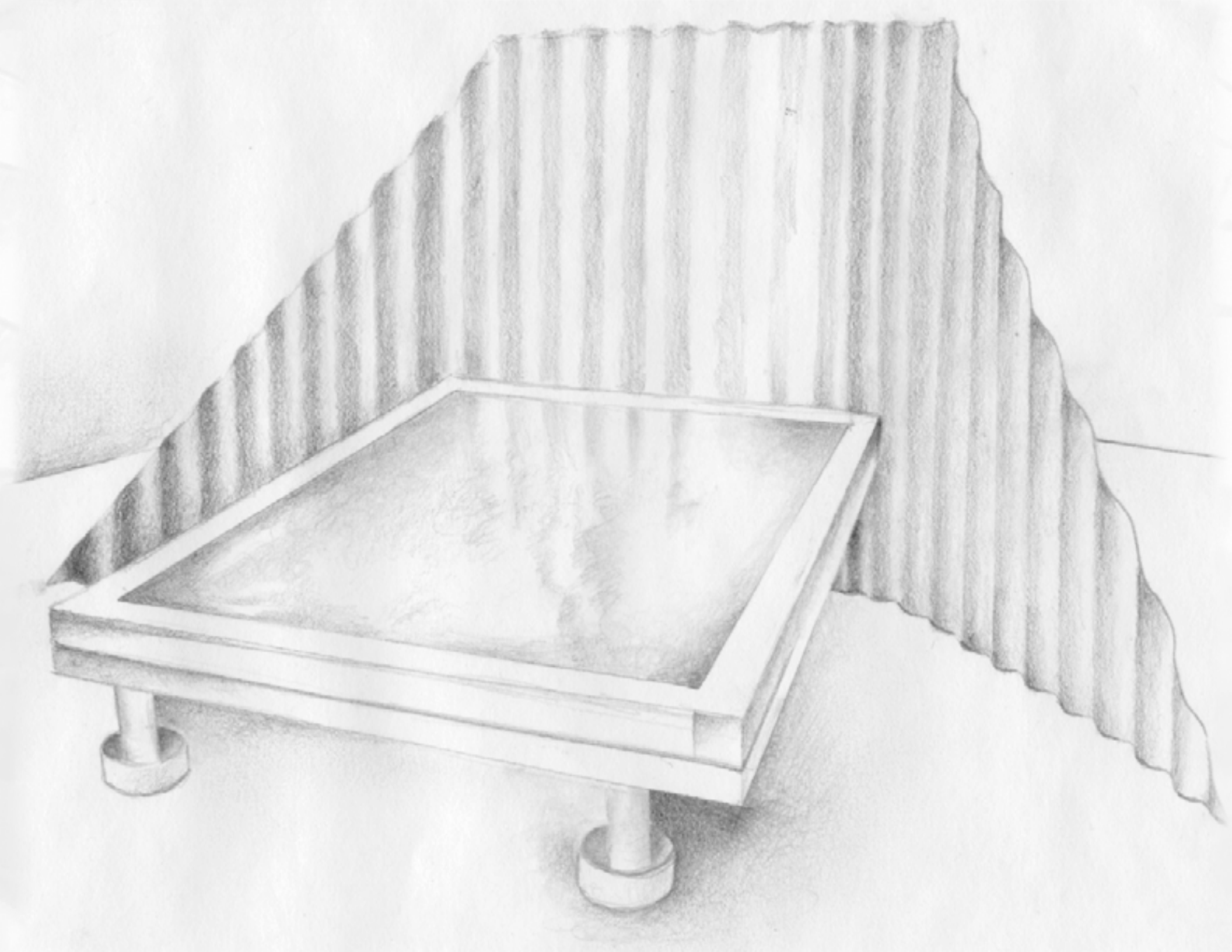

CHAPTER EIGHT

Drying Leaf Vegetables

Drying is almost certainly the oldest method that humans have practiced to preserve food for future use. Drying foods in sunlight reduced the weight and volume of the foods so that they could be more easily stored and transported by our ancestors. The baskets, clay jars and gourds used as early storage containers were likely in short supply (there was never enough closet space!), so reducing the volume of stored food was important. Since the primary mode of transportation was walking, the reduced weight of dried foods was likely much appreciated on moving day.

Two different things cause food to spoil or rot: bacteria, molds, and fungi eating the food, and enzymes within the food causing various components of the food to break down. Spoilage microbes are endemic, that is, they are essentially everywhere. In the nearly ideal conditions provided by warm moist food, the growth rate of these microorganisms is geometric. Their presence in large numbers changes the flavor, texture, and nutritional value of foods. Some of these microbes, such as salmonella and listeria, can cause food poisoning.

Enzymes are proteins that act as catalysts accelerating chemical reactions or allowing them to take place with lower energy inputs. After a plant is harvested, many enzymes in the food speed its rate of spoilage. For example an enzyme called polyphenol oxidase causes sliced apples and potatoes to turn brown. Lipoxidases are enzymes that speed up the oxidization of oils in green leaves, imparting an unpleasant fishy flavor.

Drying preserves food by evaporating water until its moisture content is too low to support the growth of the bacteria, molds, and fungi that are eating them. This generally means below 12% moisture. Most enzymatic reactions are similarly slowed if not stopped by a lack of available moisture. Usually at least some of the microorganisms survive in a state of dormancy, awaiting the arrival of more water to resume reproducing. Similarly many enzymes will not be destroyed by low moisture, merely temporarily deactivated.

PRINCIPLES OF DRYING LEAF VEGETABLES

Compared to meat or fish or fruit, green leaves are easy to dry. Because leaves on living plants usually form themselves into thin sheets for better sunshine collection, no part of the leaf is far from the surface and the surface is where the water is evaporated. Four things speed leaf drying and they are known to anyone who has dried clothes on a clothes line.

1. Temperature: Clothes dry faster on a warm day.
2. Air Flow: Clothes dry faster on a breezy day.
3. Relative Humidity: Clothes dry faster on a dry day.
4. Surface Area: Clothes dry faster if you spread them out, increasing their surface area.

Temperature

Leaves become dry when the water in them is evaporated. Evaporation rate is mainly a function of temperature and

humidity. The ideal heat for drying leaves is about 55° C (130° F). There are several possible sources for the heat needed to dry leaves (see below).

Air Flow

As air around the dryer is heated it becomes less dense and rises. This draws more air past the drying leaves. Air flow is critical because it replaces the saturated humid air surrounding the leaves with drier air. If temperature begins to exceed the optimum of 55° C (130° F) increased airflow is essential both to speed drying and to prevent overheating.

Relative Humidity

Relative humidity describes how much water is in the air compared to how much it can hold at a given temperature, given as a percentage. Warmer air can hold more water than cooler air. Evaporation is fastest when the relative humidity of the air around the food is low, because the air can absorb the moisture from the food easily. As water evaporates from the food, the air surrounding it becomes more humid and the rate of drying slows. Drying is slower at higher humidity unless the temperature is raised enough to compensate.

Surface Area

Water evaporates from the surface of the leaves. As the surface becomes dry, moisture from deeper in the food migrates to the surface where it too can evaporate. Chopping the leaves increases their surface area and speeds drying time. Spreading the leaves more thinly on the drying tray is the simplest way to increase surface area.

Quality Control

The quality of dried leaves can be improved by blanching (heating them to the boiling point for 3 minutes in steam or a microwave oven) before drying. This kills most pathogenic microorganisms and neutralizes enzymes that can affect the flavor of dried leaves being stored for more than two weeks. Make sure dried leaves are crisp before storing. Bacteria, yeast, and mold can't thrive below 12% moisture. It is essential to lower the moisture content of the leaves below 16% in the first eight hours of drying to prevent the growth of molds that can produce aflatoxins.[1]

In practice, effective solar drying of leaves requires that they be completely dried in one day. Adjust the load of leaves to be dried to the conditions, so that single-day drying can be accomplished. Protect the drying leaves from insects and dust. Keep the dried leaves in a tightly sealed container, away from sunlight and in as cool a place as possible.

When leaves are dried in direct sunlight the dark green color quickly fades to a paler grayish green. This is caused mainly by high energy ultraviolet rays in the sunlight breaking apart molecules of the chlorophyll and carotenoid pigments that give the leaves their characteristic color. This is similar to the fading of brightly colored fabric left in direct sunshine. Not only is the color of the faded leaves less appealing but most of their vitamin A value is destroyed. This is why leaves should not be dried in direct sunlight.

SOURCES OF HEAT FOR FOOD DEHYDRATORS

Electricity

There are many small electric food dehydrators or dryers on the market, and plans for building your own can be easily found on the Internet. They usually have an electrical resistance heating element and a fan to increase airflow. The best ones, like Excaliber, have thermostats to control the temperature and horizontal rather than vertical airflow. They cost about $200 and can dry a kilogram of fresh leaves in 5 or 6 hours. Electric dehydrators are capable of drying leaves at night and in any sort of weather. The big advantages of electric dehydrators are good quality control and convenience. The downside is cost: both initial costs and ongoing operating costs. Cheaper electric dehydrators with the heater and fan at the bottom are much less effective.

1 Aflatoxins are fairly common naturally occurring toxins that are produced by many species of aspergillus fungi. Aflatoxins are toxic to the liver and among the most carcinogenic substances known. Damaged peanuts and other oilseeds and grains are among the foods most frequently contaminated with aflatoxin.

Wood Heat

There are many designs for drying food by burning wood or other fuel. Most have a firebox of some sort that provides heat below one or more drying racks. Unlike solar dehydrators these can be run at night and during cloudy weather. Wood heat can also be used in combination with solar food dehydrators, supplying them with auxiliary heat so that they can continue drying after dark and on cloudy days. Wood fired dehydrators are usually more appropriate for drying large volumes of food such as coffee or corn than for drying leaves. It is difficult to control the drying temperature and to keep wood smoke from affecting the flavor and damaging the quality of the leaves being dried. In the right circumstances wood heat can be a free, local, carbon neutral and renewable energy source. Too often, however, wood is harvested in unsustainable ways and burned at too low a temperature, causing pollution of local air with soot and polycyclic aromatic hydrocarbons.[2]

Gas Heat

There are several designs for using gas heat to dry food. In general gas, whether natural gas, liquid petroleum gas or biogas is more convenient and easier to control than wood heat but less convenient and controllable than electric heat. Like wood or electric heat, gas-fired dehydrators can be used at night and in any weather. Gas burns cleaner than wood, but unlike wood, it is a fossil fuel (except for biogas) and increases climate changing atmospheric carbon.

Solar Heat

There are hundreds of designs for solar powered food dehydrators in all sizes and levels of complexity. The main benefit of solar dehydrators is that they use only the free non-polluting energy of sunshine. Their biggest drawbacks are that they don't work when the sun isn't shining, and the sunshine can't usually be turned up or down. Most solar dehydrators use glass or plastic to trap heat from the sun. They also use the natural airflow of the heated air rising to dry food. Some use rocks as a heat sink to allow drying after the sun sets. Some combine solar heat collection with an electric fan to move air.

TRADITIONAL LEAF DRYING

For most people the availability of fresh leafy vegetables was limited for much of the year especially as we migrated away from our tropical places of origin. Drying leaves in the sun was an ancient technique for preserving produce when it was abundant, using free energy. Traditionally food was dried by laying it on mats in the sunshine or by hanging it to dry more slowly in the shade.

Many traditional cultures, mainly in Africa and Asia, still dry food, including green leaves, in the sun. Sometimes leaves are left on rooftops where they can dry quickly away from the attention of grazing animals. In much of Africa cassava leaves are dried by hanging them to dry in the shade. Most often the leaves are dried until they are brittle. They are then crumbled by rubbing between the hands and used to thicken and flavor soups and stews and simple porridges.

Much of the potential benefit of drying food, unfortunately, was not achieved with these simple methods. There were two major problems. First of all the valuable beta-carotene in the leaves was almost completely destroyed in full sunlight. Even the indirect sunlight, as found in the shade, has enough UV radiation to greatly reduce the vitamin A activity of the leaves. Secondly, the food produced by this casual drying was often contaminated with excessive bacteria, yeast, or mold growth. Drying the leaves in the shade lessened the first problem, but the longer drying time gave the microbes and the enzymes more time to do damage before the leaves were fully dry.

A COMMON DESIGN FOR INDIRECT SOLAR DRYERS

The drawing in Figure 8–1 on page 86 shows a common attempt to resolve the main problems inherent in traditional drying techniques. These solar food dehydrators became an icon of a

2 Polycyclic aromatic hydrocarbons or PAHs are a group of approximately 10,000 compounds. Most are by-products of the incomplete burning of wood, oil, or coal. Many are known or suspected carcinogens.

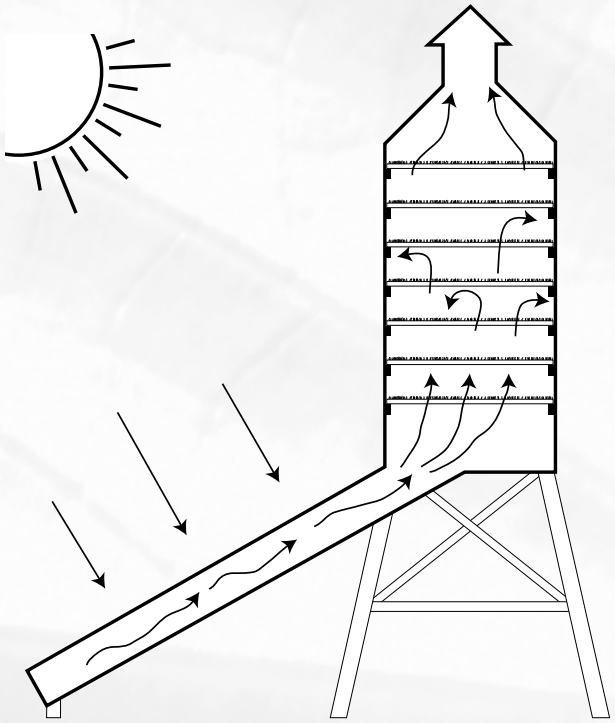

Figure 8–1
Common indirect solar dryer

well-intentioned appropriate technology movement as it tried to wrangle with extreme poverty.

It is a rather elegant concept. Sunlight passes through a glass or plastic cover and the trapped radiation warms the air in a channel. The warmer air is lighter so it rises bringing both heat and air flow to trays of leaves in the drying chamber. The warmed wet air leaves through the top creating a partial vacuum which draws in more air at the bottom of the dryer. This process continues until the leaves are dry or the sun stops shining.

Unfortunately the performance of most of these dryers is disappointing. They protect the leaves from direct sunlight and don't require electricity, but rarely do they supply enough heat or enough airflow for optimal leaf drying. There are two design problems. First the solar-energy collecting area is not usually large enough relative to the surface area of drying trays for adequate heat. And secondly the arrangement of drying trays doesn't allow for enough air speed. Often these dryers have twice as much area of drying trays as area of solar collector. Except in very hot sunny climates this is not enough area to collect the solar energy required for fast drying.

The bottom drying tray may receive enough heat for adequate drying but the top one won't. The evaporated moisture from the well-heated bottom tray tends to be absorbed by the leaves in the tray above it. Eventually the leaves will dry, but often they have begun to spoil before they do.

A SIMPLE AND INEXPENSIVE SOLAR DRYER FOR LEAVES

In situations where sunshine is plentiful and the ambient air temperature is warm, such as exist in much of the tropics or in long summer days in temperate zones, a very simple inexpensive solar dryer design will work fine for drying leaves. It is not well suited for drying fruit, meat, or fish, however. This design enlarges the solar collection area to match the area of the drying tray. It has a single drying tray that allows air to pass freely both under and over the drying leaves.

By enlarging the ratio of collector area to dryer area and removing obstacles to free air flow this dryer will normally dry leaves completely in one day. This is very important because leaves will usually reabsorb moisture overnight when the temperature drops. If leaves need to continue to dry a second day, there are far more problems with mold and aflatoxins.

These dryers are easy to build and to use. They usually cost less than $20 US and can be built in a couple of hours by do-it-yourselfers or even by village women with no carpentry experience. Where it is available, the most appropriate material to cover the top of the dryer is greenhouse grade, 6-mil polyethylene sheeting. This lets the energy in the sunlight heat the leaves, but blocks out the carotene-damaging UV

radiation. It is inexpensive, tough, and easy to work with. The greenhouse plastic is intended to last four years, though its useful lifespan may be shortened somewhat by intense tropical sunshine. Keeping the dryer out of sunlight when it is not in use will extend the life of the polyethylene.

MAKING A SIMPLE SOLAR LEAF DRYER

A. Dryer Cover

1. Make a square wooden frame about one meter (39 in) on each side with lumber approximately 4 cm x 4 cm (1.5 x 1.5 in). Use rot resistant wood if possible.
2. Reinforce the corners to make sure frame stays square. This can be done with angle braces.
3. Stretch UV treated 6-mil polyethylene or polyester film over the frame and staple securely. Double the plastic film over on the frame where it is to be stapled. Don't use regular polyethylene film or glass for the dryer cover. Both will allow ultraviolet rays to pass through and quickly destroy the beta-carotene in the leaves. Also regular 4-mil polyethylene will break down from sunlight in less than one year. Wherever there is a greenhouse industry there will be someone selling UV treated polyethylene sheeting. Even in the tropics, where greenhouses aren't normally needed, the UV treated polyethylene is frequently used in the ornamental plant industry.
4. Staple a 10 cm (4 in) strip of dark colored, open weave (like insect screen) cloth around the outside of the cover frame. This will allow air flow but prevent insects and dust from entering the dryer. Slit the corners so that it doesn't prevent the dryer cover from being easily removed from the base.

Making dried leaf powder with a simple stone grinder

B. Dryer Base

1. Make a square wooden frame identical to the cover frame.
2. Stretch strong insect screen over the frame and staple securely. Double the screen over on the frame so that the staples hold better. Use plastic screen if possible as leaves won't stick to plastic as much as to metal screen. You can also

use metal mesh if you separate the leaves from the metal with plastic screen. Food grade polypropylene screen is ideal for this, but is difficult to find.

3. Nail diagonal braces (made from scraps of the wood used for the frames) over the screen to stiffen the dryer base and raise it off the ground.

VARIATIONS ON SIMPLE SOLAR LEAF DRYER

Black Sheet Metal Cover

In parts of the tropics that don't have any greenhouse industry it is difficult to find UV treated 6-mil polyethylene sheeting for dryer covers. Old sheet metal roofing, sanded and then painted a flat black, can be substituted. Sunshine will heat the black metal, and some of that heat will pass through to warm the leaves in the dryer tray. The metal will completely block UV radiation. These dryers will perform nearly as well as those covered in greenhouse plastic in clear hot climates, but don't do as well on partially cloudy days.

Reflectors

Adding a shiny reflector behind the dryer will increase the amount of solar radiation that lands on the cover. This will increase the heat and speed the leaf drying. Reflectors are especially useful on partially cloudy days and in cooler temperatures. Old metal roofing painted with chrome paint from an auto parts store works well. A piece of this reflective roofing roughly the same size as the dryer can be held behind the dryer by two fins of the same sheet metal cut at 45° angles. A bit of testing will help determine the optimal position for a reflector in your location. The reflector needs to be stabilized so it doesn't fly off in the wind. A reflector can also make up for the slight loss of performance in using a black metal top rather than treated polyethylene.

Ant Traps

Where ants are a major problem you can protect your drying leaves by raising the dryer on short legs and putting the legs in food cans or plastic cups filled with water. Scraps of plastic plumbing pipe make good legs because they don't rot in the water.

Adjusting the Size

These dryers can be built in a variety of sizes to fit the specific needs of the people using them. For example, women at a project in Brazil preferred narrow dryers because they could carry them on bicycles. Generally if they get more than a meter wide they are unwieldy. If less than half a meter wide, they don't heat up well enough to be effective.

HOW TO USE A SIMPLE SOLAR LEAF DRYER

1. Set up the solar dryer. Put the dryer where it will have full sunshine all day. Put a sheet of plastic on the ground below the dryer to block moisture rising from the soil. Raise the base of the dryer off the ground with bricks or sticks to make sure that air can move below the dryer. Some people prefer putting the dryer on a table or on a low roof to protect it from playing children and animals. Protect your dryer cover from blowing off in the wind. Raise the side of the dryer that faces away from the noon sun (north in the northern hemisphere) to give the sunlight a more direct angle. This will help the dryer reach the ideal temperature of about 55° C (130° F). Raising one side of the dryer should also allow it to drain unexpected rain. Do not raise it so much that the leaves will slide to the low side as they dry. If the ambient air temperature is over 32° C (90° F), the dryer may get too hot. If this is the case, separate the dryer base and cover with small wooden blocks to create more air flow and reduce the temperature.
2. Harvest and wash leaves in clean water. Remove large stems, roots, rocks, weeds, etc. The stems of leaves have very little nutritional value and are high in nitrates. Removing them will speed drying and make a more nutritionally valuable leaf powder.
3. Cut leaves into pieces no longer than your thumb. This increases surface area and makes for faster, more even leaf drying.

4. Blanch leaves (see *NOTE at the end of this list) in steam or in a microwave oven for 3 minutes. Avoid blanching in boiling water as it causes too much vitamin loss. Blanching or quickly heating the leaves accomplishes several things. It kills harmful microorganisms both on the leaf surface and within the leaf. It softens the cell walls and speeds drying. Blanching also deactivates plant enzymes, such as lipoxidases, that can damage the flavor and the nutritional quality of the leaves. This step is especially important if the dried leaf powder will be stored for several months or if the leaves being dried are in the legume family.
5. Spread leaves evenly in dryer in the morning so they can dry before reabsorbing moisture from cooler night air. Between 1–1.5 kg (2–3 lb) of cut leaves per square meter of dryer is usually about the maximum. Too thick a layer of leaves will keep the dryer too cool and some leaves could spoil before they dry.
6. Check on the leaves in mid-afternoon if possible. Reposition the leaves so they will dry evenly.
7. Sift leaves. When leaves are dry enough to be uniformly brittle, carefully remove them from the dryer and sift them by rubbing them through a metal screen to remove additional fibrous stems and leaf mid-ribs that weren't stripped off before

WHICH LEAVES TO DRY

Edible
Make sure leaves, especially wild ones, can be safely eaten. Some leaves that are normally eaten in small amounts as flavorings may not be safe when eaten in larger amounts. An example of this is guaje *(Leucaena leucocephala)*, whose young leaves are eaten for their garlic-like flavor in much of Latin America, despite the presence of the toxin mimosine.

Good flavor and texture
Avoid leaves with a strong bitter taste or with white sap. Leaves that are very dry and fibrous are usually difficult to digest properly. Many leaves from trees have this limitation, as do the leaves from annual plants after they have flowered.

Nutritious
Some leaves contain far more essential protein, vitamins, minerals and antioxidants than others. For example, a serving of kale *(Brassica oleracae)* contains 4.5 times more protein, 4 times more iron, 9 times more calcium, 19 times more vitamin C, and 26 times more vitamin A than the same amount of iceberg lettuce. So if your garden space is limited, kale is the better choice to grow and to dry for improving your family's health.

Easy to grow or grow wild
Crops like mustard that quickly produce dense foliage from inexpensive seed without any special care are excellent. So are many common edible weeds and wild plants, such as nettles and lambsquarters, that don't require any planting or care at all.

Easy to harvest
It is time consuming to harvest leaves that grow high in trees, tangled in vines, or protected by thorns. Plants whose leaves run very close to the ground can also be slow to harvest and hard to clean. Time spent in harvest is often underestimated in considering costs of foods.

Easy to dry
Some leaves contain much more water than others. They dry more slowly and produce less dried leaf powder than leaves that have more dry matter per kilogram of fresh leaves, such as moringa. Leaves that are curly, like parsley, will allow air to pass through easily and as a result dry faster than leaves that lie nearly flat, such as Swiss chard.

Grown in clean soil, air and water
Green leaves should not be eaten from plants grown in soil contaminated with trash dumping or burning, sewage, or paint scraped from buildings. Also avoid plants along busy roads.

Chart 8–1
Nutritional Benefit of Moringa Enriched Pasta

	Protein g	Iron mg	Calcium mg	Vitamin A mcg RAE	Vitamin E mg
57 g (2 oz) dry unenriched pasta	7.4	0.7	12.0	0.0	0.1
57 g (2 oz) dry pasta with 20% dried moringa leaf	9.0	3.8	238.0	150.0	10.0

drying. One-quarter inch (6.4 mm) hardware cloth or mesh works well.

8. Grind the sifted leaves to a fine powder. Dried leaves can be easily ground in a hand-cranked corn mill, an electric grain grinder, a coffee mill, a household blender, or a traditional stone metate type grinder. Make sure leaves are very dry or they will clog the grinders. With some grinders you will need to grind the leaves more than once, using progressively finer settings. Grinding dried leaves too quickly or too finely can cause friction to build to the point of burning the leaves. Temperatures uncomfortably hot to touch are hot enough to cause some nutrient and flavor breakdown in the dried leaf powder.

When dried leaves are ground to a very fine powder, the consistency of flour, our bodies are better able to absorb the nutrients in the leaves. This is because finely ground dried leaves have greater surface area in contact with digestive enzymes and with the nutrient-absorbing lining of the digestive tract.

***NOTE:** Blanching adds a somewhat complicated additional step to an otherwise very simple process. For this reason it is often skipped. Blanching leaves before drying serves several purposes, but it may be reasonable to skip this step if the following conditions exist:

- The leaves are harvested well off the ground, as with moringa or from an area not likely to have had contact with fresh animal manure or human sewage. Most of the contamination of leaf crops takes place from raindrops or irrigation splashing contaminated soil onto the leaves.
- The dried leaves will always be used in dishes that are brought up to the boiling temperature. For example leaf enriched pasta is never eaten without first being boiled.
- The dried leaves will be eaten within a month or kept in a refrigerated place, so that the enzymes won't have time to damage the flavor or vitamins.
- The leaves being dried are mucilaginous, like vine spinach or jute mallow. Blanching can turn them into a goopy mess of leaves that are far more difficult to dry.
- The requirement of blanching would discourage people and keep them from drying leaves. Unblanched dried leaves are far better than none if that is the choice.

HIGHER PERFORMANCE SOLAR FOOD DRYER

In areas that are cool or cloudy much of the year, a somewhat more complex and expensive solar dryer may be more appropriate than the simple leaf dryer. This dryer uses a solar collector area three times larger than the area of the drying tray to increase the heat flowing to the leaves. It also has

a more complex and efficient mechanism for capturing solar heat and channeling it both over and under the drying leaves. This dryer has a thermometer to monitor the temperature near the drying tray and adjustable vents at the top and bottom to better control air flow and heat. It is more difficult to build and more difficult to move around than the simple two piece dryer, but it can sustain higher temperatures. This makes it more useful for drying fruits than the smaller dryer.

Step-by-step instructions for building and using this solar leaf dryer can be found and downloaded from the Leaf for Life website: www.leafforlife.org/PDFS/english/5-a-day_sun-dried_way.pdf

HOW TO USE DRIED LEAVES

1. Add leaf powder to basic recipes. Usually about 20% of the flour in most recipes can be replaced with leaf powder without an unacceptable effect on flavor or texture. Use leaf powder from mild flavored greens in sweet dishes or foods especially for children, and stronger flavored greens when chili, garlic, curry, ginger, and other spices will mask the stronger flavor to some degree.
2. If you are using leaf powder to correct malnutrition or prevent it in vulnerable people, try to give at least one tablespoon (about 8 g) or more of leaf powder to each person most days. Most children will accept leaf powder better in their diet if it is introduced slowly and in a variety of dishes. If recipes are calculated by weight, figure one cup of leaf powder equals about 120 grams.
3. Cookies in the shape of dinosaurs, frogs, and Christmas trees—which are normally green—are great ways to introduce children to leaf powder foods. Green birthday cakes have also been a big hit. Green pasta is another readily accepted food. A child will often gladly eat 50 g or 2 oz of enriched pasta, although he might refuse to eat greens. If the pasta is 20% leaf powder, a 57 g portion would have 11 g of dried leaf powder, the equivalent of 80 g or so of fresh leafy vegetables. (See Chart 8–1.) Pasta making can be a fun and educational activity. Children especially enjoy eating the pasta that they have made.
4. Keep the leaf powder in a tightly sealed container, away from light and in a cool place.

   Use within one year.

HOW DRYING HELPS OVERCOME THE LIMITATIONS OF LEAVES

Unlike leaf concentrate, drying leaves doesn't much improve the bioavailability of their nutrients. What it does do is provide an inexpensive means for us to eat a much greater quantity of green leafy vegetables. If green leaves are going to reach their potential as an important part of an improved diet for billions of people, we will need to find ways to increase both the quality and the quantity of the leaves we eat.

The most obvious thing accomplished by drying leaves is extending the shelf life, or the length of time the food remains good to eat. Freshly picked leafy vegetables lose much of their eye appeal, flavor, and nutritional value within three days if not refrigerated, and within a week or ten days even if kept in a cooler. The simple process of drying the leaves extends their useful life as food for up to one year.

Drying leaves also reduces their weight and volume greatly. How much the weight of leafy vegetables decreases with drying is a function of the original moisture content of the leaves. For instance, 100 grams of fresh lettuce will be reduced to 5 or 6 grams when fully dried, while 100 grams of fresh cowpea leaves will be reduced to about 15 grams and 100 grams of fresh moringa leaves will be reduced to about 25 grams. Assume the dried leaves still contain 10% moisture. In practice it is hard to get leaves much drier and keep them that dry. The reduction in volume parallels the weight loss closely.

By processing some or the entire vegetable crop, producers have an alternative or additional means of marketing their produce. This is important given that post-harvest losses of vegetable crops range from 30 to 40 percent, and as a result limit smallholder access to higher value markets in urban areas.

Cleome *(Cleome gynandra)*

The reduced weight and volume, coupled with a greatly extended shelf life, could radically alter the logistics of marketing leafy vegetables. Growers would have to quickly dry the harvested leaves and would have the added labor costs of drying. However, once dried, the desperate urgency of moving the leaf crop from the field to the consumer's table would be replaced by a more relaxed pace. Producers wouldn't be under such pressure to sell their crops when they were in over abundant supply. They would have the luxury of looking for the best price for their produce.

Shipping costs, which are going steadily up with higher oil prices, would be slashed. What's more, dried leaf powder doesn't need to be shipped in refrigerated trucks. Retailers could buy the leaf powder and have a much longer time period in which to sell it. Unlike the fresh leaves, it would not require more costly display in a cooler or the additional labor cost of trimming.

Much of the savings in marketing dried leaf crops would ultimately be passed on to the consumer, making green leafy vegetables a more economical part of our food budget. Integrating dried leaf powders and products made with them into our food system might also allow more producers to participate in the market. The critical advantage of selling out-of-season produce would be leveled and local growers could better compete for our leafy vegetable dollars.

Another advantage of drying leaf crops that would benefit both producer and consumer is the greater ease with which they could be grown organically. As pointed out above, much of the pesticide used on leaf crops is to enforce a visual perfection demanded by consumers. This cosmetic use of pesticides could be dropped because the leaves will be ground to a fine powder before the customer sees them. This could move leaf vegetables out of the "dirty dozen" category of foods most likely to have pesticide residue.

This is a move that most consumers, even those that don't currently buy organic produce, would welcome. In addition, drying leafy vegetables could reduce the risk of food poisoning. A three minute blanch before drying reduces bacteria count nearly 100%, and would have eliminated the *E. coli* strain that sickened hundreds and killed three people who ate fresh spinach in the US in the fall of 2006.

Drying and grinding leaf crops can yield a stabilized product and create a cluster of economic and logistical advantages for producers, distributors, and consumers of vegetables. The greatest advantage to the families that eat leaf vegetables, however, may be due to their new texture and their new versatility.

Leaf powders could be integrated into the diets of young children and the elderly. These are people who often find the tough or stringy texture of greens to be a struggle for their limited dental resources. Children under five years old are in the most critical period of their growth, when good nutrition is most vital. Worldwide, the elderly are the fastest growing segment of the human population. Making greens more useful and acceptable to these two groups is an important undertaking.

For the creative home cook, restaurant, or small bakery, the sheer number of different possibilities with dried leaf meal could be fun. Finely ground leaf powder can be mixed with garlic powder and salt and sprinkled on popcorn. Spaghetti can be made with 20% leaf powder replacing

flour. A tablespoon of leaf powder can be added to a fruit juice or yogurt smoothie in the morning. Mint chip or pistachio ice cream could have mild flavored leaf powder added. Popsicles and pudding could be enriched with leaf meal. Green tortillas could be wrapping burritos and fajitas. Kids could snack on cookies and crackers made with leaf powder instead of artificial green food coloring, and shaped like dinosaurs, alligators, turtles, and frogs. For special occasions leaf powder could enrich Christmas tree cookies and cakes, or shamrock crackers to go with green beer on St. Patrick's Day.

It is now possible to buy dried leaf powder from several different sources on the Internet. Spinach powder is commonly available at a reasonable price from food ingredient suppliers, since it is used in spinach pasta and dips. Green onion and parsley flakes are widely available in bulk as are many other leaves normally used for seasoning. Moringa leaf powder is now being offered through several outlets. Kale powder and powder from wheat and barley leaves are being sold, but mainly as high-priced supplements through alternative health sites. (Some dried leaf powder suppliers are listed in Appendix 4.) It is still quite difficult to locate dried leaf powders through ordinary retail food shops.

By extending shelf life, reducing weight and volume, and eliminating much of the risk of pesticide and microorganism contamination, drying leaf crops creates some new economic possibilities for eating more greens. Fine grinding removes most of the texture problems that have restrained use of greens, especially among children and the elderly. The versatility of green leaf powder enables it to be used in countless foods that have traditionally been outside the realm of leaf vegetables.

DRY WEIGHT

There is a great deal of confusion, some of it intentional, around the issue of dry versus wet weight. For example an impressive graphic that has been copied by hundreds of groups compares the nutrients in moringa favorably to those in oranges, carrots, milk, bananas, and yogurt. The problem is that the comparisons are between dried moringa leaf and other foods that haven't been dried. Measuring the calcium in dried moringa leaf against that in dried milk powder, or the calcium in fresh moringa versus that in fresh milk, would make for more impartial, if less impressive, comparisons. The nutritional value of moringa is excellent without trying to tilt the board in its favor.

It is worth noting that many of the differences in the nutritional values of fresh green leaves are attributable to differences in the amount of water in them. So, for example, moringa leaves have about three times as much protein and roughly twice as much iron as pumpkin leaves. However, if you remove the water, which has no nutritive value, the pumpkin leaves then have more protein and more iron than the moringa. Fresh moringa leaves are less than 80% water by weight, whereas pumpkin leaves are about 93% water. Edible fresh leaf crops average about 89% moisture.

What does this mean in practice? It means that the composition of dried leaf powder from different plants is much more similar than the composition of their fresh leaves. It also means that fresh leaves that begin with less moisture will usually dry much faster than leaves with more water in them. It also means that a yield of 30 tons per hectare of moringa will provide about 6.3 tons of actual food, while 30 tons of fresh pumpkin leaf will supply only about 2.1 tons of food after the water is removed. This is why the yields of forage crops are often calculated in terms of dry matter (DM).

It might surprise most people to know that on a dry weight basis, several types of green leaves have higher protein content than cheddar cheese or raw hamburger, and nearly as high as eggs. For example, thoroughly dried moringa leaf is about 45% protein, while dried cheddar cheese is about 40% protein and dried whole milk is about 27% protein.