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A Review and Background of the Avocado Maturity Standard

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It is difficult to know in advance whether an avocado fruit is mature enough to harvest because external appearance of avocado fruit gives no clue to the stage of maturity. A taste panel analysis is the only true test of commercial maturity; but taste testing is expensive, and a delay of several days for softening is needed before the fruit can be tested. Thus, a simple objective test which is closely correlated with the taste testing results is needed. Many different properties of the avocado fruit have been tested for use as a maturity standard by many investigators. The changes in these properties during the maturation period have been correlated with improved taste in ripened fruit.

Oil Content

It has been long recognized that there is a close relationship between the oil content and the development of an avocado fruit. One of the most outstanding features of the avocado fruit is that the oil is so rich that the fruit has been called "Mantequilla de Pobre (Butter of the Poor)". Church (1921-1922) and Church and Chase (1920-1921) showed that the oil content increased rapidly as the fruit of eight avocado varieties matured. As a result of their study, the Avocado Standardization Bill No. 422 of California was signed and became effective July 24, 1925 (Standardization Committee Report, 1924-1925). A fruit was defined as legally mature when the oil content reached 8% by weight. However, the maturity standard was not based on formal taste tests; and there were large differences in oil content among different varieties. The legal definition encompassed all varieties because a different oil standard for each different variety would increase confusion and present difficulties in enforcement (Christie, 1939; Christie, 1945).

Hodgkin (1928), of Calavo Growers, found that all California varieties passed the 8% oil content before they reached maturity. He also identified the percent oil for different varieties at the point each attained reasonably good taste and concluded that the legal standard was too low for many varieties. Therefore, the Calavo standard was set, based on satisfactory taste quality. As a consumer, inspector Roche (1937) did not believe that Fuerte avocado fruit were properly mature when they contained 8% oil. He stated that most Fuertes at 8% oil bore the flavor of "low grade laundry soap" (Roche, 1937).

Proposals to change the 8% oil content standard have stirred great controversy. Christie (1939) was opposed to any change in the 8% standard because lowering the allowable oil content would increase the quantities of immature fruit on the market; and increasing the minimum oil content would reduce the length of the picking period, causing a sudden unprofitable overabundance of avocados on the market.

Hodgkin (1939) published the results of 16 years of tests comparing oil content and the palatability of individual varieties by taste panels. It was found that the higher the oil content was, the better the taste panel results were. However, many investigators (Harkness, 1954; Hatton et al., 1957a; Erickson et al., 1970) pointed out that the percentage of oil varied widely from fruit to fruit; and that wide variation existed throughout fruit development, even within a variety and within a grove. This variation would be the most disconcerting feature about using oil content as a measure of maturity. Bean (1956) indicated that the oil was a storage product rather than an active metabolite in the fruit, and concluded that oil content reflected growing conditions more than fruit developmental stages.

There is an interesting relationship between the percentage of oil and the percentage of water during avocado fruit development. Stahl (1933a; 1933b) found that the percentage of oil increased with maturity, while the percentage of water decreased. Pearson (1975) indicated that the sum of the percentage of oil and the percentage of water during maturation was fairly constant. This implied that the rate of increase in oil was the same as the rate of decrease in water during fruit development. Davenport and Ellis (1959) showed that oil droplets accumulated in the vacuole of the cells. Thus, they theorized that the decrease in the water content of the fruit during development may be due to the displacement of water from the vacuoles by the accumulating oil.

Swarts (1976a) also examined the close relationship between oil and water content. He described a simple method for estimating the oil content by subtracting the water content from a constant (the sum of percent oil and percent water) (Swarts, 1976b). He also developed a rapid method of determining the water content of avocado fruits, using an infrared lamp (Swarts, 1976c) and a microwave oven (Swarts, 1978).

Assigned Picking Date

In Florida, where avocados of the West Indian race have been grown extensively, an assigned picking date is used based on fruit size. Stahl (1933b) studied the composition of Florida avocados in relation to maturity. He found an increase in oil content during development of the fruit. However, the oil content did not reach the same levels as in California, possibly due to differences in varieties. He found the the typically high oil compositions of some varieties did not necessarily correspond to the better tasting varieties. Trapp and Pollock, of the West Indian varieties, were good for eating and low in oil content. Wolfe et al. (1934) indicated no correlation between high oil content and good quality, and emphasized that the time of year was the best indicator of proper maturity.

Harding (1954) studied maturity with a taste panel. He found a close relationship between fruit maturity, a definite picking date, and weight within a variety. The avocado industry of Florida established a Marketing Agreement No. 121 (1954), based on the work of Stahl (1933b) and Harding (1954), with the U.S. Department of Agriculture in 1954. This agreement regulated the minimum picking date and weight for each variety.

Soule and Harding (1955) considered a series of regression analyses of picking date, fruit weight, and fruit diameter against flavor rating. Picking date always gave very high correlation coefficients. Fruit weight or diameter in regression analyses gave lower correlation coefficients than picking date. Many workers (Hatton and Campbell, 1959; Hatton and Reeder, 1965; Hatton et al., 1957a; Hatton et al., 1957b; Ruehle, 1958) were involved in considering several maturity indices. They concluded that maturity, on the basis of minimum fruit weights and diameters, in conjunction with picking dates, appeared to be the most satisfactory method for Florida avocados.

Hatton et al. (1964) improved details of the maturity standard based on minimum weights and diameters which fruit must attain by designated dates for each variety. As the season progressed, restrictions on the fruit weight and diameter were gradually lowered and eventually removed. Large fruit usually had higher flavor ratings than small fruit when tested early in the season at the time minimum acceptability had been reached. As the season advanced and fruit became more mature, the difference in flavor between larger and smaller fruit became less pronounced.

The advantages of this assigned picking date system are the good correlation of picking date to the palatability of fruit and the fact that there is no need for testing equipment. The disadvantages of this method include varietal differences, geographical influences, and the possibility that maturity dates could be different from season to season.

Dry Weight

The dry weight is the mass of the sample that remains after water is completely removed by any method. Haas (1937) noticed that the percent dry weight of the avocado flesh increased with maturity. Morris and O'Brien (1980) found a close relationship between oil content and dry weight. The increase in percent dry weight during maturation is mainly due to the increase in percent oil. However, it is far easier to analyze percent dry weight than percent oil content, and new regulations based on dry weight were formulated in New South Wales, Australia. The regulation defined a minimum maturity of avocado fruit as 21% dry weight. Morris and O'Brien (1980) also described the procedures for percent dry weight analysis. Their method is so simple that any farmer can easily determine the maturity of his avocado fruit.

Specific Gravity

The ideal method of determining maturity should be simple and quick, with little expense and no injury to the fruit. This could be accomplished by measuring specific gravity of the fruit if variation were not high. In general, there is a decreasing trend in specific gravity with maturity (Appleman and Noda, 1941; Church, 1921-1922; Church and Chase, 1920-1921; Harkness, 1954; Stahl, 1933a; Stahl, 1933b). However, the large variation in specific gravity among individual fruit, and fluctuation in the downward trend with maturity, preclude its use for accurate maturity measurements (Hatton and Campbell, 1959; Hatton et al., 1964).

The large variability in specific gravity was affected not only by variable composition but also by differences in seed size and seed cavity (Stahl, 1933a; Stahl, 1933b). The lower the water content, the lower the specific gravity. The seed size varied widely in the fruit. Fruit with loose seeds had a low specific gravity. The specific gravity of the pericarp showed less variability than that of the whole fruit (Appleman and Noda, 1941).

Seed Coat

Erickson (1966) examined the seed coat thickness of Fuerte avocado fruit. The seed coat was white, thick, and fleshy when the fruit was immature. As the fruit matured, the thickness of the seed coats decreased rapidly. Later in the season, the seed coat began to shrivel and turn brown to reveal vascular tissue. The decrease in fleshiness and thickness of the seed coat was considered to be an indication of fruit maturity. Observations of changes in the seed coat have been used for unlisted minor varieties in Florida (Hatton and Campbell, 1959).

However, high variation in these changes limited the use of seed coat condition as a reliable maturity index. Brown seed coats were found frequently, even in immature fruit. The variation of time in the changes of the seed coat was also high with different varieties and different seasons (Hatton et al., 1964). Similar changes in the seed coat were found in abnormal fruit such as an aborted, heat-damaged, or stored fruit. Therefore, the usefulness of seed coat changes as an indicator of maturity was restricted to only freshly picked normal fruit (Erickson, 1966).

Blumenfeld and Gazit (1970) showed the influence of the seed on the development of fruit. High cytokinin activity of the seed coat was found during the early stages of fruit development. The activity decreased during maturation, and disappeared completely by the time the seed coat shrivelled when the fruit matured. The vascular system in the seed coat also became dry and was not able to transport materials. Therefore, there was limited interchange of materials between the embryo and the pericarp (Blumenfeld and Gazit, 1974).

Sugar Content

Sugar content is relatively low in avocado fruit but is interesting because it disappears as the fruit matures. As the season advances and the fruit becomes more mature, the percent total sugar decreases (Biale and Young, 1971; Church and Chase, 1920-1921). According to Church (1921-1922), the decrease in sugars was almost as good an indication of maturity as the increase in oil during fruit development. Both appeared to be intimately connected with the fruit maturation.

Bean (1958) tested the sugar variation in two varieties (Zutano and Mexican seedling). In both, he found higher amounts of sugars in the early stages than in late stages of growth. A comparably sharp drop in sugar content occurred toward the end of the growing season.

This abrupt change corresponded to maturation in the Mexican seedling, but not in Zutano fruit. In both varieties, sugar content decreased during storage periods, too.

Hatton et al. (1964) described the inconsistency in the amounts of sugars present at maturity. Haas (1937) also showed the variation of sugar content in avocado fruit. More sugars were found in the stem halves of avocado fruit than in the apical halves.

Numbers of Days for Ripening and Percent Loss in Fruit Weight

The number of days required for avocado fruit to ripen under uniform conditions has generally decreased with successive picking dates (Church, 1921-1922; Hatton et al., 1964). However, the downward trend in the ripening time was too gradual to be used as a maturity index, and the variation in number of days for fruit to soften precluded its use as an accurate index (Hatton and Campbell, 1959). During the ripening process, the percent loss in fruit weight decreased with maturity. Fruits become shriveled when a large amount of weight is lost early in the season.

Percent loss in fruit weight and the number of days required to ripen, individually or in combination, were not accurate measurements of maturity due to the large variation in both (Soule and Harding, 1955; Hatton and Campbell, 1959). Another objection to the use of the number of days required for softening as a maturity index is the length of time for this determination. One or two weeks are necessary for this determination, during which the growers would lose valuable marketing time.

Electrical and Optical Methods

It would be tremendously advantageous to find a non-destructive physical method which could be utilized in a packing line in such a way that all the fruit would be automatically tested and sorted for maturity. The idea of a non-destructive physical test is attractive, but still idealistic and elusive at present. Some electrical and optical methods have been tested for this purpose.

Bean et al. (1960) measured impedance, which was defined as the sum of capacitive reactance and conductive resistance, during avocado fruit maturation. There was a tendency to drop in impedance near maturation, but the variation among individual fruit was too large to be a reliable index. Moreover different parts of the fruit showed a relatively wide range of resistances. Another difficulty with this test was the requirement for insertion of two small electrodes into the fruit flesh. This procedure caused injury and destroyed the fruit for marketing.

In many kinds of fruit, an appreciable color change occurs as the fruit mature. Thus, changes in reflectance or transmission can be used as a nondestructive measure of maturity. However, most avocado fruit do not have definite visible changes in the color of the flesh or skin during development (Zachariah and Erickson, 1965).

Erickson and Porter (1966) investigated the possibility of using infrared reflectance as a non-destructive method for maturity determination. While the signal obtained from infrared reflectance was too weak, they obtained promising results when they measured the infrared absorption of wax removed from the fruit surface with chloroform. The peak ratio of 13.93/6.85 micrometer in infrared absorption had a high correlation with increasing oil.

Heat capacity and ultrasonic measurement were considered in a maturity study by Bean (1962). It is not likely that these methods are of practical value because measurements took an extended time and the sound waves were subject to reflection.

Moreover, various layers of the fruit affect the measurement within the fruit.

Other Less Successful Methods
A number of other properties of the avocado fruit have been tested as maturity standards, including enzyme activity. Several investigators (Chase, 1921-1922; Bean, 1956; Zauberman and Schiffman-Nadel, 1972) explored changes in enzyme activity as a potential indicator of maturity, but no practical method was developed.

Corking of lenticels on the fruit surface generally became more visible as the fruit matured. However, changes were too gradual and varied to be of much value as a maturity index (Hatton and Campbell, 1959).

When the various parts of the fruit were analyzed, the percent seed increased, the percent skin decreased, and the percent flesh part remained constant throughout development. But the changes were small and variable (Stahl, 1933a; Stahl, 1933b).

The mineral content of the avocado fruit was relatively low when compared to other constituents. The change of mineral components during fruit development was too small to be used as a maturity standard (Stahl, 1933a; Stahl, 1933b).

Appleman and Noda (1941) studied changes in the iodine number of oil during fruit development. This number was highly variable during the maturation period.

The amount of protein increased with increasing maturity but the change was too inconsistent to be used a measure of maturity (Stahl, 1933a; Stahl, 1933b).

Changes in phenolic compounds or soluble solids were not consistent during maturation, and there was no difference in firmness and flesh color throughout the development period of the fruit (Hatton et al., 1964).

Concluding Remarks
Since 1925, an 8% oil standard has been used in the California avocado industry because oil content is high enough to be measured and its increase is closely related to the development of the fruit. However, oil content corresponding to acceptable taste is different for each variety, and 8% is too low to be a good maturity index for many varieties in California. Moreover, determination of oil content is not a simple process, especially for growers who lack the necessary laboratory and equipment.

Maturity based on assigned picking dates appears to be satisfactory in Florida, where the avocado growing region is small when compared to California. However, the avocado growing area in California is widely spread out in regions of different climatic conditions. Thus, it is necessary to divide this large area into several climatic regions. However, geographical competition and marketing problems could be expected. Another difficulty would be the micro-climatic variation within a small area.

Percent dry weight increases during fruit development and the increase is mainly due to the increase in oil. With a microwave oven, the analysis of dry weight is easier and quicker than oil analysis. This method is so simple that growers can determine the percent dry weight at home. Therefore, a dry weight maturity standard is recommended as a replacement for the present 8% oil requirement. This method would be convenient for both growers and packers.

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