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Review Article

Stone fruit maturity indices: a descriptive review

Carlos H. Crisosto
Pomology Department, University of California, Davis
Kearney Agricultural Center, Parlier, CA 93648, USA

ABSTRACT

Information published on nectarine, plum and peach fruit maturity between 1980 and 1992 is reviewed. The advantages and disadvantages of different maturity indexes are discussed. The use of ground color, although an imperfect index, is considered the most practical and reliable method for determining minimum maturity. Fruit firmness is an excellent indicator of maximum maturity. A combination of ground color and fruit firmness may be better than a single index to assay stone fruit maturity. Fruit soluble solids content (SSC) varies significantly among orchards, as well as from tree to tree and, therefore, is not reliable indicator of fruit maturity. It is hoped that the development of new technologies in the near future such as near infrared (NIR), magnetic resonance (MR), light transmittance (LT) and sound detection will lead to an ideal, non-destructive, reliable maturity index for the nectarine, peach and plum fruit industry.

INTRODUCTION

This review aims to summarize the published information on the development of maturity indices for peaches and nectarines. The search for an objective, easy, reliable and simple determination of maturity has occupied the attention of many horticulturists working in the different peach, plum and nectarine production areas. This literature search on the topic mainly covers the information published in the Agricola Catalog from 1980 to date.

Since the commercial production of peaches, plums and nectarines in the USA is restricted to California, South Carolina, Georgia, Michigan, New Jersey and Pennsylvania, most of the information on maturity indices has been developed in these areas.

DEFINITION AND REQUIREMENTS

Definition of Maturity

In postharvest physiology we consider "mature" as "that stage at which a commodity has reached a sufficient stage of development that after harvesting and postharvest handling, its quality will be at least the minimum acceptable to the ultimate consumer" (Reid, 1992). Stone fruit quality is a combination of attributes and properties that give them value in terms of human consumption. Growers and shippers are concerned that their commodities have good appearance and few visual defects. To receivers and distributors, firmness and a long storage life are of keen interest (Parker, *et al*., 1990). Consumers perceive quality fruit as ones that look good, are firm, and offer good flavor and nutritive value (Bruhn, 1991). Although they buy on the basis of appearance and feel, their satisfaction is dependent upon good eating quality..

A minimum maturity index is established by the industry based on the available scientific information and its needs. Mitchell (1991) suggests that a minimum maturity index should allow individual shippers to have the opportunity to produce and market a product at a somewhat higher maturity than the base level that was set up for the industry. Economic studies indicated that high quality stone fruits may obtain higher prices than lower quality stone fruits harvested above the minimum maturity (Bruhn, 1991; Jordan *et al*., 1990; Parker *et al*., 1990).

Why we need maturity indices

The definition of maturity as the stage of development giving minimum acceptable quality to the ultimate consumer implies measurable points in the commodity's development, and the need for techniques to measure maturity. The maturity index for a commodity is a measurement or measurements that can be used to determine whether a particular commodity is mature. These indices are important to trade regulation, marketing strategy and to the efficient use of labor and resources.

Characteristics of the maturity index

For maturity measurements to be carried out by producers, handlers, and quality control personnel they must be simple, readily performed in the field or inspection point, and should require relatively inexpensive equipment. The index should preferably be objective (a measurement) rather than subjective (an evaluation) and ideally the index should be non-destructive.

Requirements for maturity indices

Many features of fruit have been used in attempting to provide adequate estimates of maturity. The maturity index must consistently meet two requirements for all growers, districts, and years: firstly, it should insure minimum acceptable eating quality and, secondly, a long storage life.

PEACH, PLUM AND NECTARINE MATURITY INDEX UPDATE

Determining a maturity index involves establishing consistent physical and chemical changes which occur in the commodity throughout its development and which correlate well with maturity (Reid, 1992). After this, some of these indicators (maturity indices) are selected by using storage trials and sensory evaluation to determine which of them consistently reflects the quality of the harvested product for all seasons, cultivars and growing locations (Bhargava *et al*., 1986; Chander and Khajuria, 1981; Crochon, 1985; Josan and Chohan, 1982; Shewfelt *et al*., 1987; Sins and Comin, 1963).

Detailed information on peach and nectarine chemical and physical changes during maturation, ripening and senescence has been published (Couvillon and Krewer, 1991; Ryall and Pentzer, 1982; Salunkhe *et al.*, 1968; Sistrunk, 1985). Maturation is the time between final fruit growth and the beginning of ripening, and senescence. Maturity is the end point of maturation. An immature fruit may ripen off the tree but it will be of poor quality (Baumgardner and Delwiche, 1983; Culpepper *et al*., 1955; Deshpande and Salunkhe, 1964 Josan and Chohan, 1982; Kader and Mitchell, 1989a; Shewfelt *et al*., 1987; Sims and Comin, 1963). A mature fruit will attain good quality when ripened off the tree. Nectarines, peaches and plums are usually harvested firm-mature and ripened before consumption (Fisher *et al.*, 1943; Kader and Mitchell, 1989a; Morris, 1932). As peaches, plums and nectarines mature, substantial physical changes occur which lead eventually to ripening (Guelfat-Reich and Ben-Arie, 1966). The change in skin and flesh color, flesh softening, and flavor changes are particularly obvious, during the rapid increase in size as the fruit nears maturity (Kader and Mitchell, 1989a; Lill *et al.*, 1989; Robertson et al., 1991; Romani and Jennings, 1971; Ryall and Pentzer, 1982). As fruit matures, fructose and glucose decrease and sucrose increases. Malic acid and citric acid are the predominant organic acids. The decline in total acids as the fruit matures results from a major loss of malic acid (Deshpande and Salunkhe, 1964; Romani and Jennings, 1971; Ryall and Pentzer, 1982; Salunkhe *et al.*, 1968)..

Ripening involves changes that transform the mature fruit into one ready to eat. Changes associated with ripening include loss of green color and development of yellow, red and other color characteristics of the variety. As a fruit ripens, it softens, its acidity declines and it produces certain volatile compounds that give it its characteristic aroma (Chapman ahd Horvat, 1990; Do *et al.*, 1969; Horvat and Chapman, 1990). Increased respiration and ethylene production rates are among the physiological changes associated with ripening (Amoros et al., 1989; Sistrunk, 1985). Once the fruit ripens, senescence begins; physical and chemical changes continue after "optimum" ripeness is reached including further softening, loss of desirable flavor and complete breakdown (Harvey *et al*., 1972; Kader and Mitchell, 1989b; Mitchell, 1986).

When a relationship between chemical or physical changes and the fruit maturity has been established, potential maturity indices can be studied for their reliability (Bhargava *et al.*, 1986; Chandler and Khajuria, 1981; Mitchell *et al*., 1979). For nectarines, peaches and plums several possibilities have been suggested including size, shape, ground color change from green to yellow, firmness, soluble solids content and concentration of acids.

Size and shape: Attainment of a specific size is one possible index of maturation, but it cannot be used alone since fruit size for any variety can be influenced by crop load, climatic conditions, and cultural practices. Fruit shape and/or fullness of cheeks indicates maturity (Kader and Mitchell, 1989b; Lill *et al.*, 1989). When fruit shoulders and the suture are well developed and filled out, stone fruits are considered mature. To be reliable this criterion has to be coupled with other indicators such as skin color (Kader and Mitchell, 1989b).

Flesh firmness: Flesh firmness decreases during the maturation and ripening. In general, peaches of 10 to 12 pounds-force firmness at picking will ripen after harvest and attain better quality than those of 12 to 15 pounds-force firmness (Kader and Mitchell, 1989a; Kader and Mitchell, 1989b). Early season peach, plum and nectarine varieties are usually less firm at the minimum maturity time than late season varieties. Typical firmness levels at minimum maturity time are 9-10, 11-12 and 13-14 lbs. Available data, however, indicates that flesh firmness alone is not a satisfactory minimum maturity index, because flesh firmness among varieties and for a given variety varies in relation to fruit size, climatic conditions, and cultural practices (Blake and Davidson, 1936; Boggess *et al.*, 1974; Craft, 1955; Delwiche *et al.*, 1987; Kader and Mitchell, 1989a; McDonald and Delwiche, 1983; Mitchell et al, 1977). In California and Chile, it is suggested that flesh firmness can be used as a maximum maturity index to determine how late fruits can be harvested and still ensure good quality after transport, shipping, and marketing.

Soluble Solids Concentration: SSC increases with maturity and ripening. Use of SSC as a maturity index alone is limited by variation among varieties, production area and season (Dann and Jerie, 1988; Kader and Mitchell, 1989a). For example, in 1960, when dark color plum varieties were introduced to the industry by the University of California, soluble solids content was recommended as a satisfactory maturity index. It was used briefly by the Plum Committee for "Laroda", "Queen Ann" and "Nubiana". However, immediately there were a lot of complaints about individual growers not being able to meet the minimum maturity index and the index was dropped (Mitchell, 1991). Large differences in SSC among varieties have been reported (Mitchell et al., 1990; Mitchell *et al.*, 1991). Even fruit at different positions within the canopy (Mitchell et al., 1990; Mitchell *et al*., 1991) showed significant differences in SSC (Dann and Jerie, 1988; Mitchell *et al*., 1990). SSC cound be a good quality index.

Titratable acidity: Stone fruits lose acidity during maturation and ripening. This maturity feature is also affected by cultivar and seasonal variability (Boggess *et al.*, 1974; Rood, 1957; Salunkhe *et al.*, 1968). and measuring it is more complicated than measuring SSC. The ratio of SSC:acid content has been found to be more closely related to quality than acid content or SSC alone but it still varied between years (Kader *et al.*, 1982; Kader and Mitchell, 1989b; Lill *et al.*, 1989; Meredith *et al*., 1989).

Color: Fruit color is determined by the various pigments present in the skin and flesh tissue (Rood, 1957; Stembridge *et al.*, 1972). As fruit matures and ripens, color changes from green to red or yellow. Since development of red color in nectarines and peaches depends on exposure to light, the fruit's position in the tree influences its degree of red coloration (Kader and Mitchell, 1989b; Mitchell *et al.*, 1979; Romani and Jennings, 1971; Ryall and Pentzer 1982). Changes in ground color (background) or flesh color are not affected by sunlight and, thus, are more dependable indices of maturity.

In the 1977 fruit season, the Postharvest Group (University of California, Davis) started a detailed program to study the relationship between ground color, fruit quality and taste (Mitchell *et al.*, 1977). Since then, research has constantly been carried out as part of the stone fruit quality handling program supported by CTFA (California Tree Fruit Agreement) and led by Mitchell (Kader and Mitchell, 1989b; Mitchell *et al.*, 1877; Mitchell and Mayer, 1984a; Mitchell and Mayer, 1984b; Mitchell *et al.*, 1979; Mitchell *et al.*, 1980; Mitchell, 1986; Mitchell *et al.*, 1990; Mitchell, 1991; Mitchell *et al.*, 1991; Mitchell, 1987). In the USA, extensive study of changes in ground color of peaches and nectarines has led to the development of color chips for maturity determination in California (Mitchell *et al*., 1977; Mitchell *et al*., 1979; Mitchell, 1986; Mitchell *et al.*, 1990) and in South Carolina (Delwiche, 1987; Delwiche and Baumgardner, 1983; Delwiche, 1986; Delwiche and Baumgardner, 1985; Miller and Delwiche, 1988; Upchurch *et al.*, 1988).

In the California stone fruit industry the CTFA, which implements the federal marketing order, publishes annually the minimum maturity requirements for more than 170 peach and nectarine cultivars based on external ground color (that is, the disappearance of green and the formation of yellow color). For plums, overall skin color is widely used to determine maturity. CTFA also publishes annually the minimum maturity requirements for more than 100 plum cultivars on the basis of surface color and firmness (Kader and Mitchell, 1989b). In the case of full dark red plum cultivars, maturity can be related to the intensity of red surface color (Mitchell and Mayer 1984a; Mitchell and Mayer, 1984b). Color charts have been designed and are available from CTFA. In the orchard, the grower is responsible for deciding whether or not the crop has reached the proper minimum maturity for harvest.

In the Southeastern states, a high correlation between ground color and/or flesh color with SSC and firmness has also been reported for peaches (Sims and Comin, 1963; Stembridge *et al*., 1972), indicating that ground color could be used as a minimum maturity index. In South Carolina, for 13 peach cultivars tested, ground color at harvest correlated better with sensory panel ratings than did flesh firmness, and there was little variation among the cultivars (Delwiche and Baumgardner, 1983; Delwiche and Baumgardner, 1985).

The influence of ground color as a maturity index on postharvest quality has been widely studied on clingstone peach cultivars (Kader *et al*., 1982) and fresh peaches and nectarines (Mitchell *et al*., 1977; Mitchell *et al*., 1990; Mitchell *et al.*, 1991; Mitchell, 1987). Both researchers have shown that more mature fruit have better skin color, flavor, flesh color (less green), softer flesh, higher soluble solids concentration, and lower titratable acidity than less mature fruit. Similar information has been published by other researchers in different states (Baumgardner and Delwiche, 1983; Boggess *et al*., 1974; Delwiche, 1986).

Multiple Indices: In some cases, ground color is not satisfactory as a single maturity index, it may be more useful in combination with other indices. In California, a series of new varieties in which red coloration masks the ground color are limiting the use of ground color as a minimum maturity index. For these cases, Mitchell claims that flesh color could be useful as a destructive minimum maturity index to insure optimal fruit quality (Josan and Chohan, 1982) as it is recommended for clingstone peaches (Fuleki and Cook, 1975; Kader *et al.*, 1982). In South Africa, due to color variation from season to season, it is recommended to use flesh firmness in association with ground color as the only reliable method for establishing minimum maturity Visagie and Eksteen, 1981).

FINAL COMMENTS

During the last decade, extensive information covering fruit maturity, ripening, development of maturity indices, storage trials and taste panels for peaches, plums and nectarines has been reported. Studies focusing on understanding maturity indices and the ripening process of new full red color peach cultivars and nectarine cultivars and full black color plum cultivars are required. Non-destructive determinations of SSC, dry weight, flesh color, sugar and acid content by using near infrared light (NIR), magnetic resonance (MR), and light transmittance (LT) techniques could become available in the near future (Mitchell, 1991). Thus, traditional destructive fruit measurements could become non-destructive measurements. If this new technology becomes available, it will induce major changes in the stone fruit industry regarding determination of maturity indices and quality attributes.

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