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NUTRITIONAL PROPERTIES OF OILS FROM VARIOUS PARTS OF THREE VARIETIES OF PEARS CONSUMED IN SOUTH EAST NIGERIA

– Research paper –

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Abstract: This study evaluated the nutrient properties of parts of *Dacryodes edulis* (DE), *Persea americana* (PA) and *Canarium schweinfurthii* (CS) oils using standard methods. Pulp oils of DE and PA had the least moisture, melting point, acid, and saponification values. Occurrence of C_{10-12} fatty acids was between 0 and 1.46%, and C_{22-26} between 0 and 4.3%. Anthocyanins, epicatechin, and ribalinidine were undetected in CS seed oils, while oils from the pulp and peels of PA showed the highest amounts for catechins (57.73µg/ml) and kaempferol (57.91µg/ml) respectively. The pulp oils contained higher amounts of Na, K, Zn, Ca, vit A and D. This study has shown that the seed oils suits industrial needs, and the pulp oils for therapeutic purposes.

Keywords: Physicochemical properties, phytochemicals, fatty acids, micronutrients, oil

INTRODUCTION

Mineral oils have been characterized with low biodegradability, and high ecotoxicity (Ramchandra and Paramjyothi, 2008). Consequent to this, and the attendant increase in nutritional and industrial processes, the need to exploit underutilized and neglected vegetable sources of oils readily comes to mind (Agomuo et al., 2017). Vegetable oils are regarded as biological mixtures from plants, made up of esters of glycerol and fatty acid chains (Eqbql et al., 2011). An important characteristic of these plant sources of oils is the high degree of unsaturation in their constituent fatty acids which directly relates to their higher susceptibility to oxidative deterioration (Roxana and Ovidiu, 2016). It is therefore important to determine the constituent fatty acids in an oil, as well as measure its stability, physical and chemical properties (Agomuo and Amadi, 2018). *Dacryodes edulis* is a species that belongs to Burseraceae family, reaching a height of 18-42m, found in countries like Cameroon, Nigeria, and Liberia (Ogunka-Nnoka et al., 2017). The fruit contains a pulpy pericarp that encloses a seed coat which contains the seed. The pulp is usually consumed either cooked, raw or grilled alongside maize. Several parts of *D. edulis* fruits have been investigated for their nutritional properties (Ajayi and Adesanwo, 2009; Ogunka-Nnoka et al., 2017). Its seeds have been shown to possess about 18.70% oil, comprising majorly of arachidonic acids, among other fatty acids (Ajayi and Adesanwo, 2009), whereas no information has been presented in literature for the properties of its seed coat oils. The avocado tree is a fruit bearing plant, which belongs to the genus persea and family lauraceae. The avocado plant is regarded as one of the most productive plants per unit of the cultivated area, which makes the management of its waste, very necessary. Also, with its high lipid content, avocado is regarded as an important fruit for oil extraction (Turatti, 1992). Tucunduva, (2002) showed the usefulness of avocado in human nutrition, serving mainly as a source of monounsaturated fatty acid. Tango et al., (2004) have as well, shown that the pulp of avocado could be used to produce commercially valuable oils, capable of serving as substitutes to olive oil, as well as comparing positively in terms of physicochemical properties. Notwithstanding the extensive interest in the pulp of avocado, there is paucity of information on the seeds and peels. The *Canarium schweinfurthii* belongs to the family of Bursaraceae commonly found in Nigeria, especially the Plateau state (Amoo et al., 2017)

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and produces its fruits between the months of April and September. The pulpy pericarp encloses a triangle shaped single seed that has projections at the edges. The pulp of *C. schweinfurthii* can be processed into its constituent oils as well as the kernel oil. Several researchers have investigated both the pulp and kernel oils, especially for their potential industrial applications in the production of both personal and pharmaceutical products (Ajiwe et al., 1998; Eromosele et al., 1998). However, there is paucity of information on properties such as the physicochemical and fatty acid content of the kernel and pulp oil. Hence, it was on these premises, that this study examined the characteristics of the oils from *D. edulis* pulp, seed and seed coat, *P. americana* seed, pulp and peels, and *C. schweinfurthii* pulp and seed, with focus on their physicochemical properties, fatty acid contents, phytochemical and micronutrient analysis.

MATERIALS AND METHODS

Sample collection and identification: *Dacryodes edulis*, *Persea americana*, and *Canarium schweinfurthii* fruits were purchased from Relief Market in Owerri Imo State Nigeria, and taken to the Department of Plant Science and Biotechnology, Imo State University, Owerri for identification by the botanist.

Sample preparation and oil extraction:
The fruits were washed in clean water, and the separate parts were harvested. *D. edulis* pulp, seed coat, and seeds were separately harvested. Also, the peel, pulp, and seed of *P. americana* were obtained, while the pulp and seed of *C. schweinfurthii* were separated and collected. All the collected samples were separately sundried and pulverized into powders, and subjected to Soxhlet extraction.
The oils were extracted following the method of Agomuo et al., (2017). Briefly, the pulverized samples (100g) were put in a thimble, stuffed with a cotton wool, and soaked in 500ml isopropyl alcohol/n-hexane (2:3) for 24 hrs. Then, the solution was filtered and the residues subjected to Soxhlet extraction. The extract obtained was concentrated using a rotary evaporator, at 45^0C under low pressure and stored in a refrigerator at 4^0C.

Physicochemical analysis: Following the procedures of AOAC (2000), the moisture content, melting point, acid value, specific gravity, peroxide value, iodine value, saponification value, and oil yield of the samples were analyzed. A pH meter was applied for the analysis of pH, while a Brix refractometer was used for the analysis of the refractive index at 30^0C of the samples.

Analysis of fatty acids: This analysis was carried out following the guidelines of Agomuo et al., (2017). FAMES (Fatty acid methyl esters were obtained by refluxing the extracted oils in 2% H_2SO_4 in CH_3COH at a temperature of 70^0C for three hours before being subjected to chromatographic analysis under the following gas chromatography conditions:Type: GC-FID (Agilent 6890N) ; Column: DB-225 silica capillary (30 x 0.32m)
Injector: split (1 ml); Temp: Injector (230^0C), detector (250^0C), and oven (start: 160^0C, final: 230^0C, increment 4^0C/min); Carrier gas: Nitrogen (1.5ml/min flow rate).
The peaks were resolved by comparison of standard methyl esters, whereas a standard Chem Station system was applied for the determination of percentage area.

Phytochemical analysis: Phytochemicals were analyzed as described by Agomuo et al., (2017) using a gas chromatography machine (Buck Scientific Chromatography machine) coupled to flame ionization detector under the following conditions:Column: Hp-88 capillary column (100m x 0.25mm); Injector: split (1 ml); Temp: 220^0C for injector, 250^0C for detector, and 180^0C for oven; Carrier gas: Hydrogen (24 PSI).
Determination of the amount of the components was achieved by comparing with internal standards.

Determination of minerals and vitamins content: To determine the concentrations of sodium (Na), potassium (K), calcium (Ca), iron (Fe), magnesium (Mg), phosphorus (P), manganese (Mn), copper (Cu), and zinc (Zn), the method of Amadi et al. (2018), was employed. Briefly, the oil samples (5ml) were digested using concentrated HNO_3 and 60% (v/v) $HClO_4$ mixed together, and made up 25 ml with deionized distilled water and

afterwards, analyzed using a Buck Scientific 210 VGP model of an atomic absorption spectrophotometer and flame photometer (Jenway model). The sulphate contents of the food samples were determined turbidimetrically and the chloride level was determined titrimetrically according to AOAC (1984). Determination of vitamin A was by the method of kirk and sawyer (1991) while the vitamin E was determined spectrophotometrically.

Statistical analysis

The data obtained were analyzed and reported as Mean ± Standard deviation. One way ANOVA was used to test for significance among the triplicate data using Statistical Package for Social Sciences (SPSS) version 20 and were considered significant at 95% confidence interval ($p < 0.05$).

RESULTS AND DISCUSSIONS

The physicochemical properties of oils from *D. edulis* seed, pulp, and seed coat, *P. americana* seed, pulp, and peels, and *C. schweinfurthii* seed and pulp were shown in Table 1. The moisture contents ranged from 2.08 % in the CS seed oil to 8.22% in the pulp oil of PA. The moisture content of the PA seed oil was comparable to that of Neem Seed Kernel oil (Orhevba et al., 2013), but however higher than those for castor seed and palm kernel seed oil (3.50 and 4.87% respectively). The moisture content of a product determines its storage value and shelf life, hence, the lower the moisture content, the higher the storage value. The results shown in Table 1, presents the CS seed oil with best storage value while PA seed oil is most susceptible to deterioration. The melting points of DE seed, and seed coat oil, and CS seed oil were comparable. Similarly no significant difference was recorded between the melting points of the pulp oils.

Table 1. Physicochemical properties of oils from different parts of *D. edulis*, *P. americana*, and *C. schweinfurthii*

	DES	**DEP**	**DESC**	**PAS**	**PAP**	**PAPE**	**CSS**	**CSP**
Mo	4.29± 0.31^{a}	2.87± 0.17^{b}	3.02± 0.31^{b}	8.22± 1.93^{c}	3.16± 0.14^{b}	4.24± 0.51^{a}	2.08± 0.11^{d}	7.80± 1.01^{c}
MP	25.62± 5.21^{ac}	13.14± 1.11^{b}	20.27± 4.02^{a}	30.86± 3.40^{c}	11.27± 0.93^{bd}	28.13± 3.39^{c}	21.62± 0.77^{a}	9.17± 0.62^{d}
pH	5.04± 0.44^{a}	6.21± 0.23^{b}	5.72± 0.74^{cd}	5.18± 0.76^{a}	6.06± 0.29^{bd}	5.41± 0.31^{ac}	5.91± 0.33^{bd}	5.99± 0.74^{d}
AV	4.92± 0.17^{a}	4.14± 0.09^{b}	11.24± 0.72^{d}	4.40± 0.06^{c}	3.99± 0.09^{b}	7.32± 0.20^{e}	9.14± 0.30^{f}	4.88± 0.11^{a}
SG	0.77± 0.04^{a}	0.86± 0.01^{b}	0.62± 0.02^{c}	0.92± 0.09^{d}	0.72± 0.04^{a}	0.88± 0.03^{b}	1.02± 0.08^{d}	0.93± 0.03^{d}
RI	1.44± 0.02^{a}	1.46± 0.01^{ab}	1.38± 0.03^{c}	1.49± 0.13^{b}	1.47± 0.04^{b}	1.69± 0.08^{d}	1.40± 0.09^{a}	1.61± 0.11^{d}
PV	6.02± 0.38^{a}	8.47± 0.11^{b}	4.31± 0.06^{c}	3.21± 0.23^{d}	4.77± 0.52^{e}	4.65± 0.33^{e}	2.24± 0.09^{f}	7.14± 0.23^{g}
IV	38.21± 0.70^{a}	118.31± 9.64^{d}	23.70± 1.25^{ce}	25.30± 2.34^{e}	106.41± 6.26^{d}	24.11± 0.87^{c}	20.62± 1.68^{e}	104.51± 1.01^{d}
SV	190.15 ± 3.86^{a}	132.44± 2.19^{b}	174.54± 2.03^{c}	177.71± 2.99^{c}	127.66± 1.44^{b}	101.39± 4.62^{d}	183.76± 2.20^{e}	150.49± 3.18^{f}
OY	20.29± 2.31^{a}	44.36± 4.62^{b}	10.14± 0.20^{c}	16.62± 2.01^{d}	12.80± 2.10^{e}	19.27± 3.44^{a}	9.20± 1.55^{c}	16.21± 1.08^{d}

Values represent mean±S.D of triplicate determinations. Values bearing dissimilar superscript letters across the row (a-f) are significantly different ($p < 0.05$). Mo-Moisture, MP-Melting point (^{0}C), AV-Acid value (mg/KOH/g), SG-Specific gravity, RI-Refractive index (@ 30^{0}C), PV-Peroxide value (meq/kg), IV-Iodine Value (gI_2/100g), SV-Saponification Value (mg/KOH/g), OY- Oil Yield (%.)DES-*Dacryodes edulis* seed, DEP-*Dacryodes edulis* pulp, DESC-*Dacryodes edulis* seed coat, PAS-*Persea americana* seed, PAP-*Persea americana* pulp, PAPE-*Persea americana* peels, CSS-*Canarium schweinfurthii* seeds, CSP-*Canarium schweinfurthii* pulp

The melting points of the DE seeds presented in Table 1 were not in agreement with the reports of Arisa and Lazarus, (2008). The thermal behavior of an oil is assessed from its melting point, and indicates suitability for deep frying. For this study, oils from the seeds were shown

to be most suitable for deep frying. DE seed coat and CS seed oils produced the highest amount of acid values. These values are higher than those for oils from almond nuts and castor seeds (Afolabi, 2008). Oils from the pulps of the three fruits had comparable acid values to those of melon (Olaofe et al., 2012) and groundnut oil (Amos-Tauta and Onigbinde, 2003). With the disparities in acid values of the parts of the fruit oils, the pulp oils appears more preferred for cooking, against those from peels and seeds that could be poisonous to livestock. The specific gravity of the oils ranged from 0.62-1.02 while the refractive index was 1.38-169. Oils from DE pulp, and PA peels compared with that of melon seed oil in terms of specific gravity (Eze, 2012), whereas only DE and PA pulp oil values met the ASTM standard values (1.45-1.47) for refractive index. The specific gravities of the oils indicates that CS seed and pulp oils possess the highest thermal stability, while for their refractive index, the DE and PA pulp oils showed more purity while the PA peels and CS pulp contained higher hydrogenation and isomerization (Agomuo et al., 2017). Further, the results of the peroxide value showed that none of the samples evaluated exceeded the 10meq/kg benchmark of Adebisi and Olagunju, (2011), indicating that the oils were not prone to trace element or moisture-induced auto-oxidation. The peroxide values for the fruits parts were all higher than those from oils of commercial importance; corn oil and mustard oil (Zahir et al., 2014), but that of DE and CS pulp oils compared with that of sesame oil (Mohammed and Hamza, 2008), while the oils from PA and CS seeds compared with that of almond seed oils (Ogunsuyi and Daramola, 2013) in terms of peroxide value. The iodine value describes the degree of unsaturation in the oil as well as its susceptibility to oxidation. All the pulp oils had significantly comparable iodine values and were similar to those of the pumpkin and cashew seed oils (Aletor et al., 2007; Bello et al., 2012) but higher than those of *Opuntia dillenii* stem oil (Njoku et al., 2017). The lower iodine values of the seeds, peels and seed coat oils indicate a possible predominance of saturated fatty acids. The saponification values of the DE and CS seeds oil were comparable to those of palm kernel and sunflower seed (Afolabi, 2008). Similarly, the saponification values of processed commercial oils sold in Nigeria such as power oil and mamador (Angaye and Maduelosi, 2015), were comparable to those found for DE and CS seed oils. DE pulp provided the highest oil yield, followed by its seeds and PA peels. The oil yield for DE pulp compared well with palm kernel oil and groundnut seed oil (Eze, 2012), while coconut seed oil and bambara groundnut oil produced similar oil yields to DE seed oils and PA peel oils.

The fatty acid content of the various parts of *D. edulis*, *P. americana*, and *C. Schweinfurthii* are summarised in Table 2. The carbon chain length ranged from C_{10}-C_{26} including unsaturated fatty acids. Capric acid (C_{10}) and lauric acid (C_{12}) were highest in DE seed and CS pulp respectively, while the DE seed coat produced the highest amount of myristic acid (C_{14}). Coconut oils contained higher amounts of these above mentioned fatty acids (Orsavova et al., 2015) than those recorded for the oils investigated in this study. Myristoleic acid was only found in oils from DE, which were higher than those for cucumber and soy oils (Agnieszka et al., 2017). DE seed coat contained the highest amount of palmitic acid and palmitoleic acid. The values recorded for DE seeds were comparable to those presented by Ajayi, (2009) for palmitic acid. However, high palmitic acid is indicative of stronger potency of eliciting cardiovascular diseases which according to Nestel et al., (1994) produces similar cholesterolemic effect to palmitoleic acid. Only oils from *C. schweinfurthii* contained comparable palmitic acid levels to those of edible medicinal seed oils like sunflower oil (6.2%), grape oil (6.6%) and rape seed oil (4.6%) as shown by Orsavovaet al., (2015), but showed higher palmitoleic acid contents. The result of Table 2 also showed higher amounts of stearic acid when compared to popularly consumed seed oils analysed by Orsavova et al., (2015) except those for DE and PA seeds, and CS pulp. CS and DE pulp produced the highest amount of oleic and linoleic acids respectively which were all higher than those for soybean, coconut, and groundnut oil (Sodamade et al., 2013). Seed oils of DE and CS were shown to contain significantly higher amounts of arachidic acid than other evaluated parts whereas none contained eicosanoic acid. These values for arachidic acid were much higher than those recorded for both apricot and olive oil (Agnieszka et al., 2016) while the eicosanoic acid contents of the pulps were higher than those shown for sunflower, soy bean, and walnut oil. Furthermore, the DE seed showed

the highest amount of eicosadienoic acid which were comparable to that of underutilized oils from *Myristica fragrans*, and *Brachystegia eurycoma* (Ajayi, 2009), while only the DE seed contains eicosatrienoic acid. The behenic acid ($C_{22:0}$) contents of the fruit parts ranged from 0.90-4.33%, while the erucic acid ($C_{22:1}$) contents of the evaluated samples ranged from 0.03-0.60%. None of oils from rape seed, coconut, and almond contained erucic acid. Docosadienoic and lignoceric acid were found most abundant in PA pulp and peel oils respectively while only DE seed oil contained hexacosanoic acid. Oils from walnut, hemp, and watermelon contained much lower amounts of docosadienoic and lignoceric acid. These fatty acids are yet to have any extensive industrial application or used for any reported health benefits.

Table 2. Fatty acid contents (%) of oils from different parts of D. edulis, P. americana, and C. schweinfurthii

Fatty acids	DES	DEP	DESC	PAS	PAP	PAPE	CSS	CSP
C_{10}	1.46± 0.11^{a}	0.27± 0.01^{b}	0.08± 0.02^{c}	0.61± 0.03^{d}	ND	1.33± 0.05^{a}	ND	ND
C_{12}	0.13± 0.04^{a}	0.83± 0.14^{b}	ND	ND	0.55± 0.04^{c}	ND	ND	0.64± 0.06^{c}
C_{14}	0.84± 0.07^{a}	0.12± 0.02^{b}	6.77± 0.32^{c}	0.90± 0.11^{af}	0.30± 0.01^{d}	1.40± 0.10^{e}	1.10± 0.04^{f}	0.31± 0.02^{d}
$C_{14:1}$	1.34± 0.06^{a}	0.68± 0.13^{b}	1.41± 0.09^{a}	ND	ND	ND	ND	ND
C_{16}	40.04± 0.9^{a}	19.1± 1.88^{b}	59.23± 3.25^{c}	25.30± 1.71^{d}	20.60± 0.83^{b}	40.10± 2.21^{a}	10.62± 1.21^{e}	6.80± 0.94^{f}
$C_{16:1}$	2.29± 0.31^{a}	5.42± 1.12^{b}	10.70± 1.10^{c}	5.90± 0.62^{b}	6.40± 0.62^{d}	3.30± 0.21^{e}	1.80± 0.02^{f}	1.50± 0.07^{f}
C_{18}	4.82± 0.17^{a}	10.24± 0.54^{b}	10.86± 2.12^{b}	0.80± 0.12^{c}	ND	24.10± 1.49^{d}	56.40± 2.82^{e}	5.20± 1.05^{a}
$C_{18:1}$	17.41± 1.41^{a}	43.06± 3.74^{b}	10.44± 0.94^{c}	20.04± 0.99^{d}	50.55± 1.83^{e}	11.40± 1.01^{c}	6.30± 0.09^{f}	69.36± 3.89^{g}
$C_{18:2}$	13.10± 0.29^{a}	18.41± 1.71^{b}	0.40± 0.06^{c}	9.80± 0.42^{d}	15.50± 1.07^{a}	6.40± 0.43^{e}	4.70± 0.31^{f}	8.10± 1.16^{d}
C_{20}	11.17± 1.31^{a}	0.08± 0.00^{b}	0.21± 0.03^{c}	ND	0.60± 0.05^{d}	5.16± 0.52^{e}	14.24± 0.77^{f}	4.40± 0.71^{e}
$C_{20:1}$	ND	0.57± 0.08^{a}	0.02± 0.00^{b}	0.62± 0.13^{ad}	1.20± 0.02^{c}	ND	ND	0.80± 0.03^{d}
$C_{20:2}$	4.62± 0.27^{a}	1.21± 0.12^{b}	ND	0.41± 0.05^{c}	2.86± 0.09^{d}	1.95± 0.07^{e}	ND	ND
$C_{20:3}$	1.15± 0.07	ND	ND	ND	ND	ND	ND	ND
C_{22}	0.91± 0.02^{a}	ND	ND	0.90± 1.04^{a}	ND	2.10± 0.05^{b}	4.33± 0.39^{c}	2.10± 0.44^{b}
$C_{22:1}$	0.60± 0.04^{a}	0.03± 0.00^{b}	ND	ND	ND	ND	0.58± 0.08^{a}	0.20± 0.01^{c}
$C_{22;2}$	0.15± 0.01^{a}	ND	0.04± 0.00^{b}	0.13± 0.01^{a}	0.60± 0.03^{c}	ND	0.20± 0.01^{d}	ND
$C_{24:0}$	ND	0.02± 0.00^{a}	0.01± 0.00^{a}	2.30± 0.06^{b}	1.41± 0.07^{a}	2.80± 0.03^{c}	0.80± 0.11^{d}	2.60± 0.64^{ac}
C_{26}	ND	ND	0.21±0.01	ND	ND	ND	ND	ND

Values represent mean±S.D of triplicate determinations. Values bearing dissimilar superscript letters across the row (a-g) are significantly different ($p < 0.05$). DES-*Dacryodes edulis* seed, DEP-*Dacryodes edulis* pulp, DESC-*Dacryodes edulis* seed coat, PAS-*Persea americana* seed, PAP-*Persea americana* pulp, PAPE-*Persea americana* peels, CSS-*Canarium schweinfurthii* seeds, CSP-*Canarium schweinfurthii* pulp

The phytochemical composition of oils from different parts of *D. edulis*, *P. americana*, and *C. Schweinfurthii* are presented in Table 3. The antinutrients; oxalate, phytates, tannins and saponins were most abundant in oils from DE seed coat, PA peels, and seeds, and DE seeds respectively. This raises concerns over their suitability for consumption, with the attendant

adverse effects associated with the intake of high amounts of anti-nutrients. DE pulp showed the highest amounts of anthocyanin while oils from PA peels, C.S seed and pulp lacked anthocyanins. Anthocyanins have been found to induce apoptosis in cells (Srivastava et al., 2007), showing that about 400g of DE pulp would be sufficient to induce apoptotic effects. The pulp oils of CS and PA showed more enrichment of rutin, which in addition to DE pulp was the same case for kaempferol. Rutin is widely recognized as a potent antioxidant (Perwez et al., 2017) while for the kaempferols in the oils it is envisaged that the quantities found evaluated in this study can sufficiently protect against ER stress-induced inflammation and insulin resistance in the liver, as reported by Ok-Kyung et al., (2016). This may be the reason behind the reported antioxidant properties of DE (Omonhinmin and Agbara, 2013). Also, the pulp oil of DE produced the highest amount of epicatechin and catechin, whereas lunamarine and ribalinidine were most abundant in PA seed and pulp respectively. These values were higher than those found from oils from *Duranta repens* (Agomuo et al., 2017) used for various ethnomedicinal purposes.

Table 3. Phytochemical composition (μg/ml) of oils from different parts of *D. edulis*, *P. americana*, and *C. schweinfurthii*

Phytochemicals	**DES**	**DEP**	**DESC**	**PAS**	**PAP**	**PAPE**	**CSS**	**CSP**
Oxalate	1.18± 0.02^{a}	0.36± 0.01^{b}	9.47± 0.55^{c}	4.61± 0.21^{d}	0.10± 0.00^{e}	0.31± 0.02^{b}	8.64± 0.47^{c}	0.80± 0.12^{f}
Phytate	0.29± 0.00^{a}	0.08± 0.00^{b}	1.26± 0.04^{c}	8.24± 0.83^{d}	1.97± 0.31^{f}	18.44± 1.22^{g}	4.31± 0.62^{h}	2.26± 0.62^{f}
Tannin	19.54± 1.4^{a}	7.44± 0.48^{b}	12.71± 0.77^{c}	38.39± 1.92^{d}	18.25± 0.94^{a}	21.03± 1.19^{ae}	6.52± 0.92^{b}	24.40± 1.44^{e}
Saponin	55.53± 3.64^{a}	36.31± 1.21^{b}	50.84± 2.68^{ae}	15.31± 1.20^{c}	40.60± 2.71^{d}	33.81± 2.04^{b}	41.74± 1.84^{d}	48.69± 2.70^{e}
Anthocyanin	2.41± 0.15^{a}	15.20± 0.86^{b}	10.31± 0.89^{c}	0.22± 0.01^{d}	10.08± 0.83^{c}	ND	ND	ND
Rutin	32.34± 1.72^{a}	27.48± 0.97^{b}	15.15± 1.01^{c}	28.16± 1.03^{b}	46.81± 2.54^{d}	40.04± 2.52^{e}	10.09± 0.71^{f}	54.82± 2.31^{g}
Kaempferol	32.22± 1.09^{a}	51.09± 1.81^{b}	47.68± 2.13^{c}	1.31± 0.06^{d}	57.91± 2.18^{b}	15.50± 0.80^{e}	30.41± 1.26^{a}	41.09± 2.59^{c}
Epicatechins	2.61± 0.13^{a}	8.62± 0.53^{b}	6.31± 0.46^{c}	ND	0.13± 0.00^{d}	3.15± 0.11^{f}	ND	6.28± 0.40^{c}
Catechin	52.96± 2.91^{a}	60.90± 2.74^{b}	39.20± 1.33^{c}	15.11± 1.64^{d}	45.08± 3.06^{e}	57.73± 3.29^{ab}	24.13± 1.84^{e}	12.77± 1.52^{d}
Lunamarine	23.41± 1.25^{a}	11.21± 0.38^{b}	41.67± 2.25^{c}	30.22± 1.99^{d}	15.40± 0.88^{e}	0.31± 0.04^{f}	15.36± 1.09^{e}	20.41± 1.36^{a}
Ribalinidine	3.11± 0.22^{a}	3.91± 0.32^{b}	2.04± 0.09^{c}	1.21± 0.03^{d}	8.11± 0.80^{e}	0.73± 0.13^{f}	ND	ND

Values represent mean ± S.D of triplicate determinations. Values bearing dissimilar superscript letters across the row (a-g) are significantly different ($p < 0.05$). DES-*Dacryodes edulis* seed, DEP-*Dacryodes edulis* pulp, DESC-*Dacryodes edulis* seed coat, PAS-*Persea americana* seed, PAP-*Persea americana* pulp, PAPE-*Persea americana* peels, CSS-*Canarium schweinfurthii* seeds, CSP-*Canarium schweinfurthii* pulp

The micronutrient composition of oils from parts of DE, PA, and CS are represented in Table 4. The result indicated that among the fruit parts, pulp oils from CS and PA provided the highest amounts of sodium and calcium, and potassium respectively. Only the amounts found for calcium and potassium were equivalent to the adequate intake (AI) for infants, but below those for adults (USDA, 2005). Sodium and potassium are the major cation in extracellular and intracellular fluids respectively whereas calcium is required for the proper functioning of the bone (Amadi et al., 2017). CS seed oil contained the highest amount of magnesium while its pulp oil was most abundant in phosphorus and manganese. At these levels of magnesium and phosphorus, the CS seed and pulp oil is sufficient for children between 4-8 years, and infants from 0-0.5 years respectively (USDA, 2005). The oils from all the parts of CS can provide for the AI of manganese for children between 0.5-1 years but insufficient for pregnant and lactating women. Magnesium and manganese are

cofactors for many enzymes and supports nerve functions, and antioxidant activities, while phosphorus is crucial to the formation of teeth and bones. Oils from PA pulp and peels, and CS seeds had the significantly highest copper levels, however, all oils evaluated can sufficiently provide the AI for children between 0-8 years, while only oils from PA pulp and peels, and CS seeds are adequate for adults between 14 years above, and pregnant women from 18-50 yrs. Zinc was contained most in DE pulp oil which was comparable to the RDA for children between 0-8 years, while aside from the CS pulp oil, none of the oil sources is recommendable for adequate zinc source for infants. Cadmium and lead were undetected in the extracted oils, while CS oils showed more abundance of iron and were commensurate with the RDA for children and adult males. Further, the pulp oils of DE, and PA and CS contained the highest amounts of vitamin A and E, however, none were sufficient enough to provide for their recommended daily allowance at the sample amounts analyzed. Hence at these levels, the oils may require supplementation for the prevention of both vitamin A and E related deficiency diseases.

Table 4. Micronutrient contents of oils from different parts of *D. edulis*, *P. americana*, and *C. schweinfurthii*

Micronutrients	**DES**	**DEP**	**DESC**	**PAS**	**PAP**	**PAPE**	**CSS**	**CSP**
Minerals (mg/100g)								
Na	1.34± 0.08^{a}	8.31± 0.24^{b}	2.21± 0.54^{c}	0.31± 0.02^{d}	8.14± 0.80^{b}	0.93± 0.06^{a}	5.31± 0.97^{f}	15.32± 2.44^{g}
K	202.44± 8.83^{a}	351.77± 4.62^{b}	110.19± 5.04^{c}	108.20± 3.15^{c}	397.24± 7.31^{d}	155.6.38^{e}	64.51± 6.11^{f}	262.90± 10.40^{g}
Ca	49.72± 3.60^{a}	104.56± 2.70^{b}	101.93± 6.01^{c}	9.21± 1.40^{d}	174.48± 7.81^{e}	28.62± 3.15^{f}	21.08± 2.45^{f}	228.80± 5.04^{g}
Mg	59.75± 6.43^{ac}	48.98± 4.92^{b}	51.42± 3.77^{ab}	62.01± 5.50^{c}	29.65± 1.91^{d}	17.40± 3.36^{e}	134.88± 4.29^{f}	28.22± 1.46^{d}
P	34.60± 2.50^{a}	46.08± 1.08^{b}	61.93± 4.06^{c}	40.20± 0.77^{d}	72.80± 3.89^{e}	68.99± 3.53^{e}	60.04± 4.13^{c}	83.44± 2.90^{f}
Mn	0.26± 0.02^{a}	0.14± 0.01^{b}	ND	0.36± 0.07^{c}	0.33± 0.02^{c}	ND	0.64± 0.09^{f}	0.85± 0.05^{g}
Cu	0.60± 0.03^{a}	0.48± 0.05^{b}	0.77± 0.03^{c}	0.47± 0.02^{b}	0.90± 0.04^{d}	1.02± 0.03^{d}	0.93± 0.06^{d}	0.65± 0.01^{ac}
Zn	0.15± 0.03^{a}	4.22± 0.70^{b}	0.84± 0.12^{d}	0.19± 0.02^{a}	1.06± 0.00^{d}	1.52± 0.30^{e}	1.66± 0.27^{ef}	1.94± 0.03^{f}
Cd	ND	ND	ND	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND	ND	ND	ND
Fe	1.06± 0.04^{a}	3.11± 0.37^{b}	1.84± 0.06^{c}	0.25± 0.05^{d}	0.89± 0.11^{a}	0.61± 0.07^{e}	2.41± 0.03^{f}	7.58± 0.80^{g}
Vitamins								
Vitamin A (μg/100g)	104.77± 4.62^{a}	238.64± 6.05^{b}	44.90± 3.14^{c}	193.1± 4.01^{d}	210.51± 8.20^{e}	254.48± 7.16^{f}	71.95± 2.83^{g}	174.22± 5.40^{h}
Vitamin E (mg/100g)	0.33± 0.02^{a}	1.34± 0.28^{b}	2.07± 0.09^{c}	0.71± 0.01^{d}	2.11± 0.13^{c}	0.23± 0.03	0.66± 0.01^{d}	2.09± 0.07^{c}

Values represent mean ± S.D of triplicate determinations. Values bearing dissimilar superscript letters across the row (a-g) are significantly different ($p < 0.05$). DES-*Dacryodes edulis* seed, DEP-*Dacryodes edulis* pulp, DESC-*Dacryodes edulis* seed coat, PAS-*Persea americana* seed, PAP-*Persea americana* pulp, PAPE-*Persea americana* peels, CSS-*Canarium schweinfurthii* seeds, CSP-*Canarium schweinfurthii* pulp

CONCLUSIONS

The physicochemical and fatty acid analysis of the oils found in the various parts of the different pears showed the suitability of the pulp oils for consumption, with higher amounts of unsaturated fatty acids, while those from other parts could suit more for industrial purposes. The oils also showed rich supplies of phytochemicals, as well as indicated the prevalence of dietary minerals in CS oils equivalent to regulatory levels.

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