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REVIEW

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

JEL CLASSIFICATION
Food engineering

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1 | INTRODUCTION

Oil seeds are important crops in sub-Saharan Africa that provide a range of economic, social, and environmental benefits.[1] In West Africa, *Vitellaria paradoxa*, *Elaeis guineensis*, *Carapa procera*, *Pentadesma butyracea*, and *Lophira lanceolata* are six relatively common oil species.[2–5] Apart from these species, which received the most attention from scholars, private sectors and decision makers, other wild oil species of high interest are marginalized and underutilized.[6] Among these, *Vitex doniana* Sweet, *Cleome gynandra* (L.) Briq. and *Ricinodendron heudelotii* (Bail.) are a good source of essential fatty acids.[7–11]

Ricinodendron belongs to the Euphorbiaceae family, and only one species (*R. heudelotii)* is known. Two morphotypes of this species are recognized: *R. heudelotii* var. *heudelotii* and *R. heudelotii* var. *africanum*.[12] *R. heudelotii* (*Bail.*) is native to tropical Africa, growing generally in rain forests, and is typically found in secondary forests. *R. heudelotii* seeds are named "Njansang" (Douala local language) in Cameroon, "Sanga Sanga" in Congo; and "essang," "enguessang" or "issanguila" in Gabon.[13] *R. heudelotii* seeds are commonly used as a spice or soup thickener in many African dishes.[14–18]

Vitex was classified in Verbenaceae, a subfamily of Viticoideae.[19] *Vitex* is the only genus of this subfamily present in Africa. *V. doniana* is named "black plum," "West African plum," or "African oak."[20–22] *V. doniana* is extremely widespread in tropical areas and is generally found in dry and wet lowlands.[22] 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.[23] The genus Cleome was earlier classified under the botanical family of Capparaceae (formerly Capparidaceae), subfamily Cleomoideae,[24] 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.[24,25] In West Africa, the species is spontaneous and widely collected but is also grown by local communities in home gardens.[26,27] *C. 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.[28–31]

These three underutilized 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.[32] They are mostly used in rural and remote areas and 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 underutilized oil species could be a prospective solution to fight poverty, hunger, and malnutrition.[33] There is, therefore, a need to capitalize on the knowledge of their traditional processing and the utilization 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 *R. heudelotii, V. doniana*, and *C. gynandra* seeds and oils, and to highlight the existing traditional knowledge of oils from these species.

2 | 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.

3 | NUTRITIONAL COMPOSITION OF *R. HEUDELOTII*, *V. DONIANA*, AND *C. GYNANDRA* SEEDS

3.1 | Macronutrients

The moisture content of *R. heudelotii* seeds ranged from 8.7%[34] to 45.1%[35] (Table 1). Saki et al.[35] 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.[35] 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[37] to 58.76 g/100 g dw[34] in *R. heudelotii* seeds. Several works were carried out to characterize *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.[14,17,40,41] 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[10] found a mean crude protein content of 29.65 g/100 g dw and a crude lipid content of 25.10–.6 g/100 g dw in *C. gynandra* seeds. According to Mishra et al.,[42] *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 characterization 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 color and vigor. 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.[10]

Crude lipids in *V. doniana* seeds varied from 26.3[39] to 39.8 g/100 g dw.[36] Mean carbohydrate and crude protein contents were 19.23 and 30.05 g/100 g dw, respectively[36] (Table 1).

3.2 | Minerals and vitamins

Saki et al.[35] studied the mineral content of *R. heudelotii* seeds (Table 1). Phosphorus and potassium contents were 1.82 and 0.83 mg/100 g dw, respectively. No information was found on the mineral content in seeds of *C. gynandra* and *V. doniana*.

V. 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)[43,44] and vitamin B6 (mean of 20.45 mg/100 g dw).[44]

3.3 | Amino acids

Only Tchiegang et al.[13] 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[10] 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

TABLE 1 Composition of *Ricinodendron heudelotii*, *Vitex doniana*, and *Cleome gynandra* seeds

	***R. heudelotii* seed**				***V. doniana* seed**				***C. gynandra* seed**			
	Min	**Mean**	**Max**	**References**	**min**	**mean**	**max**	**References**	**Min**	**Mean**	**Max**	**References**
Macronutrients												
Moisture content (%)	8.7	41.9	45.1	34,35		8.25		36				
Carbohydrates (g/100 g dw)	3.03	3.16	3.29	35		19.23		36				
Crude protein (g/100 g dw)	24.51	25.79	27.07	35		30.05		36	27.9	29.65	31.4	10
Crude lipids (g/100 g dw)	44.9	51.83	58.76	34,35,37,38	**26.3**	28.55	**39.8**	7,36,39	25.10	27.35	29.6	10
Crude fiber (g/100 g dw)				35		5.27		36				
Starch (g/100 g dw)	0.43	0.455	0.48	35								
Sugars (g/100 g dw)	0.08	0.09	0.1	35								
Cellulose (g/100 g dw)	2.49	2.62	2.75	35								
pH	5.45	6.005	6.56	35								
Titratable acidity (meq/l)	2.8	2.95	3.1	35								
Minerals and vitamins												
Ash **(**g/100 g dw**)**	5.84	6.635	7.43	35		**5.65**		36				
Ca^{2+} (g/L)	0.31	0.335	0.36	35								
Mg^{2+} (g/L)	0.15	0.175	0.2	35								
Cl^{-} (g/L)	0.03	0.035	0.04	35								
P (g/100 g)	1.6	1.69	1.79	35								
K (g/100 g)	0.74	0.83	0.92	35								

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	***R. heudelotii*[13]**	***Cleome gynandra*[10]**	***V. doniana*[36]**
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

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 Reference 36 revealed 18 amino acids in *V. doniana* seeds of which 46.28% are essential and 53.72% nonessential 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 nonessential amino acids (Table 2).

4 | CHARACTERISTICS OF *R. HEUDELOTII*, *V. DONIANA*, AND *C. GYNANDRA* SEED OIL

4.1 | Oil properties of *R. heudelotii*, *V. doniana*, and *C. gynandra* seeds

The saponification value of *R. heudelotii* seed oil ranged from 104.20[8] to 190.50 mg KOH/g[37] (Table 3). An mean saponification value of 192 mg KOH/g was found for *C. gynandra* seed oil.[10]

Iodine value provides information on the degree of unsaturation of fats. The iodine value of *R. heudelotii* seed oil varied between 10.01[46] and 166.80 mg I_2/100 g.[8] As far as *V. doniana* is concerned, its iodine value varied between 110.70[39] and 114.6 mg I_2/100 g[7] (Table 4). A mean iodine value of 122.5 mg/I_2/100 g[10] was found in *C*. gynandra seed oil.

Acid value is defined as the number of milligrams of potassium hydroxide required to neutralize the free acids in 1 g of fat.[48] The acid value of *R. heudelotii* seed oil ranged from 0.39[38] to 12.29 mg KOH/g.[34] The acid value of *V. doniana* seed oil was higher and ranged from 51.80[39] to 56.60 mg NaOH/g.[7]

The percentage of free fatty acids varied between 0.94%[34] and 1.53%[46] in *R. heudelotii* seed oil. The percentage of free fatty acids of *V. doniana* seed oil varied between 25.80%[39] and 28.20%.[7] 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%.[37]

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.[49] The peroxide value of *R. heudelotii* seed oil varied between 5.87[14] and 45.95 meq/kg.[46]

The specific gravity at 28°C of *R. heudelotii* seed oil was between 0.91[38] and 0.93.[45] It was a little lower for *Vitex* seed oil and varied between 0.84[39] and 0.88.[7]

The mean refractive index at 30°C of *R. heudelotii* seed oil was 1.49.[45] At 40°C, Ekam[8] found that the refractive index varied between 1.4565 and 1.4569.

The viscosity of *R. heudelotii* seed oil varied between 60.32 and 65.42 mPa·s with an mean of 62.87 mPa·s.[14] 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).[8,14]

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.[8,34,37] This variation was due to the methods of analysis and of physicochemical parameters determination used by authors. Indeed, Ketaona et al.[14] used Standard AOCS (1993) official methods to determine the acid, iodine and peroxide values of the oil samples. Yirankinyuki et al.[38] 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.[50] 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 color was observed, and the volume was noted. Wij's method described by Diamond and Denman[51] 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.[52] In determining the saponification value, Diamond and Denman[51] method was adopted. Ekam[8] used methods that differed from those used by Ketaona et al.[14] and Yirankinyuki et al.,[38] to determine the quality index of oil samples. In fact, acid value was determined by the method of Devene and Williams[53]; iodine value was determined by the method of Strong and Kock[54] and saponification value was determined by the AOAC[55] method. Ester value was estimated by the method of Williams[56] 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.[57] The saponification equivalent

TABLE 3 Physicochemical properties of *Ricinodendron heudelotii*, *Vitex doniana* and *Cleome gynandra* seed oils

	R. heudelotii				*V. 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	8,13,34,37,38,45,46	14.50	35.50	56.50	7,39		192.00		10
Iodine value (mg I_2/100g)	10.01	88.41	166.80	8,13,14,34,37,38,45,46	110.70	113.15	114.60	7,39	120	122.5	125	10
Acid value (mg KOH/g fat)	0.39	6.34	12.29	8,14,34,38,45,46	51.80	54.20	56.60	7,39				
Peroxide index (meq/kg)	5.87	25.91	45.95	14,34,38,46								
Unsaponifiable content (%)	1.40	1.50	1.60	37								
Free fatty acids (%)	0.94	1.24	1.53	8,46	25.80	27.00	28.20	7,39				
Saponification equivalent (g fat mg/KOH)	485.00	500.00	515.00	8								
Ester value (mg KOH/g fat)	103.94	140.28	176.62	8,46								
Specific gravity (28 °C)	0.9124		0.93	38,45	0.84	0.86	0.88	7,39				
Mean molecular mass						10001.80		7				
pH	6.62		6.7	38								
Lipid color	yellow		Brownish yellow	8,38								
Heat of combustion (Kcal/g)	28.80	32.80	36.80	8								
Refractive index (40 °C)	1.4542	1.4545	1.4549	8,46								
Refractive index (30 °C)		1.49		45								
Boiling point (°C)	134.00	177.00	220.00	8,46								
Smoke point (°C)	240.00	260.00	280.00	8								
Flash point (°C)	330.00	350.00	370.00	8								
Melting point (°C)	2.00	3.00	4.00	8,14								
Slip point (°C)	2.00	3.00	4.00	8								
Relative density (25 °C) g dm^{-3}	0.84000	0.85	0.86	8,46								
Cloud point		0.50		46								
K232	1.19	1.19	1.19	14								
K270	0.35	0.35	0.35	14								
Viscosity (mPa.s)	60.32	62.87	65.42	14								
Crystallization temperature (°C)	−16.09	−16.18	−16.28	14,38								

TABLE 4 Triglyceride composition (%) of *Ricinodendron heudelotii* seed oil

Triacylglycerol (TG)	Partition number (PN)	Number of double bonds	Kapseu and Tchiegang[37]		Kapseu[47]
			Seed Type 1	Seed Type 2	
EEE	36	9	15.9	13.1	15.9
EEL	38	8	33.1	29.7	33.1
LEL	40	7	7.7	8.9	7.7
EEO	40	7	6.1	4.9	6.1
EEP	40	6	6.1	5.7	6.1
EES	42	6	5.9	5.8	5.9
OEL	42	6	7.3	7.3	7.3
LLL	42	6			7.3
PEL	42	5	5.4	2.1	3.75
OEO	44	5	0.3	1.9	1.1
OLL	44	5	10.1	8.4	10.1
PLL	44	4			—
OEP	44	4			—
PEP	44	3			—
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: E, α-elaeostearic acid; L, linoleic acid; Ln, linolenic acid; O, oleic acid; P, palmitic acid; S, stearic acid.

was estimated from the saponification value by the method of Hendrikse and Harwood.[58] The methods used by Kouamé et al.[34] varied depending on the index to be calculated. Indeed, saponification and acid values were determined by the BureauInterprofessionneld'EtudesAnalytiques[59] method. Peroxide value was determined using the method proposed by Cocks and Van Rede.[60] Iodine number was determined by the WOLFF method.[61]

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

4.2 | 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[37] worked on two morphotypes of *R. heudelotii* seed oil from two different regions of Cameroon. Kapseu[47] documented the production, processing, utilization 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[37] and Kapseu.[47]

TABLE 5 Fatty acid content (%) of *Ricinodendron heudelotii, Vitex doniana,* and *Cleome gynandra* seed oil

	R. heudelotii				*C. gynandra*				*V. doniana*			
	Min	**Mean**	**Max**	**References**	**Min**	**Mean**	**Max**	**References**	**Min**	**Mean**	**Max**	**References**
Palmitic 16:0	5.5	5.75	6	13,37	10.7	11.2	11.7	10		34.24		36
Palmitoleic 16:1					0.3	0.35	0.4	10				
Stearic 18:0	6.4	6.5	6.6	13,37	6.1	6.85	7.6	10		7.22		36
Oleic 18:1	7.2	7.3	7.4	13,37,45	19.6	21.75	23.9	10		58.54		36
Linoleic 18:2	28.3	39.7	51.1	13,37,45,47	56.3	58.7	61.1	10				
Linolenic 18:3												
Arachidic 20:0					0.1	0.15	0.2	10				
Eicosenoic 20:1		0.1		13,37		0.1		10				
Lignoceric 24:0		1.2		13,37								
α-eleostearic acid 24:3	49.3	50.2	51.1	13,37,45								

Kapseu and Tchiegang[37] and Assanvo et al.[45] 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).

C. 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%).[10] 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 color and vigor. 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[10] (Table 5).

Amah and Okogeri[36] 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).

C. 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.[62]

4.3 | 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.[46] and Odinga et al.[63] (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.[46] Odinga et al.[63] also found flavonoids, alkaloid cardiac glycosides, anthraquinone, and carotenoid contents (Table 6).

According to Odinga et al.,[63] *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,[36] 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).

5 | TRADITIONAL KNOWLEDGE OF *R. HEUDELOTII*, *V. DONIANA*, AND *C. GYNANDRA* SEED OIL

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

Many studies have been conducted on the characterization 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

TABLE 6 Qualitative phytochemical properties of crude oil extract of *Ricinodendron heudelotii* seeds

	Results	
Component	**Olasehinde et al.[46]**	**Odinga et al.[63]**
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	

TABLE 7 Quantitative phytochemical composition (mg/100 g wet weight) of *Ricinodendron heudelotii* and *Vitex doniana* seeds

		Concentration	
Component	**Subclass**	***R. heudelotii* Odinga et al.,[63]**	***V. doniana* Amah and Okogeri[36]**
Phenol		22.357	170
Tannin		399.463	
Oxalate		11.581	
Phytate		2.946	
Alkaloid	Lumamarine	79.079	11.40
	Ribalidine	56.08	
	Spartein	0.002	
Saponin	Sapogenin	142.632	
Flavonoid	Catechin	115.693	3.75
	Epicatechin	19.145	
	Rutin	59.573	
	Kaempferol	31.418	
	Naringenin	187.939	
	Anthocyanin	24.412	

oil in nutritional and industrial applications.[8] It also appears that *R. heudelotii* is a drying oil due to its high polyunsaturated acid (α-eleostearic acid) content and iodine value.[8,9,45] These qualities of *R. heudelotii* seed oil suggest its possible use in the paint industry.[8] Assanvo et al.[45] investigated the preparation and characterization 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.

R. heudelotii seed oil is affected by microwave heating as reported by Ketaona et al.[14] 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 crystallization 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 Reference 9 revealed that *R. heudelotii* seed oil could be used in the treatment of cardiovascular disease.

In Nigeria, Ajiwe et al.[7] and Chinweuba[39] 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 *C. 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.

6 | NUTRACEUTICAL POTENTIAL OF *R. HEUDELOTII*, *V. DONIANA*, AND *C. 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.[46]

Numerous publications on the Mediterranean diet have shown the beneficial role of vegetable oils, especially olives and rapeseed in the prevention of cardiovascular disease.[64] 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.[9] The study was conducted on male albino (Sprague–Dawley) rats (Harlan). 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, MDA, and some antioxidants parameters in the rats were tested. The experimental protocol consisted of taking rats aged 1 month and weighing between 140 and 151 g and feeding them for a week with food (M20 diet; Special Diets Services) ad libitum. At the end of this period, the rats were weighed and divided into groups of six. 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 (Total cholesterol (TC) serum, high density lipoprotein (HDL)-cholesterol, low density lipoprotei (LDL)-cholesterol, triglycerides, alanine aminotransferase (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 alanine transferase (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 nondying oils.[65] Drying oils consist of glycerol triesters of fatty acids. These esters are characterized 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.[7] and Chinweuba[39] 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[66] 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.,[67] 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 crystallization profiles.[14]

7 | FUTURE PROSPECTS ON THE THREE WILD OILS

Many studies have been carried out in Cameroon and Côte d'Ivoire on the composition and characterization 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 characterization 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.

V. doniana and *C. gynandra* have been characterized 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.

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Nadjidath Founmilayo Adome: Conceptualization (lead); investigation (lead); methodology (lead); writing – original draft (lead); writing – review and editing (lead). **Flora Josiane CHADARE:** Conceptualization (supporting); methodology (supporting); supervision (lead); validation (equal); writing – original draft (supporting); writing – review and editing

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

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