CENTRIFUGAL EXTRACTION OF AVOCADO OIL FROM THE PULP

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Ripe avocado fruits were obtained from the local market and processed for extraction of oil from the pulp by using a centrifuge (Osterode No. 7021 type UJ3) with maximum centrifugal force of 9,300xg. All oil extractions were carried out at the maximum centrifugal force of this centrifuge. It was observed that the average percent moisture and oil contents of avocado fruits studied were 65 ±2.3 and 32.8 ± 2.6 respectively. The oil recovery was observed to be a function of process variables such as pH, extraction time, preheating temperature, and addition of small quantities of $CaSO_4$. Oil recoveries in the range of 78-85% were obtained using pH of 5.5, extraction time of 2 hours, preheating temperature of 75-80 °C and addition of 2% $CaSO_4$. The quality parameters of the oil produced in this work compared favourably well to standard values reported in literature for the similar oil. It was concluded that the method has very promising potential of application by the Small and Medium scale Enterprises (SMEs) for extraction of this oil. However, before adopting the process further studies are needed to optimise the process parameters and evaluate its economic viability.

Keywords: *Avocado oil, extraction, centrifuge, and oil recovery*

INTRODUCTION

Avocado tree (*Persea Americana*) belongs to the family of *Laureacea*, and it is said to be a native of the lowlands of Latin America, which is currently known as Columbia, Ecuador, Guatemala, Mexico, Hondurus and Islands of West India (Morton, 1987; Koch and Thomson, 1996). There are over 80 different species of this plant, however, the most common ones are Guatemalan (*Persea nubigea*), Mexican (*Persea drymifolia blake*), and the West Indian (*Persea American Mile*) (Morton, 1987; Koch and Thomson, 1996; Reich and Allen, 1991). The climate range of avocado varies from those that are temperately cool to those that are strictly tropical. This provides the tree with wide tolerance in terms of elevation, temperature, type of soil and rainfall. However, most of avocado species do not tolerate hot climate, severe frosts, arid and semi arid regions. Among all avocado species, the Guatemalan varieties tolerate tropical conditions and they grow well on moderate temperatures (20-30 °C), medium textured soils with good drainage (Considine, 1982).

Depending on the specie, the plant produces fruits with various types of shapes and nutritional content. The average nutritional content for West Indian, Guatemalan and Mexican avocado species is shown in Table 1.

Avocado fruit is conventionally used for human consumption. It is a potential source of vitamins (A, B, C, D and E), minerals (Ca, K, Fe, etc), oil, proteins and carbohydrates (Table 1). Other uses of the fruit include: production of cosmetics, exotic soaps, skin and hair care products. The fruit has also been used as an alternative medicine (aromatherapy) for treatment of various diseases. Because of these nutritional potentials along with its ability to tolerate various weather conditions,

Table 1: Average Nutritional Content of Avocado Pulp (Morton, 1987; Considine, 1982)

Parameter	Moisture	Oil	Protein	Minerals	Carbohydrates	Vitamins
% w/w	56-88	15-35	1-4	0.5-3	0.3-2	0.2-1.5

the plant is now grown in various parts of the world. In Tanzania the Guatemalan species are dominant and they are grown in regions such as Kilimanjaro, Arusha, Tanga, Morogoro, Dar es Salaam, Mbeya and Kigoma.

Due to poor transportation infrastructure in Tanzania, most of the fruits deteriorate before reaching the consumers which most of them are in urban areas. As a result of this, it is estimated that about 30% of all avocado produce is usually wasted due to deterioration. Since avocado fruit contains up to 35 % oil (Table 1), the development of technology for extracting this oil will significantly reduce the spoilage and consequently encourage farmers to increase production. Avocado oil is expensive product, typical prices in the world market for 100 ml range 10-15 US$ and 20-25 US$ for unrefined and double refined oil respectively (Avoil Enterprises NZ, 2000; Estoteric Oils, 2001; Olivado, 2000). This suggests that production of oil will add value to the fruit.

OBJECTIVES OF THE RESEARCH

The main objective of the research was to extract avocado oil from the pulp using centrifugal method. Other specific objectives were, first, to investigate the effects of various parameters such as temperature, extraction time, pH and addition of additives, on the oil recovery. Second, to characterise the oil produced; this includes measurement of quality parameters such as free fatty acids (FFA), iodine value, viscosity, moisture, refractive index, density, and comparing them with recommended standard values for the oil.

THEORETICAL BACKGROUND

Oil classification

Oils are normally divided into three classes depending on the chemical structure of the fatty acid contained in the oil. The classes are saturated, monounsaturated and polyunsaturated (Gordon, 1998). Saturated fatty acids contain no double bonds in their structure. They are usually found in large percentages in animal fats such as meat, butter, lard and cheese. Monounsaturated fats contain one double bond in their chemical structure and they are usually found in large quantities in agricultural products such as avocado, olive and groundnuts. Polyunsaturated fatty acids contain more than one double bond in their structure and they are normally found in plant and vegetable products such as sunflower, soybeans and cottonseeds (Table 2)

Importance of various types of oils in human body

Research studies (Gordon, 1998; Ravnskov, 2000) have shown that, when the three classes of oils are taken into the human body, they influence differently the level of different types of cholesterol in the blood stream. Saturated fatty acids tend to increase the "bad cholesterol" or low-density lipoprotein (LDL) and decrease the "good cholesterol" or high-density lipoprotein (HDL).

Table 2: Approximate Fatty acid composition of Various Oils (Morton, 1987; Avoil Enterprise NZ, 2000)

Fatty acid	Double bonds in the molecule	w% Fatty acids					
		Avocado	Olive	Sunflower	Cotton	Groundnut	Soy bean
Palmitic (C16)	0	7	11	7	25	10	13
Stearic (C18)	0	0.7	2.1	3	2	3	3
Oleic (C18)	1	79	82	23	21	50	23
Linoleic (C18)	2	13	4	65	51	37	52
Linolenic (C18)	3	0.5	0.9	1	1	-	7

Polyunsaturated fatty acids tend to lower LDL. However, taking diet that is rich in monounsaturated fatty acids provides two benefits; first LDL in the blood decreases and secondly the HDL increases. The high level of LDL in the blood stream is known to be associated with life-threatening diseases such as heart attack, arteriosclerosis (hardening of the arteries) and hypertension. This therefore suggests that diets containing high monounsaturated fatty acids are healthier than those containing high amounts of saturated fatty acids.

Olive oil is well known not only because of its good taste but also because of its high percentage (82%) of monounsaturated fatty acids (Table 2). Avocado oil has also high amount (79%) of monounsaturated fatty acids (Table 2). This gives avocado oil properties that are similar to those of olive oil.

Methods of oil extraction

Oil can be extracted from the oil containing material using three methods: mechanical pressing, solvent extraction and centrifugal extraction (Formo *et al,* 1979).

In mechanical pressing, oil is liberated from the oil-bearing material by application of pressure. Depending on the type of the oil-bearing material, the material is usually decorticated or de-hulled followed by size reduction and then preheated to about 80-110 °C. After this pre-treatment the material is subjected to mechanical pressing. The aim of preheating is mainly two fold, first, is to reduce the moisture content of the material to a value suitable for efficient pressing. This depends on the type of the material, for cotton seeds it is 5-6% whereas for sesame and soybean it is 2-3% moisture (Swern *et al,* 1982). Second, is to reduce the viscosity of oil and make it easier to flow from the oil containing cells during pressing. This method is usually suitable for edible oils as it involves less chemical contamination as compared to the other methods. However, with this method the residual oil content in the cake is usually in the range of 2-5 % w/w for efficient pressing and it can be higher (up to 15%) depending on the efficiency of the press and type of the oil-bearing material (Swern *et al,* 1982). This suggests that this method leaves significant amount of oil in the cake.

Solvent extraction usually employs organic solvents that are oil loving to extract the oil from the oil containing material. Solvents of this nature include n-hexane, petroleum ether, and ethanol. In this method, minimum heat treatment is employed and the solvents are usually selected such that the solubility of solute (oil) in the solvent is high. The solvent is then recovered using various methods such as vacuum distillation leaving out the oil. Oils produced using this method are normally not denatured due to minimum heat treatment involved; however, processing edible oil using this method requires specialised techniques to ensure that the oil remains free from the solvent used. This method is suitable for extraction of oil from small oil containing material and with this method the residual oil content in the cake could be less than 1%. The method is capital intensive due to the specialised equipment and skilled labour required. Danger of explosion as a result of using volatile flammable solvents is also a possibility (Formo *et al,* 1979).

Centrifugation extraction involves subjecting the oil containing material in a centrifugal force. Thus the oil droplets move from the oil containing cells to the bulk surface by the influence of centrifugal force. It can be shown that the time taken for complete separation of oil and the bulk is inversely proportional to the square of the angular velocity used (Coulson and Richardson, 1980). Thus increasing the angular velocity of the centrifuge increases the separation force. This results into considerable q1decrease in separation time. For separation of avocado oil, centrifugal forces in the range of 12,000-13,000xg have been reported to give separation time in the range of 10-15 minutes (Bizimana *et al,* 1993). Residual oil content in the cake obtained using this method is typically less than 1% and because of absence of chemical contamination this method is suitable for edible oils. Due to the potentials of this method, it was therefore amenable for investigation in this work.

Table 3: Various Standard procedures used in this work (Avoil Enterprises NZ, 2000; American Oil Chemists Society, 1980; Tanzanian Standards, 1979)

Parameter	Standard method used
Moisture	America Oil chemists society (AOCS) Ca 2e-84
Total oil content	Soxhlet extraction
Specific gravity	AOCS Cc 10a-25
Refractive index	AOCS Ca 7-25
Acid value	Tanzanian Standard, TZS 35: 1979
Peroxide value	TZS 35:1979
Iodine value	AOCS Cd 1b-87
Free fatty acid (FFA)	TZS 35:1979
Saponification value	AOCS Cd 3-25
Protein content	Kjeldahl
Viscosity	Sychro electric viscometer

MATERIAL AND METHODS

Ripe avocado fruits were obtained from local market, the outer skin was peeled off and the seed was taken out and kept for other research work. Two samples of the pulp were taken for moisture content and total oil content determination using standard procedures shown in Table 3. The remaining pulp was mashed and mixed with prescribed amount of distilled water (solids: water ratio of 1:5 was used) and the weight of the mixture was recorded. The mixture was then transferred into the bucket (300 ml) of the centrifuge (Osterode No. 7021 type UJ3, 750 Watts). Similar procedures were followed for preparing samples for the other buckets. For the cases where the pH had to be adjusted, this was done by addition of small quantities of NaOH and HCl and the pH was measured using a pH meter (WTW pH 422). For the cases where the effect of additives was to be studied, this was done by addition of small quantities of calcium sulphate. The buckets were then inserted in the centrifuge (4 buckets could be processed at the same time) and the centrifuge was run. All experiments were repeated at least three times to ascertain their reproducibility and the results were averaged. All experiments were performed at a centrifuging force of 9,300xg. The effects of the following parameters on the oil yield were studied.

(i) The effect of pH

(ii) Preheating the mixture

(iii) Time taken for separation

(iv) Addition of additive

The quality of all oils produced was determined by measuring quality parameters using standard procedures as shown in Table 3.

RESULTS AND DISCUSSION

The percentage moisture and oil contents of the flesh of avocado fruits investigated were observed to be 65.6 ± 2.3 and 32.8 ± 2.6 respectively. However, this may vary depending on the specie, geographical location and weather conditions of the place were the plant is grown.

The effect of centrifuging time on oil yield is presented in Figure 1. From this it can be seen that the oil recovery increases as the centrifuging time increases. However, after about 2 hours the oil yield appears to decrease with increase in time. This observation suggests that at prolonged extraction time, a reverse mass transfer occurs i.e. the solid material absorbs the oil. This implies that once the optimal extraction time has been reached (about 2 hours for the centrifuge used) then the oil should be quickly separated from the residue to avoid this reverse process.

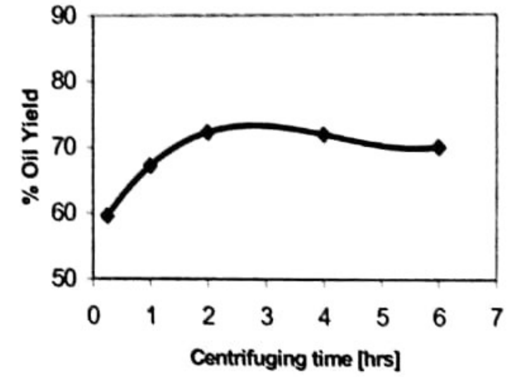

Figure 1: Oil yield as a function of centrifuging time (pH not adjusted, temperature 29 °C, and no additives)

The effect of pH on oil yield is shown in Figure 2, from this it can be seen that the oil yield shows an increasing trend as the pH increases from 3.5 to 5.5. However, after this pH range the oil yield decreases. This suggests that the maximum oil yield can be obtained at a pH of around 5.5. This observation was also reported by Werman and Neeman (1987) and Bizimana *et al* (1993).

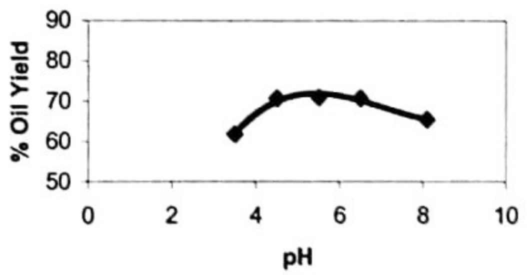

Figure 2: Oil yield as a function of pH of the mixture (extraction time 2 hours, temperature 29 °C and no additives)

Preheating the mixture appears to increase the oil yield (Figure3). However as the preheating temperature increases the oil yield tends to level out suggesting that further increase in temperature does not improve the oil yield. This occurs in the temperature range of 80-100 °C where the yield is about 85- 89%. This observation suggests that increasing the temperature enhances the flow of oil from the oil cells and thus the yield increases. However, temperatures above 95 °C appear to have little effect on oil yield suggesting that this could be a point of onset denaturing of the oil. Bizimana *et al* (1993) also observed this trend, however, in their study the relationship between oil yield and temperature was linear in the temperature range of 75 – 98 °C.

Figure 4 shows the effect of adding small quantities of calcium sulphate on the oil yield. From this it can be seen that the amount of oil recovery increases slightly as the amount of $CaSO_4$ is increased. At about 2% $CaSO_4$ the oil recovery appears to be optimal (about 78%) further increase of $CaSO_4$ results to decrease in oil yield. It can be noted that addition of 2% $CaSO_4$ improves the oil yield from about 72% (Figure1 and 2) to 78% (Figure4). This trend was also observed by Bizimana *et al* (1993), in their study it was observed that addition of about 5% of $CaSO_4$ or $CaCO_3$ improved the oil yield for about 3-4%.

This observation can be explained by considering the interactions that occur between the calcium ions and the constituents of the material. Oil-bearing materials usually contain phosphatides and proteins in small (1-4%) proportions. These constitute to the substances that are collectively referred to as surface-active agents. During oil extraction, they tend to inhibit the flow of oil from the cells. Since the agents are essentially colloidal particles, they can easily be coagulated by addition of multivalent ions according to the Schulze – Hardy rule (Hunter, 1996). This makes the cell wall of the oil-bearing material permeable and allows the oil to flow form the cells with little resistance, which results to the observed improved oil yield.

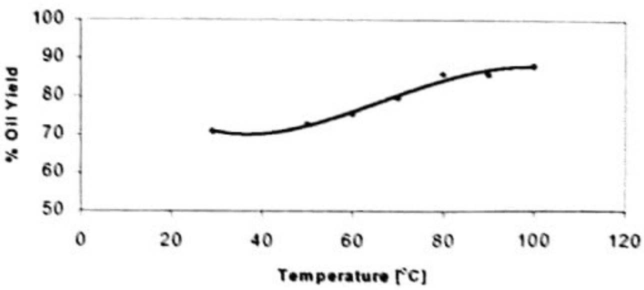

Figure 3: Oil yield as a function of temperature of the mixture during centrifugal extraction (pH 5.5, extraction time 2 hours, no additives)

Table 4: Comparison of quality parameters determined in this work and those reported in literature

Parameter	This work	Required specification (Avoil Enterprise NZ, 2000)
Specific gravity	0.872-0.910 (at 29 °C)	0.905 – 0.925 (at 20 °C)
Refractive index	1.466 - 1.472 (at 29 °C)	1.468 – 1.4720 (at 20 °C)
Acid value	0.8-1%	< 1%
Free fatty acid (FFA)	0.2-0.5%	< 1.0%
Peroxide value	3.8- 4	< 1.0
Moisture content	0.5 - 2%	< 0.1%
Iodine value	82-84	80 – 85
Saponification value	194-196	177.0 – 198.0
Protein content	1.8-2%	1-4%
Viscosity	0.1-0.18 Pas (at 29 °C)	0.1-0.2 Pas (at 20 °C)

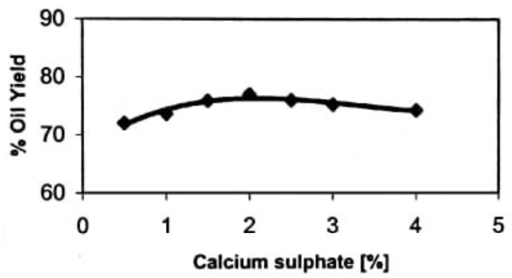

Figure 4: Effect of adding small quantities of calcium sulphate on oil yield (pH 5.5, temperature 29 °C, extraction time 2 hours)

The quality parameters of avocado oil determined in this work are compared to those reported in literature in Table 4. From this Table it can be seen that with the exception of peroxide value and moisture content, all other parameters determined in this work are within the recommended values of the oil, suggesting that the oil extracted is of good quality. It can also be noted that with the exception of free fatty acid, moisture and viscosity, the variations in the remaining parameters for oils produced in this work are within ±12% (Table 4) suggesting that there was no significant difference in the quality of oil for the different procedures used for extraction.

CONCLUSIONS AND RECOMMENDATIONS

From this study the following conclusions can be made:

(a) The percentage moisture and oil contents of the flesh of avocado fruit are 65.6 ± 2.3 and 32.8 ± 2.6 respectively. This may however vary depending on cultivars and growing conditions.

(b) Extraction of avocado oil using centrifugation is a very promising oil recovery method. Oil recovery of up to 89% can be obtained by varying process variables such as pH, extraction time, temperature and addition of small quantities of additives.

(c) For the centrifuge used in this study, the following set of parameters produced oil recoveries in the range of 78-85%: pH 5.5, extraction time 2 hrs, temperature 75-80 °C and presence of 2% $CaSO_4$.

(d) The quality of avocado oil extracted in this work compares favourably well with the standard specifications for this oil.

Based on the study in this work it is recommended here that further studies should be carried out to optimise the process. The method provides very high efficiency of oil recovery and it is less labour intensive and thus suitable for adoption by small scale and medium enterprises (SMEs).

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