Citrus Maturity and Packinghouse Procedures

I. Fruit Structure and Composition

The citrus fruit is classified botanically as a hesperidium, a particular kind of berry with a leathery rind and divided internally into segments. Its size ranges from an inch (2.5 cm) or less in calamondin (Citrus madurensis) or kumquat (Fortunella spp.) to 5-7 inches (12.5-17.5 cm) in grapefruit (C. paradisi) or pummelo (C. grandis). Shape varies from oblate as in grapefruit and mandarin (tangerine, C. reticulata), spherical or slightly oblong as in sweet orange (C. sinensis) to prolate as in lemon (C. limon), citron (C. medica) or lime (C. aurantifolia), with some fruit distinctly pyriform (e.g., some pummelos, 'Ponderosa' lemon, etc.). Rind color ranges from yellow in lemon or lime (sold, however, green) through shades of orange to reddish orange or red in some mandarins. The rind is usually roughened from numerous small pits or infrequently small protrusions. Species of Citrus typically have 8 to 15 segments, or occasionally 17 ot 18 in the case of grapefruit or pummelo, kumquats (Fortunella), 3 to 5 segments and trifoliate orange (Poncirus), 6 to 8 segments. Seeds vary in number from none in a few cultivars (e.g., 'Tahiti' lime and navel oranges) to 40 or 50 in seeded forms of grapefruit or pummelo, as well as in both shape and size.

A. Structure (Figure 2)

A citrus fruit has a far more complex structure than that of a typical berry, such as grape (Vitis spp.) or blueberry (Vaccinium), drupe (e.g., peach, Prunus persica) or pome (e.g., apple, Malus spp., or pear Pyrus spp.). Several distinct tissues are readily apparent when the fruit is cut transversely or longitudinally, denoted as flavedo, albedo, segments, seeds, central axis and vascular bundles (Figure 2). The usually 5 pointed calyx at the stem end of the fruit has an abcission zone at its base, so that the calyx will remain attached to the branch if this zone is mature enough for separation to occur.

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Fruit Structure and Composition (cont.)

1. Flavedo: The outer, colored, portion of the rind consists of the epicarp, hypodermis, outer mesocarp and oil glands. A protective zone of cuticle and wax platelets is extruded towards the outside from the epidermal cells. This outer surface is dull and easily washed, polished or abraded away. Numerous stomata are scattered over the surface of the epicarp and remain functional throughout the life of the fruit unless blocked by wax. The epicarp also has cells with plastids initially containing chlorophylls which are gradually replaced with carotenoid compounds during the process of degreening. (The actual process whereby chloroplasts become chromoplasts is unknown.) Layers of cells denoted as hypodermis and outer mesocarp lie immediately below the epicarp and contain oil glands. The latter are formed through a combination of splitting and dissolution of cells, their size, number, distribution and aromatic (volatile) constituents being characteristic for a given species

2. Albedo: The inner, colorless or sometimes tinted, portion of the rind consists of a loose, anastomosing network of cells with numerous air spaces as part of the inner mesocarp. This zone acts as a shock absorber, pressure which would make large bruises on an apple causing little or no damage to a citrus fruit.

3. Segments: Each of the more or less broadly triangular lunate segments are surrounded with a membrane, the endocarp proper. Pulp vesicles are multicellular sacs consisting of a threadlike stalk and enlarged spindle-shaped body with a minute oil gland in the center. They are attached to the tangential and outer third to half of the radial segment membrane. (Such extrusions, denoted "pulpa," are unique to citrus and a few other fruits.)

4. Seeds: These extend into the segment from the inner tangential wall in 2 rows with 4 to 6 superposed seeds per row. Some or occasionally all of the seeds in a fruit are abortive. Few cultivars have no seeds whatever, commercially seedless forms, such as 'Hamlin' or 'Valencia' orange or 'Marsh' grapefruit, having up to 6 seeds present.

5. Central axis: This tissue is composed of the same type of colorless or tinted, loose spongy network of cells as the albedo and connected with it by membranes extending between each segment. The central axis of sweet orange and grapefruit is normally solid but may become open as the fruit reach senescence. That of mandarins and their hybrids is normally open.

6. Vascular bundles: The vascular system of the fruiting stem is divided into a series of discrete bundles as it enters the fruit. These are arranged in a circle with a bundle opposite the inner tangential wall and the membrane separating each segment. These traverse the central axis longitudinally to the stylar and then curve back upwards through the inner part of the albedo until they terminate near the point where they first entered the fruit. Each vascular bundle has a number of branches extending between the segments, along the outer tangential walls of the segments and into the hypodermis so that water and other nutrients can move readily into cells of the various tissues. Curiously, there is little or no apparent branching of the individual bundles immediately below the calyx, thus the stem-end portion of the segments are near the end of the vascular network.

B. Composition

At least 200 different constituents have been isolated from fruit of various species of Citrus. It may be seen from the average composition of orange juice in Table 6 that carbohydrates comprise three-fourths and organic acids nearly a tenth of the total soluble solids. Over 20% of the constituents are volatiles, the indispensable components of flavor and aroma, although percentagewise they form a minute fraction of the total. Free amino acids, inorganic ions and vitamins represent nearly a third of the constituents and about 11% of the total soluble solids.

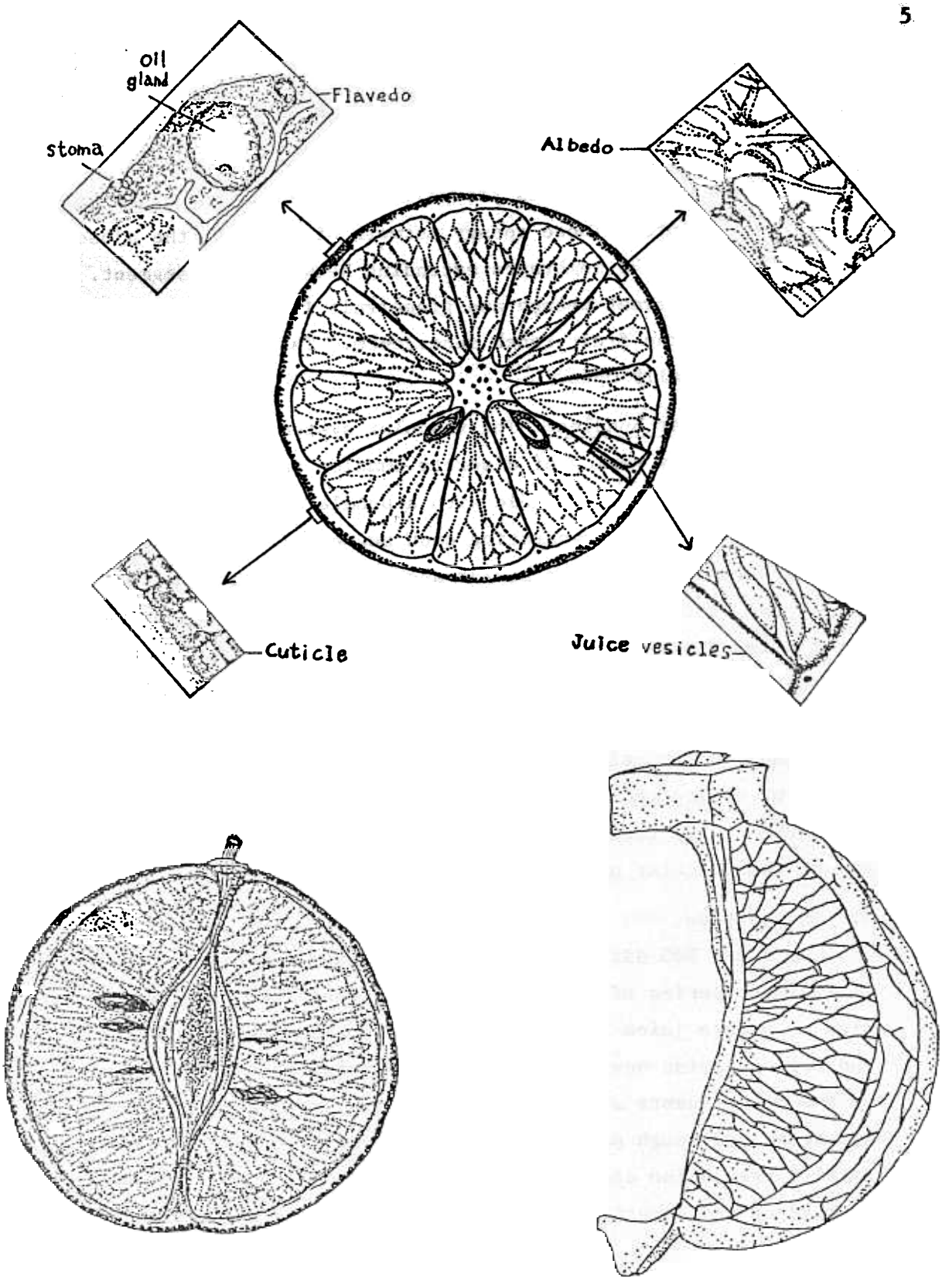

Figure 2. Structure of a citrus fruit: Above cross-section of whole fruit with enlargement of 4 important tissues; below longitudinal sections of whole fruit with single segment at right. (Adapted from Grierson, 1964; Praloran, 1972; Soule, 1974)

Table 6. Average composition of orange juice (U.S. Dept. Agr. Handbk. 98)

	Constituents	Total soluble solids (no.)	(%)
1.	Carbohydrates (Sucrose, glucose, fructose, pectins, etc.)	7	76.0
2.	Organic acids (Citric, malic, traces of tartaric, benzoic, succinic, oxalic, formic)	7	
3.	Free amino acids	17	5.4
	Nitrogenous bases, glutathione	5	.9
4.	Inorganic ions (K, Mg, Ca, Fe, etc.)	14	
5.	Vitamins (ascorbic acid, β-carotene, etc.)	14	
6.	Flavonoids (hesperidin)	1	0.8
	Volatiles	33	.38
	Carotenoids	22	.013
	Enzymes	12	-
7	Lipids (fats, wax components, etc.	18	1.2
		150	100.00

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Fruit Structure and Composition (cont.)

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Fruit Structure and Composition (cont.)

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