RESEARCH ARTICLE

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Frontiers in Advanced Materials Research

# Study on Performance of modern Solar Dryer

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**Abstract:** This paper presents the state of various kinds of solar dryers that are widely used today and about drying process that has been perform during drying of various food products and percentage containing moisture in different food products. The indirect, direct and mixed mode dryers that have shown potential in drying agricultural products in the tropical and subtropical countries are discussed. A side from identifying the active and passive mode solar dryers, we also highlight the environmental influence on solar energy (harnessing) that plays a vital role in the solar drying sector and says that the indirect solar dryer is more suitable than other dryers and recirculation of air in an indirect dryer can reduce the drying time of food product in comparison to normal indirect solar dryers. The dryer having recirculation of air have more efficiency than other dryers.

**Keywords:** Solar dryers, environmental influence, food product, solar energy, agricultural products.

## 1. Introduction

Drying is a complicated process involving simultaneous heat and mass transfer. The required amount of energy to dry a particular product depends on many factors, such as initial moisture content, final moisture content, drying air temperature, relative humidity and velocity. Various mathematical models describing the drying behavior of different food materials have been proposed to optimize the drying process and design efficient dryers. Modelling is advantageous because full scale experimentation of different products and configurations of drying system is very time consuming and costly. In order to improve the quality, the traditional natural sun drying must be replaced by modern drying methods. Drying characteristics of specific products should be determined to improve the quality.

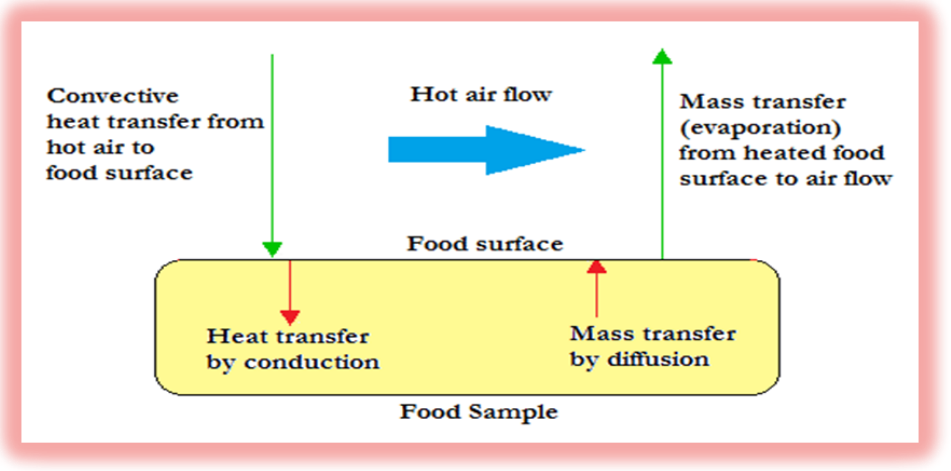


Figure1. Simultaneous Heat and Mass Transfer Process on a Food Surface

## Classification of Solar Dryer

On the basis of their operating temperature ranges that is high temperature solar dryer and low temperature solar dryer:

- ✓ Air movement modeInsulation exposure
- ✓ Air flow direction
- ✓ Dryer arrangement
- ✓ Solar contribution
- ✓ Type of fruit to be dried

## On the basis of air flow

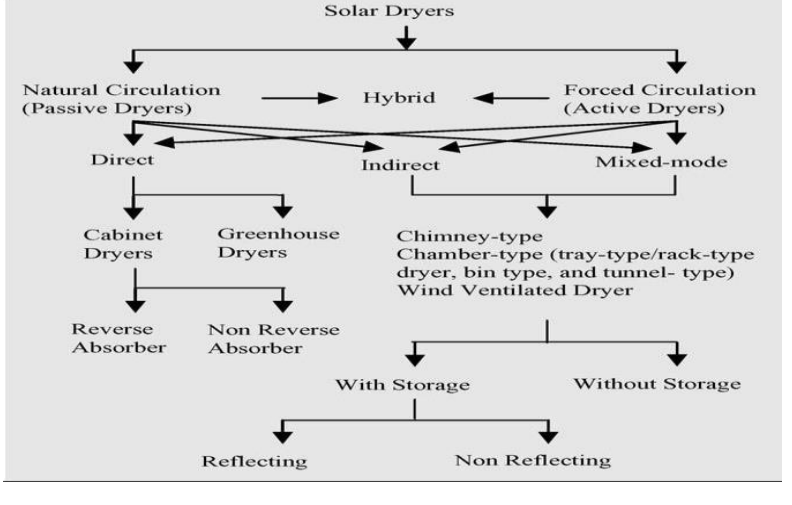


Figure 2. Classification of Solar Dryer

Table 1. Moisture Contents of Solar Drying of Various Agricultural Produces.

| Product | Moisture Content | | Max. Allowable Temp. (°C) | Drying Time (h) |
|---|---|---|---|---|
| | Inital % | Final % | | |
| Onions | 85 | 6 | 55 | 48 |
| Onions Flakes | 80 | 10 | 55 | 24 |
| Onion Rings | 80 | 10 | 55 | |
| Tomatoes | 95 | 7 | 60 | 36 |
| Green Peas | 80 | 5 | 60 | 8–10 |
| Grapes | 80 | 15–20 | | 32–40 |
| Apples | 82 | 11–14 | 65–70 | 24–26 |
| Figs | 70 | 20 | 70 | 32 |
| Bananas | 80 | 15 | 70 | 15 |
| Cassava | 62 | 17 | - | - |
| Copra | 30 | 5 | - | - |
| Tobacco | 90 | 10 | - | 96 |
| Coffee | 65 | 11 | - | 288 |
| Garlic Flakes | 80 | 4 | - | 48 |
| Chillies | 80 | 5 | - | 48 |
| Ginger | 80 | 10 | - | 168 |
| Cabbage | 80 | 4 | 65 | 48 |
| Tea | 80 | 3 | - | 96 |
| Pepper | 71 | 13 | - | 48 |
| Turmeric | 80 | 10 | - | 120 |
| Potato Chips | 75 | 13 | 70 | 72 |
| Paddy Raw | 22–24 | 11 | 50 | - |
| Paddy, Parboiled | 30–35 | 13 | 50 | - |
| Maize | 35 | 15 | 60 | - |
| Wheat | 20 | 16 | 45 | |

| | | | | |
|---|---|---|---|---|
| Millet | 21 | 4 | - | |
| Corn | 24 | 14 | - | |
| Rice | 24 | 11 | 50 | |
| Cauliflowers | 80 | 6 | 65 | |
| Carrot | 70 | 5 | 75 | |
| Green Beans | 70 | 5 | 75 | |
| Garlic | 80 | 4 | 55 | |
| Cabbage | 80 | 4 | 55 | |
| Sweet Potato | 75 | 7 | 55 | |
| Red Lauan | 90 | 20 | - | |
| Potatoes | 75 | 13 | 75 | |
| Spinach | 80 | 10 | - | |
| Prunes | 85 | 15 | 55 | |
| Apricots | 85 | 18 | 65 | |
| Peaches | 85 | 18 | 65 | |
| Guavas | 80 | 7 | 65 | |
| Mulberries | 80 | 10 | 65 | |
| Okra | 80 | 20 | 65 | |
| Pineapple | 80 | 10 | 65 | |
| Yams | 80 | 10 | 65 | |
| Nutmeg | 80 | 20 | 65 | |
| Sorrel | 80 | 20 | 65 | |
| Coffee | 50 | 11 | - | |
| Coffee Beans | 55 | 12 | - | |
| Cocoa Beans | 50 | 7 | - | |
| Cotton | 50 | 9 | 75 | |
| Cotton Seeds | 50 | 8 | 75 | |
| French Beans | 70 | 5 | 75 | |
| Ground Nuts | 40 | 9 | - | |

## Methods Of Solar Drying Technologies

### Direct Solar Drying

Direct solar drying is the conventional way of drying the products. In this methodthe products are directly exposed to the solar radiation and reduce the moisture content to atmospheric air. The air movement is due to density difference. It is broadly classified into two categories:

(1) The outdoor open air solar drying.

**Figure 3.** Open Air (Direct) Solar Dryer

(2) Through a transparent cover which protects partly the foodstuff from rain and other natural phenomena i.e. a passive solar drying method.

**Figure 4.** Transparent Glass Covered Direct Solar Dryer

This technique involves the thin layer of product spread over large space to expose to solar radiation. This process for a long time until the products will dry to a required level. The surface floor made from the concrete or particular area of soil is making applicable for Outdoor direct sun drying. This type of drying method is useful for grains. Material is led on outdoor floor for a long time, usually 10– 30 days. It is easiest method product drying but it has following disadvantage: [1–4]

(1) It depends on climate conditions and requires a large surface and long time of exposure to the sun. Final product condition is on observations of unskilled human being.

(2) Final condition of dried product will never control scientifically.

(3) Product may loss quantity wise on attack of birds, animals and rodents.

(4) Product may expose to all kinds of weather changes.

(5) Drying rate is very low for direct solar drying.

(6) The direct exposure to sunlight can greatly reduce the level of nutrients such as vitamins in the dried product.

## Indirect Solar Drying

Indirect solar drying or convective solar drying is the new technique of product drying. It is very efficient method than the direct type of solar drying. In this method the atmospheric air is heated in flat plate collector or concentrated type solar collector. The heating process is either passive or active. This hot air then flow in the cabin where products are stored. Therefore moisture from the product may lost by convection and diffusion. This method of drying is used to avoid direct exposing to the solar radiation. This method mainly reduces the disadvantages of direct solar drying [5, 6].

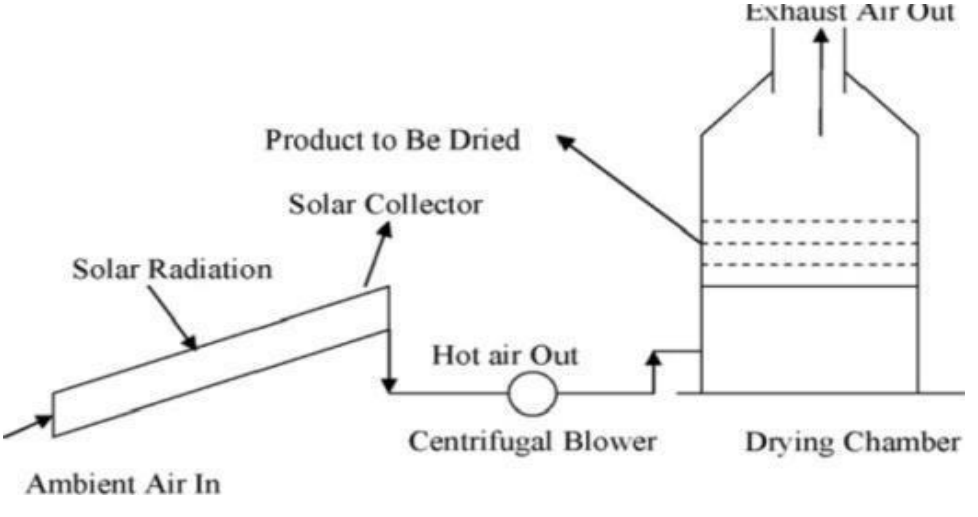


Figure 5. Line Diagram of Indirect Solar Dryer

Figure 6. Experimental Indirect Solar with Airflow Control [7]

## An Indirect Solar Dryer with the Re- Circulation of Air

In this solar dryer a duct is provided from moter to drying chamber to recirculate the hot air from moter to the chamber so the losses gets reduces and the time taken in drying the food product is less than the time taken in normal indirect dryers and from experimental results the moisture removal rate is also increased in comparison to before its approximately 80 to become 10.5% instead of 13.5%.so an indirect faced solar dryer having recirculation of hot air is more suitable then others from the food preservation as well as time conservaration and energy conservation also.

## Advantages and Disadvantages of Indirect Solar Drying [3]

1. Drying rate is high as compare to direct solar.
2. Final condition of product after drying can be controlled scientifically.
3. Losses in product are avoided on the circumstances of natural phenomena.
4. Floor surface area required is very low for the same quantity of material in direct solar drying.
5. Same dryer can be used for different seasonal products.
6. Preserve the nutrient content in product as avoiding direct exposure to solar radiations.
7. Main disadvantage of indirect solar drying is the high initial cost.

## Mixed Mode Solar Drying

It is combination of direct and indirect solar drying method. Product may dry with both direct exposure to solar radiation and hot air supplier on it. Air may heated in solar energy collector first then pass to the chamber where products are stored. In this process product may dry according to convective moisture loss. The same chamb System is divided into three main components: an air-heater, drying chamber, and a chimney.

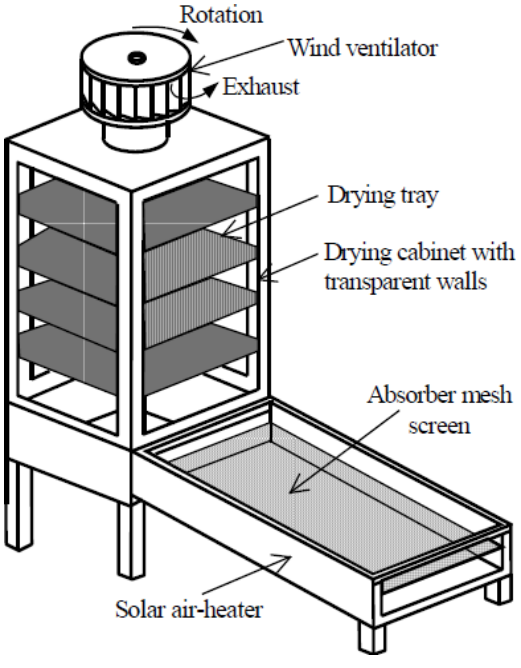


Figure 7. Solar Cabinet Dryer

Table 2. For Finding Different Type Solar Dryer

| Name of Solar Dryer | Name of Designers | Findings |
|---|---|---|
| Direct Solar Dryer | Mühlbauer | This is one of the simplest solar dryer of low capacity |
| | Ondier et al. | Solar radiation is the main source and overcome the discolorness of the crops |
| | Al-Juamily et al. | Temperature is the main factor on drying rate and in off shine hours the drying technology is affected |
| Indirect Solar Dryer | Goyal and Tiwari | Reverse flat plate collector was used and gave best result |
| | Sharma et al. | High quality drying products get by producing higher efficiency |
| | Sharma et al. | It is available for small farms and under bad weather it produces good quality products |
| | El-Sebaii et al. | The drying time is eminently decrease dand drying efficiency isgood |
| Mixed Mode Solar Dryer | Exell and Kornsakoo | Get optimal value of drying sectors using computer modelling |
| | Simate | Contains separate collector sand this dryer is used for drying crops in wet season |
| | Zaman and Bala | The drying rate was highest and this kind of dryer is used for drying rough rice |
| | Zomorodian et al. | This dryer gives satisfactory result for best drying efficiency and moisture content |
| | Bala et al. | Artificial network is used and predicting the potentiality of the dryer |
| Natural Convection Solar Dryer | Oosthuizen | It is a low cost solar dryer and gives vary satisfactory result |
| | Garg and Kumar | It is low cost and its performance is satisfactory |
| | Later Ezeike | Design of this dryer is very simple and gives high efficiency |
| Forced Convection Solar Dryer | Midilli | Simple, available and locally found materials are used to make this type of dryer |
| | Sodha et al. | Save a large amount of fuel. Product quality is better than any other sand keeps products neat and clean |
| | Ratti and Mujumdar | In ambient temperature this kind of dryer is more appropriate for drying pistachio and sample is perfectly dried in this dryer |
| | Arata and Sharma | This dryer is suitable for prediction the temperature and moisture content under control and constant rate |
| | Pawar et al. | The parameter s of drying system are time dependent and it is performed to predict the drying rate |

Air-heater through which the drying air is heated as it flows over and under an absorber plate that is heated in turn by direct absorption of incident radiation. Crop to be dried is placed in drying chamber. The moist air flows through chimney and escapes into the surrounding is partially or totally covered with the transparent material to exposure the products to solar radiation.

**Figure 8.** Experimental Set-Ups for Forced Convection Mixed Mode Solar Dryer in Real Climatic Condition.

## Disadvantages of Solar Drying System

1) Quality of products are not obtained in some cases.
2) Adequate solar radiation is required.
3) It is more expensive.
4) Require more time for drying.

## Applications of Different Solar Dryers

Direct solar drying is mainly used in on- farming sectors. It is also suitable for small farmers in rural areas, where electrical power is not available. This kind of dryer is more efficient in drying small amounts of crops, fruits, and vegetables. A locally made indirect- type natural convection dryer is useful for drying fruits and vegetables in rural areas. A solar tunnel dryer can be used for drying jackfruit bulb sand leather. The mixed- mode dryer is cheap, readily available, and can be easily made by local farmers. Tomatoes, mango slices, and grains can be dried using this dryer, which is driven by a fan .Therefore; agricultural products are dried within a short time at ambient temperature. The natural convection dryer is more advantageous and applicable than other types. Mean while, the low-cost indirect- type natural convection solar dryers are used for drying cassava, bananas, and rough rice, among other products .The forced convection solar

dryer is used in small Firms with limited financial support from large industrial sectors .This efficient dryer requires a short time to dry products and is built to last.

## Conclusion

After the study of various type of dryers, an indirect foced solar dryer having recirculation of hot air is more suitable then others from the food preservation as well as time conservaration and energy conservation also because there is no risk of proper sun light as that in direct solar dryer and losses of air in that type of indirect solar dryer where there is no recirculation of air and takes more time in drying process in comparision to air recirculating solar dryer.the direct driers are mainly best for those areas where the proper resources (such as electricity and other fabricating material which is used the fabrication of indirect and mixed mode dryer )are not available.

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