Composition, nutritional value and uses of *Ricinodendron heudelotii, Vitex doniana* and *Cleome gynandra* seed oil, three indigenous oil species sources of omega 3, 6 and 9 fatty acids: a review

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Abstract

Ricinodendron heudelotii, *Vitex doniana* and *Cleome gynandra* are three indigenous species of Benin/West Africa. This review focuses on the physicochemical characteristics of their seeds and the nutritional and functional properties of their oils. In this systematic review, scientific articles and reports were used to collect information. The minima, maxima and mean values were considered and converted into a dry basis and/or the same units by using the international system of units when needed to allow comparison. Seeds of *Ricinodendron, Vitex* and *Cleome* fat contents were 51.83 g/100 g dw, 28.55 g/100 g dw and 27.35 g/100 g dw, respectively. The three seed oils contained 58.54 to 87% mono and polyunsaturated fatty acids. *Ricinodendron* seed oil contained a conjugated polyunsaturated fatty acid α-eleostearic acid (49.3–51.1%). Data varied from one author to another due to the methods used. *R. heudelotii* seeds oil is traditionally used for the treatment of several diseases. Its oil showed phytochemical and antimicrobial properties suggesting its possible use in pharmaceutical industries. *Ricinodendron* and *Vitex* seed oil should not be used for cooking at high temperatures or frying because of their high and medium levels of unsaturation.

Keywords: wild oil, fat content, essential fatty acids, food applications, pharmaceutical applications

Introduction

Oil seeds are important crops in sub-Saharan Africa that provide a range of economic, social, and environmental benefits (Sanginga and Bergvinson 2015). In West Africa, *Vitellaria paradoxa*, *Elaeis guineensis*, *Carapa procera*, *Pentadesma butyracea*, and *Lophira lanceolata* are six relatively common oil species (Badoussi *et al*,. 2014, Honfo *et al*,. 2014, Nonviho *et al*,. 2015, Tchobo *et al*,. 2009). Apart from these species, which received the most attention from scholars, private sectors and decision makers, other wild oil species of high interest are marginalised and underutilised (Hammond 2003). Among these, *Vitex doniana* Sweet, *Cleome gynandra* (L.) Briq. and *Ricinodendron heudelotii* (Bail.) are a good source of essential fatty acids (Ajiwe *et al*,. 1998, Ekam 2003, Leudeu *et al*,. 2009, Mnzava 1990a, Mnzava and Chigumira 2004).

Ricinodendron belongs to the Euphorbiaceae family, and only one species (*Ricinodendron heudelotii)* is known. Two morphotypes of this species are recognised: *R. heudelotii* var. *heudelotii* and *R. heudelotii* var. *africanum* (Plenderleith 1997). *Ricinodendron heudelotii* (*Bail.*) is native to tropical Africa, growing generally in rain forests, and is typically found in secondary forests. *Ricinodendron heudelotii* seeds are named 'Njansang' (Douala local language) in Cameroon, 'Sanga Sanga' in Congo; and 'essang,' 'enguessang' or 'issanguila' in Gabon (Tchiegang *et al*,. 1997). *Ricinodendron heudelotii* seeds are commonly used as a spice or soup thickener in many African dishes (Ketaona *et al*,. 2013, Leakey 1999, Mosso *et al*,. 1998, Tchiégang *et al*,. 2004b, Tshiamala-Tshibangu *et al*,. 1999).

Vitex was classified in Verbenaceae, a subfamily of Viticoideae (Meerts 2018). *Vitex* is the only genus of this subfamily present in Africa. *Vitex doniana* is named 'black plum', 'West African plum' or 'African oak' (Akoègninou *et al*,. 2006, Hounkpèvi *et al*,. 2016, Ky 2008). *Vitex doniana* is extremely widespread in tropical areas and is generally found in dry and wet lowlands (Ky 2008). The young leaves are harvested as leafy vegetables and used in home cooking and for sale.

In opposition to previous studies, some recent molecular studies placed the genus of *Cleome* in the Cleomaceae family (Shilla *et al*,. 2019). The genus Cleome was earlier classified under the botanical family of Capparaceae (formerly Capparidaceae), subfamily Cleomoideae (Chweya and Mnzava 1997)**,** but the taxonomic classification of the genus is still under debate. Different synonyms of *C. gynandra* (spider plant) were reported: *Gynandropsis gynandra* (L.) Briq., *Cleome pentaphylla* L. and *Gynandropsis pentaphylla* (L.) DC (Chweya and Mnzava 1997, Waithaka 1991). In West Africa, the species is spontaneous and widely collected but is also grown by local communities in home gardens (Kiebre *et al*,. 2015, Achigan-Dako *et al*,. 2010). C*leome gynandra* is one of the traditional leafy vegetables in Africa and Asia, which contribute to the balance of micronutrients in the diets of local populations (Smith and Eyzaguirre 2007, Houdegbe 2018, Van Jaarsveld *et al*,. 2014, Schönfeldt and Pretorius 2011).

These three underutilised seed crops contain appreciable amounts of oil, which could warrant their screening for increased edible oil production. They provide a wide diversity of fatty acids, which are nutritionally beneficial to human health (Kumar *et al*,. 2016). They are mostly used in rural and remote areas; their processing technologies and related ethnobotanical uses are held by local people and are part of traditional food systems. These species are less exploited, and their nutritional and economic values are not completely determined. In fact, these neglected and underutilised oil species could be a prospective solution to fight poverty, hunger and malnutrition (Padulosi *et al*,. 2013). There is, therefore, a need to capitalise on the knowledge of their traditional processing and the utilisation of their oils. This information should be made available to local people, the private sector and decision makers within the larger context of the existing potential of wild oil species for future valorisation.

The present review aimed to document the nutritional composition of *Ricinodendron heudelotii, Vitex doniana* and *Cleome gynandra* seeds and oils, and to highlight the existing traditional knowledge of oils from these species.

Methodology

Research articles were collected from online sites (AGORA, Web of Science, Scopus, Science Direct and Google Scholar) between March and August 2020. The keywords used for online searches were: 'seed oil', 'oil', 'seeds', 'kernels', 'kernel oil', and 'nutritional value', 'nutritional composition', which were combined with each of the three species '*Vitex doniana*' or 'black pulm', '*Cleome gynandra*' or 'spider plant' and '*Ricinodendron heudelotii*' or 'njansang'. A total of 225 studies were found on the three species. After screening for eligibility, about 91 searched documents were found. Data collected were related to the species taxonomy and ecology, traditional uses of the seeds and seeds and kernels composition. The literature review focused on the nutritional composition of seeds, particularly the triglyceride and fatty acid profiles of the oils. The quality indices and physical properties of the derived oils, as well as phytochemical properties, were documented. For each component, the reported values were, as much as possible, converted into the same units and on a dry-weight basis. Their minimum, mean, and maximum values were calculated and reported, based on data from various authors. Similarities and divergences were also noted.

1. Nutritional composition of Ricinodendron heudelotii, Vitex doniana and Cleome gynandra seeds

1.1. Macronutrients

The moisture content of *R. heudelotii* seeds ranged from 8.7% (Kouamé *et al*,. 2015) to 45.1% (Saki *et al.*, 2005) (Table 1). Saki et al,. (2005) investigated the carbohydrate and crude protein content of *R. heudelotii* seeds and found a mean value of 3.16 g/100 g dry weight (dw) and 25.79 g/100 g dw, respectively. Saki *et al*,. (2005) reported the starch content (0.43–0.8 g/100 g dw), sugar content (0.08–0.1 g/100 g dw) and cellulose content (2.49–2.75 g/100 g dw) in *R. heudelotii* seeds from seven regions (Soubré, Issia, Bouaflé, Yakro, Lakota, Divo, Bondoukou) in Côte d'Ivoire. Crude lipids varied from 44.9 g/100 dw (Kapseu and Tchiegang 1995) to 58.76 g/100 g dw (Kouamé *et al*,. 2015) in *R. heudelotii* seeds. Several works were carried out to characterise *R. heudelotii* seed oil. A variation should be noted between the values reported for the oil yield of the seeds after extraction. This variation may be due to several factors, namely the extraction and analytical methods, treatments of samples before extraction, origin (provenances) of samples (Cameroon, Côte d'Ivoire), morphotypes, etc. Considering studies on the seeds of *R. heudelotii*, it was noticed that two types of extraction methods were mainly used: extraction by pressing using a hydraulic press for oilseeds (MC 2000 AUF with a vertical manual screw of UNATA models) developed at the ENSAI (National School of Agro-Industrial Sciences) of Ngaoundéré (Cameroon), and chemical extraction (Soxhlet method) with hexane as solvent. Another study was conducted to assess the influence of different wet- and dry-seed embrittlement treatments on the quality of the crude oil extracted from the seeds (Aboubakar Dandjouma 2000, Ketaona *et al*,. 2013, Tchiegang *et al*,. 2005, Tchiégang *et al*,. 2004a). For that purpose, before the extraction, the samples underwent several treatments depending on the objectives of the study. It emerged from this work that the extraction method and the different treatments undergone by the seeds influenced the oil yield. However, according to the authors' results, the quality and stability of the oil did not depend on the extraction.

Mnzava (1990b) found a mean crude protein content of 29.65 g/100 g dw and a crude lipid content of 25.10 to 29.6 g/100 g dw in *C. gynandra* seeds. According to (Mishra 2011), *C. gynandra* seed lipids had a high degree of unsaturation, as shown by the high iodine and saponification values (123 mg KOH/g and 192 mg KOH/g, respectively). It was noticed that very few studies have been conducted on the chemical composition of the seeds of *C. gynandra* and the characterisation of its oil. Data obtained on protein, lipid and amino acid composition of seeds of this species were obtained from four ecotypes (purple stem, NIRS-2, NIRS-3, green stem). These morphotypes collected from different areas of Zambia differ in stem colour and vigour. Seeds of these morphotypes were multiplied in laboratories in an isolated medium to get enough material for different analyses. The results showed the highest content of protein and lipid in seeds of the 'Purple stem' morphotype and the lowest content/and a lower content in the 'Green stem' morphotype (Mnzava 1990b).

Crude lipids in *V. doniana* seeds varied from 26.3 g/100 g dw (Chinweuba 2014) to 39.8 g/100 g dw (Amah and Okogeri 2019). Mean carbohydrate and crude protein contents were 19.23 g/100 g dw and 30.05 g/100 g dw, respectively (Amah and Okogeri 2019) (Table 1).

Table 1

Composition of *Ricinodendron heudelotii*, *Vitex doniana* and *Cleome gynandra* seeds

	***Ricinodendron heudelotii* seed**				***Vitex doniana* seed**				***Cleome gynandra* seed**			
	min	mean	max	References	min	mean	max	References	min	mean	max	References
Macronutrients												
Moisture content (%)	8.7	41.9	45.1	(Saki *et al*,. 2005, Kouame *et al*,. 2015)		8.25		(Amah and Okogeri 2019)				
Carbohydrates (g/100g dw)	3.03	3.16	3.29	(Saki *et al*,. 2005)		19.23		(Amah and Okogeri 2019)				
Crude protein (g/100g dw)	24.51	25.79	27.07	(Saki *et al*,. 2005)		30.05		(Amah and Okogeri 2019)	27.9	29.65	31.4	(Mnzava 1990)
Crude lipids (g/100g dw)	44.9	51.83	58.76	(Kapseu and Tchiegang 1995, Saki *et al*,. 2005, Kouame *et al.*, 2015, Yirankinyuki *et al*,. 2018)	26.3	28.55	39.8	(Ajiwe *et al*,. 1998, Amah and Okogeri 2019, Chinweuba 2014)	25.10	27.35	29.6	(Mnzava 1990
Crude fibre (g/100g dw)				(Saki *et al*,. 2005)		5.27		(Amah and Okogeri 2019)				
Starch (g/100g dw)	0.43	0.455	0.48	(Saki *et al*,. 2005)								
Sugars (g/100g dw)	0.08	0.09	0.1	(Saki *et al*,. 2005)								
Cellulose (g/100g dw)	2.49	2.62	2.75	(Saki *et al*,. 2005)								
pH	5.45	6.005	6.56	(*Saki et al*,. 2005)								
Titratable acidity (meq/l)	2.8	2.95	3.1	(*Saki et al*,. 2005)								
Minerals and Vitamins												
Ash **(g/100g dw)**	5.84	6.635	7.43	(Saki *et al*,. 2005)		5.65		(Amah and Okogeri 2019)				

Ca^{2+} (g/l)	0.31	0.335	0.36	(Saki *et al*,. 2005)
Mg^{2+} (g/l)	0.15	0.175	0.2	(Saki *et al*,. 2005)
Cl^{-} (g/l)	0.03	0.035	0.04	(Saki *et al*,. 2005)
P (g/100g)	1.6	1.69	1.79	(Saki *et al*,. 2005)
K (g/100g)	0.74	0.83	0.92	(Saki *et al*,. 2005)

1.2. Minerals and Vitamins

Saki *et al*,. (2005) studied the mineral content of R. *heudelotii* seeds (Table 1). Phosphorus and potassium contents were 1.82 mg/100 g dw and 0.83 mg/100 g dw, respectively. No information was found on the mineral content in seeds of *C. gynandra* and *V. doniana*.

Vitex doniana pulp was rich in potassium, phosphorus and calcium. It also contained a good proportion of vitamins, especially vitamin C (34.01–81.7 mg/100 g dw) (Agbede and Ibitoye 2007, Vunchi *et al*,. 2011) and vitamin B6 (mean of 20.45 mg/100 g dw) (Vunchi *et al*,. 2011).

1.3. Amino acids

Only Tchiegang *et al*,. (1997) studied the amino acid composition of *R. heudelotii* seeds, which were found to be rich in glutamic acid (10.2 g/100 g protein), arginine (5.14 g/100 g protein) and aspartic acid (4.93 g/100 g protein). Small amounts of histidine (1.63 g/100 g proteins), lysine (1.47 g/100 g proteins) and proline (in traces) were found (Table 2).

Mnzava (1990b) studied the amino acid composition of four ecotypes of *C. gynandra* (purple stem, NIRS-2, NIRS-3, green stem) from Zambia. He found that all four ecotypes were rich in glutamic acid, arginine, aspartic acid, leucine and valine. The NIRS-3 seemed to be a little richer in glutamic acid (18.6 g/100 g protein), arginine (11.1 g/100 g protein), aspartic acid (9.3 g/100 g protein) and leucine (6.3 g/100 g protein). All four ecotypes contained small amounts of tyrosine and histidine (Table 2).

A study by (Amah and Okogeri 2019) revealed 18 amino acids in *V. doniana* seeds of which 46.28% are essential and 53.72% non-essential amino acids. Among the essential amino acids, threonine (7.55 g/100 g protein) and methionine (6.22 g/100 g protein) were the most abundant, whereas proline (8.64 g/100 g protein) and glutamic acid (7.33 g/100 g protein) were the predominant non-essential amino acids (Table 2).

Table 2

Amino acid composition (g/100 g crude protein) **in *Ricinodendron heudelotii*, *Vitex doniana* and in Zambian selections of *Cleome gynandra* seeds (*Gynandropsis gynandra* L. Briq)**

Amino acid	***Ricinodendron heudelotii*** **(Tchiegang *et al*,. 1997)**	***Cleome gynandra*** **(Mnzava 1990b)**	***Vitex doniana*** **(Amah and Okogeri 2019)**
Glutamic acid	10.2	17.43	7.33
Arginine	5.14	10.33	4.26
Aspartic acid	4.93	8.43	5.51
Leucine	3.06	5.88	5.31
Valine	3.23	5.63	3.12
Glycine	2.56	5.33	3.48
Proline	Traces	4.93	8.64
Phenylalanine +Tyrosine	4.17	6.48	5.28
Isoleucine	1.9	4.15	3.95
Threonine	1.82	4.08	7.55
Alanine	2.26	3.9	2.71
Serine	2.86	3.75	3.18
Lysine	1.47	3.25	492
Histidine	1.63	2.33	3.25
Cysteine	-	-	1.07
Methionine	-	-	6.22
Asparagine	-	-	4.53

2. Characteristics of Ricinodendron heudelotii, Vitex doniana and Cleome gynandra seed oil

2.1. Oil properties of R. heudelotii, V. doniana and C. gynandra seeds

The saponification value of *R. heudelotii* seed oil ranged from 104.20 mg KOH/g (Ekam 2003) to 190.50 mg KOH/g (Kapseu and Tchiegang 1995) (Table 3). An mean saponification value of 192 mg KOH/g was found for *C. gynandra* seed oil (Mnzava, 1990).

Iodine value provides information on the degree of unsaturation of fats. The iodine value of *R. heudelotii* seed oil varied between 10.01 mg I_2/100 g (Olasehinde *et al*,. 2016) and

166.80 mg I_2/100 g (Ekam 2003). As far as *V. doniana* is concerned, its iodine value varied between 110.70 mg I_2/100 g (Chinweuba, 2014) and 114.6 mg I_2/100 g (Ajiwe *et al*,. 1998) (Table 4). An mean iodine value of 122.5 mg/I_2/100 g (Mnzava 1990b) was found in *C.* gynandra seed oil.

Acid value is defined as the number of milligrams of potassium hydroxide required to neutralise the free acids in one gram of fat (Louni 2009). The acid value of *R. heudelotii* seed oil ranged from 0.39 mg KOH/g (Yirankinyuki *et al*,. 2018) to 12.29 mg KOH/g (Kouamé *et al*,. 2015). The acid value of *V. doniana* seed oil was higher and ranged from 51.80 mg NaOH/g (Chinweuba, 2014) to 56.60 mg NaOH/g (Ajiwe *et al*,. 1998).

The percentage of free fatty acids varied between 0.94% (Kouamé *et al*,. 2015) and 1.53% (Olasehinde *et al*,. 2016) in *R. heudelotii* seed oil. The percentage of free fatty acids of *V. doniana* seed oil varied between 25.80% (Chinweuba, 2014) and 28.20% (Ajiwe et al., 1998). These values of free fatty acids were obtained from oils extracted from dry seeds/kernels and which were submitted directly to chemical analyses.

The mean value of unsaponifiable in *R. heudelotii* seed oil was 1.50% (Kapseu and Tchiegang 1995).

Peroxide value is a characteristic of the oxidation of unsaturated fatty acids. It is determined based on the release of iodine from potassium iodide in acidic solution (Lion 1955). The peroxide value of *R. heudelotii* seed oil varied between 5.87 meq/kg (Ketaona *et al*,. 2013) and 45.95 meq/kg (Olasehinde *et al*,. 2016).

The specific gravity at 28 °C of *R. heudelotii* seed oil was between 0.91 (Yirankinyuki *et al*,. 2018) and 0.93 (Assanvo *et al*,. 2015). It was a little lower for *Vitex* seed oil and varied between 0.84 (Chinweuba, 2014) and 0.88 (Ajiwe *et al*,. 1998).

The mean refractive index at 30 °C of *R. heudelotii* seed oil was 1.49 (Assanvo *et al*,. 2015). At 40 °C, Ekam (2003) found that the refractive index varied between 1.4565 and 1.4569 (Ekam 2003).

The viscosity of *R. heudelotii* seed oil varied between 60.32 mPa·s and 65.42 mPa·s with an mean of 62.87 mPa·s (Ketaona *et al*,. 2013). The mean values for other physical properties for *R. heudelotii* seed oil were heat of combustion (32.80 Kcal/g), boiling point (177.00 °C), smoke point (260.00 °C), melting point (3.00 °C), slip points (3.00 °C), refractive index at 40 °C (1.4567), and relative density at 25 °C (0.85) (Ekam 2003, Ketaona *et al*,. 2013).

Great variation was noticed between the minimum and maximum values reported for the physicochemical properties of *R. heudelotii* seed oil. The same variation was also noted for values reported for the quality index of *R. heudelotii* seed oil (Ekam 2003, Kapseu and Tchiegang 1995, Kouamé *et al*,. 2015). This variation was due to the methods of analysis and of physicochemical parameters determination used by authors. Indeed, Ketaona *et al*,. (2013) used Standard AOCS (1993) official methods to determine the acid, iodine and peroxide values of the oil samples. Yirankinyuki *et al*,. (2018) used different methods for the determination of quality index of the oil samples. Acid value was determined using the method described by Danbature *et al*,. (2015) in which a mixture of diethyl ether, ethanol, oil and a few drops of phenolphthalein indicator was titrated with NaOH with consistent shaking until a dark pink colour was observed, and the volume was noted. Wij's method described by Diamond and Denman (1966) was used in determining the iodine value with sodium thiosulphate solution as a reagent and starch solution as an indicator. Peroxide value was determined by titration with sodium thiosulphate (0.01 M) solution using starch indicators as described by Nkafamiya *et al*,. (2007). In determining the saponification value, Diamond and Denman (1966) method was adopted. Ekam (2003) used methods that differed from those used by Ketaona *et al*,. (2013) and Yirankinyuki *et al*,. (2018) to determine the quality index of oil samples. In fact, acid value was determined by the method of Devene and Williams (1961); iodine value was determined by the method of Strong and Kock (1974) and saponification value was determined by the AOAC (1984) method. Ester value was estimated by the method of Williams (1950) as the difference between the saponification value and the acid value. The percentage of free fatty acids was estimated from the acid value using the method of Gunstone *et al*,. (1986). The saponification equivalent was estimated from the saponification value by the method of Hendrikse and Harwood (1986). The methods used by Kouamé *et al*,. (2015) varied depending on the index to be calculated. Indeed, saponification and acid values were determined by the BureauInterprofessionneld'EtudesAnalytiques (1976) method. Peroxide value was determined using the method proposed by Cocks and Van Rede (1966). Iodine number was determined by the WOLFF method (Wolff 1968).

It should be noted that very few authors have worked on the physicochemical properties of *V. doniana* and *C. gynandra* seed oil.

Table 3: Physicochemical properties of *Ricinodendron heudelotii*, *Vitex doniana* and *Cleome gynandra* seed oils.

	Ricinodendron heudelotii				*Vitex doniana*				*Cleome gynandra*			
	min	mean	max	References	min	mean	max	References	min	mean	max	References
Saponification value (mg KOH/g)	104.20	147.35	190.50	(Kapseu and Tchiegang, 1995, Tchiegang et al,. 1997, Ekam 2003, Kouame *et al*,. 2015, Assanvo *et al*,. 2015, Olasehinde *et al*,. 2016, Yirankinyuki *et al*,. 2018)	14.50	35.50	56.50	(Ajiwe *et al*,. 1998, Chinweuba 2014)		192.00		(Mnzava 1990)
Iodine value (mg I_2/100g)	10.01	88.41	166.80	(Kapseu and Tchiegang 1995, Tchiegang *et al*,. 1997, Ekam 2003, Ketaona *et al*,. 2013, Kouame et al,. 2015, Assanvo et al,. 2015, Olasehinde *et al*,. 2016, Yirankinyuki *et al*,. 2018)	110.70	113.15	114.60	(Ajiwe *et al*,. 1998, Chinweuba 2014)	120	122.5	125	(Mnzava1990)
Acid value (mg KOH/g fat)	0.39	6.34	12.29	(Ekam 2003, Keaton *et al*,. 2013, Kouame *et al.*, 2015, Assanvo *et al*,. 2015, Olasehinde *et al.*, 2016, Yirankinyuki *et al*,. 2018)	51.80	54.20	56.60	(Ajiwe *et al*,. 1998, Chinweuba 2014)				
Peroxide index (meq/kg)	5.87	25.91	45.95	(Ketaona *et al*,. 2013, Kouame *et al*,. 2015, Olasehinde *et al*,. 2016, Yirankinyuki *et al*,. 2018)								
Unsaponifiable content (%)	1.40	1.50	1.60	(Kapseu and Tchiegang 1995)								
Free fatty acids (%)	0.94	1.24	1.53	(Ekam 2003, Olasehinde *et al*,. 2016)	25.80	27.00	28.20	(Ajiwe *et al*,. 1998, Chinweuba 2014)				
Saponification equivalent (g fat mg/KOH)	485.00	500.00	515.00	(Ekam 2003)								
Ester value (mg	103.94	140.28	176.62	(Ekam 2003, Olasehinde *et al*,.								

KOH/g fat)				2016)				
Specific gravity (28 °C)	0.9124		0.93	(Assanvo *et al*,. 2015, Yirankinyuki *et al*,. 2018)	0.84	0.86	0.88	(Ajiwe *et al*,. 1998, Chinweuba 2014)
Mean molecular mass						10001.80		(Ajiwe *et al*,. 1998)
pH	6.62		6.7	(Yirankinyuki *et al*,. 2018)				
Lipid colour	yellow		Brownish yellow	(Ekam 2003, Yirankinyuki *et al.*, 2018)				
Heat of combustion (Kcal/g)	28.80	32.80	36.80	(Ekam 2003)				
Refractive index (40 °C)	1.4542	1.4545	1.4549	(Ekam 2003, Olasehinde *et al.*, 2016)				
Refractive index (30 °C)		1.49		(Assanvo *et al*,. 2015)				
Boiling point (°C)	134.00	177.00	220.00	(Ekam, 2003, Olasehinde *et al*,. 2016)				
Smoke point (°C)	240.00	260.00	280.00	(Ekam 2003)				
Flash point (°C)	330.00	350.00	370.00	(Ekam 2003)				
Melting point (°C)	2.00	3.00	4.00	(Ekam 2003, *Ketaona et al,* . 2013)				
Slip point (°C)	2.00	3.00	4.00	(Ekam 2003)				
Relative density (25 °C) g dm^{-3}	0.84000	0.85	0.86	(Ekam 2003, Olasehinde *et al*,. 2016)				
Cloud point		0.50		(Olasehinde *et al*,. 2016)				
K232	1.19	1.19	1.19	(Ketaona *et al*,. 2013)				
K270	0.35	0.35	0.35	(Ketaona *et al*,. 2013)				
Viscosity (mPa.s)	60.32	62.87	65.42	(Ketaona *et al*,. 2013)				
Crystallisation temperature (°C)	-16.09	-16.18	-16.28	(Ketaona *et al*,. 2013, Yirankinyuki *et al*,. 2018)				

2.2. Triglycerides and fatty acids in R. heudelotii, V. doniana and C. gynandra seed oil

Table 4 shows the triacylglycerol composition of seed oil from two varieties of *R. heudelotii*. From this table, it appears that *R. heudelotii* seed oil contained about 21 triacylglycerols. Two main triacylglycerols (linoleic-α-eleostearic: EEL and tri-α-eleostearic: EEE) and six secondary triacylglycerols (OLL, LEL, LLL, OEL, EES, EEO, EEP) are shown.

Indeed, Kapseu and Tchiegang (1995) worked on two morphotypes of *R. heudelotii* seed oil from two different regions of Cameroon. Kapseu (2009) documented the production, processing, utilisation and fatty acid and triglyceride compositions of oleo proteins from sub-Saharan Africa from oil species including *R. heudelotii*. A low variation is noted between the values reported by Kapseu and Tchiegang (1995) and Kapseu (2009).

Table 4

Triglyceride composition (%)of *Ricinodendron heudelotii* seed oil

<table>
<tr><th rowspan="2">Triacylglycerol (TG)</th><th rowspan="2">Partition number (PN)</th><th rowspan="2">Number of double bonds</th><th colspan="2">Kapseu and Tchiegang (1995)</th><th rowspan="2">Kapseu (2009)</th></tr>
<tr><th>Seed Type 1</th><th>Seed Type 2</th></tr>
<tr><td>EEE</td><td>36</td><td>9</td><td>15.9</td><td>13.1</td><td>15.9</td></tr>
<tr><td>EEL</td><td>38</td><td>8</td><td>33.1</td><td>29.7</td><td>33.1</td></tr>
<tr><td>LEL</td><td>40</td><td>7</td><td>7.7</td><td>8.9</td><td>7.7</td></tr>
<tr><td>EEO</td><td>40</td><td>7</td><td>6.1</td><td>4.9</td><td>6.1</td></tr>
<tr><td>EEP</td><td>40</td><td>6</td><td>6.1</td><td>5.7</td><td>6.1</td></tr>
<tr><td>EES</td><td>42</td><td>6</td><td>5.9</td><td>5.8</td><td>5.9</td></tr>
<tr><td>OEL</td><td>42</td><td>6</td><td rowspan="2">7.3</td><td rowspan="2">7.3</td><td>7.3</td></tr>
<tr><td>LLL</td><td>42</td><td>6</td><td>7.3</td></tr>
<tr><td>PEL</td><td>42</td><td>5</td><td>5.4</td><td>2.1</td><td>3.75</td></tr>
<tr><td>OEO</td><td>44</td><td>5</td><td>0.3</td><td>1.9</td><td>1.1</td></tr>
<tr><td>OLL</td><td>44</td><td>5</td><td></td><td rowspan="4">8.4</td><td>10.1</td></tr>
<tr><td>PLL</td><td>44</td><td>4</td><td></td><td>-</td></tr>
<tr><td>OEP</td><td>44</td><td>4</td><td>10.1</td><td>-</td></tr>
<tr><td>PEP</td><td>44</td><td>3</td><td></td><td>-</td></tr>
</table>

POO	44	2			-
PEO	46	4	0.4	0.4	0.8
OES	46	4	0.9	1.6	1.5
SOLn	46	4	-	-	0.9
SLL	46	4	1.8	1.8	1.8
SLO	48	3	1.4	1.4	1.4
SLP	48	2	1.6	1.6	0.9

Abbreviations O = oleic acid; P = palmitic acid; L = linoleic acid; Ln = linolenic acid; S = stearic acid; E = α-elaeostearic acid

Kapseu and Tchiegang (1995) and Assanvo *et al.* (2015) investigated the fatty acid profile of *R. heudelotii* seed oil and found it was mainly composed of linoleic acid (omega 6 fatty acid) (28.3–51.1%) and with a conjugated polyunsaturated fatty acid named α-eleostearic acid (49.3–51.1%) (Table 5).

Cleome gynandra seed oil is mainly composed of omega 6 fatty acids (linoleic acid :56.3–61.1%) and omega 9 fatty acids (oleic acid:19.6–23.9%) (Mnzava 1990b). A study was conducted on four ecotypes (purple stem, green stem, NIRS-2, NIRS-3) of *C. gynandra* seeds from different parts of Zambia. The ecotypes differed in stem colour and vigour. The ecotypes exhibited slight variations in the proportions of fatty acids and had generally lower amounts of stearic acid (6.85%) than palmitic acid (11.2%). Arachidonic and eicosenoic acids occurred in similar proportions (Mnzava 1990b) (Table 5).

Amah and Okogeri (2019) investigated the fatty acids profile of *V. doniana* seed oil and found that this oil was mainly composed of omega 9 fatty acid (oleic acid: 58.54%), palmitic acid (34.24%) and stearic acid (7.22%) (Table 5).

Cleome gynandra contained octadecadienoic and hexadecanoic acids at a higher concentration (68.07% and 23.78%, respectively). 1,2 benzenedicarboxylic acid, in its ester forms (e.g. diisooctyl ester and bis(2 methylpropyl) ester) was found in *C. gynandra* seed oil (Aparadh and Karadge 2010).

Table 5

Fatty acid content (%) of *Ricinodendron heudelotii, Vitex doniana* and *Cleome gynandra* seed oil

	Ricinodendron heudelotii				*Cleome gynandra*				*Vitex doniana*			
	min	mean	max	References	min	mean	max	References	min	mean	max	References
Palmitic 16:0	5.5	5.75	6	(Kapseu and Tchiegang 1995, Tchiegang *et al*,. 1997)	10.7	11.2	11.7	(Mnzava 1990)		34.24		(Amah and Okogeri 2019)
Palmitoleic 16:1					0.3	0.35	0.4	(Mnzava 1990)				
Stearic 18:0	6.4	6.5	6.6	(Kapseu and Tchiegang 1995, Tchiegang *et al*,. 1997)	6.1	6.85	7.6	(Mnzava 1990)		7.22		(Amah and Okogeri 2019)
Oleic 18:1	7.2	7.3	7.4	(Kapseu and Tchiegang 1995, Tchiegang *et al*,. 1997, Assanvo *et al*,. 2015)	19.6	21.75	23.9	(Mnzava 1990)		58.54		(Amah and Okogeri 2019)
Linoleic 18:2	28.3	39.7	51.1	(Kapseu and Tchiegang 1995, Tchiegang *et al*,. 1997, Kapseu 2009, Assanvo *et al*,. 2015)	56.3	58.7	61.1	(Mnzava 1990)				
Linolenic 18:3												
Arachidic 20:0					0.1	0.15	0.2	(Mnzava 1990)				
Eicosenoic 20:1		0.1		(Kapseu and Tchiegang 1995,		0.1		(Mnzava 1990)				

				Tchiegang *et al*,. 1997)
Lignoceric 24:0		1.2		(Kapseu and Tchiegang 1995, Tchiegang *et al*,. 1997)
α-eleostearic acid 24:3	49.3	50.2	51.1	(Kapseu and Tchiegang 1995, Tchiegang *et al*,. 1997, Assanvo *et al*,. 2015)

2.3. Phytochemical properties of crude oil extracts of R. heudelotii, V. doniana and C. gynandra

Phytochemical and antimicrobial properties of oil extracts from *R. heudelotii* seeds have been studied by (Olasehinde *et al*,. 2016) and Odinga *et al*,. (2016) (Table 6). The results showed that these oils contained important phytochemical products (saponins, terpenoids, steroids, tannins, trace amounts of phenol) that were mainly used for medicinal purposes (Olasehinde *et al*,. 2016). Odinga *et al*,. (2016) also found flavonoids, alkaloid cardiac glycosides, anthraquinone, and carotenoid contents (Table 6).

Table 6

Qualitative phytochemical properties of crude oil extract of *Ricinodendron heudelotii* seeds

Component	**Results**	
	Olasehinde *et al*,. (2016)	**Odinga *et al*,. (2016)**
Tannins		positive
Phlobatannins	negative	negative
Flavonoid	negative	positive
Alkaloid	negative	positive
Cardiac glycoside	negative	positive
Terpenoids	positive	positive
Saponin frothing	positive	positive
Saponin emulsifying	positive	positive
Combined anthraquinone		positive
Free anthraquinone	negative	negative
Carotenoid		positive
Reducing compound		negative
Steroids	positive	
Volatile	positive	

According to (Odinga *et al*,. 2016), *R. heudelotii* seed oil is rich in flavonoids (437.5 mg/100 g), in particular naringenin (187.9 mg/100 g), tannins (399.5 mg/100 g) and saponins (142.6 mg/100 g) (Table 7).

According to Amah and Okogeri (2019), the seed oil of *V. doniana* contained three phytochemicals, which are flavonoids (3.75 mg/100 g), alkaloids (11.4 mg/100 g) and phenols (170 mg/100 g) (Table 7).

Table 7

Quantitative phytochemical composition (mg/100 g wet weight) of *Ricinodendron heudelotii* and *Vitex doniana* seeds

Component	Subclass	Concentration	
		Ricinodendron heudelotii **Odinga *et al*,. (2016)**	***Vitex doniana*** **(Amah and Okogeri 2019)**
Phenol		22.357	170
Tannin		399.463	
Oxalate		11.581	
Phytate		2.946	
Alkaloid	Lumamarine	79.079	
	Ribalidine	56.08	11.40
	Spartein	0.002	
Saponin	Sapogenin	142.632	
Flavonoid	Catechin	115.693	
	Epicatechin	19.145	
	Rutin	59.573	3.75
	Kaempferol	31.418	
	Naringenin	187.939	
	Anthocyanin	24.412	

3. Traditional knowledge of Ricinodendron heudelotii, Vitex doniana and Cleome gynandra seed oil

Ricinodendron heudelotii has been used traditionally for the treatment of various diseases and sickness.

Many studies have been conducted on the characterisation of *R. heudelotii* seed oil. The results of these studies showed that the percentage of free fatty acids and acids were low suggesting increased stability and usefulness of *R. heudelotii* seed oil in nutritional and industrial applications (Ekam 2003). It also appears that *R. heudelotii* is a drying oil due to its high polyunsaturated acid (α-eleostearic acid) content and iodine value (Assanvo *et al*,. 2015, Ekam 2003, Leudeu *et al*,. 2009). These qualities of *R. heudelotii* seed oil suggest its possible use in the paint industry (Ekam 2003). Assanvo *et al*,. (2015) investigated the preparation and characterisation of the alkyd resins based on *R. heudelotii* oil and their blending with epoxy resin. They concluded that this oil could be used for the preparation of fast drying binder and in resins suitable for surface coating applications.

Ricinodendron heudelotii seed oil is affected by microwave heating as reported by Ketaona *et al*,. (2013). In fact, many changes were observed in the oil samples such as the formation of free fatty acids, hydroperoxides and secondary oxidation products, decreased levels of unsaturated fatty acids and changes in viscosity, melting and crystallisation profiles. The authors concluded that *R. heudelotii* oil should not be used for cooking at high temperatures or frying. It could be good for salad dressings.

A test on the effects of consumption of *R. heudelotii* seed oil carried out by (Leudeu *et al*,. 2009) revealed that *R. heudelotii* seed oil could be used in the treatment of cardiovascular disease.

In Nigeria, Ajiwe *et al*,. (1998) and Chinweuba (2014) carried out studies on *V. doniana* seed oil. They showed that its low saponification and medium iodine values ranked the seed oil as a semi-drying oil. This property suggested that the oil could be used to produce resins, paint and skin cream. To this end, manufacturing trials of some products such as alkyd resin, paint, black shoe polish and skin cream were carried out using oil from *V. doniana* seeds in combination with other chemicals/compounds. These products were found to be better than the previously marketed ones.

Studies carried out on *Cleome gynandra* showed that its seeds were oleiferous, and the oil extracted from the seeds contained polyunsaturated oil. The oil was extracted by pressure and did not need refining.

In Benin, extraction of *V. doniana, C. gynandra* and *R. heudelotii* seeds oils was not mentioned.

4. Nutraceutical potential of Ricinodendron heudelotii, Vitex doniana and Cleome gynandra seed oil

Many studies related to the phytochemical and therapeutic aspects have been carried out on *R. heudelotii* seeds and oil. The seeds and oils were rich in phytochemical constituents such as saponins, terpenoids, and steroids. Indeed, the effect of *R. heudelotii* seed oil on Gram-negative and Gram-positive bacteria and a fungus has been tested. The results showed that the extract exhibited appreciable antimicrobial activity against all the test organisms: *Escherichia coli, Staphylococcus aureus* and *Candida albicans* but not *Pseudomonas aeruginosa.* This work concluded that *R. heudelotii* seed oil could be used in therapeutic and pharmaceutical industries due to its phytochemical compounds and potent biological activities (Olasehinde *et al*,. 2016).

Numerous publications on the Mediterranean diet have shown the beneficial role of vegetable oils, especially olives and rapeseed in the prevention of cardiovascular disease (Wahrburg *et al*,. 2002). A test on the effects of consumption of *R. heudelotii* seed oil on serum lipids, plasma fatty acids, malondialdehyde (MDA) and some antioxidants was carried out by Leudeu *et al*,. (2009). The study was conducted on male albino (Sprague-Dawley) rats (Harlan, France). The study was based on the hypothesis that the consumption of the oil could alter the quality of lipids in the blood of rats. The effects of *R. heudelotii* oil consumption on serum lipids, plasma fatty acids, malondialdehyde (MDA), and some antioxidants parameters in the rats were tested. The experimental protocol consisted of taking rats aged one month and weighing between 140 and 151 g and feeding them for a week with food (M20 diet; Special Diets Services, Paris, France) ad libitum. At the end of this period, the rats were weighed and divided into groups of 6. The first group (RHO group) was fed with a diet containing *R. heudelotii* oil (at a rate of 5%) as a lipid source, and the control group was fed with a commercial diet (M20 diet; Special Diets Services). This experiment lasted 60 days at the end of which the body weight of the rats and the food consumed were determined. Tissue and blood samples from the different rats were taken for analysis. The analysis of biochemical parameters in serum (TC serum, HDL-cholesterol, LDL-cholesterol, triglycerides, ALAT, alkaline phosphatase, and total bilirubin) of rats fed with *R. heudelotii* seed oil showed that there was no significant difference between the biochemical parameters. However, the levels of TC, LDL-C, triglycerides, and ALT in the control group rats were high compared to those of the RHO group. Regarding the plasma fatty acid content, changes were noted for the saturated fatty acids palmitic acid (23.06% for the RHO group and 24.22% for the control) and stearic acid (10.40% for the RHO group and 7.20% for the control). For monounsaturated fatty acids, in addition to palmitoleic and oleic acid, trans-vaccenic acid was identified in the plasma of all rats. The linoleic acid content was higher in the control group (30.30%) than the RHO group (16.90%). Despite the high α-eleostearic acid content in the diet of the RHO group, this acid was not detected. However, a new fatty acid was detected: a conjugated linoleic fatty acid (4.02%). Arachidonic fatty acid was detected at levels of 19.91% and 24.90%, respectively, in the control group and the RHO group. The authors concluded that the oil contributed to the reduction of cardiovascular diseases risk. Another study on the management of cardiovascular diseases revealed that *R. heudelotii* seed oil was a potential source of rumenic acid. In fact, *R. heudelotii* seed oil is rich in α-eleostearic acid (-ESA), which is a Conjugated Linolenic Acid (CLA). Tests were performed *in vivo* and *in vitro* to follow the conversion of α-eleostearic acid. Prior to this, α-eleostearic was isolated and purified. After *in-vivo* metabolism, the conversion rates of α-ESA to CLA were 66% and 85%, respectively, in the intestine and in the liver. The *in vitro* test indicated conversion proportions of 66% and 77%, respectively, in the S9 fractions of the intestine and the liver of rats. Those studies have not yet been performed on humans.

Vegetable oil can be classified as drying or non-dying oils (Axtell and Fairman 1992). Drying oils consist of glycerol triesters of fatty acids. These esters are characterised by high levels of polyunsaturated fatty acids, especially alpha linoleic acid. One common measure of the 'siccative' (drying) property of oils is iodine value, which is an indicator of the number of double bonds in the oil. It appears that *R. heudelotii* seed oil is a drying oil due to its high level of polyunsaturated acid (α-eleostearic acid) content and iodine value. In Nigeria, Ajiwe *et al*,. (1998) and Chinweuba (2014) carried out studies on *V. doniana* seed oil. They showed that the low saponification and medium iodine values of the seed oil placed it as a semi-drying oil.

Frying is widely used in the food industry and in households as a method of cooking food. Edible oils are mainly made up of triglycerides (fatty acid triesters of varying sizes or/and different unsaturations). But during oil frying, a certain number of new chemical compounds are formed (Graille 1998) due to the physical and chemical phenomena that take place, such as Maillard reactions, degradation of the quality of the oils, etc. According to the work of Funami *et al*,. (1999), fried foods contain undesirable compounds such as acrylamide, trans/saturated fatty acids, and a high amount of oil, even up to 50% of the total weight.

Studies have concluded that oil from the seeds of *R. heudelotii* is not suitable for high-temperature cooking or deep-frying. *R. heudelotii* oil is suitable only for salad dressings. *R. heudelotii* and *V. doniana* seed oil are unsuitable for cooking because of their high and medium levels of unsaturation. Heating or frying the oil of *R. heudelotii* would cause changes in the composition of the oil such as the formation of free fatty acids, hydroperoxides and secondary oxidation products, decreased levels of unsaturated fatty acids and changes in viscosity, melting and crystallisation profiles (Ketaona *et al*,. 2013).

5. Future prospects on the three wild oils

Many studies have been carried out in Cameroon and Côte d'Ivoire on the composition and characterisation of *R. heudelotii* seed and its oil. Some studies have also been done on the possible uses and applications of this oil. Further studies could be carried out on the physicochemical characterisation of *R. heudelotii* oils from other regions/countries to compare the results obtained by different authors. Studies could also assess the effect of enzymatic treatment prior to oil extraction by pressing. The use of lower enzyme concentrations for longer times could also be considered in further studies in order to reduce the cost of this process.

Vitex doniana and *Cleome gynandra* have been characterised for their seed oil. But most of these studies were not recent and date back several decades. It is therefore necessary to carry out new physico-chemical analyses of the seeds and oils to determine the fatty acid profiles and the possible applications of these oils.

Further, the search for cheaper foods, feed or industrial oils from indigenous plant species is of relevance to developing countries.

Ethics Statement

This is a review article. No additional experiments were performed.

Declaration of Competing Interests

There are no conflicts of interest.

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Authors' Contribution Statement

Nadjidath F. Adome: Methodology, Writing - Original Draft, Writing - Review & Editing. Flora J. Chadare, Fernande G. Honfo, Joseph D. Hounhouigan: Methodology - Review & Editing and Supervision. All authors approved the final version of the manuscript.

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