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Avocado Apple (*Persea americana*) Pericarp Waste: A Source of Oil for Industrial Application Obtained and Characterized Using Extraction With Different Solvents

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ABSTRACT

This work compared the extraction of oil from the pericarp (peels) of avocado apples using two different solvents namely *n*-hexane and anhydrous ethanol. Direct and indirect leaching methods were used to extract the oil from the pericarp of the apples. The extraction was carried out at different particle sizes, times, and boiling points of the solvents. These were as follows: 0.75mm, 1.00mm, 1.59mm and 2.00mm; 30, 60, 90 and 120 minutes; 60°C and 78°C for *n*-hexane and anhydrous ethanol respectively. The oil extract (active principle) was further refined. The crude and refined oils were characterized to define their physicochemical properties and hence their suitability for industrial applications. Comparative analysis of the results at optimal thermodynamic conditions of reaction time (120minutes), particle size (0.75mm), boiling point of solvents used (*n*-hexane, 60°C and anhydrous ethanol, 78°C) revealed an optimum oil yield of 21.2% and 23.9% for indirect and direct extraction using *n*-hexane, 35.9% and 42.0% for indirect and direct extraction using anhydrous ethanol respectively. Physicochemical analysis of the refined oil showed a saponification value of 196.4, iodine value of 5.653, free fatty acid value of 0.0872, specific gravity of 0.90261, refractive index of 1,600, viscosity of 181.180cp, and boiling point of 89°C. Based on the conformity of these properties to the international standard (ISO/TR 21092, ISO/TR 210, ISO 212, AOCS), the present oil is a potential substitute for most oils used for cosmetics and health care production.

Keywords; Extraction, Characterization, Avocado Apple pericarp, Solvents.

INTRODUCTION

Avocado apple (*Persea americana*) variously known as the avocado pear, alligator pear, ahuacatl or agvacate, is a highly nutritional fruit rich in proteins, fats and oils and low in sugar¹. The total

food value is high; providing nearly twice the energy of an equivalent weight of meat. It also contains an abundance of several vitamins such as A, B, C, D and E. Generally, the fruit's composition by weight is about 65% mesocarp, 20% endocarp (seed) and 15% pericarp (peels). In addition to the oil, the avocado contains a small amount of about 1.5% by weight of unsaponifiable matter, as a distinct fraction, which by itself is a very valuable component useful in many creams and medicated ointments. Three different species have been identified². All the three species are largely cultivated and produced to varying degrees in the tropical rainforest and savannah belts of Nigeria. However, with the abundant production of avocado apple in Nigeria, 15% of avocado apple (pericarp/peels) is discarded as waste which ought to have been a potential source for the production of oils for industrial applications, specifically, the fruits' pericarp that are reported to have antiviral, antibiotic and insecticidal properties³ and employed as a vermifuge and remedy for dysentery and in the production of cosmetics.

Background

Several methods have been developed for the extraction of oils for fruits and other oil bearing plant materials^{4,5,6}. One of such involves the use of chemical solvents that are later removed during the final stages of production. This is the solvent extraction method of oil production. In most cases, the methods of extraction are mainly mechanical and chemical extraction processes. The chemical extraction method is in particular applied when the value of the oil is considerably greater, thus requiring a more complete extraction with volatile solvents. Solvent extraction (leaching) involves separating the components or constituents of the mixture based on their chemical differences rather than differences in physical properties. It depends on the selective dissolution of one or more liquid constituents of the mixture into a suitable immiscible liquid solvent. The basic principle behind the extraction involves the contacting of a solution with another solvent that is immiscible with the original. The solvent is also soluble with a specific solute contained in the solution^{7,8}. Two phases are formed after the addition of the solvent due to the differences in densities. The solvent is chosen so that the solute in the solution has more affinity towards the solvents. Hence, mass transfer of the solute from the solution to the solvent occurs and thus, separation is achieved when the component to be separated dissolves in the solvent. This is based on the concept of an "equilibrium" or "ideal" stage which is the stage from which the resultant solution is of the same composition as the solution adhering to the solids leaving the stage^{9,7} defined thus;

$$dm/dt = K'A (C_s - C) \text{-----} 1$$

Where A = area of solid-liquid interphase, b = effective thickness of the liquid film surrounding, C = concentration of the solute in the bulb of the solution at time, t, C_s = concentration of the saturated solution in contact with the particle, m = mass of solute transferred in time, t, k¹ = diffusion coefficient.

$$\text{Hence, } dm = Vdc \text{ and } dc/dt = k^1A/V_b (C_s - C) \text{-----} 2$$

Where V = volume of solution assumed to be constant.

Integrating thus;

$$\int \frac{dc}{C_s - C} = \int \frac{K' A}{V_b} dt \text{-----(3)}$$

This yield

$$\ln \frac{C_s - C_o}{C_s - C} = \frac{K' A}{V_b} dt \text{-----(4)}$$

If pure solvent is used initially then $C_o = 0$, and

$$1 - \frac{C}{C_s} = e^{-(K' A/V_b)t} \text{-----(5)}$$

$$\text{Or } C = C_s \left[1 - e^{-(K' A/V_b)t} \right] \text{-----(6)}$$

A well known method of extracting oil is the use of the soxhlet extractor. This is an indirect method of extracting oil from oil-bearing tissues. It involves flooding the solute containing the material with solvent and then allowing it to soak for some period of time. During this period, the oil being the solute leaves its initial location and diffuses preferentially into the solvent. Maximum extraction is obtained by continually contacting the feed with either fresh solvent or recycled solvent. This method however, gives a comparatively low yield of oil and requires large quantity of solvent for small oil extracted¹⁰.

Direct leaching is usually employed for oil-bearing fruits of low oil content containing less than 20% oil. Prepress solvent extraction is used for high oil content (more than 20% oil) oil-bearing fruits. However, in all types of fruits, through solvent extraction, about 90% of oil is extracted and only 10% remain in the meal^{7,4,5}.

In solvent extraction (leaching) processes, two types of solid – liquid contacting methods may be distinguished. Fixed bed contacting in which the solid particles are stationary and dispersed contact which involves motion of particles relative to each other and also relative to the liquid. Also, certain factors influence the rate of extraction and these includes the physical characteristics of solid, solvent selected, temperature of extraction, equipment and the operating pressure. In all cases, the principal flow configuration for solvent extraction (leaching) processes includes single-stage batch processing, multi-stage cross-flow extraction, multi-stage countercurrent extraction and continuous counter current extraction

Aims and Objectives of the Study

The aims and objectives of the research was to find possible uses of the avocado apple's pericarp/peels that hitherto has been discarded as wastes. In essence, the work is aimed at extracting oil from the pericarp(peels) of the avocado apple using two different solvents and two extraction (leaching) methods: Direct and indirect extraction (leaching); thus identifying which of the methods and solvent gave the highest yield of oil taking into consideration variations in thermodynamic conditions(temperature and time) and particle size. Furthermore, the aim covered the characterization of both the crude and refined oils from the avocado apple's pericarp.

Significance of Research

The study evaluated the extraction methods of direct and indirect leaching using the two solvents on the production of oil from the pericarp of the avocado apple vis-a-vis the affinity of the

sample for either solvents based on the yield or output of oil. Furthermore, the crude and refined oil extracts (active principle) were characterized to ascertain its physicochemical properties in comparison to international standards, hence its suitability or otherwise for industrial applications.

MATERIALS AND METHODS

The experimental procedures involved the procurement of materials and equipment; pretreatment of avocado apple and peels (pericarp); extraction of the oil from the avocado's pericarp and characterization of both the crude and refined oils.

In this work, only the unconventional materials and major equipment set-up used in the experiments are given in Tables 1.0 and 2.0 respectively.

Table 1.0: List of Materials Used for the Experiment

Materials	Source	Research code name	Comment
Avocado Apple	Obollo–Afor Market, Nsukka, Enugu, Nigeria	AVOA	Fresh greenish to dark blue in colour.
Avocado Peel/Pericarp	Avocado Apple	AVOP	Amber, dark brown in colour.
N – Hexane	WR International Ltd. Poole, BH15 1TD, England	UN 1208 (N – H)	bp 60 ⁰ C. n–hexane>>99% BDH (ANALAR) highly flammable volatile liquid.
Anhydrous Ethanol	BDH Chemicals Poole, England	UN 1170 (ABS)	99.7 – 100% ethanol, bp 78 ⁰ C. Analytical Grade.

Table 2.0: List of Equipment Used for the Experiment

Equipment	Source	Model	Comment
Soxhlet Extractor	Pyrex, England	BDB24	Glass Apparatus
Reflux condenser	Pyrex, England	BDB24	Glass Apparatus
Weighing balance	Ohaus, U.K	B300D	Digital Display
Measuring cylinder	Technico, England	BS604	Glass Apparatus
Oven	GallenKamp, England	CE94	Vacuum drier
Stack of sieves	Chemical Engineering laboratory, F.U.T., Minna	SOS241	Stainless steel
Heating mantle	Electrothermal Britain	B300	Stainless case

Procurement and Pretreatment of Avocado Apple and Peels (Pericarp)

The avocado apple was sourced locally from Obollo- Afor market, Nsukka in Enugu state of Nigeria. The fruits were thoroughly washed and screened to remove foreign bodies. The pericarp (peel) was removed from the mesocarp (flesh), leaving the mesocarp and the endocarp (seed). The pericarp was dried at room temperature (25⁰C) for five days to eliminate moisture. The dried pericarp was thereafter reduced to particle sizes ranging from 0.75mm to 2.00mm.

Experimental Procedure

Indirect (Soxhlet) Extraction of Oil from AVOP

In this process, 10g of AVOP each from particle sizes 0.75mm, 1.00mm, 1.59mm and 2.00mm and two solvents namely n-hexane and anhydrous ethanol were used alternatively in the indirect extraction (leaching) using the Soxhlet extractor. 10g of AVOP; 0.75mm particle size, was placed inside a thimble and inserted into the inner tube of the soxhlet extractor. This apparatus was then fitted to a round bottom flask which contained 200ml of the solvent (n-hexane or anhydrous ethanol). A reflux condenser was also mounted and fitted on the apparatus. The set up was held tight with a retort stand and then placed on a heating mantle that was switched-on for extraction times of 30, 60,90 and 120minutes at the boiling point of the solvent (n-hexane, 60⁰C or anhydrous ethanol, 78⁰C). The vapour passed up through the tube, condensed by the condenser and the condensed solvent falls into the thimble and slowly fills the body of the soxhlet. When the solvent reached the top of the tube, it siphoned over into the flask and thus removed the portion of the sample that has been extracted in the thimble. The process repeated itself automatically for the extraction times and the apparatus was dismantled. The mass of AVOP after extraction and drying in an electric oven was weighed and the weight recorded.

These procedures were repeated for particle sizes 1.00mm, 1.59mm and 2.00mm using fresh samples of the same mass (10g) and the same solvent (n- hexane or anhydrous ethanol) at the boiling point of the solvent (60⁰C for n- hexane, or 78⁰C for anhydrous ethanol) for each samples at extraction times of 30.60,90 and 120minutes respectively for each particle size and solvent.

The solvent recovery process involved using the same soxhlet extractor. The mixture of solvent and oil (also called miscella) was heated in the flask. On constant heating, the solvent evaporated and thereafter condensed in the thimble chamber. The solvent was collected before it siphoned back into the flask. The extracted oil was then recovered and the mass recorded.

Direct Extraction of Oil from AVOP

In this process,10g of AVOP each from particle sizes 0.75mm, 1.00mm, 1.59mm and 2.00mm and two solvents namely n-hexane and anhydrous ethanol were used alternatively in the direct extraction (leaching) of oil from AVOP. 10g of AVOP; 0.75mm particle size, was measured into a round bottom flask which contained 200ml of the solvent (n-hexane or anhydrous ethanol). The mixture was vigorously agitated by swirling the flask. A reflux condenser was mounted and fitted onto the conical flask. The condenser was then connected to a tap water source. The vent of the flask was made air tight to prevent the escape of the evaporating solvent. The set-up was held tight with a retort stand and the mixture placed on an electric heater and the thermostat adjusted to maintain a constant heating rate at the boiling point of the solvent (n-hexane,60⁰C and anhydrous ethanol,78⁰C). The mixture was allowed to boil for extraction times of 30, 60, 90 and 120minutes respectively. The vapour from the boiling solvent was made to condense and return to the mixture by means of a reflux condenser which was mounted on the flask through which water was constantly flowing. After the extraction had been completed, the heater was switched-off and the solvent decanted and filtered. The raffinate was weighed and its weight recorded after drying in an electric oven.

These procedures were repeated for particle sizes 1.00mm, 1.59mm and 2.00mm using fresh samples of the same mass (10g) and the same solvent (n– hexane or anhydrous ethanol) at the boiling point of the solvent (60⁰C for n– hexane or 78⁰C for anhydrous ethanol) for each samples at extraction times of 30, 60, 90 and 120 minutes respectively for each particle sizes and solvent. Solvent recovery process was further carried out on the extract phase to obtain the oil extract (active principle). This involved the use of the soxhlet extractor. On constant heating, the solvent evaporated and thereafter condensed in the thimble chamber. The solvent was collected before it siphoned back into the flash. The extracted oil was then recovered and its mass recorded.

Finally, the active principle (extracted oil) from the direct and indirect extraction (leaching) processes were further refined. The crude and refined oils were then characterized to define their physiochemical properties and hence their suitability for industrial applications.

Subsequently, the crude AVOP oil was refined with activated clay (bleaching earth) which was previously sieved to 70 – 5microns. 0.1% by weight of the clay was added to 10g of the oil sample. The mixture was then heated to a constant temperature of 100⁰C with stirring for 30minutes. The oil was then filtered at the same temperature and the filtered characterized.

Characterization of the Crude and Refined Oils

The crude and refined oil samples were subjected to various physicochemical analysis accordingly (ISO/TR 21092, ISO 212, ISO/TR 210, AOCS) to determine its properties such as saponification value, iodine value, peroxide value, free fatty acid value, acid value, specific gravity, refractive index and viscosity.

Results and Discussions

The optimized yields of extraction (indirect leaching) of avocado apple's pericarp at optimum thermodynamic condition and particle sizes of the avocado apple's pericarp using n–hexane and anhydrous ethanol are given in Table 3.0 – 4.0.

Table 5.0 shows the yields of oils from indirect leaching at varying extraction time, 0.75mm particle size (optimum particle size) and the use of n-hexane and anhydrous ethanol.

Similarly, the optimized yields of extraction (direct leaching) of avocado apple's pericarp at the optimum thermodynamic condition and particle sizes of the avocado apples's pericarp using n-hexane and anhydrous ethanol are given in Table 6.0 and 7.0.

Table 8.0 shows the yields of oils from direct leaching at varying extraction times, 0.75mm particle size (optimum particle size) and the use of n-hexane and anhydrous ethanol.

The physicochemical properties of both crude and refined oils are given in Tables 9.0 and 10.0.

Yields of Indirect Extraction (Leaching) of Avocado Apple's Pericarp

The optimized yields of indirect extraction (leaching) of avocado apple's pericarp at optimum thermodynamic conditions (temperature and time) and particle sizes of the avocado's pericarp using n–hexane (bp 60⁰C) and anhydrous ethanol (bp 78⁰C) are given in Tables 3.0 and 4.0.

Table 3.0 gives the optimal oil yield of 21.2% from 10g of avocado's pericarp size of 0.75mm at the 120minutes extraction time. The result from the table showed that the yields of oils were time and particle size dependent which was in accordance with literature value (Table 3.0).

Table 3.0: Yields of Oils from Indirect Leaching Using N-Hexane (bp, 60⁰C) at Varying Particle Size and 120minutes Extraction Time

Mass Of AVOP (g)	Particle Size (mm)	Time (mins)	No. Of runs	Mass of AVOP after Extraction and Drying (g)	Mass of Oil Extracted (g)	Average Mass of Oil Extracted (g)	% Yield
10	0.75	120	1	7.90	2.10	2.12	21.2
		120	2	7.86	2.14		
10	1.00	120	1	8.09	1.91	1.91	19.1
		120	2	8.10	1.90		
10	1.59	120	1	8.20	1.80	1.79	17.9
		120	2	8.22	1.78		
10	2.00	120	1	8.29	1.71	1.71	17.1
		120	2	8.30	1.70		

Table 4.0 gives the yields of oils at varying particle size, boiling point of solvent, 78⁰C, and 120minute extraction time. From the table, the highest yield of oil was achieved from 0.75mm particle size and this was 35.9%. The oil yields decreased with increase in the size of the particle at the extraction time. This was in accordance with literature.

Table 4.0: Yields of Oils from Indirect Leaching Using Anhydrous Ethanol (bp 78⁰C) at Varying Particle Size and 120 Minutes Extraction Time

Mass of AVOP (g)	Particle Size (mm)	Time (mins)	No. of runs	Mass of AVOP after Extraction and Drying (g)	Mass of Oil Extracted (g)	Average Mass of Oil Extracted (g)	% Yield
10	0.75	120	1	6.40	3.60	3.59	35.9
		120	2	6.43	3.57		
10	1.00	120	1	6.60	3.40	3.40	34.0
		120	2	6.60	3.40		
10	1.59	120	1	6.80	3.20	3.19	31.9
		120	2	6.83	3.17		
10	2.00	120	1	6.83	3.17	3.15	31.5
		120	2	6.88	3.12		

In Table 5.0, the yields of oils at varying extraction time, 0.75mm particle size (optimum particle size) and two solvents are presented. From the table, the maximum oil yield for the indirect leaching process was achieved at 120 minutes extraction time using anhydrous ethanol at its boiling point of 78⁰C. This was 35.9%. However, at a similar time (120minutes) using n-hexane (bp 60⁰C) the oil yield was 21.2% (Table 5.0).

Table 6.0 gives the optimal oil yield of 23.9% from 10g of avocado's pericarp size of 0.75mm. This was at 120minuts extraction time. The results from the table revealed that the yields of oils were time and particle size dependent which agreed with literature values (Table 6.0).

Table 5.0: Yields of Oils from Indirect Leaching at Varying Extraction Time, 0.75mm Particle Size (Optimum Particle Size) and Two Solvents

Mass of AVOP (g)	Solvent	Boiling Point (⁰ C)	Particle Size (mm)	Time (mins)	No. of runs	Mass of AVOP after Extraction and Drying (g)	Mass of Oil Extracted (g)	Average Mass of Oil Extracted (g)	% Yield
10	n-hexane	60	0.75	30	1	8.53	1.47	1.46	14.6
				30	2	8.55	1.45		
10	n-hexane	60	0.75	60	1	8.11	1.89	1.86	18.6
				60	2	8.18	1.82		
10	n-hexane	60	0.75	90	1	7.96	2.04	2.02	20.2
				90	2	8.01	1.99		
10	n-hexane	60	0.75	120	1	7.90	2.10	2.12	21.2
				120	2	7.86	2.14		
10	Anhydrous ethanol	78	0.75	30	1	6.82	3.18	3.21	32.1
				30	2	6.76	3.24		
10	Anhydrous ethanol	78	0.75	60	1	6.58	3.42	3.40	34.0
				60	2	6.62	3.38		
10	Anhydrous ethanol	78	0.75	90	1	6.49	3.51	3.50	35.0
				90	2	6.51	3.49		
10	Anhydrous ethanol	78	0.75	120	1	6.40	3.60	3.59	35.9
				120	2	6.43	3.57		

Table 6.0: Yields of Oils from Direct Leaching Using N-Hexane (bp 60⁰C) at Varying Particle Size and 120minutes Extraction Time

Mass of AVOP (g)	Particle Size (mm)	Time (mins)	No. of runs	Mass of AVOP after Extraction and Drying (g)	Mass of Oil Extracted (g)	Average Mass Of Oil Extracted (g)	% Yield
10	0.75	120	1	7.60	2.40	2.39	23.9
		120	2	7.62	2.38		
10	1.00	120	1	7.80	2.20	2.21	22.1
		120	2	7.78	2.22		
10	1.59	120	1	8.00	2.00	2.00	20.0
		120	2	8.00	2.00		
10	2.00	120	1	8.04	1.96	1.97	19.7
		120	2	8.02	1.98		

Table 7.0 gives the yields of oils at varying particle size, boiling point of solvent; 78⁰C, and 120minutes extraction time. From the table, the highest yield of oil was obtained from 0.75mm particle size and this was 42.0%. The oil yields decreased with increase in the size of the particle at the time period for extraction. This was in accordance with literature value.

Table 7.0: Yields of Oils from Direct Leaching Using Anhydrous Ethanol (bp 78⁰C) at Varying Particle Size and 120minutes Extraction Time

Mass of AVOP (g)	Particle Size (mm)	Time (mins)	No. of runs	Mass of AVOP after Extraction and Drying (g)	Mass of Oil Extracted (g)	Average Mass of Oil Extracted (g)	% Yield
10	0.75	120	1	5.78	4.22	4.20	42.0
		120	2	5.82	4.18		
10	1.00	120	1	6.30	3.70	3.71	37.1
		120	2	6.28	3.72		
10	1.59	120	1	6.42	3.58	3.58	35.8
		120	2	6.42	3.58		
10	2.00	120	1	6.53	3.47	3.48	34.8
		120	2	6.51	3.49		

Table 8.0: Yield of Oils from Direct Leaching at Varying Extraction Time, 0.75mm Particle Size (Optimum Particle Size) and Two Solvents

Mass of AVOP (g)	Solvent	Boiling Point (⁰ C)	Particle Size (mm)	Time (mins)	No. of runs	Mass of AVOP after Extraction and Drying (g)	Mass of Oil Extracted (g)	Average Mass of Oil Extracted	% Yield
10	n-hexane	60	0.75	30	1	8.06	1.94	1.98	19.8
				30	2	7.98	2.02		
10	n-hexane	60	0.75	60	1	7.82	2.1	2.13	21.3
				60	2	7.92	2.08		
10	n-hexane	60	0.75	90	1	7.69	2.31	2.29	22.9
				90	2	7.72	2.28		
10	n-hexane	60	0.75	120	1	7.60	2.40	2.39	23.9
				120	2	7.62	2.38		
10	Anhydrous ethanol	78	0.75	30	1	6.24	3.76	3.78	37.8
				30	2	6.21	3.79		
10	Anhydrous ethanol	78	0.75	60	1	6.03	3.97	4.00	40.0
				60	2	5.98	4.02		
10	Anhydrous ethanol	78	0.75	90	1	5.83	4.17	4.14	41.4
				90	2	5.89	4.11		
10	Anhydrous ethanol	78	0.75	120	1	5.78	4.22	4.20	42.0
				120	2	5.82	4.18		

In Table 8.0, the yields of oils at varying extraction time, 0.75mm particle size (optical size) and two solvents are presented from the table; the maximum oil yield for the direct leaching process was achieved at 120 minutes extraction time using anhydrous ethanol at its boiling point of 780C. This was 42.0%. However, at a similar time (120 minutes) using n-hexane (bp 600C), the oil yield was 23.9% (Table 8.0).

Physicochemical Properties of Crude and Refined AVOP Oils

The physicochemical properties of both crude and refined oils are given in Tables 9.0 and 10.0 respectively.

Table 9.0 gives the results of the analysis on the crude AVOP oil samples, that is, the physicochemical properties. From the table, the values of properties fall within the range of values for oils used in similar applications with reference to organizations such as the American oil chemists' society (AOCS) and the International Organization for Standardization (ISO) standards.

Table 9.0: Physicochemical Properties of the Crude AVOP Oil

Properties	Value
Saponification value (ml/kg)	198
Iodine value (from GLC)(mg/l)	72.4
Peroxide value (meq/kgfat)	3.07
Free fatty acid value (oleic)(%)	0.08729
Acid value (ml/kg)	6.8943
Specific gravity (@25 ⁰ C)	0.9162
Refractive index	1,465
Viscosity (cp)	180.43
Boiling point (⁰ C)	89 - 90

Table 10.0 gives the values of the physicochemical properties of the refined AVOP oil which are most commonly used to establish the identity of oils. Each of the property was chosen to measure a specific characteristic of the oil.

Table 10.0: Physicochemical Properties of the Refined AVOP Oil

Properties	Value
Saponification value (ml/kg)	196.4
Iodine value (from GLC)(mg/l)	67.7
Peroxide value (meq/kg fat)	1.27
Free fatty acid value (as oleic)(%)	0.0872
Acid value (ml/kg)	5.653
Specific gravity (@ 25 ⁰ C)	0.90261
Refractive index	1,600
Viscosity (cp)	181.180
Boiling point (⁰ C)	89

From Tables 9.0 and 10.0, the properties of the oil such as specification value, iodine value, peroxide value, free fatty value and acid value are mostly used to specify the characteristic of the

oil. The others are empirical in nature though they also give useful guidance in identifying the oil.

Comparison of Tables 9.0 and 10.0 revealed that the difference in saponification value between the crude and refined oils was less than 1.0 (0.81%). This is attributable to the fact that the oil's many natural constituents are still present and hence, little lipase activity.

Also, from the tables, a 65% level decrease in iodine value between the crude and refined oils implied that less amount of hydrogen would be required in converting the unsaturated components of the oil into saturated oil for industrial use.

Similarly, the lower peroxide value (58.63%) of the refined oil implied that the oil cannot be easily decomposed and neither can it become rancid as a result of the presence of triglyceride esters of the oil to form peroxide when compared to the crude oil.

An acid value of less than 10 enhances the stability of most oils and both values fall within this range. This, the refining quality of the oil is enhanced.

The low value of the FFA for both the crude and refined oils implied that the oil contains acid that are uncombined with glycerol and thus, do not easily decompose nor become rancid, indicating little lipase activity.

Other constituents of the crude and refined oil includes its richness in vitamins A, B, G and E; it has digestibility coefficient of 93.8% but can't be used extensively as edible oil due to its cost; its amino acid content is as follows: palmitic, 7.0, stearic, 1.0, oleic, 79.0 and linoleic, 13.0. It has a high lipid content of both saturated and unsaturated fatty acids in the form of palmitic, stearic, oleic and linoleic in varying composition. However, the oil is predominantly monosaturated and is low in saturates. It has the added benefit in that it contains beta-sitosterols in significant amounts (0.5-1.0%) and thus, its consumption is recommended especially for the elderly in alleviating the symptoms of benign prostatic hypertrophy. The oil has excellent keeping quality staying as long as possible with only slight rancidity and can be used as hair-dressing, making facial creams, hand lotions and fine soap.

CONCLUSION

The conclusions emerging from this work include the following:

1. That high quality oil could be obtained from the pericarp of the avocado apple which hitherto was discarded as waste.
2. The rate of extraction was known to proceed favorably with increasing time and decreasing particle size at the temperature of extraction. The results of this work using indirect and direct extraction (leaching) were supportive of that fact.
3. The yields of oils from indirect and direct leaching using n-hexane and anhydrous ethanol increased progressively with decreased particles size and increasing extraction time at the boiling points of the solvents. Also, the affinity of the sample materials toward either of the solvent used showed that anhydrous ethanol was more useful as the leaching solvent based on the yields of oils obtained than n-hexane for this particular work

4. Comparison of the results of indirect and direct leaching showed that, at a similar reaction time (120 minutes), particle size (0.75mm) and boiling points of the solvents (n-hexane 60⁰C, anhydrous ethanol 78⁰C), the optimum yields of oils of 21.2% and 23.9% for indirect and direct leaching using n-hexane and 35.9% and 42.0% for indirect and direct leaching using anhydrous ethanol were obtained. The physicochemical properties of both the crude and refined oils were found comparable with oils of similar structural constituents used for industrial applications.

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