FRUIT MATURITY, RIPENING, AND QUALITY RELATIONSHIPS

A.A. Kader
Department of Pomology
University of California
One Shields Avenue
Davis, CA 95616, USA

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Abstract

Maturity at harvest is the most important factor that determines storage-life and final fruit quality. Immature fruits are more subject to shrivelling and mechanical damage, and are of inferior flavour quality when ripe. Overripe fruits are likely to become soft and mealy with insipid flavour soon after harvest. Fruits picked either too early or too late in their season are more susceptible to postharvest physiological disorders than fruits picked at the proper maturity.

All fruits, with a few exceptions (such as pears, avocados, and bananas), reach their best eating quality when allowed to ripen on the plant. However, some fruits are usually picked mature but unripe so that they can withstand the postharvest handling system when shipped long-distance. Most currently used maturity indices are based on a compromise between those indices that would ensure the best eating quality to the consumer and those that provide the needed flexibility in marketing.

Fruits can be divided into two groups: 1) fruits that are not capable of continuing their ripening process once removed from the plant, and 2) fruits that can be harvested mature and ripened off the plant. Group 1 includes berries, cherry, citrus fruits, grape, lychee, pineapple, pomegranate, and tamarillo. Group 2 includes apple, apricot, avocado, banana, cherimoya, guava, kiwifruit, mango, nectarine, papaya, passion fruit, pear, peach, persimmon, plum, quince, sapodilla, sapote.

Group 1 fruits produce very small quantities of ethylene and do not respond to ethylene treatment except in terms of degreening (removal of chlorophyll); these should be picked when fully-ripe to ensure good flavour quality. Fruits in Group 2 produce much larger quantities of ethylene in association with their ripening, and exposure to ethylene will result in faster and more uniform ripening.

1. Introduction

Quality, i.e., the degree of excellence or superiority, of fresh fruits and their products is a combination of attributes, properties, or characteristics that give each commodity value in terms of human food. The relative importance of each quality component depends upon the commodity and its intended use (e.g., fresh or processed) and varies among producers, handlers, and consumers. To producers a given commodity must have high yield and good appearance, must be easy to harvest, and must withstand long-distance shipping to markets. Appearance quality, firmness, and shelf-life are important from the point of view of wholesale and retail marketers. Consumers judge quality of fresh fruits on the basis of appearance (including "freshness") and firmness at the time of initial purchase. Subsequent purchases depend upon the consumer's satisfaction in terms of flavour (eating) quality of the product. Consumers are also concerned about the nutritional quality of fresh fruits, which are not only colourful and flavourful components of our diet, but also a good source of energy, vitamins, minerals, dietary fibers, and many bioactive compounds that enhance human health.

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Maturity indices are important for deciding when a given commodity should be harvested to provide some marketing flexibility and to ensure the attainment of acceptable eating quality to the consumer. These two goals are not always compatible. The necessity of shipping fruits long distances has often resulted in harvesting them at less than ideal maturity. This, in turn, has resulted in less than optimum quality to the consumer. Most maturity indices are also factors of quality, but there are many important quality indices which are not used in determining optimum harvesting stage. The flavor quality of fruits cannot be accurately determined by appearance factors alone. Also, postharvest-life of fruits based on flavour is generally shorter than their postharvest-life based on appearance factors (such as colour and absence of defects and decay).

Future consumption trends of fresh fruits will depend on continued efforts by producers and handlers to make available a year-round supply of good quality fresh produce to the consumers in both domestic and export markets.

2. Maturity

Maturation is the stage of development leading to the attainment of physiological or horticultural maturity. Physiological maturity is the stage of development when a plant or plant part will continue ontogeny even if detached. Horticultural maturity is the stage of development when a plant or plant part possesses the prerequisites for utilisation by consumers for a particular purpose.

Maturity at harvest is the most important factor that determines storage-life and final fruit quality. Immature fruits are more subject to shrivelling and mechanical damage, and are of inferior quality when ripe. Overripe fruits are likely to become soft and mealy with insipid flavour soon after harvest. Any fruit picked either too early or too late in its season is more susceptible to physiological disorders and has a shorter storage-life than fruit picked at the proper maturity.

All fruits, with a few exceptions (such as European pears, avocados, and bananas), reach their best eating quality when allowed to ripen on the tree or plant. However, some fruits are usually picked mature but unripe so that they can withstand the postharvest handling system when shipped long-distance. Most currently used maturity indices are based on a compromise between those indices that would ensure the best eating quality to the consumer and those that provide the needed flexibility in marketing.

California's mandatory quality standards (California Food and Agriculture Code) for most fresh fruits include objective indices of maturity to ensure minimum acceptability of their flavour quality to consumers (Tab. 1). Examples of these indices are total solids concentration (avocado) soluble solids concentration (cherry, grape, grapefruit, kiwifruit, mandarin, orange, and pear), titratable acidity concentration (pomegranate), ratio of soluble solids to titratable acidity (citrus fruits, grape) and flesh firmness (apple, pear). Enforcement of these standards is the responsibility of fruit producers and is monitored by the Agriculture Commissioner in each county representing the California Department of Food and Agriculture (CDFA).

Colour is used as the index of maturity for apricot, nectarine, peach, persimmon, plum, raspberry, and strawberry fruits. I propose that the industries involved in producing and marketing these fruits petition CDFA to add a minimum soluble solids concentration, a maximum acid concentration, and/or a minimum soluble solids/acid ratio as maturity indices for each of these commodities. It may be necessary to specify different values for each group of cultivars in the case of nectarine, peach, and plum. Implementation of this proposal will most likely eliminate most of the poor flavour quality fruits from the market, increase sales and profit to the producers and handlers, and help build consumers' confidence in the good eating quality of all California's fresh fruits.

Table 1. California minimum maturity indices for selected fruits

Fruit	Minimum maturity indices
Apple	Starch pattern, above 10.5 to 12.5% SS and below 18 to 23 lb-force firmness (depending on cultivar)
Apricot	Colour of the external surface area: >3/4 yellowish green or >1/2 yellow
Avocado	17 to 20.5% dry weight (depending on cultivar)
Cherry	Entire surface solid light-red and 14 to 16% SS (depending on cultivar)
Grape	14 to 17.5% SS (depending on cultivar and production area) or a SS/A ratio of 20 or higher
Grapefruit	SS/A ratio 5.5 or 6.0 (desert areas), 2/3 of fruit surface showing yellow colour
Kiwifruit	6.5% SS
Lemon	30% juice by volume
Nectarine & Peach	Surface ground colour change from green to yellow, shape (fullness of shoulders and suture)
Orange	SS/A ratio of 8.0 (and orange colour on 25% of the fruit surface) or 10.0 (and less intense orange color)
Pear (Bartlett)	Yellowish-green colour, and/or below 23 lb-force firmness, and/or above 13% SS
Persimmon	Yellowish-green to orange colour (depending on cultivar)
Plum	Surface colour and flesh firmness (depending on cultivar)
Pomegranate	Red juice colour and below 1.85% acid in juice
Strawberry	>2/3 fruit surface showing a pink or red colour
Tangerine	SS/A ratio 6.5 and yellow, orange, or red colour on 75% of the fruit surface

SS=soluble solids, A=acidity

3. Ripening

Ripening is the composite of the processes that occur from the latter stages of growth and development through the early stages of senescence and that results in characteristic aesthetic and/or food quality, as evidenced by changes in composition, colour, texture, or other sensory attributes.

Fruits can be divided into two groups: 1) fruits that are not capable of continuing their ripening process once removed from the plant, and 2) fruits that can be harvested mature and ripened off the plant. Following are examples from each group:

Group 1: Berries (such as blackberry, raspberry, strawberry), cherry, citrus (grapefruit, lemon, lime, orange, mandarin, and tangerine), grape, lychee, pineapple, pomegranate, tamarillo.

Group 2: Apple, pear, quince, persimmon, apricot, nectarine, peach, plum, kiwifruit, avocado, banana, mango, papaya, cherimoya, sapodilla, sapote, guava, passion fruit.

Fruits of the first group produce very small quantities of ethylene and do not respond to ethylene treatment except in terms of degreening (removal of chlorophyll); these should be picked when fully-ripe to ensure good flavour quality. Fruits in Group 2 produce much larger quantities of ethylene in association with their ripening, and exposure to ethylene treatment will result in faster and more uniform ripening. Bananas must be treated with 10-100 ppm ethylene to initiate their ripening during transport or at destination handling facilities. Ripening of avocado, kiwifruit, mango, and pear fruits before marketing is increasingly being used to provide consumers with the choice of purchasing ready-to-eat, ripe fruits or mature fruits that can be ripened at home. This practice has, in many cases, resulted in increased sales and profits.

Once fruits are ripened they require quick marketing and careful handling to minimise bruising. If delays can not be avoided, the ripe fruits should be cooled to their minimum safe temperature and kept at that temperature until ready for retail display. Ripe, chilling-sensitive fruits tolerate lower temperatures than unripe fruits. Removal of ethylene and decreasing oxygen concentration to the 3-5% range can be useful supplements to maintaining the optimum temperature and relative humidity for delaying further ripening and deterioration of partially-ripe fruits.

4. Flavor quality

Table 2. Proposed minimum soluble solids content (SSC) and maximum titratable acidity (TA) for acceptable flavour quality of fruits

Fruit	Minimum SSC (%)	Maximum TA (%)
Apple	10.5-12.5 (depending on cultivar)	
Apricot	10	0.8
Blueberry	10	—
Cherry	14-16 (depending on cultivar)	
Grape	14-17.5 (depending on cultivar) or SSC/TA ratio of 20+	
Grapefruit	SSC/TA ratio of 6+	
Kiwifruit	14	—
Mandarin	SSC/TA ratio of 8+	
Mango	12-14 (depending on cultivar)	
Muskmelons	10	—
Nectarine	10	0.6
Orange	SSC/TA ratio of 8+	
Papaya	11.5	—
Peach	10	0.6
Pear	13	—
Persimmon	18	—
Pineapple	12	1.0
Plum	12	0.8
Pomegranate	17	1.4
Raspberry	8	0.8
Strawberry	7	0.8
Watermelon	10	—

Volatiles are responsible for the characteristic aroma of fruits. They are present in extremely small quantities (<100< g/g fresh wt.). The total amount of carbon involved in the synthesis of volatiles is <1% of that expelled as CO_2. The major volatile formed in climacteric fruits is ethylene (50-75% of the total carbon content of all volatiles). Ethylene does not have a strong aroma and does not contribute to typical fruit aromas.

Volatile compounds are largely esters, alcohols, aldehydes, and ketones (low-molecular weight compounds). Very large numbers of volatile compounds have been identified in fruits, and more are identified as advances in separation and detection techniques and gas chromatographic methods are made; however, only a few volatiles are important for the particular aroma of a given fruit. Their relative importance depends upon threshold concentration, which can be as low as 1 ppb potency, and interaction with other compounds.

Several attempts have been made to develop portable instruments with sensors that detect volatile production by fruits as a way to detect maturity and quality. Other strategies include the removal of a very small amount of fruit tissue and measurement of total sugars or soluble solids content. Near-infrared detectors have great potential for nondestructive estimation of sugar content in fruits. Until such methods become widely available, we will continue to depend on destructive techniques, such as soluble solids determination by a refractometer and titratable acidity measurement by titration, to evaluate flavour quality of fruits.

Table 2 summarises the proposed minimum soluble solids content and maximum titratable acidity for acceptable flavour quality of fruits. These values will not guarantee the optimum flavour quality for each consumer but it assures a minimum acceptability level for the majority of consumers. Additional research will likely result in a few changes in the values shown in table 2. Use of these indices in a quality assurance program must be coupled with tolerances of deviation from the proposed averages because of the large variation among cultivars, production areas and seasons, maturity at harvest and ripeness stage at the time of evaluation.

5. Future research needs

5.1. Identification of the important components of quality and the interrelationships among these quality factors for the various fruits destined for the fresh market or for processing.

5.2. Developing objective and non-destructive methods for determination of quality attributes, especially those, which are related to flavour and nutritional quality of fresh fruits.

5.3. Conducting consumer acceptance research aimed at relating maturity indices at harvest to the final organoleptic acceptability by the consumer.

5.4. In collaboration with plant breeders, continue efforts aimed at development of new genotypes with better flavour and nutritional quality in all the major fruits.

5.5. Studying the effects of preharvest factors (climatic conditions, cultural practices, etc.) on flavour quality attributes of fresh fruits.

References

Eskin, N.A.M. (ed.), 1991. Quality and Preservation of Fruits. CRC Press, Boca Raton, FL, p. 212.

Kader, A.A. (ed.), 1992. Postharvest Technology of Horticultural Crops. Second edition, Univ. Calif., Div. of Agr. and Nat. Resources, Publ. 3311, p. 296.

Nagy, S. and Shaw, P.E. (eds.), 1980. Tropical and Subtropical Fruits: Composition, Properties, and Uses. AVI Publ. Co., Inc., Westport, CT, p. 570.

Pattee, H.E. (ed.), 1985. Evaluation of Quality of Fruits and Vegetables. AVI Publ. Co., Inc., Westport, CT, p. 410

Seymour, G.G., Taylor, J.E. and Tucker, G.A. (eds.). 1993, Biochemistry of Fruit Ripening. Chapman and Hall, London, p. 454.

Watada, A.E., Herner, R.C, Kader, A.A., Romani, R.J. and Staby, G.L., 1984. Terminology for the description of developmental stages of horticultural crops. HortScience 19: 20-21.