Extraction and Characterization of Oil from Avocado Peels

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***Abstract*—**The peels of avocados, like other fruit peels, are commonly discarded, not knowing their potential use. This study carried out to extract oils from avocado peels and to characterize the extracted oils with the view to determine their suitability for consumption and other uses. Soxhlet apparatus was used for extraction using n-hexane as a solvent, which is chosen based on the fact that it has a very low value of toxicity and a great extraction rate. The proximate analysis and physicochemical properties of the extracted oil were investigated. The percentage yield of oil extracted from the peel was found to be 40.6%. From this study, the optimum operating conditions for the extraction of oil from avocado peel oil for the particle size of 2.6 mm, solvent type N-hexane and extraction time of 3-5 hr. were considered. A general factorial design was applied to investigate the effect of process variables on oil yield. Maximum oil yield of 40.6% was obtained at an extraction time of 5 hr. The extracted avocado peel oil can be widely used in pharmaceutical and energy production.

***Keywords*—**Avocado fruits, avocado oil, avocado peel oil, characterization.

I. Introduction

AVOCADO (*Persea americana*) originated in Mexico and belongs to the Lauraceae family. It is now planted and grows in tropical and subtropical regions throughout the world. Avocados are one of the most important commercial tropical fruits and many varieties exist. The fruit is exceedingly variable in shape, size, and color [1]. Few countries are involved in the production of avocado oil namely; Mexico (34%), USA (8%), Israel (4%), South Africa (< 2%) and New Zealand (< 1%) and these are the countries involved in growing and trading of the fruit [2], [3]. Avocado is one of the most promising fruit crops with the highest potential production expansion in Ethiopia. The volume of production has expanded [4].

Currently, the avocado fruit is extensively considered as an important fruit for its multi-nutritional values, as it is rich in vital human nutrients. The avocado fruit is second-grade fruits with relatively high oil. Avocado oil has generated growing interest among consumers due to its nutritional values, which is evidenced by an increase in the number of technological characteristics or scientific articles that have been published on it [5].

Avocado peel is a waste where so many people are throwing away after using the fruit flesh. It is one of the most popular fruit in Ethiopia as a result there is a significant rise in avocado fruit consumption and consequently an increase in avocado peel waste generation. Therefore, alternative routes are needed for this waste management. This waste cannot be used still for any consumption. On the other hand, compared to other avocado varieties, the non-edible portions (peel and seed) of the Hass avocados constitute a smaller proportion of the whole (35%), whereas the edible yellowish pulp constitutes the major portion (65%) of the fruit [6].

The presence of nitrogen allows it to be directly used as fertilizer or as soil improver (or compost). Avocado peels are used to evaluate the possibility of using and transforming waste to something valuable product, namely for, pharmaceutical, cosmetic industries, and biodiesel thereby contributing towards alternative energy supply as well as recycles what would be discarded and resolves energy scarcity [7].

The avocado fruit is widely regarded today as an important fruit for its nutritional values, as it is rich in vital nutrients for the human body. There has recently been an increasing demand in antioxidants, given their beneficial effects on human health. In this respect, avocado contains three most important vitamins. Avocado fat consists predominantly of monounsaturated oleic acid, which has been found to reduce harmful low-density lipoprotein cholesterol, while maintaining beneficial high-density lipoprotein cholesterol, and to perform better than typical low-fat diets. Depending on the location of the orchard, the oil content of these fruit flesh can range from 16-17% in September to 25-30% in April depending on the fruit ripening stage [8].

The common characteristic of avocados is the maturation of the fruits on the tree, which ripen after harvest. It takes 5–7 days after harvesting at room temperature for the ripening process to proceed. In general, avocado fruit can be divided into three parts, consisting of peel, flesh, and seed (Fig. 1). Different parts of the avocado fruit have different contents of functional compounds. The peel is rich in fibre and phenolic compounds, with antioxidant and colorant properties [9].

The avocado pulp contains from 67 to 78% moisture, 13.5 to 24% lipids, 0.8 to 4.8% carbohydrate, 1.0 to 3.0% protein, 0.8 to 1.5% ash, 1.4 to 3.0% fiber, and energy density between 140 and 228 kcal [8].

Avocado oil is obtained from its pulp – 15 to 30% depending on the variety. Almost all the oil is concentrated in the pulp. The avocado tree grows well in Ethiopia but it is one of the agricultural products that are highly under-utilized in the country. Awareness of the health benefits of avocado is not widespread and a substantial quantity is also wasted. The avocado fruit is rich in nutrients, high in proteins,

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antioxidants, and dietary fiber. Thus, there is a need for value-added products using avocado pear, to not only reduce waste but also for the economic benefit of the country [10].

Solvent extraction is the recent method of extracting oil from crops, hexane has become the solvent of choice for solvent extraction because of high stability of the solvent, low evaporation loss, low corrosiveness, little greasing residue and better odor and flavor of the extracted product. Solvent extraction has several drawbacks, including high capital equipment cost and operational expenditure. The primary prerequisite for solvent extraction for oil is the rupturing of the seed or feed material to render the cell wall more porous [12]. As for oil extraction with solvents, the extraction efficiency for different compound classes is highly dependent on the properties of the selected solvent.

The physicochemical characteristics and proximate composition of the oil show that it has some industrial potential and utilization of this oil will reduce dependence on the popular vegetable oils like groundnut, coconut, and palm oil for domestic use [11].

Avocado oil is extracted from the pulp of the fruit. Owing to the fast absorption and high skin penetration ability, avocado oil is widely used in the pharmaceutical and cosmetic industry to produce various skin or hair care products. Compared to other varieties of avocado, high oil yield in Hass avocado pulp makes it more suitable for the purpose of edible oil extraction [7]. Also, it easily forms an emulsion, ideal for the manufacture of fine soaps [13].

A. Review of Avocado Production in Ethiopia

The relatively early establishment of the avocado industry in Ethiopia is in its beginning and has not until now utilized the vast potential of this crop. In the context of increasing the high-value production of agricultural commodities and fruit trees play an important role. According to CSA (2013) avocado is one of the second potential fruit crops produced in Ethiopia [1].

TABLE I
SUMMARY OF MAJOR FRUIT CROPS PRODUCED IN ETHIOPIA IN THE 2016/2017 CROPPING SEASON [18]

Crop	Area in Ha	Production in Quintal	Yield (Qt / Ha)
Fruits	107,890.6	7,923,665.02	
Avocados	17,834.58	649,821.04	36.44
Bananas	63,212.97	5,383,023.41	85.16
Guavas	3248.59	43,265.32	13.32
Lemons	1426.25	77,814.52	54.56
Mangoes	15,413.76	1,046,461.25	67.85
Oranges	2619.8	206,559.48	78.85
Papayas	3489.47	503,961.70	144.42
Pineapples	645.19	12,758.30	*

Avocados are one of the few fruits that contain significant quantities of oil. Oil content is a key part of the sensory quality. Oil quality is very similar to that of olive oil [14]. However, the avocado peel is one of the waste materials removed from avocado fruit. In some cases, it is used for animal feeding. The avocado fruit comprises a dark green peel, green oily pulp, and a large seed, which represents 10-22% of the total weight depending on the species. The peel (skin) is mainly composed of moisture, while the remaining 10% is lipids, proteins, ashes, fiber, and others.

TABLE II
PHYSICOCHEMICAL PARAMETERS OF THE DIFFERENT FRACTIONS OF THE AVOCADO [15]

Parameter	Pulp	Skin	Seeds
Moisture (%)	70.83 ± 3.53	69.13 ± 2.58	54.45 ± 2.33
Ash (%)	1.77 ± 0.16	1.50 ± 0.08	1.29 ± 0.03
Proteins (%)	1.82 ± 0.07	1.91 ± 0.08	2.19 ± 0.16
Fat (%)	43.5 ± 4.62	2.20 ± 1.65	14.7 ± 0.32
Total soluble solids	43.5 ± 4.62	3.01 ± 2.03	3.54 ± 1.97
Acidity	1.07 ± 0.02	2.05 ± 0.24	2.67 ± 0.17

The moisture content is one of the most important indices evaluated in foods, especially fruits. It is a good indicator of their economic value because it reflects solid contents and serves to assess its perishability, especially in avocado fruits it contains 65% moisture or water and it is a good indicator of their economic value chain. The avocado skin indicated in Table II has the second water content (69.13%) next to a pulp (70.83%) and followed the seed (54.45%). The skin fat and ash quantified were significantly higher than those found in the pulp. The yields of avocado produce 2638 liters of oil per ha and it is one of the third feedstock for different energy production like biodiesel production next to oil palm and coconut [7].

II. MATERIALS AND METHODS

A. Sample Collection and Preparation

All the avocado fruits collected used in this study are purchased from the markets. The avocado was cut into two pieces and the peels were removed from avocado fruits by hand. The waste avocado peels are collected from hotels, cafeteria, and juice processing houses. The raw material (sample) preparation process includes manual size reduction (Knife cutting), drying, and grinding. Waste peel of avocado 10 kg was used for the sample preparation.

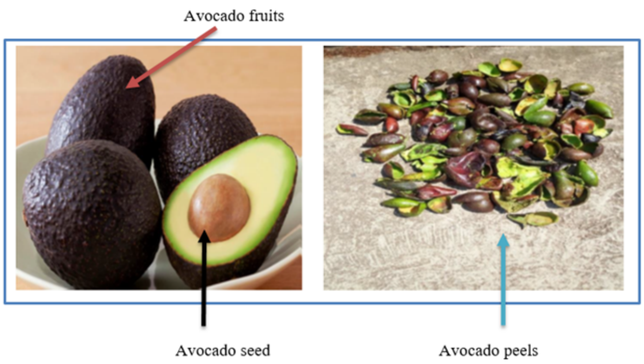

Fig. 1 Avocado fruit, avocado seed, and avocado peel

B. Drying Process

The drying process is important in removing water contents from the avocado peel. To determine the most appropriate moisture content of avocado peels, they were manually cut with a knife and the peels were dried until all of its moisture content was removed. The peel was dried by oven at 70 °C until a constant weight was achieved. The oil was extracted using a Soxhlet extractor and extraction was done separately with hot water and N- hexane. The determination of oil yield, proximate analysis, and physicochemical parameters was done.

1. Determination of Moisture Content of the Avocado Peel

10 kg sample of the avocado peel was weighed and dried by the oven and the weight was measured every two hours. The procedure was repeated until a constant weight was obtained and the percentage moisture content of the peel was determined. After a constant weight, the moisture content of the sample was obtained by calculating the water lost upon the drying process.

$$\text{Moisture content } (\%):\ W = \frac{M_0 - M}{M_0} \times 100 \quad (1)$$

where: M = the final weight of the dried sample (peel); M_0 = initial weight of the fresh sample (peel)

2. Milling Process (Size Reduction and Sieve Analysis)

Size reduction is major unit operation in industries handling particulate solid and it is very important and useful in many chemical and other industries. The equipment used for size reduction is centrifugal miller. The purpose of milling is to size reduction by cutting action that is carried out by feeding dried avocado peels against the rotating cutter. The particle size was standardized with a 2.6 mm sieve. This particular size was selected because literature revealed that to have a higher yield of oil the particle size should be less than 5 mm and higher than 0.2 mm [15], we use the mean of the two. Finally, the powder was stored in a dark bottle until we use it.

3. Oil Extraction Process and Determination of Percentage Yield

Soxhlet extraction was one of the most commonly used oil extractions. A ratio of crushed avocado peels (powder) to a solvent of 1:5 (m/v) was used. 100 g of avocado peel powder with an average size of 2.6 mm sieve was placed into the thimble and placed in the Soxhlet chamber. The solvent used for oil extraction was n-hexane.

The extraction was carried out using 500 ml with n-hexane at 69 °C (below the boiling temperature) of hexane with purity 99.0% for 3-5 hr were placed in a round bottom in 1000 ml flask and assembled for Soxhlet extractor. Then, the thimble is made from thick filter paper, which is loaded in the main chamber of Soxhlet extractor. The Soxhlet extractor is placed onto a flask containing an extraction solvent. The Soxhlet is than equipped with a condenser. The solvent is heated to reflux. The solvent hexane forms vapors, which travels up a distillation arm, and floods into the chamber housing the thimble of solid. The condenser ensures that any solvent vapor that cools drips by the siphon sidearm, with hexane running back to the distillation flask. This cycle was repeated for varying time. During each cycle, a portion of the oil is dissolved in hexane. After many such cycles, the desired oil was concentrated in the distillation flask. After extraction hexane was removed, yielding the extracted compound. The insoluble portion of the crushed avocado peels (powder) remains in the thimble [16].

Finally, the oil obtained from 100 g of avocado peel powder was 70 ml (52.2 g) for 3 hr at 60 °C and 4 and 5 hrs 74.74 ml (55.74 g) and 80.3 ml (59.9 g) at 65 & 69 °C respectively.

Fig. 2 Extraction of oil by Soxhlet extraction

C. Evaporation Process

After completing the extraction process, the flask containing the solvent and lipid is removed and the distillation (recovered) process of oil was begun. The solvent and extractor were placed on a water bath to evaporate the solvent. The solvent was evaporated at 70 °C, the oil remains in the flask because of its low volatility [17], the solvent (n-hexane) evaporates through a condenser, and we use this solvent for other extraction.

D. Degumming Process

In the degumming process, distilled water was heated to 100 °C and left to boil for several minutes. Then crude avocado peel oil was poured into a beaker and an equal volume of hot distilled water was added and stirred vigorously to remove the gums. The mixture was allowed to settle for 5 minutes; the oil-water mixture separated into layers with the oil layer on top. The oil was decanted and the process repeated.

III. Results and Discussions

Proximate composition (moisture contents and percentage of crude oil yield) of the avocado peels were determined. Physicochemical parameters of the n-hexane extracted avocado peel oil were also determined.

A. Procedure Determination of Proximate Composition of Avocado Peels

1. Determination of Moisture (Water) Content of the Avocado Peels

The total weight of the avocado peel we use (weight of the sample before dry) was 10 Kg, but the weight of the sample after dry was 2.9 kg. The percent moisture content of the peel was calculated by substituting these values into the equation;

$$\text{Moisture content } (\%):\ W = \frac{W_1 - W_2}{W_1} \times 100$$

where: W_1 = Original weight of the sample before drying; W_2 = Weight of the sample after drying.

$$W = \frac{10 - 2.9}{10} \times 100 = 71\%$$

This meets the physicochemical properties of avocado skin. Therefore, 71% of the avocado peel was moisture it contains.

2. Determination of the Percentage of Oil Yield Extracted from Avocado Peel

100 g (W_1) of the sample was placed in the thimble and about 500ml of n-hexane was poured into the round bottom flask. The apparatus was heated at 70 °C and allowed for 5 hrs for the extraction process. After the extraction, the solid avocado powdered was dried in the oven at 105 °C and weighed until the constant weight (W_2) is attained, and the percentage of oil extracted was determined as:

$$\%\ \text{crude oil yield}: \ W = \frac{W_1 - W_2}{W_1} \times 100 \qquad (2)$$

where, W_1 = weight of a sample before extraction; W_2 = weight of a sample after extraction

TABLE III
RESULT OF SOXHLET EXTRACTION WITH PARTICLE SIZE 2.6 MM AT DIFFERENT TEMPERATURES AND TIMES WITH (2)

Trial	Temperature (^{0}c)	Time (hr)	W_1(g)	W_2(g)	Oil yield (%)	Average (%)
1	60	3	100	64.6	35.6	
2	65	4	100	62.8	37.8	38
3	69	5	100	59.4	40.6	

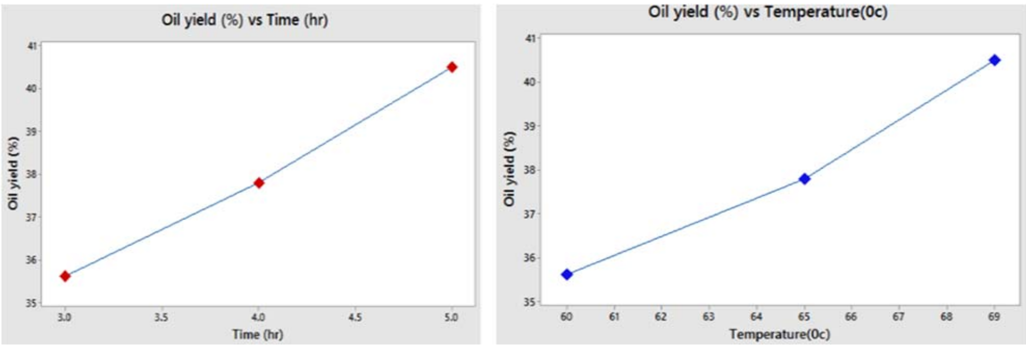

Fig. 3 Oil yield (%) of oil extraction by Soxhlet extraction at different temperatures and times

B. Physicochemical Properties of Avocado Peel Oil

The oil extracted by Soxhlet extraction was used after analyzing the physicochemical properties. Physical properties such as density, kinematic viscosity, pH value, and chemical properties like acid value, free fatty acid value, saponification value, and iodine value, were determined for oil physicochemical properties using optimum operating parameters. The details of the properties are discussed as:

1) Specific Gravity

The density of the oil was determined by using density beaker. Densimeter was inserted into the cylinder. Then, the reading was taken. The specific gravity observed was 0.91. Hence, the density of the oil is determined using specific gravity.

$$SG = \frac{\rho_{oil}}{\rho_W} = \rho_{oil} \qquad (3)$$

where, ρ_{oil} = Density of avocado peel oil; ρ_w = Density of equal volume water = 1 g/ml. Therefore, the density of the oil was 0.91g/ml or 910 kg/m^3.

2) Kinematic Viscosity

The viscosity of oil was measured using Vibro viscometer. The device detects the dynamic viscosity, which is resistance to flow with vibration. The observed dynamic viscosity was at 40 °C was 47.2 mpa.s.

$$V = \frac{\mu}{\rho} \qquad (4)$$

where, μ = dynamic viscosity, mm^2/s; ν = kinematic viscosity, mpa.sec; ρ = density, Kg/m^3.

$$V = \frac{\mu}{\rho} = \frac{4.72 \times 10^{-2} \frac{kg}{m} sec}{910 \frac{kg}{m^3}} = 5.2 \times 10^{-5} \ \frac{m^2}{s}$$

This value is in the range of literature data [19].

3) Molecular Weight Determination

The molecular weight of oil was determined from the saponification value and acid value of avocado peel oil [16]. The molecular weight of the oil was calculated as:

$$M_W = \frac{168300}{S_V - A_V} \qquad (5)$$

where, M_W - molecular weight of oil; S_V - Saponification value of oil; A_V - acid value of oil.

$$M_W = \frac{168300}{200 - 8.8} = 880 \text{ g / mol}$$

TABLE IV
PHYSICOCHEMICAL PROPERTIES OF THE OBTAINED AVOCADO PEEL OIL AND THE STANDARDS OF THE UNITED STATES AND EUROPE

Property	Avocado peel oil	EN 14214	ASTM D-6751
Density at 15 ^{0}C, kg/m^3	910	860-900	
PH	6.2	5- 6.7	7-9
kinematic viscosity at 40 ^{0}C, cSt	5.1	3.5- 5.0	1.9-6
Specific gravity	0.91	0.86-0.9	
Fire Point, (^{0}C)	250		--
Iodine value , g I_2/100 g	82	< 120	
Acid value , mg NaOH/g	8.8	-	-
Free fatty acids	4.4	-	-
Saponification value (mgKOH/g)	200		
Melting point (^{0}C)	38.5		
Fire point (^{0}C)	250		
HHV (MJ/kg)	40	36 – 40	40 – 42

IV. CONCLUSION

Fruit peels, such as avocado peel, are not generally consumed and are therefore discarded. Avocado oil has an important cosmetic and nutritional value to produce various skin or hair care products. Its nutritional properties are similar to olive oil. Avocados are extremely nutritious fruits that are locally abundant but have a small local market in Ethiopia. The edible fruit has high oil content and the oil contains high amounts of anti-cholesterol agents and other essential nutrients which makes it a very valuable product. Fruit peels, such as avocado peel, are not generally consumed and are therefore discarded. After an investigation on the properties of the avocado peel oil, it was used as a source of energy that was suggested as a way of reusing these discarded peels. The oil extracted from avocado peels and the oil is low in levels of saturated fats. The avocado peels can be used as an alternative to energy oil. Its physicochemical characteristics show that it has some industrial potential and utilization of this oil will reduce our dependence on the popular fossil fuels which brings environmental pollutions.

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