Avocado Oil Production and Chemical Characteristics

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Centrifugal force separation is a relatively new industrial process for extracting avocado oil. This study examined the influences of temperature, pH and NaCl concentration on oil extraction efficiency by centrifugal processing. Optimal separation conditions occurred at 75 C, with a pH of 5.5 and NaCl concentration of 5%.

Differences in chemical characteristics exist between avocado oils produced by industrial processes and those oils that were produced in the laboratory by organic solvent extraction. The highest amount of chlorophyll, 192.9 ppm, was obtained by ethanolic extraction in the laboratory. Unsaponifiables content reached 1.95% in industrial oil produced by organic solvent extraction. The highest acid value, 8.35, was obtained from industrial oil produced by centrifugal separation. Hydroxyl values in our oils were found to be 2-3 times higher than those reported in the literature.

Avocado is one of the few cultivated fruits in which oil is a main component (on the dry basis) (1). The avocado's fleshy mesocarp is composed mostly of uniform isodiametric parenchyma cells of about 60 μ in diameter in the mature fruit. Throughout the tissue there are specialized oil cells, although small droplets of oil also can be detected in the parenchyma cells. The oil cells, or idioblasts, are distinguished by their large size and lignified walls.

Unlike many other fuits, the ripening or softening of avocado does not follow maturity on the tree, but takes place several days after the fruit has been picked (2). It seems that there is a flow of inhibitive components from the leaves to the fruit, preventing fruit-softening on the tree (3). Fruit maturity and picking time are determined according to external marks (color and size) or by measuring oil content in the flesh.

The high oil content, 15-30% depending on the variety (4-7), is one of the distinguishing features of avocado fruit. The oil is unsaturated and the predominant fatty acid is oleic (8). Of all fruits only the olive and the palm can rival the avocado in oil content.

Large surpluses of avocado are expected in the near future. One way of using these surpluses is to extract the oil from the fruit. Crude avocado oil is used mainly in the cosmetic industry. Refined avocado oil has only recently been introduced in the food industry and the world food market.

There are two major methods for production of avocado oil. The first method dries and then presses the fruit at elevated temperatures and extracts the oil with an organic solvent. The second method separates the oil from fruit by centrifugal force. In the solvent extraction method hard, mature, unseeded fruit is used. During extraction, presence of the seed increases the unsaponifiable fraction of the oil. The seed oil contains 55% unsaponifiable materials (9), while the seed contains only 1-1.5% oil (7). On the other hand, soft mature seeded fruit is used for oil separation by centrifugation. Production of avocado oil by centrifugal separation was developed recently in order to reduce energy costs and to minimize air pollution caused by organic solvents. The separation process is based on the mechanical and enzymatic destruction of oil cells.

The effects of temperature, pH and NaCl concentration on oil production efficiency by the centrifugal process were determined. In addition, differences in the chemical characteristics between avocado oils produced industrially and in the laboratory were examined.

MATERIALS AND METHODS

Industrial avocado oil. Crude avocado oil (unknown variety) produced by organic solvent extraction was obtained from Miluot Ltd., Haifa, Israel. Crude and refined avocado oil (Hass variety) produced by centrifugal separation was obtained from Avochem,

TABLE 1

The Influence of Temperature, pH and NaCl Concentration on Avocado Oil Extraction Efficiency by Centrifugal Separation[a]

Temperature (C)	Ext. Eff. (%)	pH at 75 C	Ext. Eff. (%)	NaCl (%) at 75 C and pH 5.5	Ext. Eff. (%)
25	57.2	4.5	54.7	0	72.7
30	58.5	5.5	72.7	2	64.1
40	62.8	5.8	64.5	4	69.1
45	61.6	6.0	51.2	5	75.3
50	56.6	6.5	46.8	6	64.1
55	58.5	7.0	57.8	8	62.4
65	59.6	8.0	64.5		
75	64.5				
85	61.5				

[a]The values presented in this table are the average of three determinations.

Santa Paula, California.

Fresh avocado extracts. Fresh avocado fruit (Fuerte variety) was sliced, the seed discarded and the flesh freeze-dried at a vacuum of 0.23 torr at 40 C for 24 hr. Five portions of the dried flesh were each ground and then extracted in a Soxhlet apparatus with either petroleum ether (PE), ethanol, ethyl acetate, hexane or isopropanol for 24 hr.

Moisture and oil content of fresh avocado flesh. Fresh avocado fruit was sliced, the seed discarded and 25 g of the flesh chopped in a household blender and dried at 110 C to constant weight.

$$\text{Moisture content (\%): } W = 100(M_o - M)/M_o$$

Where M_o is the initial weight of the fresh sample and M is the final weight of the dried sample.

For oil determination 5 g of dried flesh was ground and the oil extracted with hexane for 24 hr in a Soxhlet apparatus.

$$\text{Oil content, on wet basis (\%): } S_o = (100 - W)Z/Y$$

Where W is the calculated moisture content, (%); Z is the weight of extracted oil (g), and Y is the weight of dried flesh sample, (g).

Efficiency of centrifugal separation. Fresh avocado flesh (25 g) was blended with 75 g of water. The mass was then pounded in a Teflon tissue mortar for 5 min and held at suitable temperature, pH and NaCl concentration, with constant stirring. After 30 min, the mass was centrifuged at 6,000×g. The supernatant was transferred to a separatory funnel, and a small amount of PE was added. The dissolved oil phase was dried with anhydrous sodium sulfate, the PE was evaporated, and the oil was dried in a vacuum oven at 60 C overnight.

$$\text{Efficiency, (\%): } E = 100\ S/S_o$$

Where S_o is the calculated oil content (%) in fresh avocado flesh, extracted by hexane, and S is the calculated oil content (%) obtained by centrifugal separation.

Unsaponifiable material, chlorophyll content, hydroxyl value and the acid value were determined in accordance with AOCS official methods (10-13). Protein and fiber material content in oil cake were determined in accordance with the AOAC standard procedure (14).

The fatty acid composition of avocado extracts was determined by gas liquid chromatography (GLC). The analysis was carried out on a Packard gas chromatograph at 190 C with nitrogen as the carrier gas and a column packing of GP 10% SP-2300 on 80/100 Supelcoport obtained from Supelco Inc., Bellefonte, Pennsylvania. Sulfuric acid, 1% (w/v), in absolute methanol was used for preparing methyl esters (15). Quantitative evaluation of chromatogram peak areas was done according to the absolute calibration method described by Andreev et al. (16). Standard methyl esters were obtained from Sigma Chemical Co., St. Louis, Missouri.

RESULTS AND DISCUSSION

Centrifugal force separation. The influence of temperature was examined first. Several temperatures were tested, and the optimal was found to be 75 C. Oil extraction efficiency, at 75 C, reached 64.5% (Table 1). Somewhat lower efficiency, 62.8%, was obtained at 40 C which is probably due to enzymatic activity. Avocado fruit contains pectolitic and cellulitic enzymes which cause decomposition of the oil cell membrane allowing oil release. The fruit also contains lipolytic enzymes which cause oil hydrolization and oxidation. Therefore, the optimal temperature, 75 C, is that at which enzymes are inactivated.

Investigation of the influence of pH on oil production, at 75 C, indicated that emulsion stability was lowest at pH 5.5 (Table 1). The addition of NaCl assists oil separation from the emulsion by physical means. NaCl increases the difference in specific gravity between the oil and aqueous phase and also suppresses stability of the double layer at O/W interface. Maximal extraction efficiency, 75.3%, was obtained at 5% NaCl and pH 5.5 at 75 C. The efficiency without added salt was somewhat lower, 72.7%. Since this improvement was not significant, it might be better to dispense with NaCl in the future and not risk a possible corrosion effect, especially on metallic equipment parts.

Residual oil was found after centrifugation in the emulsion and in the oil cake.

Organic solvent extraction of avocado pulp. Because

TABLE 2

Extraction of Freeze-Dried Avocado Pulp (Fuerte Variety) with Different Organic Solvents[a]

Characteristics	Organic solvents				
	Hexane	Petroleum ether	Ethanol	Ethyl acetate	Iso propanol
Extract concentration[b] (%)	66.1	65.4	52.1	65.7	64.5
Extracted chlorophyll (ppm)	69.2	68.9	192.9	115.8	100.6
Extracted unsaponifiables (%)	1.8	1.7	8.1	1.5	1.4
Oil cake proteins[b] (%)	18.3	17.5	5.1	19.1	18.7
Oil cake fiber materials[b] (%)	18.2	17.8	20.1	17.9	17.3

[a]The values presented in this table are the average of three determinations.
[b]Dry basis.

TABLE 3

Fatty Acid Composition of Avocado Oil from Different Sources (% of total fatty acids)[a]

Sources	Fatty acid				
	16:0	16:1	18:0	18:1	18:2
Industrial refined oil[b]	11.8	2.2	0.7	71.2	14.2
Industrial crude oil[b]	12.2	3.5	trace	74.1	9.7
Industrial crude oil[c]	17.8	5.6	—	64.4	12.7
Laboratory crude oil[d]	14.3	4.0	—	70.5	11.3
Laboratory crude oil[e]	13.3	2.8	trace	68.2	15.6
Laboratory crude oil[f]	12.7	2.5	trace	66.1	18.1
Avocado seed oil[g]	3.2	10.4	0.7	5.1	15.5

[a]The values presented in this table are the average of three determinations.
[b]Centrifugal separation.
[c]Organic solvent extraction.
[d]Hexane extraction.
[e]Petroleum-ether extraction.
[f]Chloroform-methanol (2:1) extraction.
[g]Fuerte variety, hexane extraction.

hexane and PE are forbidden solvents in some states in the U.S., alternate solvents such as ethanol, ethyl acetate and isopropanol can be used for oil extraction (17).

The results of extracting dry avocado (Fuerta variety) pulp with these solvents, in comparison to hexane and PE, are presented in Table 2. There are no apparent differences in extract concentration, oil cake protein and oil cake fiber materials among the solvents, excepting ethanol. There are differences, however, in chlorophyll and unsaponifiable content. The highest amount of chlorophyll, 192.9 ppm, and 8.1% unsaponifiables, were obtained by ethanolic extraction.

Unsaponifiables have a pharmacological interest. Especially unsaponifiables of avocado oil are used in the treatment of connective tissue diseases (18). Because ethanol extraction increases the unsaponifiables content in the extract, there is a possibility of recovering more unsaponifiables by ethanolic extraction of oil cakes than by the other tested solvents. The relatively high dielectric constant, 25.7, of ethanol results in the increased extraction of high boiling point unsaponifiable fractions in contrast to the other test solvents (17). Fortunately, these high boiling point unsaponifiables are not lost during solvent evaporation. Ethanolic oil cake contains only 5.05% protein, from which we may conclude that most of the proteins have been extracted by ethanol and exist in the ethanolic extract. Proteins are not considered as unsaponifiables; therefore, by re-extracting the ethanolic extract with a less polar solvent such as PE or chloroform, we might get more then 8.1% unsaponifiable material in the reextracted fraction.

Chemical characteristics of avocado oil from different sources. Differences in fatty acid composition, unsaponifiables content, chlorophyll content, acid values and hydroxyl values between industrial and laboratory-extracted avocado oils were examined.

Fatty acid composition. The predominant fatty acid is oleic. Industrial crude avocado oil produced by centrifugation contains 74.1% oleic acid, while industrial crude oil, organic solvent extracted, contains only 64.4%. Fatty acid composition of industrial avocado oils is influenced by fruit variety, location of growth, seasonal and annual variations and processing methods. Differences in fatty acid composition of laboratory-extracted avocado oils (Fuerte variety) are due to different extracting capabilities of the extracting solvents [hexane, PE and chloroform:methanol (2:1)], (Table 3).

Unsaponifiables. The highest amount of unsaponifiables, 1.95%, was obtained from industrial crude oil produced by organic solvent extraction (Table 4). Crude oil obtained by centrifugation contains only 1.40% unsaponifiables, but this decreases to 1.35% after oil refining. A comparison of unsaponifiables in avocado oil obtained from hexane or PE extraction suggests no apparent difference (1.79% and 1.68%, respectively). In order to increase the unsaponifiable fraction, the whole fruit can be extracted. The enriched oil is used mainly in the cosmetic and pharmaceutical industry.

Chlorophyll. Industrial crude avocado oil obtained by organic solvent extraction has been subjected to high temperatures during processing. Therefore, no chlorophyll can be found in it. Crude avocado oil produced by centrifugation contains 41.3 ppm chlorophyll, but after refining only trace amounts are found. The chlorophyll extraction ability of hexane and PE are similar (69.2 and 68.8 ppm, respectively). The green color of the oil derived from chlorophyll is an attractive benefit for cosmetic products as it gives the product a more "natural" appearance. This is a desirable characteristic because of the recent trend to consumption of products derived from natural sources. On the other hand, high chlorophyll content may cause oil stability problems, because chlorophyll serves as a photosensitizer in oxidative processes (19).

Acid value. Crude avodaco oil obtained by laboratory extraction with PE and hexane had similar acid values (2.04 and 2.06, respectively). High acid value, 8.35, was obtained in industrial crude oil produced by centrifu-

TABLE 4

Chemical Characteristics of Avocado Oil from Different Sources[a]

Source	Chemical characteristics			
	Chlorophyll (ppm)	Unsaponifiables (%)	Hydroxyl value[f]	Acid value[g]
Industrial refined oil[b]	trace	1.35	18.1	0.11
Industrial crude oil[b]	45.3	1.40	15.2	8.35
Industrial crude oil[c]	—	1.95	23.2	1.83
Laboratory crude oil[d]	69.2	1.79	27.4	2.06
Laboratory crude oil[e]	68.8	1.68	29.9	2.04

[a]The values presented in this table are the average of three determinations.
[b]Centrifugal separation.
[c]Organic solvent extraction.
[d]Hexane extraction.
[e]Petroleum-ether extraction.
[f]The hydroxyl value is defined as mg potassium hydroxide equivalent to the hydroxyl content of one g oil.
[g]The acid value is mg potassium hydroxide necessary to neutralize the free acids in one g oil.

gation, while after refining, the acid value was decreased to 0.11. Industrial crude oil obtained by organic solvent extraction had an acid value of 1.83 (Table 4). High acid values are an indicator of the large free fatty acid content in crude oil produced by centrifugation. During fruit softening, free fatty acids are formed as a result of lipolytic activity of internal enzymes. External mycetic enzymes are also involved. In order to increase process efficiency by centrifugation, only soft ripe avocado fruit is used.

Hydroxyl values. Crude avocado oil produced by laboratory extraction of avocado freeze-dried pulp (Fuerte variety) with hexane and PE had hydroxyl values of 27.4 and 29.9, respectively. Avocado oil obtained by industrial organic solvent extraction had a hydroxyl value of 23.2. The lower value, 15.2, of centrifugally produced crude avocado oil is because the hydroxyl-containing component remains in the emulsion during oil separation. Oil refining increased the hydroxyl value to 18.1 in refined centrifuged avocado oil (Table 4). Hydroxyl values obtained in this research are 2-3 times higher than those reported in the literature (7). By stoichiometric calculation for theoretical evaluation of hydroxyl values of avocado oil based on hydroxyl-contributing components, we reached values similar to those reported (7). Calculations were based on the assumption that avocado oil contains 87% triglycerides, 6% diglycerides and 3% monoglycerides (oleic being the main fatty acid in these fractions). Comparison of experimental and calculated results leads to the assumption that avocado oil contains more hydroxyl donor components. Possible sources of these components are waxes in the unsaponifiable fraction (20) and hydroxylated fatty acids. The high amount of phospholipids, 1.7% (7), and relatively high hydroxyl values explain the use of avocado oil as a stabilizer in cosmetic products.

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