9.8.2 Dehydrated Fruits And Vegetables

9.8.2.1 General[1-2]

Dehydration of fruit and vegetables is one of the oldest forms of food preservation techniques known to man and consists primarily of establishments engaged in sun drying or artificially dehydrating fruits and vegetables. Although food preservation is the primary reason for dehydration, dehydration of fruits and vegetables also lowers the cost of packaging, storing, and transportation by reducing both the weight and volume of the final product. Given the improvement in the quality of dehydrated foods, along with the increased focus on instant and convenience foods, the potential of dehydrated fruits and vegetables is greater than ever.

9.8.2.2 Process Description[1-2]

Dried or dehydrated fruits and vegetables can be produced by a variety of processes. These processes differ primarily by the type of drying method used, which depends on the type of food and the type of characteristics of the final product. In general, dried or dehydrated fruits and vegetables undergo the following process steps: predrying treatments, such as size selection, peeling, and color preservation; drying or dehydration, using natural or artificial methods; and postdehydration treatments, such as sweating, inspection, and packaging.

Predrying Treatments -

Predrying treatments prepare the raw product for drying or dehydration and include raw product preparation and color preservation. Raw product preparation includes selection and sorting, washing, peeling (some fruits and vegetables), cutting into the appropriate form, and blanching (for some fruits and most vegetables). Fruits and vegetables are selected; sorted according to size, maturity, and soundness; and then washed to remove dust, dirt, insect matter, mold spores, plant parts, and other material that might contaminate or affect the color, aroma, or flavor of the fruit or vegetable. Peeling or removal of any undesirable parts follows washing. The raw product can be peeled by hand (generally not used in the United States due to high labor costs), with lye or alkali solution, with dry caustic and mild abrasion, with steam pressure, with high-pressure washers, or with flame peelers. For fruits, only apples, pears, bananas, and pineapples are usually peeled before dehydration. Vegetables normally peeled include beets, carrots, parsnips, potatoes, onions, and garlic. Prunes and grapes are dipped in an alkali solution to remove the natural waxy surface coating which enhances the drying process. Next, the product is cut into the appropriate shape or form (i. e., halves, wedges, slices, cubes, nuggets, etc.), although some items, such as cherries and corn, may by-pass this operation. Some fruits and vegetables are blanched by immersion in hot water (95° to 100°C [203° to 212°F]) or exposure to steam.

The final step in the predehydration treatment is color preservation, also known as sulfuring. The majority of fruits are treated with sulfur dioxide (SO_2) for its antioxidant and preservative effects. The presence of SO_2 is very effective in retarding the browning of fruits, which occurs when the enzymes are not inactivated by the sufficiently high heat normally used in drying. In addition to preventing browning, SO_2 treatment reduces the destruction of carotene and ascorbic acid, which are the important nutrients for fruits. Sulfuring dried fruits must be closely controlled so that enough sulfur is present to maintain the physical and nutritional properties of the product throughout its expected shelf life, but not so large that it adversely affects flavor. Some fruits, such as apples, are treated with solutions of sulfite (sodium sulfite and sodium bisulfite in approximately equal proportions) before dehydration. Sulfite solutions are less suitable for fruits than burning sulfur (SO_2 gas), however, because the solution penetrates the fruit poorly and can leach natural sugar, flavor, and other components from the fruit.

Although dried fruits commonly use SO_2 gas to prevent browning, this treatment is not practical for vegetables. Instead, most vegetables (potatoes, cabbage, and carrots) are treated with sulfite solutions to retard enzymatic browning. In addition to color preservation, the presence of a small amount of sulfite in blanched, cut vegetables improves storage stability and makes it possible to increase the drying temperature during dehydration, thus decreasing drying time and increasing the drier capacity without exceeding the tolerance for heat damage.

Drying Or Dehydration -

Drying or dehydration is the removal of the majority of water contained in the fruit or vegetable and is the primary stage in the production of dehydrated fruits and vegetables. Several drying methods are commercially available and the selection of the optimal method is determined by quality requirements, raw material characteristics, and economic factors. There are three types of drying processes: sun and solar drying; atmospheric dehydration including stationary or batch processes (kiln, tower, and cabinet driers) and continuous processes (tunnel, continuous belt, belt-trough, fluidized-bed, explosion puffing, foam-mat, spray, drum, and microwave-heated driers); and subatmospheric dehydration (vacuum shelf, vacuum belt, vacuum drum, and freeze driers).

Sun drying (used almost exclusively for fruit) and solar drying (used for fruit and vegetables) of foods use the power of the sun to remove the moisture from the product. Sun drying of fruit crops is limited to climates with hot sun and dry atmosphere, and to certain fruits, such as prunes, grapes, dates, figs, apricots, and pears. These crops are processed in substantial quantities without much technical aid by simply spreading the fruit on the ground, racks, trays, or roofs and exposing them to the sun until dry. Advantages of this process are its simplicity and its small capital investment. Disadvantages include complete dependence on the elements and moisture levels no lower than 15 to 20 percent (corresponding to a limited shelf life). Solar drying utilizes black-painted trays, solar trays, collectors, and mirrors to increase solar energy and accelerate drying.

Atmospheric forced-air driers artificially dry fruits and vegetables by passing heated air with controlled relative humidity over the food to be dried, or by passing the food to be dried through the heated air, and is the most widely used method of fruit and vegetable dehydration. Various devices are used to control air circulation and recirculation. Stationary or batch processes include kiln, tower (or stack), and cabinet driers. Continuous processes are used mainly for vegetable dehydration and include tunnel, continuous belt, belt-trough, fluidized-bed, explosion puffing, foam-mat, spray, drum, and microwave-heated driers. Tunnel driers are the most flexible, efficient, and widely used dehydration system available commercially.

Subatmospheric (or vacuum) dehydration occurs at low air pressures and includes vacuum shelf, vacuum drum, vacuum belt, and freeze driers. The main purpose of vacuum drying is to enable the removal of moisture at less than the boiling point under ambient conditions. Because of the high installation and operating costs of vacuum driers, this process is used for drying raw material that may deteriorate as a result of oxidation or may be modified chemically as a result of exposure to air at elevated temperatures. There are two categories of vacuum driers. In the first category, moisture in the food is evaporated from the liquid to the vapor stage, and includes vacuum shelf, vacuum drum, and vacuum belt driers. In the second category of vacuum driers, the moisture of the food is removed from the product by sublimination, which is converting ice directly into water vapor. The advantages of freeze drying are high flavor retention, maximum retention of nutritional value, minimal damage to the product texture and structure, little change in product shape and color, and a finished product with an open structure that allows fast and complete rehydration. Disadvantages include high capital investment, high processing costs, and the need for special packing to avoid oxidation and moisture gain in the finished product.

Postdehydration Treatments -

Treatments of the dehydrated product vary according to the type of fruit or vegetable and the intended use of the product. These treatments may include sweating, screening, inspection, instantization treatments, and packaging. Sweating involves holding the dehydrated product in bins or boxes to equalize the moisture content. Screening removes dehydrated pieces of unwanted size, usually called "fines". The dried product is inspected to remove foreign materials, discolored pieces, or other imperfections such as skin, carpel, or stem particles. Instantization treatments are used to improve the rehydration rate of the low-moisture product. Packaging is common to most all dehydrated products and has a great deal of influence on the shelf life of the dried product. Packaging of dehydrated fruits and vegetables must protect the product against moisture, light, air, dust, microflora, foreign odor, insects, and rodents; provide strength and stability to maintain original product size, shape, and appearance throughout storage, handling, and marketing; and consist of materials that are approved for contact with food. Cost is also an important factor in packaging. Package types include cans, plastic bags, drums, bins, and cartons, and depend on the end-use of the product.

9.8.2.3 Emissions And Controls[1,3-6]

Air emissions may arise from a variety of sources in the dehydration of fruits and vegetables. Particulate matter (PM) emissions may result mainly from solids handling, solids size reduction, and drying. Some of the particles are dusts, but other are produced by condensation of vapors and may be in the low-micrometer or submicrometer particle-size range.

The VOC emissions may potentially occur at almost any stage of processing, but most usually are associated with thermal processing steps, such as blanching, drying or dehydration, and sweating. Particulate matter and condensable materials may interfere with the collection or destruction of these VOC. The condensable materials also may be malodorous. The color preservation (sulfuring) stage can produce SO_2 emissions as the fruits and vegetables are treated with SO_2 gas or sulfide solution to prevent discoloration or browning.

Wastewater treatment ponds may be another source of VOC, even from processing of materials that are not otherwise particularly objectionable. Details on the processes and technologies used in wastewater collection, treatment, and storage are presented in AP-42 Section 4.3. That section should be consulted for detailed information on the subject.

No emission data quantifying VOC, HAP, or PM emissions from the dehydrated fruit and vegetable industry are available for use in the development of emission factors. However, some data have been published on VOC emitted during the blanching process for two vegetables and for volatiles from fresh tomatoes. Van Langenhove, et al., identified volatiles emitted during the blanching process of Brussels sprouts and cauliflower under laboratory and industrial conditions. In addition, Buttery, et al., performed a quantitative study on aroma volatiles emitted from fresh tomatoes.

A number of VOC and particulate emission control techniques are available to the dehydrated fruit and vegetable industry. No information is available on the actual usage of emission control devices in this industry. Potential options include the traditional approaches of wet scrubbers, dry sorbents, and cyclones.

Control of VOC from a gas stream can be accomplished using one of several techniques but the most common methods are absorption and adsorption. Absorptive methods encompass all types of wet scrubbers using aqueous solutions to absorb the VOC. Most scrubber systems require a mist eliminator downstream of the scrubber.

Adsorptive methods could include one of four main adsorbents: activated carbon, activated alumina, silica gel, or molecular sieves. Of these four, activated carbon is the most widely used for VOC control while the remaining three are used for applications other than pollution control. Gas adsorption is a relatively expensive technique and may not be applicable to a wide variety of pollutants.

Particulate control commonly employs methods such as venturi scrubbers, dry cyclones, wet or dry electrostatic precipitators (ESPs), or dry filter systems. The most common controls are likely to be the venturi scrubbers or dry cyclones. Wet or dry ESPs could be used depending upon the particulate loading of the gas stream.

Condensation methods and scrubbing by chemical reaction may be applicable techniques depending upon the type of emissions. Condensation methods may be either direct contact or indirect contact with the shell and tube indirect method being the most common technique. Chemical reactive scrubbing may be used for odor control in selective applications.

References For Section 9.8.2

1. L. P. Somogyi and B. S. Luh, "Dehydration Of Fruits", *Commercial Fruit Processing*, Second Ed., J. G. Woodroof and B. S. Luh, Editors. AVI Publishing Company, Inc., 1986.

2. L. P. Somogyi and B. S. Luh, "Vegetable Dehydration", *Commercial Vegetable Processing*, Second Ed., B. S. Luh and J. G. Woodroof, Editors, An AVI Book Published by Van Nostrand Reinhold, 1988.

3. J. L. Jones, *et al.*, "Overview Of Environmental Control Measures And Problems In The Food Processing Industries", Industrial Environmental Research Laboratory, Cincinnati, OH, K. Dostal, Food and Wood Products Branch, Grant No. R804642-01, January 1979.

4. H. J. Van Langenhove, *et al.*, "Identification Of Volatiles Emitted During The Blanching Process Of Brussels Sprouts And Cauliflower", *Journal Of The Science Of Food And Agriculture*, 55:483-487, 1991.

5. R. G. Buttery, *et al.*, "Fresh Tomato Aroma Volatiles: A Quantitative Study", *J. Agric. Food Chem.*, 35:540-544, 1987.

6. H. J. Rafson, "Odor Emission Control For The Food Industry", *Food Technology*, June 1977.