Characterization of Avocado (*Persea americana* Mill.) Varieties of Low Oil Content

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Several avocado varieties of low oil content (6.73−8.07%) from Venezuela (Booth 1, Booth 7, Ceniap 2, Figueroa, Guacara Morado, Luiz de Queiroz, Princesa, Quebrada Seca, Santa Clara, Santa Cruz, Taylor, and Tonnage) were characterized for pulp oil and moisture; weight (whole fruit, seed, pulp, and peel); length, width, and fruit shape; peel characteristics (roughness, color, and hand peeling); and ripeness time. Oil plus moisture percentages were between 87.62 and 93.71. Pulp percentage of Quebrada Seca was the lowest of the 49 varieties studied, and its seed percentage the highest. Princesa had the highest pulp percentage (76%). Seven varieties were pyriform and five ovate, seven had rough peel and five smooth peel, and four of them had purple peel and the others green. Five varieties were easy to hand peel. Peak ripening of some varieties was at 4−9 days. Princesa is the variety with the highest potential yield with 67944 kg of fruit/ha, 51675 kg of pulp/ha, 3679 kg of oil/ha, and 3016 kg of starch/ha.

Keywords: *Avocado; fruit characterization; tropical fruits; Venezuelan fruits; Venezuelan avocados*

INTRODUCTION

Avocados (*Persea americana* Mill.) may have originated in southern Mexico, but they were cultivated from the Río Grande River to central Peru long before the arrival of Europeans. Nowadays, they are grown in places as far from the Americas as Australia, Israel, and South Africa (Morton, 1987). In Venezuela, this fruit is eaten raw, in salads, and filled with shrimps or used to prepare a sauce called "guasacaca" (Vélez and Valery, 1990).

The main feature of avocado is its high amount of oil, which can be as high as 40% of the pulp weight (Pearson, 1975); the oil is mainly composed of unsaturated fatty acids, predominantly oleic acid (Sciancalepore and Dorbessan, 1981; Gaydou, et al., 1987).

Avocado is a healthy fruit. A diet enriched with avocado was found to lower total cholesterol and low-density lipoprotein levels, without changing high-density lipoprotein levels (Colquhoun et al., 1992). Its essential amino acid profile has been considered to be adequate for children 10−12 years of age (Fox et al., 1988), and Smith et al. (1983) advised it in therapeutic diets.

Criteria to select avocado varieties have changed in recent times. Formerly, organoleptic properties were a key feature in the decision, but nowadays the new uses of avocado, for example, as a raw source of oil (Southwell et al., 1990), have changed the criteria and opened new possibilities for this crop, including the use of its oil for cosmetic purposes (Swisher, 1988). In addition, it would be possible to use the seed, which is a byproduct of some oil extraction techniques from the pulp, as source of a starch characterized as suitable for foods that have to be heated to 100 °C, such as soups and sausages. The yield of starch of an avocado pit was found to be 29.6% on a wet-weight basis (59.2% on a dry-weight basis) (Kahn, 1987).

Introduction and selection of avocado varieties to improve quality and production in Venezuela date back to 1937. Nowadays, there is a germplasm bank with 99 varieties, the description of which is in process (Avilán et al., 1994). Forty-nine of these varieties have been studied to date and classified in four categories using pulp oil amount as an assortment criterion; the characteristics of the very low oil content category have been reported previously (Gómez-López, 1998). Results of the low-oil category are shown in this work to help growers and researchers choose specific varieties according to their objectives.

MATERIALS AND METHODS

Samples belong to the collection of Centro Nacional de Investigaciones Agropecuarias, Maracay, Venezuela. In 1993, between 21 and 27 fruits of each of the following avocado (*P. americana* Mill.) varieties were picked: Quebrada Seca, Luiz de Queiroz, Santa Clara (synonym of St. Clair), Figueroa, Princesa, Booth 1, Booth 7, Ceniap 2, Tonnage, Santa Cruz, Taylor, and Guacara Morado. The samples were brought to the Instituto de Ciencia y Tecnología de Alimentos, Caracas, Venezuela, and kept in environmental conditions until ripeness, which was characterized according to the method of Gómez-López (1998). When samples were ripened, five fruits of each variety were randomly selected, and some analytical determinations were performed.

Pulp moisture and oil contents were measured according to the method of Gómez-López (1998) in a pulp pool from five fruits.

Fruit weight (whole fruit, seed, pulp, and peel); length, width at widest point, and shape; and peel characteristics (roughness, hand peeling, and color) were determined. Color results are the average of five readings taken equidistantly at the equator of the fruit, by means of a Colormet tristimulus colorimeter in the Lab Hunter System.

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Table 1. Pulp Oil and Moisture Percentages of 12 Avocado Varieties

variety	% oil[a]	% moisture[b]
Quebrada Seca	6.73	84.63
Luiz de Queiroz	6.78	84.15
Santa Clara	6.84	84.80
Figueroa	6.94	86.01
Princesa	7.12	80.50
Booth 1	7.25	83.14
Booth 7	7.26	83.14
Ceniap 2	7.28	82.28
Tonnage	7.56	80.82
Santa Cruz	7.70	84.25
Taylor	7.76	85.95
Guacara Morado	8.07	81.86

[a] Data are means of two samples of a pool of five avocados. [b] Data are means of four samples of a pool of five avocados.

Table 2. Fruit Weight and Pulp, Seed, and Peel Proportions[a] of 12 Avocado Varieties

variety	wt (g)	% pulp	% seed	% peel
Quebrada Seca	256.73^{abc}	54.07^{a}	34.16^{f}	11.77^{c}
Luiz de Queiroz	400.29^{de}	68.68^{de}	19.11^{cd}	12.21^{cd}
Santa Clara	271.33^{bc}	73.40^{fg}	13.20^{a}	13.40^{d}
Figueroa	350.38^{d}	71.49^{ef}	20.65^{d}	7.86^{ab}
Princesa	219.14^{ab}	76.00^{g}	15.16^{ab}	8.84^{b}
Booth 1	465.02^{fg}	61.33^{b}	31.34^{f}	7.32^{a}
Booth 7	501.64^{g}	70.85^{def}	18.10^{bcd}	11.05^{c}
Ceniap 2	467.59^{fg}	68.03^{cde}	24.77^{de}	7.20^{a}
Tonnage	372.86^{de}	70.92^{ef}	17.70^{bcd}	11.39^{c}
Santa Cruz	290.11^{c}	73.53^{fg}	17.30^{bc}	9.18^{b}
Taylor	423.88^{ef}	67.43^{cd}	20.58^{cd}	11.99^{c}
Guacara Morado	213.13^{a}	63.92^{bc}	24.90^{e}	11.18^{c}

[a] Data are means of five avocados. Means within columns followed by the same letter are not significantly different ($p \leq 0.05$).

Data in Table 2 were analyzed by one-way ANOVA and least statistical difference tests, both at $p \leq 0.05$, using Statgraphics version 6.0.

RESULTS AND DISCUSSION

The existence of interrelationships between avocado ripeness and textural changes has been pointed out by Peleg (1978). Dolendo et al. (1966) found that MacArthur avocados are at ideal ripeness just after the climacteric peak, which occurred simultaneously with a sharp decrease of firmness due to a decrease of proto pectin and pectin esterification and an increase of soluble pectin. Therefore, textural measurements are suitable indicators of the ripening point of avocados, which were characterized for each variety by the following results in the penetration tests, in kilograms (mean ± standard deviation): Quebrada Seca, 1.53 ± 0.06; Luiz de Queiroz, 1.47 ± 0.14; Santa Clara, 1.03 ± 0.08; Figueroa, 3.18 ± 0.22; Princesa, 0.77 ± 0.20; Booth 1, 1.28 ± 0.24; Booth 7, 2.98 ± 0.55; Ceniap 2, 2.39 ± 0.66; Tonnage, 1.19 ± 0.25; Santa Cruz, 1.21 ± 0.30; Taylor, 1.30 ± 0.18; and Guacara Morado, 1.16 ± 0.15.

Information about four of the varieties described in this work (Ceniap 2, Guacara Morado, Quebrada Seca, and Santa Cruz) was not found in the literature, so this could be the first time they are depicted.

Figures of oil and moisture percentages are shown in Table 1. The oil percentages indicated were usually lower than the same from other works. Booth 1 oil percentage according to Salazar et al. (1971) was 10.52 and by the California Avocado Society (1946), 8−12. The values reported for Booth 7 and Taylor, 10−14 and 13−17, respectively, by the California Avocado Society (1946) were higher than those reported in this study. However, the value for Tonnage obtained in this work is in agreement with the result published by the California Avocado Society (1946), 6−8%, but lower than the level reported by Rouse and Knight (1991), 16.7%.

The addition of the oil and moisture percentages were between 87.62 for Princesa and 93.71 for Taylor. These are constants that enable the calculation of oil percentage by means of a moisture determination and a simple mathematical computation. Equations for this kind of calculation have been reported by Pearson (1975), Lee et al. (1983), and Brown (1984). The value for Princesa was a bit low but agrees with a former determination.

The fruit weights of Booth 1, Booth 7, and Taylor found in this work were similar to the ones obtained by Fersini (1975) and the California Avocado Society (1946), but the weight of Tonnage was lower than the values reported by Rouse and Knight (1991) and the California Avocado Society (1946). The weight of Taylor and Booth 7 were higher than the values reported by Rouse and Knight (1991) and Haendler (1965), respectively. According to the categories stated by Avilán et al. (1994), varieties Booth 1, Ceniap 2, and Booth 7 were very heavy; Figueroa, Tonnage, Luiz de Queiroz, and Taylor were heavy; Quebrada Seca, Santa Clara, and Santa Cruz were medium; and Guacara Morado and Princesa were light.

In the comparison of data of weight and oil content from different sources it is important to remember that there are some factors affecting these variables such as fruit physiological condition at the time of picking (Hatton and Reeder, 1972) and soil and climatic conditions.

Pulp proportions of Booth 1, Taylor, and Tonnage were lower and seed proportions higher than the values reported by Salazar et al. (1971) and Rouse and Knight (1991). The pulp amount of Quebrada Seca, Guacara Morado, and Booth 1 was very low due to the big seed in these varieties. Quebrada Seca had the lowest pulp ratio (Table 2) and the higher seed weight/total weight ratio ($p \leq 0.05$), including the 49 varieties characterized to date. Also, the last ratio was higher than the ones reported previously in works from six different countries (Vogel, 1958; Tango et al., 1969/1970, Salazar et al., 1971; Bleinroth et al., 1979; Lizana and Luza, 1979; Lozano et al., 1987; Rouse and Knight, 1991) including >80 varieties. This feature is inauspicious for growing this variety for the direct consumption market because of its low pulp yield.

According to the descriptors employed by Avilán et al. (1994), Quebrada Seca, Booth 1, Ceniap 2, Guacara Morado, Taylor, and Luiz de Queiroz varieties had low pulp percentage; Figueroa, Booth 7, Tonnage, Santa Clara, and Santa Cruz had medium pulp percentage; and Princesa had high pulp percentage. According to the same authors, Guacara Morado, Quebrada Seca, Booth 1, Ceniap 2, and Figueroa varieties had a heavy seed; Taylor, Luiz de Queiroz, Booth 7, Tonnage, Santa Cruz, and Princesa had a medium weight seed; and Santa Clara had a light seed. Although the average consumer chooses avocados almost entirely by eye appeal, reduced wastage can be expected to increase consumer satisfaction and repeat sales (Storey et al., 1973/1974).

The size of this avocado category was between 10.52 and 14.13 cm length and between 6.40 and 9.44 cm width. No data were found in the literature to compare the sizes of the varieties studied in this work (Table 3) and in another works.

Table 3. Size[a] of 12 Avocado Varieties

variety	length (cm)	width (cm)
Quebrada Seca	13.14 ± 0.61	6.40 ± 0.62
Luiz de Queiroz	10.52 ± 0.44	8.80 ± 0.31
Santa Clara	14.04 ± 1.00	6.78 ± 0.33
Figueroa	12.08 ± 0.55	8.20 ± 0.38
Princesa	10.58 ± 0.29	6.58 ± 0.71
Booth 1	10.74 ± 1.41	9.00 ± 0.41
Booth 7	11.06 ± 0.69	9.44 ± 0.25
Ceniap 2	14.13 ± 1.26	8.68 ± 0.30
Tonnage	13.26 ± 0.65	8.08 ± 0.54
Santa Cruz	12.08 ± 0.89	7.10 ± 0.63
Taylor	10.60 ± 0.62	9.12 ± 0.38
Guacara Morado	12.14 ± 1.70	6.58 ± 0.13

[a] Data are means of five avocados.

Table 4. External Characteristics of 12 Avocado Varieties

variety	shape	skin texture	color[a] L^b	color[a] a^c	color[a] b^d
Quebrada Seca	pyriform	smooth	6 ± 3	7 ± 3	16 ± 4
Luiz de Queiroz	ovate	smooth	26 ± 3	−7 ± 2	43 ± 5
Santa Clara	pyriform	rough	7 ± 4	6 ± 1	1 ± 2
Figueroa	pyriform	smooth	39 ± 4	−11 ± 1	46 ± 2
Princesa	ovate	rough	44 ± 3	−8 ± 1	36 ± 3
Booth 1	ovate	smooth	23 ± 3	−9 ± 2	42 ± 4
Booth 7	ovate	rough	28 ± 1	−8 ± 2	43 ± 6
Ceniap 2	pyriform	rough	27 ± 3	−7 ± 0	43 ± 5
Tonnage	pyriform	rough	30 ± 2	−10 ± 1	34 ± 4
Santa Cruz	pyriform	rough	23 ± 3	8 ± 1	13 ± 3
Taylor	ovate	smooth	27 ± 1	−8 ± 1	35 ± 5
Guacara Morado	pyriform	rough	17 ± 2	10 ± 3	14 ± 2

[a] Data are means of five readings taken at the equator of five avocados. [b] Luminosity. [c] Red/green chromaticity. [d] Yellow/blue chromaticity.

Five of the 12 varieties were ovate and 7 pyriform (Table 4), but without large necks, so all of them might be marketed without danger of neck breaking (Camacho and Ríos, 1972). Seven had rough peel and five smooth peel; roughness of some varieties depends on the tendency of lenticels to break the epidermis (Biale and Young, 1971). Four varieties had purple peel, as can be observed in the positive values of the chromaticity parameter *a*; the others were green. This difference has been assigned to the presence of anthocyanins in the purple peel varieties due to an anthocyanin synthetase absent in green peel avocados (Prabha et al., 1980). Quebrada Seca variety had a very good appearance, with a shiny purple peel with green spots. Selection of cultivars regarding appearance depends on cultural preferences. For example, California consumers preferred varieties that produced small fruits with smooth green peels until the rise of the Hass variety; in contrast, in Latin American countries large fruits are preferred (Storey et al., 1973/1974).

With regard to hand peeling, two different kinds of difficulties are encountered: skin could be prone to breaking or could be very adherent.

Figueroa, Guacara Morado, Booth 1, Booth 7, and Quebrada Seca varieties were easy to hand peel; the rest were difficult due to an adherent peel, with the exception of the Tonnage variety, which had an easily broken peel. Difficulties in hand peeling could be a problem for direct consumption but not necessarily for industrial purposes.

Peak ripeness time was reached in 4 days by Guacara Morado, Quebrada Seca, and Princesa varieties, in 8 days by Princesa, and in 9 days by Taylor.

Table 5. Average Potential Yield of Some Avocado Varieties

variety	kg of fruit/ha[a]	kg of pulp/ha[b]	kg of oil/ha[c]
Princesa	67944[d]	51675	3679
Santa Clara	59052[d]	43108	2949
Tonnage	35378[e]	25118	1899
Taylor	31863[e]	21667	1681
Luiz de Queiroz	29640[e]	20452	1387
Figueroa	24396[d]	17321	1202

[a] Estimated by multiplying kg of fruit/tree × 228 trees/ha. [b] (kg of fruit/ha) × (% pulp). [c] (kg of pulp/ha) × (% oil). [d] From Avilán et al. (1994). [e] Estimated from Figueroa (1982).

Princesa is the variety with the highest potential yield (Table 5) as kilograms of fruit per hectare, kilogram of pulp per hectare, and kilograms of oil per hectare among the 15 varieties characterized to date for which productivity data were available. As Rouse and Knight (1991) pointed out, yield is important in the evaluation of avocado cultivars, but only if they have high quality. For direct consumption purposes, authorities have advised the planting of the Princesa variety in Venezuela at least since 1982 (Figueroa, 1982), and this recommendation was made again in 1994 (Avilán et al., 1994) due to this variety's high quality. Informal sensory evaluation described its taste as very good and sweet-buttery. Moreover, the potential starch yield of Princesa would be 3016 kg of starch/ha, obtained by multiplying the potential yield as kilograms of fruit per hectare, the seed ratio, and the seed starch ratio obtained by Kahn (1987). Other cultivars with poor appearance and other poor sensorial qualities might be advised for industrial purposes. All of the varieties included in Table 5 have a potential yield much higher than the average yield obtained in Venezuela between 1975 and 1988, 3.9−4.5 ton/ha (MAC, 1992). Data for the rest of the varieties included in this paper were not available.

No emphasis is made in this paper to choose or recommend any variety because of the high variability of different markets and the new possibilities to use this fruit.

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