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Dehydrating Fruits and Vegetables for Home Use

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Abstract

Many farm-harvested or market-purchased fresh fruits and vegetables are consumed fresh or frozen, with little to none utilized as dry products; in general, dried fruits and vegetables are purchased directly from the market whenever needed. With the wide availability of tabletop kitchen equipment for fruit and vegetable processing (mechanical cutters, slicers, homemade dehydrators, blenders, etc.), consumers and small farmers with excess harvest or unsold fresh products can take the opportunity to process their fresh fruits and vegetables into dried snacks for direct use or sale at a farmer's market. The advantage of these dried products is their stable shelf life, versatility, and overall value addition. Dried products can be used at any time (6-12 months) with little or no loss in quality and can be used as intermediate goods in other products such as breakfast cereals. This publication presents easy-to-follow guidelines and conditions for processing selected fruits and vegetables into dried products.

Introduction

Importance of fruits and vegetables

Eating more fruits and vegetables has been associated with various health-promoting and disease-preventing benefits. Different medical and scientific studies have linked eating fruits and vegetables with reduced risks of chronic diet–related diseases such as cardiovascular diseases, high blood pressure, cancer, diabetes, and aging [1-3]. Fruits and vegetables contain multiple type and amounts of phytonutrients and bioactive compounds that are responsible for these health benefits. Some examples of these nutrients include ascorbic acid, vitamin E, phenols and polyphenols, flavonoids, isoflavones, terpenes, phytoestrogens, lignans, lycopene, coumestrol, and glucosinolates [4, 5].

Because of this body of research supporting the benefits of fruit and vegetable consumption, the United States Departments of Health and Human Services (HHS) and U. S. of Agriculture (USDA) have jointly recommend in their publications for over three decades that Americans eat more fruits and vegetables. The advice at the top of their list of diet recommendation for 2015-2020, is to eat a variety of vegetables ranging from root vegetables to greens, and whole fruit in addition to grains, fat-free or low-fat dairy, and a variety of sources of protein and oil, all within an appropriate calorie level range [6]. For example, the USDA Food Patterns suggestion for a 2000 calorie diet would be: 2 cups of fruits, 2 ½ cups of vegetables, 6 oz of grains, 5 ½ oz of protein-containing foods, 3 cups of dairy, and 27 g of oils. However, the research shows that the eating habits of Americans do not follow the Dietary Guidelines for Americans (DGA);and the majority of Americans still get most of their energy from fat and added sugar [7]. Even though Americans are not currently eating enough fruits and vegetables, despite having enough available, we will need even more land to grow enough fruits and vegetables to meet the projected 2020 DGA recommendations, assuming people consistently follow them. The largest food supply gap will be in fruits followed by vegetables [7]. Blanchette and his group [8] reviewed

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numerous articles in the PubMed and 1Psychinfo electronic literature databases and showed that the ability to find and buy fruits and vegetables is the most predictable factor in whether 6-12 year-old children have them in their diets.

One key point to note here is food availability. Fresh fruits and vegetables are not always available year-round, due to when the crops ripen and how long they can be stored without spoiling. Processes that lead to produce deterioration need water, and thus drying obviously stabilizes most products. In fact, drying is one of the oldest methods of food preservation, and can be done for both fruits and vegetables. The advantage of drying over other types of preservation, such as modified atmosphere packaging, edible coating, irradiation, and other non-thermal techniques is that, drying provides products with significantly extended shelf life—typically beyond six months, depending on how they are stored. This means dried fruits and vegetables can be available to consumers at any time of the year. Dried fruits and vegetables can be used many ways, including being added to foods like bread, cereals, and pastries. They are easier and cheaper to transport than fresh fruits and vegetables, and dried fruits provide similar health benefits to fresh as well.[9-12].

Dehydration of selected fruits and vegetables for home consumption

Choice of a dryer

There are many kinds of appliances available for drying fruits and vegetables, ranging from small tabletop dryers to large commercial kitchen dryers and very large industrial dryers. You can tell them apart by how much produce they dry, their power rating, and how they dry the produce. This paper will focus on the table-top, hot-air electric dryer, which is a more likely choice for home use (fig. 1). While we will not recommend a brand of dryer, we want to use our own experiences to help consumers find one that works best for their needs, based on airflow, how moisture is drained, and how easy it is to clean.

Points to note when choosing/buying a hot-air-table dryer

1. Make sure the dryer has a holding compartment with a door or some kind of lid that is not air-tight (to allow moisture to escape).
2. The dryer must have a way to adjust temperature to multiple settings. It is helpful to choose one that also has a time control knob.
3. Ensure that the dryer has removable trays with mesh or vents that are not too large to let small pieces fall through (typically 3-5 mm holes). Trays made from stainless steel or plastics are preferable.
4. Make sure the trays can take the heat (often ≤ 194 °F) and are easily cleaned between uses, since some foods are sticky and residue may contaminate other foods being dried later.
5. Avoid a dryer with a heating element directly under the trays. Any moisture that drips from the trays onto the heating element will make cleaning difficult and, more importantly, may damage or short out the device.
6. The dryer must have a fan to remove moist air. If air flows across (parallel to) the surface of the drying food, it will dry more quickly than if the air flows down on it or up through it (perpendicular).
7. Note that the fan should also not be placed directly under the trays or moisture from the food will drip onto it and potentially destroy the machine.

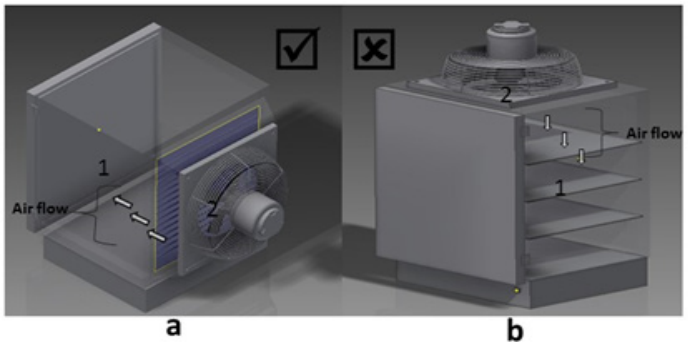

Figure 1. An example of two dryers: (a) a dryer with a fan blowing air across the trays, and (b) a dryer with a fan blowing air on top of the trays. The diagram also shows a chamber with removable trays (1) and with a combined fan and heating unit (2).

Moisture content (MC) and Water activity (aw) tells the end of drying process

To be completely sure if the dried products are fully dried as desired and to determine the overall quality of the fruits and vegetables after drying, we recommend performing a quality test on the products after the set drying time (table 1). This is recommended because the necessary drying time

may vary based on the condition of the fruit (ripe and mature fruit dries faster), the relative humidity at the time of drying (low humid air means faster drying and low final moisture), loading of the dryer (small loads dry faster) and the type of dryer (capacity or brand). The two tests to show that the drying process is complete and that the dried products are of acceptable quality are **moisture content** and/or **water activity**. *Moisture content* is the amount of moisture present in the food products and it is determined from the following equation:

$$MC\ (\%) = \frac{\text{Weight of product before oven drying} - \text{Weight of product after oven drying}}{\text{Weight of product before oven drying}}$$

To determine the value of the terms in the equation, 1 - 4 ounces of the dried product picked randomly across the tray is further dried in an oven set to 221 °F for 18h. The weights of the dried products before and after oven-drying is recorded and used to calculate the moisture content as shown above. The moisture content determined this way is called moisture content by wet basis (%wb). Generally, the safe moisture content for fruit and vegetables is about 20%wb or below, depending on the product, the pretreatments, and the final desired product texture.

A quicker way to measure the moisture content is to use a moisture analyzer (fig. 2a). The moisture analyzer can determine the moisture content of your product in minutes.

Water activity on the other hand is a measure of how much of water is available in the fruits/vegetables to support spoilage by microorganism. Water activity is a better measure of stability than moisture content. It is determined from the equations:

$$a_w = \frac{\text{Partial pressure of water vapor from dried product}}{\text{Saturated water vapor of ordinary vapor}}$$

or

$$a_w = \frac{\text{Equilibrium Relative Humididty of the Dried product with air, as percent}}{100}$$

The information needed for calculating water activity is not easily measured with ordinary instruments such as balances. There are specialized instruments called water activity meters for measuring the water activity of food directly. See example below (fig. 2b).

Fruits and vegetables dried to a water activity ≤ 0.6) are generally safe from microbial growth for a much longer time and may be stored and eaten for weeks or months, unlike fresh fruits and vegetables that go bad in a few days.

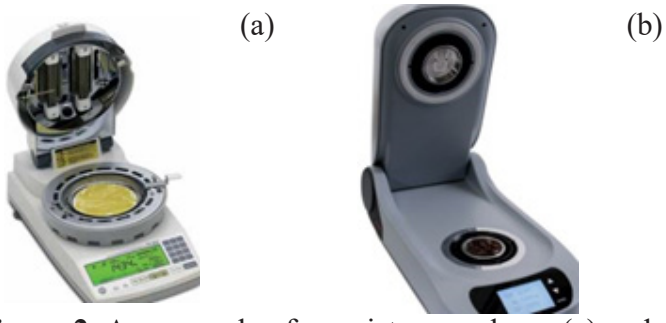

Figure 2. An example of a moisture analyzer (a) and a water activity meter (b).

Packaging and storage

The required moisture content that translates to a water activity of 0.6 at about 70 °F (close to room temperature) varies for different fruits and vegetables; for instance, dried carrots are about 20%wb moisture content, whereas dried potatoes, raisins, and prunes are 12%,, 11%, and 11% wb moisture content, respectively. As a general guideline, produce dried to a moisture content of less than 15% wb moisture content is safe and stable. After drying, it is a good practice to cool down your dried product and then store it in an air-tight, water –impermeable container, such as freezer bags (a thick plastic bag specifically designed to be used at freezing temperatures), glass jars, or cans with lids. Store the product in a cool, dark area. If dried products are stored in hot or warm conditions in the air-tight container, water vapor from the product will condense on the product or run down the walls of the container, which could cause some of the food to have a higher moisture content or water activity, and possibly spoil. If properly stored, dried products can last for 6 months at 70 °F or 1 year at 60 °F[33].

Special case of fruit and vegetable dehydration – osmo-convective dehydration

Although fruits and vegetables can be dried directly in a dehydrator, it is a common practice to pre-treat these products to improve their quality and sometimes to help them dry more easily. Some pretreatments were mentioned in the drying recipes in section 2.2, such as blanching with water or steam,

Table 1: *Preparation and drying suggestions for selected fruits and vegetables.*

Product		Process condition				
		Shape/ Thickness	*Pretreatments*	*Temperature & Duration*	*Final moisture content (MC) or Final water activity (a_w) of dried fruit snacks*	
	*Apples*	0.6” slice 0.4’’ cube 0.4” halve	Wash, core, peel, and slice	158 °F 3½ h 176 °F, 3 h	a_w 0.39 a_w 0.25 – 0.49	[13] [14]
	*Bananas*	Whole 1.08” 0.17” slice 0.29” slice 0.55” slice	Wash, peel, and slice	158 °F, 8 ¼ h 140 °F, 8 h 140 °F, 10 ¼ h 140 °F, 13 h	MC 61.5 % MC 9 %	[15] [16]
	*Black berries*	Native shape	Wash and remove stalk	194 °F, 4½ h	MC 4 %	[17]
	*Blueberries*	Fresh Fresh	Wash, remove stalk, and put in warm sugar solution for 6 ½ h Wash with no other treatment	165 °F, 10 h 140 °F, 23 ¼ h 158 °F, 13 ¼ h 176 °F, 8 ¼ h	a_w 0.4 MC 15 %	[18] [19]
	*Broccoli*	*Stalk* 0.24” slice Floret pieces (0.39” thickness)	Wash and cut Wash, cut and blanch in 194 °F water for 2 min, then cool	140 °F, 3 ¾ h 167 °F, 2 ¼ h	MC 10 % MC 15 %	[20] [21]
	*Carrots*	0.2” slice	Wash, remove stalk, cut and blanch in 203 °F hot water for 1.45 min,	104 °F, 8 h	MC 17 %, a_w 0.4	[22]
	*Cherries*	Native shape	Wash and remove stalk, with no other treatment Wash, and remove stalk, and steam-blanch for 1.5 min Wash, remove stalk, and pit, with no other treatment	131 °F, 40 h 158 °F, 10 h 158 °F, 14 h	MC 10 % MC 30 - 40 %, $a_w \leq 0.6$	[23] [24]
	*Kiwi fruits*	0.12”slice 0.2” slice 0.2” slice	Wash, peel, and cut	140 °F, 3 ¾ h	MC 28 %	[25]

	*Mango*	0.11” thick	Wash, cut, remove seed, and blanch for 2 min in water at 122 °F Wash, cut, remove seed, with no other treatment	140 °F, 3 h	MC 7.5 – 11 %	[26]
	*Okra*	Native shape (0.67”)	Wash with no other treatment	122 °F, 15 ½ h 140 °F, 10 ½ h 158 °F, 8 h	MC 15 %	[27]
	*Peach*	0.17” slice	Blanch with 1 % ascorbic acid at 122 °F for 2 min.	131 °F, 3 ½ h 149 °F, 3 h	MC 14 – 17.5 %	[28]
			Wash and cut, with no other treatment	131 °F, 4 h 149 °F, 3 ½ h		
	*Raisins (grapes)*	Native shape	Wash with no other treatment	140 °F, 40 h	MC 10 %	[29]
	*Prunes (plum)*	Native shape	Wash with no other treatment	149 °F, 29h	MC 20 %	[30]
	*Strawberry*	Native shape	Wash and remove stalk, with no other treatment	131 °F, 22 h 149 °F, 15 h	MC 20 %	[31]
	*Sweet Potatoes*	0.12” slice 0.16” slice 0.24” slice 0.31’’slice	Wash , cut and blanch for 2 min in hot water at 158 °F and cool	158 °F	1 ¼ h 1 ¾ h 1 ½ h 1 ¼ h	MC 10 % [32]

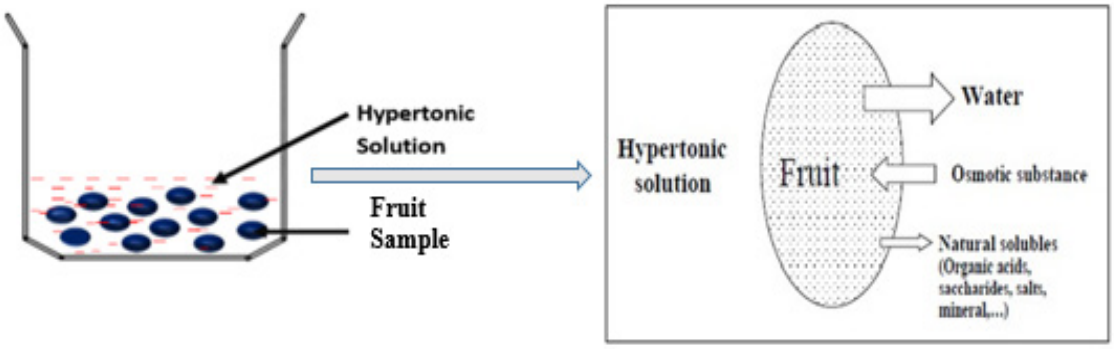

Figure 3. Schematic diagram of the osmotic dehydration process.

dipping in ascorbic acid, or dipping in alkaline solutions. Osmotic dehydration (fig. 3) is a common industry practice which works by soaking the product in an edible hypertonic solution (a sugar solution such as honey, fruit juices, or just sugar in water) at moderate temperature (77- 122 °F) for some time (1/2 – 4 h) before subsequent air drying. The amount of fruit soaked to the sugar solution is usually in a ratio 1:3 to 1:6. For instance, one pound of fruit will be soaked in three pounds of sugar solution or up to six pounds of sugar solution. The high concentration of sugar in the solution forces the produce to release water and absorb sugar into its cells. This process reduces the moisture content of the produce, increases the weight from sugar infusion, and keeps the produce from losing nutrients as it dries.

Different ingredients (vitamins, minerals, flavors, etc.) can be added into the osmotic solution to produce dried fruits and vegetables with enhanced nutritional quality like dried zinc-fortified apples and potatoes. The process of osmotic dehydration is easy, low cost, and saves energy during drying.

Summary

The dried fruit and vegetable market is under-utilized globally. Currently, the United States imports more than 40% of the total produce we consume. Ironically, much of this still goes to waste. Converting unused fresh fruit and vegetables to dried products provides food security and is good for everyone. It will not only cut post-harvest loss, but also will allow us to grow a bigger variety of produce, increase the availability of fruits and vegetables in our diet, and provided increased income from the sale of these value-added products. Consumers at home can take advantage of drying technology by buying produce in bulk during peak seasons when it is cheaper, converting it into dry products that have much the same nutrient content as fresh, and using these products during off-seasons when produce is likely to be more expensive.

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