FSHN0522

UF UNIVERSITY of FLORIDA
IFAS Extension

Major By-Products of the Florida Citrus Processing Industry[1]

R.M. Goodrich and R.J. Braddock[2]

On-tree value of the Florida citrus industry is close to $1 billion, with a total industry value estimated at $9 billion annually. A significant portion of this "added-value" is derived from products, employment and services that focus on citrus by-products, i.e. products other than citrus juice. The primary citrus by-products are cattle feed, essential oils and essences, d-limonene, pulp and pulpwash. There are other compounds of potential value present in small amounts such as naringin and hesperidin. This fact sheet, one in a series titled *Florida Citrus Products and By-Products*, will provide an overview of the most common citrus by-products for commercial use. More detailed information on each major by-product can be found in the references listed, as well as in other titles of this series.

The growth of the citrus juice industry in Florida over the past 50 years has driven the large-scale processing of citrus that is common today. The average annual production of Florida oranges has been about 240 million boxes over the past few years, with 1 box equaling 90 pounds of fruit. Since only about half of the fruit is juice, the remainder results in an abundant supply of "waste" material. Citrus by-product technology was driven by the concurrent need for disposing of processing waste as well as obtaining all possible value from the fruit. Table 1 summarizes the potential amounts of citrus by-products that could be recovered per box from oranges and grapefruit. Figure 1 illustrates typical by-product streams and mass balances.

Table 1. Typical amounts of various citrus by-products from orange processing.

Product	kg/box oranges[1]
Dry pellets (10% H_2O)	4.0
Molasses (72 °Brix)	1.4
Essential oil and d-limonene	0.3
Pulpwash soluble solids	0.3
Pectin (150 grade)	1.3
Frozen pulp	2.0
Flavonoids	0.2

[1]Oranges = 40.8 kg/box, juice yield 55%.

1. This document is FSHN05-22, one of a series of the Food Science and Human Nutrition Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date October 2004. Revised February 2006. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.
2. R.M. Goodrich, assistant professor, and R.J. Braddock, professor, Food Science and Human Nutrition Department, Citrus REC, Lake Alfred; Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville 32611.

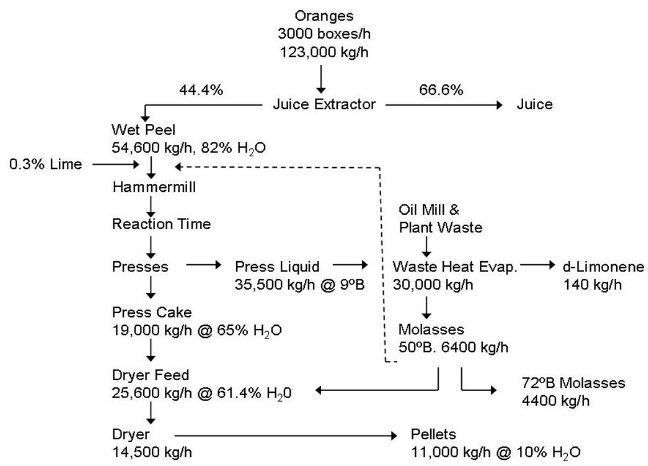

Figure 1. Dried citrus pellets process flow diagram.

Essential Oils

The peel of the citrus fruit has numerous glands that contain oil that is typically recovered as a major by-product. Each type of citrus fruit has its own characteristic set of compounds that comprise the oil and that are responsible for its flavor and aroma. The recovery and use of essential oils has occurred since prehistoric times and commercially for several hundred years, but today's industry has expanded the technology to recover essential oils on a large scale.

The oil is typically recovered from the fruit either prior to or during juice extraction. Two types of juice extractors are used in Florida, either FMC or Brown Citrus Systems equipment. In the FMC process, the oil is washed away by a water spray on the outside of the fruit as it undergoes extraction. The oil-water stream, which is an emulsion, is collected and sent to a finisher (or screen) to remove small particles of peel. The stream is then sent to centrifuges where the water component is removed and the now-concentrated oil is collected as cold-press oil (CPO). In the Brown system, oil is removed just prior to the extractor by a Brown Oil Extractor (BOE). The whole fruits roll across the BOE, which is made of toothed rollers partially set in a flowing bed of water and that propel the fruit across the machine and simultaneously cut the peel of the fruit and release the oil from the glands. As the oil is collected into the water and the fruit proceeds to the extractor and the oil-water mixture proceeds to centrifugation and oil recovery. In both processes, the oil-water emulsion normally requires a two-step centrifugation process; desludging, then polishing. Both processes can yield high-quality oil products. Commercial processes typically recover about 65 to 75% of the typical oil in the fruit, although recent, more stringent air quality environmental laws are making higher oil recoveries more attractive to processors.

The chemical composition of cold-pressed oil differs from citrus fruit to citrus fruit, and even among different varieties of the same species. The most prominent compound is d-limonene, a hydrocarbon that is the major constituent of all citrus CPOs. Other terpenes (and their derivatives), aldehydes, ketones, esters, and alcohols are all components of oils that contribute to the characteristic flavor and aroma of a particular oil. The aldehyde content, optical rotation, and chemical composition of the oils are all means of evaluating cold-pressed oil quality.

Essential oils are used as food and beverage flavors, in the perfume industry, for personal care and consumer products, and in specialty chemical commerce. Cold-pressed orange oil is used as a flavoring for orange juice, and to a large degree, is responsible for the characteristic orange flavor of the juice.

d-Limonene

d-Limonene is a monocyclic terpene that is the major constituent of oils recovered from citrus peel. It has the chemical formula $C_{10}H_{16}$ and the chemical name (4R)-(+)-4-isopropenyl-1-methylcyclohexene. One defining characteristic of citrus-derived limonene is its ability to rotate polarized light to the right (+). The designation “d” in the common name d-limonene refers to an older convention where chemicals that rotated light to the right, dextrorotary, were referred to as “d” and to the left, levorotatory, “l”. The most common analytical test for d-limonene is the Scott oil test, a wet chemistry method that is based on a bromination reaction with the double bonds of the molecule. For most flavor and specialty chemical applications, d-limonene is analyzed instrumentally by GC/MS.

d-Limonene can be recovered from citrus waste streams and from folding of cold-pressed oils, where d-limonene is removed in order to concentrate the more desirable constituents in the oils. The primary point of recovery is after the feed mill waste heat evaporator, where it is readily separated from the evaporator condensate by simple decantation.

d-Limonene is used industrially as feedstock for adhesives, degreasers, flavors, cleaners, and solvents and as a diluent for other flavors.

Cattle Feed (Dried Pulp)

The majority of the solid waste product from processing plants is the citrus fruit peel and the membranes from inside the fruit. This material amounts to about 40 to 50% of the entire mass of the incoming fruit, and is the material from which cattle feed is produced. The use of citrus residue for dried citrus pulp pellets (CPP) for cattle feed has been utilized since the 1920s, when nutritional studies with livestock were performed with grapefruit residue at the University of Florida. Cattle were known to eat wet peel, but there was simply too much wet material available and there was a need for a product that was readily transported and stored. The feed mill is the part of the citrus processing plant where the conversion from wet waste product to a dried, higher value by-product occurs.

Peel from the juice extractors, culled fruit, organic trash such as leaves and stems and juice pulp and membrane are conveyed from various sites around the processing facility to the feed mill. Screw conveyors are usually used to transport the material as they are relatively simple and durable machines. After collection in the peel bins, the residue is metered into size reduction equipment (usually hammermills) where the particles are reduced to a uniform size range of about 0.25 to 0.75 inch. Lime is added to the residue as a means of enhancing water removal; the calcium oxide reacts with bound water in the residue and frees it so that it can be more readily pressed out. The mixture is conveyed through a reaction screw to the pressing operation where the limed mixture is fed to a vertical or horizontal press that removes the liquid (press liquor). The residue, now termed press cake, is then further dried in drum dryers to a moisture level of about 10 to 12%. The pulp may be sold in this loose form, or pelletized for easier handling. The press liquor is concentrated in waste heat evaporators to about 72% sugar; this product is known as citrus molasses and is added back to the dried pulp process or sold separately as a feedstock for ethanol production.

Flavonoids and Limonoids

Citrus fruit is particularly high in flavonoids and limonoids, compounds that have garnered interest for their potential pharmaceutical and medical applications. The properties and chemistry of citrus flavonoids, particularly hesperidin and naringin, have been studied for decades, along with limonin, the principle limonoid compound in citrus. These compounds reside in the peel and seeds and must be recovered by extraction, which means that extraction solvents and wastes must be added to the cost of recovery. This, and the fact that there are questionable uses for these chemicals, means that they could only be considered potential by-products, at best.

Summary

The growth and consolidation of the citrus juice industry in Florida has resulted in the large-scale processing of citrus that is common today. Citrus by-product technology was driven by the concurrent need for disposing of processing waste as well as obtaining all possible value from the fruit. Future research efforts in citrus by-products will continue to develop technologies that increase recovery efficiencies, value, and quality of citrus by-products. Examples of on-going research include quantitation and modification to improve existing extraction and recovery processes, including food safety documentation and performance, and improved analytical techniques to determine raw material composition and relate to new process development, modifications, and quality. As both producers and processors face increased economic pressures, the added-value from the production and sale of citrus by-products will continue to be important to the overall competitive position of the Florida citrus industry.

Resources

Braddock, R.J. 1995. By-products of citrus fruit. *Food Technology*. 49(9): 74, 76-77.

Braddock, R.J. 1999. Handbook of Citrus By-Products and Processing Technology. John Wiley & Sons, Inc. New York, NY.

Braddock, R.J. 2004. Importance of by-products to citrus juice processing. *Fruit Processing*. 5: 310-313.

Kimball, D.A. 1999. Citrus Processing – 2nd Edition. Aspen Publishers, Inc. Gaithersburg, MD.