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Characterization of D*acryodes edulis* (African pear*)* pulp oil obtained with different extraction methods.

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Abstract

The characterization of *Dacryodes edulis* pulp oil obtained using different extraction methods (Soxhlet, traditional and screw press) was studied. Commercial soybean oil was used as reference sample. Oil yield, chemical composition, quality parameters, physicochemical properties and sensory characteristics were determined. The oil yields realized from Soxhlet, traditional and screw press methods were 34.09%, 10.26% and 7.10% respectively. Chemical composition ranged from 26.00 to 63.90 g I_2/100g, 1.47 to 13.26% and 128.00 to 227.50 mg KOH/g for iodine value, unsaponifiable matter and saponification value respectively. Quality properties ranged from 2.12 to 7.08% for free fatty acid, 0.94 to 2.55 meq O_2/kg for peroxide value, 0.02 to1.11 mg/g for thiobarbituric acid and 4.23 to 14.15 mg KOH/g for acid value. Physicochemical properties ranged from 0.90 to 0.93 g/cm^3 for specific gravity, 1.42 to 1.46 for refractive index, 0.00 to 37.00°C for melting point, 174.00 to 236.50°C for smoke point, 186.60 to 309.50°C for flash point and 0.08 to 12.23% for moisture content. Conclusively, SOXHLET had the highest oil yield, better chemical composition and quality properties and was best generally accepted (8.52) in terms of sensory properties. The quality and sensory characteristics of the oil samples suggested the necessity of refining.

Keywords: Characterization, *Dacryodes edulis*, extraction, pulp oil.

1. Introduction

Vegetable oils are important for both food and non-food industry. They are found in plant tissues such as seed and pulp (Mariana *et al.*, 2013), and can be used in frying, baking, production of mayonnaises, shortenings, margarines and other valuable products (Falade *et al*., 2017). *Dacryodes edulis (D. edulis)* also known as bush butter and native pear (Miguel *et al*., 2017), is one of such fruits from which vegetable oil can be obtained. It could serve dual purpose of being a food for direct consumption and raw material for industries, if properly harnessed (Duru *et al*., 2012). The fruit is also known as *safou* in French, *ube* in Ibo, *elemi* (Yoruba), *eben* (Efik) and *orumu* (Benin) (Nwokeji *et al*., 2005). *D. edulis* fruit has a seed that is covered by a pulpy edible mesocarp. Its on-season in Nigeria is from April to September (Onuegbu and Ihediohanma, 2008), and it is conventionally eaten raw, roasted or in boiled form alongside cooked or roasted maize (Ondo-Azi *et al*., 2013). According to Agwu *et al*.

(2017), *D. edulis* has the potential to improve nutrition and food security. Its pulp constitutes 32.56% fat, 9.17% dietary fibre, 5.90% total titratable acidity, 5.07 pH, 164.84 mg/100g ascorbic acid, 17.11 mg/100g niacin, 3.60 g/100g lysine and 10.52 g/100g aspartic acid (Onuegbu *et al*., 2011). *D. edulis* pulp is rich in lipid content; hence, it could be an important source of vegetable oil (Ondo-Azi *et al*., 2013). Ikhuoria and Maliki (2013) reported that *D. edulis* pulp oil possesses 80ºC average melting point, 1.46 refractive index, 0.33 poise viscosity, 1.10% free fatty acid, 143.76 mg KOH/g saponification value, 44.08 g/100g iodine value, 15.28 mg KOH/g acid value and 128.48 KOH/g ester value.

Method of extracting vegetable oil from crops such as *D. edulis* varies with its nature and oil content. Various methods were adopted with the purpose of extracting good quality and quantity of vegetable oil with minimum costs (Mariana *et al*., 2013). Currently, solvent extraction method, supercritical fluid extraction method, steam distillation method and mechanical extraction method have been utilized as the basic methods of extracting vegetable oil (Mariana *et al*., 2013). However, little has been done in exploring the best extraction method for this. Extensive characterization of, *D. edulis* pulp oil for industrial use is necessary. Over-dependency on conventional vegetable oils such as groundnut oil and soybean oil, as well as their increasing scarcity and processing cost has led to improved interest in extracting oil from non-conventional, cheap and available crops like *D. edulis*. Apart from this, *D. Edulis* experiences a lot of wastage in its on-season as a result of poor knowledge of processing. There are no commercially available products made from the fruit pulp; thus, its industrial potential has not been harnessed. The fruits are only consumed locally and sold as produce in local market (Onuegbu *et al*., 2011). Thus, the characterization of *D. edulis* pulp oil with respect to different extraction methods would reveal its potential as an industrial raw material in food systems.

2. Materials and Methods

2.1. Sample preparation

D. edulis fruits were procured from Ubani market in Umuahia, Abia State, Nigeria. The reference sample (soybean oil) was purchased from Shoprite market, Umuahia, Abia State. Three (3) kg of *D. edulis* fruits was sorted, washed thoroughly with distilled water and split open with a sharp stainless knife to remove the seed from the pulp. The de-seeded fruits were cut into smaller pieces, dried at a temperature of 70°C in a Gallenkamp hot air oven (Model OV 160) for 36 hours and milled with attrition mill to obtain *D. edulis* pulp powder prior to Soxhlet extraction. Another 3 kg of the fruits was sorted, washed with water and split open with a sharp stainless knife to remove the seed from the pulp. The *D. edulis* pulp was cut into smaller pieces (2 cm) and packaged in an air-tight cellophane bag at room temperature for 18 hours to soften the pulp prior to oil extraction by traditional and screw press methods.

2.2. Extraction of D. *edulis pulp* oil

2.2.1. Extraction of *D. edulis* pulp oil using Soxhlet extraction method

The Soxhlet extraction method described by Musa *et al*. (2015) was used in the extraction of *D. edulis* pulp oil. Two hundred and fifty millilitres (250 ml) of n-hexane was poured into a round bottom flask. Ten (10) g of *D. edulis* pulp powder was introduced into the thimble and was placed at the centre of the Soxhlet extractor. The extractor was then heated to 79°C (this temperature was chosen because n-hexane has an optimum boiling point of 78^0C.) and was held at that temperature throughout the duration of the reflux process (5 hours). The *D. edulis* oil was then recovered and heated in an oven at 80°C for 10 minutes to allow any residual n-hexane in the mix to evaporate. The oil samples obtained were packaged in an air-tight container and stored in a refrigerator prior to analysis (Plate 1).

2.2.2. Extraction of *D. edulis* pulp oil using traditional extraction method

The method described by Adedokun and Onuegbu (2011) was used. Three (3) kg of the softened pulp was mashed manually with mortar and pestle and transferred to a stainless bowl with subsequent addition of 4000 ml of boiled water. Cleaned sieving cloth was used to separate the mixture of oil and water from the mashed pulp. The mixture was further separated by distillation process and the oil samples were heated on fire at 120°C for 2 minutes to remove water. The obtained oil samples were packaged in an air-tight container and stored in a refrigerator prior to analysis (Plate 2).

2.2.3. Extraction of *D. edulis* pulp oil using screw press extraction method

Screw press extraction of *D. edulis* pulp oil was carried out using the modified method of Adedokun and Onuegbu (2011). Three (3) kg of softened *D. edulis* pulp was mashed manually with mortar and pestle, and was subjected to low heat for 2 minutes to loosen the fat globules before transferring it to a sieving cloth. The mashed pulp was tied in a sieving cloth with rope (to curb leakage) and placed in a screw press; pressure was applied and the oil collected. The obtained oil samples were packaged in an air-tight container and stored in a refrigerator prior to analysis (Plate 3).

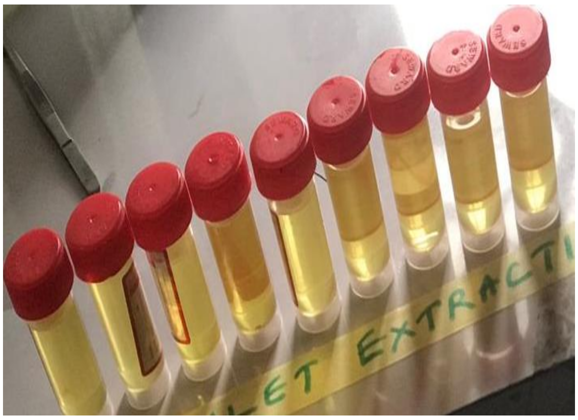

Plate 1: *D. edulis* pulp oil extracted using Soxhlet extraction method

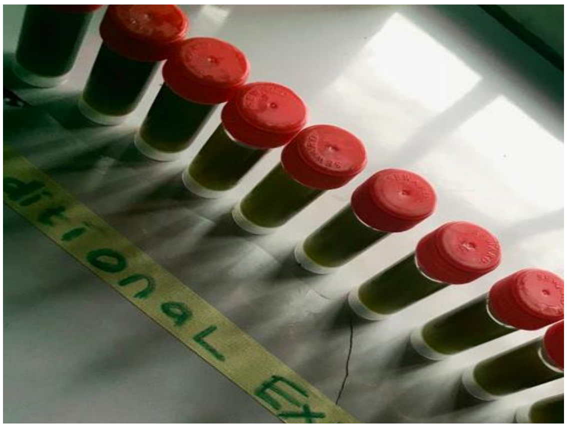

Plate 2: *D. edulis* pulp oil extracted using traditional extraction method

Plate 3: *D. edulis* pulp oil extracted using screw press extraction method

2.3. Sample codes

Codes representing each oil sample are presented in Table 1.

Table 1: Codes representing *D. edulis* pulp oil samples

Sample	Code
Soybean oil (reference sample)	SOYBEAN
Soxhlet extracted *D. edulis* pulp oil	SOXHLET
Screw press extracted *D. edulis* pulp oil	SCREW
Traditional extracted *D. edulis* pulp oil	TRADITIONAL

2.4. Determination of percentage oil yield

The oil yield was calculated by taking into account the mass of the extracted *D. edulis* pulp oil and the mass of the *D. edulis* pulp used for oil extraction as described in (1) by Rebolleda *et al*. (2012):

$$\text{Oil yield (\%)} = \frac{\text{Mass of extracted oil}}{\text{Mass of } D.\, edulis \text{ pulp}} \text{ x } 100$$

2.5. Methods of analyses

2.5.1. Determination of quality parameters

The acid value, peroxide value and thiobarbituric acid number were determined as described by AOCS Official Method Cd 18 – 90. (1996).

2.5.2. Determination of chemical composition

Determination of iodine value (IV) and saponification value (SV) was done using the method described by AOCS Official Method Cd 16b – 93. (1997) while the unsaponifiable matter (USM) was determined by the method described by Egwim *et al.* (2015).

2.5.3. Physicochemical analysis

The specific gravity, refractive index, melting point, smoke and flash point of the oil samples were determined as described by Onwuka (2018). The method of Enyoh *et al.* (2017) was used in determination of moisture content. The method described by Onwuka (2018) was used in determination of viscosity of the oil samples.

2.5.4. Sensory analysis

Sensory evaluation of the oil was carried out according to the method described by Iwe (2014). A 25-member (trained) panel and 9-point hedonic scale were used; where 1 = Dislike extremely and 9 = Like extremely. Sensory parameters tested include appearance, aroma, taste, consistency and general acceptability.

2.5.5. Statistical analysis

The experimental data was expressed as mean ± SD (standard deviation). The data was subjected to one-way analysis of variance (ANOVA) while the Duncan Multiple Range Test (DMRT) method was used to compare the means of experimental data at 95 % confidence interval. All statistical analyses were done using the Statistical Product of Service Solution version 20.0 software.

3. Results and Discussion

3.1. Oil yield of *D. edulis* pulp

The percentage oil yields of *D. edulis* are presented in Table 2. SOXHLET had the highest oil yield (34.09%), followed by TRADITIONAL (10.26%) while SCREW had the lowest oil yield (7.10%). The high oil yield recorded for SOXHLET might be due to the milling process prior to extraction which increased the surface area for solvent penetration to bring out the oil by leaching. Also, the high temperature and long-time associated with Soxhlet extraction could have played a major role in dissolving the fat globules and allowing an extended time for sufficient extraction respectively.

Table 2: Percentage oil yield of *D. edulis* pulp

Sample	Percentage yield (%)
Soxhlet	34.09±0.02
Screw	7.10±0.03
Traditional	10.26±0.02

Values are means ± standard deviation of duplicate determination.

This claim agrees with Akindele and Nsuhoridem (2018) who stated that solvent extraction is considered the most effective means of oil extraction in terms of oil yield and oil extraction efficiency. Least oil yield in SCREW agrees with the assertion that mechanical expression has a relatively low oil yield compared to SOXHLET and is therefore comparatively inefficient, often with a large portion of oil left in the cake after extraction (Yusuf, 2018). Similar research on the effects of extraction methods on the yield and quality characteristics of oils from Shea nut affirmed that oil extracted using Soxhlet extraction method had higher oil yield (47.50%) compared to traditional methods (34.10%) (Ikya *et al*., 2013). More so, Arrisson *et al*. (2019) revealed that vegetable oil extracted from *D. edulis* seed using Soxhlet extraction method had higher oil yield (18.28%) compared to those extracted using maceration method (11.18%). The result from this study therefore suggests that Soxhlet extraction method might provide a better yield of *D. edulis* pulp oil than other extraction methods so far investigated.

3.2. Characterization of *D. edulis* pulp oil

3.2.1. Chemical composition

The chemical composition of the oil samples is presented in Table 3. The iodine values (IV) of *D. edulis* pulp oil samples were lower (26.00 to 36.00 g Iodine/100g) than that of the reference sample (63.90 g Iodine/100g).

Table 3: Chemical composition of *D. edulis* pulp oil

Sample	Iodine value (g Iodine/100g)	Unsaponifiable matter (%)	Saponification value (mg KOH/g)
Soxhlet	$36.00^{b}\pm1.41$	$12.37^{b}\pm0.08$	$224.00^{b}\pm1.41$
Screw	$26.00^{d}\pm1.41$	$13.12^{a}\pm0.02$	$227.50^{a}\pm0.71$
Traditional	$31.00^{c}\pm1.41$	$13.26^{a}\pm0.01$	$226.50^{a}\pm0.71$
Soybean	$63.90^{a}\pm0.01$	$1.47^{c}\pm0.01$	$128.00^{c}\pm1.41$

a-d: Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different (p<0.05).

However, among the extracted oil samples, SOXHLET had the highest value (36.00 g Iodine/100g), suggesting the presence of higher number of double bonds (Sunmonu *et al*., 2017) than other *D. edulis* pulp oil samples. The IV obtained in this study agree with the values reported by Adedokun and Onuegbu (2011) (32.47 to 37.11 g Iodine/100g) but below the values reported by Noumi *et al*. (2014) (52.54 to 58.22 g Iodine/100g) for *D. edulis* pulp oils. Iodine value (IV) is an indicator of the degree of unsaturation in fat or vegetable oil (Asuquo *et al.,* 2012). It measures the amount of iodine consumed by fatty acids. The lower IV recorded for *D. edulis* pulp oil samples suggests lower level of unsaturated fatty acids compared to the reference sample but higher oxidative stability (Gharby *et al.,* 2015).

Saponification value (SV) is an indicator of the average molecular weight of fatty acid in the oil sample; hence, the chain length. SV is also used in checking adulteration, presence of impurities and projecting oil stability (Akintayo and Bayer, 2002; Sabinus, 2012). *D. edulis* pulp oil samples had higher saponification value (SV) (224.00 to 227.50 mg KOH/g) than the reference sample (128 mg KOH/g), suggesting the dominant presence of shorter chains fatty acids that favour stability (Akintayo and Bayer, 2002). The different extraction processes did not influence the SV of the oil samples. The SV values obtained for *D. edulis* pulp oils are above the values obtained for cashew nut oil (168.3 mg KOH/g) and sunflower oil (197.14 mg KOH/g) (Mengistie *et al*., 2018) but below the values reported for coconut oil (253.0 mg KOH/g), and palm oil (247.0 mg KOH/g) (Olatidoye *et al.,* 2010). Furthermore, the SV of the *D. edulis* oils exceeded the minimal levels (189.0 to 198.0 mg KOH/g) set by Codex Alimentarius Commission for oilseeds (Codex Alimentarius Commission, 2011).

Unsaponifiable matter (USM) includes all components that are almost insoluble in aqueous solvents but are soluble in organic solvents after saponification (alkaline hydrolysis) of a fatty substance. Less than 2% of oil's content is generally unsaponifiable. If present in a high amount, it retards the oil's ability to produce soap that forms lather easily, although crude fats contain higher amounts (Huang *et al.,* 2014). The USM values obtained for the oil samples exceeded 2% except SOYBEAN (1.47%). This might be due to the fact that the *D. edulis* pulp oil samples are still in their crude form (Huang *et al.,* 2014), and might therefore contain higher quantities of hydrocarbons, pigments, and tocopherols (Farhoosh and Mohammad, 2010). SOXHLET had the lowest USM (12.37%) among the extracted oil samples. This might be due to the fact that SOXHLET had undergone some level of refining; thus, eliminating large proportion of USM.

3.2.2. Quality parameters

The quality parameters of the oil samples are presented in Table 4. The Free Fatty Acid (FFA) value ranged from 0.33 to 7.08%. Extraction method had significant effect on the FFA of the oil samples. *D. edulis* oil samples had higher FFA (2.12 to 7.08%) than the reference sample (0.33%). This might be due to cell damage resulting from bruising of the seed during size reduction (Soxhlet extraction) and compression (screw press extraction); such bruises help to release hydrolytic enzymes (lipases) that cause lipid hydrolysis and elevated FFA as well as possible presence of moisture in the oil extracted using traditional method (Atinafu and Bedemo, 2014).

Table 4: Quality parameters of *D. edulis* pulp oil

Sample	Free fatty acid (%)	Peroxide value (meq O_2/kg)	Thiobarbituric acid (mg/g)	Acid value (mg KOH/g)
Soxhlet	$2.12^{d}\pm0.02$	$2.55^{a}\pm0.15$	$0.97^{c}\pm0.01$	$4.23^{d}\pm0.03$
Screw	$7.08^{a}\pm0.04$	$1.70^{b}\pm0.10$	$1.07^{b}\pm0.01$	$14.15^{a}\pm0.07$
Traditional	$5.13^{c}\pm0.01$	$0.94^{c}\pm0.01$	$1.11^{a}\pm0.01$	$10.25^{c}\pm0.01$
Soybean	$0.33^{b}\pm0.01$	$1.01^{c}\pm0.01$	$0.02^{d}\pm0.00$	$0.55^{b}\pm0.01$

a-d: Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$).

FFA determines the suitability of vegetable oil for any direct consumption or industrial application (Al-Bachir, 2015), because ingestion of FFA appears to increase blood cholesterol (Matsumori *et al*., 2013). High FFA accelerates oxidation by decreasing the surface tension of edible oil and increasing the diffusion rate of oxygen from the headspace into the oil (Tamzid *et al*., 2007). The FFA of *D. edulis* oil obtained in this study exceeded the limit (<0.05 to 0.50%) set by Codex (Codex Alimentarius Commission, 2011), suggesting that the oil samples were not suitable for direct consumption.

The peroxide value (PV) of the oil samples ranged from 0.94 to 2.55 meq O_2/kg fat. Notably, extraction method influenced PV significantly, with SOXHLET having a higher PV (2.55 meq O_2/kg) than SCREW (1.70 meq O_2/kg) and TRADITIONAL (0.94 meq O_2/kg). Peroxide value (PV) is a measure of oxidation during storage and the freshness of lipid matrix (Atinafu and Bedemo, 2011). A low PV does not indicate that the oil is good; it only gives an indication of the current state of oxidation of an oil sample (Ghosh *et al.,* 2015). The lower PV recorded for TRADITIONAL and SCREW could be attributed to increased amount of microcomponents such as tocopherol which have the tendency to improve crude edible oils' stability to primary oxidation. The low PV could still be attributed to advanced oxidation process, resulting in the formation of secondary oxidation products and reduction in the amount of the initially formed peroxides (Mohammed and Ali, 2015). However, the PV of the oil samples conformed to Codex standard for vegetable oil (10 meq O_2/kg fat) (Codex Alimentarius Commission, 2011), suggesting that the oil samples might still be considered fresh.

The thiobarbituric acid (TBA) value ranged from 0.02 to 1.11 mg/g, with extraction method influencing the TBA values. *D. edulis* oil samples had higher TBA values (0.97 to 1.11 mg/g) than the value (0.02 mg/g) obtained for SOYBEAN. This might be due to the possible occurrence of secondary oxidation and the presence of its products such as aldehydes and ketones.TBA is a measure of the occurrence and extent of secondary oxidation that results to rancid smell (Iqbal and Mido, 2017). Higher TBA values in TRADITIONAL and SCREW is indicative of increased presence of secondary oxidation products which might possibly explain why TRADITIONAL and SCREW had lower PV values. However, the TBA values of the oil samples were below the maximum limit (5.00 mg/g) recommended by Codex (Codex Alimentarius Commission, 2011), which explains the absence of objectionable odour.

The acid value (AV) ranged from 0.55 to 14.15 mg KOH/g. *D. edulis* pulp oil samples had higher AV than the reference sample. Acid value (AV) is a measure of the free fatty acids in oil (Enengedi *et al*., 2019). The higher AV of *D. edulis* oil samples might suggest higher FFA values which translate into decreased oil quality (Katkade *et al*., 2018; Enengedi *et al*., 2019). The AV obtained in this study is proportionally higher than the 19.21 mg KOH/100g reported by Amos-Tautua *et al*. (2013) for crude soybean oil. Similarly, the value reported by Amos-Tautua *et al*. (2013) for crude groundnut oil (4.63 mg KOH/100g) was proportionally lower than the value obtained for TRADITIONAL and SOYBEAN. Furthermore, the AV of the extracted *D. edulis* pulp oils exceeded Codex standard for acid value of edible oil (<0.6 mg KOH/100g) (Codex Alimentarius Commission, 2011); thus, implying high amount of FFA and the necessity for refining.

3.2.3. Physicochemical properties

The physicochemical properties of the oil samples are presented in Table 5. The specific gravity (SG) of the oil samples ranged from 0.90 to 0.93 g/cm^3. It is particularly useful because it allows access to molecular information in a non-invasive way (Mohammed and Ali, 2015). Extraction method did not influence significantly the SG of *D. edulis* oil samples. SOYBEAN had higher SG than *D. edulis* oil samples which may be attributed to the difference in fatty acid composition, total solid content and degree of unsaturation (Mengistie *et al*., 2018). The SG values obtained in this study agree with the values (0.91 to 0.93 g/cm^3) reported for coconut oil extracted using fermentation, centrifugation, freezing and solvent method (Ndife *et al*., 2019) as well as the value of 0.93 g/cm^3 each reported for soybean oil and sunflower oil (Mengistie *et al*., 2018), suggesting an appreciable presence of unsaturated fatty acids in the oil samples (Mohammed and Ali, 2015).

The refractive index of the oil samples ranged from 1.42 to 1.46. Extraction method had minimal effect on the refractive index of the extracted oil samples. However, the *D. edulis* oil samples had lower refractive index than the reference sample (SOYBEAN: 1.46), suggesting lower level of unsaturation since refractive index is used mainly to measure the change in unsaturation as the fat or oil is hydrogenated and could be used to ascertain the presence of impurities (Katkade *et al*., 2018). The values obtained for *D. edulis* oil samples were lower than 1.47 reported for safflower oil, 1.48 reported for soybean oil and 1.47 reported for sesame oil (Katkade *et al*., 2018) as well as the values recommended by FAO/WHO (1.466 to 1.470) (CODEX, 2011), suggesting the presence of impurities.

Table 5: Physicochemical properties of *D. edulis* pulp oil

Samples	Specific gravity (g/cm^3)	Refractive index	Melting point (°C)	Smoke point (°C)	Flash Point (°C)	Moisture content (%)
Soxhlet	0.90^{bc}±0.01	1.42^{b}±0.00	34.35^{b}±0.21	174.00^{d}±1.41	186.00^{d}±1.41	2.14^{c}±0.01
Screw	0.91^{b}±0.01	1.42^{b}±0.00	37.00^{a}±0.28	188.50^{b}±0.71	206.00^{b}±1.41	10.21^{b}±0.01
Traditional	0.91^{b}±0.02	1.42^{b}±0.00	35.35^{b}±0.64	185.50^{c}±0.71	202.50^{c}±0.71	12.23^{a}±0.04
Soybean	0.93^{a}±0.00	1.46^{a}±0.00	0.00^{c}±0.00	236.50^{a}±0.71	309.50^{a}±0.71	0.08^{d}±0.04

a-d: Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different ($p<0.05$).

The melting point (MP) of the oil samples ranged from 0.00 to 37.00°C. Melting point is the temperature at which fat melts when left at different temperatures. It provides useful information in predicting their suitability in food systems like table margarine, cake margarine and mayonnaise. *D. edulis* oil samples had higher MP than SOYBEAN. Extraction method had significant influence on the fatty acid composition and triacylglycerol profile of *D. edulis* oil samples (Enengedi*et al*., 2019), resulting to variable MP. The values from this study were higher than the values (23.05 to 24.05°C) reported by Ndife *et al*. (2019) for coconut oil extracted using fermentation, centrifugation, freezing and solvent methods and the values reported by Enengedi *et al*. (2019) for *D. edulis* (23°C) and avocado pear (16°C) oils. The results from this study imply that *D. edulis* oil samples might experience melting around the temperature range of 34.35 to 37.00°C, suggesting their suitability for bakery (cake) margarine production since bakery margarine such as cake margarine has a melting point of 34 to 45°C (Dewettinck and Fredrick, 2011).

The smoke point (SP) of the oil samples, which is the temperature at which oil starts to be visibly releasing fumes, ranged from 174.00 to 236.50°C. It tells the temperature at which edible oil should be maximally heated. The presence of impurities causes an oil to smoke faster which makes it a valuable parameter in checking the purity of oil. The more refined an oil, the higher its smoke point and the higher its suitability for cooking and frying at high temperatures (Enengedi*et al*., 2019).The reference sample (SOYBEAN) had the highest smoke point (236.50°C) because it is a refined oil while the crude *D. edulis* oil samples had lower smoke points (174.00 – 188.50°C), suggesting the presence of impurities. The results also suggested that *D. edulis* oil samples might not be suitable for high temperature cooking and frying above 190°C (Ndife *et al.,* 2019). SP values obtained in this study were lower than 210.00 to 212.00°C and 216.00°C reported for *D. edulis* and avocado pear oils respectively (Enengedi *et al*., 2019). Furthermore, the values were below the recommended minimum smoke point (215°C) for vegetable oil (Codex Alimentarius Commission, 2011), suggesting the need for refining.

The flash point values of *D. edulis* oil samples (186.00 to 206.00°C) were lower than the value (309.50°C) obtained for SOYBEAN. Flash point was significantly influenced by extraction method. Flash point is the temperature at which oil produces a certain vapour that mixes with air and forms an ignitable mixture, resulting in a momentary flash or flame (Egbuna *et al*., 2016). The flash point values obtained in this study were lower than 315.00°C, 312°C, 309°C and 320°C reported by Shanthi and Syed (2017) for sesame oil, cotton seed oil, sunflower oil and groundnut oil respectively. However, *D. edulis* oil samples might possess the tendency to prevent the risk of fire that might result in accidental ignition since edible oils with flash point above 66°C are considered as safe oils (Zaharadden *et al*., 2013).

The moisture content of the oil samples ranged from 0.08 to 12.23%. *D. edulis* oil samples had higher moisture content (2.14-12.23%) than the reference sample (SOYBEAN) (0.08%). Extraction method significantly influenced the moisture content of the oil samples. Soxhlet extraction method produced oil with minimal moisture content. The moisture values from this study were higher than the values reported by Enengedi *et al*. (2019) for *D. edulis* oil (1.14 to 1.22%) and avocado pear oil (1.24%) as well as the value (0.47%) reported for sunflower oil (Mengistie *et al*., 2018), suggesting proneness to deterioration.

3.2.4. Sensory properties of the oil samples

Sensory properties of the oil samples are presented in Table 6. The scores for appearance ranged from 5.04 to 8.48. There was no significant difference (P>0.05) in the appearance of TRADITIONAL and SOYBEAN; also SOXHLET and SOYBEAN did not differ significantly. The low scores recorded for TRADITIONAL and SCREW could be attributed to their greenish-yellow colouration as seen in Plate 2 and Plate 3. The similar appearance of TRADITIONAL and SCREW could be due to the ability of their extraction methods to extract other liquid-dissolving extractable components like chlorophyll and other pigments as opposed to Soxhlet extraction which has the ability to selectively extract only the lipid component of the sample. Thus, the result showed that among the extracted oil samples, the appearance of SOXHLET with a rating of 8.40 was more preferred by the panelists.

The scores for aroma ranged from 3.92 to 7.96. The lowest rating for aroma was recorded for SOXHLET (3.92) which might be due to the residual odour of the n-hexane used in its extraction; de-odourization is therefore recommended. The oil samples, except SOXHLET, had aroma that was moderately liked.

Table 6: Sensory properties of *D. edulis* pulp oil

Samples	Appearance	Aroma	Taste	Consistency	General acceptability
Soxhlet	$8.40^{a}\pm0.76$	$3.92^{b}\pm2.33$	$3.84^{c}\pm1.95$	$8.72^{a}\pm0.61$	$8.52^{b}\pm1.10$
Screw	$4.84^{b}\pm1.49$	$7.96^{b}\pm1.40$	$7.72^{a}\pm1.40$	$5.48^{b}\pm0.82$	$6.16^{c}\pm1.11$
Traditional	$5.04^{b}\pm1.59$	$7.12^{b}\pm1.67$	$6.76^{b}\pm1.61$	$5.48^{b}\pm0.96$	$5.96^{c}\pm1.02$
Soybean	$8.48^{a}\pm0.71$	$7.56^{a}\pm1.00$	$7.72^{a}\pm0.68$	$8.64^{a}\pm0.49$	$9.96^{a}\pm0.59$

a-d: Values are means $\pm$ standard deviation of duplicate determination. Mean values in the same column with different superscripts are significantly different (p<0.05).

Taste scores ranged from 3.84 to 7.72. SOXHLET had the lowest value (3.84). The scores revealed that the taste of SOYBEAN (7.72) and SCREW (7.72) were moderately liked by the panelists, while TRADITIONAL (6.76) was slightly liked. The low taste score recorded in SOXHLET could be attributed to the effect of the extraction solvent in altering the taste of the oil sample.

Scores for consistency ranged within 5.48 to 8.72. The consistency of SOXHLET was comparable to the reference sample and was liked very much while SCREW and TRADITIONAL had consistency that was neither liked nor disliked by the panelists.

Scores for general acceptability (GA) ranged from 5.96 to 9.96. The scores showed that the sensory characteristics of SOYBEAN (9.96) was best accepted and was liked extremely by the panelists, followed by SOXHLET with a rating of 8.52 which was liked very much. The sensory characteristics of TRADITIONAL (5.96) and SCREW (6.16) were least accepted by the panelists, suggesting the need for further improvement in the extraction conditions as well as necessity of refining.

4. Conclusion

The findings of this study showed that the different extraction methods had significant effect on the oil yield and properties of *D. edulis* pulp oil. The FFA of the oil samples exceeded the recommended (Codex) limit while the peroxide values were within the recommended limit for edible oils. The study further revealed that *D. edulis* pulp has the potential to become a good source of oil for bakery (cake) margarine manufacture. Relative ease of extraction, fairly high yield, oxidative stability and good peroxide value are some of the attributes that make *D. edulis* pulp oil commercially important. However, further research is needed to refine the oil and reduce the FFA to acceptable limit for edible oils. This study recommends Soxhlet extraction method for highest yield of *D. edulis* pulp oil (34.09%), better chemical composition, better quality/physicochemical properties as well as best general acceptability in terms of sensory properties.

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