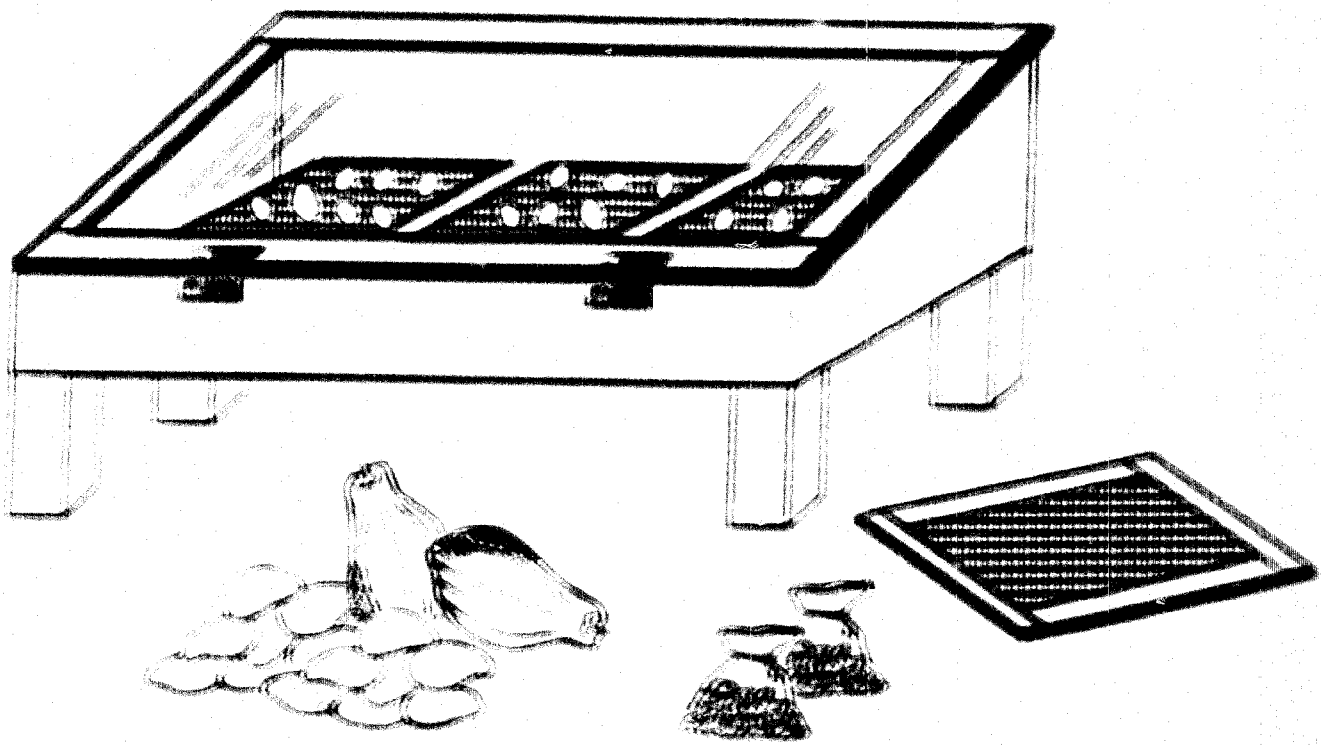
SOLAR DRYING FOR VITAMIN A



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Authors:

Mary Linehan
Katarina Paddack
Mohamed Mansour

Technical Reviewers:

Judy Edmister, Postharvest Institute for Perishables
Robert J. Haggerty, University of Idaho
John McKigney, VITAL Consultant
Jean Sebastien Roy, CDRH
Tina Sanghvi, VITAL
Marilyn Swanson, University of Idaho
Ronald Toussaint, Save the Children/Haiti
Larry G. Williams, University of Idaho

Illustrations:

CDRH
Peter Dhlarmina
Benedict Tisa
Mary Linehan

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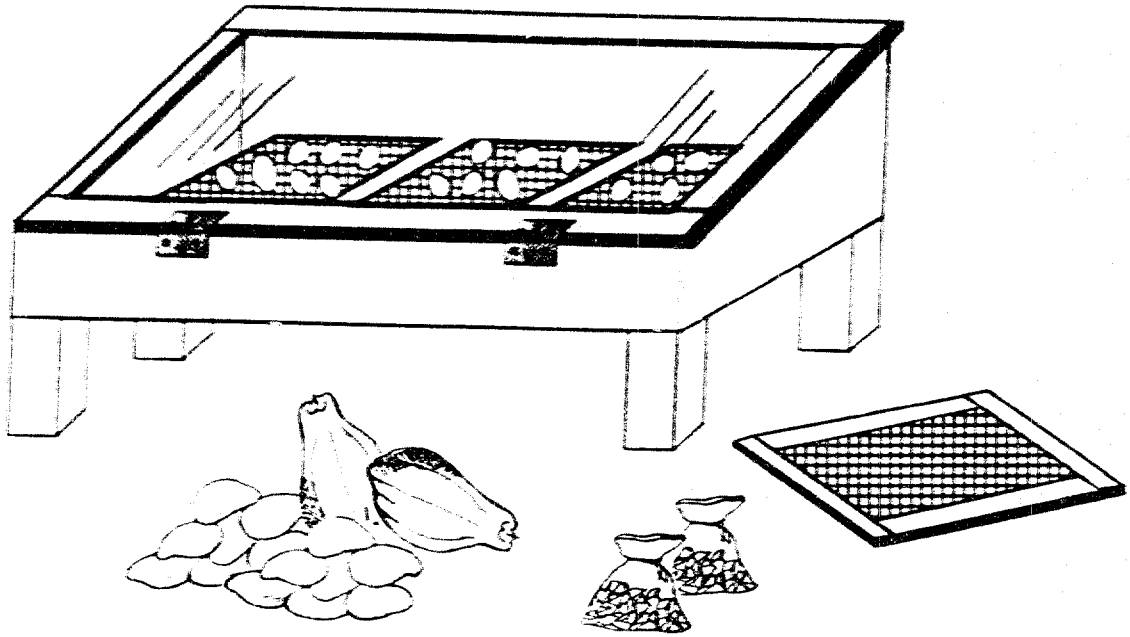

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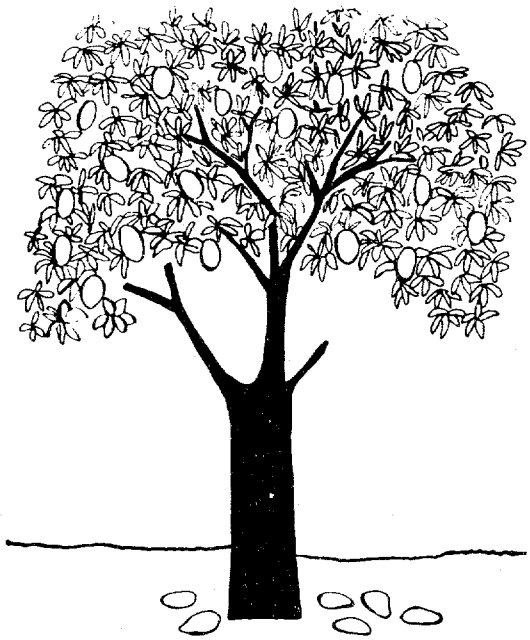
Preface

This manual is intended to provide basic instruction in the construction and use of a solar dryer and the methods for preservation of vitamin A-rich foods for VITAL programs. It has been designed as a program guide for use by field and community-level development workers and trainers working with community groups to promote increased production and consumption of vitamin A-rich foods.

The solar box dryer introduced in this manual is one of the simplest dryers to build and use. For individuals or groups interested in more advanced and efficient solar dryer models, additional references are listed at the end of the manual.

This manual can be used as a reference guide or as a training tool in any educational setting, such as a classroom, extension meeting, or workshop. Each chapter concludes with a summary that can be copied and distributed to those participating in training sessions.

We have found solar drying to be most useful in places where there is an abundance of vitamin A-rich foods available to the local community during certain seasons, which can be preserved for the off-season, when vitamin A-rich foods are scarce. The technology is proven and can be adapted and modified to fit local conditions and community needs. A variety of materials can be tested for building the dryers, and the acceptability and preferred use of the dried foods may vary from place to place. We encourage programs to experiment with the technology and adapt it to their own needs and environment.

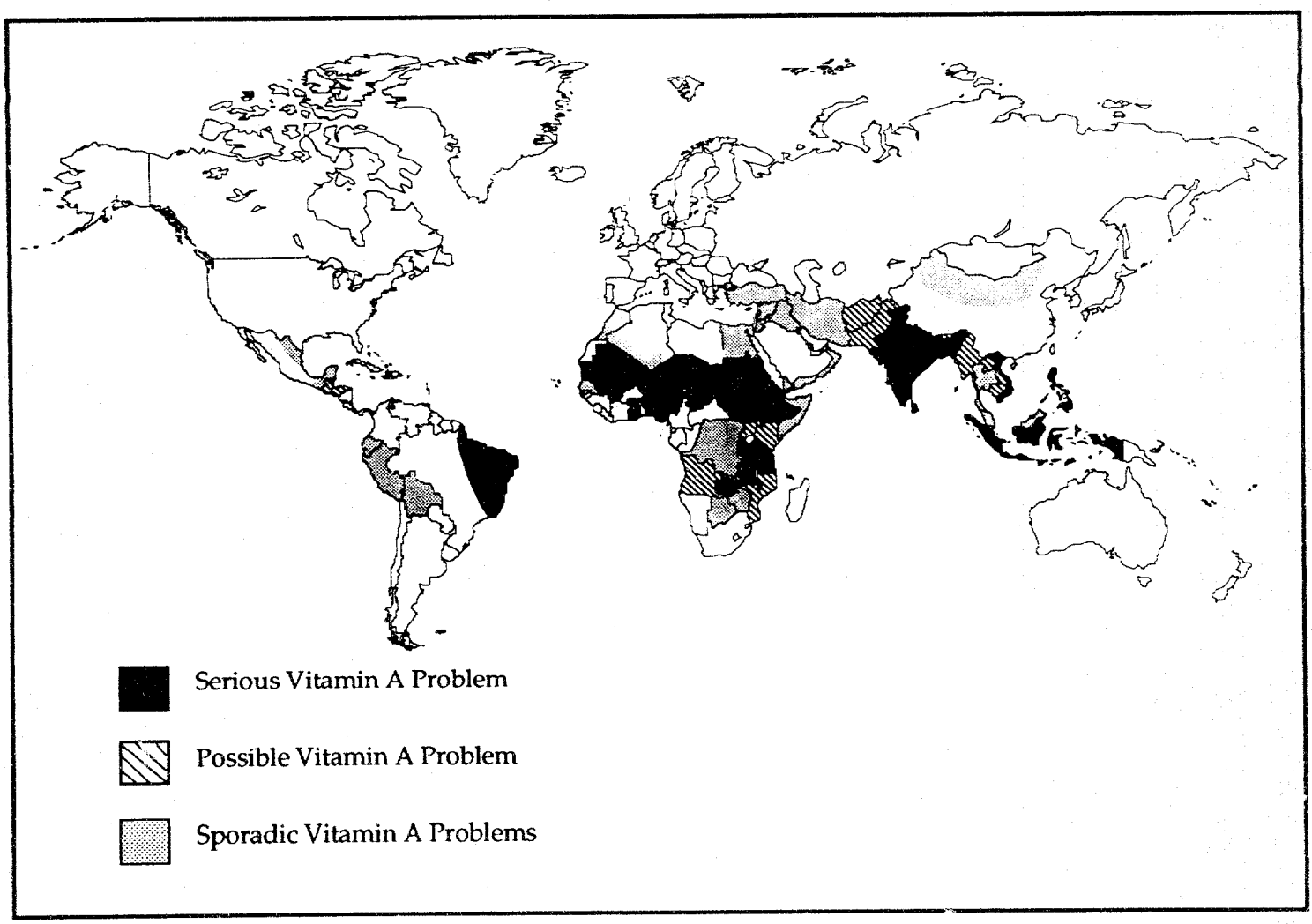


Introduction

Importance of Vitamin A

Vitamin A is important for the health of children. Vitamin A deficiency affects millions of children throughout the world.

Vitamin A protects against death from childhood illnesses such as measles, diarrhea and respiratory infections. It is required by the body for proper maintenance and functioning of the immune system and is essential to ensure the integrity of the respiratory and digestive tracts. Vitamin A deficiency is the largest cause of blindness in the developing world. One-million preschool-age children develop severe eye disease each year.



What can be done to improve the situation of people most affected by vitamin A deficiency? What can the populations do to protect their children from vitamin A deficiency?

The most economical and appropriate long-term method of increasing the intake of vitamin A is to increase the consumption of vitamin A-rich foods through better nutritional practices. Vitamin A is found in many low-cost foods commonly available to communities throughout the world. Through a variety of interventions, vitamin A deficiency can be greatly reduced or eliminated in the future.

In areas where vitamin A-rich food sources are seasonally available or expensive, small-scale gardening and simple food preservation can help make important foods available year round.

Solar Drying of Vitamin A-Rich Foods

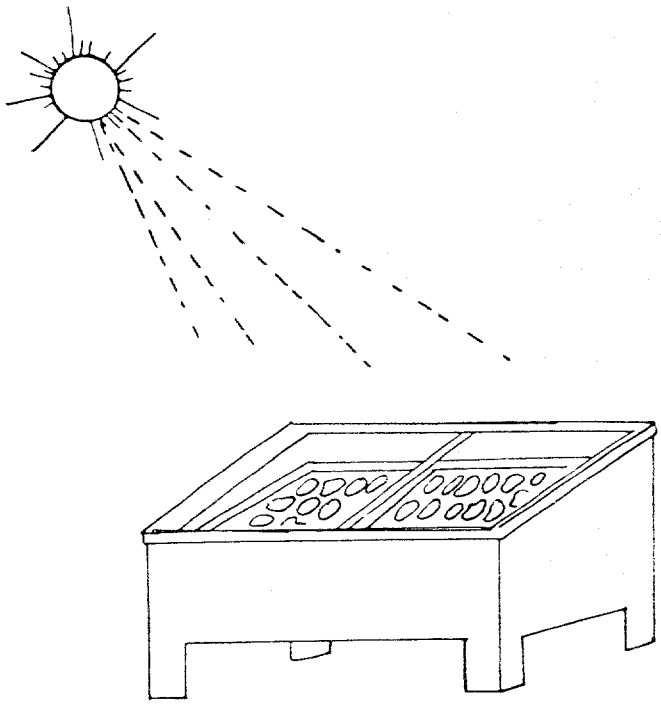
Solar drying technology has been used around the world to preserve a variety of fruit and vegetable crops as well as fish and meat. It is an affordable and appropriate method of preserving food products for storage for later sale or consumption when fresh crops are not available. In places where there is an abundance of vitamin A-rich foods during certain seasons, the surplus can be preserved for the off-season when vitamin A-rich foods are scarce. The technology is proven and can be adapted and modified to fit local conditions and community needs.

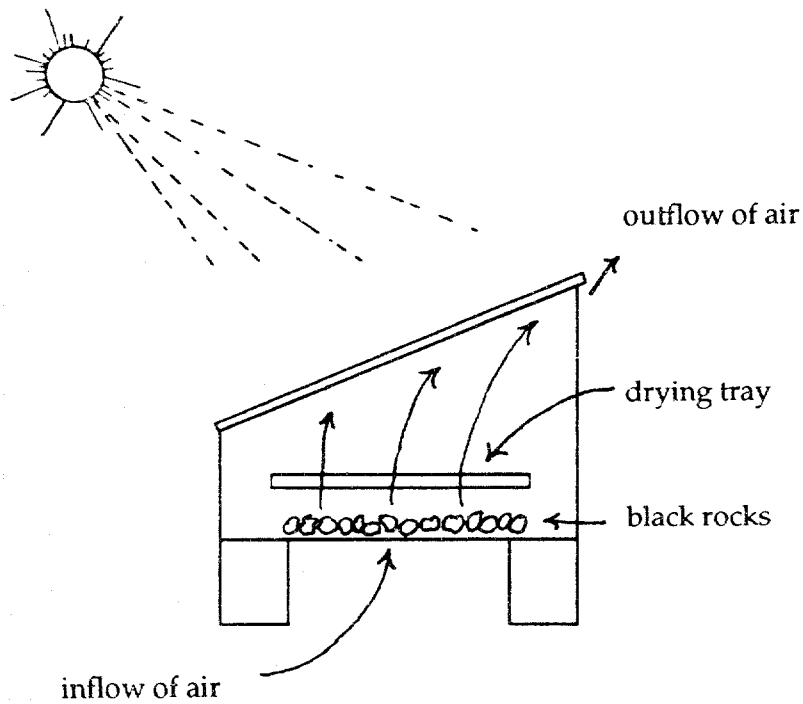
Chapter I
Overview of Solar Drying

- What is solar drying?
- How does it work?
- Benefits of solar drying.
- What you will need.

What Is Solar Drying and How Does It Work?

In many countries, the sun is a valuable resource. In most tropical countries, people traditionally use the sun to dry products such as fruits and vegetables, fish and meats, tubers, cereals, legumes, spices, coffee and cocoa. The traditional method usually involves laying the food directly in the sun, which often damages the nutritional value of the foods and does not maximize the role of air circulation. These traditional techniques can be improved to better utilize of the sun's energy. This manual presents information about solar dryers that will enable you to dry foods, especially fruits and vegetables, better and faster than traditional methods.





The basic solar-drying principle is to use the sun to dry out the moisture in food so that the food can be preserved for use at a later time. In a solar box dryer, the sun's rays heat the air that passes through the box dryer. As the air passes through the dryer, it is heated and evaporates moisture from the food in the dryer. The moisture-laden air is carried out of the dryer as the hot air rises and escapes from the dryer box through its top. The design of the dryer causes the temperature inside the dryer to rise and allows the air to circulate around the food and out of the dryer so that drying occurs more rapidly than with traditional methods. A solar box dryer is designed to shorten the drying time and improve the quality of the dried food by protecting the nutrient content. The drying techniques presented in this manual build on traditional methods used throughout the world. Accordingly, the techniques should be easily accepted by local populations.

Benefits of Solar Drying

Improved solar-drying techniques have many advantages and may be easily understood and mastered by anyone.

Increased Efficiency

- Solar drying uses energy sources that do not have to be bought but instead are found freely in nature, such as sun and wind.
- A solar dryer can be built by using local materials.
- A solar dryer requires less human labor and time to operate than traditional sun-drying methods.

Nutrition

- A solar dryer can provide quality foods during the off-season for a healthy, balanced diet. Solar drying allows the product to retain as much as 50 to 80 percent of its vitamin content. Drying fruits and vegetables such as mango and pumpkin can help resolve the problems of vitamin A deficiency found in many children under six years old.

Income

- Families or groups that use the solar dryer can produce enough dried produce to feed themselves and sell the balance for extra income. Community groups can also develop solar-drying activities for commercialization.

Decreased Crop Loss

- In a solar dryer, products are not damaged by turning during the drying process and are protected from insects and dust. The products dry faster and are protected from contamination, producing better quality fruits, vegetables, and seeds.

- Less of the crop will be wasted due to damage or spoilage. A solar dryer can help conserve surplus fruits and vegetables.

- When the products are properly dried they can be easily stored from three to eight months for consumption in the off-season.

- Drying allows products to be transported and sold in different areas, with less effort and loss, for comparable or superior commercial prices.

Basic Requirements for Solar Drying

In planning a solar-drying activity, keep in mind that several elements will be necessary:

At least six hours of direct sun per day.

Clean water for washing and preparing the foods.

A place to locate the dryers free from dust and shade and a secure place to store the dryers and equipment.

A work area. At the household level, the family kitchen can be used. For community-level production, a separate work area may be required.

A clean, dark, dry storage place for the dried products.

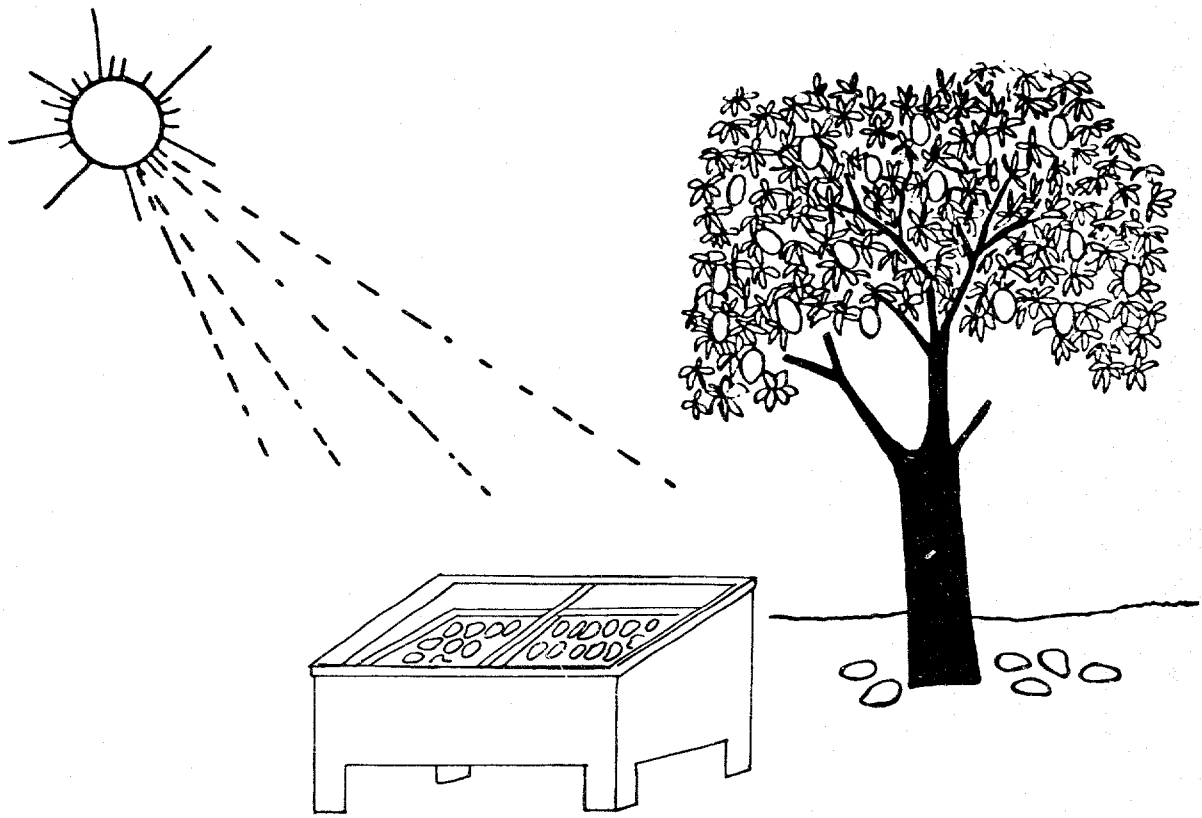
Summary of Chapter I

- Vitamin A is important for child health because it protects against childhood illness and mortality.

- Solar-drying technology has been used successfully around the world to preserve a variety of fruit and vegetable crops as well as fish and meats. It is an affordable and appropriate method of preserving food products to be sold or consumed at a later time when fresh crops are scarce or not available.

- Drying technology can be an important step in ensuring that there is always a supply of vitamin A-rich foods available throughout the year.

- Solar drying of foods can produce enough dried produce to feed a family and produce a surplus that can be sold for extra income.



Chapter II
Importance of Vitamin A

- Importance of vitamin A.
- Food sources of vitamin A.
- Vitamin A foods year round.
- Vitamin A foods you can dry.

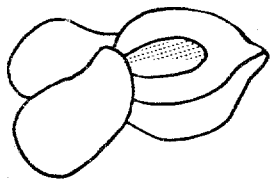
Important Vitamins Found in Fruits and Vegetables

Everyone should eat fruits and vegetables every day. Cereals and root crops are important for the energy they provide for the body, while meat, fish, eggs, and beans provide protein. Fat is also important because it helps the body absorb the vitamins in food. Fruits and vegetables provide the essential vitamins and minerals needed to stay healthy and to help prevent disease. They are also important for good digestion. Different vitamins provide different benefits to the body.

Vitamin A: Helps the body fight infectious disease, protects against eye diseases and promotes growth in children.

B Vitamins: Help the body use the energy and protein from the food people eat.

Vitamin C: Is important for children's growth, creation of red blood cells to fight infections, and protection against respiratory infections.



The Importance of Vitamin A to Good Health

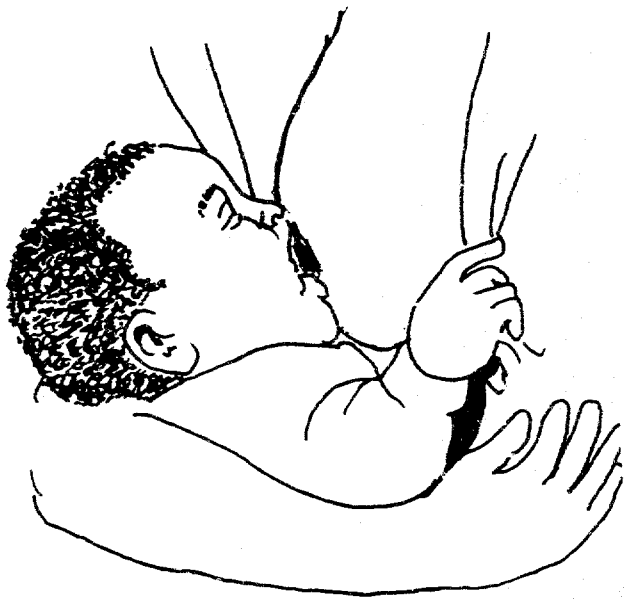
Vitamin A helps prevent infections that may cause death. It is necessary for maintaining good general health, especially in children. Vitamin A helps children grow and protects them against death from illness such as diarrhea, measles, malnutrition and respiratory infections.

Vitamin A is especially important for

- All children under five years old, because they frequently suffer from diarrhea, fevers and infectious diseases. During these illnesses, the body loses much of the vitamin A that it has stored. Blindness can result.

- Preschool- and school-age children because they grow very quickly and need vitamin A to grow up healthy.

- Pregnant women and women who are breastfeeding because they need to store and pass on vitamin A to their newborn babies to protect them from infection and disease.



Vitamin A is important for good vision. Preschool-age children who do not have enough vitamin A will have great difficulty finding their way in dim light. These children tend to stay quiet and avoid playing with other children after sunset. One name for this condition is night blindness. If children do not eat fruits and vegetables that contain vitamin A, their eye problems may become even more severe. The eye will become dry, and white foamy spots will appear on the eye's surface. At this stage, you can still reverse and stop the eye disease by feeding the child vitamin A-rich foods such as liver, butter or, whole milk and vitamin A-rich fruits and vegetables or by giving vitamin A capsules. If the child does not receive vitamin A-rich foods or supplements the eye will be more severely damaged which may lead to partial or total blindness. Vitamin A deficiency is the number one cause of childhood blindness in the developing world.

By maintaining a daily source of vitamin A in the diet, you can help make sure that your children grow up healthy and strong.

Food Sources of Vitamin A

For infants, breastmilk is the primary source of vitamin A. For children over six months of age, vitamin A deficiency can be prevented by eating foods such as:

- Dark green leafy vegetables, including spinach, amaranth, broccoli, watercress, parsley, manioc leaves, pumpkin leaves and avocado; and

- Vegetables and fruits with a dark yellow or orange color such as carrots, squash, sweet potatoes, mango, papaya, tomatoes and pumpkin.

Not all of these foods are available everywhere. Select from Box 1 the vitamin A-rich foods that are available locally and make your own list.

Box 1
Examples of Vitamin A-Rich Foods from around the World

Amaranth leaves
Baobab leaves
Basil leaves
Broccoli
Butter
Carrot
Cassava leaves
Cowpea leaves
Eggs
Kale
Liver
Mango (ripe)
Papaya
Pumpkin
Red palm oil
Red pepper
Red sorrel
Spinach
Sweet Potato (yellow/orange)
Tomato

Box 2
Daily Approximate Vitamin A Requirements

Age Group	Breastfeeding	Food Sources: Carrots	DGLV*	Mango
Children	Exclusive			
0-5 months	Breastfeeding			
6-11 months	Breastfeeding +	1/3	1/4 cup	1/4
12-35 months		1/2	1/3 cup	1/4
4-6 years		3/4	1/2 cup	1/2
Pregnant Women		2	1 cup	1
Lactating Women		3	1 1/2 cup	1 1/2

* DGLV = Dark Green Leafy Vegetables
Sources: *Vitamin A + Sieve*, 1986; The Composition of Foods Commonly Eaten in East Africa, 1988.

Daily vitamin A-rich foods are important for children even if they are not sick or do not have difficulty seeing. One-third cup of greens or one-quarter of a medium-size mango each day will fulfill the daily vitamin A requirements of children aged six months to three years.

Box 2 shows how much of some vitamin A-rich foods children and women should eat every day.

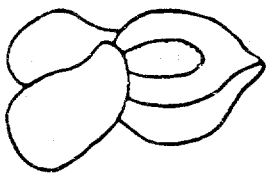
Having Vitamin A-Rich Foods Available Year Round

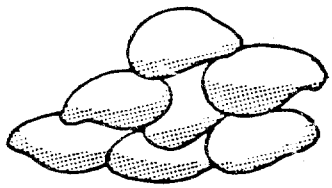
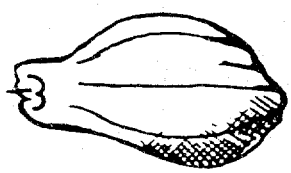
In some countries, such as Haiti and the Dominican Republic, children do not suffer from vitamin A deficiency during the mango season because they eat mangos when they are available. Women's groups in these countries are drying the mangos to ensure that this important vitamin A food source is available all year round.

Many fruits and vegetables do not grow all year round. When vitamin A-rich fruits and vegetables are out of season or are not available, there is a greater risk of not having enough vitamin A in your diet. Vitamin A can also be found in foods such as liver, butter, milk, meat and eggs, but these are often too expensive to eat every day. Fruits and vegetables can be preserved by solar drying to make sure that they are available all year round. The drying method described in this manual can help preserve vitamin A-rich fruits and vegetables for the whole year.

Summary of Chapter II

- Vitamin A helps prevent infections that may cause death.
- Vitamin A is important for good vision.
- Daily intake of vitamin A-rich food is important for children even if they are not sick or do not have trouble seeing. One-quarter of a ripe mango each day will fulfill the daily requirement of vitamin A for children aged six months to three years.
- Fruits and vegetables that can be dried for vitamin A include green leaves, mango, papaya, sweet potato, tomato and pumpkin.
- Because children are at highest risk for vitamin A deficiency, fruits such as mango and papaya are especially good to dry. Children can eat them as snacks, or mothers can mix the fruits into other recipes.



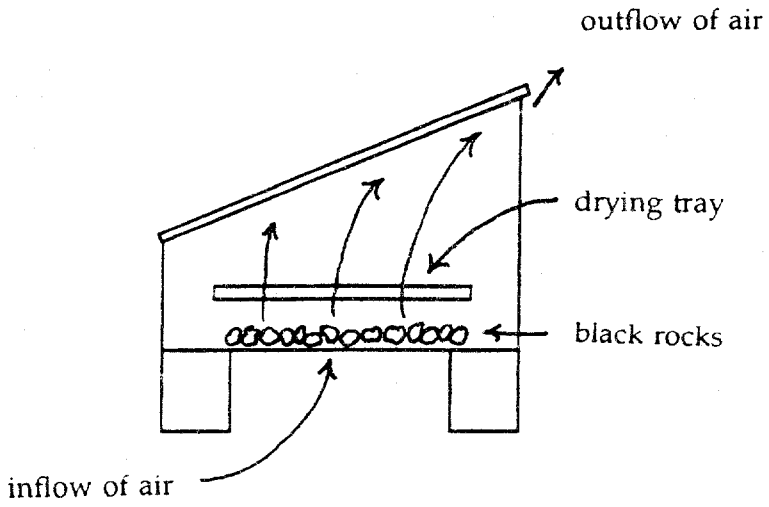



Chapter III
Building and Using the Solar Dryer

- How a solar dryer works.
- How to construct a solar dryer.
- How to use a solar dryer.

Although there are many types of solar dryers, they all use the same basic principle: air enters the dryer and is heated. The warm air then circulates around and between the drying products, which causes evaporation of water from the product. The design of the dryer increases the speed of drying and protects the quality of the food.

The flow of air in the solar box dryer is shown below. The air enters the solar dryer from below and is heated over the dark rocks in the insulated box that collects heat from the sun. As the air temperature rises, the food begins to release moisture. The warm air absorbs the moisture and rises, escaping through the air passage at the top of the dryer and carries the moisture with it. Fresh air is drawn in by natural convection through holes at the dryer base. The flow of air upward and out of the dryer is essential. If the warm moist air cannot escape, the moisture will condense and drip back down on the food in the dryer.



For the solar dryer described in this manual, the optimum drying conditions are eight to 10 hours of direct sun, raising the air temperature in the dryer to 40° to 60°C. Drying time for the foods depends on several factors: the kind of food and its moisture content, the thickness of the food slices, the air flow in the dryer and the temperature of the air inside the dryer. Experimentation with these factors will allow you to improve your drying technique based on your specific environment and needs.

Instructions

Materials Needed

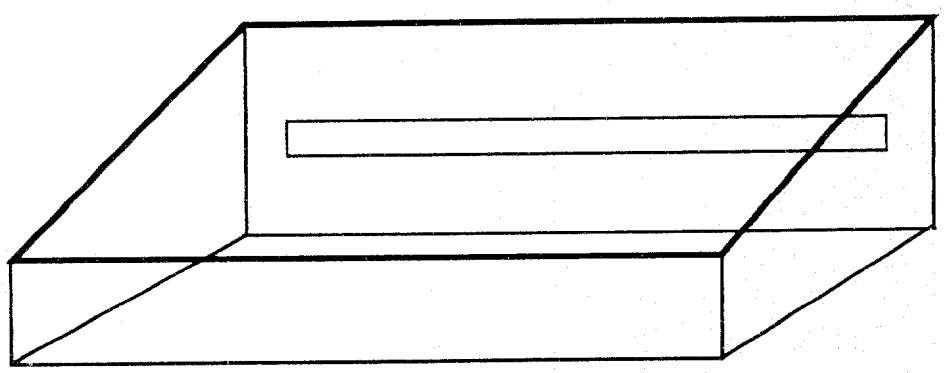
- Wood for sides, roof and drying trays
- Coconut husks, paper, etc., for insulation
- Nails or screws
- Metal grate or bamboo mat for the dryer floor
- Dark stones (about the size of your fist) to cover the grate
- Black paint or charcoal
- Heavy clear plastic to make the roof
- Metal or leather hinges
- Plastic screen for drying trays
- Large stones, bricks, blocks or wood for the legs
- Scrap tin sheeting

Determine what size you want to make your solar dryer. It can be any size that you wish, but keep in mind that to minimize the amount of shading, the box frame should be at least two times as long as it is wide. For 2-square meters of drying space the dryer should be built 1-meter wide by 2-meters long. The top edge of the side walls should be cut on a slant to catch the most sunlight. To determine the best angle of the roof, determine the latitude of your project site. For example, Haiti is between 15° and 20° latitude; the dryer roof should therefore be at an angle of 15 to 20°.

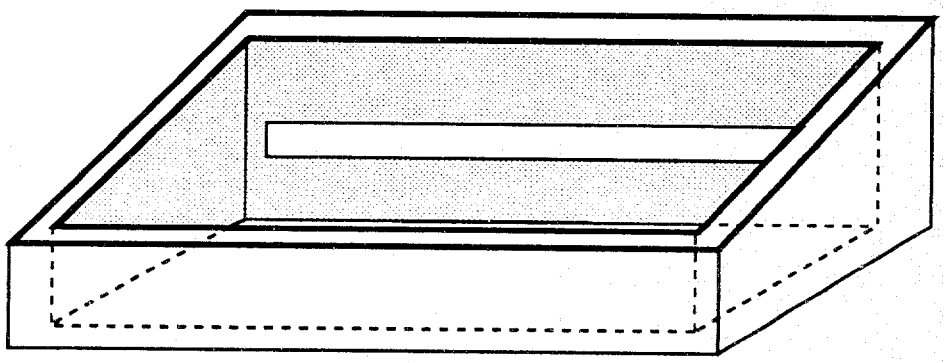
The following instructions are for a dryer 1 meter wide by 2 meters long, with a roof angle of 15°.

The dryer has two sets of walls with insulation in between the inner and outer walls to hold the heat within the dryer.

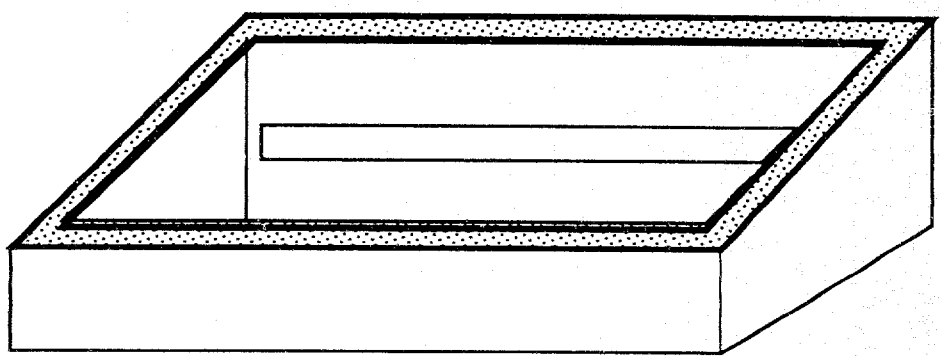
Begin by assembling the four outer walls. Notice in the picture that the back wall has an opening along the length of the dryer approximately 10 cm from the bottom of the wall. This opening will be used insert the drying trays into the dryer when it is finished. The opening may be made be cutting a hole in a plywood board or by leaving a space between two boards.

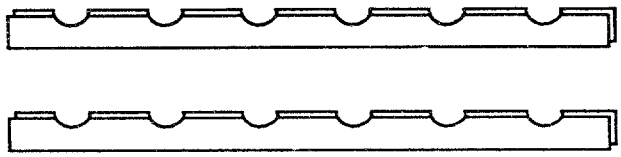


Assemble the inner walls. Remember to leave approximately 5 cm of space between the two sets of walls for the insulation. Notice that the inner back wall also has the opening for the drying trays.

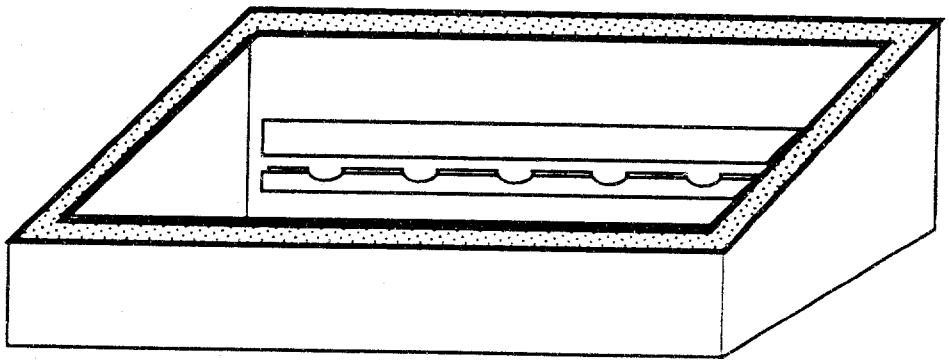


Fill the space between the walls with insulating material such as coconut husks, sawdust or wood shavings, or straw. Then cover the insulated space between the two walls with wood pieces or strong tape.

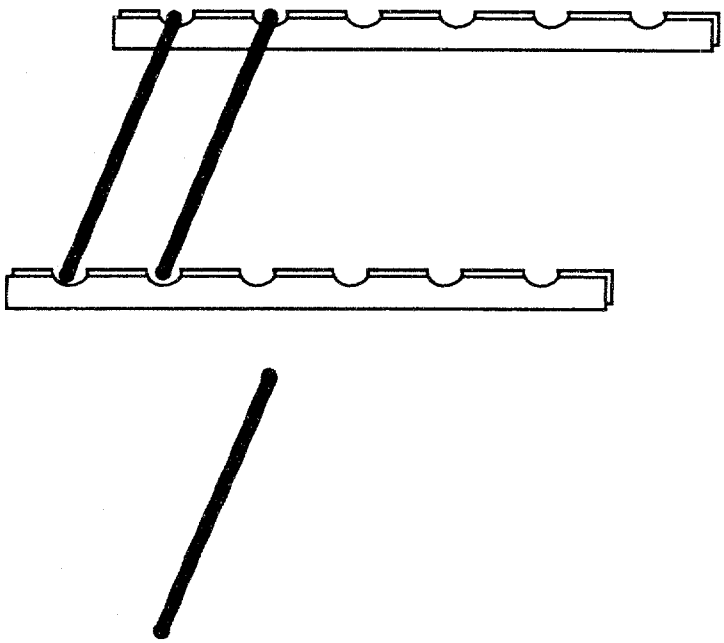




Prepare two narrow strips of wood the length of inside wall of the dryer. Cut grooves in these strips, matching the distance between them on the two strips.

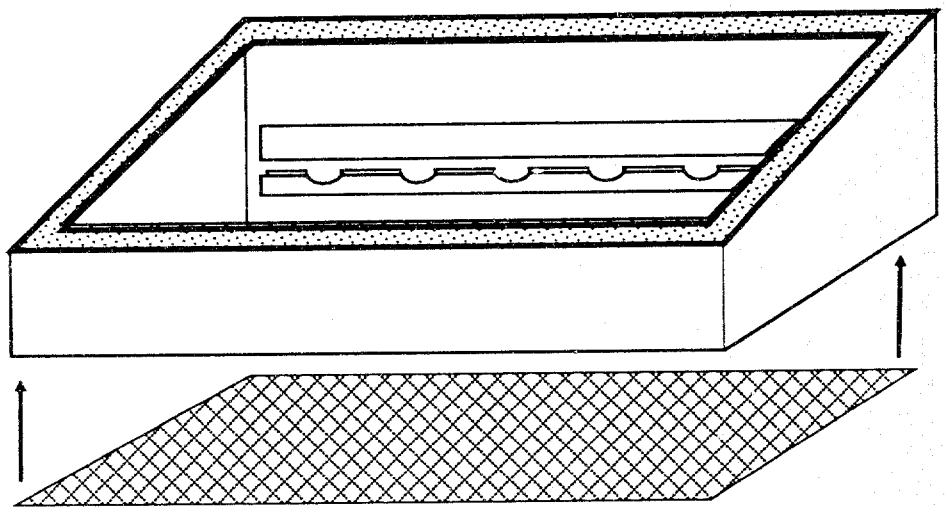


Attach one strip to the inside back wall of the dryer just below the opening in the back, as shown. The strip should be approximately 15 cm from the bottom of the wall. Attach the other strip on the inside front wall at the same level as the back wall strip.

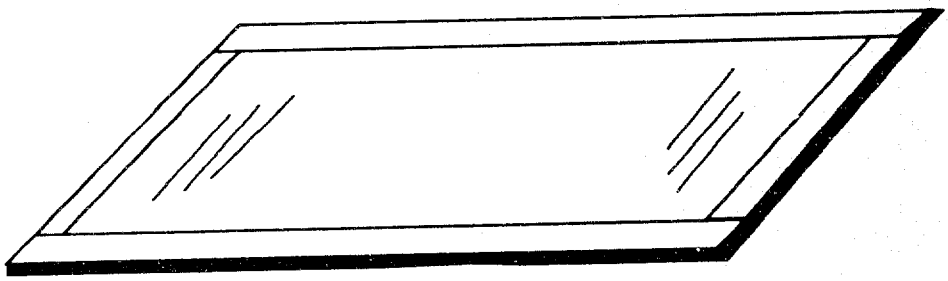


Cut rods to fit in the grooves as shown. These will support the dryer trays.

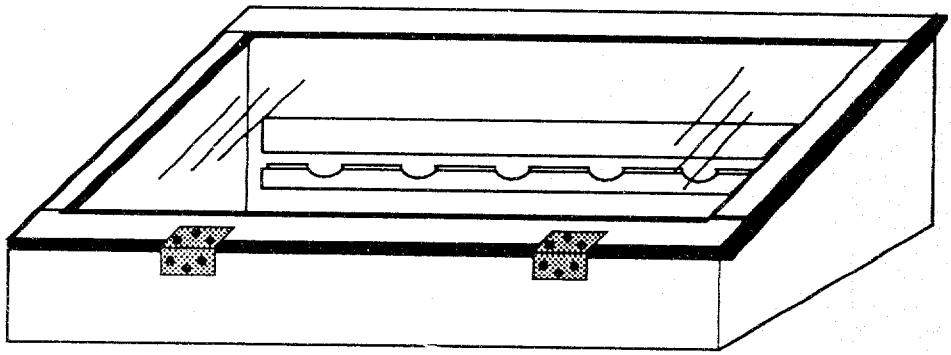
Attach the floor of the dryer. This should be a grate of metal, woven mat, strips of wood, or a sheet of wood with holes drilled in it. The floor of the dryer must allow air to pass through and be strong enough to hold rocks, which will be placed on the dryer floor.



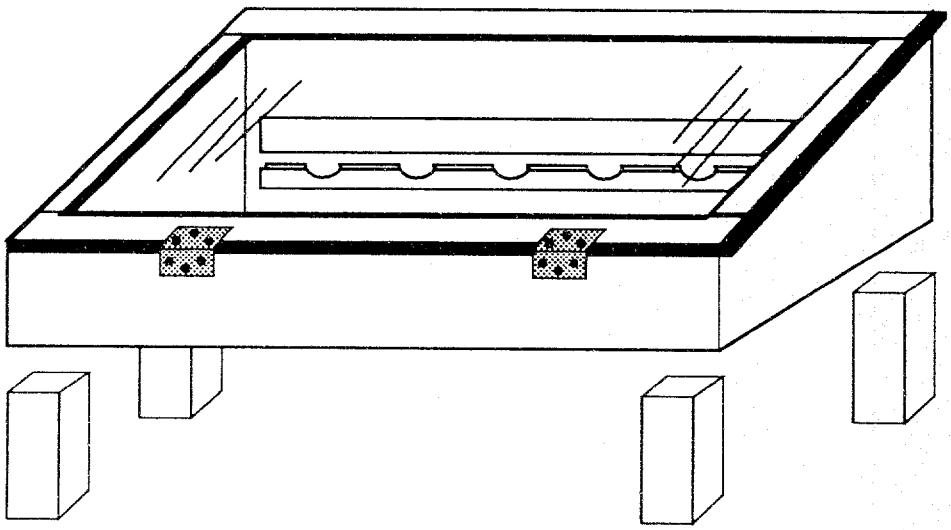
Measure and cut frame pieces for the dryer window. Cover the frame with clear heavy plastic sheeting.

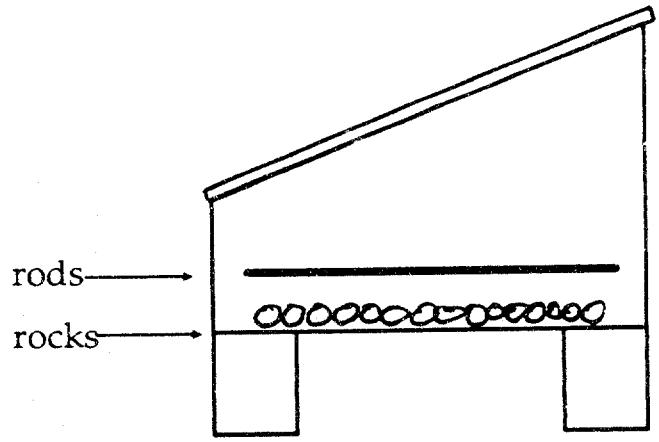


Attach the window to the front of the dryer with hinges. A latch is needed to hold the window down to prevent heat from escaping and to keep the wind from blowing the dryer open.

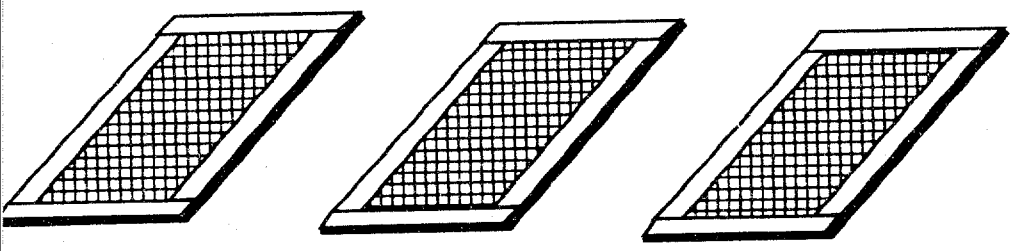


Place the dryer on legs or blocks for ventilation.

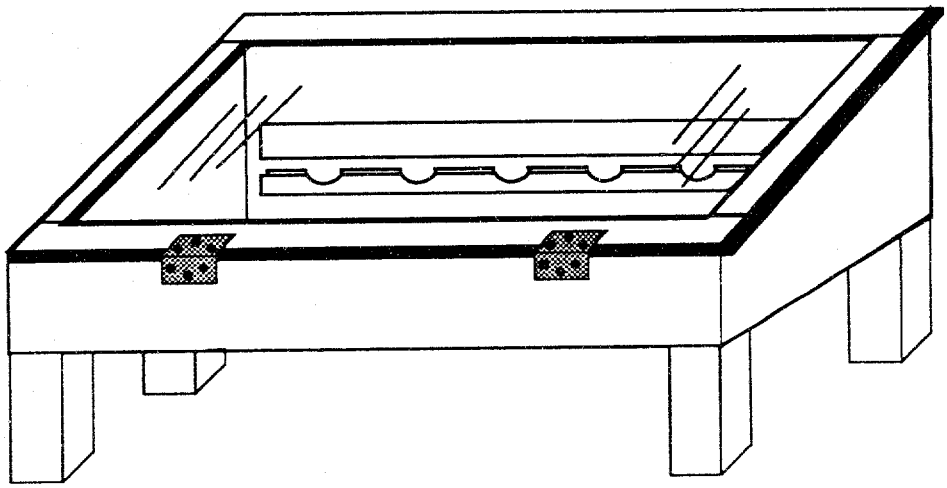




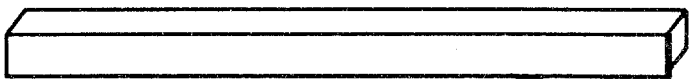
Cover the grate floor of the dryer with dark stones about the size of a fist. If the stones are light colored, paint them black to collect more heat.



Measure and cut the drying trays to fit inside the dryer. Measure the inside of the dryer to determine how many trays to build and their dimensions. Stretch plastic screen over the drying tray frames and nail in place. Be sure to use plastic instead of metal screen, since metal may rust and contaminate the food.

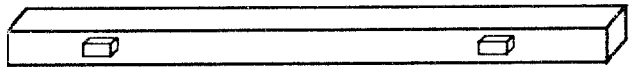


The trays are inserted through the hole in the back of the dryer.

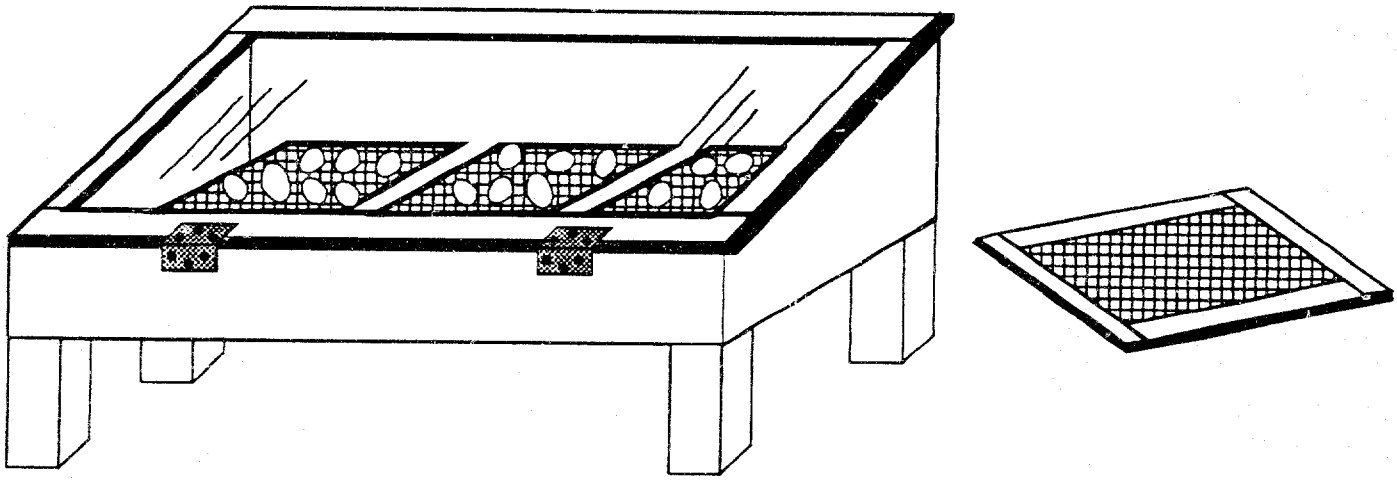


Prepare a wedge to close the hole in the back of the dryer. This will serve as a door for inserting and removing the drying trays, while minimizing the amount of heat lost.

After the trays are inserted, replace the door to retain the heat in the dryer. Add small handles to make it easy to remove and replace the door.



Paint the inside walls black to increase the temperature inside the dryer. The outside walls of the dryer can also be painted black, or, for increased efficiency, they can be covered by scrap metal siding.



Drying Time and Temperature

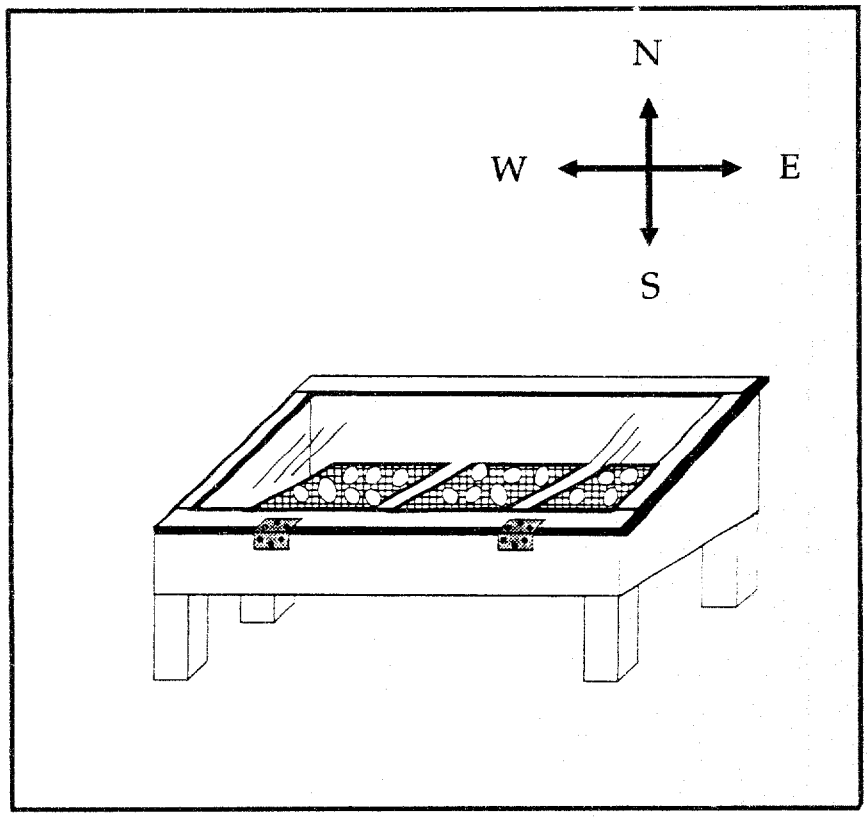
The optimal temperature for drying foods is between 40° and 60°C. In the morning when the sun is low, the temperature inside the dryer will be lower. If the sun becomes very hot during the day, the temperature may become higher than 60°C. Low temperatures will delay drying. Very high temperatures may cause the foods to burn.

To monitor the temperature inside the dryer, place a thermometer protected from sunlight in a corner of the dryer. Check the temperature at intervals during the day. If you keep a record of the temperature during different times of the day and different seasons, you will be able to plan and improve your drying schedule. The hours between 10:00 a.m. and 2:00 p.m. are the most important for drying. The dryer should be cleaned and ready for drying early in the morning so that foods can be placed in the dryer before 9:00 a.m., when it begins to heat up. The rocks in the bottom of the dryer will help keep the dryer hot late in the afternoon.

	Monday	Tuesday	Wednesday	Thursday	Friday
9:00					
10:00		26°			
11:00					
12:00 (noon)					
13:00		52°			
14:00					
15:00					
16:00		33°			
17:00					

Do not raise the roof of the dryer except when necessary because raising the roof will allow heat to escape. Sometimes the air inside the dryer may get too hot and the foods may burn. To decrease the temperature inside the dryer, the roof can be propped open a little bit to allow some heat to escape.

Positioning the Dryer To Receive Maximum Solar Energy



When drying fruits or vegetables, the dryer should remain fully exposed to the sun's rays for the whole day. It is essential that the site be chosen carefully and that the roof of the dryer faces southwest.

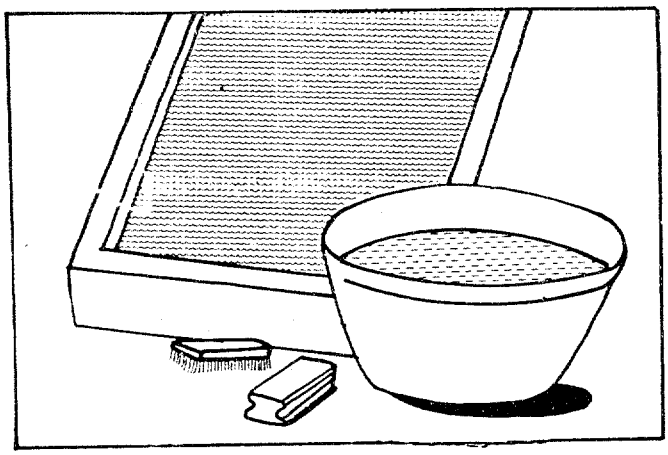
When finding a site for the solar dryer, it is important to keep the following in mind:

- Choose a site that is free of any shadow from houses, buildings and trees. Shadows will decrease the dryer's efficiency in collecting heat.

- Choose a site that is in a clean area, away from garbage and dirty water that could contaminate the products.

- Select level ground with good drainage.

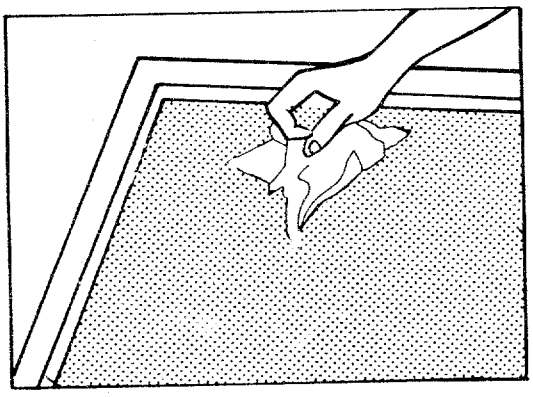
- Choose a site that is as near as possible to the building or area where the food is prepared in order to facilitate moving the products to the dryer.

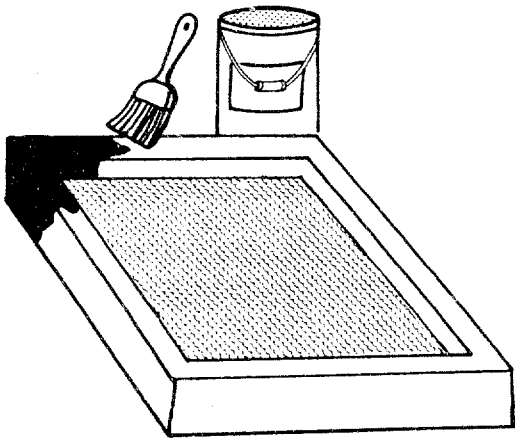


Taking Care of the Solar Dryer

To get the best results from the solar dryer, it should be cleaned carefully after every use.

- Wash the screened drying trays in soapy water to remove dried food residue, then rinse thoroughly and dry in the sun.





- The walls of the solar dryer should be repainted black when the paint becomes faded or begins to peel. If there is no black paint, make a thick paste with water and charcoal and use it as paint. The screen on the drying trays should never be painted because the paint may contaminate the food.

Summary of Chapter III

- Although there are many different types of solar dryers, each uses the same basic principle: air enters the dryer and is heated. The warm air then circulates around and between the drying products, causing water to evaporate from the products. The warm moist air rises and escapes through the top of the dryer, and fresh air is drawn in by natural convection through holes in the dryer floor.

- A solar box dryer is rectangular and set on legs. It has a plastic-covered, slanted roof to catch the most sunlight. The floor is wood with holes or a metal grate. To absorb the sun's energy, stones painted black are placed inside the dryer on top of the grate. The inside of the dryer is painted black to absorb heat.

- A solar dryer should be placed on a site that is free of any shadow from houses, buildings and trees.

- The hours between 10:00 a.m. and 2:00 p.m. are the most important for drying. Food should be placed in the dryer early, before it begins to heat up.

- The optimal temperature for drying foods is between 40° and $60^{o}C$.

- To get the best results from the solar dryer, it should be cleaned carefully after every use.

Chapter IV
How To Prepare Fruits and Vegetables for Solar Drying

- Preparing foods.
- Cleaning and slicing.
- Blanching.
- Drying and testing.

Before beginning to dry fruits and vegetables, you must identify which products can be dried for families' needs during the off-season. Develop your own agricultural calendar to determine when different foods are available in your area and to identify the season when vitamin A-rich foods are scarce. Which products are harvested in the same season? Which grow throughout the entire year?

SAMPLE AGRICULTURAL CALENDAR

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Mango				—	—	—					—	—
Carrots				—	—	—						
Tomatoes					—	—	—					
Pumpkin								—	—	—		
Banana	—	—	—	—	—	—	—	—	—	—	—	—
Sweet potatoes				—	—	—	—	—	—	—	—	—
Green leaves				—	—	—	—	—				

According to this sample calendar, mango will need to be dried in large quantities during the short growing season to ensure that the supply will last until the next harvest and to make certain that this important crop is not wasted. During the months of January, February and March, none of the important

vitamin A-rich foods is available. This is the season when the dried foods are most important.

What You Need To Prepare Food

Containers or bowls to wash fruits and vegetables

Clean, boiled water

Spatulas, spoons, knives

Food grater, grinder, or mill

Steamer to blanch the vegetables

Strainer with fine holes

Preparing Foods to Dry

Step 1. Decide which fruits and vegetables to dry. Fruits and vegetables to be dried should be chosen with respect to their seasonal availability, appropriateness for drying, and how they can be used once dry. Once you begin to dry foods, experiment by drying different types of produce to determine which will be the most useful and how much produce is needed.

Fleshy fruits such as mango, pineapple and pumpkin are ideal for solar drying because of their lower water content. However, fruits such as watermelon, which are almost entirely made up of water, will not dry well since there is nothing left of the fruit when it is dried. Similarly, avocado is not an appropriate food for drying because its oil content prevents it from drying properly.

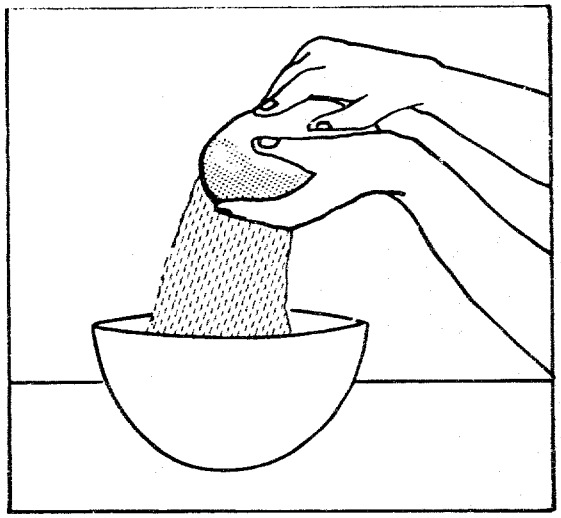
It is important to chose vitamin A-rich foods to store for the off-season.

Step 2. Fruits or vegetables should be dried on the same day that they are harvested. If fruits and vegetables are ready to be eaten, they are ready to be dried. Choose fruits that are well ripened and sweet, but be careful that they are not too ripe or soft.

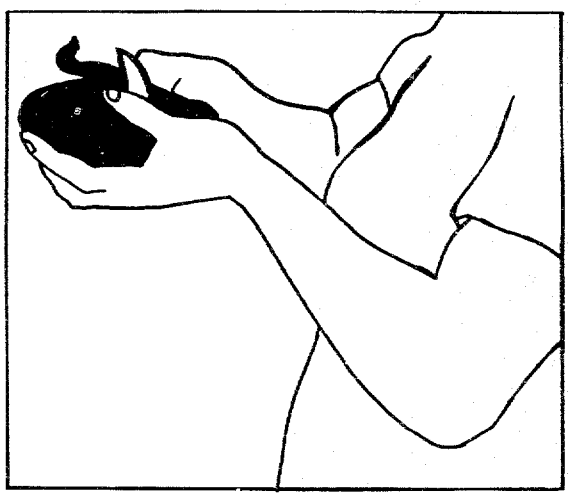
Choose vegetables that are as fresh as possible and ready for cooking.

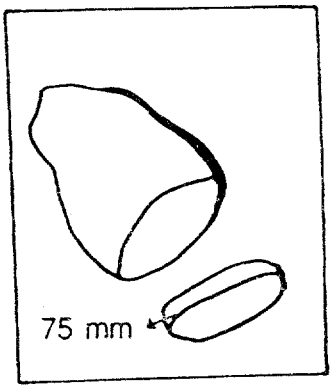
Step 3. Carefully wash your hands, knives and all the containers used to prepare the fruits. If you are not careful enough about cleanliness, your hands and kitchen utensils can transfer germs to the products.

Step 4. Carefully wash and brush all the fruits and vegetables in clean water. If you are not sure about the quality of the water, boil it for 15 minutes before using.



Step 5. Peel the fruits and vegetables with a clean, sharp knife. Cut off the bruised parts of the fruit. They may contain bacteria that could spoil the dried products.

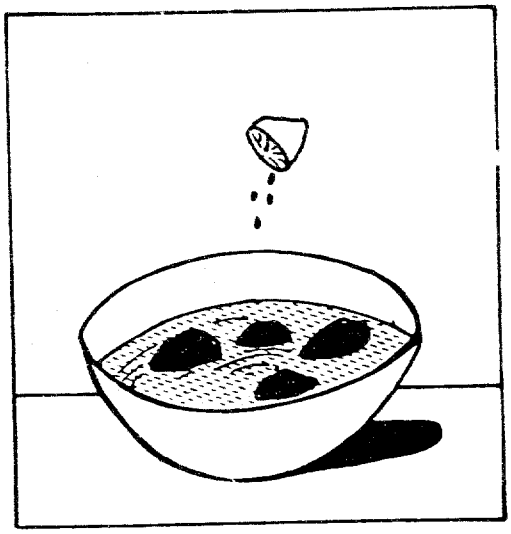




Step 6. Using a clean, sharp knife, cut the fruit into even slices. Different fruits and vegetables may need to be sliced in different ways to dry best. Mangos, papayas, pineapple, banana and sweet potato should be sliced about 75 mm thick. Remember that the way the dried fruit looks will depend on how carefully it is prepared. Bruised or over-ripe fruits will not dry well as slices, but they can be used to make fruit leathers.

Leathers are puréed fruits and vegetables that have been dried to a chewy, leathery consistency. They may be made from a single fruit or from a combination of different fruits. If you are drying mangos, there will be fruit close to the seed that is difficult to slice. This fruit should not be wasted. Cut it off and use it in fruit leathers.

Carrots can be diced or sliced very thinly. Coconut should be shredded. Green leafy vegetables such as spinach can be laid directly on the drying trays.



Each food can be tested at a variety of thicknesses and drying times to achieve the best product. If the slices are too thick, they may dry unevenly. The outside may dry too quickly and form a crust while the inside remains moist, leading to spoilage during storage. If the slices are too thin, they may become too dry and difficult to chew. Experimenting with your own dryer and technique will allow you to determine the optimum thickness of the foods you are drying.

When sliced, some fruits may turn brown; to prevent this you can sprinkle the fruit slices with lemon juice to preserve their color or place the slices in clean water and add lemon juice.

Blanching Vegetables

Vegetables and leaves should be blanched before they are dried. "Blanching" means to cook the vegetables partially by steaming or boiling in water to prevent the vegetables from losing their color, taste and vitamins. If vegetables are not blanched, the vitamins may be lost during storage. Blanching time will vary depending on the food and the thickness of the slices. The food is properly blanched when it becomes a very bright color and is tender. Green leaves may be blanched in one minute, pumpkin and sweet potato slices may require three to four minutes.

There are two ways of blanching.

1. Water blanching

Chopped or sliced vegetables are cooked directly in boiling water for two to three minutes and then rinsed in cool water. Drain immediately and place directly on the drying trays.

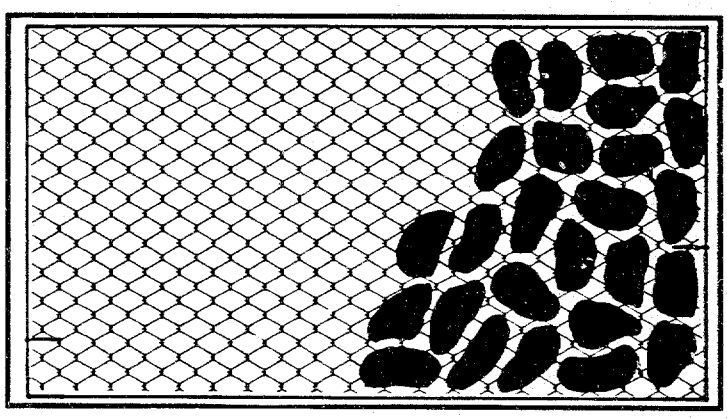
2. Steam blanching

Vegetables are placed in a wire basket suspended over boiling water for two to three minutes and cooked by the steam. Place immediately on the drying trays.

Steam blanching is the preferred method because fewer vitamins and essential minerals are lost in the water, but it is much slower than water blanching, especially when the water does not fully boil.

Arranging Fruits or Vegetables on the Drying Trays

The fruit or vegetable slices should be spread out evenly on the drying trays. They should not be placed in piles or on top of each other, as this will slow down the drying process. Ideally, at least 1/2 cm should separate each individual piece so air can pass between the slices. Since the box solar dryer is designed to heat up the air inside of the dryer and carry the moisture from the drying food, air flow between the pieces of food is very important.



Products such as grated coconut can be put in piles 2 cm deep but, for optimal dryness, they should be stirred during the drying process.

Once the products are placed on the trays, the trays can be put into the dryer. It is important that the products are protected from insects and dust, which will damage their quality.

Drying Time

Several factors influence the amount of time it takes for each food to dry, including the size of the pieces being dried, the heat inside the dryer, and the moisture level of the air.

When the sun is very strong, with no cloud cover, sliced mangos can dry in approximately seven to 10 hours. Green leaves can dry in three to four hours. Shredded coconut can dry in a few minutes.

Because of differences in the sun's heat at different times of the day and at different times of the year, you need to experiment with drying times for various produce.

Optimally, fruits and vegetables should be dried within one or two days. The shorter the drying period, the better is the food quality. If the drying process takes longer than two days (for example, when the weather is rainy), the product may darken and loose flavor and vitamins. However, it is more important to dry the foods adequately before storage, than to dry them quickly.

If the fruit does not dry within one day, the trays should be covered with a clean cloth or plastic sheet to keep out dirt and insects and then stored in a dry place. The trays can be put back in the dryer the next day.

How To Recognize if the Food Is Well Dried

When the food is dry, it is important to package it promptly and store it properly. For the product to last several months without spoiling, adequate drying is essential. To test if the food is adequately dried, three methods can be used.

1. Plastic Bag Method

Place the dried food inside a tightly closed plastic bag or a clean, tightly closed metal container. Then place the bag or container in a dry, shaded area.

After one day, check to see if moisture has developed in the plastic bag or container. If there is moisture, the fruits and vegetables must be placed back in the solar dryer. If this is not done, the products will spoil. If there is no moisture, you can store the dried produce in a plastic bag.

2. Touching Method

You can test mangos, papayas, and apricots by squeezing a piece in your hand. If you do not feel any moisture, the fruit is thoroughly dry. When you open your hand, the piece should spring back more or less to the same shape as before you squeezed it. If pumpkin, plantains, and coconut are well dried, they will break when squeezed in your hand. Green leaves will become brittle and crumble easily when dry.

3. Weighing Method

Another method is using a scale to weigh the products before and after drying them. When the products have dried, compare the fresh and dry weights of the product. Dried mangos, papaya, and apricots will weigh approximately 80 percent less than they did when fresh. Dry coconut or plantains will weigh approximately 50 percent less than they did when fresh.

Summary of Chapter IV

- Steps in preparing foods to dry:

  1. Decide which fruits and vegetables to dry.

  2. Fruits or vegetables should be harvested on the same day they will be dried. Choose fruits that are well ripened and sweet, but be careful that they are not too ripe or soft.

  3. Wash hands, knives and all the containers used to prepare the fruits.

  4. Wash and brush all the fruits and vegetables in clean water.

  5. Peel the fruits and vegetables with a clean, sharp knife. Cut off the bruised parts of the fruit.

  6. Cut the fruits or vegetables into even slices. Carrots can be diced or sliced very thinly. Coconut can be shredded. Green leafy vegetables can be laid directly on the drying trays.

- Lemon juice will prevent fruit slices from turning brown.

- Blanch vegetables to prevent them from losing their color, taste and vitamins.

- Spread fruit or vegetable slices evenly on the drying trays.

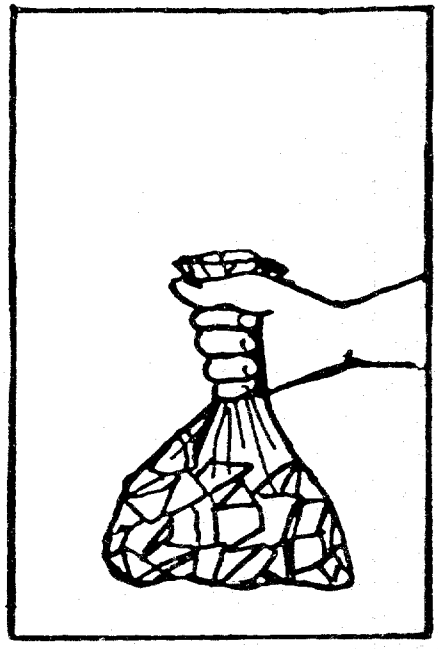
- The size of the pieces being dried, the heat inside the dryer and the moisture level of the air all affect the length of drying time.

- Three methods to test food are by using a plastic bag, by touching and by weighing.

Chapter V
Packaging and Storing Dried Fruits and Vegetables

- Packaging.
- Storing.

Packaging and Storing the Dried Product

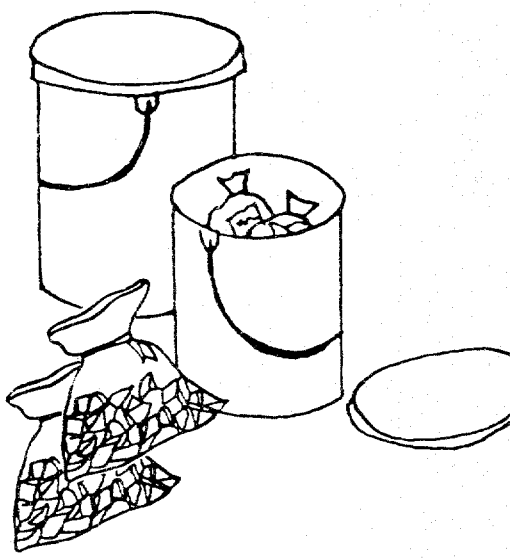


When the products are adequately dry, they can be packed for long-term storage. One storage method is to use plastic bags.

Choose plastic bags that are thick and do not tear easily, do not have holes, and can be tightly closed. You should not be able to smell the food when it is inside the plastic bag.

Use small-size bags for storing your products, just large enough to hold an amount that can be used in one day or for one meal. If the bags are well sealed, the quality of the foods will be preserved for several months. However, once the bag has been opened, the quality of the food will decline rapidly. The products should be consumed or used in cooking right away.

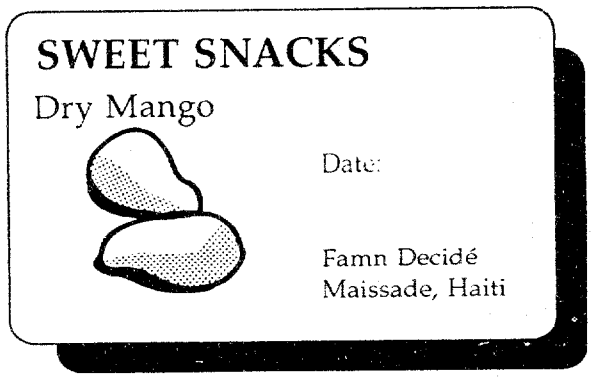
When the dried product has been placed in a plastic bag, squeeze out the air and close the bag tightly to prevent air from re-entering the bag. The best method for sealing the plastic bags is by using an iron to melt the bag's ends together. The bags can also be tied with string or wire.



If any moisture gets into the closed plastic bags or if the fruit is not sufficiently dry, your dried fruits or vegetables can spoil. Sunlight can also damage the quality of your dried foods. To prevent spoilage, store the plastic bags in a dark, dry area. Dried products stored in cool areas will last longer. The sealed plastic bags should be stored in a well-sealed jar, aluminum or hard plastic container.

Some dried products such as bananas, breadfruit, pumpkin or sweet potato can be made into flour. The products must be dried very well and then mashed into flour or milled. Sift the flour in a strainer to make it very fine before storing it in plastic bags.

Putting stickers/labels on the bag will help make the product more attractive if you want to sell it. Pictures and important information can be put on the stickers, including the type of food, its cost, where it comes from, who makes it, and the date it was dried.



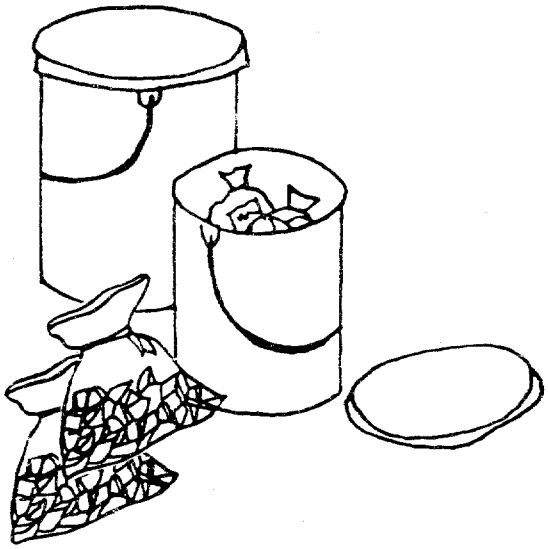
Summary of Chapter V

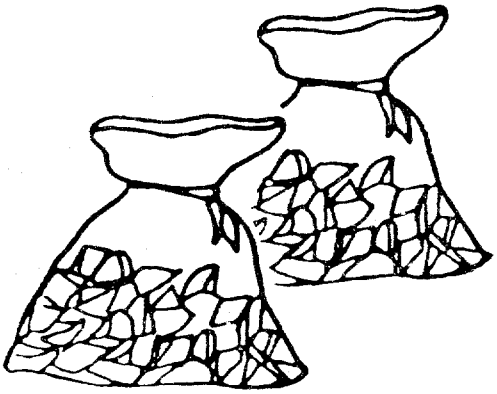
- When products are adequately dry, they can be packed for long-term storage. One easy and safe method is to use plastic bags.

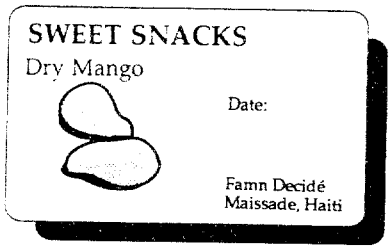
- When the dried product has been placed in a plastic bag, squeeze out the air and close the bag tightly to prevent air from re-entering.

- Putting stickers/labels on the bag will help make the product more attractive if you want to sell it.

- Some dried products such as bananas, breadfruit, pumpkin or sweet potato can be made into flour.







Chapter VI
How to Use Dried Fruits and Vegetables

- Ways to use dried food.
- Fruit snacks.
- Vegetables.
- Baby foods.

The Many Ways You Can Use Dried Fruits and Vegetables

There are many ways to prepare and eat dried fruits and vegetables and to use them in children's food so that they are easily digested.

- **Dry**: Eat dried fruit slices as a snack. Mango slices and banana chips are very popular and healthy treats for children.

- **Cooked**: You can add the rehydrated fruits and vegetables to other recipes while cooking. Add them to the weaning food of very small children. Vegetables can be added to soups and stews.

- **Candies**: You can make candies and desserts from the dried fruit.

- **Rehydrated**: Adding water to the dried food (called rehydration) will soften the food and make it easier for young children to eat. To rehydrate means to put back the water that the dryer took out. Food can be stored better and longer when there is no water in it. But fruits or vegetables that have been dried can reabsorb the water if put into fresh, clean water for about one-half hour.

For example, two months after drying mango or pineapple slices, you can placed them in a bowl and cover them with clean,

fresh water. The fruit will absorb the water that was taken out by the drying process. After swelling with water, the fruit can be eaten like fresh or cooked fruit. For small children, the rehydrated fruits and vegetables can be mashed and mixed with weaning foods and cereal or rice. Dried green leaves can be cooked in soups or sauces, or placed in water so they can be used in cooking, just like fresh leaves.

Eat the rehydrated fruits and vegetables the same way you eat fresh food. Mash the rehydrated fruits and vegetables for small children. The water it was soaked in makes a nutritious drink. Remember to boil the water for 20 minutes before adding the dried food.

These are only a few ideas. Communities can experiment with many ways to use the fruits and vegetables to make foods that children will eat. Solar drying provides a way to make sure that children have enough vitamin A-rich foods all year long.

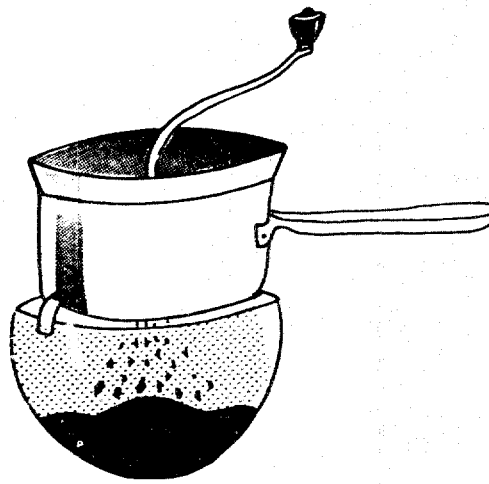
Dried foods can be used in recipes, as snacks for children and adults, and as an ingredient in baby foods. Because the foods can be stored for several months, they can be used in the off-season when the fresh foods are not available.

Fruit

Fruits dried in a solar dryer can be eaten as tasty, sweet snacks, especially by children. Mangos are especially important as a source of vitamin A and can be made available to children all year long through solar drying. Solar-dried fruits can be used in place of the fresh ingredients in your own recipes. Simply rehydrate the dried food in water and then proceed with the recipe.

In addition to drying fruit slices, fruit leathers can be made by using a solar dryer. A variety of fruits can be mixed together in a purée and dried as a sheet. The following recipe can also be used for bruised or over-ripe products or parts of the fruit that cannot be easily sliced.

How To Make Fruit Leathers

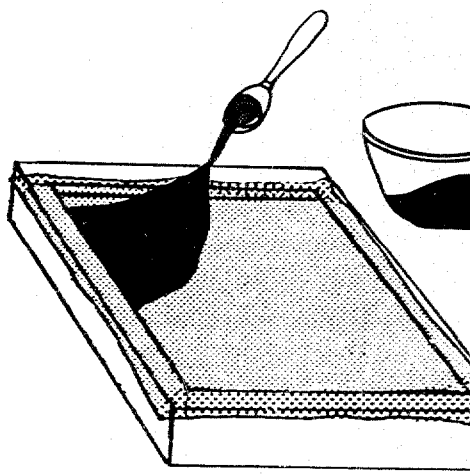


Step 1. Purée the fresh fruits (such as mangos, papayas and bananas) in a mill or strainer and collect in a clean cooking container.

Step 2. Heat the purée for about 15 minutes at medium heat. This will help kill bacteria and decrease the quantity of water in the purée. The purée will dry faster and, more importantly, it can be stored longer.

Step 3. Place a clean plastic sheet or cellophane directly on the tray's screen or woven mat. The plastic should be big enough to drape over the sides of the frame.

Step 4. Pour the fruit purée to a 1 cm depth on the plastic. If you are planning to dry a lot of fruit leathers, it is a good idea to build drying trays with a 1.5-2 cm depth. When the purée is dried, it will become a thin, chewy leathery sheet. Let it cool on the plastic sheet before peeling it off.



Once dry, you can roll the fruit leaf or cut it into small squares for snacks. Put the pieces in plastic bags and store in an airtight container in a cool, dry, dark place.

You can create many different types of leathers by using your favorite fruits and vegetables individually or blended together before drying. You can also garnish the leathers by adding grated coconut, nuts, and spices such as vanilla, cinnamon, and honey to suit your family's taste. Garnishes may be sprinkled on the fruit leather before drying, or mixed into the pureé before pouring onto the tray.

Vegetables

Dried vegetables need to be rehydrated, or they may be added to soup or stew. Because the dried vegetables have already been partially cooked by blanching, they will cook more quickly. In the Dominican Republic, a group of women developed a dried soup mixture of pumpkin, green leaves, spices, sweet potato,

and carrots. The soup mixture is packaged and ready to cook. Because dried foods cook faster, the soup takes only 10 minutes to prepare.

Solar-dried vegetables can be used in place of fresh ingredients in your own recipes. Simply rehydrate the dried food in water and then proceed with the recipe. It is important to remember to use clean, boiled water to rehydrate dried foods.

Baby Foods for Children 6-to 24-Months Old

Vitamin A is especially important for children six to 24 months old who are beginning to eat solid foods and to stop breastfeeding. Children at this age are especially likely to get infectious diseases and need to have special foods that they can eat.

How to make a weaning food

A good vitamin A-rich weaning food has four ingredients.

1. Staple food—rice, wheat, potatoes;
2. Protein from plant or animal food—beans, nuts, milk, meat, chicken, fish, egg;
3. Vitamin A—fruit or vegetable; and
4. Energy—fat, oil.

When these ingredients are used together in the right amounts, they make a complete meal. For example, one part protein such as beans mixed with two to three parts staple such as rice, a handful of green leaves, and a teaspoon of oil make a complete weaning food.

Breastmilk is a complete food as well as an important source of vitamin A. Solar-dried fruits and vegetables can ensure the availability of vitamin A ingredients for weaning foods. Dried foods such as mango, pumpkin and green leaves can be rehydrated and then added to the weaning food mixture. A small amount of fat or oil is also necessary to make sure that the vitamin A is absorbed and used by the body.

In Guatemala, women have developed weaning food mixtures that use dried sweet potato. Hot water, a small amount of sugar, and some fresh or rehydrated fruit are mixed with the dried sweet potato and fed to young children. The mixture is fast and easy to prepare and provides an excellent vitamin A-rich food for babies.

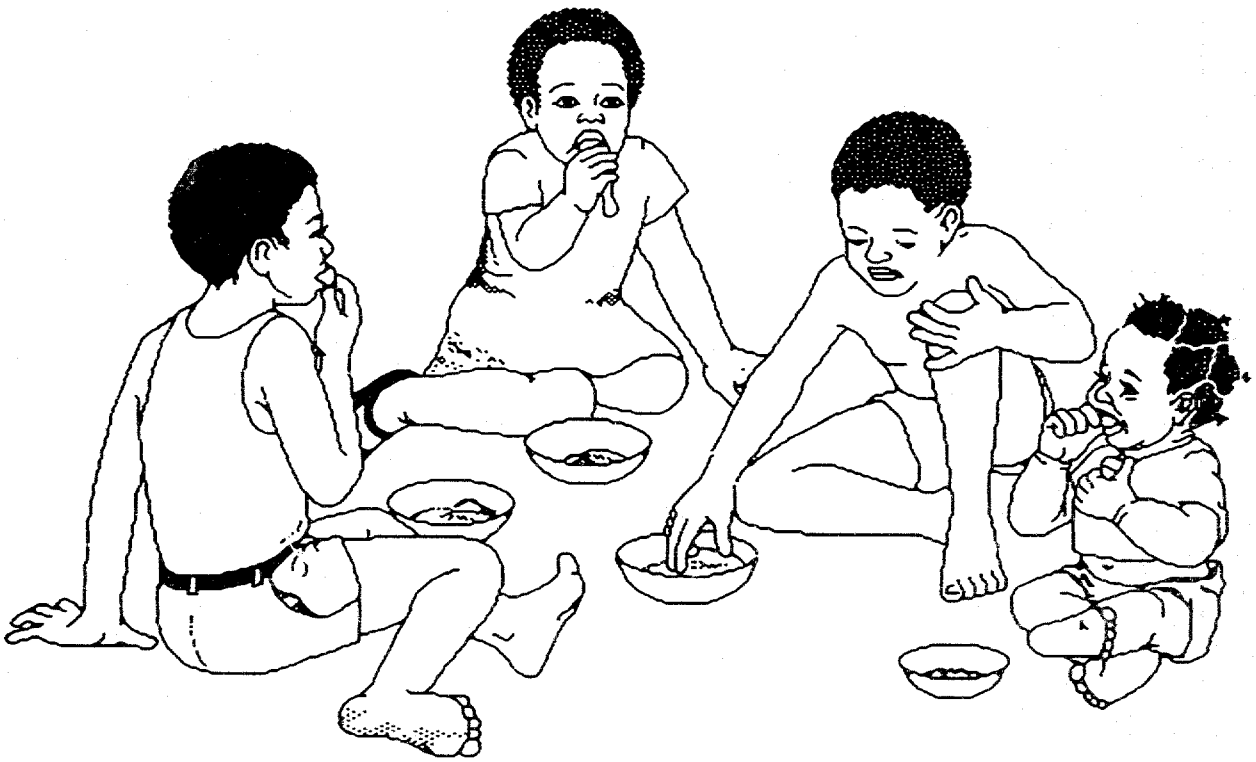
Summary of Chapter VI

- There are many ways to eat dried fruits and vegetables and to use them in children's food so that they are easily digested. You can add dried foods to the family meal foods. Dried fruit slices make a healthy snack for children.

- Vitamin A is especially important for children six- to 24-months old who are beginning to eat solid foods and to stop breastfeeding.

- It is importan[illegible] to use clean, boiled water to rehydrate dried foods.

- Solar-dried fruits and vegetables can be used in your recipes in place of the fresh ingredients. Simply rehydrate the dried food in water and then proceed with the recipe.

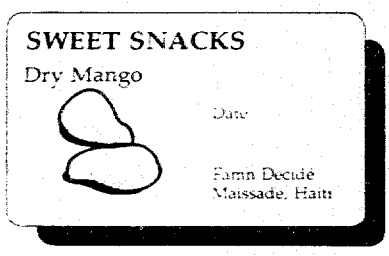


Chapter VII
Community and Small-Scale Commercial Solar Drying

- Small-scale commercial drying.
- Community education.

Families can dry produce from their own gardens. After enough of the dried foods have been stored for the off-season, extra produce can be sold. You can, for example, prepare small bags of mango, papaya, coconut or banana and sell them in the community, in front of schools, in the market or at the cinema. Communities can work together to produce larger quantities of dried products and to make solar drying activity profitable. The community group can be divided into individuals or groups with specific duties, including responsibility for getting the fruits and vegetables; preparing the products; monitoring the drying process; drying the produce; and packaging the dried fruit.

Presentation of the food is very important. You need to buy bags, stickers and wire to close the bags. Look for nice boxes and bags to put the product in. The better the merchandise is presented, the more people will want to buy and eat it. The stickers should look nice and identify what is in the bag, what group made it, the address of the group, and information about how the product was made. Information about the importance of vitamin A to children may also be added to the sticker. If the address is easily seen on the bag or sticker, it is easier for people to contact you for more products.



When fruit is dried, it shrinks in size because the water is removed from it. In one small plastic bag you can store many fruits that can be packed in a box to be sent to market in a truck, on the back of a mule, on a bicycle, or on a motorcycle. The merchandise will not spoil easily even if it has to be transported for many days.

Planning is essential for this kind of activity. An important consideration for the project is how the foods will be marketed, including managing the business and bookkeeping. Look for buyers and stores in the area and big stores and markets in

larger cities that will agree to buy your products. In planning to sell your dried foods, consider the groups who will eat your product, such as children under six years of age who are at risk of vitamin A deficiency.

Education

While planning the solar drying activity, you will need to plan an education program for the community. Teaching people about the importance of vitamin A-rich foods can help protect the health of children. Teaching the community about how to use the dried foods will help increase demand for the products and increase consumption of vitamin A-rich foods. The information in Chapter II can be used to teach your community about the importance of eating vitamin A-rich foods.

Women's groups can develop new recipes to use the dried foods. Cooking contests and demonstrations are a good way for the community to experiment with the dried products. Children in schools can test the new foods and recipes. Groups of women can work together to create new recipes to use the foods and promote their use by other families. The development of new recipes will help increase the amount of the foods that children eat and help create demand for the dried products.

Haitian women have developed many uses for dried mango in an effort to promote the use of the food and to provide many products for sale in the market. Dried fruit slices are a favorite snack for all children. Dried mangos are rehydrated and mixed with milk, egg yolk and corn flour to make a child's weaning food. The women have also developed recipes for fruit sauces and jellies that use the dried foods.

Quality Control

As part of the education program, special emphasis on high-quality food products and sanitation is essential. A good source of clean water is necessary for preparing the foods for drying, as well as for rehydration and consumption.

Careful and attractive presentation of the foods, adequate drying time, and proper storage of the dried products are all important for ensuring the health of children and the success of the project.

Summary of Chapter VII

- Families can dry produce from their own gardens.
- Surplus food can be sold.
- Teaching people in your community about the importance of vitamin A-rich foods can help protect the health of children.
- Cooking demonstrations and recipe contests will increase the community's awareness of the usefulness of solar drying.
- Quality control is essential for project success.

References

Organizations to contact for further information:

Vitamin A Field Support Project (VITAL)
1616 N. Fort Myer Drive
Suite 1240
Arlington, VA 22209, USA
Tel: (703) 841-0652
Fax: (703) 841-1597

Brace Institute
McGill University
Ste-Anne de Bellevue, Quebec, Canada
Canada H9X1C0

Postharvest Institute for Perishables
College of Agriculture
University of Idaho
Moscow, Idaho 83843, USA
Tel: (208) 885-6791
Fax: (208) 885-6624

FUDECO
Jacinto Mañón, No. 32, Ens. Paraíso
A.P. 366-2, Centro de los Héros
Santo Domingo, Dominican Republic
Tel: (809) 567-3351
Fax: (809) 566-8297

Save the Children/Haiti
25 Rue Babiole
Port-au-Prince, Haiti
Tel: (509) 453795
Fax: (509) 450036

Tanzania Food and Nutrition Centre
P.O. Box 977
Dar es Salaam, Tanzania
Tel: (255) 51-29621
Fax: (255) 51-28951

Publications:

Annual Report, Postharvest Institute for Perishables, University of Idaho, Moscow, ID, 1991.

Axtell, B. and Bush, A. *Try Drying It: Case Studies in the Dissemination of Tray Drying Technology*, Russell Press Ltd., Nottingham, UK, 1991.

Fahy, C. et al., *Preserving Food by Drying: A Math-Science Teaching Manual,* Peace Corps, Boston, MA, July 1980.

Food Drying, Proceedings of a workshop held at Edmonton, Alberta, ed. by Gordon Yaciuk, International Development Research Center, Ottawa, Canada in collaboration with the Alberta Department of Agriculture, Edmonton, Canada, July 1981.

Islam, Mir N. et al., *Manual for Solar Dehydration of Fruits and Vegetables in Rural Communities,* Partners of the Americas, Washington, DC, May 1987.

Klippstein, Ruth N. and Humphrey, Katherine J.T., *Home Drying of Foods*, Information Bulletin 120, Cornell University, Ithaca, NY, 1983.

Mitzner, K., Scrimshaw, N., Morgan, R., eds., *Improving the Nutritional Status of Children During the Weaning Period,* HOVIPREP, Cambridge, MA, November 1984.

Rankins, Jenice et al., "Palatability and Nutritional Significance of Solar Dried Mangoes for Senegal," *Ecology of Food and Nutrition*, Vol. 23, pp.131-140, May 1989.

Solar Dryer Construction & Food Processing of Tropical Crops, Postharvest Institute for Perishables, University of Idaho, Training Course Report.

Solar Food Dryer, Solar Energy Association of Idaho, Boise, ID, November 1979.

Sun-King: The World's Best Solar Food Dryer, Natural Food Institute, Dudley, MA.

Swanson, Marilyn, *Nutritional Significance and Acceptance of Solar Dried Foods of Rural Leyte Philippines,* Doctoral Dissertation, Washington State University, May 1987.

Williams, Larry and Haggerty, Robert, *Solar Drying and Food Preservation Training Session*, University of Idaho, Moscow, ID, January 1986.