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AVOCADO FRUIT MATURITY

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Identification of criteria for maturity has been a vexing problem for many different fruit. The determination of a minimum maturity standard is an economically important decision because the price of fruit is usually higher early in the picking season. Growers are anxious to take advantage of a good market, but consumers are disappointed when immature fruit find their way to the market, which in the long run is a disadvantage to the grower as well. This is especially true with avocado fruit where outward appearance gives no clue as to the stage of maturity.

Maturity can be defined as the stage of development at which the fruit, after detachment from the tree, will ripen and result in a product desirable for eating. The characters which lead to a fruit desirable to eat include not only a particular balance of flavor and aroma, but also particular colors and textures which are not apparent until ripening is complete. Thus it is generally not possible to determine the time of maturity on the basis of characters by which judgment is finally made by the consumer. Taste panel analysis of the ripened fruit is the only true test for maturity, a determination which is rarely commercially practical.

Most maturity standards depend on measuring the change in concentration of one component of the fruit for which increase or decrease has been correlated with an improved taste of the ripened fruit. The component measured may or may not be a determining factor of the complex of characters upon which taste maturity is finally judged. Following such trends may allow prediction of the time the fruit will be mature which is what the grower and processor need to know.

In the specific case of avocado fruit, Church (6) and Church and Chase (7) showed in 1922 that oil content increased in 8 varieties of avocados throughout the development and maturation periods. As a result of these and subsequent similar studies where oil content was related to maturity by informal taste tests, the Avocado Standardization Bill was approved in 1925 which defined maturity as the time in all varieties when they contained 8 % oil by weight. The standard was not based on formal taste panel results and the correlation of improved taste with increased oil relied on composite samples from 8 varieties only. The law was made to cover all varieties because it was thought to be too difficult to enforce a regulation which had different criteria for each variety. Eight percent oil was recognized as early as 1928 by Hodgkin (12) as being "too low for some varieties, but not too high for any California variety." The oil content is still the most generally used criterion of maturity in exporting countries. South Africa uses the 8% standard although workers there report that Fuerte fruit in South Africa were tasteless until they reached the 12% oil level (personal communication). Workers in Israel (10) recommend 7 to 10 % oil depending on the variety; in Australia, Fuerte, Edranol, Zutano, and Rincon fruit can be sold only at 15% oil, and 8 other commercial varieties

were considered mature at 10 % (13). In California, Calavo grades of Fuerte fruit were long required to test 12 % oil. Thus it appears that in major growing areas of the world, Fuerte fruit at least, often appear to be immature at the 8% oil level.

In Florida where the West Indian race of avocados predominates, an assigned picking date is used based on size of fruit and taste tests. Many of these varieties contain less than 8% oil even late in the picking season.

Maturity based on 8 % oil content has never been a completely satisfactory standard. Church and Chase (7), in fact, did not recommend any standard based on their analytical data and all but one of the samples which they analyzed in December contained more than 8 % oil. With new varieties, the standard has come under increasing criticism. Of the varieties studied by Church and Chase (7) and by Appleman (1), only Fuerte is still extensively cultivated. Even when initially formulated, it was recognized that 8 % was too low for some varieties, but it was thought to be impractical to propose a different standard for each variety and there was concern that the picking season would be compressed into too short a period if the percentage was set higher for all varieties. Oil determination has the further disadvantage that it is slow, expensive, and destructive of fruit.

A number of other properties of the avocado fruit have been tested as maturity standards. Chase (5) explored changes in the activity of several enzymes as potential indicators of maturity, an idea also explored by Bean (2) and by Zauberman and Schiffman-Nadel (15), but thus far no enzyme change has been identified which is diagnostic of maturity. Changes in the concentration and properties of other constituents, especially sugars, have been studied extensively (4), but none has proven reliable as a maturity index for avocado fruit. Change in specific gravity was studied by Church and Chase (7) as well as by others more recently (14), but the change is small and is probably related primarily to oil content. Physical tests including sound transmission, heat capacity, electrical capacitance, electrical impedance, and light transmission were explored by Bean (3) and by Erickson (14). In most cases the changes measured were small and again probably reflected mainly the oil level. Changes in seed coat thickness and color were shown by Erickson (8) and by Hatton (11) not to be related reliably to maturity. Likewise, changes in lenticel corking or cuticular wax (Erickson and Porter [9]) have not proven useful.

In 1975, we noticed, in careful measurements of the growth rate of attached fruit, a change in the rate of growth close to the time fruit contained 8 to 10% oil. We have continued growth measurements along with taste tests for three seasons to determine whether maturity may be predicted by the change in growth rate or even if a picking date may be reliably assigned by variety and district.

Methods

Three size classes of Fuerte and Zutano fruit were tagged on trees at Irvine, Fallbrook, and Corona, California in July. Five fruit of each size class were tagged on each of four

trees distributed across the plot. Fruit volume, length, and diameter were measured at 14 day intervals. Between September 10 and January 15 four fruit of each size class, but not the fruit being measured, were harvested at 14 day intervals, ripened, tasted, and assayed for oil content. While it would be desirable to use more fruit of each size for oil and taste tests, four fruit represents the sample size used by maturity inspectors. Further, the trend was established using data of all nine picks for regression analysis. During 1976 and 1977, taste was evaluated by only two or three persons, while in 1978 a taste panel of 18 persons was used.

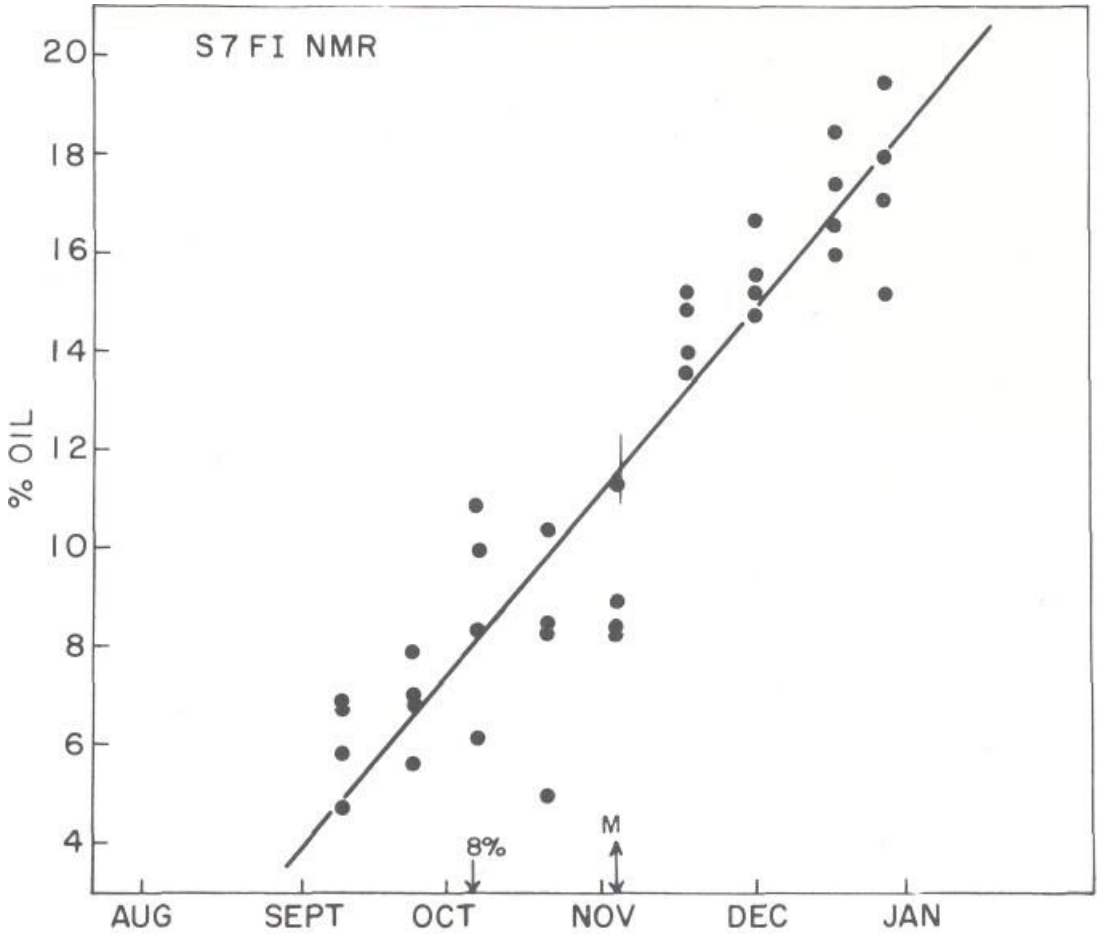

Figure 1. Percent oil in Fuerte avocado fruit at Irvine, California, throughout the 1977-78 season for the "small" classification of fruit. Average fruit weight on the first pick on September 8 was 3.7 oz and increased to 7.2 oz on January 13. The line represents the regression of all points. The arrow marked "8%" denotes the date average fruit accumulated 8% oil. The arrow marked "M" is the date taste scores reached the mature value.

Results and Discussion

Oil content was measured on individual fruit rather than pooled samples. The solid points in Figure 1 show the percent oil in each of four fruit for each of nine picks for the

small Fuerte fruit in 1977. The solid line is the linear regression for all of the fruit and may be taken to represent the average oil content for a composite sample for any particular time. On the basis of the regression line, one would conclude that 8 % oil level was reached on October 5 which would represent the oil content of a composite sample of a large number of fruit. However, it is clear that the variability between individual fruit is very great. For the October 6 pick, one fruit contained 6.2 and another 10.8% oil. Differences of three percentage units were common in both Fuerte and Zutano fruit at all locations and the difference in oil for a single pick was as great at 8 %. Thus even if 8 % oil was a reliable criterion of maturity, this great variability means that half of the fruit may contain considerably less than 8 % oil. While an average value of 8 % may satisfy the letter of the law, 50 % of the consumers who buy only one or two fruit would not be pleased with their purchases.

TABLE I. Fuerte Avocado Fruit Distribution of Size and Oil Content

	Size Class		
	Small	Medium	Large
Weight (oz.)	5.0-6.5	6.6-7.7	7.8-12.2
Number of Fruit	23	22	14
Max. % Oil	9.91	9.34	17.31
Min. % Oil	5.51	5.41	7.29
Average % Oil	7.18	7.85	10.32
Standard Dev.	1.23	1.11	3.22
Standard Error	0.25	0.24	0.86

On October 20,1978, 59 Fuerte fruit were picked from 4 adjacent trees at the South Coast Field Station of the University of California at Irvine. Size and oil content are shown in Table I. Fruit size varied between 5.0 and 12.2 oz. Oil content was determined on each of the 59 fruit. Percent oil in 5 to 6.5 oz. fruit varied from 5.5 to 9.9% . Fruit over 8 oz. in weight varied in oil content from 7.3 to 17.3 %. In this sample of 59 fruit, an inspector sampling three fruit could have found the small fruit mature and the large fruit immature based on the 8% criterion.

It is quite generally believed that large fruit contain more oil and are more mature than smaller fruit. In the above experiment, 23 fruit were put in the small class and ranged in size from 5.0 to 6.5 oz. with an average oil content of 7.2 %. The intermediate class of 22 fruit ranged in size from 6.8 to 7.7 oz. and had 7.35 % oil, which is not significantly different from the small class. In the large class of 8.3 to 12.3 oz., five of the 14 fruit contained less than 8% oil. Three fruit weighed exactly 8.7 oz. and contained 7.5,10.4 and 14.4 % oil respectively. We conclude that large fruit size is not a reliable predictor of high oil content and that the variability in oil content is so large that size cannot be used reliably as an estimate of oil content.

Growth Measurements

Growth of fruit was measured by change in (1) length, (2) diameter, and (3) volume. The latter measurement was least reproducible as well as most difficult to make and was discontinued in 1978. Length measurement was highly reproducible and easiest to make and provided the most useful data.

The growth curves for increase in length of Fuerte fruit at Irvine for the 1977 season are shown in Figure 2. The three curves represent fruit which were (1) relatively small, (2) average size, and (3) relatively large. Each curve is composed of a straight line between July 15 and August 15 followed by a curved portion and then another straight line starting in early November. Experiments in 1976 showed that the line continued as a linear function at least through March. Each curve represents the mean of 18 fruit and the vertical bars are standard errors. The arrows marked "1" denote the time that average fruit attained 8 % oil, while "2" mark the time acceptable mature flavor developed, and "3" the time of the transition from curved to linear growth. For the example in Figure 2, large fruit had 8 % oil 48 days before mature flavor developed, while small fruit accumulated 8% oil 24 days before mature flavor. For all three sizes mature flavor developed at a time very close to the time of the transition to linear growth.

Table II compares the dates at which mature flavor, 8% oil, and linear growth developed for Fuerte fruit at Irvine and Fallbrook, and Zutano fruit from Fallbrook and Corona. These data make clear that 8 % oil content correlates poorly with mature flavor while the transition to linear growth coincides well with the time of mature flavor for Fuertes at Irvine and Fallbrook as well as Zutano at Fallbrook. Zutano fruit at Corona have a somewhat different growth pattern which requires a different analysis.

Table III compares dates of development of mature flavor for two seasons for Fuerte and Zutano fruit. For a given size, difference in date of mature flavor is only 15 days for these two seasons. This suggests that it may be possible to assign picking dates, or at least a range of picking dates, which could be adjusted on the basis of growth rates to correct for unusual seasonal variations in weather conditions.

Conclusion

Oil content of avocado fruit is too variable to serve as a reliable index of maturity. In both Fuerte and Zutano fruit, 8% oil developed earlier than mature flavor in large fruit and either earlier or later in small fruit. Judged on the basis of taste, large fruit attained maturity only 5 to 15 days before small fruit. The transition from exponential to linear growth in length correlated well with development of mature flavor. Over two seasons, mature flavor developed at nearly the same time. It appears that an assigned picking date or growth rate will be much more reliable than oil determination as an index of maturity.

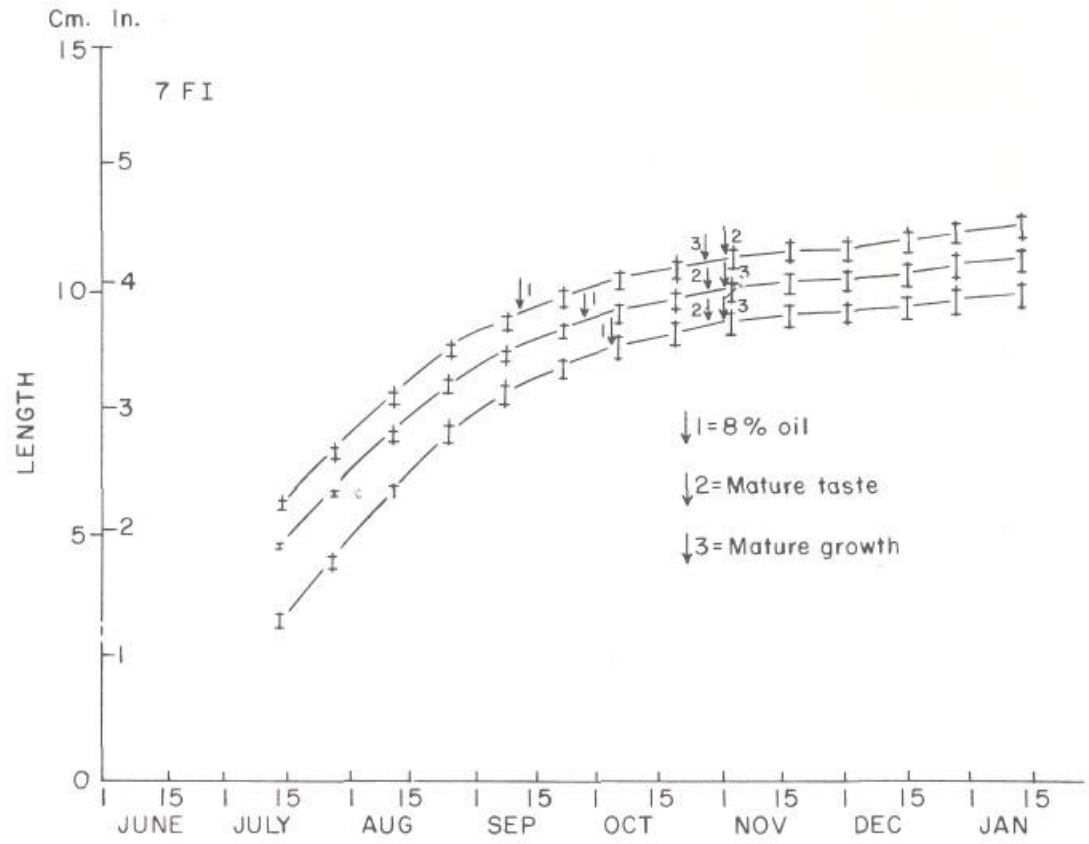

Figure 2. Growth in length of small, medium, and large Fuerte fruit at Irvine, California for the 1977-78 season. Vertical bars show standard errors of measurement of 18 fruit. Arrows marked "I" indicate the time average fruit accumulated 8% oil. Those marked "2" show the time fruit were considered mature by taste, and "3" denotes the date of maturity by change in growth rate.

TABLE II. Picking Dates Estimated by Three Methods for 1977

	Taste	Oil	Δ 1	Growth In length	Δ 2
Fuerte, Irvine					
Large	10/27	9/12	-48	10/28	+ 1
Medium	11/3	9/28	-32	11/3	0
Small	11/2	10/5	-24	11/2	0
Fuerte, Fallbrook					
Large	11/2	9/19	-45	10/27	-6
Medium	11/6	11/3	-3	11/8	+2
Small	11/8	11/17	+9	11/9	+1
Zutano, Fallbrook					
Large	11/4	10/11	-24	11/2	-2
Medium	11/6	10/24	-13	11/2	+8
Small	11/8	11/2	-6	11/8	0
Zutano, Corona					
Large	11/5	11/3	-2	10/14	-22
Medium	11/10	11/12	+2	10/16	-37
Small	11/12	11/21	+9	10/15	-28

1 is the number of days that the picking date estimated by oil differs from the determination by taste.
2 is the number of days that the picking date estimated by growth measurement differs from the determination by taste.

TABLE III. Dates of Acceptable Flavor for Two Seasons

Fruit Location	Size	Fuerte 1977	Fuerte 1978	Fuerte Fruit wt. (oz.)	Zutano 1977	Zutano 1978	Zutano Fruit wt. (oz.)
Fallbrook,	Large	11/2	11/2	10.8	11/4	10/21	12.4
	Medium	11/6	11/12	8.9	11/6	11/1	8.8
	Small	11/8	11/18	7.2	11/8	11/2	7.5
Irvine	Large	10/29	10/25	11.8		10/23	10.8
	Medium	10/29	11/4	6.3		11/7	9.7
	Small	11/3	11/9	5.1		11/21	6.8
Corona,	Large				11/5	11/10	8.1
	Medium				11/10	11/16	7.0
	Small				11/12	11/27	5.0

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