DIVISION OF AGRICULTURE
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FOOD INDUSTRY CONCEPTS

DRYING FOOD PRODUCTS

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Drying is probably the oldest method of food preservation. Early mankind quickly learned that placing food in the sun until it no longer contained water was a good way to make the food last longer. Today, while sun drying is still used in some parts of the world, modern drying techniques are available which allow control of factors, like drying rate and temperature, which affect the quality of the final product.

Drying preserves food by removing moisture from them. This stops microbial growth and prevents spoilage. Although removing the moisture helps extend the shelf-life of the product, care must be taken during the drying process to preserve as much of the product's nutritive value, natural flavor, and cooking quality as possible.

It is important to remember that drying does not improve the quality of a food product. For this reason, only fully-ripened produce should be used for drying. If a product is not suitable for eating fresh, it is not suitable for drying.

Advantages of Drying Food

- It is the simplest of all food preservation methods.
- Removal of water results in products that weigh less and take up less space. This means dried foods are easier and less expensive to store and transport than other types of preserved foods.
- Foods can be dried without destruction of the cellular tissue of the food.

Limitations of Drying

- Drying is a fairly slow compared to other forms of food preservation. Depending on the product and the drying conditions, drying times can be as long as 12 to 24 hours.
- Mold can grow on partially dried foods, so once drying is started it should continue without interruption.
- Not all foods dry well. For some fruits and several vegetables other preservation methods such as canning or freezing are better methods of preservation.
- Appropriate pretreatment is often necessary to prevent discoloration and other undesirable changes that may occur during drying.
- Drying causes physical changes, like shrinkage. For example, plums become prunes and grapes become raisins. Due to these changes adding water back the product may not return it to its original state.

THE DRYING PROCESS

There is more to producing good quality dried products than simply removing the water. Food often requires a pretreatment to halt enzyme activity. The food is then dried to remove moisture and halt the growth of microorganisms.

Preparing Foods for Drying

Selection and Preparation of Produce

Select high quality, fresh, fully ripened produce for drying. Immature materials will lack flavor and color. Over-mature produce may be fibrous or mushy. Foods that are not in good condition for eating fresh and/or cooking are not suitable for drying.

Prepare the product immediately after harvest and begin drying it as quickly as possible. Most products should be washed thoroughly to remove any dirt or spray. Sort and discard any imperfect material. Decay, bruises, or mold on any piece may affect an entire batch.

Trim, peel, cut, slice, or shred the product. Pieces should be relatively uniform. Thinner, smaller pieces will dry faster than larger, thicker ones resulting in some product being over-dried before other pieces are dried enough.

Pretreating

Enzymes in plant material are responsible for color and flavor changes during ripening. Unless these enzymes are stopped, changes will continue during drying and storage. Fruits and vegetables that will be dried are often given a treatment to slow or stop enzymatic action prior to being placed in the dehydrator.

Blanching

Blanching is the process most often recommended for inactivating enzymes in vegetables and some fruits before drying. Blanching is a heat treatment that inactivates enzymes but is not severe enough to cook the food. It may be done with water, steam or high pressure processing.

Water blanching involves placing the product in boiling water for a specified amount of time. Once the blanching time is over, the product is removed from the boiling water and immediately plunged into cold water to stop the cooking process.

A variation on water blanching used for “candied” dried fruit is blanching in a sugar syrup. This type of blanching helps hold the color of fruits very well, but the fruit will take longer to dry and will tend to attract insects if not packaged properly.

Fruits such as grapes, prunes, and small dark plums, cherries, figs and some firm berries like blueberries have relatively tough skins with a waxy coating. These tough surfaces serve to seal in moisture. To allow interior moisture to be drawn out during drying, the skins are often cracked or “checked” to remove this waxy substance. To crack the skins, the fruit is dipped into briskly boiling water, then in a very cold water before drying.

For steam blanching, the product is heated by exposing it to steam, rather than placing it in boiling water. As with water blanching, the product should be cooled as soon as the blanching process is complete to prevent overcooking. Steam blanching usually results in less leaching of solids and greater retention of water soluble vitamins than occurs with water blanching.

Emerging techniques such as high pressure processing and infrared blanching are offering food processors new approaches to pretreating products for drying.

Other Pretreatment Methods

Blanching can be used to prevent enzymatic activity in fruits, however, blanching may cause the fruit to darken slightly. It may also give a cooked flavor to some fruits, such as apricots, peaches, and pears, and blanched fruits may be soft and a little difficult to handle. For these reasons, other methods may be chosen for pretreating fruits.

Some pretreatment methods used with fruits include:

- Dipping the fruit in a solution of a food acid, such as ascorbic acid or citric acid, to inactivate the enzymes on the surface of the pieces. Any edible acid will inactivate the enzymes but if the acid used is one already present in the fruit, no new flavor will be added.
- Soaking the fruit for about 10 minutes in a salt solution will work as a pretreatment. This treatment has the disadvantage of introducing a salty flavor to the fruit.
- A fruit juice high in ascorbic acid (vitamin C) can also be used as a pretreatment dip. This is generally not as effective as a pure ascorbic acid

dip and tends to add some of the color and flavor of the fruit juice to the product being treated. Juices high in ascorbic acid include lemon, orange, pineapple, grape, and cranberry.

Suggested preparation methods and pretreatments for selected fruits and vegetables are provided in Appendices 1 and 2.

Drying Equipment

There are a number of types of dryers/dehydrators available and the choice of which is best for a particular operation varies with factors such as:

a) the nature of the raw material,
b) the quantity of material to be dried and
c) post-drying handling and packaging requirements.

All food dehydrators have three things in common. They all use heat high enough to draw out the moisture but not so high it cooks the food; they use dry air to absorb the moisture released by the food; and air movement to carry the moisture away from the food.

Batch (tray) dryers handle a single batch of product at a time. The product is placed on trays that are loaded into the drier. The drier is turned on. When the product is dry, the trays are removed from the drier and the product removed from the trays. These driers are fairly simple in design but are also somewhat inefficient for large scale operations since they are not operational while the trays are being filled, loaded into the dryer and unloaded when drying is complete. Batch dryers are most often used for small-scale operations and in pilot plants, like AFIC.

Figure 1. In a batch (tray) dryer product is dried on trays inserted into the dryer. (Photo courtesy of Commercial Dehydrator Systems, Inc.)

Continuous driers are designed so that the food enters the dryer on a conveyer belt, passes through the drying treatment, and then exits without stopping the dryer. Since product can be placed on the conveyor continuously, there is no need to stop the process between batches. These dryers are best when there is a need to run large amounts of product over long periods of time.

Food Trays

Regardless of type of dryer, the food should be spread in a single layer on the drying surface. This will assure all pieces of the product have equal exposure to heat and air movement in the dehydrator.

Most drying surfaces, are made so that air can circulate around the food both from the top and the bottom. This makes drying faster.

Stainless steel trays with perforations in them are often used in batch dryers. For products like liquids, fruit leathers, and seeds, that would fall or flow through the perforations, a solid tray may be used or a tray liner may be used to cover the holes while still allowing air flow from the bottom.

Because the trays become warm during the drying process, some foods, especially those high in sugar, will tend to stick to the tray. This makes it difficult to remove the food when drying is finished.

Figure 2. A variety of kinds of tray liners are available to keep fluids and small foods from falling through perforations in trays and to prevent foods from sticking to the trays.. (Photo courtesy of Commercial Dehydrator Systems, Inc.)

This sticking can be prevented by lining the tray with a tray liner such as parchment paper, or a mesh liner made of food-grade plastic or Teflon. Spray-on or wipe-on releasing agents can also be used to prevent sticking.

Temperature and Air Speed are Critical

The key to successful drying is to remove moisture as quickly as possible at a temperature that does not seriously affect the flavor, texture, and color of the food. In most dryers this is accomplished by a flow of hot air pulling moisture from the surface of the product. The challenge is to determine the appropriate levels of heat and air flow to dry the product with a minimum loss of quality.

Since many food components are sensitive to heat, determination of the best drying temperature for

Table 1. Water activity values of selected foods. (Adapted from Water Activity of Foods Table, Penn State Extension - http://extension.psu.edu/food/preservation/issues/water-activity-of-foods/water-activity-of-foods-table)

a_w	Food Examples
0.95	Fresh and canned fruits, vegetables, meat and fish; milk; cooked sausages; breads; foods with up to 4% sucrose or 7% NaCl
0.91	Some cheese (Cheddar, Swiss, Provolone); cured meat; fruit juice concentrates; foods with 55% sucrose or 12% NaCl
0.87	Fermented sausage; sponge cakes; dry cheese; margarin; foods with 65% sucrose or 15% NaCl
0.80	Most fruit juice concentrates; sweetened condensed milk; chocolate, maple, and syrups; flour; rice; fruit cake and other high-sugar cakes
0.75	Jam, marmalade, marzipan, marshmallows
0.65	Rolled oats containing approx. 10% moisture; jelly; molasses; some dried fruits; nuts
0.60	Dried fruits with 15-20% moisture, caramel, honey
0.50	Noodles, spaghetti, etc with 12% moisture; spices with 10% moisture
0.30	Cookies, crackers, etc. containing 3-5% moisture
0.03	Whole milk powder containing 2-3% moisture; dried vegetables containing about 5% moisture; dehydrated soups, some cookies and crackers

your product is critical to assuring the quality and safety of the dried product. If the temperature is too low in the beginning, microorganisms may survive and even grow before the food is adequately dried. If it is too high, the surface will dry out too quickly, basically sealing internal moisture in the product (case hardening) and food components sensitive to heat may be damaged.

The rate of air movement is also critical. Heated air absorbs moisture from the product. Movement of the air then takes this moisture away. The goal is to establish a rate of air movement that allows good moisture removal.

While there are elaborate mathematical models to calculate the best temperatures and air movement rates, there are a number of factors individual to your product that must be considered. These include such things as the original condition of the product, product components such as sugar and salt levels, the size and shape of the pieces, the humidity of the environment, and the method of operation of your dehydrator.

In general, a temperature of 140^{o}F provides a good drying rate with minimum loss of food quality. Seeds, grains, herbs and spices are often dried at slightly lower temperatures. However, these recommendations should be considered only a starting point for experimntation with your product to define the best drying conditions to give a good product.

Testing for Dryness

A water activity (a_w) test should be performed to determine the safety of the finished product.

Water activity is a measure of the amount of water available to support the growth of bacteria, mold, and yeast. The goal of drying is to lower the water activity of the food to a point where microorganisms that cause foodborne disease can no longer grow.

Water activity is measured on a scale that ranges from 0 which is no water available to 1, pure water. Most fresh produce has an a_w above 0.95 and that is enough to support the growth of bacteria, mold, and yeasts (Table 1). It is important to note that a_w is the amount of water available, not the total water content of the food. Some water in the food may be tied up by food components, like sugar or salt, so not available for use by bacteria.

Each type of microorganism has a unique a_w range for survival. Although most bacteria require an a_w of at least 0.91, some can survive at levels as low as 0.75. Foods that depend on water activity as a means of preventing bacterial growth should have an a_w of 0.85 or lower. Some yeasts and molds can grow at a_w levels as low as 0.60. Preventing spoilage by these organisms requires lowering the a_w to below this level.

Packaging and Storage

Dried foods can easily reabsorb moisture from the air so must be packaged as soon as they are cooled. Packaging material should protect the product from exposure to moisture. Because light can cause many dried foods to deteriorate, packaging that prevents exposing the product to light may be desirable.

Product color should be uniform throughout the package. Discolored pieces that appear toasted or burned should be avoided. Pieces should be uniform sized and shaped without ragged edges. All pieces must be consistently dry throughout the package.

Fruits should have no signs of mold, have a leathery and pliable texture (for example, if the piece of fruit is folded over itself, it springs back), not be sticky or brittle, and be free from cores and seeds or peel. Vegetables should be brittle and crisp, and be dry enough to rattle. Herbs should be like dust when rubbed between fingers.

Recommended storage times for dried fruits and vegetables range from six months to one year.

LEATHERS

Leathers are made by drying pureed fruit or vegetables on a flat surface. They get their name from the fact that, when dry, the product is shiny and has the texture of leather. They are often packaged rolled into tube-like shapes.

Any type of fruit or vegetable may be made into a leather, however, fruit leathers are more common than vegetable ones. Purees of more than one type of fruit and/or vegetable may be made for unique flavor combinations.

To make leathers, select ripe or slightly overripe produce. Wash and prepare as if for eating fresh. Purees may be made from canned or frozen product so produce can be canned or frozen right after harvest then made into leathers later.

Produce should be pureed until smooth. If using light colored fruits, lemon juice or ascorbic acid should be added to the puree to prevent browning.

Spices such as cinnamon, cloves, ginger, or nutmeg, or flavorings like vanilla extract or lemon or lime peel may be added to achieve unique flavors.

Purees are spread into a thin layer on drying trays. Trays should be lined with an appropriate liner or with plastic wrap to prevent the puree from flowing through the holes in the tray and to make it easier to remove the dried leather from the tray. If desired, puree may be portioned into uniform portions rather than being poured out as a single sheet.

Leathers should be dried at 140°F. Leathers dry from the outside to the center so the edges may appear dry before the centers are dried. Dried leathers should peel easily from the tray liner/ plastic wrap.

JERKY

Jerky, or dried meat, is a favorite of hikers and campers because it is as much as 75% lighter than fresh meat. Because most of the moisture is removed, the meat can be stored without refrigeration. Jerky can be made from almost any lean meat.

The USDA recommends that, to make jerky safely, red meats should be steamed or roasted to 160°F and poultry to 165°F (as measured with a meat thermometer) before drying. This step assures that any bacteria present

will be destroyed. After heating the meat to the indicated temperature, a constant dehydrator temperature of 130 to 140°F should be maintained during drying. At these drying temperatures, drying is fast enough to get the meat dry before it spoils and enough moisture is removed to prevent microorganisms from growing.

To make jerky, slice the heated meat with the grain into strips 1/4– to 1/2-inch thick and 1 to 1 1/2 inches wide. Remove any fat because fat tends to become rancid during drying.

Salted jerky is made by sprinkling the strips liberally with salt and, if desired, other seasonings. Salted strips are stacked in a bowel or crock and weighted down so they become immersed in the liquid that the salt draws from the meat. The strips are allowed to stand in this brine for several hours before being drained and placed in a dehydrator.

Unsalted jerky is made skipping the brining step. The seasoned meat is placed directly in the dehydrator. The meat may be marinated before drying if additional flavoring is desired.

When jerky is dried, a piece of cooled meat will crack but not break when bent. After removing the jerky from the dehydrator, pat off any surface oil and cool before packaging.

FREEZE DRYING

Freeze drying is a method of drying food by freezing it, then putting the frozen food in a vacuum. The vacuum causes the frozen water in the food to evaporate. This ice-to-vapor process, called sublimation, results in a dried product that is essentially the same size and shape as the original product but much lighter due to the removal of the water. Because freeze-dried products have spaces where the ice had been, they readily absorb water when rehydrated. The downside of freeze drying is that it requires specialized equipment to produce and is relatively energy intensive.

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Appendix 1. Preparation and pretreatment recommendations for drying selected fruit.

Fruit	Preparation	Recommended Pre-Treatment (Choose from options listed)			
		Sulphur*	Steam Blanch (minutes)	Syrup Blanch (minutes)	Other
Apples	Peel and core, cut into slices or rings about 1/8-inch thick	X	3-5	10	- ascorbic acid solution or - fruit juice dip or - sulfite dip
Apricots	Pit and halve. May slice as desired.	X	3-4	10	- ascorbic acid solution or - fruit juice dip or - sulfite dip
Bananas	Use solid yellow or slightly brown -flecked bananas. Avoid bruised or overripe bananas. Peel and slice 1/4-inch to 3/8-inch thick crosswise or lengthwise.		3-4	10	- ascorbic acid solution or - fruit juice dip or - sulfite dip
Berries	Wash and drain berries				For firm berries like blueberries, cranberries, currants, gooseberries, and huckleberries – Plunge into boiling water to "check" (crack) skins. Stop cooking by placing hot fruit in ice water. Drain before drying. For soft berries like strawberries and boysenberries, no pretreatment is needed.
Cherries	Stem, wash, drain, and pit fully ripe fruit. Cut in half, chop or leave whole.			10 (for sour)	If cut or chopped, no pretreatment needed If whole, dip in boiling water for about 30 sec. to check skins.
Figs	Select fully ripened fruit. Immature fruit may sour before being drying completely. Wash or clean whole fruit with a damp cloth. Leave small fruit whole. Cut large fruit in half.	X			Whole: Plunge into boiling water to "check" (crack) skins. Stop cooking by placing hot fruit in ice water. Drain before drying.
Grapes Seedless With seeds	Leave whole Cut in half and remove seeds				Whole: Plunge into boiling water to "check" (crack) skins. Stop cooking by placing hot fruit in ice water. Drain before drying. Halves: no treatment necessary
Peaches	When sulfuring, cut in half and remove pit. If desired remove skin. For steam or syrup blanching, leave whole while blanching. Half and pit after cooling. May also be quartered or sliced.	X	8	10	- ascorbic acid solution or - fruit juice dip or - sulfite dip
Pears	Cut in half and core. Peeling is preferred. Slice or quarter, if desired.	X	6	10	- ascorbic acid solution or - fruit juice dip or - sulfite dip
Plums (Prunes)	Leave whole or if sulfuring, halve the fruit.	X (optional but gives good flavor)			Clean by rinsing in hot tap water.

* Consult with processing expert about options for use of sulfur when drying fruits.

Appendix 2. Preparation and pretreatment recommendations for drying selected vegetables

Vegetable	Preparation	Recommended Pre-Drying Treatment (Choose from options listed)	
		Water Blanch (minutes)	Steam Blanch (minutes)
Asparagus	Wash thoroughly. Halve large tips.	3 ½-4 ½	4-5
Beans, green	Wash thoroughly. Cut in short pieces or length-wise.	2	2-2 ½
Beets	Cook as usual. Cool; peel. Cut into shoestring strips about 1/8-inch thick.	None	
Broccoli	Trim, cut as for serving. Wash thoroughly. Quarter stalks lengthwise.	2	3-3 ½
Cabbage	Remove outer leaves; core and quarter. Cut into strips 1/8-inch thick.	1 ½-2	2 ½-3 (until wilted)
Carrots	Use only crisp, tender carrots. Wash thoroughly. Cut off roots and tops; preferably peel, cut in slices or strips 1/8-inch thick.	3 ½	3-3 ½
Celery	Trim stalks. Wash stalks and leaves thoroughly. Slice stalks into pieces about 1/8-inch thick.	2	2
Corn	Husk, trim, cut kernels from the cob after blanch-ing.	3-4	5-6
Garlic	Peel and finely chop bulbs.	None	
Horseradish	Wash; remove small rootlets and stubs. Peel or scrape roots. Grate or cut into 1/8-inch slices.	None	
Mushrooms	Scrub thoroughly. Discard any tough, woody stalks. Cut tender stalks into short sections. Do not peel small mushrooms or “buttons.” Peel and slice large mushrooms.	None	
Okra	Wash, trim, slice crosswise into 1/8- to 1/4-inch disks.	None	
Onions	Wash, remove outer “paper shells.” Remove tops and root ends, slice 1/8- to 1/4-inch thick.	None	
Peas, green	Shell.	2	3
Peppers and pimen-tos	Wash, stem, core. Remove “partitions.” Cut into disks about 3/8-inch thick.	None	
Potatoes	Wash; peel. Cut into shoestring strips 1/4-inch thick or slices 1/8-inch thick.	5-6	6-8
Squash Winter/Pumpkin Summer	Cut or break into pieces. Remove seeds and cavity pulp. Cut into 1-inch wide strips. Peel rind. Cut strips crosswise into pieces about 1/8-inch thick. Wash, trim, cut into 1/4-inch slices	1 1 ½	2 ½-3 2 ½-3
Tomatoes	Steam or dip in boiling water to loosen skins. Chill in cold water. Cut into sections about ¾-inch wide or slice. Cut small cherry or plum tomatoes in half.	1	3