IV Fruit Characters

Citrus fruits derive their unique qualities from about 20 individual factors, which are conveniently arranged in 3 groups, internal, external and miscellaneous. Several of these, notably sugars (measured as total soluble solids of which they are the principal component), organic acids (measured as "total" = titratable acidity), sugar:acid ratio (total soluble solids:acid ratio), juice and color, are of vital concern in consumer acceptance and preferences. The first 4 form the basis for Florida's maturity (internal quality) standards, while the last is a major component, along with discoloration and blemishes, of U.S. and Florida standards for grade (external quality).

A. Seasonal Changes

The original maturity standard for Florida citrus in 1911 simply stated it was "unlawful to ship green, immature fruit." The U.S. Supreme Court upheld this law when it was contested. Growers and shippers realized some sort of legal requirements were necessary if the industry was to expand. They were also dimly aware that knowledge of fruit characters and the changes taking place in these during the season was a necessary antecedent to the establishment of workable standards.

S. E. Collison conducted the first study of seasonal changes in Florida with a survey of over 500 samples of oranges and grapefruit between October 1912 and May 1913. This work, which set the stage for Harding et al.'s comprehensive study many years later, included tests for percentage juice, total, non-reducing (sucrose) and reducing (glucose and fructose) sugars, percentage acid, sugar:acid ratio and taste but unfortunately was carried out over only one season. Samples taken monthly showed the now familiar pattern of a rise in sugars and a decrease in acid during the course of the season. Collison was the first to point out there were distinct differences between oranges and grapefruit with respect to the relative proportions of sucrose and glucose-fructose late in the season. Oranges samples had roughly equal amounts of both; whereas those of grapefruit contained mainly reducing sugars from about March on. Collison also found an 8:1 sugar:acid ratio was the minimum acceptable level for oranges and this value (measured as total soluble solids:acid from 1915 on) remained the legal minimum until it was raised in 1949.

There was a lapse of nearly 25 years before Harding and his associates began their studies on seasonal changes of Florida citrus at the U.S. Department of Agriculture station, Orlando in 1935. Twenty to 40 individual samples representing the main commercial scion varieties, rootstocks, soil types and groves of oranges, grapefruit, tangerines, 'Temple', tangelos and 'Murcott' (now 'Honey' tangerine) were harvested about once a month from well before to well after the normal shipping season over a period of 3 to 5 years. Tests included measurement of physical characters (weight, juice content, rind color and thickness, flesh color and texture, etc.) and chemical constituents (total soluble solids, total acid, solids:acid ratio, ascorbic acid, pH, and total, non-reducing and reducing sugars, the last 3 for oranges only). Taste tests conducted with sliced fruit were rated on a numerical scale by a panel of 30 to 50 people. Samples consisted of 25 fruit for physical and chemical tests plus 25 to 30 more for tasting. Fruit of average size were collected at random from several designated trees in a grove. These studies formed the basis for the numerous major changes made in legal maturity requirements when the Florida Citrus Code was adopted in 1949 and for amendments to the Code when those on tangelos and 'Murcott' were completed in the 1950's. Similar research on seasonal changes of grapefruit has been published in Texas (Wood and Reed, 1938), California (Rygg and Getty, 1955) and Arizona (Hilgeman, 1941 on), of which the last also dealt with oranges.

Anyone who peruses Harding et al.'s seasonal changes bulletins is usually overwhelmed by the huge mass of data presented in the form of graphs and appendix tables. It is clearly evident from even a cursory examination that each of the several factors studied for a given variety or kind of fruit is subject to wide variations depending upon the time of year, rootstock, location, tree age, year, etc. The purpose of the seasonal changes work was to make a comprehensive survey including as many variables as possible and thus determine the natural limits of individual fruit characteristics. Details from these definitive bulletins are summarized in the form of graphs in the Appendix.

B. Edibility

Neither Collison nor any of the later research workers on seasonal changes, including Harding, realized the significance of a curious anomaly in their chemical analyses, namely the virtual total absence of starch at any stage before or after the fruit were palatable. Harding, who worked with apples prior to coming to Florida, applied the same terminology to citrus with respect to "maturity" and "ripening." These terms appear repeatedly in the citrus literature yet they are erroneous because there is no starch, oil, etc., present capable of being converted to sugars or other soluble products. Citrus fruit are non-climacteric: they do not possess a well-defined ripening mechanism in contrast to climacteric fruits, like apple, pear, banana, mango or avocado, as is plainly evident in Figure 1. Citrus fruit gradually become edible and remain so over a more or less extended period, which may be a month or 2 for tangerines and up to 7 or 8 months for grapefruit. Quality continues to improve to the peak for a given variety then declines gradually while the fruit remain on the tree. Changes subsequent to harvest result in loss of edible qualities simply because the fruit continues to burn up sugars through respiration so long as it remains alive.

C. Fruit Characters

Information on individual citrus fruit characters presented here has been summarized from Harding et al.'s seasonal changes studies and various collateral sources, including the authors' own experience. Further details may be found in the list of selected references for Fruit Characters.

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

1. Internal:

a. Organic acids: Citrus fruits contain mainly citric and malic acids, with trace amounts of several others. The principal acid of the juice is citric, with a ratio of about 9:1 to malic, while that of the rind is malic, with a ratio of about 9:1 to citric. Acidity is customarily determined through titration with standard alkali (1 ml. 0.3125 N NaOH equals 20 mg anhydrous citric acid, or approximately 0.077%, for maturity tests in Florida) to the phenolphthalein endpoint (pH 8.3). This procedure does not measure the acids bound in organic compounds, hence the term "titratable acidity" is correct rather than "total acid." (True total acid is rarely measured since it involves a double titration, first with standard HCl to break up the esters, etc., and then with standard alkali to the phenolphthalein endpoint.) The curves in Fig. 5A show the average seasonal pattern of titratable acidity for 2 varieties of orange, tangerines, 'Duncan' grapefruit and 'Temple'. All except grapefruit show a rapid decrease early in the season with a gradual decline thereafter. Fruit noticeably low in titratable acidity like 'Parson Brown' usually also have low total soluble solids. Maximum acid permitted in citrus fruit in Florida is governed through standards for total soluble solids:total (titratable) acid ratio. There is also a minimum standard of 0.4% for natural color and 0.5% for color-added oranges shipped fresh.

b. Total soluble solids (Brix): About three-quarters of the total soluble solids in citrus juice are sugars (Table 6), chiefly sucrose and glucose and fructose with trace amounts of several others. Total soluble solids are measured easily and rapidly either in terms of specific gravity with a hydrometer (official maturity tests) or refractive index with a refractometer. The scale in both is calibrated in terms of percentage pure sucrose (= °Brix) at 17.5°, 20°, 25° or 28°C, readings being interconvertible with the appropriate temperature correction. (Allowance for organic acids is usually not made unless the juice contains more than 2 or 3%, as would be true for tests involving acid citrus fruits.) Curves in Fig. 5B show the trends in average % total soluble solids for early ('Parson Brown') and late ('Valencia') oranges, seedy ('Duncan') grapefruit, tangerines and 'Temple' over the crop season. Specialty fruits, including tangelos and 'Murcott' not shown, have a wider range during the year and attain appreciably higher soluble solids than 'Parson Brown' orange (except for January) and show little change from December through May. Legal requirements for total soluble solids in Florida are complex, involving different minimum values for each kind of fruit and from 2 to 5 periods during the crop year.

c. Total soluble solids:total (titratable) acid ratio: Curves in Fig. 5C show 2 distinct patterns for total soluble solids:acid ratio during the season. Ratio increases rapidly and in nearly parallel fashion for early and late oranges, tangerines and 'Temple'. There is comparatively little change in that for grapefruit, reflecting slow decreases in acidity and increases in total soluble solids. Ratio is widely used as a maturity (edibility) standard throughout the world. Indeed, it is often the only legal requirement as in California where the minimum for oranges is 8:1 and for grapefruit 6:1 (south and east of San Gorgonio pass) or 5.5:1 (north and west of San Gorgonio pass). These are too low for good acceptability in Florida. The latter actually has 2 standards for each kind of fruit, except 'Murcott', an absolute minimum ratio regardless of % total soluble solids and the so-called "sliding ratio" or permitted minimum ratio based on % total soluble solids in the juice. The latter was actually incorporated in Florida's maturity requirements in 1925 but Harding et al.'s studies provided the necessary background information with many thousands of taste tests. The rationale for the flexible permitted minimum ratio is that fruit with high % total soluble solids can have higher acidity, hence a lower ratio, and be palatable. An example of this rather complicated, but workable, arrangement under Florida conditions is shown for 'Duncan' grapefruit in Fig. 6. Here, for instance, a lot of grapefruit which has 8 (the minimum from August 1 to January 1) to 9% total soluble solids must have a 7:1 ratio but a lot with 10% total soluble solids needs only 6.5:1 ratio.

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

d. Juice content: Curves showing the changes during the season in average juice content, as % by weight of early, midseason and late oranges and white seedless, pink and red seedless and white seedy grapefruit are presented in Fig. 5D. Early and midseason oranges contain about 50% juice at the beginning of September and have 57-58% in November-December; whereas late oranges increase from about 52% in October to 60% and above from January on. All of the oranges show a decline in juice content as the fruit dry out towards the end of their respective seasons. Grapefruit show a different pattern in commencing with a lower juice content of about 36-38% which increases rapidly in September and October and then more slowly until a peak of about 50 (seedy) to 55% (seedless) is reached in January or February. There is also a narrower range at any given date among the 3 types of grapefruit than the oranges, as a result of being more closely related. The proportion of rind and other non-juice parts (rag) is larger as a rule in grapefruit, and seedy fruit also have part of their volume occupied by seeds.

Florida's orange maturity standards specify a minimum of 4.5 gallons per 1.3-5 bu. (90 lb.) box for natural color and 5 gallons per box for color-added fruit shipped fresh, equivalent to 17.0 and 18.9 liters per 40.8 kg box, respectively. These values translate to approximately 43.4 and 48.3%, respectively, assuming the juice contains 10 to 12% total soluble solids (in which case 1 ml = 1.04 g.). It may be seen in Fig. 5D that these requirements are substantially lower than juice content at the beginning of the season. Legal standards for grapefruit are based on cc per fruit, with specified amounts for each size and 3 periods during the year. For example, minimum juice content for size 35 (based on 4/5 bu. box = 19.228 kg) is 230, 220 and 210 cc per fruit for August 1 to November 15, November 16 to March 1, and March 2 to July 31, respectively, which give approximate values (assuming 1cc = 1.04 g) of 43.7, 41.7, and 39.7%. Comparable ones for size 48 grapefruit are 48.1, 46.8 and 44.2% (185, 180 and 170 cc per fruit). It

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

may be seen in Fig. 5D that % juice of all 3 types does not exceed the legal minima until mid-October for medium sized (size 35) and November or later for small-sized (size 48) fruit. In fact, it is juice content rather than total soluble solids or solids:acid ratio which delays shipment of grapefruit, particularly the smaller sizes, early in the season.

Curves for lemons, which are certified for fresh shipment only on a voluntary basis and then required only to meet the U.S. (California) standard of 30% by volume, in Fig. 7 show an interesting, if confusing, pattern among varieties, time of year and seasons. Lemons flower several times during the year and are spot picked for small sizes if they are to be shipped fresh, hence fruit of widely differing age and stage of development may be harvested. These curves illustrate well the inherent danger in shipping lots of fruit which have not been tested, in this instance for juice content. Tests of limes, which are also not included in the maturity standards for citrus, are mandatory under a federal marketing agreement, with a back-up standard in Florida statutes should the latter lapse.

e. Ascorbic acid (Vitamin C): Citrus is a good natural source of ascorbic acid, with 25 to 60 mg per 100 ml juice. The concentration in most varieties is highest early in the season with a gradual decrease as for citric acid. 'Temple' is a notable exception, the concentration remaining nearly static throughout the season. Ascorbic acid concentration is highly variable from one kind of fruit to another and among fruit on a tree. Sites and Reitz (1950b) found an average increase of 0.74 mg per 100 ml per foot (30 cm) of height in a 'Valencia' orange tree. Their study showed low light conditions, green rind color, low total soluble solids and low vitamin C concentration were all highly correlated, that between solids and vitamin C having an r value of 0.942 (equivalent to slightly over 11% unexplained variation). Other studies (e.g., Winston, 1948) have also shown a strong gradient from the peel inward.

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

f. Active acidity (pH): The pH of juice from oranges, tangerines, 'Temple' and tangelos varies from slightly less than 3.0 (2.75 for tangerines) to about 4.0, grapefruit having a much narrower range from about 3.0 to 3.4. Indeed, the change is so small during the season that most workers have tended to ignore it. Active acidity does, however, have a decided influence on palatability through the buffering action of certain compounds, such as potassium citrate. A small increment in pH thus has a disproportionate influence on taste.

g. Flesh color and texture: Changes in flesh color and texture follow a regular (subjectively observed) sequence corresponding to those in juice content. Flesh color typically appears greenish yellow at first, then yellow, followed by orange, tan (white-fleshed grapefruit) or reddish orange in specialty fruits. Flesh texture changes from ricey (very little juice) to coarse (moderate juice, thick vesicle walls) to prime (juice vesicles fully distended with consequent thin walls) to overripe (less juice and thicker vesicle walls from drying out). Some fruit like navel oranges or grapefruit have relatively thick vesicle walls, while others, notably tangelos, have very thin walls as a rule. (An interesting commentary on flesh texture is it is used in Jamaica as a measure of maturity for grapefruit.)

h. Volatiles: The typical flavor and aroma of oranges, grapefruit, etc., result from non-volatile glucosides (e.g., naringin, responsible for the distinctive bitter flavor of grapefruit) and various alcohols, ketones, esters and aldehydes which are volatile. Immature fruit have a raw, resinous flavor and little aroma; overripe fruit have a flat or stale (aged) flavor and little aroma. Both lack the volatile constituents which supplement the blend of sugars and acids in fruit at peak maturity (edibility).

i. Seeds, rag: Non-juice portions of citrus fruit include seeds, central axis, vascular bundles, segment walls, and portions of the albedo, collectively called "rag", aside from the peel proper. Seediness is a varietal characteristic, with little influence from modifiers of fruit quality, except for weakly parthenocarpic cultivars,

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

such as 'Orlando" tangelo, in which fruit size is proportional to the number of seeds present. Seedless fruit are desired for fresh consumption despite the fact that seedy varieties generally have higher total soluble solids, acid and aroma than seedless, hence varieties of mediocre quality may be grown for fresh use simply because they have few or no seeds. In general, rag is also a varietal characteristic but is subject to seasonal variations being influenced by numerous modifiers of fruit quality, including the stage of edibility at time of harvest. Most varieties of orange have a comparatively low proportion of rag, so are utilized for juice purposes. Navel oranges, however, have thicker segment walls and juice vesicle membranes hence they are consumed mainly as dessert or salad fruit rather than juice.

2 External:

a. Color: There are distinct, pronounced changes in the rind color of citrus fruit from bloom to maturity (edibility). Chlorophylls mask the yellow or orange carotenoids initially so that fruit are dark green during the season of growth (to August for early and midseason varieties and to December-February for late varieties) and early stages of the season when they become edible. Chloroplasts in the flavedo are gradually transformed into chromoplasts as the nights become cooler and longer in the fall until the yellow or orange pigmentation predominates. Color break, the stage when the transition from green to yellow becomes evident, occurs when night temperatures fall below about 50° to 55°F (10°-12.8°C). The sequence is dark green, light green, near white (a transitory stage most noticeable with lemons and grapefruit), yellow, orange and reddish orange up to the peak for a cultivar, after which there is a very gradual dulling as the fruit dries out and the rind roughens late in the season.

Fruit color is basely almost entirely on subjective judgements, although instrumental measurements are used routinely for research purposes. A large part of the difficulty in assessing color of an individual fruit or a lot arises from the fact color is simply not

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

uniform over the surface under Florida conditions, thus any measurement, whether visual or instrumental, is essentially a compromise among tints which may range from light yellow to deep orange on the same specimen.

There are both quantitative and qualitative changes in color components of citrus fruit as the season progresses. There is not only an increase in carotenoid content but also a shift to longer chain, hence darker (redder) individual components. These changes and color development in general are dependent upon numerous factors, including exposure to light (best color in full sunshine, i.e., in the top outside or outside portions of a tree), length of time fruit hang on the tree (and after harvest under certain conditions, as has been ascertained in experiments at AREC Lake Alfred), locality (best color for oranges being obtained near the climatic limit, grapefruit just the reverse although usually not a problem), weather conditions (cool, dry weather being conducive to good and warm, wet weather to poor color), tree age (younger, more vegetative trees have greener, paler fruit as a rule), and rootstock (deeper and brighter on sour orange, etc., as compared to rough lemon, etc., mainly because of location and greater vigor, hence more vegetative tendency, of rough lemon group). Some cultivars, such as 'Owari' satsuma, 'Hamlin' and 'Parson Brown' oranges and other early-season fruit, may reach acceptable or even peak edibility while fruit are still more or less green. Certain varieties like 'Dancy' tangerines frequently have poor color early in their shipping season. Others such as 'Murcott' or late oranges may be essentially fully colored months before the fruit has attained peak quality. Late oranges, which become edible after growth has resumed and the trees are then carrying 2 crops, may regreen, particularly at the stem end, in years with a warm, wet spring. Color of Florida oranges and specialty fruits is notably lighter and much less uniform than that of the same varieties grown in California, Arizona or Texas, where the groves must be irrigated and atmospheric humidity is low.

b. Texture: Smoothness or roughness of the rind is mainly a varietal characteristic. It is associated with size, small fruit

<u>Citrus Maturity and Packinghouse Procedures</u>

<u>Fruit Characters</u> (cont.)

always being less rough than larger ones. Many factors influence texture, including rootstock, weather conditions, soil type, mineral nutrition, water relations, tree age and position of fruit on the tree. Conditions favoring vigorous (vegetative) growth in general accentuate roughness. Inside fruit also have rougher texture than those nearer the outside of a tree. Texture is associated with brightness of color, a rough fruit always being duller in appearance than a smooth one. This is purely physical in nature, since reflectance is greatest when there is least interference among the light rays striking a surface.

c. Discoloration: Russeting caused by rust mite infestation has been a factor in fruit appearance from the beginning of the Florida citrus industry. U.S. standards for grades of Florida oranges and tangelos, grapefruit and tangerines have subclasses based on the percentage of the fruit surface affected with a light to medium brown smooth discoloration produced by a slight rust mite infestation late in the season. (Certain subclasses also allow light scars and scattered speck type melanose to be included as discoloration.) Infestations early in the season before the fruit begins to reach edibility may produce a dull light tan smooth ("buckskin") or distinctly rough ("sharkskin") blemish on the rind. Heavy infestations late in the season after the fruit are edible may result in a dark brown russeting. Amounts of dark brown russeting, buckskin or sharkskin affecting more than about 10% of the fruit surface are considered blemishes, since they are dull in appearance (do not shine when waxed) and adversely affect keeping quality.

d. Blemishes: Numerous disorders disfigure citrus fruit in Florida groves, particularly in the Ridge area of the state. Those caused by mites, insects, diseases, nutritional problems, chemicals, or careless handling are controllable under normal grove management. Many others, however, result from weather or other conditions beyond the grower's control or are so sporadic in occurrence that control measures are either not feasible or applied only on a spot basis.

1) Scars: These are the most important single cause, except for green color, of fruit being eliminated during grading for fresh shipment. Scars occur in all degrees from small, irregular,

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

smooth light-colored patches to large, often sunken, frequently dark-colored blotches on the rind, including various types of healed cuts, light scratches, thorn pricks and the like. Scars result from a wide range of causes, such as wind rubbing fruit against leaves, limbs or thorns, grasshopper, katydid or cricket injury, feeding of thrips, mechanical injury, melanose infection, rust mite infestation, etc., separately or in combination.

Recent work in Australia (Dodson, 1966; Campbell, 1967; Freeman, 1974) and Florida (Albrigo, 1976) has cleared up much of the mystery concerning when and how wind scars occur. These studies, originally in Australia and since corroborated in Florida, indicate a newly set fruit is protected from injury until it has grown large enough that the calyx can no longer act as a bumper to ward off lateral blows or rubbing against adjacent leaves, twigs or thorns. The rind remains sensitive until about the twelfth week by which time it has grown thick and hard enough for any subsequent injury to involve a rupture of tissues rather than superficial scarring. Barriers erected even at a substantial angle to the prevailing wind direction were effective in reducing scarring. Wind breaks with openings sufficient to permit some air movement while substantially reducing its velocity were recommended. Scars are more prevalent on fruit from young trees or in areas subject to continual windy weather, hence temporary barriers which could be installed during the period of greatest susceptibility and removed later so as not to impeded normal grove operations might well be feasible.

2) Melanose: The usual form consists of individual circular rough black lesions on the rind. More severe infections produce tear-stain patches, where spores have run down the sides of the fruit (most noticeable on grapefruit), or the mud-cake form, where spores in mass produce rough brown raised patches usually on the upper half of the fruit. Star melanose, in which the lesions have rays jutting out from the original infection, occurs when fruit is sprayed after individual speck type spots have begun to appear. Actually, many of the blemishes

on Florida fruit result from melanose spores infecting wind scar lesions and spreading from there. Melanose is more prevalent on fruit in older trees where dead wood provides a source of inoculum.

3) Scab (Sour orange or lemon scab): Certain varieties, notably grapefruit, most tangelos, 'Temple', lemons and satsumas, are highly susceptible to scab, especially when the trees are young; sweet oranges and tangerines are highly resistant, although not completely immune. Affected fruits have bumps or rough patches on the rind covered with light-colored lesions. (Bumps caused by mealybugs feeding where fruits hang together or around the calyx are similar in appearance except that there are no lesions; mealybug bumps are much less prevalent than scab since the insects are usually controlled by predators or the regular scalicide.)

4) Scales: Infestations of scale cause 2 different types of blemish. Many scales, such as Florida red, purple, chaff, long, etc., adhere to fruit after washing. Certain ones, notably chaff and purple, may be washed off but the rind fails to degreen in the areas where the scales have been feeding, thus producing green spots. Similar spots resulting from other causes (possibly spray injury) can also occur on otherwise fully colored fruit.

5) Unhealed cuts: Injuries which penetrate the rind or segments deeply enough to cause wounds that will not heal over smoothly are classified as unhealed cuts. Affected fruits in most instances are culls, unfit for human consumption. Certain types of unhealed cuts, such as plugging or mechanical injuries, are controllable through care in grove operations, harvesting and handling; most others, however, are uncontrollable.

(a) Plugging: Tearing of the rind when the calyx (button) is removed at the time of harvest. Fruit with tears larger than an ordinary pencil eraser will be sent to the cannery unless decay has developed.

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

(b) Mechanical injury: Cuts from grove machinery brushing fruit, fingernail scratches, clipper cuts, box cuts (from jagged edges or corners), and the like.

(c) Growth splits: Small cracks or tears in the rind usually at the stylar end are commonly called "growth cracks". Splitting sufficient to expose segments may result from sudden changes in moisture stress or be a symptom of nutritional deficiency (e.g., copper), the former usually being longitudinal across the stylar end and the latter often transverse of diagonal.

(d) Split navels: Tearing of the rind around the navel as the fruit expands (often produced by the same conditions as growth cracks in non-navel fruit).

(e) Bird pecks: Deep puncture-type wounds sometimes found in fruit in the tops of trees used as roosting places.

(f) Thorn or branch scratches or pricks: Lesions deep enough to pierce the rind and cause leakage of juice from a fruit being impaled on a thorn or broken-off end of a small branch.

(g) Rat bites: Irregular wounds where the animal has gnawed the fruit to obtain the seeds.

(h) Cricket holes: Wounds caused by crickets chewing on the fruit, the brown cricket being a particular offender

6) Bruises: Nearly mature or mature fruits banging against limbs, rough handling during harvest and overfilling of containers can rupture and cause the collapse of internal tissues along with more or less damage to the rind. Bruises are not permitted shipment as fresh fruit.

7) Oil spotting (oleocellosis): Rind cells ruptured from abrasion or bruising exude oil which causes a superficial but distinctive burn in the affected area. The injury may be from green to brown in color depending upon the stage of maturity (spots with oleocellosis often do not degreen along with the rest of the rind). It is

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

most prevalent early in the season and on fruit handled while still wet but can be produced through rough handling at almost any time. Severe lesions soon decay.

8) Oil blotch and spray burn: Oil emulsion sprayed on fruits between 3/4 and 1-1/2 inches in diameter will often produce dark sunken spots. Herbicides allowed to drift and certain other spray materials may be phytotoxic and produce dark irregular sunken patches on fruit.

9) Hail damage: Hail stones glancing off fruits may produce irregular, shallow or deep lesions. Such injury can usually be distinguished from other types of scarring by the presence of shredded leaves. Direct hits on nearly mature or mature fruits frequently result in their bursting open.

10) Grasshopper and katydid injury: Insects chewing on young fruits produce lesions which may heal and appear later as irregular, light or dark sunken spots. These may be classed as scars if not too unsightly (e.g., too deep or too dark in color).

11) Sunburn and sun scald: The former results from prolonged exposure of the side or stylar end of a fruit to bright sunshine, affected areas ranging from a slightly ligher shade of color after degreening to a hard, dark necrotic spot over distinctly malformed, usually dry segments. Sun scald is a scale type of injury produced when fruit are left out in the sun after harvest and get rained on, the droplets of water acting as lenses.

12) Sprouted seeds: Seeds in grapefruit sometimes germinate inside the fruit late in the season, giving it a pronounced bitter taste and often an unpleasant aroma if they have died.

13) Rough or protruding navels: Many varieties of navel orange in Florida, particularly the older ones (e.g., 'Washington'), may produce fruit badly misshapen from excessive growth of the navel. The

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

latter may extend well beyond the normal contour and be distinctly rough, in which case the fruit cannot be shipped fresh.

14) Creasing: A fairly common disorder of mature or overmature 'Pineapple' orange and 'Temple' consists of irregular sunken lines in the rind where the albedo has torn and separated. Creasing is often difficult to see, since only one side of the fruit will burst under light pressure (as in packing and shipment). Tangerines will often burst on the tree or in handling subsequent to harvest about 48 hours after a heavy rain from similar tearing and separation of the albedo. The origin of creasing is almost certainly nutritional but in very complex fashion. Potassium is definitely involved but with interactions with other elements

15) Rind breakdown: Characteristically, rind breakdown in any of several forms is a group of postharvest disorders whose incidence is influenced by handling conditions. Prolonged cold weather or freezing can cause breakdown of rind cells ranging from slight discoloration to large sunken pits, similar to postharvest chilling injury, on fruit prior to harvest. Fruit picked too soon after heavy rains, notably tangerines, 'Temple', mature 'Pineapple' oranges, and satsumas, often develop stem-end rind breakdown. Sloughing of red grapefruit, where large areas of rind can be sloughed off with light finger pressure is of unknown origin but is also caused by conditions in the grove.

16) Mushiness or dryness (freeze damage): Fruit may show little outward sign of injury but have portions of segments at the stem end disorganized or partially dried out from freeze damage. The internal appearance of the fruit is quite different and readily distinguished from granulation.

17) Granulation: Fruit held on the tree late in the season will gradually dry out at the stem end, the juice vesicles being filled with jelly-like or solid material instead of the fluid they once contained. Varieties on vigorous rootstocks like rough lemon will show the condition earlier than on sour orange, sweet orange seedling and similar rootstocks. Fruit of tangerine types, except 'Murcott', are notably subject to granulation if grown on rough lemon rootstock

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

18) Miscellaneous:

(a) Stylar-end breakdown of 'Persian' ('Tahiti') lime: A physiological disorder found on mature fruit in the grove and others not handled with great care while they are turgid, i.e., when the trees or weeds around them are still wet from dew.

(b) Lime blotch: A genetic disorder confined to certain strains of 'Persian' ('Tahiti') lime in which fruit have longitudinal rows of necrotic cells in the rind

(c) Nutritional disorders: Copper, zinc, or boron deficiencies on fruit are seldom encountered in commercial bearing groves at the present time but are seen infrequently in young groves. Copper deficiency appears either as dark, raised rough spots on the rind (ammoniation) or gumming of the albedo or central axis (also boron deficiency). Zinc deficiency produces small, poorly colored fruit with very little juice and ricey or woody flesh.

3. Miscellaneous:

a. Weight: There is a slow increase during the season of growth (bloom to August or December-February), then a rapid, consistent gain during the season of maturity (edibility) up to the period of prime edibility and a slow, often variable gain thereafter until a gradual decrease ensues as the fruit dry out, usually well past the normal shipping season. Trends in the various kinds of citrus are similar to those for juice content (Fig. 5D).

b. Size and form (shape): Each species and its cultivars have a characteristic range in size which is influenced by the crop load, rootstock and other factors. Large fruit always have lower total soluble solids, acid and juice content than small fruit of the same cultivar and tree.

Form (shape) is also a varietal characteristic that can be influenced by off-bloom, grove location, tree age, weather conditions and various cultural practices, including control of pests. All citrus fruit show some variations in form but the tendency towards deviations from the cultivar norm seems more pronounced for tangerines and other specialty fruits and grapefruit, particularly among fruit on young trees and in warm, wet seasons. Off-bloom fruit are often recognizable as such simply because they are "sheep-nosed" or some other aberration in shape (and texture)

c. Firmness: This is associated with fruit turgidity and rind thickness. Fruit become less firm as the rind tends to pull awa from the segments late in the season, most noticeably with specialty types, and with excessive development of the albedo typical of late-bloom fruit. Too thin an albedo renders the fruit more susceptible, however, to creasing.

d. Age: There are marked changes in internal fruit characters during the rise to peak edibility and the gradual decline later. Many varieties, notably navel oranges and tangerines have a short period of peak edibility, before or after which the fruit are noticeably lacking in flavor and aroma. Fruit harvested early in the season or late in the season generally have poorer keeping quality and greater susceptibility to postharvest disorders than those picked near peak edibility. Over-ripe fruit or those held too long after harvest usually have a stale, aged or dull taste and little aroma.

e. Decay: Numerous fungi which cause decay of fruit either on the tree or at some subsequent stage following harvest are present in citrus groves. Entrance of such organisms as green mold (Penicillium digitatum), anthracnose (Colletotrichum gloeosporioides) and others is through wounds or a breakdown of the rind caused by oleocellosis, etc. Certain organisms, notably stem-end rots (Diaporthe citri and Diplodia natalensis) and alternaria (Alternaria citri), gain entrance to floral or fruit tissues at an early stage, usually at petal fall and either remain quiescent in and around the calyx, as in the case of the stem-end rots, or penetrate the interior of the fruit, as in alternaria rot. Fruit with the latter appear outwardly sound except for a slight premature degreening at the stylar end and are often brilliantly colored later. The center is black from rot when the fruit is cut open. The same organism causes a serious disease of lemons in California and target-shaped lesions (formerly attributed to anthracnose) on leaves of nursery seedlings in Florida. Two other fungi, *Phytophthora* spp. (mainly *P. parasitica* in Florida and *P. citrophthora* in California) and *Geotrichum candidum*, are the causal agents of brown rot and sour rot, respectively. These organisms inhabit the soil. Brown rot occurs occasionally in Florida from spores splashed onto low-hanging fruit but is a serious disease in California where groves must be irrigated. Sour rot is seldom seen in fruit on the tree, the chief means of entrance being through minute abrasions when fruit are dropped on the ground or they come in contact with sand, etc., in the bottom of a container during harvesting operations.

D. Consumer Factors

Consumers are interested in 3 main characteristics when they purchase citrus fruit in the retail store, appearance, palatability and keeping quality. The first 2 are highly subjective, appearance referring to external and palatability to internal qualities. The last has to do with the postharvest life of the fruit.

1. Appearance:

The housewife buys fruit initially on the basis of eye appeal (assuming an equivalent price). The color must be bright, shiny and uniform. The surface must be essentially free of disfiguring discoloration or blemishes. The size and form must also be uniform, particularly if the fruit are not packaged in bags or other containers. Certain cosmetic treatments, such as waxing or color-add (oranges, 'Temple', tangelos only), may be applied in the course of packinghouse handling along with skillful packaging which minimize the fruit's defects and thereby enhancing their eye appeal.

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

2. Palatability:

The only reliable index of fruit quality is palatability. Numerous characters, such as aromatic constituents, sugars, acidity, pH, sugar: acid ratio, and age, as well as the likes and dislikes of the individual who consumes the fruit, influence palatability. There are marked year to year variations along with changes during a given season as to when fruit have acceptable taste. The best correlations between palatability and fruit characters are between taste and total soluble solids or total soluble solids:acid (actually sugar:acid) ratio. A tarter (i.e., more acid) fruit will actually be more acceptable than a sweeter one if the former has high enough total soluble solids (sugars) because of the buffering action of potassium citrate in the juice. Correlations are lower with respect to color or juice content, although Sites and Reitz (1949, 1950) noted a positive relationship between good color and total soluble solids. Color, of course, contributes to eye appeal and one expects a bright, highly colored fruit to be sweet. Citrus juice is an excellent thirst quencher and a source of energy, vitamins and minerals. Several studies involving taste tests have been conducted in California and Florida.

a. The Pritchett tongue (Baier, 1954): Samples of orange juice going to a cannery were tested for Brix (total soluble solids) and Brix:acid ratio, then tasted, after which the data were plotted as a scatter diagram. The latter was dubbed the "Pritchett tongue", since it showed there was a broad, tongue-shaped area throughout which taste of the juice was acceptable (Fig. 8). The lower limit of acceptability was an 8:1 ratio, the legal maturity standard in California. A similar scatter diagram was prepared in Florida which did not show such clear-cut results as to the lower limit although the pattern otherwise was much the same.

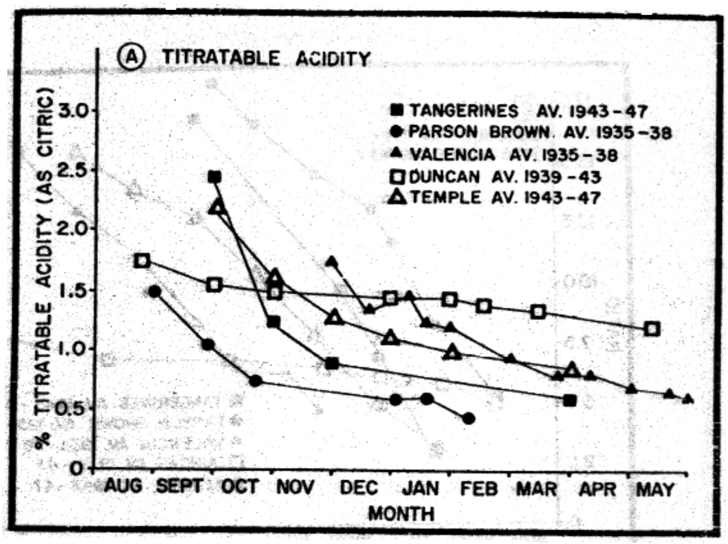
b. Harding et al.'s nomographs: The last stage in each group of seasonal studies of oranges, etc., was to plot nomographs. Points on vertical scales for % total soluble solids (scale increasing upwards) and % total (titratable) acid (scale increasing downwards) above a certain minimum taste panel score (usually 70, but 80 for tangelos) of individual samples after a certain date were connected by straight lines. Data from hundreds of samples over several seasons were utilized to establish minimum levels of total soluble solids and acid as legal standards to ensure harvesting of good quality fruit while permitting every grower to market his fruit at some time during the season (Fig. 9). Note that the limit of acceptability is not a straight line across the nomograph but convex from the intersection of 2 lines, the reason being fruit with lower total soluble solids must have a higher solids:acid ratio (i.e., lower acidity) than those with higher total soluble solids. (Unfortunately, no attempt was ever made to prepare other nomographs comparing data for color or juice content with either total soluble solids or solids:acid ratio for given taste scores.)

c. Variation of grapefruit within a packed box: Data from Harding et al.'s seasonal changes studies and Sites and Reitz's variation of fruit on a 'Valencia' orange tree work (covered in the next section on Preharvest Modifiers) clearly indicate substantial variations among fruit characters whether samples consist of many or a single specimen. Fresh grapefruit are consumed principally as halves or cut up as a breakfast food in contrast to oranges where several are squeezed for juice. Fruit to fruit variations thus become more important in the former situation. Five thousand individual grapefruit, 1200 'Duncan' and 3800 'Marsh' were analyzed at the U.S. Horticultural Research Station, Orlando, over the course of several seasons (1953-54 to 1957-58). Primary emphasis was placed on early- and late-season fruit, because these periods were those in which most variations occurred among samples of the earlier grapefruit study (Harding and Fisher, 1945). Thirty fruit of each of 6 sizes, 96 to 46 (present 48 to 23) were obtained from packing bins in commercial packinghouses. Data were obtained on physical characters and chemical constituents of individual fruit, with ascorbic acid determined for composite samples of each size. The study was instructive in showing the variability of individual grapefruit (Tables 7 and 8), including the failure of some samples to meet legal standards,

Citrus Maturity and Packinghouse Procedures

Fruit Characters (cont.)

but there was nothing well enough correlated to utilize as a means of eliminating poor quality fruit. Good quality fruit (acceptable total soluble solids, solids:acid ratio and juice content) were heavy for their size (as any grower in Florida knows full well), poor ones were light. (Unfortunately, taste tests were not run on any of the fruit; however, experience suggests the following admonition: "Always take the blossom end and give your wife the stem end!")



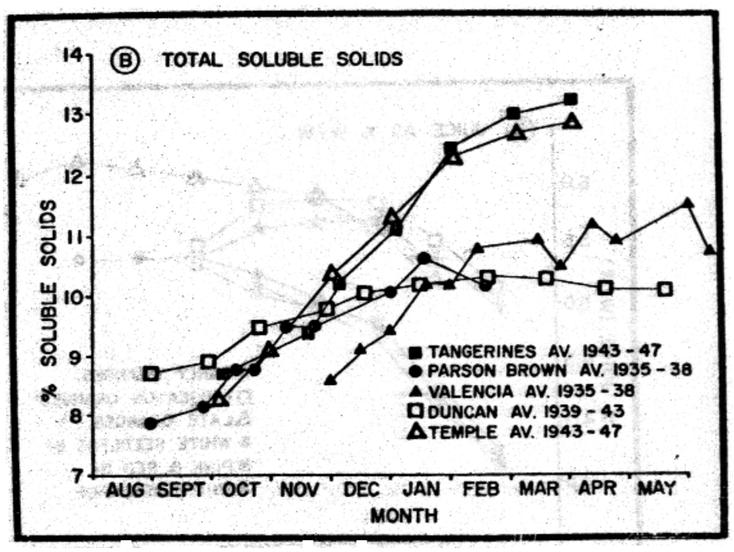
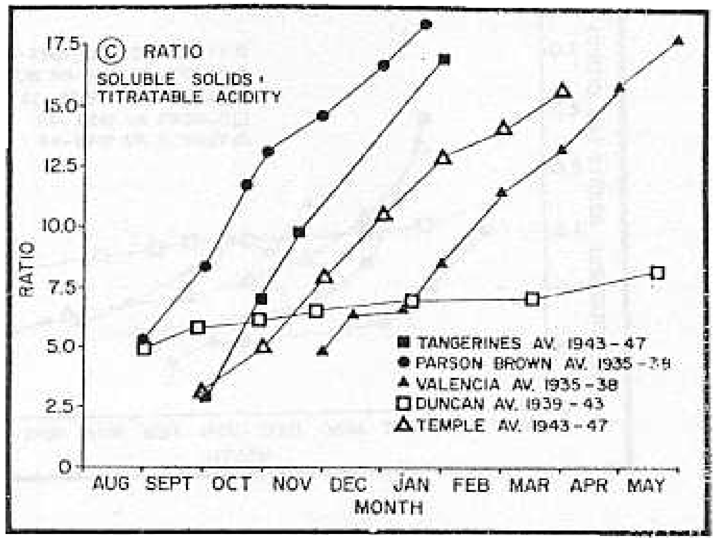


Figure 5 A-B. Seasonal changes in A. titratable acidity and B. total soluble solids of oranges, grapefruit, tangerines, and 'Temple'. (From Grierson and Ting, 1978, as adapted from Harding et al., 1940, 1945, 1949, 1953).



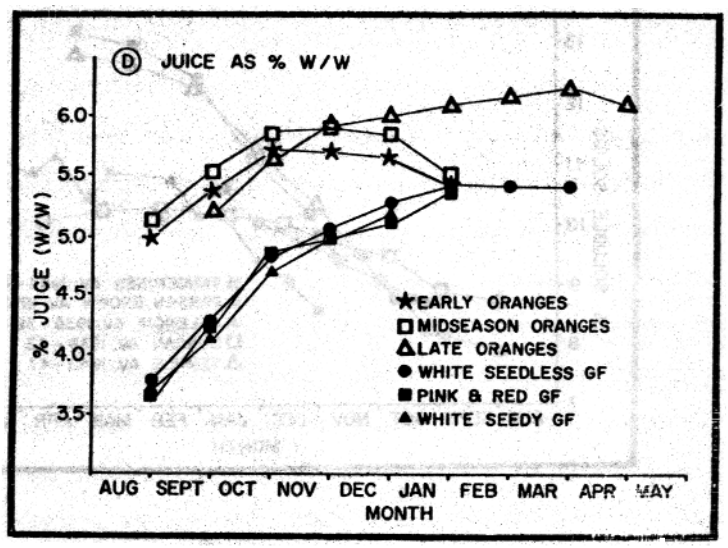


Figure 5 C-D. Seasonal changes in C. soluble solids:titratable acidity ratio of oranges, grapefruit, tangerines and 'Temple' and D. juice as % w/w of oranges and grapefruit (From Grierson and Ting, 1978, as adapted from Harding et al., 1940, 1945, 1949, 1953 and Crop Estimation Service reports).

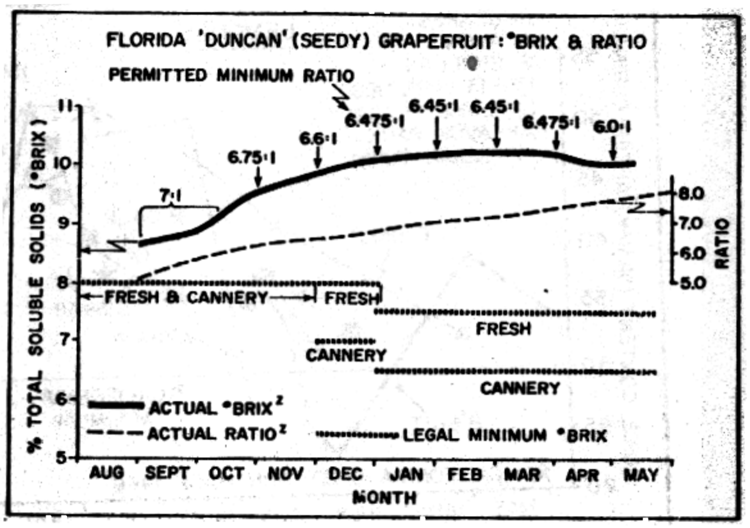


Figure 6. Legal maturity requirements for Brix and ratio of 'Duncan' grapefruit with actual Brix (---) and ratio (——). (From Grierson and Ting, 1978, with actual Brix and ratio values from Harding et al., 1945).

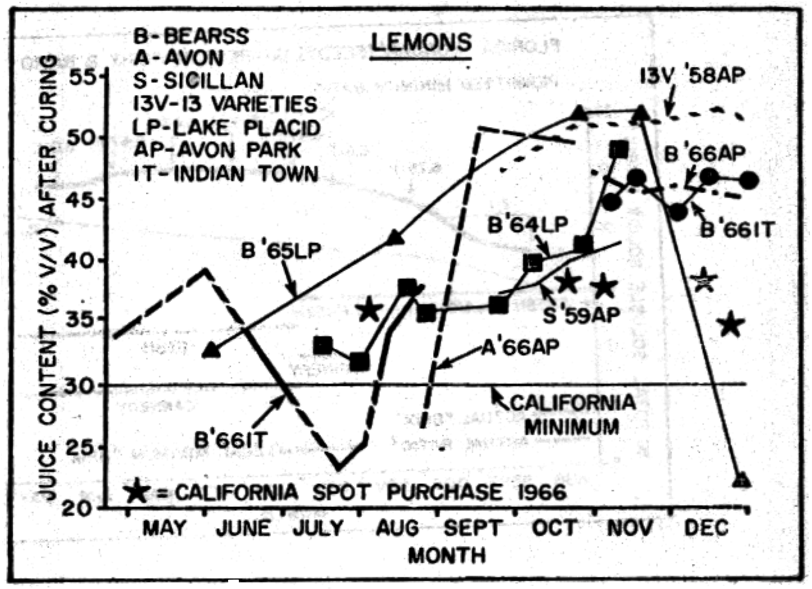
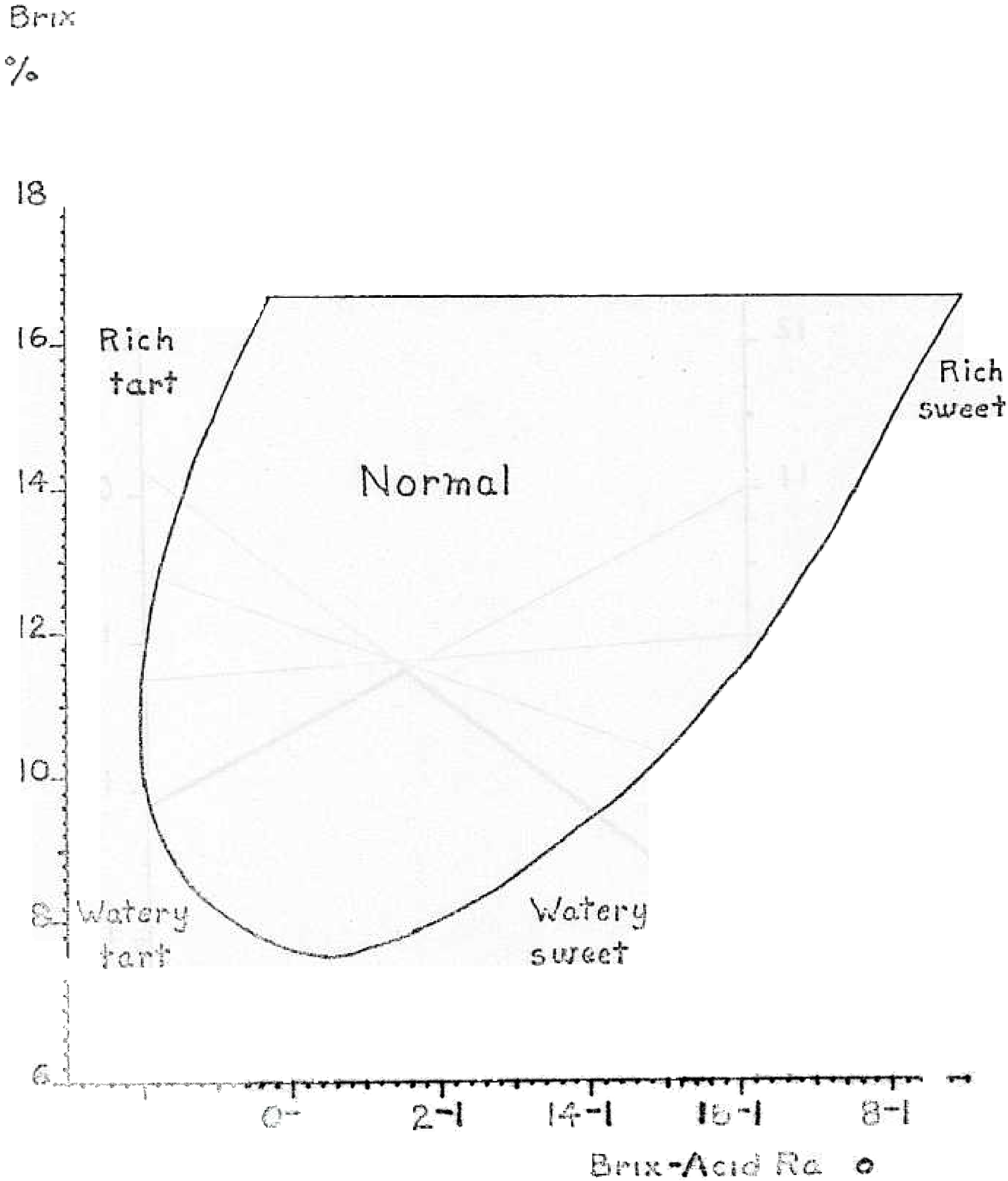


Figure 7. Juice content of lemons (From Grierson and Ting, 1978, as adapted from Fla. Agr. Expt. Sta. Ann. Rept., 1957).



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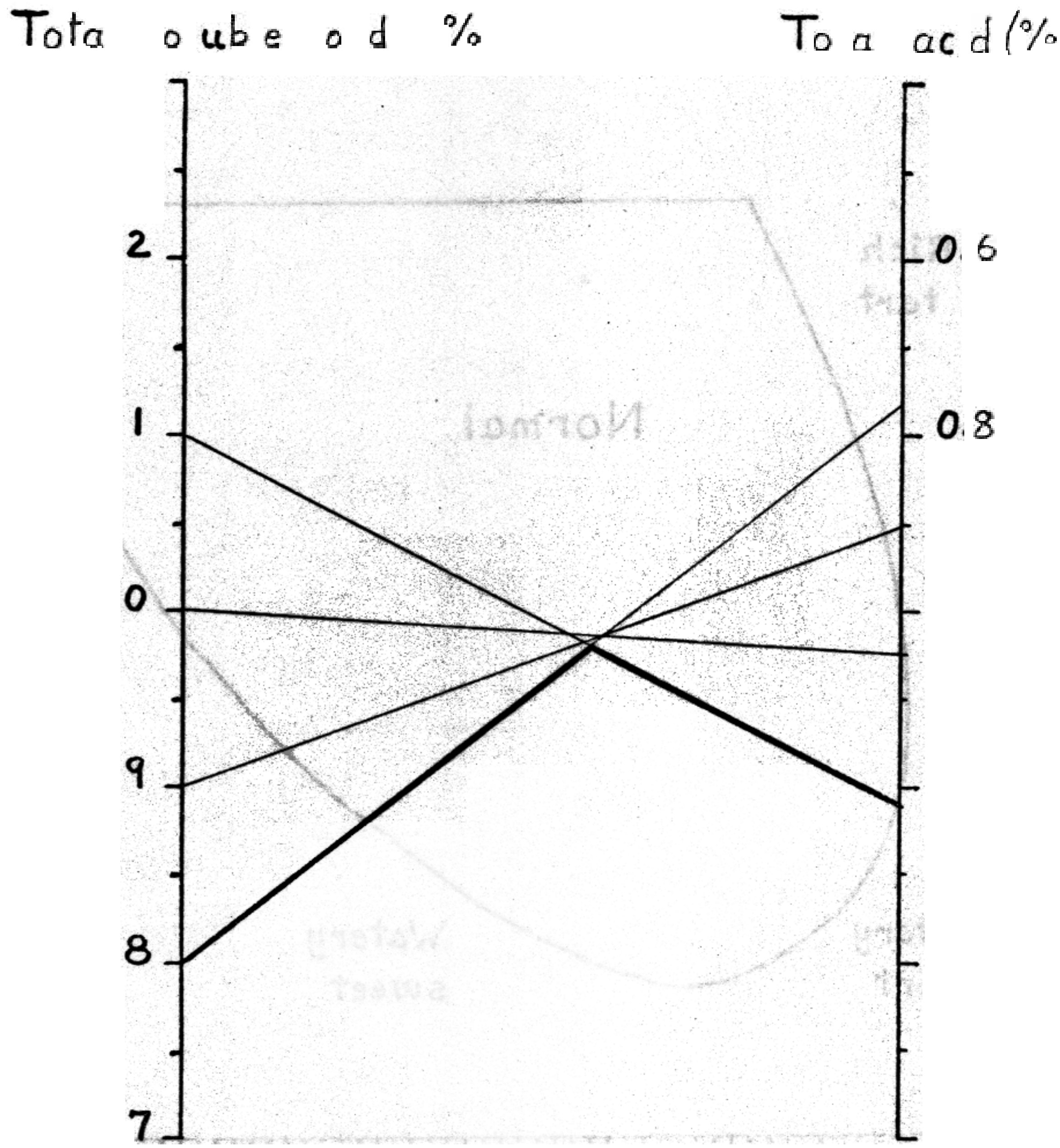

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Table 6A.

Grades and grade-lowering defects of citrus fruits

(Talk by W. Grierson at OECD meeting

Zaragoza, Spain

Nov. 19-22, 1980).

INTRODUCTION

VARIETIES (CULTIVARS)

Seedy, seedless, sparsely seeded

Varietal characteristics

Oranges

Valencia

Navel

Shamouti

Hamlin

Pineapple

Pera

Blood oranges

Grapefruit

Duncan

White Marsh Seedless

Red-fleshed grapefruit

Tangerines and hybrids

Clementine

Dancy

Temple

Ortanique

Ellendale

Murcott (Honey Tangerine)

Mineola

Orlando

Other mandarin-type hybrids

Lemons

Limes

Tahiti (Persian)

NON-PARASITIC DEFECTS ORIGINATING IN THE GROVE (ORCHARD)

Nutritional

Nitrogen deficiency

Copper deficiency

Boron deficiency

Magnesium deficiency

Potassium deficiency

Phosphorus deficiency

Creasing

Spray burns

"DN" injury

Oil blotch

Star melanose

Sulphur burn

Weather

Freeze injury

Windscar

Table 6A. (Cont.)

Hail

Zebraskin of tangerines

Physiological

staining of navels

Stem-end rind breakdown

Sloughing

Chimeras

PARASITIC DEFECTS ORIGINATING IN THE GROVE (ORCHARD)

Insects & mites

Rustmites

Mealybugs

Purple scale

Red scale

scale

Fruit flies

Leprosis

FUNGI

Fungi causing surface blemishes

Sooty mold

Sooty blotch

Melanose

Anthracnose

Scab

Pitting of grapefruit

Fungi causing fruit rots

Green mold

Blue mold

Table 6A. (Cont.

Stem-end rot

Alternaria rot

Sour rot

Brown rot

Bacteria

Canker

HARVESTING RELATED PROBLEMS

Immaturity

Oleocellosis

Blossom-end clearing

Stylar-end breakdown of limes

Stem-end rind breakdown

Mechanical injury

PACKINGHOUSE, STORAGE & TRANSIT

Ethylene burn

Brush burn

Fruit distortion

Chilling injury

Fungicide burn

EDB burn

EXAMPLES OF ACCEPTABLE GRADES

Representative slides

REFERENCES CITED