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11. FRUIT RIPENING

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a. Determination of Picking Date

With the expansion of avocado exports and the Marketing Board's efforts to advance the picking season, we were asked in 1965 to determine objective standards for estimating fruit maturity and to carry out tests on fruit designated for export. Ettinger, being the earliest commercial variety harvested, posed the greatest problem in determining a picking date.

An avocado fruit can be described as commercially ripe if it fulfills the following conditions: The fruit softens properly without much shriveling, the taste and texture of the flesh are acceptable or better, and the flesh after cutting looks attractive. Early in the trials it was found that the degree of shriveling depends on the temperature and relative humidity at which the fruit is kept, and that it can be avoided by keeping the fruit under suitable conditions. Non-shriveling has therefore been removed from the list of requirements. The decisive factors are the palatability and appearance of the flesh. In a preliminary survey it was found that the best criterion for determining the degree of maturity of our varieties is the oil content of the flesh. Immature avocado flesh contains approximately 2-4% oil. As it matures, the percentage of oil increases rapidly, reaching 15-20% and even more in most of the varieties commonly grown in Israel.

Many tests to correlate oil content with flesh quality were performed in the years 1965-68. In the light of the results it was decided that one minimal value for oil content cannot be fixed for all varieties, and that oil analyses and inspection need to be performed only at the beginning of picking of each variety.

The following temporary regulations for export practice were issued in 1968 on the basis of our results (Table B. 11.1).

TABLE B. 11.1

TEMPORARY REGULATIONS FOR PICKING OF AVOCADOS INTENDED FOR EXPORT

Variety	*Earliest picking date for export*	*Earliest export date without limitation*	*Minimal oil content required in fruit (%)*
Ettinger	Sept. 1	Oct. 20	9
Fuerte	Oct. 1	Nov. 15	10
Benik		Dec. 15	10
Hass		Jan. 15	10
Anaheim		Jan. 15	8
Nabal		Feb. 15	7

During the period of controlled export, representative fruit samples from orchards intended for picking are analyzed for their oil content. If the oil reaches the required value, permission for picking for export is given. Most analyses were made with the early variety Ettinger. In this variety, a good correlation was found to exist between the size of fruit and its oil content — in fruit from one particular orchard. The oil content of-fruits of different size is determined, and picking instructions are issued according to fruit size. In late-ripening varieties the correlation between size and oil content was not found to be good enough to enable its use for picking practice.

Oil content in the firm fruit is determined by the refractometer method. Two separate determinations are made per fruit sample, and each determination represents a mean value for five fruits. The fruit is cut symmetrically lengthwise and a thin layer is removed from the cut with a grater. Grated flesh from five fruits is mixed. 7.5 g of the gratings + 5 ml Halowax oil (1-chloronaphthalene) + 170 ml water + 5 g Na_2CO_3 are blended for 5 minutes in a Waring Blendor at high speed. Two 50 ml samples of this blend are centrifuged for 10 minutes at 12,000 rpm. Three layers are formed after centrifugation: the lowest a mixture of avocado and Halowax oils, the middle one a stable solid mass of cell debris, and the top one water. The water is poured off, the solid mass is perforated, and a drop of oil is removed for determination of its refractive index. There is a big difference between the refractive index of Halowax oil and avocado oil. Thus, the higher the oil content in the avocado, the greater will be the deflection in the R. I. of the Halowax oil. The R. I. values obtained are converted to percentage oil in the flesh with the aid of a calibration curve prepared by testing the deflection of R. I. of Halowax oil by weighed quantities of avocado oil (Fig. B. 11.1).

In 1967, approximately 600 oil content analyses were performed by the refractometer method described, concurrently with the accepted oil analysis Soxhlet extraction with petroleum ether. Most of the tests were carried out on Ettinger fruits. The results obtained by both methods were very similar (Fig. B. 11.2).

The method described above has not been found suitable for soft fruit. We are now trying to adapt it for use with such fruit.

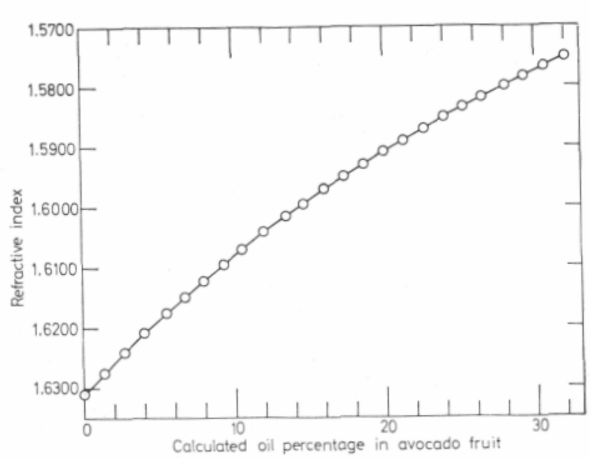

Fig. B.11.1. Calibration curve. (Based on R.I. of known avocado and Halowax oil mixture and calculated as R.I. of 5 ml Halowax oil and 7.5 g avocado flesh blend.)

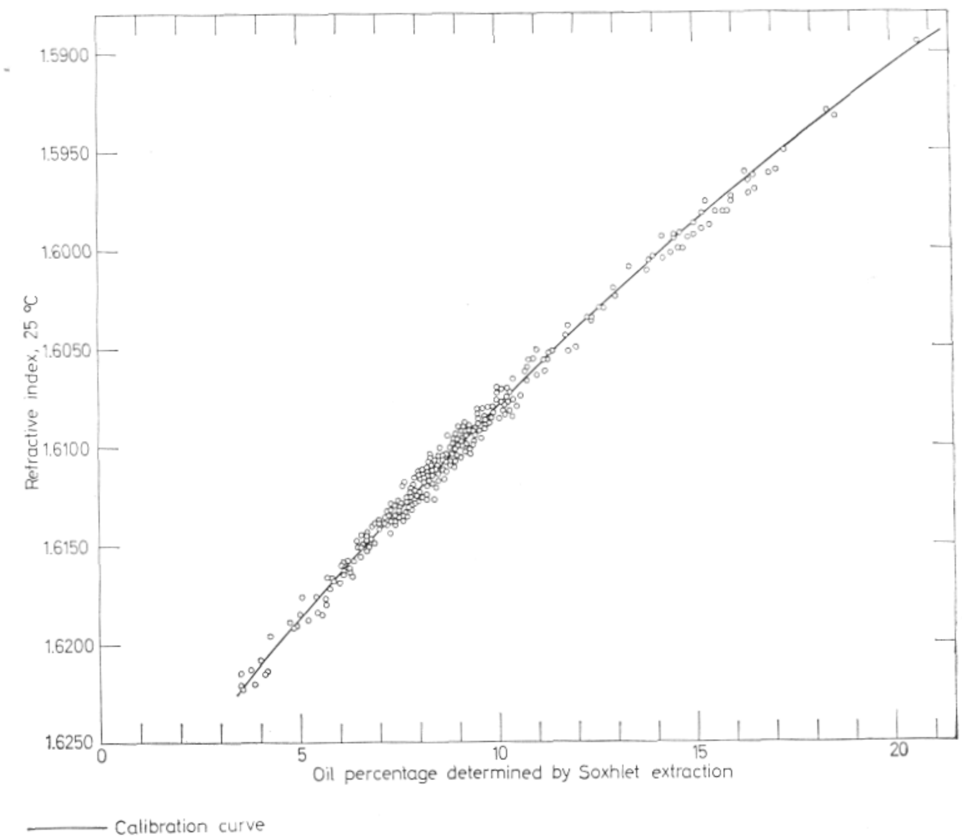

Fig. B.11.2. Correlation between values of oil content obtained by extraction with petroleum ether (Soxhlet method), and R.I. of the blend of 5 ml Halowax oil and avocado oil from 7.5 g of Ettinger avocado flesh.

b. The Problem of Partial Fruit Softening

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This problem was first described in Israel and has not yet been reported from anywhere else in the world. Parts of the fruit flesh remain hard while the rest softens normally. In bad cases the hard part may amount to half the weight of the fruit while in the least-affected fruits only a minute portion of the flesh does not soften. The position of the hard spot is always close to the seed, generally near the tip of the seed and on the raised shoulder side of the fruit. In bad cases, the hard region completely surrounds the seed. The outer layer of the flesh always softens and therefore even in ripe fruit the defect cannot be felt by hand. In some orchards defective fruit may amount to 25-30% of the crop.

Among the varieties grown commercially in Israel, the defect has appeared only in Fuerte, and not in Ettinger, Benik, Hass, Nabal or Anaheim. Partial softening has been found in all ten Fuerte types present in Israel as well as in seven other varieties (Lewin, Scotland, Bonita, Corona, Helen, Rincon and Irving). Most of the affected varieties belong to the Mexican x Guatemalan hybrid group, and only a few of them are Guatemalan.

Up to now, we have not found any characteristic of the firm fruit which can indicate its inability to soften normally. Both the anatomy and cell wall structure of non-softening tissue is similar to that of normal tissue. The respiration rate of the defective fruit is identical with that of normal fruit. All experiments to find a practical method of identifying defective firm fruit have been unsuccessful. However, we did find that, on the average, defective fruit is heavier and has a lower specific gravity than normal fruit. Since there is much overlapping in these characteristics between the two groups, they cannot be used for identification of defective fruit, Seed size is no different in the defective fruit. X-ray photographs and measurement of electrical conductivity did not uncover anything special in the defective fruit.

Early in the study it became clear that the defect appears more frequently when the yield is low, when fruit is big and more mature, and at late harvest. The defective fruits tend to soften within a relatively short time of picking. These data indicate a positive, though not absolute, relationship between the incidence of the defect and the maturity of the fruit. On the one hand, one can find defective softening in December, when the degree of maturity is not advanced (small fruit, 12-14% oil, seed coat intact); on the other hand, one can find normally softening fruits after the picking season is over, when they are generally considered 'over-ripe' (large fruit, 25-30% oil, germinating seed). We assume, therefore, that an advanced degree of maturity is not directly responsible for the development of the defect.

The problem exists in all parts of the country in orchards planted on many different types of soil. The extent of the defect varies greatly from orchard to orchard and the variability often bears no relationship to the degree of maturity. The most frequent appearance of the defect was found in orchards planted on sandy loams where yields are low.

To avoid picking and marketing defective fruit, special picking arrangements have been made for the Fuerte variety and, for practical purposes, the problem has been solved. Picking in orchards which tend to produce defective fruits must be completed by mid-November if the yield is low and by the end of December if the yield is medium; but if the yield is heavy, fruits may be left safely on the tree until March. If there is any doubt, a representative sample should be picked and examined after softening.

The basic reason for this defect and the fact that it appears only in Israel, is as yet a mystery. Relying on a number of clues, we have suggested that the defect results from a lack of balance between inorganic elements in the pericarp, which gets worse as the fruit ripens. Laboratory analyses gave contradictory results. Fertilizer experiments have yielded no positive results, so far, since the yield in the experimental orchard rose sharply in recent years and the incidence of non-softening has dropped almost to nil.

c. Response of the Fruit to Pre-and Post-Harvest Ethylene Treatments

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This study was carried out as part of a project investigating the role of growth regulators in the development and ripening of avocados. The project was financed by a grant from the U.S. Department of Agriculture. The studies to be described were carried out in 1967/68 and 1968/69.

It is well known that keeping avocados in an atmosphere with ethylene will bring about their softening within a number of days of treatment. An almost maximal effect is obtained when avocados are held in 10 ppm ethylene for 24 hours. The picked fruit responds at a slower rate to concentrations as low as 0.1 ppm. This is approximately the concentration of ethylene found in the internal atmosphere of the unpicked fruit. In explaining the fact that fruit does not soften on the tree, it has been postulated that unknown substances supplied to the fruit by the tree raise the threshold of sensitivity to ethylene and, therefore, the fruit does not respond to its own ethylene.

To test the sensitivity of unpicked fruit, mature avocados were enclosed in polyethylene bags and exposed to a constant flow of air containing 50 ppm ethylene. When this treatment lasted up to 48 hours, no change was observed in the fruit. Prolonged treatment caused fruit drop beginning 5-6 days after the start of the treatment. The fruit dropped was completely firm. These results show that ripening processes do not start in the fruit while attached to the tree even when the concentration of ethylene is raised to a level which causes the immediate activation of ripening processes after harvest.

In 1968/69 we examined the response of harvested avocados to 24-hour 100 ppm ethylene treatments given at various times after picking. We found that when the treatment was given immediately after picking, there was no response. The softening of fruits receiving treatment starting 24 hours after picking was markedly hastened, but the response was not uniform. Fruits receiving treatment starting 48 hours after picking gave full and uniform response. These results were obtained in several repeated trials with mature fruits of the varieties Hass and Nabal. Similar experiments with Fuerte did not give such clear results because the controls softened as rapidly as ethylene-treated fruits. (This phenomenon remains unexplained, but was common in the 1968/69 season.)

The above results may be explained as follows: The substances preventing unpicked fruits from responding to ethylene do not disappear immediately on picking. They continue to exert their influence for some time after harvest. The period in which picked fruit does not respond to ethylene may vary with its stage of maturity and its growing conditions. This variability seems to be responsible for the differences often found in the response of harvested fruit to ethylene treatments.