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Green House Drying : A Comprehensive Review

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ABSTRACT: *Energy crisis has demonstrated drying of agricultural products as one of the essential subjects of concern. Drying is also required in various cyclic necessities of life. Various methods are available to carry out the process and selection of technology depends on moisture content in crop. One of the technologies that top the list of call is green house drying technology. Much advancement has been gained in green house technology like tunnel dryer, tent dryer etc. This paper reviews the modus operandi of various technologies that have been developed as well as their applications so far. The present study acknowledges about different type of dryer available and also help to choice the best among them which further could be operated in both in active and passive convection mode.*

KEYWORDS: Solar drying, green house dryer, tunnel dryer, crops, mode of drying.

BACKGROUND

Drying of food for preservation for long duration is an old practice followed from the time when human beings have gain their social existence. In early 1900's, the canning of agricultural products as well as freezing was done to preserve it. Then, advent of the idea of drying crops in open sun to dehydrate was done at trial. The concept behind it was that drying of food items makes it possible to cease the growth of bacteria, yeast and mold in food items. Desiccation of some products like potato, bitter guard, tomato, meat etc. is done to preserve it on long run from one season to other. Drying of some food products is done to take out the bitter oils which further can be promoted for medicinal purposes like coriander, basil leaves, ginger, mint etc.

Favourable result for drying depends only on the day chosen for drying of products and attaining optimum temperature for that product for removal of moisture in proper content. But as this segment cannot be anticipated properly, so in premature times the product was kept in open field to dry out. But this has an advantage that if the item to be dried is kept in open environment in sun and left to dry out for numerous days, the items remains to be exposed to rodents, extreme conditions. Therefore, much advancement was required to overcome all the issues across the globe. Many food items might not have been part of today's kitchen, if the concept of removal of moisture has not come in picture. This has not only helped from kitchen point of view that is adding flavors to food but also economically. Thus, to bring situation on track, researchers across the world started working on finding the method and its advancements so that problem faced could be treated well to satisfy the drying process properly.

INTRODUCTION

Drying is an old practice and is a process in which moisture content is removed by application of heat. The heat can be transferred through air, fluid or direct exposure. Drying is the prevalent procedure to carry out to safeguard the agricultural product for prolong period.

Maintenance of the product is necessary to avoid the losses caused due to the wastage, and extraction procedure and for such removal of moisture from the product helps to protect it on long run. The main aim of drying is extraction of free water from food items to preserve it because moisture present in the crop promotes the bacterial and fungal growth which degrade the crop. An agricultural product, according to its required range, should be kept under regulated condition of specific humidity and temperature. Most of the agricultural products require temperature for safe drying in the range from 45-60^{o}C. Supply of hot air leads to vaporization of moisture as well as separate the water vapour after drawing out of food products. The drying is not limited only to food items for human consumption, but also find its use in other areas like drying of organic crops i.e., timber and rubber and inorganic material like paint etc. Decrease in volume and weight, reduces packing,

storage and transportation cost as well as allows storing ability of the product under ambient temperature. Countries that are on the path of developing, needs feature like this.
Two stages that happen in drying are:

a) One occurs at the constant rate on drying material surface which is identical to the vaporization of water into the ambient.
b) Following first, the second occurs according to the properties of product under drying process with decreasing drying rate.

Pre-treatment of the selected products is necessary as diseased and rotten agricultural products may form the basis of degradation of other product set aside also. This even leads poor processing of the foods. Even the size and thickness of the product also affect the drying process and rate of drying. Most practiced solar drying method is open sun drying.
Drying in open sun was started as a method to preserve food for long time in 1800's and 1900's and even before and carried out now-a-days also. In it, radiations are allowed to directly fall on the crop, placed on the mat in a open ground. This provides heat to the crop and leads to evaporations of moisture from crop. In this process, heat energy is lost due to reflection, radiation, convection and conduction. On a survey, it was reported that this method is labour intensive and time consuming, as the product placed is vulnerable to pest, attack by animals and prone to get damaged due to ill-weather conditions like rain, wind etc. So taking into consideration many limitations, it was considered not suitable for comprehensive production.
Advancement in this field is solar dryer system in which the product to be dried is kept protected from rodents, animals, and any weather conditions. Drying takes place inside a chamber which is closed. Every food product require a specified temperature and has a range of requirement which can be provided in to a chamber through auxiliary systems like fans, heaters and proper ventilation, this being the main advantage of solar dryer As optimum radiations are present throughout year, sun drying technologies is widespread method all over the world. There are two types of dryers:

a) ***Passive dryers***:

These are the dryers with natural circulation of air and exposure to sunlight.

b) ***Active dryers***:

These are those dryers which are hybrid and may or may not have natural circulation of air and have no direct exposure to sunlight.
The prime design objective of the dryer is to attain optimal heat for drying of product, than the ambient condition available which in turn also improves the vapour pressure of the crop moisture, thereby migrating the moisture from the product more efficiently. Numerous dryer operating on mechanical energy are commercial accessible to achieve target and even decrease the duration of drying but not beneficial from economical point of view. But due to their unreasonable price make small budget farmer unable to apply them to their use. Output of a study has also resulted to show that even expenses of simple oil-fired batch dryers cannot meet by farmers. In a study, conducted by Chavda and Kumar, revealed that dryer using conventional fuel have more expenses i.e. 1/3rd higher than the dryer using power of solar[62]. Though, there are some disadvantages of solar technology like not meeting the requirement at night but when solar dryer if put on in absolute way and used appositely have significant potential, mainly in agricultural sectional where post harvest losses are high.

METHODS

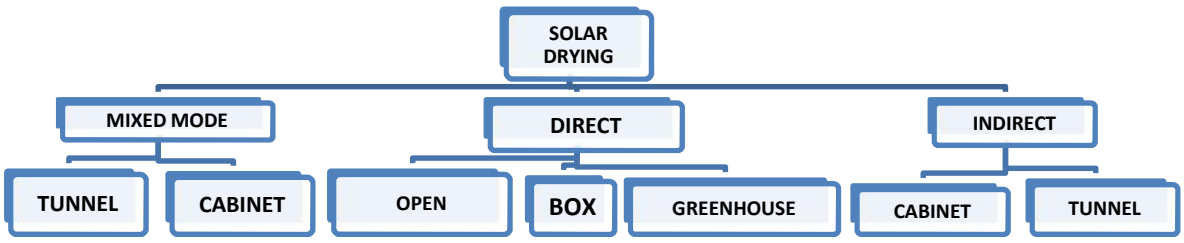

Fig 1: Classification of drying methods

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A. Direct:

This method is old method of drying the food items in sun. One of its types is open drying. This mechanism involves the produce distribution in thin layer, exterior on mat open to radiation without any shelter. This technique is mostly applied for grains and making of pickle traditionally.

In this condition

a) The crop is vulnerable get attacked by rodents, animals and uncertainties like rain and wind etc.
b) At hot sunny days, when temperature is higher than required for drying of the item, it could also affect the output that is required at the end.
c) Drying length also increases.
d) Output is also poor as it may be contaminated with dirt, dust and microorganism.

In order to get better of the mentioned limitations an improvement in this method was found. The drying was carried out in direct radiation of sun but instead of placing it in open, it is kept inside the box covered with mirror or transparent sheet. The item to be dried is kept inside the chamber covered with plastic sheet or mirror so that the food can be protected from qualms and stray animals. This also reduces the manual labour as there is no need to check it for dust, dirt, and rodents as well as no need to change its place to protect it from rain, wind. Also, the temperature range of 30-70^{o} C is easily achievable which necessities for crop to get dried are. Higher temperature and moisture trapped can be removed off through fan/exhaust and ventilation holes.

Keeping it inside the chamber also decreases the duration of drying process. Material to be dried is led for 20-30 days as the required temperature is attained easily and rapidly and removed. This process can be implemented in following ways:

a) **Box type**

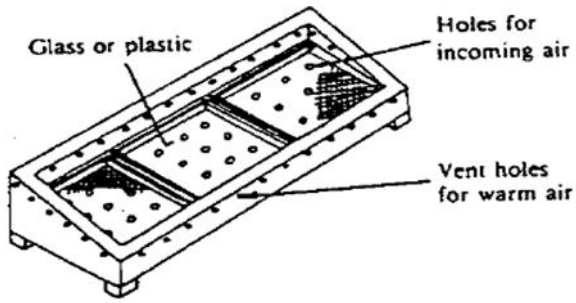

Fig 2: Box type solar dryer [52]

b) Greenhouse

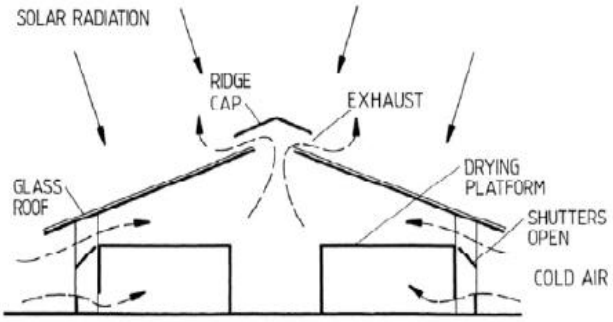

Fig 3: Green house dryer [52]

B. Indirect

This method is advancement for direct mode solar dryer. It is also known as distributed solar dryer. It is more productive than direct method. In it, solar radiation gets trapped and produce drying takes place in separate units.

In it, three units are:

i) *Collector*: It is covered with transparent lid i.e. glass.
ii) *Cabinet*: it is the unit in which hot air enters and item to be dried is kept in.
iii) *Chimney*: It is also present on either side of the drying chamber or above it.

Hence, the output is obtained through diffusion and convection.

This method is useful in dropping the duration of obtaining output and improving the product quality as no direct exposure to sunlight is there. The temperature achieved is in the range of 60^{o}-70^{o} C. It maintains the advantage of labour extensive and easy constructive systems..The only disadvantage of this kind is high initial cost.

This operation is carried out in following ways:

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a) Cabinet dryer

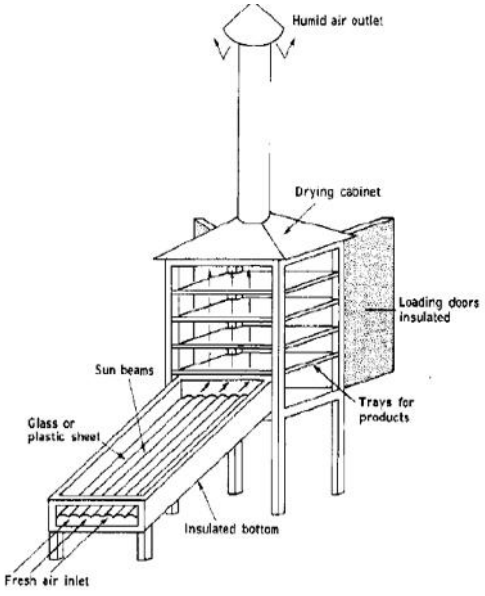

Fig 4: Cabinet type indirect dryer[52]

b) Tunnel dryer

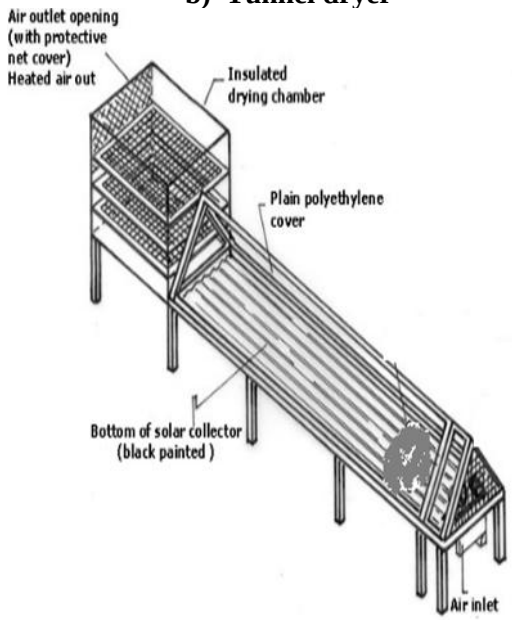

Fig 5: Tunnel type indirect dryer[60]

C. Mixed mode

This type is the integration of direct as well as indirect dryer. This type of dryer are appropriate for drying of material which have higher water content and need high temperature for drying purpose. It has three parts included in the system:

i) *Air heater*: It is similar to absorber covered with transparent lid i.e. glass which receive radiation and allow it to penetrate inside. Air inlet is provided at the bottom of it.

ii) *Drying chamber*: It is covered with glass or translucent sheet which also gets the radiations and heats the environment. It is recommended to shape it as trapezoidal as it should have the ability to allow radiation to fall on large area.

iii) *Chimney*: It is also present on upper side of the drying chamber.

Product under consideration, use both exposure to sun and hot air coming from collector/air heater for getting dried. In this process the product may lose its moisture due to convective losses. It fits for the use in the temperature range up to 80^{o} C. This mechanism adds as an advantage of reduction in drying time. The disadvantages surveyed were that quality of output obtained is less as well as it is not helpful from economical point of view as maintenance required is high.

This approach is carried out in following designs:

a) Cabinet:

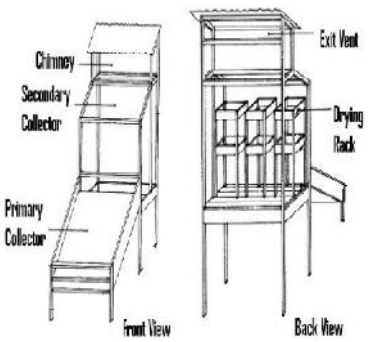

Fig 6: Cabinet type mixed mode dryer [25]

b) Tunnel:

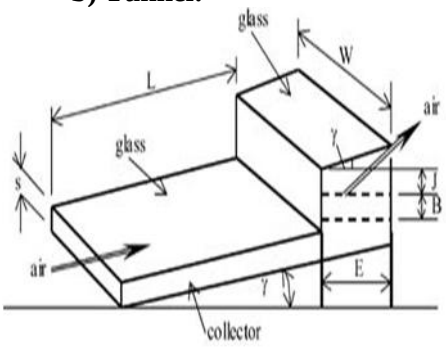

Fig 7: Tunnel type mixed mode dryer[61]

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LITERATURE REVIEW

Nidhi et al. reviewed about different experiments / analyses conducted on different designs and type of green house and tunnel dryer, hence depicting the different designs of green house dryer.[1]. Ajeet Kumar Rai et al. experimented for different parameters on green house dryer like heat transfer coefficient, constants like C and n and concluded that green house is finer when different factors are checked and also revealed that average convective heat transfer coefficient was higher in greenhouse than in open sun drying.[23].Bhagyashri Dhurve et al. designed and developed modified green house dryer thereby reducing the drying time. The comparative study between open sun drying, green house dryer, modified green house dryer was performed graphically on different parameters like temperature, relative humidity, wind velocity and weight reduction etc. and concluded that modified as first on the list and finer of all.[29].Ashish D. Chaudhari et al. stated about different technologies and methods in drying process and gave a result that solar drying is best alternative for conventional drying of agricultural products.[32].S. Preethi Vardhini et al. conducted the experiment on variety of locally existing chili in open sun drying and green house dryer for same time in same weather conditions and gave the results on different parameters graphically and they also gave the method for calculation of efficiency. He also concluded that green house tunnel dryer decrease the drying rate as compared to other dryers.[57]. D.K.Rabha et al. performed comparative study of drying in open sun and indirect forced type convection solar tunnel drying on ghost chilli pepper. They carried out mathematical modelling of thin layer drying kinetics for it and hence deduced that drying process was faster in indirect solar dryer than open sun dryer.[49]. A.G.M.B Mustayen et al. reviewed different designs, performance and application of different type of dryer and also discussed different solution for obtaining high quality dried products using traditional dryer as well as provided ways to create trouble-free, and reasonably priced dryers.[55]. AnupamTiwari provided detailed study of different methods system of drying as well as discussed advancement achieved till date. Information about different organization that are dealing with solar dryer is also provided.[52].Margarita Castilotellez et al. checked hoe indirect type forced convection tunnel dryer act upon for different value of controlled temperature of 45^0C,55^0C and 65^0C and at different air velocity of 2, 3 and 5 m/s. Modelling and statistical analysis of data was carried out graphically. The observation was that mass had influence on drying rate. Different velocities of air causes different drying rate too.[50].Sumit Tiwari et al. proposed forced mode PVT Green house solar dryer and analyzed for different climatic conditions of New Delhi. Thermal modeling taken into consideration different parameters as well as calculated thermal efficiencies, energy payback time, and concluded PV module increases the overall efficiency of dryer.[56].Prashant Singh Chauhan et al. fabricated green house dryer with insulated north wall under natural convection mode for evaluated its performance under no-land conditions for two different cases. The result obtained were represented graphically and concluded that NWIGHD with solar collector was found to be more effective and temperature of 65.2^0 C was attained.[58].

R.K. Sahdev reviewed the comparison between open sun drying and green house drying furthermore demonstrated the phenomenon using diagram and suggested green house dryer technology to be improving the quality of product and reducing drying period as well.[2].S. Wang et al. analyzed the distribution of air speed in the natural ventilation green house dryer experimentally. Result also presented that calculated air speed was less than the measured value. Thus depicting the average speed of air in green house dryer is basic determinant for computing heat transfer between green house component and interior air.[3].M. Condori et al. examined solar tunnel dryer and inferred that green house dryer is a solar collector and maintained a linear relation which led to improvement of 160% in contrast to single chamber and when set side by side to dual chamber dryer it was 40%.[4].T. Koyunce observed two type of dryer, the green house dryer and open sun drying and arrives at a judgment that green house dryer technologies are 2-5 times more effective and produce a much higher quality product than the latter.[7].Oguntola J. Alamu et al. provided the design, design criteria and material used in solar dryer. He demonstrated that the design made exhibited sufficient ability to dry agricultural products to significant level.[44].S. Jangai et al. executed the testing of drying banana in pv ventilated green house dryer and interpreted that duration of moisture removal in banana in open sun drying is high than green house dryer and quality of output obtained is also high in latter than former.**[**14].Nidhi put forward the drying characteristics of vermicelli in slant height dryer and suggested that moisture removal rate

and content of moisture on dry basis (%) decrease as drying time increase.[16].V P Sethi et al. improved green house solar dryer by inclining reflection of north wall for natural and forced convection mode. Results obtained inferred that total solar radiation and heat can be increased inside the green house solar dryer by optimally inclining the reflective north wall, under both modes.[10].S. Sadodin et al. prepared a model of solar green house tunnel dryer and analyzed numerically for copra drying and provided the design equation for green house dryer. The moisture in copra lessens from 52.2% to 8% in 55h. He also suggested that this model can prove beneficial in rural areas without electricity supply and payback periods for it is 2.3 years.[12].A. Ganguly et al. reviewed the literature dealing with ventilation and cooling of green house dryer. He studied different factor that effect the environment inside the green house chamber as well as discussed the development procedures that need to be done inside green house to increase the capability of it for future.[13].Babagana Gutti et al represented the solar dryer as most vital device for drying purposes of agricultural products for small as well as large scale productions. They also discussed various methods of solar dryer and ways of evaluating it.[26].H.P. Garg et al compared performance of natural circulation and forced circulation semi-cylindrical solar tunnel dryer for Delhi climate. They concluded that performance of forced circulation semi-cylindrical solar tunnel dryer was beneficial as per required output.[38].Serm Jangai develops and disseminates the usefulness of green house dryer for small scale dried food industries. It showed that drying through green house works well on small scale categories. Auxiliary supply of fan was also kept to help drying procedure when climate was not favorable.[41].Serm Jangai et al. solar green house dryer covered with poly carbonate cover, for large scale , by testing the drying of 1000 kg banana, 100 kg of chili , 200 kg of coffee with original moisture content of 68%, 75%, and 52% (wb). Drying time for each product in green house dryer when compared to open sun drying was less under same weather conditions.[42]. Om prakash et al studied operation of modified green house dryer for active and passive mode by applying thermal storage in three different ways and compared it with normal green house dryer. The result revealed that active mode modified green house dryer under active mode proved better for crop with high moisture content and for low moisture content, both have approx same results. He concluded that payback of MGHD IS 1.11 years, and CO_2emission in kg/yr is 17 kg for passive and active mode.[59].Sahu T. et al. analyzed open, simple and modified green house dryer under natural convection mode for dryer potato and evaluated the result graphically for different parameters. Experiment concluded the modified green house dryer to be better of all in every way. The weight loss for potato in modified and simple green house is 79.9% and 79.4% and established for open sun drying it was 79%.[31].

CONCLUSION

A comprehensive study on work of different authors on the subject related to green house solar drying field has been reviewed. Different type of designs and methods opted by them have been analyzed various type of solar drying technology are discussed, and it was deduced that each and every technology are discussed and it was deduced that each and every technology has proven beneficial for different type of crops (different from moisture content in it),but green house type drying technology was recommended from many point of view.
The study showed that solar drying technology is entering commercial areas with fast pace for small as well as large scale industries. If compared to conventional dryer and other solar technology for crops drying, they have proved to be advantageous economically and financially too. By appropriately designing of dryer, solar dryer in forced mode are more effective than solar dryer in passive mode. But for rural areas and less electricity supply passive mode active dryer provide the best application. It should be optimized with low cost, less floor area, less maintenance and less operational cost benefits to farmers. Also, the product obtained after drying is of high quality when compared to open sun drying. Using the drying frequently rather than using seasonally decreases the cost of drying and payback.

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