International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 08 | August - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

Experimentation for thermal parameters to check the performance of Solar Dryer for Onion (Allium cepa) in Vidarbha Region

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Abstract - The solar drying system utilizes solar energy to heat up air and to dry any food substance loaded, which is beneficial in reducing wastage of agricultural product and helps in preservation of agricultural product. Based on the limitations of the natural sun drying e.g. exposure to direct sunlight, liability to pests and rodents lack of proper monitoring, and the escalated cost of the mechanical dryer, a solar is therefore developed to cater for this limitation. This project presents the development and performance of a natural convection solar dryer for Allium species crop preservation. In the dryer, the heated air passes through a separate solar collector which consists of absorber plate and transparent cover to the drying chamber. Inside the drying chamber food commodities are kept to be dried.

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 temperature rise inside the drying cabinet was up to 65% for about three hours immediately after 12.00h (noon). 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.

***Key Words*:** Solar Energy, Allium Species, Natural Convection Solar Dryer, Solar collector

1.INTRODUCTION

1.1 Background of the study

Solar air heaters are simple devices to heat air by utilizing solar energy and it is employed in many applications requiring low to moderate temperature below 80°C, such as crop drying and space heating. Drying is one of the styles used to save food products for longer ages. The heat from the sun coupled with the wind has been used to dry food for preservation for several times. Drying is the oldest preservation fashion of agrarian products and it's an energy ferocious process.

High prices and deficiency of fossil energies have increased the emphasis on using indispensable renewable energy coffers. Drying of agrarian products using renewable energy similar as solar energy is environmental friendly and has lower environmental impact. Different types of solar dryers have been designed, developed and tested in different regions of the tropics and subtropics. The major two orders of the dryers are natural convection solar dryers and forced convection solar dryers. In the natural convection solar dryers the tailwind is established by buoyancy convinced tailwind while in forced convection solar dryers the tailwind is handed by using addict operated either by electricity/ solar module or reactionary energy. Solar thermal technology is a technology that's fleetly gaining acceptance as an energy saving measure in agrarian operations. It's preferred to other indispensable sources of energy similar as wind and shale, because it's abundant, indefatigable and non-polluting. Solar air heaters are simple bias to toast air by exercising solar energy and it's employed in numerous operations taking low to moderate temperature below 80 °C, similar as crop drying and space heating. [1]

1.2 Part of Solar Drying in Indian Agriculture and its Economics

In a developing country like India, having the second largest population and husbandry as the source of income to nearly 60 of total population, post-harvest and storehouse loss is a major double bind, which needs to be addressed in due industriousness. Numerous food preservation ways like cold storehouse, drying, etc. have been evolved out over the times to attack the below losses. The major constraint is that nearly all the technologies are exercising reactionary energy coffers, which are a depleting veritably presto and wise use of this precious coffers are preferred for long term energy sustainability thus, sustainable styles for food preservation are the need of the hours. Solar Drying is one of the stylish choices in this environment. Different models of solar dryers have been developed and good amount of exploration is progressing in utmost of the countries to propagate the solar drying technology for value addition of agrarian products.[2]

1.3 Problem Statements

We frequently observe that utmost of the food products are lost only because of lack of effective conserving styles and structure. Indeed the food products spoil during transportation and storehouse. The main reason for food products to turn useless is humidity. This makes it veritably much necessary to maintain only minimal or required position of humidity and remove excess of it from the food products. The most popular system used for removing this humidity in colorful corridor of world is open air drying as this system is free of cost and doesn't bear any special system. But during open air drying there's threat of crops being attacked by insects indeed the ultraviolet shafts may deteriorate the nutritive position in the crops. This makes the food hygienic.

Problems of onion growing farmers as identified in the study include:

- Poor storage capacity, leading to qualitative and quantitative losses and price fluctuations.
- Storage losses comprise of loss due to moisture, shrinkage, decay and sprouting.
- In case of glut in the market and with improper storage facilities, prices crash and sometimes the farmers are forced to destroy their crops

Therefore increasing the shelf life of onions assumes great importance. The important suggestions of the study include:

- Radiation to reduce storage losses.
- Onion dehydration to reduce gluts.
- Attempts to improve the share of farmers in terminal price and also to reduce the length of marketing channels should be undertaken.
- Co operative marketing and direct marketing to final consumers by the farmers should be promoted.
- Pledge financing should be made popular.

1.4 Project Objectives

The main aim of this project is to design and fabricate Solar Dryer for *Allium* family Crop Species Drying**.**

The main objectives of our project are:

1. To Study different types of Solar Dryers.
2. Promote use of nonconventional energy for agricultural food processing.
3. Develop efficient and low cost Allium crop species drying technology.
4. To improve eco-efficiency.

2 LITERATURE REVIEW

This chapter discusses about the former inquiries that have been done which is related to this design. This design requires good understanding and knowledge about drying styles. Hence executing a exploration is necessary to gain all the information available and affiliated to this content. The information or literature review attained is basically precious to help in the fabrication and specification of this final time design. With this ground established, the design can be fulfilled with guidance and fierceness in achieving the target mark. The sources of the review are uprooted from journal, composition, books and websites.

The solar drying technology is a classical illustration to show how sun's free energy could be effectively employed for the benefit of humanity. India has one of the oldest societies in the world with the different culture, climate, food habits, etc we learned the art of husbandry in our army itself and it has taken speedy growth since its independence. As of now, India holds the second largest husbandry account to179.9 million hectares. Green Revolution has elevated into the second largest import and consumer of food grains in the world. [3]

2.1 Types of Solar Driers

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:

- Active solar-energy drying systems (most types of which are often termed as hybrid solar dryers) and
- Passive solar-energy drying systems (conventionally termed natural-convection solar drying systems).

Three distinct sub-classes of either the active or passive solar drying systems can be identified which vary mainly in the design arrangement of system components and the mode of utilization of the solar heat, namely:

- Direct (integral) type solar dryers;
- Indirect (distributed) type solar dryers.

2.1.1 Open Sun Drying (OSD)

Fig. 1 shows the working principle of open sun drying by using solar energy. The short surge length solar energy falls on the uneven product face. A part of this energy is reflected back and the remaining part is absorbed by the face. The absorbed radiation is converted into thermal energy and the temperature of product starts adding. This results in long wavelength radiation loss from the face of product to ambient air through wettish air. In addition to long surge length radiation loss there's convective heat loss too due to the blowing wind through wettish air over the material face. Evaporation of humidity takes place in the form of evaporative losses and so the material is dried. Further piecemeal from absorbed thermal energy is conducted into the innards of the product; this causes a rise in temperature and conformation of water vapor inside the material and also diffuses towards the end face and eventually losses the thermal energy in the form of evaporation.[4]

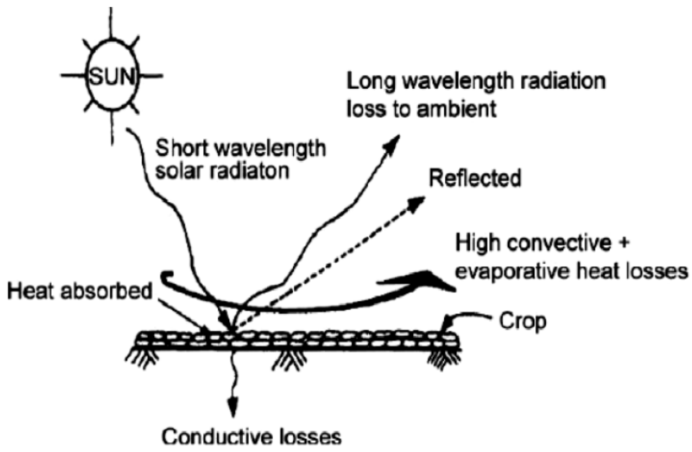

Figure 1: Working principle of open sun drying

2.1.2 **Direct Type Solar Drying (DSD)**

Direct solar drying is also called Natural Convection Cabinet Drying. 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. Further, a part of transmitted radiation is reflected back from the surface of the product. The remaining part is absorbed by the surface of the material. Due to the absorption of solar radiation, product temperature increases and the material starts emitting long wave length radiation which is not allowed to escape to atmosphere due to presence of glass cover unlike open sun drying. Thus the temperature above the product inside chamber becomes higher. The glass cover server one more purpose of reducing direct convective losses to the ambient which further become beneficial for rise in product and chamber temperature respectively.

2.1.3 Direct Solar Drying in Passive Mode

Sengar (2009) designed a low-cost and simple design that used for drying fish. It has been designed for dry commodities under hot and humid conditions prevailing in Konkan region of Maharashtra where most of the agricultural products needs drying. The drying chamber was constructed by bamboo for a 92 cm x 75 cm frame and UV stabilized 200 micron plastic film was used for collection of solar energy. Drying chamber designed in such way that it consist 16 trays of 70 cm x 50 cm size. Mosquito net was used for trays as it betters performance in humid region. Bottom and topside of the dryer was provided with openings for air circulation which will carry away the moisture evaporated from the food.

2.1.4 Indirect Type Solar Drying (ISD)

Fig. 2 describes another principle of indirect solar drying which is generally known as conventional dryer. In this case, a separate unit termed as solar air heater is used for solar energy collection for heating of entering air into this unit. The air heater is connected to a separate drying chamber where the product is kept. The heated air is allowed to flow through wet material. Here, the heat from moisture evaporation is provided by convective heat transfer between the hot air and the wet material. The drying is basically by the difference in moisture concentration between the drying air and the air in the vicinity of product surface. A better control over drying is achieved in indirect type of solar drying systems and the product obtained is good quality.[5]

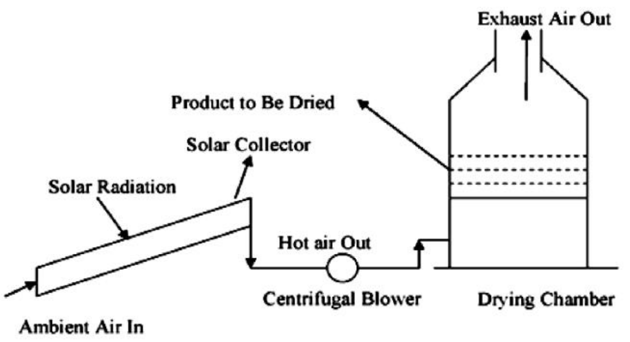

Figure 2 Indirect solar drier (Forced convection solar drier)

3 MATERIALS AND METHOD

3.1 Solar Dryer Components

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

3.1.1 Collector (Air Heater):

The heat absorber (inner box) of the solar air heater was constructed using 5 mm thick Galvanized Iron (GI) plate, painted black, is mounted in an outer box built from GI Plate. The space between the inner box and outer box is filled with heatlon material of about 40 mm thickness and thermal conductivity of 0.043 $Wm^{-1}K^{-1}$. 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 610 mm by 1066 mm and of transmittance above 0.7 for wave lengths in the rage 0.2 – 2.0 μm and opaque to wave lengths greater than 4.5 μm. The effective area of the collector glazing is 0.6 m^2. One end of the solar collector has an air inlet vent of area 0.066 m^2**.**

3.1.2 The Drying Cabinet:

The drying cabinet together with the structural frame of the dryer was built from Galvanized Iron which could withstand 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. This consists of three removable trays made of 13 mm iron nets.

3.1.3 Drying Trays:

The drying trays are contained inside the drying chamber and were constructed from a wire mesh with a fairly open structure to allow drying air to pass through the food items.

3.1.4 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 30° to the horizontal. This inclination is also to allow easy run off of water and enhance air circulation.

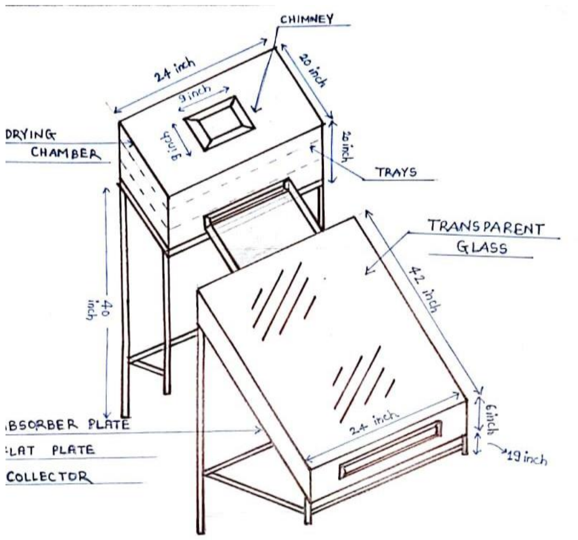

Figure 3 Isometric Drawing of Natural Convection Solar Dryer

3.2 Mathematical Models and Formulations

3.1.2 **Operation of the Dryer**

Fig. 3 shows the isometric drawing of the natural convection solar dryer. The dryer is a passive system in the sense that it has no 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 green house 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. Therefore, an air current is maintained, as cooler air at a temperature *Ta* enters through the lower vents and hot air at a temperature *Te* leaves through the upper vent.

When the dryer contains no items to be dried, the incoming air at a temperature Ta has relative humidity Ha and the out-going air at a temperature Te, has a relative humidity He'. Because Te>Ta and the dryer contains no item, Ha >He. Thus there is tendency for the out-going hot air to pick more moisture within the dryer as a result of the difference between Ha and He. Therefore, insulation received is principally used in increasing the affinity of the air in the dryer to pick moisture.

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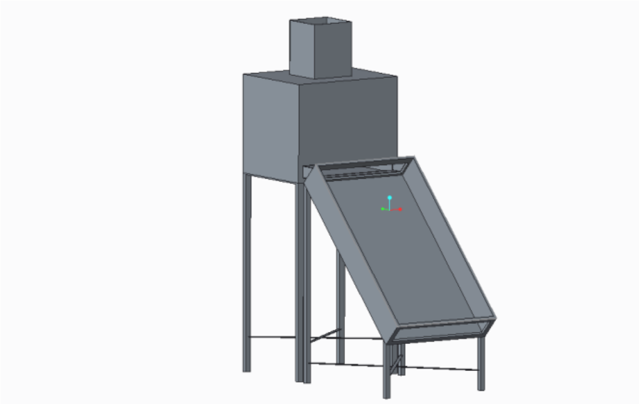

Figure 3 CAD Model of Solar Dryer

3.1.2 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 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 product.

3.1.3 Basic Theory (Formulations)

Some important formulae used are given as follows:

1. Determination of percentage moisture removed from the commodities:

M.R = Mi-MfMi*100

Where,

M.R = % moisture Removed

M_i= initial mass of the sample

M_d= final mass of the sample.

2. Collector efficiency

η_c = Q (useful)Ic*Ac

Where,

Qu= mCpΔt

Ac = collector surface area

I_s = Solar Radiation.

3. Drying efficiency (η_d):

η_d= M.R*L Ic*Ac

Where,

M.R. = mass of moisture evaporatedin one hour of drying.

L= latent heat of evaporation in the dryer temperature.

4. CALCULATIONS

1. **Determination of percentage moisture removed from the commodities in one day**:

M.R = Mi-MfMi*100

For Onion **(*Allium Cepa*)**

M.R = 55100*100

= 55 %

For Garlic **(*Allium sativum*)**

M.R = 52100*100

= 52 %

2. Collector Efficiency (η_c)

η_c = Q (useful)Ic*Ac

= m Cp (T3-Tatm)Ic*Ac

Where, m is mass flow rate from the collector

m = ρ*A*V

= 1.225*(0.0225)*0.25

= 0.007 kg/s

Hence,

η_c= 0.007*1005*(56-34)660*0.636 * 100

η_c = **36.87%.**

3. Drying efficiency (η_d):

The drying Efficiency of Natural Convection Solar Dryer range from 10% to 15%. [16]

η_d= M.R*L Ic*Ac

Where, M.R is Mass of moisture evaporated in one hour of drying.

L is Latent Heat of Vaporization

Ac = collector surface area

I_s = Solar Radiation.

For Onions (*Allium Cepa*)

η_d= M.R*L Ic*Ac

= 0.55*2257000450*0.636*3600*9

= 13.38 %

For Garlics (*Allium sativum*).

η_d= M.R*L Ic*Ac

=0.52*2257000450*0.636*3600*3

= 12.65 %

4. Drying efficiency

- One day Drying efficiency (η_d) for onions = 13.38 %
- One day Drying efficiency (η_d) for garlics = 12.65 %

The average drying efficiency is found out to be **13.01%** for one day.

RESULT AND DISCUSSION

After study we have found that the solar dryer gives more than three-four times heat inside the chamber than that of the outside atmospheric temperature. In 6 hours continuous drying under the same climatic condition and same time it removed 28.73 % (upper tray) and 27.28 % (lower tray) moisture content from inside chamber, whereas at outside only 12.75 % moisture content was removed.

Our experiment of average dryer efficiency for one day was found to be 13.01% while the moisture content for various samples like onions, garlics after drying was found to be 45%, 48% respectively. All the readings were on a day basis i.e for one day.

Conclusion

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 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 Allium Crops such as Onion (*Allium Cepa*)**,** Garlic (*Allium sativum*), etc. There is ease in monitoring when compared to the natural sun drying technique. The capital cost involved in the construction of a solar dryer is much lower to that of a mechanical dryer. 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. 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 64°C during mid-day (3pm) and in an average approximately 60°C-62°C in a full sunny day (9:00AM to 03:00PM). In 9 hours continuous drying in one full sunny day under the same climatic condition and in same time the solar dryer removed a maximum of 52-55% 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 preservation and 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.

The data concluded while performing this experiment is shown in the following table for different samples:

Sr.no	Commodity	Drying Efficiency	Moisture removed in one day
1.	Onion(***Allium Cepa***)	13.38 %	55%
2.	Garlic (***Allium sativum***)	12.65 %	52%

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