

Low-cost Solar Drying

ABSTRACT

In many countries of the world, the use of solar energy in the agricultural area to preserve vegetables, fruits, coffee and other crops has shown to be practical, economical and the environmentally responsible approach. Solar heating systems to dry food crops can improve the quality of the product, while reducing wasted produce and traditional fuels - thus improving the quality of life, however the availability of good information is lacking in many of the countries where solar food processing systems are most needed.

This work presents the performance of several individual, medium and large-scale food processing systems, which incorporate solar drying. Demonstrated achievements through individual medium and large scale commercial applications will be studied, emphasizing technology transfer in rural areas. Works studied are catalogued with summaries, and use of the Internet is featured as a medium to facilitate the availability of this information.

INTRODUCTION

"Drying is an excellent way to preserve food and solar food dryers are an appropriate food preservation technology for a sustainable world." [1] Actually, solar food drying is one of the oldest agricultural techniques related to food preservation, but every year, millions of dollars worth of gross national product are lost through spoilage. Reasons include, ignorance about preservation of produce, inadequate transportation systems during the harvest season (mostly climate related), and the low price the rural farmer receives for products during the harvest season.

Drying of crops can change this trend and is useful in most areas of the world, especially those without a high humidity during the harvesting season. If drying of produce were widely implemented, significant savings to farmers would be achieved. These savings could help strengthen the economic situation of numerous developing governments as well as change the nutritional condition in these same countries. Unfortunately many of the areas that could benefit from solar drying technology lack adequate information related to how to employ this technology and which technology to use under specific conditions. Many of the latest developments in solar drying technology, as well as significant achievements through applying this body of knowledge are not available in libraries or the Universities of developing countries.

1. SOLAR DRYING

1.1 OVERVIEW

Drying preserves foods by removing enough moisture from food to prevent decay and spoilage. Water content of properly dried food varies from 5 to 25 percent depending on the food. Successful drying depends on:

- enough heat to draw out moisture, without cooking the food;
- dry air to absorb the released moisture; and
- adequate air circulation to carry off the moisture.

When drying foods, the key is to remove moisture as quickly as possible at a temperature that does not seriously affect the flavor, texture and color of the food. If the temperature is too low in the beginning, microorganisms may grow before the food is adequately dried. If the temperature is too high and the humidity is too low, the food may harden on the surface. This makes it more difficult for moisture to escape and the food does not dry properly. Although drying is a relatively simple method of food preservation, the procedure is not exact. [\[2\]](#)

1.2 Applications

For centuries people of various nations have been preserving dates, figs, apricots, grapes, bananas, pineapples, other fruits, herbs, cassava, yams, potatoes, corn, peas, onions, garlic, carrots, peppers, milk, coffee, meat, and fish by drying.

(Photos)

But drying is also beneficial for hay, copra (kernel of the coconut), tea and other income producing non-food crops. It is worth noting that until around the end of the 18th century when canning was developed, drying was virtually the only method of food preservation.

1.3 Benefits of Solar Dried Food

"Dried foods are tasty, nutritious, lightweight, easy-to-prepare, and easy-to-store and use. The energy input is less than what is needed to freeze or can, and the storage space is minimal compared with that needed for canning jars and freezer containers.

"The nutritional value of food is only minimally affected by drying. Vitamin A is retained during drying; however, because vitamin A is light sensitive, food containing it should be stored in dark places. Yellow and dark green vegetables, such as peppers, carrots, winter squash, and sweet potatoes, have high vitamin A content. Vitamin C is destroyed by exposure to heat, although pretreating foods with lemon, orange, or pineapple juice increases vitamin C content.

"Dried foods are high in fiber and carbohydrates and low in fat, making them healthy food choices. Dried foods that are not completely dried are susceptible to mold.

"Microorganisms are effectively killed when the internal temperature of food reaches 145 degrees Fahrenheit (F)." [\[7\]](#)

1.4 Solar Drying Recommendations

The El Paso Solar Energy Association [\[9\]](#) provides some practical information and links to other resources. They state that their information is prompted by the need for solar dryers in areas where fruit is plentiful in summer months, but because there is no simple and economic method to preserve it, much of it is left to rot, while in the winter there is hunger.

They agree that solar food drying can be used in most areas but clarify that how quickly the food dries is affected by many variables, especially the amount of sunlight and relative humidity. They provide some basic guidelines to drying food.

- Most of the resources researched recommend pre-treatment of the food, such as blanching, (boiling/steaming).
- Wash fresh fruits and ripe vegetables thoroughly.
- Effective drying is accomplished with a combination of heat and air movement.
- Remove 80 to 90% of moisture from the food.
- Typical drying times range from 1 to 3 days, again depending on sun, air movement, humidity, quantity, and type of food.
- Once the drying process has started it should not be interrupted, do not allow to freeze.
- Direct sunlight is not recommended.
- Temperature ranges of 100 to 160 degrees F. (37.2 C to 71.2 C) will effectively kill bacteria and inactivate enzymes, although temperatures around 110 degrees F. (43.2 C) are recommended for solar dryers.
- Too much heat especially early in the process will prevent complete drying.
- Food should be cut into thin slices, less than 1/2" thick (1.25cm) and spread out on trays to allow free air movement.
- Rotate trays 180 degrees daily for uniform drying. Move dryer food to bottom racks.
- Safe tray materials include Stainless steel rack - wood slats - cheesecloth - Teflon - Teflon coated fiberglass - nylon - food grade plastics

- Allow food to cool completely before storing.
- Store food in airtight jars or plastic containers, and do not expose dried food to air, light or moisture.
- Most fruits taste great dried including apples, apricots, bananas, grapes etc.
- Vegetables are best reconstituted by covering with cold water until they are near original size. They can be added in their dry form to soups/stews. Vegetables can also be ground into powders and used for instant soups or flavoring.

[1] **Scanlin, Dennis:** THE DESIGN, CONSTRUCTION AND USE OF AN INDIRECT, THROUGH-PASS, SOLAR FOOD DRYER; extracted from Home Power magazine, Issue No. 57, pages 62 -72, Feb/March 1997.

[2] **Kendall P. and Allen L.:** DRYING VEGETABLES; Food and Nutrition Series - Preparation - ; Colorado State University Cooperative Extension Service Publication 10 / 1998.

BLANCHING

Blanching is a method of pretreating fruits and vegetables by heating them in boiling water or steam before drying. Some people believe that almost all vegetables should be blanched before drying. They claim that blanching destroys enzymes that cause dried vegetables to deteriorate when stored.

On the other hand, enzymes are an important element of the nutritional value of food and should be preserved as best as possible. Blanching not only robs food of these enzymes but leeches out many other important vitamins and minerals.

Certainly, blanching has both its advantages and disadvantages. Whether you decide to blanch may depend on several things.

HOW YOU INTEND TO USE THE DRIED PRODUCT

Blanched vegetables rehydrate much faster, are more tender, and since they are already slightly cooked require less cooking time.

This makes it a preferable method when preparing quick-cook meals for activities such as backpacking or climbing. However, vegetables destined for casseroles that will be baked awhile might become mushy and overcooked if pre-blanched.

HOW LONG YOU INTEND TO STORE THE DRIED PRODUCT

Compared to fruit, vegetables have a relatively short shelf life. Most vegetables should not be stored longer than 6-8 months. This can be extended considerably longer if the dried vegetables are kept tightly sealed in a cool place (below 60° F.) If you plan to store vegetables more than 5 months, blanching will help prevent them from discoloring or developing an off flavor or strong odor.

THE TYPE OF VEGETABLE

Whether or not you decide to blanch also depends a great deal on the type of vegetable. Some vegetables dry well, rehydrate easily, and can be stored for long periods of time without being blanched. Others, such as potatoes, however, must be cooked in order to prevent blackening. On the following page is a guide for preparing vegetables.

MORE ON BLANCHING

You can see from the following table that blanching is optional for the majority of vegetables. One rule of thumb is if the vegetable you are preparing is one you would not normally eat raw (i.e. winter squash, potatoes, yams), you probably will want to blanch. Experiment, try vegetables prepared both ways. Let your own needs and tastes guide you.

NO BLANCHING NEEDED: Cucumbers, mushrooms, onions, peppers, tomatoes.

BLANCHING OPTIONAL: Asparagus, beans, beets, broccoli, cauliflower, celery, corn, eggplant, okra, parsnips, peas, rutabagas, squash, turnips, zucchini.

BLANCHING REQUIRED: Potatoes, yams.

BLANCHING TECHNIQUES

There are two methods of blanching. With Water Blanching the vegetables are submerged in boiling water for a set amount of time. In Steam Blanching the vegetables are suspended over the boiling water and steamed for a certain length of time.

IF YOU DECIDE TO BLANCH, WE RECOMMEND USING THE STEAM METHOD AS FEWER WATER SOLUBLE VITAMINS AND MINERALS ARE LOST.

HOW LONG TO STEAM

In most cases, vegetables should be steamed until they are firm yet tender. With the exception of potatoes and yams, they should not be cooked as long as they would be for eating, rather they should be just barely heated all the way through. The length of time a particular vegetable should be steamed will vary according to the following.

Dryer Design:

Trays, if used, are sized to comfortable dimensions (24" x 24" or 20" x 30", for instance). Then a supporting rack is made to that size. Air flow is essential so it is important that trays be sufficiently far apart to ventilate properly -- 6 to 8 inches if using natural ventilation. Less for forced ventilation. Tray frames should be light, but strong -- 1 1/4 inch x 1/4 inch or 3/4 inch x 1/2 inch small wood strips are sufficient for most purposes. The wood strips for the tray frames are cut to the full length and the full width of the tray. They are overlaid at the corners, notched if they are very thick, glued and screwed. Or they may be nailed with small nails which are bent over on the under side and pounded flat. Screen is stapled on. It may be secured with silicon sealant or thin lightweight wood or both.

One or two heavier screens made from 1" x 2" pine and covered with galvanized hardware cloth, are useful for drying non-food items -- clothing, wool, kindling and so forth. For support of extra heavy loads, rigid galvanized trays may be used under food safe screen. Galvanized screens may also be used to

make fruit leathers. The sauce is protected from the galvanized metal by a sheet of Tedlar or of regular kitchen plastic taped to the frame.

UPDRAFT SOLAR DRYER designs are the most frequently seen cabinet form. In this design, the hot air flows upward through a solar heat collection trough and enters the bottom of a cabinet underneath the food. The dry air rises through the trays and around the food, exiting through a vent at the top or near the top of the shadowed side. (See the Bibliography -- Valdez) The theoretical basis for this design is that hot air rises and therefore when heated, the air flows naturally upward through the trays of food.

DIRECTLY HEATED SOLAR cabinet dryers allow the sun to directly heat and dry the food inside an enclosed one-piece cabinet. Direct heating tends to be very efficient and produces fast drying. Proper air flow is essential to achieve maximum performance.

General guidelines for fruits and vegetables follow:

- Good quality food cut in thin pieces, not more than about 1/4 to 3/8 inch thick)
- Spread thinly on trays initially so there is a third to a half of the screen area clear for the passage of air. Can be more compact after the first moisture is gone.
- Label all food on the trays and carry the label along through processing to storage.

Thick vegetables need to be blanched or lightly pre-cooked. Leafy vegetables may be wilted slightly with steam, or dried directly from the garden. Cook potatoes and green beans completely. Fruit is pretreated by dipping in quite sour lemon water, or Ascorbic Acid (Vit.C) 2000mg/quart. After a short soak, the fruit is drained and spread on trays. This retards browning. (Later, the sour soak water flavored by the fruit can be used as a concentrate for making cool drinks.) Sugar, honey or salt are optional. Sulfuring is no longer used in most homes due to the possibility of breathing the hazardous fumes and allergic reactions to sulfur compounds. It has been found to be unnecessary anyway.







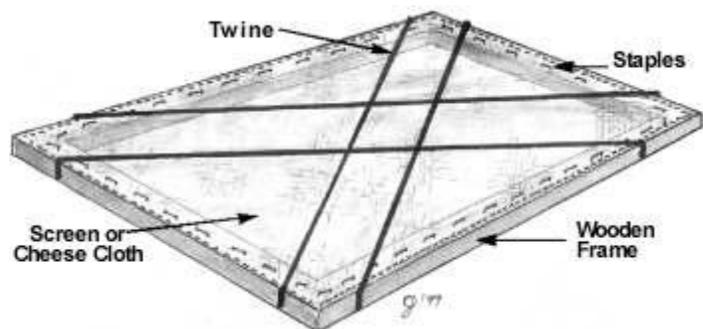
Solar drying basics

Dried food is preserved by its moisture content, or rather the lack of it. It is always better to have food overly dry than not dry enough. Mold, due to inadequate drying, is the main cause of food spoilage while stored.

Climate can affect solar drying. The ideal climate is one with low humidity and bright, strong sunshine. If you live in a humid or rainy area you may wish to dry foods with a dehydrator or in the oven. While drying in this manner will require some form of energy, the other benefits of dried food will still be available to you.

Do not dry your food outside in an area with a lot of traffic or air pollution. Contamination is possible from airborne emissions.

After food is prepared for drying, spread it in a single layer (pieces not touching) on drying trays and place in a sunny spot which permits good air circulation. Turn food daily. Dry strong-flavored or odored



foods by themselves.

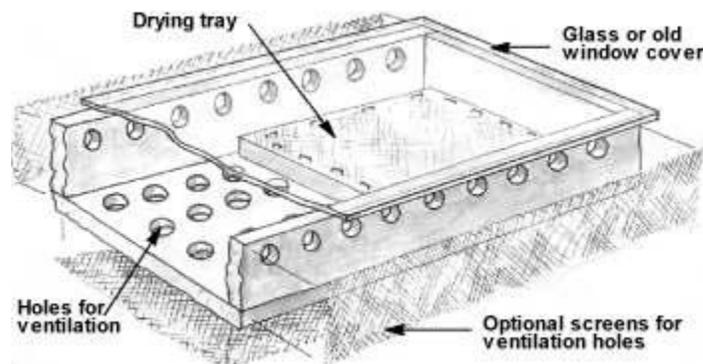
Drying trays can be made by simply using a frame and covering it with cheesecloth or plastic screen. Stretch tightly and fasten on the back with staples or tacks. A string can be placed across the back for reinforcement to prevent sagging (See illustration).

Do not use metal screen unless you cover it with cheese cloth. It may contaminate or ruin your food. Window frames, window screens, door frames, or discarded screen doors all make good drying trays. Set the tray on rocks or pieces of wood to permit air circulation from all sides. If insects are a problem while drying, loosely drape cheesecloth or other such fabric over the drying food. Arrange it so it does not touch food or it may stick.

To intensify the heat from the sun, an old window or piece of glass, can be placed above the food on the drying rack, allowing several inches of space for air circulation.

A simple solar dryer can be built from scrap material and an old window. Build a box similar to a gardening cold frame and cover with a piece of glass or plastic. Ventilation holes can be covered with screen to control insects if you wish. If the temperature inside gets too high (over 135-140 degrees F) provide more ventilation by raising the glass top a few inches.

Selecting a warm spot, like a heat reflecting driveway or roof-top, can help also.



Bring your trays inside at night or if rain threatens. Finish drying in the oven or over your heating stove if necessary.

Variables like your particular locality and climate, humidity, heat, and the food itself can affect the length of time it takes for food to dry, so it is impossible to give specifics. The following guidelines offer some dryness indications for particular foods.

Harvest your fruits and vegetables when they are at the peak of flavor. It is better if they are slightly immature than overly ripe.

Never place dried food which is still warm directly into the storage containers. Always let it cool completely first.

Fruits

Wash and dry fruit. Peel if desired and slice thinly. Apples, peaches, and other fruits may darken when exposed to air. This is caused by oxidation which can damage flavor and vitamin content. To prevent oxidation you can dip the fruit slices in a preserving solution. One solution is a salt water dip which is made by adding six tablespoons of pickling salt to one gallon of water. Soak for two to three minutes, then drain. Pat dry. Another solution is two tablespoons of ascorbic acid powder to one quart of lukewarm water. Soak, drain, and dry as above. Commercial fruit preservatives can also be purchased for this purpose.

Fruits are dry when somewhere between leathery and brittle. Drying times are affected by a number of factors, so experience and common sense are the best guides. After sun drying fruit it needs to be “equalized.” Remove from trays and place in a bowl inside the house. Several times per day, for one week, stir the fruit pieces. This will allow any moisture from pieces that are not totally dry to be transferred to those which are overly dry.

Another way to equalize dried fruit is to place it in a paper bag after removing from drying trays. Fold over the top of the bag and hang from the clothesline. Shake gently several times a day for two days.

Fruit leathers

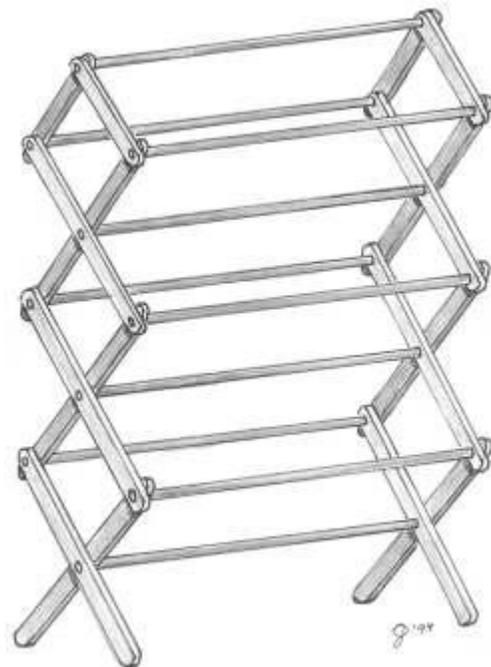
Overripe fruit can be used to make fruit leathers and is actually better than fruit which is at its peak. To prepare fruit for leathers, rinse then turn into puree by grinding, putting through a food mill, or mashing with a masher. Remove peels, pits, and seeds. Add fruit juice if necessary until it is of a consistency that will pour. If the fruit is too runny, thicken by cooking over low heat to evaporate water or add a thickener, such as wheat or oat bran.

Sweetening or spices can be added if you choose. Begin by adding only one to two spoons of sweetener since many totally ripe fruits need nothing more. If you are making leathers from light colored fruits such as apples or peaches, heat to almost boiling before beginning to dry. This will help prevent browning.

Line a cookie sheet or tray with plastic (don’t use wax paper or foil) or coat with a non-stick vegetable spray or cooking oil. Pour the puree in and spread evenly by tilting the tray or sheet back and forth to spread it out. The thinner and more consistent the thickness, the better and quicker it will dry. Three milimeter inch thick works well. If it is too thick it may spoil before drying, and if not consistent it will not dry evenly.

When top side is dry, remove from backing and turn over. Let the other side dry. Cut into squares or strips and roll up. Leather which is slightly sticky to touch will keep for about four to six weeks. Leather which is completely dried will keep longer but may be too brittle to roll.

Store leather in airtight containers with plastic wrap or paper between them to prevent sticking. Leather can be used as snacks or dissolved in water and used in any recipe calling for fruit.



Vegetables

Vegetables, like fruits, should be harvested at their peak of flavor. Wash to remove dirt, then prepare for drying by peeling, slicing, etc., as desired.

Controversy abounds over blanching vegetables before drying. Some insist on it, while others feel it is not necessary and successfully preserve without it. To blanch vegetables, steam them over boiling water until they are heated throughout and look translucent when cut with a knife. Remove from steamer and cool

immediately with cold running water or plunging into a pan of ice water. Drain, then pat dry with cloth or towel.

Spread on drying trays, as with fruits, and dry in the sun. Most vegetables are dry when they are brittle and will shatter when struck. Slices will snap when bent.

Storing dried food

Often fruit, even when dry, will stick together when stored. A tasty way to help prevent this is by “dusting” before storing. Powdered sugar, spices, or powdered oats can be used as “dust.” Place it in a bag then add fruit and shake to coat the pieces. Dusting fruit leather or placing pieces of paper between the rolls will prevent them from sticking.

Almost anything can be used as a storage container, as long as it has a tight fitting lid. Recycled jars or other containers work well, as well as storage bags or canning jars. If using a metal lid, place a piece of paper between the food and lid. Light causes oxidation, so store the dried food in a dark place or put the containers inside paper bags or a cardboard box to block light. Keep in a cool place.

Storing in small batches is wise. In the event one piece is not dry, it will not ruin the entire batch. Check weekly for signs of mold for the first several weeks. Label the food before storing.

Using dried foods

Add dried vegetables to soups or stews. The liquid will “re-hydrate” them while cooking. They can also be used in casseroles, sauces like spaghetti, and in nearly any recipe requiring vegetables.

Fruits can be eaten as they are for snacks. They can also be “re-hydrated” by soaking or cooking in juice. The warmer the liquid, the quicker the fruit will soak it up. Use dried fruits to stew, in baking, jams, sauces, or for syrups.

Dried foods will keep a minimum of six months in storage under the proper conditions.

