MAINTENANCE AND MEASUREMENT OF FRUIT CONDITION

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Fruit Condition - Definition and Measurement

The salability of fresh citrus in the marketplace can often depend on the visual appearance of the fruit. Maintaining, and in some cases enhancing, the appearance of the fruit is essential in the development of strong markets for citrus The appearance of citrus fruit is affected by many physical and physiological characteristics which ultimately describe fruit condition. Several aspects of fruit condition can be measured. The objective of this section of the Packinghouse Short Course is to define and discuss fruit condition and its measurement

Gloss

Gloss is a surface luster or brightness which is a result of reflected light. In the past, fruit gloss has been measured by visual evaluation, and this remains the most reliable means of assessment to date. Many variables affect the evaluation of gloss. The uniformity of the fruit surface, or peel texture, can influence the perception of gloss. Smooth fruit have a higher natural gloss before waxing than rough fruit (Newall and Grierson 1956) since light is more uniformly reflected on a smooth surface. A given wax will also impart a higher gloss to fruit with a smooth rather than a rough surface texture. In general, when applied without error, water waxes will impart a slightly higher gloss or shine to citrus fruit than solvent waxes (Hall 1981). Other factors, such as peel dehydration and deformation, which tend to distort the surface, will result in loss of fruit gloss. Gloss is also lost during storage (Newhall and Grierson 1956), so that a fruit high in gloss will not necessarily retain that appearance further down the marketing sequence.

Although gloss is most often visually evaluated packinghouse personnel trained in gloss assessment, gloss can be measured with the use of a Photovolt glossmeter (Newall and Grierson 1956). The instrument, used largely in the paint industry, will measure gloss only on a flat surface. For this reason, peel pieces must be excised and flattened before the gloss measurement. This action may result in cracking of wax and distortion of the surface, and therefore errors in measurement may occur. The glossmeter is not routinely used in the fresh fruit industry, but could possibly be utilized if individuals trained in gloss assessment are unavailable.

When gloss is evaluated, several points should be considered:

1. Evaluate gloss in a well-lit room and preferentially under consistant illumination
2. If waxes are to be evaluated for their gloss characteristics, comparisons are only valid when the same variety is used. Even fruit chosen evaluation within the same variety should have uniform peel texture.

Firmness

1. Deformation - Fruit firmness can be estimated by determination of permanent fruit deformation (Sarig and Nahir 1973; Rivero *et al*. 1979). Fruit deformation can be a serious economic problem, especially when fruit in overfilled cartons are inspected upon arrival at a terminal market. Increases in deformation are highly correlated with loss of fruit moisture (Kawada and Albrigo 1979; Turrell *et al*. 1965) which occurs predominantly from the peel (Kaufmann 1970). Deformation usually increases as fruit mature and senesce (Rivero *et al*. 1979) and this is associated with loss of firmness. Any treatment which retards moisture loss, such as low temperature storage (and high relative humidity), proper waxing, or film wrapping, will usually result in the retention of fruit firmness (Kawada and Albrigo 1979; Rivero *et* 1979).

Deformation of fruit can be measured several ways. Simple thumb pressure on the fruit will result in fruit deformation which can then be evaluated by visual inspection. Time be allowed for elasticity of the fruit to equilibrate before inspection. The test is a common practice and is referred to as the "Thumb-Test" (Sarig and Nahir 1973). Although rapid and easy to perform, the subjective nature of the test would require some training of personnel to minimize error in evaluation. An objective determination of deformation ("Grierson Creep Tester") can be used to quantify fruit firmness (Rivero et al. 1979, Kawada and Albrigo 1979). With this static load test, fruit are loaded linearly in a vertical chamber and the height noted. A constant load is applied to the column of fruit. The amount of load applied is a matter of trial and error, and would depend in part on variety, peel thickness, and general fruit condition. Load values are usually in the range of 400 g/fruit. After a set period of time, the load is removed, and, after the full elastic response is attained, the final height recorded. Percent fruit deformation (% FD) is an indicator of fruit firmness, and can be calculated by the following:

$$\% \text{ FD} = \frac{\text{(initial fruit column height - final height)}}{\text{initial fruit column height}} \times 100$$

The above equation indicates that, as the final column height of fruit decreases under a static load for a constant period of time, % fruit deformation increases. An inverse relationship exists between deformation and firmness, and therefore, as fruit firmness decreases, % deformation increases.

2. Puncture - The susceptibility of the fruit to puncture has been used as an index of maturity and firmness in many fruit crops, especially apples (Reid 1985), where a loss of fruit firmness can be measured and correlated to pressures required to puncture the fruit surface. In citrus, the relationship between puncture pressure and firmness is clouded by differences in tissue types directly beneath the puncture probe. Nevertheless, puncture pressure has been used as an

index of firmness in citrus (Oberbacher 1965; Turrell et at. 1964; Coggins and Henning 1988; Ferguson et al. 1982). There is a strong negative correlation in citrus between puncture pressure and water content of the peel and pulp. For this reason, puncture pressure has been more successfully used as an index of tissue turgidity (Oberbacher 1965; Turrell et al 1964; Reid 1985; Wardowski et al. 1976). An example of this is the use of puncture pressure to predict optimal harvest time for oleocellosis-susceptible cultivars (Oberbacher 1965, Wardowski et al. 1976).

To estimate firmness by the use of puncture pressure values, the effect of underlying tissues must be kept at a minimum. Because of this, instruments with larger puncture probes, such as the Magness-Taylor Pressure Tester, the Blake Peach Tester, and the Penetrometer have been disfavored Still, these instruments can be equipped with smaller probes and utilized for a general estimation of firmness (or turgidity). Fruit are placed against a backing on a table or bench with the blossom or stem end down. The equatorial region is then punctured with the probe. The force required to puncture the fruit can be read directly from the instrument. Usually the equatorial region is punctured more than once; four equally-spaced punctures are recommended (Turrell et al. 1964).

The Instron penetrometer has also been used to estimate peel firmness in citrus (Coggins and Henning 1988, Ferguson et al 1982). Equipped with a small probe (1.0 mm in diameter or less), peel or rind firmness has been assessed. The fruit is placed in a holder to prevent rotation and the stem and blossom axis oriented perpendicular to the plane of probe penetration. The probe, which moves at a constant rate, will penetrate the surface of the peel in the equatorial region of the fruit. The force required to pierce the surface is recorded by a chart recorder. Two to four equally-spaced equatorial punctures are recommended (Churchill et al. 1980; Miller 1987).

As previously mentioned, a close correlation exists between water content of the tissue and puncture presssure required to pierce the fruit surface. An increase in the water content of a tissue will result in a decrease in the pressure required to puncture the fruit (Oberbacher 1965; Turrell et al. 1964). In addition, a relationship exists between fruit dry matter/volume and puncture pressure, such that high puncture pressures are associated with high dry weight/volume ratios. With this is mind, a firm fruit would be expected to have a high water content, a low dry matter/volume ratio, and would require low pressures to puncture the surface. A direct relationship is difficult to establish between fruit firmness and puncture pressure, however. It has been suggested that puncture pressure is more closely related to tissue turgidity (Oberbacher 1965; Turrell et al. 1964; Reid 1985), and, as puncture probe diameter is decreased, measurements more closely resemble pressures required to shear the tissue (Miller 1987)

Weight Loss

The maintenance of fruit weight after harvest is in most cases crucial to the maintenance of desirable fruit condition. Loss of postharvest fruit weight is closely tied to loss of water (Albrigo and Ismail 1981; Kawada and Hale 1980; Reid 1985), most of which initially comes from the peel (Kauffman 1970). In citrus fruit, loss of water means an increase in deformation and puncture pressure with resulting loss of fruit firmness and turgidity. The natural wax found on the surface of citrus fruit tends to retard weight loss. When fruit are washed in the packinghouse, the natural waxes have been reported to be either removed (Kaplan 1986) or only redistributed (Albrigo 1973). Commercial water or solvent waxes are then applied to impede water or weight loss. When waxed fruit are stored, proper humidity control is essential for the control of fruit weight loss. Individual film-wrapping can also restrict water movement from the fruit into the surrounding atmosphere and result in decreased weight loss (Albrigo and Ismail 1981; Kawada and Albrigo 1979) the control of weight loss, individual film-wrapping is superior to fruit waxing

Weight loss can be easily assessed in citrus fruit. only piece of equipment required is a balance or scale which is sensitive enough to measure changes in fruit weight. With citrus fruit, a scale with a sensitivity range of 0.1 gram is sufficient to measure weight changes. To determine weight loss, a fruit is weighed and the weight recorded. After a period of time, the fruit is reweighed. The percent weight loss can then be calculated:

$$\% \text{ weight loss} = \frac{\text{initial fruit weight} - \text{final fruit weight}}{\text{initial fruit weight}} \times 100.$$

Waxing and Fruit Condition

The purpose of waxing is to reduce shrinkage from water loss and to improve appearance by application of a shiny coating. Fruit waxing has also been reported to reduce susceptibility to chilling injury (Grierson 1971). In addition, the wax can be used as a carrier for fungicides.

desirable characteristics of fruit waxing outweigh the disadvantages which are reduced gas exchange for respiration

consumer misconceptions about the unnatural nature of waxed fruit. Delays in waxing can lead to weight loss with subsequent susceptibility to deformation, especially with excessive fruit loads and when improper holding conditions are implemented. In addition, delays may result in increased likelihood of decay when fungicides are incorporated into the wax (Kaplan 1986)

The packingline sequence should provide clean, dry (solvent waxes) or nearly dry fruit (water waxes) before entering the waxer. Clean fruit have higher consumer acceptance Commercial waxes are more likely to adhere to the natural fruit waxes than to surface debris on unclean fruit. Although fruit cleanliness is an important pre-waxing condition, excessive washing may result in fruit injury and lead to increased weight loss and decay susceptibility. Trial and error, as well as following manufactures' specifications, are important in determining the proper levels of cleanliness for good fruit condition. Success of the waxing operation not only depends on fruit cleanliness, but also on fruit surface moisture level. Fruit must be completely dry before waxing if solvent waxes are to be used. Coating uniformity is lost if wet fruit are waxed with a solvent wax. Fruit can be slighltly damp or completely dry if water waxes are to be used. Too much surface water will dilute the wax and result in improper "set up". In addition, water waxed fruit are more likely to chalk or water spot if the wax is applied to an excessively wet surface.

If waxes are applied in the proper quantity and distribution at the proper temperature and brush speed, and dried with the proper air flow, temperature, roller speed, and time, then the fruit will be ready for post-waxing evaluation Application of excessive wax will further impede gas exchange and result in off-flavor development. Excessive weight loss will be the consequence of insufficient waxing. Weight loss should not exceed 5% or 10% of the total initial fresh weight for short or long-term storage, respectively. If drying is incomplete, the result will be a "tacky" fruit. If water waxes are used, fruit emerging from the drier can be slightly tacky but must be completely dry by the time the fruit reach the final grading table, sizer, and packing machines. In addition, insufficient drying can be indicated by a build-up of wax on the surface of the first set of rollers directly after the drier and the fruit sizer. A poor waxing originating from the waxer or the drier will result in weight loss with subsequent deformation and loss of gloss

Good waxing can be negated by improper holding conditions. Avoid humidity and temperature conditions where fruit temperature is below the dew point of the surrounding Condensation of water will occur on the fruit surface and may lead to chalking or water spotting. Conversely, fruit stored in very dry conditions at any temperature will result in fruit desiccation. Proper precooling or temperature control as well as humidity control are crucial to good arrivals.

Often, waxing is assessed simply by subjective measurements. Tackiness and gloss are commonly evaluated. Although these characteristics can be used quickly to evaluate waxing, little information is obtained on its long-term effectiveness. Many times waxing can be assessed by evaluation of weight loss. Sufficient waxing should provide increased weight loss control over field-run fruit. Washed fruit should not be compared with waxed fruit. If weight loss of waxed fruit is equal to or greater than field-run fruit, then excessive washing or inadequate waxing may have been the cause. Effectiveness of different waxes can be assessed by comparison of weight loss as well. Flow meters can be used to monitor wax amount for a given dump volume and surface area. Measuring weight loss of the wax drum can also give an indication of delivered wax for a given dump volume and surface area

SELECTED REFERENCES

Albrigo, L. G. 1973. Some parameters influencing development of surface wax in citrus fruits. Proc. Int. Soc Citriculture 3:107-115.

Albrigo, L. G. and Ismail, M. A. 1981. Shipment and storage of Florida grapefruit using Unipack film barriers. Proc Int. Soc. Citriculture 2:714-717.

Coggins, C. W. and Henning, G. L. 1988. A comprehensive California field study of the influence of preharvest applications of gibberellic acid on the rind quality of Valencia oranges. Israel J. Bot. 37:145-154.

Churchill, D. B., Sumner, H. R. and Whitney, J. D.1980. Peel strength properties of three orange varieties. Trans. ASAE 23: 173-176.

Ferguson, L., Ismail, M. A., Davies, F. S. and Wheaton, T A. 1982. Pre- and postharvest gibberellic acid and 2,4-dichlorophenoxyacetic acid applications for increasing storage life of grapefruit. Proc. Fla. State Hort. Soc. 95:242-245.

Grierson, W. 1971. Chilling injury in tropical and subtropical fruits: IV. The role of packaging and waxing in minimizing chilling injury in grapefruit. Proc. Trop. Region, Amer. Soc. Hort. Sci. 15:76-88.

Hall, D. J. 1981. Innovations in citrus waxing - an overview. Proc. Fla. State Hort. Soc. 94:258-263.

Kaufmann, M. R. 1970. Water potential components in growing citrus fruits. Plant Physiol. 46:145-149.

Kaplan, H. J. 1986. Washing, waxing, and color-adding. IN: Wardowski, W. F., Nagy, S. and Grierson, W. (eds). Fresh Citrus Fruits. AVI Publishing Co., Westport, CT

Kawada, K. and Albrigo, L. G. 1979. Effects of film packaging, in-carton air filters, and storage temperatures on the keeping quality of Florida grapefruit. Proc. Fla State Hort. Soc. 92:209-212

Kawada, K. and Hale, P. W. 1980. Effect of individual film wrapping and relative humidity on quality of Florida grapefruit and condition of fiberboard boxes in simulated export tests. Proc. Fla. State Hort. Soc. 93:319-323.

Miller, W. M. 1987. Physical properties data for postharvest handling of Florida citrus. Applied Engineering in Agric. 3:123-128.

Newhall, W. F. and Grierson, W. 1956. A low-cost, self-polishing, fungicidal water wax for citrus fruit. Proc. Amer. Soc. Hort. Sci. pp. 146-154.

Oberbacher, M. F. 1965. A method to predict the post-harvest incidence of oleocellosis on lemons. Proc. Fla. State Hort. Soc. 78:237-240

Reid, M. S. 1985. Product maturation and maturity indices. IN: Postharvest Technology of Horticultural Crops. Univ. of Calif. Ext. Special Pub. No. 3311

Rivero, L. G., Grierson, W. and Soule, J. 1979. Resistance of 'Marsh' grapefruit to deformation as affected by picking and handling methods. J. Amer. Soc. Hort. Soc 104:551-554

Sarig, Y. and Nahir, D. 1973. Deformation characteristics of 'Valencia' oranges as an indicator of firmness HortScience 8:391-392

Turrell, F. M., Monselise, S. P. and Austin, S. W. 1964 Effect of climatic district and of location in tree tenderness and other physical characteristics of citrus fruit. Bot. Gaz. 125:158-170.

Wardowski, W. F., McCornack, A. A. and Grierson, W. 1976 Oil spotting (oleocellosis) of citrus fruit. Fla. Coop Ext. Serv. Circ. 410.