Avocado Oil Extraction with Appropriate Technology for Developing Countries

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Some published procedures for extraction of oil from avocado fruit mesocarp tissue were compared and modified for the purpose of creating applicability in developing countries. Highest recoveries were obtained at a 5:1 water-to-avocado ratio, pH 5.5 and centrifugal force of 12,300 × *g*. Addition of 5% $CaCO_3$ or $CaSO_4$ allowed extraction without organic solvents. The relationship was linear between heating temperature (75–98°C) and the time for oil release from slurries. Gravity settling for four days at 37°C followed by centrifugation improved oil yield. Optimal oil recoveries were 70–80%.

KEY WORDS: Avocado, $CaCO_3$, $CaSO_4$, centrifugation, extraction, heating, oil, yield.

Avocados (*Persea americana* Mill) contain 8–32% oil (1), and in some developing countries, such as Rwanda, avocados could be an important domestic source of cooking oil to help improve the nutritional status of the citizens (2,3). Extraction of the oil requires disruption of both the oil cells and the finely dispersed oil emulsion in the fruit pulp (4). Solvent extraction, mechanical pressing and centrifugation of pulp slurries have been used in processing avocados for their oil. Previous studies (5–12) have investigated singly a number of factors affecting the separation of avocado oil from the pulp. Building on these studies, our objective was to develop an appropriate oil extraction process for cottage or small-village industries in developing countries. In this paper, we systematically examine the interplay among factors such as centrifugation force, extraction pH, pulp/water ratios, inorganic salt type and concentration, and the temperature and time factors for optimizing a simple procedure for extracting avocado oil.

EXPERIMENTAL PROCEDURES

Avocados. A 25-lb case of preclimacteric avocados (*cv.* Hass), purchased from a local produce wholesaler, was stored for not more than 2 wk at 4–5°C. Fruits were ripened as needed at room temperature for 3–4 d to a reading of 4–5 lb, as measured by a Magness-Taylor fruit pressure tester (D. Ballauf Mfg. Co., Washington, D.C.), peeled, sliced, pitted and ground to a paste with mortar and pestle. The pH of the paste was approximately 7.0.

Chemicals and extraction aids. Reagent-grade (AR) calcium carbonate, calcium sulfate, calcium chloride and sodium chloride were used as extraction aids. Anhydrous sodium sulfate was used to dry some of the oil samples, and pH was adjusted with 1 N HCl. Petroleum ether (boiling range 30–60°C) was used in some of the extraction procedures and for analyses.

Heating temperature/time. Quadruplicate 25-g samples of avocado paste, diluted 3:1 (w/w) with distilled water and adjusted to pH 5.5 (7), were heated in a water bath at 75, 80, 85, 90, 95 and 98°C, and the time (min) was noted when a surface oil layer became evident.

Oil extraction procedures. On the basis of previous studies (7,9,11), we examined the effects on oil recovery of dilution ratio (5:1 or 3:1, w/w), pH of the diluted slurries (4.0 or 5.5) and centrifugation (6,000 or 12,300 × *g*) with or without gravity settling for four days at 37°C.

Recovery of oil. The fruit was peeled, pitted and comminuted in an Osterizer blender; quadruplicate 1.5–1.6-g samples (accurate to 0.0001 g) were dried in an air oven at 110°C for 4 h to determine moisture content. Small pieces of mesocarp of three fruits were freeze-dried and then finely ground in an Osterizer blender. Quadruplicate 1.6–1.7-g portions (accurate to 0.0001 g) of the powder were extracted with petroleum ether for 24 h in a Soxhlet apparatus. Percent oil recovery was determined gravimetrically.

RESULTS AND DISCUSSION

The avocado mesocarp contained about 24–25% oil and about 65% moisture. Some preliminary studies were conducted to assess the feasibility of certain treatments suggested in the literature. Werman and Neeman (7) recommended (among other factors) that avocado/water/pulp slurries at pH 5.5 be heated at 75°C for 30 min for best oil extraction. However, Lanzani *et al.* (9) recommended extraction at pH 4.0, and Haendler (5) cautioned that excessive heating can damage oil quality.

Heating temperature/time relationship. During our heating experiment with diluted avocado paste, we observed a sudden appearance of oil, which signaled the oil's release from the oil cells. An inverse linear relationship between heating temperature and the time for this oil separation was found between 75 and 98°C (slope = −1.97, R^2 = 0.999). To minimize the chances for heat damage to the oil and to minimize processing time, we adopted a heat treatment of 98°C for 5 min for this essential step in the extraction process.

Effects of pH, dilution and centrifugal force. Having defined an appropriate and efficient heat treatment protocol and using the basic procedure of Werman and Neeman (7), we next studied the effect of extraction pH (5.5 *vs.* 4.0), dilution ratio (3:1 *vs.* 5:1) and centrifugal force (6,000 *vs.* 12,300 × *g*). Results are given in Table 1. Oil recovery was higher at pH 5.5 than at pH 4.0 and was further improved by increasing both the dilution factor and the centrifugal force. Oil release was also quicker at pH 5.5 and at the 5:1 dilution factor. Based on these data, subsequent experiments were conducted at pH 5.5, dilution factor 5:1 and centrifugal force 12,300 × *g*.

Effect of inorganic salts. Table 2 shows the effects of $CaCO_3$, $CaSO_4$, $CaCl_2$ and NaCl at 0–20% (w/w) on oil recovery. Addition of $CaCO_3$ and $CaSO_4$ increased oil recovery at all treatment levels, but with little, if any, benefit above 5%. $CaCl_2$ was of no benefit and actually decreased oil recovery above 5%. NaCl improved oil recovery only at lower concentrations (<15%). Werman and Neeman (7) showed similar results for NaCl, but recommended against

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TABLE 1

Effects of Different Combinations of Centrifugal Force, Dilution Ratio (water/avocado paste, w/w), pH and Water-Washing Step on Avocado Oil Recovery[a]

Centrifugal force (× g)	pH	Dilution ratio	Recovery[b] (%)
6,000	5.5	5:1	76.57
6,000	5.5	3:1	71.31 (0.004)[c]
6,000	4.0	3:1	65.77
6,000	5.5	3:1	71.45 (0.004)
12,300	5.5	3:1	78.36
6,000	5.5	3:1	72.08 (0.002)

[a]Each set of two lines represents a separate experiment.
[b]Values are means of three determinations.
[c]Means within sets are significantly different (*P*-values are given in parentheses).

TABLE 2

Effects of Salt Treatments on Avocado Oil Recovery

Salt (%)	Oil recovery (%)[a]					HSD[b]
	Control	$CaCO_3$	$CaSO_4$	$CaCl_2$	NaCl	($P < 0.05$)
5	63.8	69.8	71.6	63.7	70.9	2.8
10	63.3	72.8	70.8	59.0	67.2	4.0
15	64.1	73.0	70.5	56.3	65.2	3.6
20	63.6	74.7	67.3	49.2	55.7	3.4
HSD ($P \leq 0.05$)	3.8	4.7	3.3	2.4	3.9	

[a]Means of two determinations.
[b]HSD, honestly significant difference.

its use because of excessive corrosion of equipment. Precipitated solids were clearly evident after centrifugation of the slurries treated with $CaCO_3$ and $CaSO_4$, but not with the other salts. $CaCO_3$ at the 5% level appears most suitable from a cost and availability standpoint in developing countries. Salt concentrations above 5% increase costs, increase corrosion of equipment and limit the utilization of the extracted residue.

Effect of gravity settling. In developing countries, at the household level, centrifugation likely would not be an option for oil extraction. Southwell *et al.* (13) examined settling of oil "foots" as a means of isolating oil from the pulp. We examined gravity settling further as a substitute for centrifugation and as a possible adjunct to centrifugation for use at an industrial level.

The results of this study suggest the following recommended procedure for industrial use. Dilute avocado paste with water (5:1, w/w) and add 5% (w/w) $CaCO_3$ or $CaSO_4$. Mix in blender at high speed, acidify with 1 N HCl to pH 5.5 and heat at boiling for 5 min with constant stirring. Let stand four days at 37°C and centrifuge at 12,300 × *g* for 10 min. Let stand 30 min at ambient temperature and discard the aqueous phase. Wash with two parts water per part original paste (w/w) in three steps; discard aqueous phase. Dry overnight in vacuum oven at 60°C.

When this procedure was followed in triplicate with $CaCO_3$, oil recovery was increased substantially to 80.1 *vs.* 69.8% in the no-prior-settling procedure (Table 2). For extraction at the household level for home use, centrifugation may be supplanted by gravity settling but oil recovery will be lower.

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