A PAPER ON GREEN HOUSE SOLAR DRYER

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***ABSTRACT*: Drying is an ancient method use for preserving food stock, over a period of time this method is sophisticated by the use of dryer. Green house solar dryer uses the thermal energy of the sun and principle of greenhouse effect. In this project we studied the most effective way of drying agricultural products like carrot, tulsi, potato etc. In a closed solar dryer, products are protected from rodents, birds, debris, rain and other environmental factors. There are various types of solar dryer available for construction; type can be selected according to the requirement and environment of drying. High temperature is achieved in a closed solar dryer which reduces the amount of time required for drying. Forced convection drying method which increases the flow of air inside the dryer and removes the excess of moisture to the atmosphere. Experiments were conducted by using sample of tulsi, carrot, chili and potato in which comparison was made between open sun drying method and close sun drying method.**

1.1 Introduction

Green house solar drying the thermal energy from the sun generates heat which help in drying different types of product. This technology can be used for various other industrial purposes. Preservation of agricultural produce is one of the problems faced by developing countries. And as time goes on, these problems will be aggravated by the growing dietary needs of the ever increasing population of these countries. In many developing countries large quantities of fruits and vegetables spoil due to inadequate infrastructure, insufficient processing capacities, and growing marketing difficulties caused by intensifying competition and protectionism in the worldwide agricultural markets (http://www.innotech-ing.de/Innotech/english/Processing.html). Up to 70 per cent of agricultural products spoil during the traditional process of open-air drying, especially in tropical and subtropical regions. Drying these products can help solve these problems, while also making an important contribution to improving the population's income and supply situation (http://www.hedon.info/OptionsForDryingOnASmallScale?bl=y). Drying is an important form of food preservation that is often carried out at farm level right after harvest, or especially with highly perishable crops, at peak harvest time when local markets are saturated. Drying vegetables, fruits and meat with thermal energy enables longer storage times and easier transportation. Up to 70 per cent of agricultural products spoil during the traditional process of open-air drying, especially in tropical and subtropical regions.

Solar energy has been used for the preservation of agricultural produce since generations all over the world. Recent research on drying reveals the shortcoming of the open sun drying. In order to minimize the shortcoming of the open sun drying, various drying techniques are proposed. Among them previous effort on greenhouse dryer has been presented in this study. It can be used to do low temperature drying of cereal grains, fruits, vegetables, spices etc. The greenhouse dryer is operated in the two different modes of drying— natural convection and forced convection. Recently development of greenhouse dryer's namely solar tunnel dryer, solar tent dryer, improved solar tunnel dryer, and roof type even span solar greenhouse dryer have been studied. Products dried in the greenhouse dryer were found to be superior in quality as compared to those in open sun drying. In addition, the product is completely protected from external calamities such as rain, insects, and animals (OmPrakash, anilkumar 2014).

2.1 Solar Drying

Solar dryers are devices that use solar energy to dry substances, especially food. There are two general types of solar dryers: Direct and indirect (Norton, Brian ,2013).

2.2 Types of solar dryer

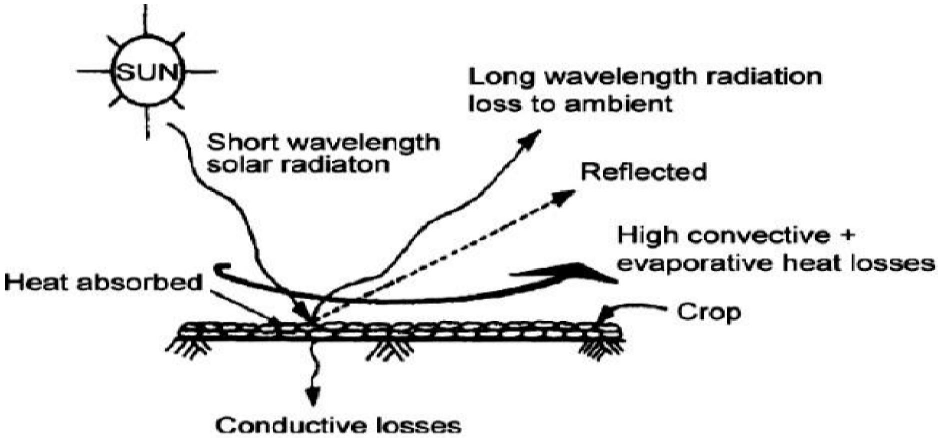
Solar-energy drying systems are classified primarily according to their heating modes and the manner in which the solar heat is utilized. In broad terms; they can be classified into two major groups, namely

• 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 as on 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.



(i)Open sun drying (OSD)

Figure 1: Open sun drying (Sharma et al., 2009)

From fig 1 we can see that 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 starts 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 loss there 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 the drying 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 solar drying (DSD)

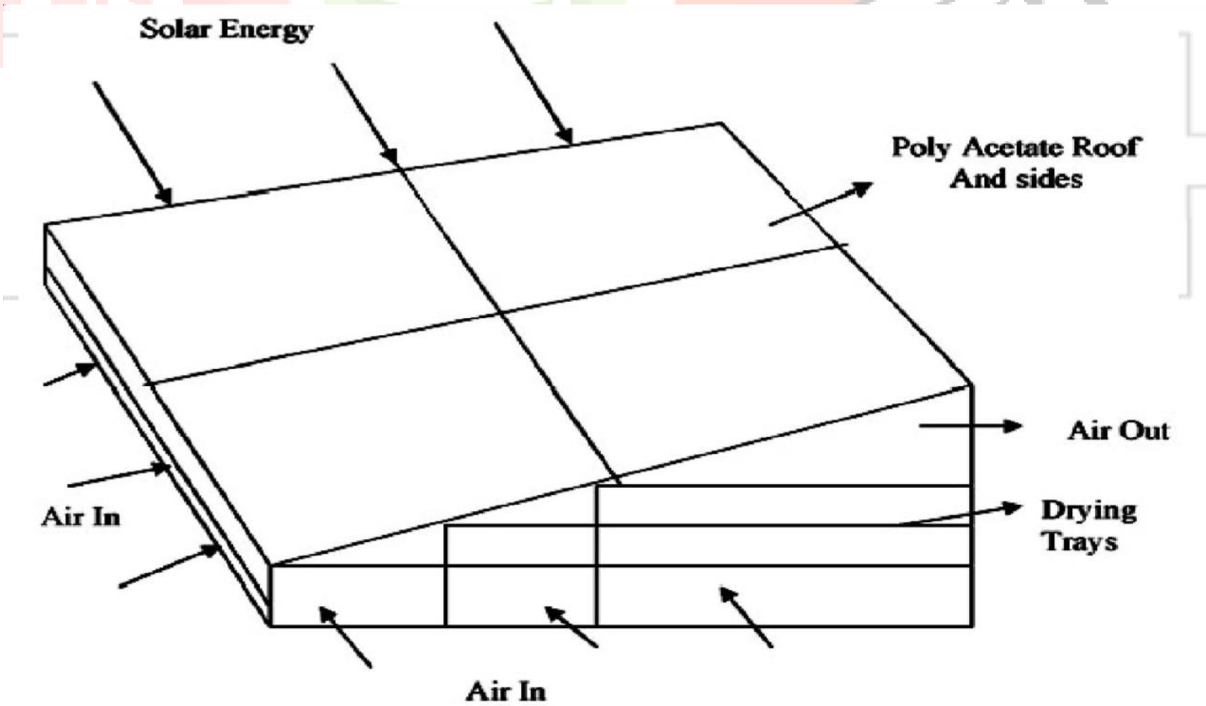


Figure 2: Direct solar drying (Ekechukwu, Norton, 1999)

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 shows a schematic of a simple direct dryer. 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.

(iii)Indirect type solar drying (ISD)

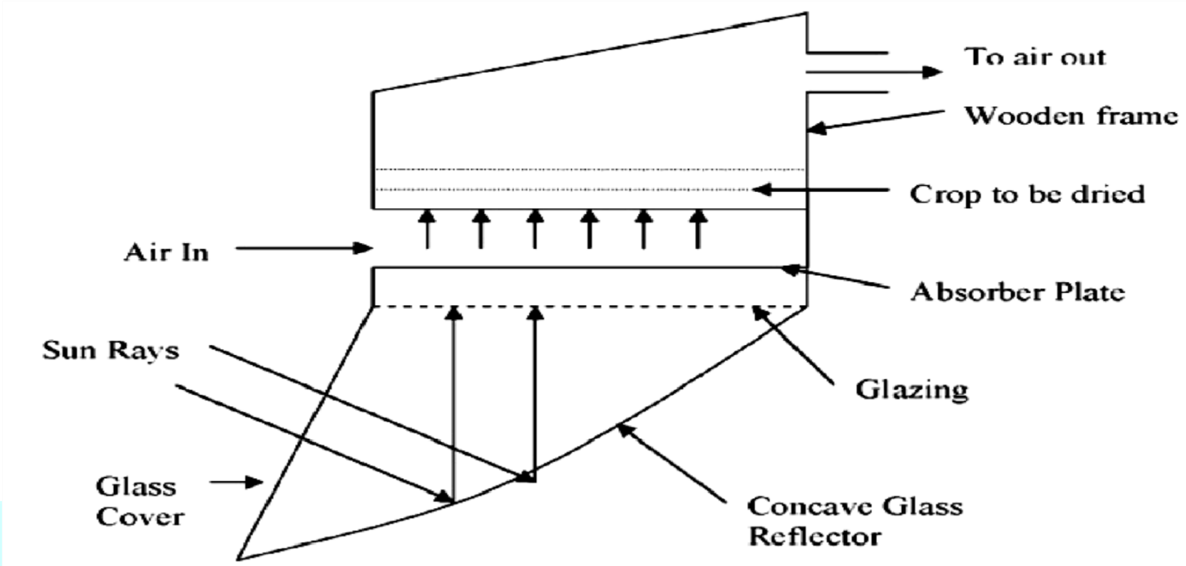


Figure 3: Indirect solar drying (Goyal, Tiwari1999)

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. Fig 3 shows schematic representation of indirect solar dryer. The area of 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.

2.2 Green House Solar Dryer

In dependent a green house solar dryer the thermal energy from the sun generates heat which helps in the drying different types of product, has been successfully used. This technology can be utilized for various other industrial drying purposes. Greenhouse drying has no harmful impact on the environment and is on weather condition.
Difference between green house solar dryer and solar dyer is that, solar dryer can use any electric device for enhancement of efficiency, but green house solar dryer uses the effect of green house effect only.,

2.4 Types of greenhouse solar dryer

Natural convection greenhouse solar dryer:
In this type of dryer product to be dried is place on the platform or mesh plate. Air flow is natural. It flows through the inlet, gets heated and passes through the product. Heat is transferred and moisture is removed from the product. Moisture then is let out from the upward direction.

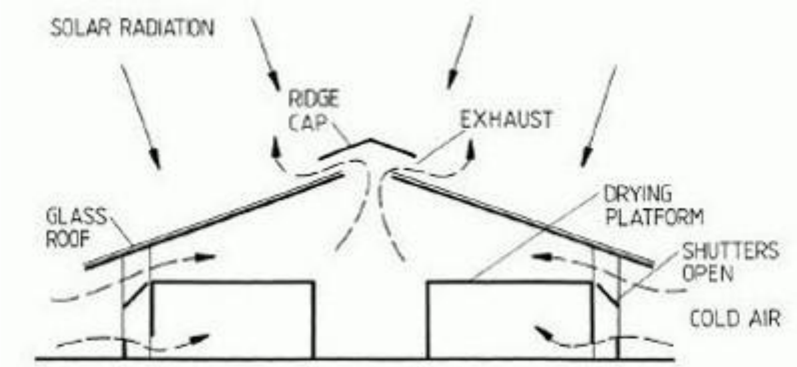


Figure 4: natural convection green housedryer (https://sites.google.com/site/solardryingmodelling/project-overview-1)

● Forced convection greenhouse solar dryer

This dryer uses an external device for flow of air unlike natural convection. Device used can be a fan or blower. The important difference between the two types of dryers is that whereas in the case of natural dryers air flow is induced by thermal gradients, in case of forced convection dryers air is forced through a solar collector.

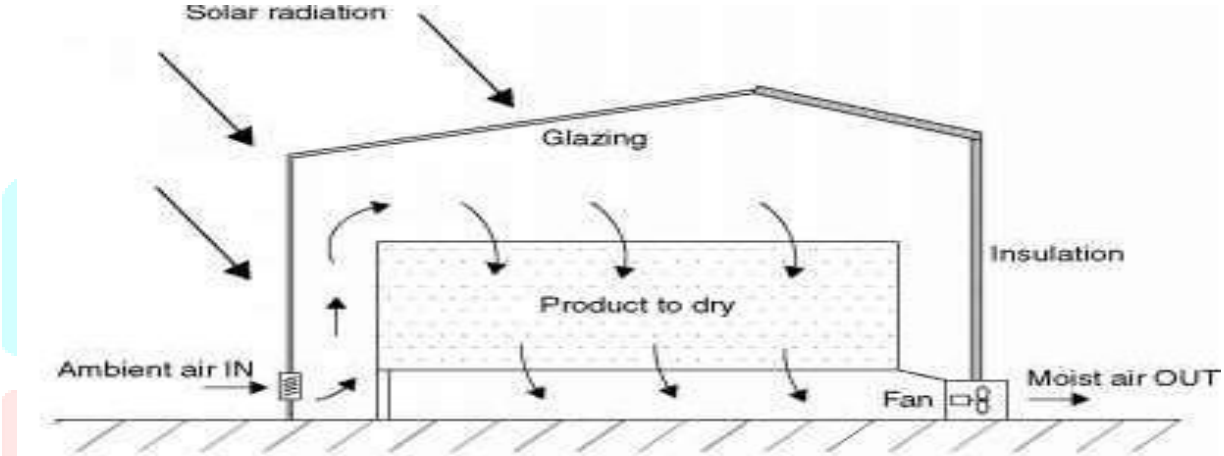


Figure 5: forced convection green house solar dryer (https://sites.google.com/site/solardryingmodelling/proje ct-overview-1)

3.1 Experimental Methodology

Drying is one of the methods used to preserve food products for longer periods. It has been established as the most efficient preservation technique for most tropical crops. This project presents the design, construction and performance of a green house solar dryer for food preservation. In this dryer, the solar radiation passes through the glass and was absorbed by
the product and therefore increases the temperature inside the drying cabinet. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. 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.

3.2 Experimental set up

Figure 6: Arrangement of trays

Figure 7: Top view of green house solar dryer

3.3 Dimensions of dryer:

Table 1: Dimensions of dryer

Equipment	scale
overall length	**0.47m**
Overall height	**0.66m**
absorber plate dimension	**0.6*0.3m**
glass cover thickness	**0.002m**
Insulation total thickness	**0.06m**
Gap between absorber plate and glass cover	**0.005m**
Gap between absorber plate and insulation	**0.05m**
No of trays	**2**
Tray dimension	**0.3*0.6m**
Distance between trays	**0.15m**
Tilt angle of the collector	**13^0**

3.5 Design approach:

There are two basic mechanisms involved in the drying process. The migration of moisture from the interior of an individual material to the surface, and the evaporation of moisture from the surface to the surrounding air. 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. The rate 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 (Thoruwa, T.F.N., Johnstone, M.C., Grant, A.D., Smith, J.., 2000).

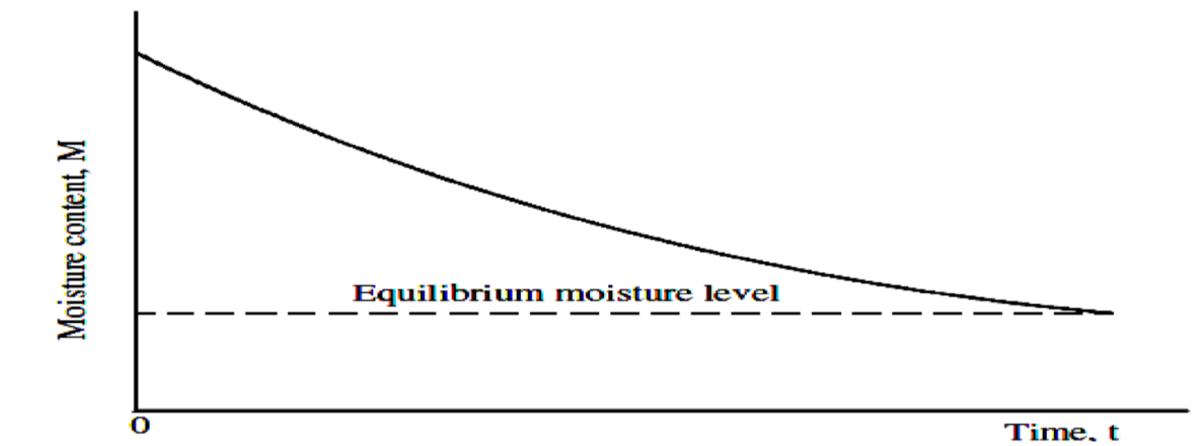


Figure 8: Rate of moisture loss (Sarvasindhumishra, Rrishabhyadav, 2015)

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 was migrated by diffusion and in the products with high moisture content, the diffusion of moisture was 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 vapor pressure and hence reduce the moisture evaporation rate(sarvasindhumishra, rishabhyadav, 2015)**.**

3.6 Air properties:

The properties of the air flowing around the product are major factors in determining the rate of removal of moisture. The capacity of air to remove moisture is principally dependent upon its initial temperature and humidity; the greater the temperature and lower the humidity the greater the moisture removal capacity of the air. The relationship between temperature, humidity and other thermodynamic properties is represented by the psychometric chart. It is important to appreciate the difference between the absolute humidity and relative humidity of air. The absolute humidity is the moisture content of the air (mass of water per unit mass of air) whereas the relative humidity is the ratio, expressed as a percentage, of the moisture content of the air at a specified temperature to the moisture content of air if it were saturated at that temperature.

3.7 Solar component:

Collector: The heat absorber of the solar air heater was constructed using well-seasoned woods painted black. The solar collector assembly consists of transparent cover (glazing). The solar radiations from the sun get trapped inside the collector.

Drying cabinet: It is constructed from wood. 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.

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

4.1 Process description

A green house solar dryer was placed under the sun, were heat was directly received to the collector surface of the dryer all-round the day without obstruction. Then the known amount of sample was inserted inside the drying cabinet and was placed on the upper and bottom tray. The sample was chopped into thin sliced if the surface area of the sample increases, which speeds up the process of the drying. Temperature of the cabinet was monitored and controlled by the duct provided at the top and the bottom. They are use to take out the excess of moisture from the cabinet

4.2 Experimental Procedure:
Procedure for dryer

1. First we insert known amount of sample in the dryer. Sample may be sliced, so that surface area of the product is increased and thus rate of drying.

2. After that the sample was placed on the mesh plates and they should not get overlapped, which would reduce the surface area and rate of drying
3. Place the sample in the mesh plates and then place the dryer under the sun.

4. At a time interval of every one hour or as per samples necessity we will take the temperature of the green house solar dryer and adjust the air flow so that the excess of heat and moisture was taken out into the surroundings.

5. After 5 to 6 hours the sample was taken out from the drying cabinet and weight of final sample was to be measured.

Procedure for oven

1. To calculate initial moisture content of the sample we place the known amount of sample in oven.
2. Keep the sample in oven for 5 hr at 101^{0}C, or adjust the temperature and time as per the requirement of the sample.
3. Remove the sample and calculate the final weight of the sample.

5 Results and Discussion:

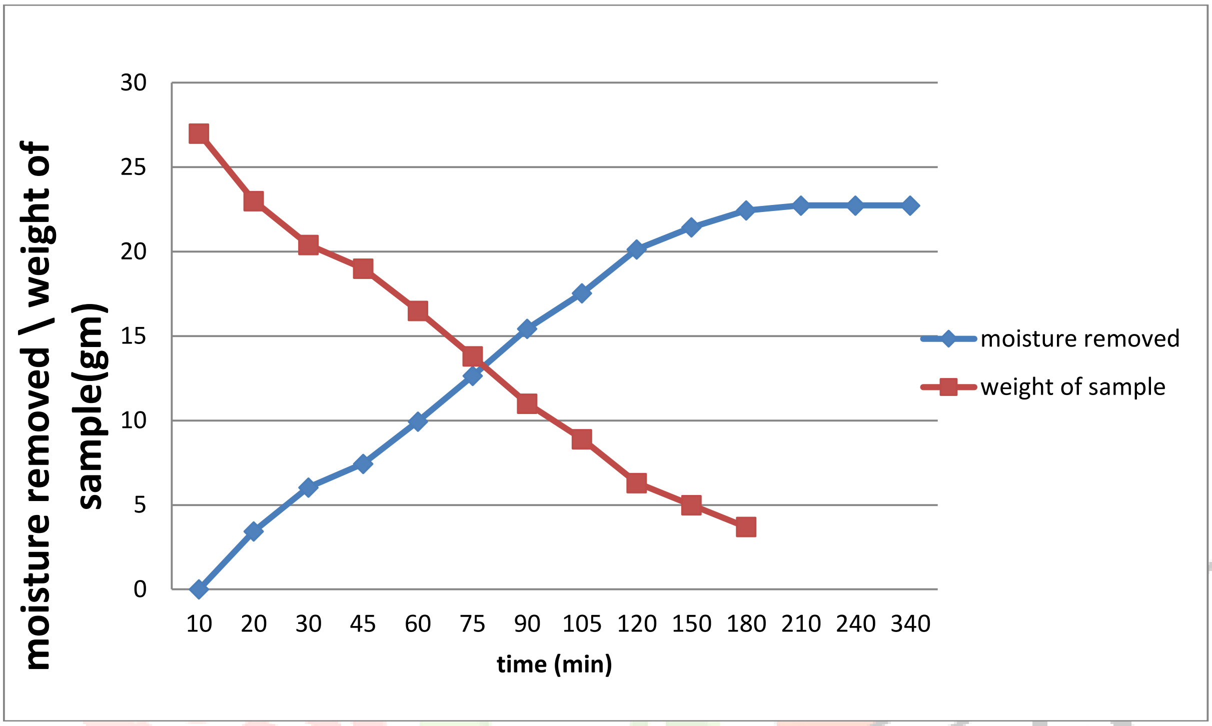


Figure 9: Rate of moisture removal for tulsi

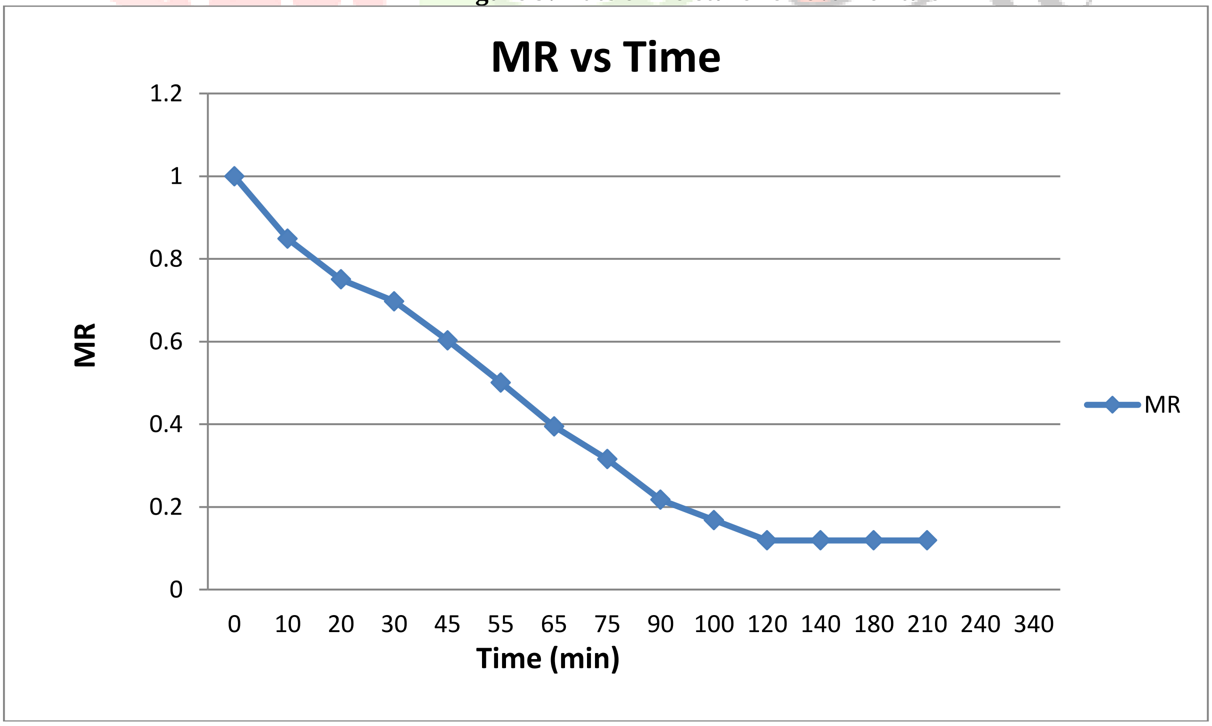


Figure 10: Rate of moisture on dry basis removal for tulsi

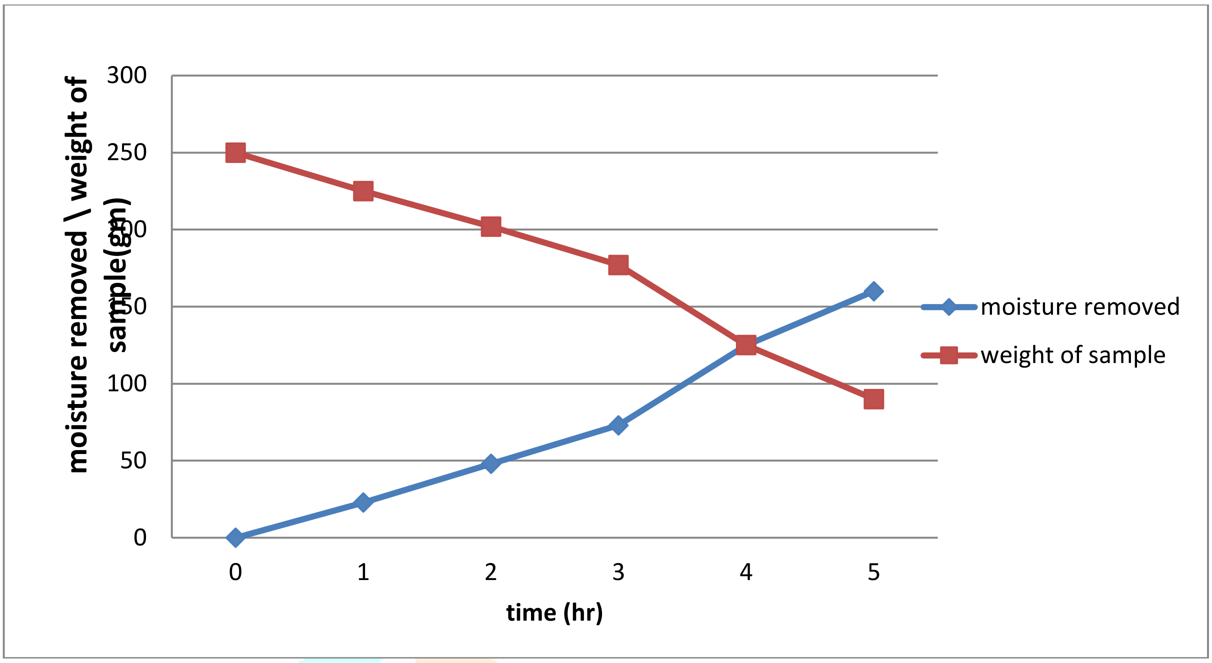


Figure 11: moisture removed/ weight of sample vs time for chili

In the experiment conducted, from the graph we can asses that rate of moisture removal increases rapidly but at a point it becomes very slow and point reaches were rate of moisture removal nil. Dryer was capable to remove total 55.51% of moisture from the sample in 5 hours.

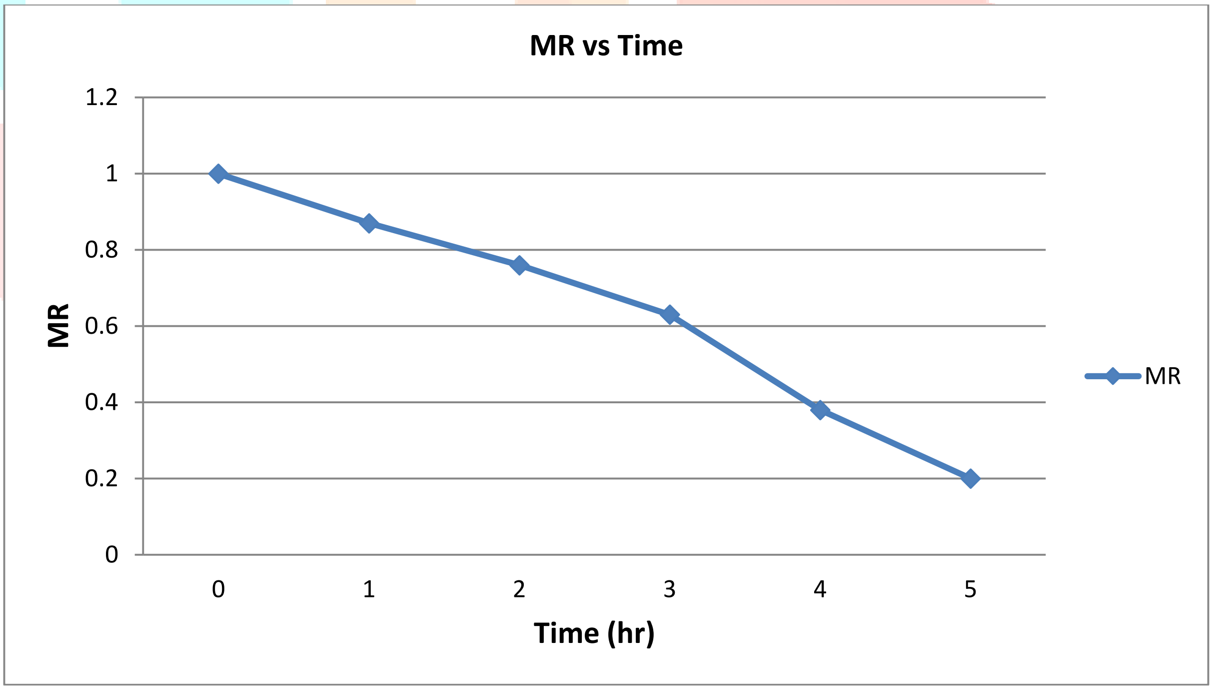


Figure 12: Moisture removed on dry basis vs time for chili

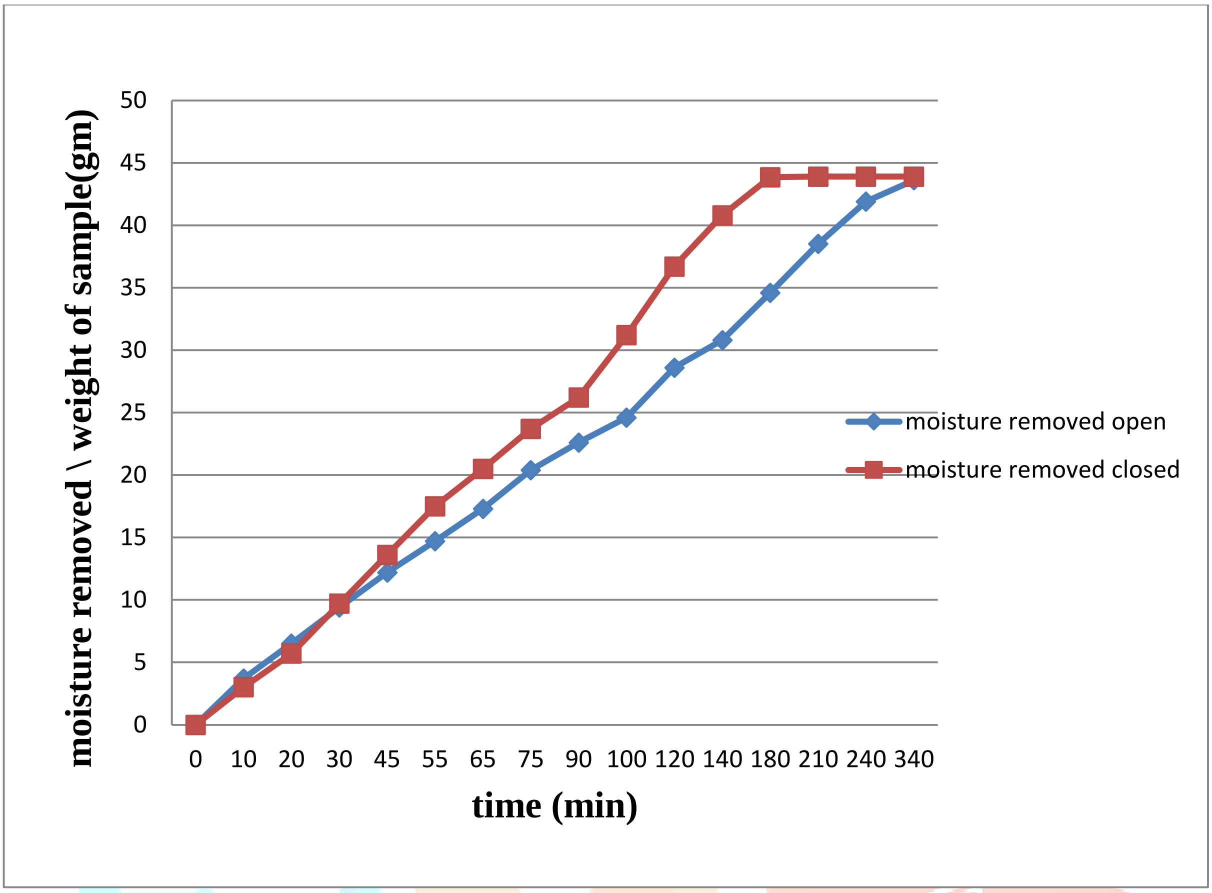


Figure 13: Comparison between open and close method for their moisture removal for potato

In above we have the graph of moisture removed in open and close method with respect to the time. Initially when the drying begins the open drying method has slightly higher temperature then that of close method due to which moisture removal is also high. This is because in close drying method it take time for the dryer to increase the temperature of the air within, but once the increase in temperature is achieved it removes the moisture at much higher and faster rate than that of the open drying method. As this drying goes on in close method it reaches the critical point after which there is no moisture removal obtained in dryer. In open sun drying it takes additional three hours to remove same quantity of moisture as that of the dryer.

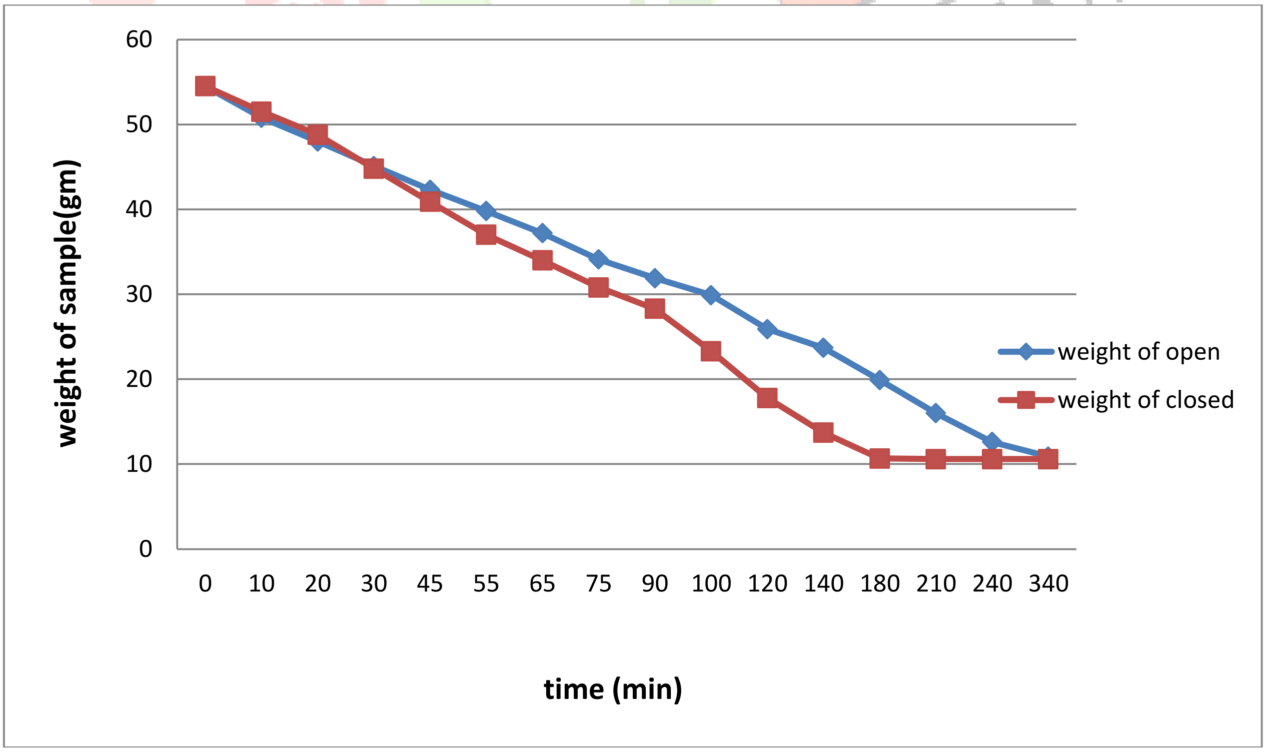


Figure 14: Comparison between open and close method for their weight reduced for potato

In above graph there is comparison between weights of sample decreasing with respect to the time for both the method. Weight reduced is nothing but moisture removed from the sample same as above graph instead of moisture removed we have considered the weight of the sample.

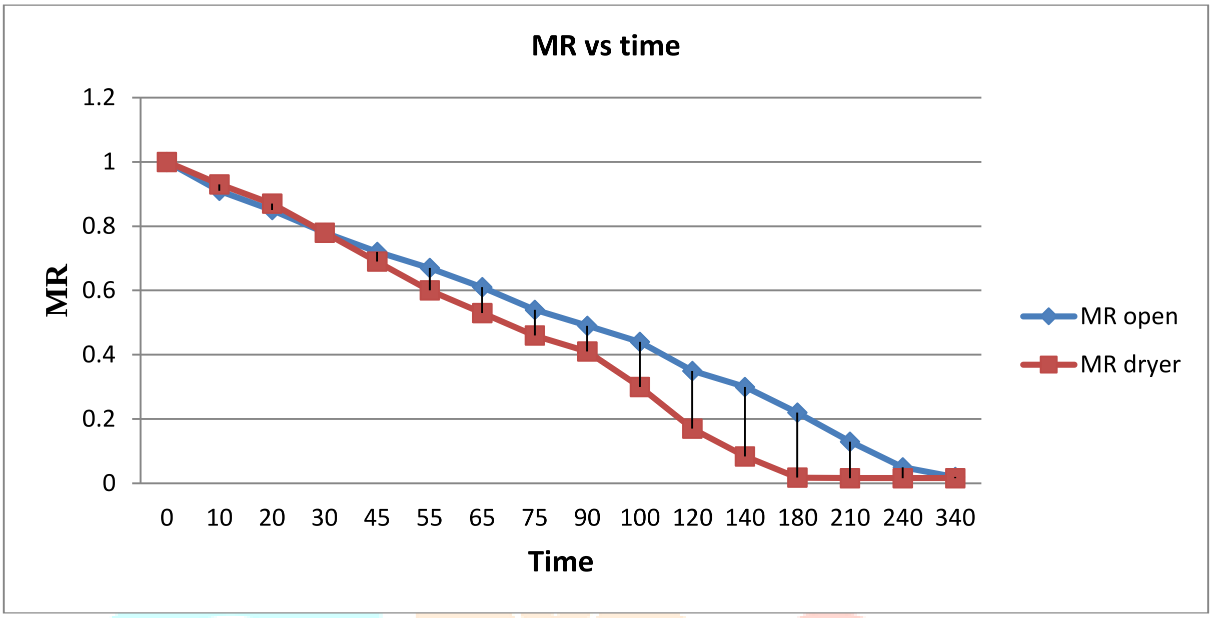


Figure 15: Comparison between open and close method for their MR on dry basis vs. time

As we can see in the above graph rate of moisture removal on dry basis is comparatively higher in the dryer then that of the open drying method due to increase in the temperature.

By comparing the readings we obtained, we took chili's with initial moisture content of 80.91% over a time duration of 7 hr we were able to remove 55.47% moisture from the sample. But when same experiment conducted by other person on chili, use sample with initial moisture content of 80% over time duration of 48 hr were capable in removal of 75% of total moisture content. Moisture removed by our experiment was quiet low compare to that of others. But time duration used by us was of 7 hr compared to that of theirs 48 hr (Jyoti Singh, 2015).
Potato experiment we conducted had initial moisture content of 80.89% over time period of 5hr 40 minutes, moisture removed was 76.41%. When compared to others who conducted the same experiment on potato chips, with initial moisture content of 75% over duration of 72 hr was capable in removal of 62% of moisture content (Jyoti Singh, 2015). Other experiment conducted in mixed mode dryer, sample took were potato with initial moisture of 82% over time duration of three hundred and thirty minutes final moisture content was 12% (Tripathi, 2013).

After study we have found that the green house solar dryer gives more heat inside the chamber than that of the outside temperature. After 5 hr 40 minutes of drying, initial moisture content of tulsi which was 97.96%, dryer was capable in removing 86% of moisture from the sample. For potato, with initial moisture content of 80.91%, over a period of 5 hr 40min, dryer was capable in removing 76.41% of moisture. Chili with initial moisture content of 80% were dried in dryer for 5 hr, and dryer was capable in removing 55.51% of moisture. Rate of moisture removal was higher for tulsi and potato as compared to chili; this was because tulsi leaves were thin, due to which not only it had higher surface area but also heat was effectively penetrated, which in return removed the moisture effectively. Potato also had high rate of moisture removal, potato were sliced and evenly distributed on drying trays without overlapping each other, which increased the surface area of drying and thus effective in moisture removal. But in case of chili's they were not sliced, but were placed whole in the dryer due to which rate of moisture removal was less compared to other samples. Green house solar dryer is the best alternative technology to avoid disadvantages of conventional drying methods. This type of dryer is designed for a particular crop and atmospheric conditions of location. Various types like mixed mode, natural circulation, forced circulation, green house type and tunnel type of solar dryer. In mixed mode of drying the product may dry in less time compared to direct and indirect mode drying. But indirect mode of product drying will essential whenever requires avoiding direct exposure of product to the solar radiation. Forced circulation solar drying shows better result with reduced drying time than open air solar drying and natural circulation solar drying. But natural and forced circulation solar drying should use for limited quantity of product. For large quantity of product drying, it is better to use the green house type solar dryers.

The performance of existing greenhouse solar dryercan still be improved upon especially in the aspect of reducing the drying time, and probably storage of heat energy within the system by increasing the size of the solar collector, making dryer air tight and avoiding any leakages.

Conclusion

The Greenhouse solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of agricultural crops. The product inside the dryer requires less attentions, like attack of the product by rain or pest (both human and animals), compared with those in the open sun drying. The dryer was used to dry tulsi leaves, potato and green chili. There was ease in monitoring when compared to the natural sun drying technique. The capital cost involved in the construction of a greenhouse solar dryer was much lower to that of a mechanical dryer. Also from the test carried out, the simple and inexpensive dryer was designed and constructed using locally sourced materials. . In this experiment we find that how much moisture removed from the sample which was present in solar dryer. In this experiment we took different samples, they were sliced thin in round shape to increase the surface area of drying, then were placed inside the dryer. We found that temperature inside the dryer is higher than outside temperature. As per our experiment the maximum peak temperature inside the drying chamber is 65°C during mid-day (3pm).

Experimental observation shows that the solar dryer can be used as an alternative in case of food preservation and the efficiency was 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.

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