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# Preservation of Food Items Using Solar Dryers: A Review

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**ABSTRACT**
In order to conserve the food products like chillies, grapes, potatoes & other agricultural products, for a longer period of time & with same the quality they need to be dried by using any form of energy, for example heat energy from fossil fuels or solar energy etc. This is done to reduce the moisture content to a predetermined level which prevents the growth & reproduction of micro organisms like bacteria, yeasts etc. that causes many moisture mediated deterioration reactions**.** One of the drying methods involves drying the produce with the help of direct sun light by spreading them in an open space. This process is labor intensive & requires a large area for spreading the produced to dry out. The disadvantage of this method involves uneven heating, loss of produce due to birds, animals, bad weather etc. Another method of drying involves artificial mechanical drying which is an energy intensive, expensive and costly method. Green house drying or solar drying gives the best results as it does not compromise the product quality, aesthetic etc. Moreover it makes the transportation process easy as the volume of dried product reduces. This paper reviews the solar drying process & gives complete in depth of all the elements involve in solar drying.

***Keywords:*** Artificial Drying, Solar dryer, Moisture Content, Productivity, Solar Drying.

## I. INTRODUCTION

Swift exhausting of non renewable energy sources is one of the major concerns of today's world since energy is by far the largest merchandise in the world and a huge amount of energy is extracted, distributed, converted and consumed in our society daily. Swift exhausting of the non renewable sources of energy is forcing the society to use renewable energy sources so that energy from non renewable sources can be saved & used where renewable energy cannot be used or is expensive to use. One of the major areas of usage of energy is in drying the agricultural crops for conserving them for a longer period of time. There can be two methods for this process. **(i)** Use of artificial mechanical drying systems which is energy intensive, expensive process which increases the product cost. **(ii)** Use of traditional methods, in which the produce is kept in an open ground, heated, with the help of direct solar radiation. This method is called open sun drying. This method is effective for small amount of food items. However for large amount of food items this method has many disadvantages like, spoilt products due to rain, wind, moisture, fungi, dust etc, loss of produce due to birds & animals, deterioration in the harvested crops due to decomposition, insect & fungi attack etc. Further the process is labor intensive, time consuming & requires a large area for spreading the produce out to dry. The area needed for sun drying expands with food quantity and since the food is placed in the open air, it can easily be contaminated. Also due to uneven heating of the product the quality of product suffers.

A more feasible & affordable replacement for these two earlier discussed methods is solar drying for domestic as well industrial use. In this method the food items are heated with the help of a device called Solar Dryer. Agricultural & other industrial products can easily be dried in a solar dryer. There are two methods that are used in solar dryers. In the first method the produce is kept in an enclosed structure & then heated by solar radiation which directly impinges on the product to be dried in such a manner that product directly absorbs the solar radiation. The product is heated by direct absorption & also by the air which gets heated in the drying chamber by natural or forced convection. In other method the solar energy is first entrapped by solar collectors which heats up the air inside it & then this hot air is circulated to another chamber by natural or forced convection manner. In this method the produce does not absorb the solar radiation directly.

## II. OPEN SUN DRYING VS SOLAR DRYING

Food materials and crops are very sensitive to the drying conditions. Drying must be done in a way that does not change their color, flavor, texture or nutritional value. Thus the appropriate selections of drying conditions, temperature, are very significant. Various products need pretreatment prior to drying, similar to pretreatment applied to conventional drying systems. Some products must be pre treated before solar drying so as to facilitate drying or to keep their desired properties.

Open sun drying suits to fruits. Their high sugar value and acid content make the open direct sun drying safe. On the other hand vegetables have low sugar and acid content which does not suit to open sun drying due to increased risk of spoilage during open sun air drying.

Solar dryers are very basic devices. They range from very ancient ones which were used in small, desert or remote communities up to more technologically upgraded sophisticated small size industrial units. Though the more technologically upgraded solar dryers are still very few and are undergoing development phase, such as solar dryers for timber dring. Until today they have been not yet standardized and/or widely commercialized and in many cases they are constructed on experience base rather than in scientific design and technical calculations. Solar drying is a possible substitution for sun drying or for standard dehydration process. In terms of sun drying solar drying is carrying out with an approach that is deeply ingrained in the way of life for most possible users. Sun drying is by no means a complete process with problems coming due to potential contamination of the product, feasibility in drying times, rain damage and so on.

### 1.1 Advantage Of Open Sun Drying

The use of open sun drying in various parts of the world is due to the following reasons.

1. Simpler to use when compared to solar drying.
2. Very less or negligible initial cost is involved.
3. Less difficult for the uneducated or less educated farmers.
4. Lack of curiosity of farmers to use a productive method for produce.
5. Lack of alertness on the part of local government.

### 1.2 Advantage Of Solar Drying

Following are the advantages of solar drying method compared to the open air sun drying process

1. The higher temperature movement of air & lower humidity increases the rate of drying.
2. Since food is kept in a chamber therefore it is safe from contamination by rodents, birds, insects, animals & dust.
3. The higher temperature deters the insects & the high drying rate diminishes the risk of spoilage by micro organisms.
4. Higher productivity as higher drying rate also gives a higher output of food & therefore a smaller area is required for the drying process (Approx 1/3).
5. Safe to use in rainy seasons as the dryers are closed installation & therefore can be used in this season too.
6. Dryers can be constructed from materials that are easily & locally available. Since the locally available materials are cheap hence the cost of production is low if manufactured in large quantity.
7. The dried products can be stored for a longer period of time due to better drying process.

## III. PROCESS DURING SOLAR DRYING

The main purpose of using of a solar dryer is that it can supply sufficient heat to the product as compared to the heat which is available in the atmosphere, so that it can increase the pressure of vapor of the moisture caught within the product adequately & decreasing the relative humidity of the drying air properly and thereby increasing its moisture carrying capacity and ensuring adequately low equilibrium moisture content. The moisture carrying capacity of air depends upon its temperature since warm air can hold more moisture than cold air, therefore the amount required depends upon the temperature to which it is heated in the collector as well as the amount held (absolute humidity) when it enters in the collector. A solar dryer is a simple device in which direct & indirect solar radiation can be used. The principle of the solar drying process is that it collects solar energy by heating-up the air volume in solar collectors and conduct the hot air from the collector to an attached enclosure, the food drying chamber where the products to be dried are kept. In this closed system, which consists of a solar collector and a food drying chamber, without direct exposure of the food to the surroundings, food drying is more clean as there is no secondary contamination of the products through rain, dust, insects, rodents or birds. In solar dryers the produce are dried by movement of hot air only. In most of the cases the solar radiation is first collected by solar collectors & then used to dry the product indirectly. In some solar dryers the product is heated by direct solar radiation too in addition to the indirect heating process therefore increasing the efficiency of the dryer. The solar energy makes the air hot in the solar collector which ultimately increases the temperature of a given volume of air resulting in decreasing the relative air humidity and increasing the water absorption capacity of the air. Now this heated air is sent to the drying chamber by either natural convection or forced convection circulating through and over the food items resulting in continuous and efficient drying process **[1]**.

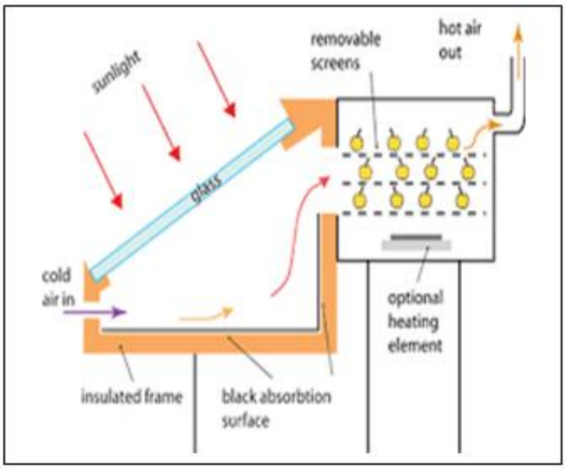


**Fig. 1:** Process during Solar Drying

## IV. DRYING PRINCIPLE

In drying water is removed from solid by evaporation process. The principles that govern the drying processes can be applied to conventional drying and can also be applied to solar drying. These principles do not depend on the type of energy being used for drying processes. A major part of energy used in drying is for the evaporation of liquid water in to its vapor. A solid can have water in various forms such as free moisture or bound form which can affect the drying rate. Moisture content can be expressed by two methods such as on dry basis or on wet basis. Moisture content in wet basis (m) is defined as the mass of moisture per unit of wet material. On dry basis (M) it may be defined as the ratio of water content to the mass of the dry material **[2]**.

Following are the simple processes that are involved in drying process.

**(i) Converting sun light into heat**: Sun light can be converted to heat by using black coating inside the solar dryer. Coating of black colour improves the efficiency of this conversion process.

**(ii) Trap the heat inside the dryer**: Solar dryers are made with an enclosed structure so that this heat can be kept inside the dryer that ultimately increases the temperature inside the drying chamber by the help of green house effect. This is achieved by the use of transparent glass or plastic cover. The clear glass or plastic cover allows the light to enter the chamber, but once it is absorbed and converted to heat, it does not allow the heat to transfer to surrounding by inducing thermal resistance. Similar temperatures can be achieved in cold days as well by the use of same phenomenon.

**(iii) Movement of Heat:** Circulating the heat to the food can be done by natural convection or by forced convection. Both the natural convection dryer and the forced convection dryer use the convection of the heated air to move the heat to the food. While several different designs of the solar dryers exist, the basic components of a solar dryer are illustrated in Fig 2. In the case of a forced convection dryer, an additional component would be the fan.

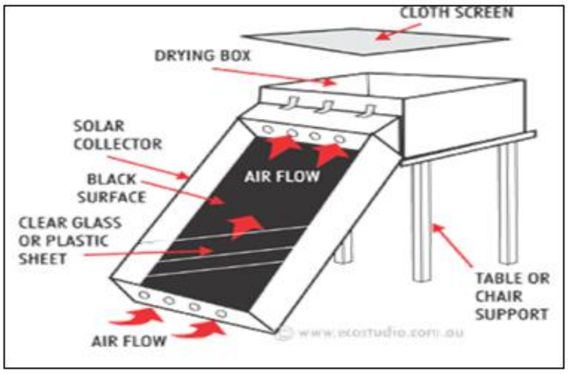


**Fig. 2** Basic components of a solar dryer

### 1.3 Drying Rate

The rate at which a product gets dried is directly proportional to the moisture content of the product. It means that the product having more moisture content gets dried at a faster rate. The drying rate is also proportional to the temperature of the product. Product kept at higher temperatures gets dried at a faster rate. Three basic stages are involved in the drying of the product. In most of the agricultural products drying stops before phase III is achieved. The drying time of each period depends on the nature of the product and the drying conditions. Most of the food products do not show a constant-rate stage at all as many crops have initial moisture content near the critical point and they quickly reach the so called critical point. These stages are

**Stage I:** This is an early constant-rate drying stage during which the surface is saturated with vapor and evaporation takes place endlessly as the material's surface has adequate water to evaporate.

**Stage II:** This is defined as first falling rate period. In this period the surface is not vapor saturated, i.e. at the critical point. Moisture transmission is governed by internal liquid movement while surface becomes continuously exhausted by water.

**Stage III:** This is defined as second falling rate period. In this second falling rate period the moisture content continues to decrease until equilibrium is attained and drying stops.

## V. TYPES OF SOLAR DRYERS:

Solar dryers can be classified on the basis of various parameters. **[3]** One of the main parameter is the type of convection phenomenon used. They are mainly classified as active & passive solar dryers on the basis of whether the circulation of air is done based on forced convection of natural or free convection. Other important parameter is that whether the collection of solar energy & heating of product are done in separate or integrated chambers **[4]**. On this base solar dryers can be classified as distributed and integrated solar dryers respectively. On the basis of various design parameters all the drying systems can be broadly classified as follows.

- Based on the Operating temperatures.
- Based on the Heating sources.
- On the basis of utilization of solar energy.
- On the basis of design arrangement of system components.
- Based on the heating modes.
- Other dryers such as Green House Dryers, Tunnel Dryers & In house Dryers.

| SN | Basis of Classification | Dryers |
|---|---|---|
| 1 | Operating temperatures | High Temperature |
| | | Low Temperature |
| 2 | Heating Sources | Fossil fuel Dryers |
| | | Solar Dryers |
| 3 | Utilization of Solar energy | Direct solar Dryers |
| | | Indirect Solar Dryers |
| | | Mixed Solar Dryers |
| 4 | Design Arrangement of System Component | Distributed Dryers |
| | | Integrated Dryers |
| 5 | Heating Modes | Active Solar Dryers |
| | | Passive Solar Dryers |

**Table 1:** Different types of Solar Dryers

### 5.1 Active Dryers

Active solar dryers are those dryers which use the phenomenon of forced convection to transfer the hot air to the drying chamber. In such kind of dryers an external agency is used to transfer the hot air from collector to the drying chamber. These external agencies may be a fan, a blower etc. **[5]**. In active type of solar dryers hot air is circulated due to forced convection in which Reynold's number plays a significant role.

### 5.2 Passive Dryers

Passive solar dryers are those dryers which use the phenomenon of free or natural convection to transfer the hot air to the drying chamber. Passive solar dryers are those dryers which do not use any external agency to transfer the hot air from collector to the drying chamber. In such kind of solar dryers the hot air is circulated due to natural convection only in which Grashoff's number plays a significant role.

### 5.3 Direct Type Solar Dryers:

In the direct type of solar dryers, solar radiation penetrates the transparent glass cover or plastic sheet & is directly absorbed by the product kept for drying. The glass cover or plastic sheet used provide the necessary thermal resistance due to which the temperature inside the dryer increases.

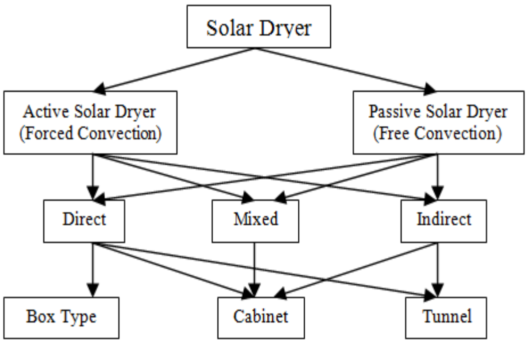


**Fig 3** Types of Solar Dryers

### 5.4 Indirect Type Solar Dryers:

In these types of solar dryers solar radiation does not impinge on the products directly. They are first collected in the solar collectors & then the hot air is sent to the drying chamber. Following are the two types of indirect solar drying systems. They are: Natural circulation solar dryers & Forced circulation solar dryers.

### 5.5 Integrated Or Mixed Dryers:

In these types of solar dryers the properties of direct and indirect type solar energy dryers are combined. In these types of solar dryers the product is heated both by the direct solar radiation & also by the pre heated air [6]. This combined action produces heat required for the solar drying process. In an integrated solar dryer the solar energy gathering and drying take place in a single unit. Normally, this dryer is little in size and is an individual unit.

## VI. THERMODYNAMIC ASPECTS

The quantity of air required to heat a particular mass of drying product can be calculated. There are two basic methods for this calculation. They are as follows.

### 6.1 The Psychrometric Chart

Psychrometry is very important in drying process since it refers to the properties of air vapor mixture that controls rate of drying. The moisture carrying capability of air depends on its humidity and temperature. The study of connection between air and its linked water is quantity is called psychrometry. Psychrometric chart shows the various thermodynamic properties of moist air such as vapor pressure, relative humidity, humidity ratio, dry bulb temperature, wet bulb temperature, dew point temperature, enthalpy and specific volume etc. When any two of the three temperatures are known, i.e. dry bulb, wet bulb or dew point, all other properties can be found with the help of the psychrometric chart.

Humidity ratio is shown on the ordinate on the psychrometric chart and dry bulb temperature is shown on the abscissa. The upper curve of the chart is labeled wet bulb and dew point temperatures. The other curves on the psychrometric chart that are similar in shape to the wet bulb lines are lines of constant relative humidity (%).The constant wet bulb temperature is shown by the straight lines sloping gently downward to the right. The intersection of a dry bulb and a wet bulb line gives the state of the air for a given moisture content and relative humidity. The amount of air required for drying a particular mass of product can be found using psychrometric chart.

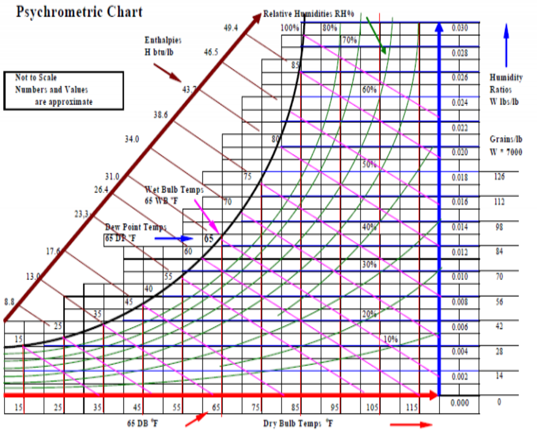


**Fig 4:** Psychrometric Chart

### 6.2 Energy Balance Equation

The energy balance is an equation that mathematically shows the balance between the energy available & energy spent: The shows the balance between the energy available from the air conducting through the food inside the dryer & the energy needed to evaporate the amount of water to be removed from the product. [7] For removal of water from the product surface by evaporation latent heat of evaporation of water is needed plus a current of air transferring over the surface to carry away the water vapour produced. Hence, the task in solar dryer is to calculate such amount of energy & then achieving optimum temperature,

$$M_r h_{fg} = m_a\, C_p\, (T_i - T_f) \qquad ------(3)$$

Where,

$M_r$ = mass of water evaporated; $h_{fg}$ = latent heat of evaporation; $m_a$ = mass of air circulated; $C_p$ = specific heat of air; $T_f$ = final temperature, $T_i$ initial temperature.

## VII. EFFECTS OF PARAMETERS ON DRYING

Mass flow rate & the temperature of air are the most important parameters which decide the quality of the dried product. Other parameters of importance are air velocity, humidity and the required final moisture content. Various effects of different parameters on drying are discussed below.

### 7.1 Temperature

Drying temperature is a main deciding factor, which mainly determines the quality of the dried product. High drying temperature may damage the germination capacity of seeds and also can damage the product either changing the chemical combination or shoulder the product. Lower drying temperature may lead to longer drying time which may lead microbial contamination. The temperature should be maintained to the allowable level so that the drying will not damage the product.

### 7.2 Mass Flow Rate

Mass flow rate also plays a vital role in the solar drying process. The optimum mass flow rate is found using the temperature requirement and also the maximum air velocity which can be maintained inside the drying chamber.

| Product | Moisture Content (%) | | |
|---|---|---|---|
| | Initial | Final (Permissible) | Maximum Drying Temperature (°C) |
| Maize | 35 | 15 | 60 |
| Wheat | 20 | 16 | - |
| Carrots | 70 | 5 | 75 |
| Onions | 80 | 4 | 55 |
| Garlic | 80 | 4 | 55 |
| Potato | 75 | 13 | 75 |
| Chilly | 75 | 5 | 65 |
| Fish | 80 | 15 | 50 |
| Apples | 75 | 24 | 70 |
| Grapes | 80 | 15-20 | 70 |
| Banana | 80 | 15 | 70 |
| Pineapple | 80 | 15 | 65 |
| Coffee | 50 | 11 | - |

**Table 2** Initial, final & maximum moisture content drying temperature for different food products

### 7.3 Relative Humidity Of Air

The relative humidity of air is an important factor same as that of temperature because humidity gradient between air and the product will be a major driving force in a natural convection system. Lower relative humidity of the air can increase the drying rate and will help in reducing the drying time.

**7.4 Moisture Content Of The Drying Product**

The market value of the product depends upon its optimum moisture content since it determines the quality of the product. Products with higher moisture content are found to have lesser drying time than those having very lesser moisture content. It is because the higher moisture content product may have better mass flow of the moisture from the interior of the product to the surface so that it is removed where the one with lower moisture content may have a thick outer skin.

**7.5 Effect Of Drying On Nutritional Value**

Dried products when dried in optimum manner are very good source of nutrients but the drying process may change the quality of the products. The quality of the product can be optimized by using proper pre-treatment processes of the materials and also by controlling the drying process. Some of the quality parameters which must be considered are colour, visual appeal, flavour, preservation of nutrients, free from contaminant, etc. These factors determine the market value of the product.

## VIII. PRE-TREATMENT AND ITS INFLUENCE ON NUTRITION LOSS

Steam blanching is the most common pretreatment process which is done on the products to be dried. Steam blanching is done by directly injecting the steam into the blanching chamber followed by rapid cooling. Dipping in solution like sulphites are also some of the most commonly pretreatment methods. In some cases, concentrated sugar solution is used. But such pre-treatments processes result in nutrient loss. Reports show that there is around 80 % loss of carotene content when steam blanching is done. Loss of vitamins and other nutrients are also occurring due to blanching. Processes like osmotic treatments should be preferred over blanching & dipping so that better results in retaining vitamins may be obtained.

## IX. CONCLUSION

In order to preserve the food items solar energy can be the energy source. Places which are not connected to national electric grid shall take the best advantage. Though the application of solar energy is still in the preliminary stages yet its use has been increasing amongst the small farmers and various drying industries. This paper presents a review on solar drying technology and its uses so that researchers and others can take advantage of it.

## REFERENCES

[1]. Warner W., Josef B, Solar drying, Institute of sustainable technologies, Austrian development cooperation.

[2]. V, Belessiotis, E. Delyannis, Solar drying. Solar energy reviews 2011; 85 (2011):1665-1691.

[3]. A. Sharma, C.R. Chen, N.V. Lan, Solar energy drying systems: A Review. Renewable sustainable energy reviews 2008; 13 (2009):1185-1210

[4]. O.V. Ekechukwu, B. Norton, Review of Solar energy drying systems: I &II, Overviews of Solar Drying Technology. Energy Conservation & Management 1997, 40(1999), 593-613.

[5]. C.L. Hii, S.V. Jangam, S.P. Ong, A.S. Mazumdar, Solar drying, fundamentals, applications, & innovations, e-book, 2012.

[6]. A.D. Chaudhary, S.P Salve, A review of solar dryer technologies, International journal of research in advent technology, 2014, 2(2).

[7]. M.A. Aravindh, A. Sreekumar, Solar drying—A sustainable way of food processing 2015, Centre for Green Energy Technology, Pondicherry University, Pondicherry.