does not involve any cost but it has some limitations, first one is that this process takes long time also there are high possibilities of addition of external contamination as dying material is kept in open for long time.

Open drying of products is a common technique used due to its simplicity from last thousands years, but with time small changes in the open drying technique has been incorporated. But the quality of product is sacrificed in open drying process as it gives poorly dried products. If the improves open drying techniques are adopted then food products can be dried fastly and bitterly even in the rainy season where humid and cloudy climate is present.

In order to overcome limitations and disadvantages of natural or sun drying process a vacuum dryer can be used. Vacuum dryers will give clean product as drying takes place inside a closed chamber and no physical particle will enter into the drying chamber. Also drying rate in vacuum chamber will be higher than the natural drying. Hence a vacuum dryer can be a good option for the natural drying when drying time and quality of product has prime importance.

II. DRYING

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 dried 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 tonnes out of which India accounts for 1.2 million tonnes. Drying the grape produces raisins.

Drying is nothing but removal of liquid from the body. Drying basically consists of two processes that simultaneously occur:

i. Heat flow for evaporation of liquid
ii. Mass transfer of vapour from the body of solids.

The factors governing the rates of these processes will finally decides total the drying rate. The different dryers may utilize heat transfer by convection, conduction, radiation. The drying process of any agricultural good or product is a complex phenomenon which consists of both heat and mass transfer processes which depends on different variables such as temperature, humidity and velocity of the air stream and internal variables which depend on parameters like surface conditions (rough or smooth surface) and size-shape of products.

III. SOLAR DRYING TECHNOLOGY

Solar drying has been adopted by farmers since time immemorial for drying of grains, fish, plants, seeds, fruits, meat and other agricultural goods. Many researchers developed many designs to utilise the solar energy which is free, clean and renewable to dry the products. But open sun drying method has many limitations like high labour cost, large area requirement, lack of control over the process, contamination and most importantly longer drying times. Drying of products inside a close chamber will reduce the drying times as well reduce the other limitations of open sun drying. In many rural countries, electricity and supplies of other non-renewable energy sources are either unavailable, unreliable or too costly. These cases will make suitable grounds for the use of solar dryers. Over last few years many researchers are working in the field of to replace electric energy consumption by usage of solar energy. Solar energy and its advantages and economy reasons offer a good opportunity for using solar drying all over the world

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IV. DEVELOPMENT OF EXPERIMENTAL SETUP

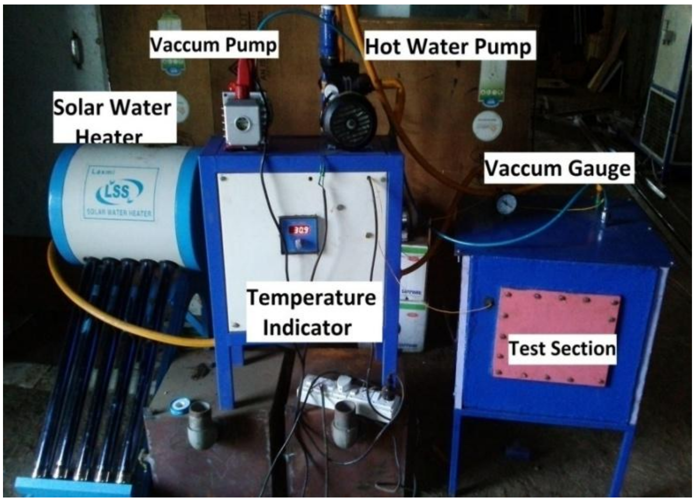


Fig. 1 Experimental Setup

Above fig. 1 shows the arrangement of different components used in the experimental Setup. The main components Solar water heater, Vacuum pump, Hot water pump, vacuum gauge, test section are shown in this figure. First water will be heated in the solar water heater where water heating will be done by using solar radiations. This hot water will be circulated using pump in a drying chamber where vacuum is maintained using vacuum pump.

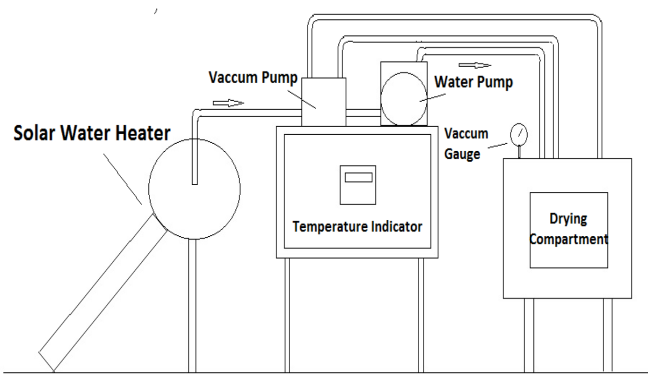


Fig. 2 Experimental setup

Fig 2 shows the schematic arrangement of the experimental set up used for current research work. The connections and arrangement of different components of the system can clearly be observed in this figure.
A solar water heater is used to heat the water which will be sent to drying chamber. Fig shows a drying compartment in which grapes are kept for drying. And drying process will be continued using a heat exchanger in which hot water will be circulated using a hot water pump, hot water in the heat exchanger will heat the space

inside the drying chamber and moisture in the grapes will be removed. A vacuum pump is used to create a vacuum inside the drying chamber.

The vacuum in the drying chamber will be observed by a vacuum gauge installed at the top of drying compartment. And temperature of different points in the system will be observed using temperature indicator.

V. CALCULATIONS

1. Amount of moisture removed:

$$\text{Amount of moisture removed} = \begin{pmatrix}\text{initial weight of} \\ \text{grape sample}\end{pmatrix} - \begin{pmatrix}\text{Final weight of} \\ \text{grape sample}\end{pmatrix}$$

= 0.250 -0.244

= 0.006 kg

2. % of moisture loss :

$$\% \text{ of moisture loss} = \frac{\begin{pmatrix}\text{initial weight of} \\ \text{grape sample}\end{pmatrix} - \begin{pmatrix}\text{Final weight of} \\ \text{grape sample}\end{pmatrix}}{\substack{\text{initial weight of} \\ \text{grape sample}}} *100$$

$$\% \text{ of moisture loss } = \frac{0.250 - 0.244}{0.250} \text{x}100$$

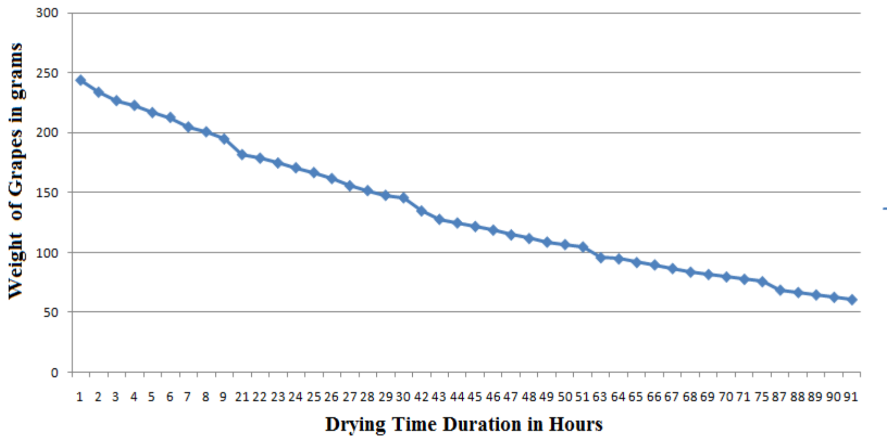
= 2.4%

3. Drying Rate:

$$\text{Drying Rate} = \frac{\text{Weight of Sample in kg}}{\text{Drying Time in hour}}$$

$$= \frac{0.244}{01}$$

FOR VACUUM PRESSURE 55 MM OF HG
Drying Time Vs Weight of Grapes



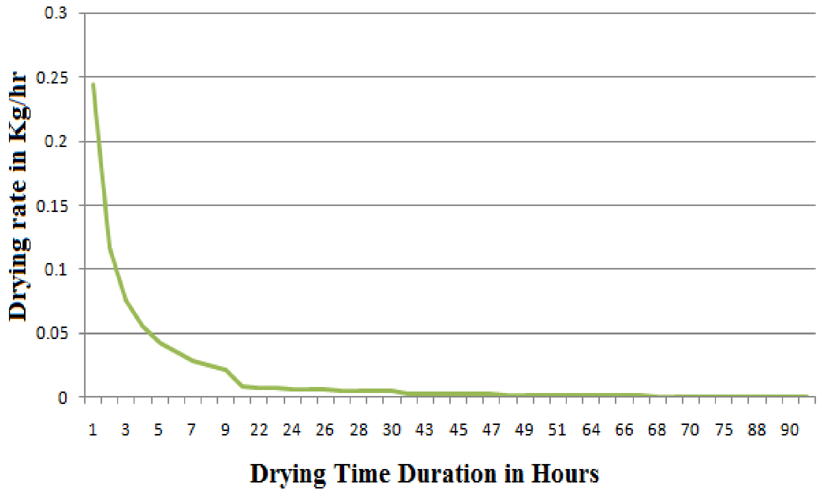
Graph No. 1 Drying Time Vs Weight of Grapes

The experiment is conducted for four and half day until the weight of grapes reached to the required 63.33 grams which have 25% moisture essential for good quality of raisins.

From graph 1 reductions in weight of grapes with respect to drying time can be observed. It can be seen that the weight of grapes goes on increasing from 250 grams to 63.33 gram which is the minimum amount of moisture required in the raisins. Initially a heat will be given to the drying chamber through the heat exchanger provided inside the drying chamber by hot water from solar heater. The moisture in grapes will be removed by the heat and vacuum created by vacuum pump. This will lead to reduction in weight of the grapes sample, this reduction in weight is nothing but the moisture removed by dryer. It can be also seen in this study is on single day reduction in weight of grapes is lower in the morning, it increases after noon and it again decreases at evening. This is due to the fact that water heated in solar heater will have same fluctuations in its output temperature which will affect the space heating in the drying chamber which will further affect the moisture removal process.

Graph 1 also shows small fluctuations at the open night drying, as it is night and heating is stopped the moisture removal process is reduced averagely grape samples only lost 10 grams of moisture in open dying which is achieved in single hour at the start of drying through vacuum dryer.

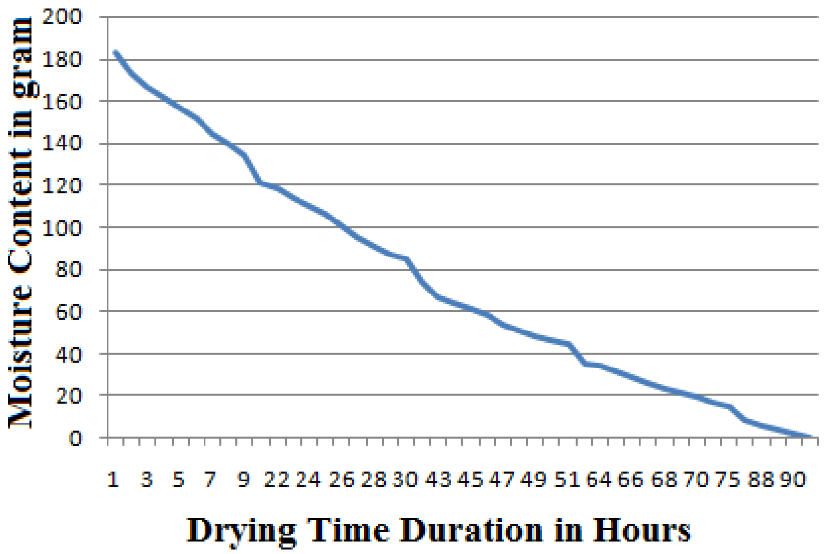
DRYING TIME VS DRYING RATE



Graph No. 2 Drying Time Vs Drying Rate

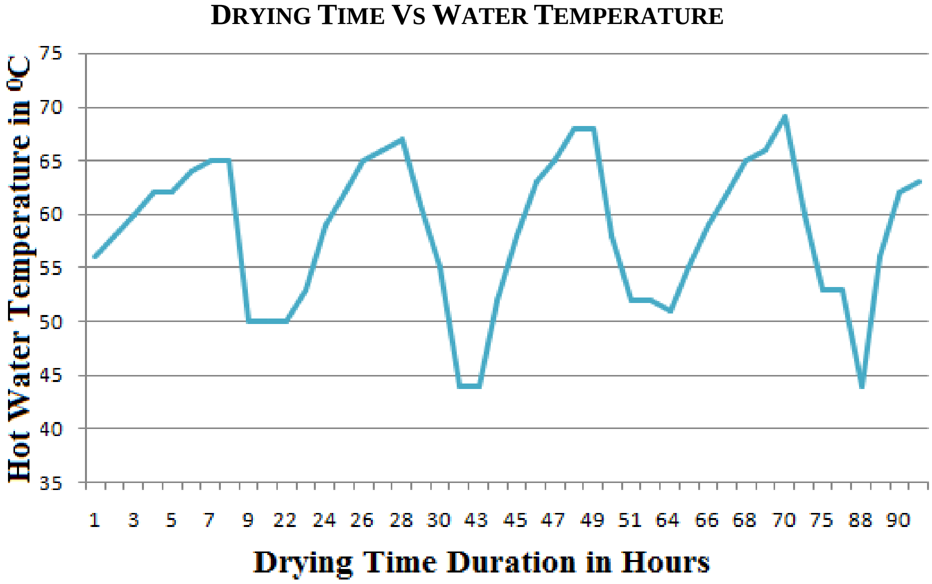
Graph 2 shows the drying rate of grapes with respect to drying time. From this graph it can be observed that the drying rate of grapes is high at the initial period of drying and it decreases at the end of drying. This is due to fact that initially there will be high moisture content present in the grapes so the moisture rmoval will be much easier trough heating and vacuum but as the moisture content decreases the further removal of moisture becomes much difficult. It can be seem that at highest drying rate observed is 0.244 kg/ hour which is at initial hours, it further decreases lowly and after 22 hours of drying it becomes 0.0071 kg/hr this low value of drying rate becomes a 0.0007 kg/hr at the end of drying process.

DRYING TIME VS MOISTURE CONTENT



Graph No. 3 Drying Time Vs Moisture Content

Graph 3 shows the moisture content present in the grapes with respect to drying time. For vacuum dryer at 55 mm of Hg pressure the drying process takes 91 hours, so reduction of moisture in the grapes over these 91 hours is presented on this graph. For good quality of raisins the 25% moisture should be present in the raisins otherwise raisins becomes completely dry and will not taste good. So as sample weight is 250 grams dryer has to remove 186.66 grams of moisture and remaining 63.33 grams should remain in the raisins. This graph shows the removal of these unwanted 186.66 grams of moisture with respect to time. It can be observed that the moisture content in the grapes decreases with increase in the drying time, the moisture content reduction is almost linearly except the some fluctuations arise at the time of open night drying. This graph shows that over a period of 91 days grape sample losses 186.66 grams of moisture through mostly vacuum drying and partly due to open night drying.



Graph No. 4 Drying Time Vs Water Temperature

Graph 4 shows the temperature of hot water out let coming out of the evacuated tube solar heater provided in the experimental setup with respect to drying time. This hot water is provided to the drying chamber where it will circulate through a heat exchanger and heat exchanger will transfer heat to space in the drying chamber and space heating will occur inside the drying chamber. Graph shows the fluctuations occurred in the temperature of hot water, these fluctuations are occurred due to daily cycle of sun, the water will get heated by absorbing thermal energy from sun radiations. It can be observed that the drying took place for four and a half days, in this at morning temperature will be low and it increases as intensity of solar radiations are increased. In the afternoon hot water temperature attains its highest values and it decreases in evening. For the simplicity of work and presentation of graph temperature at the end of vacuum drying in the evening is kept constant for night, in the night temperature will be lower but as water will not be circulated in dying chamber at the night it is considered as constant throughout night and the next day again same pattern of hot water temperature is presented on graph.

It can be observed from the graph that drying is continued for four and half day, the highest temperature of hot water observed in these days is 650C, 670C, 680C, 690C and 630C respectively.

VI. CONCLUSIONS

The vacuum solar dryer is evaluated and its different performance characteristics are carefully studied in this work. The effects of different parameters on the drying grapes are carefully observed in this study and conclusions drawn from this study are presented as below;

- The use of vacuum solar grape dryer is found to efficient as compared to sun drying and it also delivers good quality of raisins as it will not contain any external contaminants as drying takes place inside the vacuum chamber.
- Vacuum solar grape dryer reduces the drying time required production of raisins. The vacuum dryer used in this study shows the maximum drying time of four and half days (91 hours) at 55 mm of Hg vacuum pressure as compared to natural drying which can take more than 10 days.
- The use of vacuum solar dryer is efficient and time saving, it should be preferred where good quality of raisins and minimum time is required. But when that is not the case then it will not be preferred as it requires vacuum pump and water pump which requires the electric supply and natural drying does not require any kind of power supply.

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