



SOLAR DRYING

Introduction

The heat from the sun coupled with the wind has been used to dry food crops for preservation for several thousand years. Other crops such as timber need to be dried before they can be used effectively, in building for instance. This sun-drying has often developed into solar-drying, where the drying area is in an enclosed ventilated area – often with polythene, acrylic or glass covering – as a more efficient harnessing of the elements of the drying operation. There are innumerable designs in use and each has its advantages and disadvantages. However, there are three basic designs upon which others are based: solar cabinet dryer, tent-dryer, and solar tunnel dryer. These are discussed below after a brief description of the principles of drying.

Basic principles of drying

Drying depends upon:

- Temperature, humidity and quantity of air used
- Size of the pieces being dried
- Physical structure and composition
- Airflow patterns within the drying system

Heat is not the only factor which is necessary for drying. The condition, quality and amount of air being passed over and through the pieces to be dried determine the rate of drying. The amount of moisture contained in the air to be used for drying is important and is referred to as absolute humidity. The term relative humidity (RH) is more common and is the absolute humidity divided by the maximum amount of moisture that the air could hold when it is saturated. RH is expressed as a percentage and fully-saturated air would have an RH of 100%. This means that it cannot pick up any more moisture. Air containing a certain quantity of water at a low temperature will, when heated, have a greater capacity to hold more water. The table below gives an example of air at 29°C with an RH of 90%. Such air, when heated to 50°C will then have an RH of only 15%. This means that instead of only being able to hold only an extra 0.6 grams of water per kilogram (at 29°C), it is able to hold 24 grams per kilogram. Its capacity to pick up moisture has been increased because it has been heated.

When placed in a current of heated air, food initially loses moisture from the surface. This is the constant rate period. As drying proceeds, moisture is then removed from inside the food material, starting near the outside. Moisture removal becomes more and more difficult as the moisture has to move further from deep inside the food to the surface. This is the falling-rate period. Eventually no more moisture can be removed and the food is in equilibrium with the drying air.

The effect of air temperature upon relative humidity

Air temperature °C	RH%	Amount of water/kg air needed to reach 100% RH (grams)*
29	90	0.6
30	50	7.0
40	28	14.5
50	15	24.0

* ie the potential for the air to pick up moisture (RH = Relative Humidity)

During the falling-rate period, the rate of drying is largely controlled by the chemical composition and structure of the food. Design of a dryer depends upon the drying rate curve of the material to be dried but these curves are indicative only and depend upon the factors mentioned above. The heat required to evaporate water is 2.26kJ/kg. Hence, approximately 250MJ (70kWh) of energy are required to vaporise 100kg water. If the ambient air is dry enough, no heat input is essential. The greatest potential for drying crops in a short time is when the ambient air is arid and warm. If the air is warm then less air is needed. This temperature will itself depend mainly on the air temperature but also on the amount of solar radiation received directly by the food being dried.

Solar drying Operation

All dryers need ventilation to be able to dry crops effectively. Air movement can be by natural convection or can be assisted using fans. Solar food drying can be used in most areas but how quickly the food dries is affected by the variables indicated above, especially the amount of sunlight and relative humidity. Typical drying times in solar dryers are from 1 to 3 days depending on sun, air movement, humidity and the type of food to be dried. Most dryers are black inside, either painted or with black polythene inserts to absorb as much solar radiation as possible.

Cabinet dryers

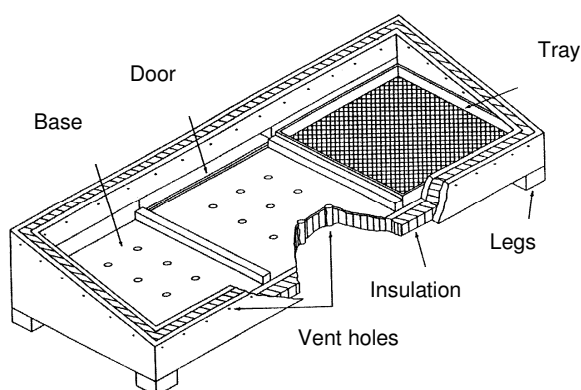


Figure 1: The Brace solar cabinet dryer

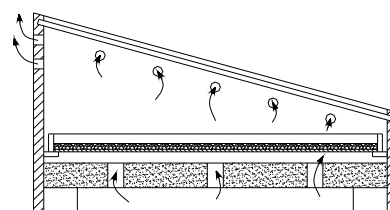


Figure 2: Section through the cabinet dryer showing the flow of air in through the vent holes in the underside past food placed on the drying trays and out of the holes at the top of the cabinet.

Tent dryers

The distinguishing feature of tent and cabinet dryers is that the drying chamber and the collector are combined. Such dryers provide protection from dust, dirt, rain, wind, and pests.

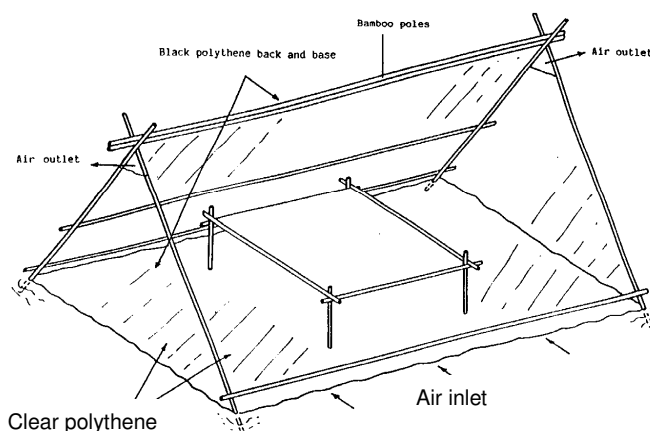


Figure 3: Tent Dryer

A much smaller tent dryer is shown below. Very similar to a cabinet dryer, it demonstrates the overlap in designs between solar dryers):



Figure 4: A small solar tent dryer, Ghana.
Photo: Tony Swetman.



Figure 5: Large solar tent dryer, Ghana. Photo: Tony Swetman.

Solar tunnel dryers

Many solar dryers employ the use of photovoltaic cells to power fans to blow air across the drying area. Chief among this type of dryer is the Hohenheim dryer produced by Innotech in Germany. By using a fan to create the airflow, drying time can be reduced substantially. Air flows across an area usually painted black (the collector area) to absorb the sun's heat and is blown across trays containing the material to be dried. The diagram below shows the features of the dryer.

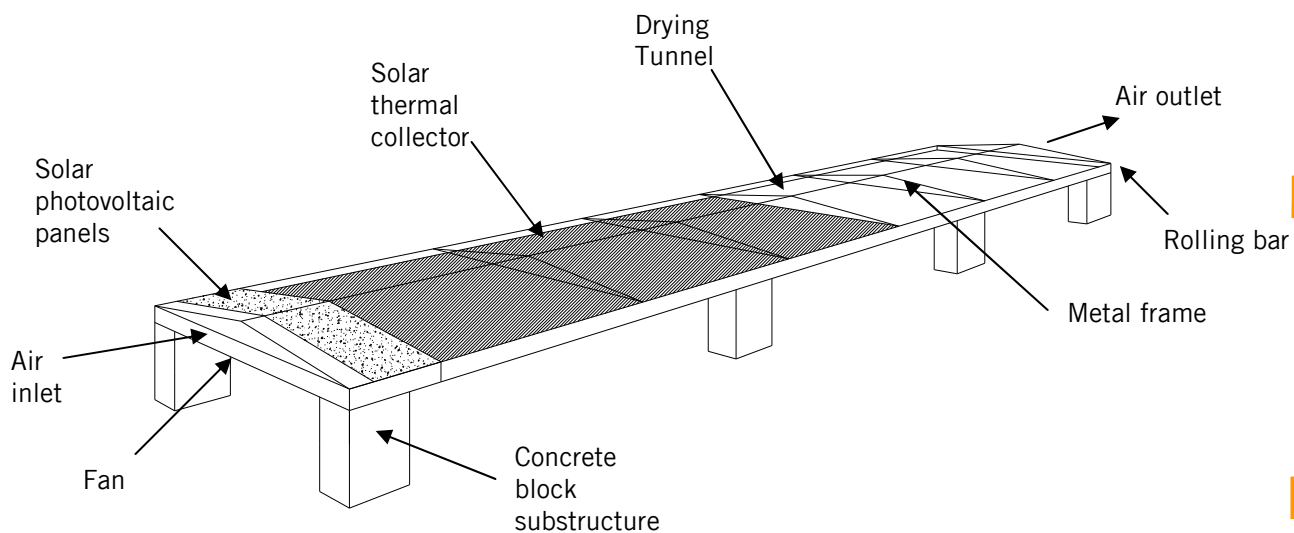


Figure 6: Solar tunnel dryer layout.



Figure 7: A Hohenheim dryer, Ghana. Black paint being applied to the collector. Photo: Tony Swetman.

There are several other types of solar dryer, many involving insulation and different air-flow methods. Some have a chimney fitted to the outlet to encourage better airflow, other make use of external heating sources such as hot water to allow further drying at night or when cloud cover prevents efficient drying. However, all are essentially variations on the three described above.

Sun drying compared with solar drying



Figure 8: View inside a Hohenheim solar tunnel dryer. Photo: Tony Swetman.

The great advantage of open-air drying is that there is minimal capital outlay. It is labour-intensive, although where labour is cheap this is not a drawback. An important advantage of solar drying is that the product is protected from rain, insects, animals and dust. This improves the hygiene and quality of the product as well as avoiding the covering, or transferring the crop to a sheltered area during rain. Solar drying, especially when using fans, gives some control of the drying process at elevated temperatures, and can be faster, which reduces the likelihood of mould growth and spoilage of the product. However care is needed when drying food at too high a temperature since too rapid drying can result in the outside of the food becoming dry on the outside and still wet on the inside. This is called “case-hardening”. This can give a false impression that the whole food is dry. On subsequent storage the trapped moisture will migrate to the outside of the food, raising the humidity and resulting in mould growth and spoilage.

Solar driers compared to fuel-fired dryers

The choice between using solar radiation or fuel-fired dryers using, for instance, wood, charcoal, diesel, gas or electricity depends upon the equipment capital cost, cost of raw material to be dried, operating costs of running the dryer and the likely price obtained for the final dried product. Fuel heating allows much better control of the drying operation than solar heating and does not depend on the sun to be shining. However, it is possible to combine solar drying with a fuel-source to reduce fuel costs. Such systems include pre-heating of air by solar energy.

Choice of solar dryer

The choice between alternative types of solar drier will depend on local requirements including scale of operation as well as the budget available. If intended for smallholder farmers drying crops for their own needs then capital cost may well be the main constraint and so low-cost plastic-covered tent or box driers may be the most suitable choice. However, commercial farmers with an assured market for their product may consider banks of fan-assisted, glass-covered solar dryers more appropriate for their needs.

Manufacturers

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Hohenheim Dryer

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Information

- *A Review of Solar Food Drying* by [Barbara Kerr](http://www.solarcooking.org/dryingreview.htm)
<http://www.solarcooking.org/dryingreview.htm>
- *Solar drying equipment*. FAO - Labour-saving technologies
http://www.fao.org/sd/teca/tools/lst/LSTP19_en.html
- *An Introduction to Solar Energy Applications for Agriculture*
<http://www.powernaturally.org/publications/agguide.pdf>
- *HEDON Household Energy Network*
[Construction and Use of a Simple Solar Drier to Preserve Food for Off Season](http://www.hedon.org.uk/construction-and-use-of-a-simple-solar-drier-to-preserve-food-for-off-season)

Further reading

- *Drying of foods*, Practical Action Technical Brief
- *Small-scale drying technologies*, Practical Action Technical Brief
- *Drying of Chillies*, Practical Action Technical Brief
- *Drying of Apricots*, Practical Action Technical Briefs
- *Drying Food For Profit: A Guide for Small Business*, Barrie Axtell, 2002, Practical Action Publishing ISBN 1 85339520 X
- *Setting up a Food Drying Business: A Step-by-step Guide*, Fabrice Thuillier, 2002, Practical Action Publishing, ISBN 1 85339 498 X
- *Drying Foodstuffs*, Jean François Rozis, 1997, Backuys Publishers
- *Producing Solar Dried Fruit and Vegetables for Small-scale Enterprise Development*. Natural Resource Institute, Central Avenue, Chatham Maritime, Kent ME4 4TB. 1996
- *Try Drying It!* Case studies in the dissemination of tray drying technology. IT Publishing. 1991

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This document was produced by Tony Swetman for Practical Action, November 2007.

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