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Nutritional, physicochemical, and phenolic profiles of seeds and seed fats from three native oleaginous Combretum Loefl. species in West Africa

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SUMMARY: *Combretum adenogonium*, *Combretum glutinosum,* and *Combretum paniculatum,* are indigenous oleaginous species of West Africa. This study was designed to assess the nutritional, physicochemical, and phenolic profiles of seeds and seed fats from three native oleaginous *Combretum* Loefl. species in West Africa. The AOAC and AOCS methods were used to determine the nutritional composition and physicochemical characteristics of the seeds and seed fats. The seeds of *C. paniculatum* had the highest fat (42.20 %), protein (26.50 %), and ash (4.17 %) contents. The dominant fatty acids identified in the seed fats of the three species were oleic acid (38.31-8.16 %), palmitic acid (27.52-22.48 %), myristic acid (23.82-11.04 %), and linoleic acid (19.15-8.46 %). *C. paniculatum* seed fat had the highest saponification value (218.19 mg KOH/g), oxidative stability index (3.78h), and phenolic content (15.78 mg EAG/100g). The seed fat of *C. paniculatum* showed the highest potential for use in cosmetics and as a frying oil in the food industry.

KEYWORDS: *Combretum adenogonium; Combretum glutinosum; Combretum paniculatum; Seed fat; Nutritional composition; Physicochemical properties.*

RESUMEN: ***Perfiles nutricionales, fisicoquímicos y fenólicos de semillas y grasa de semillas de tres especies oleaginosas de* Combretum Loefl. *nativas de África occidental.*** *Combretum adenogonium, Combretum glutinosum* y *Combretum paniculatum* son especies oleaginosas autóctonas de África occidental. El estudio fue diseñado para evaluar los perfiles nutricionales, fisicoquímicos y fenólicos de semillas y grasa de semillas de tres especies oleaginosas de *Combretum Loefl.* nativas de África occidental. Se utilizaron los métodos AOAC y AOCS para determinar la composición nutricional y las características fisicoquímicas de las semillas y grasa de semillas. Las semillas de *C. paniculatum* tuvieron los contenidos más altos de grasa (42,20 %), proteína (26,50 %) y ceniza (4,17 %). Los ácidos grasos dominantes identificados en la grasa de las semillas de las tres especies fueron el ácido oleico (38,31-8,16 %), el ácido palmítico (27,52-22,48 %), el ácido mirístico (23,82-11,04 %) y el ácido linoleico (19,15-8,46 %). La grasa de las semillas de *C. paniculatum* presentó el mayor índice de saponificación (218,19 mg KOH/g), estabilidad oxidativa (3,78 h) y contenido fenólico (15,78 mg EAG/100 g). La grasa de las semillas de *C. paniculatum* mostró el mayor potencial de uso en cosméticos y como aceite para freír en la industria alimentaria.

PALABRAS CLAVE: *Combretum adenogonium; Combretum glutinosum; Combretum paniculatum; Composición nutricional; Grasa de las semillas; Propiedades fisicoquímicas.*

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1. INTRODUCTION

Combretum includes about 370 species distributed in Sub-Saharan Africa, Central and South America, Southern Asia, and Northern Australia (Lima *et al.,* 2012). The most extensive species distribution is in sub-Saharan Africa, where 163 species have been registered (Jordaan *et al.,* 2011). *Combretum adenogonium* Steud. ex A.Rich*, Combretum glutinosum* Perr. ex DC*,* and *Combretum paniculatum* Vent. are indigenous species of West Africa (Thiombiano and Dorothea, 2010). The three species are shrubs or trees with heights of 2 to 8, 2 to 9, and 1 to 4 m for *C. adenogonium, C. glutinosum,* and *C. paniculatum*, respectively. The seeds are yellowish or orange and measure 10 to 14, 10 to 14, and 8 to 12 mm long by 4 to 6, 3 to 5, and 3 mm wide for *C. adenogonium, C. glutinosum,* and *C. paniculatum*, respectively (Thiombiano *et al.,* 2012).

Extracts from the roots, stems, and leaves of *C. adenogonium, C. glutinosum*, and *C. paniculatum* are used in folk medicine against bacterial infections, such as gonorrhea and syphilis, to treat hypertension, influenza, tumors, diarrhea, colds, bronchitis, malaria, anemia, amoebic dysentery and urinary disorders, edema, cough, severe jaundice, oedemas, and they possess analgesic, aphrodisiac and anthelmintic properties (Fyhrquist *et al.,* 2002). The people of Mbah in Tanzania commonly used decoctions of the roots and leaves of *C. adenogonium* for the treatment of venereal diseases, skin diseases, syphilis, influenza, malnutrition, tumors, diarrhea, muscle pain, and edema (Fyhrquist *et al.,* 2002). Assouma *et al.* (2018) have shown that the roots, leaves, and bark of the *C. glutinosum* trunk are used in traditional medicine in Togo to treat uterine fibroids, sexually transmitted infections, female sterility, and painful menstruation (Assouma *et al.,* 2018). Fyhrquist *et al.* (2002) have reported the antibacterial effects of methanolic root extracts of *C. adenogonium* against *Escherichia coli, Staphylococcus aureus, Micrococcus luteus, Bacillus subtilis, Staphylococcus epidermidis, Enterobacter aerogenes, Candida albicans*, and *Sarcina sp (*Fyhrquist *et al.,* 2002).

Previous studies have shown that species of the combretum genus are oleaginous. The oil content of 32.7, 24, 23, 7, and 4.8 % have been reported for *C. aculeatum*, *C. elaeagnoides, C. glutinosum*, *C. grandiflorum*, and *C. ovalifolium,* respectively (Bazongo *et al.,* 2014; Daulatabad and Ankalgi, 1983; Gunstone *et al.,* 1972). Myristic, palmitic, oleic, and linoleic acids have been reported as the dominant fatty acids in *C. aculeatum* and *C. ovalifolium* seed oils (Bazongo *et al.,* 2014; Daulatabad and Ankalgi, 1983; Gunstone *et al.,* 1972). The suitability of the seed oils of *C. aculeatum* and *C. ovalifolium* for making soap has been reported by Bazongo *et al.* (2014), and Daulatabad and Ankalgi (1983). Bazongo *et al.* (2014) reported the high tocopherol content (800 ppm) and oxidative stability of *C. aculeatum* seed oil. The oleaginous potential of C. *glutinosum, C. adenogonium,* and *C. paniculatum* has not yet been investigated. The aim of the present work was to determine the nutritional composition, physicochemical properties, and phenolic content of the seeds and seed fats of the three species.

2. MATERIALS AND METHODS

2.1. Chemicals and reagents

HPLC- and GC-grade solvents (acetone, n-hexane, methanol for free amino acids analysis, triethylamine), fatty acid methyl esters (FAME) and triglyceride standards, gallic acid, and Kjeldahl catalyst were purchased from Sigma Aldrich, (St. Louis, MO, USA) and Supelco (Bellefonte, PA, USA). Chlorohydric, nitric, and sulfuric acids were provided by Hiperpur, Panreac AppliChem, Darmstadt, Germany. Phenylisothiocyanate, Pico Tag diluent, and sodium hydroxide were obtained from Thermo Scientific (USA), Waters (USA), and Carlo Erbo (France), respectively.

2.2. Seed collection

Approximately 6 kg of fully mature fruits of *C. adenogonium*, *C. glutinosum* and C. *paniculatum* (Figure 1) were hand-collected in Banon (11°11’23.2”N; 01°05’30.9”W), Bion (11°36’17.0”N; 01°13’15.7”W)*,* Komkombouri (11°19’09.5”N; 01°03’38.6”E)*,* Koualou (11°02’11.5”N; 00°55’53.7”E)*,*

Po (11°11'50.0''N; 01°08'25.4''W), Tambarga (11°26'18.7''N; 01°2'20.5''E), Tambolo (11°05'09.2''N; 01°07'53.0''W) and Zabré (11°08'24.9''N; 00°40'1.9''W) from December to February in Burkina Faso. For each species, a voucher was deposited under numbers 3075, 7094, and 3145 *for C. adenogonium, C. glutinosum,* and *C. paniculatum*, respectively, at the herbarium of Joseph KI-ZERBO University. Samples were dried under laboratory conditions. Samples of each species from several stands were pooled to form composite samples. The dried seeds were ground in a hammer mill, and the flour, obtained through a 250 µm mesh sieve, was stored at -23 °C.

FIGURE 1. Seeds of *Combretum adenogonium, Combretum glutinosum* and *Combretum paniculatum.*

2.3. Determination of proximate seed composition

The AOAC official methods were used to assess seed moisture (method 934.01), fat (method 963.15), protein (method 960.52), and ash (method 923.03) (AOAC, 2019). Total carbohydrates were determined by employing the differential method of Al-Hooti *et al.* (1998).

2.4. Seed mineral composition analysis

To assess the mineral profile (Ca, Na, K, Mg, Zn, and Fe), 5 g of seed cake were incinerated at 550 °C for 12 h. The ash was dissolved in 50 mL of an HNO_3 solution (0.5 M) and then filtered using Whatman filter paper before analysis with an atomic absorption spectrometer (Varian 240FS, USA) (Pinheiro *et al.,* 2010).

2.5. Determination of seed amino acid compositions

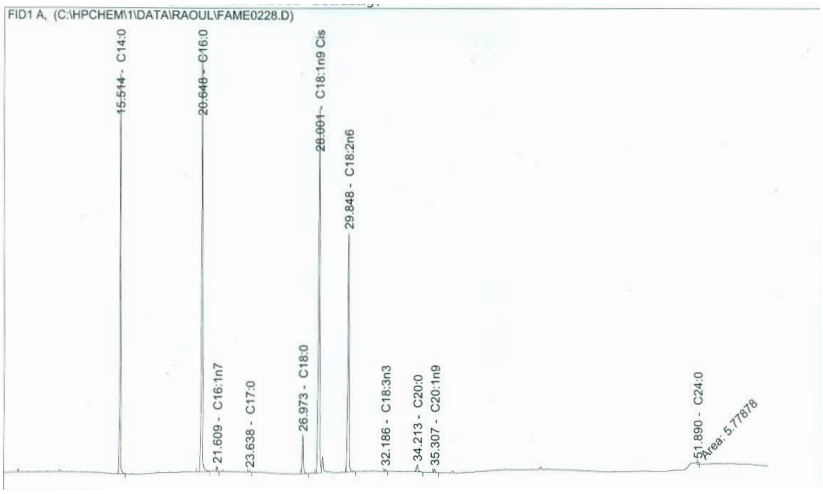
The seed flour amino acid and fat fatty acid compositions were assessed using the AOAC method 994.12 (AOAC, 2019) and AOCS methods Ce 2-66 and Ce 1h-05 (AOCS, 2017), respectively.

2.6. FAME analysis

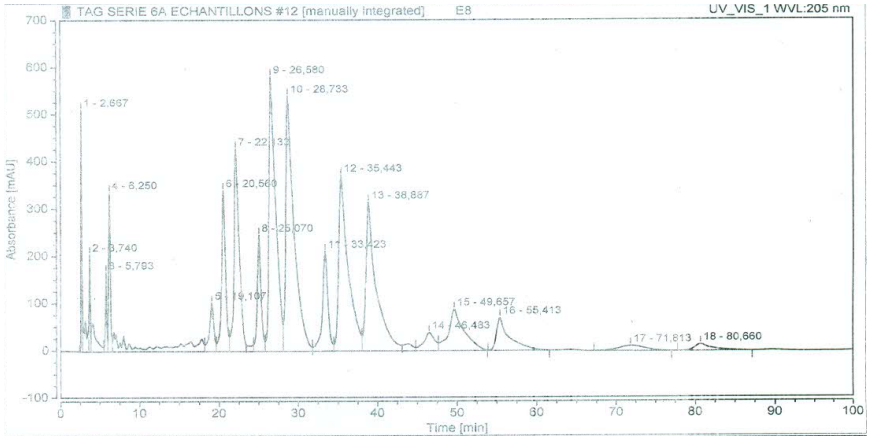
The preparation of fatty acid methyl esters was carried out using the method recommended by Thermo Scientific (Khan, 2013). The FAME analysis was performed using an Agilent 6890N GC-FID (Agilent, Palo Alto, CA. US). FAME was separated with a DB23 capillary column (60 m ID: 0.25 mm; Film: 0.25 pm; J&W Scientific Co. CA. USA). Nitrogen was used as the carrier gas. The sample injection volume was set at 1 µL in splitless mode. The analytical conditions were the same as those described by Bougma *et al.* (2021), (Figure 2a).

2.7. Triacylglycerol (TAG) composition of seed fats

An ultimate 3000 HPLC system was used to determine the triacylglycerol (TAG) compositions (Podlaha and Toregard, 1989). The sample was prepared in acetone at 5 % (w/v). A Hypersyl ODS-2 C18 column 250x4 mm, 5 µm (Thermo Scientific, USA) and a DAD detector (DAD-3000(RS) were used. The TAGs were identified using their equivalent carbon number (ECN) and the retention times of the standards (Figure 2b).



a) Example of a fatty acid chromatogram



b) Example of triglyceride composition chromatogram

FIGURE 2. Fatty acid and triglyceride chromatograms of seeds fat.

2.8. Physicochemical characteristics of seed fats

The melting point, oxidative stability index, acid, peroxide, saponification, and iodine values were assessed following AOCS Cc 3-25, AOCS Cd 12b-92, Ca 3a-63, Cd 8-53, Cd 3-25, and Cd 1c-85 methods (AOCS, 2017), respectively.

2.9. Determination of total phenol content in seed fats

The phenolic compounds were extracted with methanol/water (80/20). Three (03) mL of methanol (80 %) were added to 1 g of each fat, then vortexed for two minutes and centrifuged for 5 minutes at 3000 rpm. The total phenolic content was assessed by using the method described by Singleton *et al.* (1999). The absorbance was read at 760 nm with a spectrophotometer (Epoch, Biotek, USA). A calibration curve was plotted using gallic acid as the standard, and the results were expressed in milligrams equivalent to Gallic acid per 100 g of fat. The linearity range of the calibration curve was 0,05–0,25 mg of equivalent to Gallic acid /L (r = 0.9991).

2.10. Statistical analysis

All the experiments were done in triplicate. The results were reported as mean value ± standard deviation. The differences among seeds and seed oils were assessed by one-way analysis of variance (ANOVA). Tukey's

multiple comparison test was used to compare seeds and seed oils at the significance level of $p < 0.05$ using XLSTAT software for Windows (XLSTAT 2016.02.27444).

3. RESULTS

3.1. Proximate composition of *C. adenogonium*, *C. glutinosum*, and *C. paniculatum* seeds

The proximate compositions of *C. adenogonium*, *C. glutinosum,* and *C. paniculatum* seeds are reported in Table 1. The seeds of the three species had low moisture content ranging from 7.40 to 5.20 %. The compositions of the three species were significantly different. *C. adenogonium* had the highest carbohydrate content (54.73 %), while *C. paniculatum* exhibited the highest fat (42.20 %), protein (26.50 %), and ash (4.17 %) contents (Table 1).

TABLE 1. Proximate composition of Combretum adenogonium, Combretum glutinosum, and Combretum paniculatum seeds.

Proximal composition	*C. adenogonium*	*C. glutinosum*	*C. paniculatum*
Moisture (%)	7.40 ± 0.10^{a}	7.00 ± 0.20^{b}	5.20 ± 0.20^{c}
Crude fat content (%)	20.73 ± 0.30^{c}	24.33 ± 0.23^{b}	42.20 ± 0.00^{a}
Protein content (%)	20.83 ± 0.26^{c}	22.15 ± 0.25^{b}	26.50 ± 0.22^{a}
Carbohydrates content (%)	54.73 ± 0.61^{a}	49.98 ± 0.40^{b}	26.50 ± 0.22^{a}
Ash content (%)	3.70 ± 0.06^{b}	3.54 ± 0.04^{c}	4.17 ± 0.06^{a}

Values are the mean ± SD (n=3). Different letters in the same row indicate significant differences ($p < 0.05$) according to Tukey's test.

3.2. Mineral composition of *C. adenogonium, C. glutinosum*, and *C. paniculatum* seeds

Significant variations were observed in the mineral profiles of the seeds of the three species (Table 2). The highest content of Ca (673.54 mg/100 *g*) and Zn (4.17 mg/100 *g*) were found in *C. adenogonium* seeds. *C. glutinosum* seeds had the highest content of Mg (504.18 mg/100 *g*) and Na (7.16 mg/100 *g*). *C. paniculatum* seeds were the richest in K (1214.94 mg/100 *g*) and Fe (5.31 mg/100 *g*).

TABLE 2. Mineral composition (mg/100g dry matter) of *Combretum adenogonium, Combretum glutinosum,* and *Combretum paniculatum* seeds.

Mineral elements	*C. adenogonium*	*C. glutinosum*	*C. paniculatum*
Calcium	673.54 ± 0.0^{a}	470.45 ± 0.04^{b}	258.83 ± 0.00^{c}
Magnesium	485.09 ± 0.00^{b}	504.18 ± 0.00^{a}	223.14 ± 0.00^{c}
Potassium	$1\,064.49 \pm 0.00^{c}$	$1\,087.07 \pm 0.00^{b}$	$1\,214.94 \pm 0.00^{a}$
Sodium	6.18 ± 0.00^{b}	7.16 ± 0.00^{a}	3.90 ± 0.01^{c}
Iron	3.41 ± 0.00^{b}	3.42 ± 0.00^{b}	5.31 ± 0.08^{a}
Zinc	4.17 ± 0.01^{a}	3.41 ± 0.00^{c}	3.66 ± 0.03^{b}

Values are the mean ± SD (n=3). Different letters in the same row indicate significant differences ($p < 0.05$) according to Tukey's test.

3.3. Amino acid compositions of *C. adenogonium, C. glutinosum*, and *C. paniculatum* seeds

The amino acid compositions of the seeds of *C. adenogonium, C. glutinosum,* and *C. paniculatum* are shown in Table 3. The contents of some individual essential and nonessential amino acids were significantly different. Both *C. adenogonium* and *C. glutinosum* had the highest phenylalanine + tyrosine, methionine + cysteine, and alanine contents. Glutamic acid and glutamine were found in the highest contents in the *C. adenogonium* and *C. paniculatum* seeds. The highest amounts of threonine, valine, isoleucine, lysine, and serine were found in *C. paniculatum* seeds, whereas *C. glutinosum* was characterized by the highest proline content.

TABLE 3. Amino acid profiles (g/100 g of protein) of *Combretum adenogonium, Combretum glutinosum* and *Combretum paniculatum seeds.*

Amino Acids	*C. adenogonium*	*C. glutinosum*	*C. paniculatum*	Requirements (FAO/WHO/UNU)
Phénylalanine + Tyrosine	8.02 ± 0.32[b]	8.02 ± 0.09[b]	6.69 ± 0.15[a]	3.8
Leucine	7.49 ± 0.20[a]	7.07 ± 0.14[a]	7.33 ± 0.84[a]	5.9
Threonine	6.42 ± 0.17[b]	6.61 ± 0.31[b]	7.82 ± 0.37[a]	2.3
Valine	5.35 ± 0.14[b]	5.18 ± 0.23[b]	6.69 ± 0.15[a]	3.9
Isoleucine	4.28 ± 0.11[a]	3.78 ± 0.88[a]	4.55 ± 0.88[a]	3
Lysine	3.21 ± 0.09[b]	3.29 ± 0.32[b]	3.91 ± 0.19[a]	4.5
Histidine	2.67 ± 0.46[a]	2.83 ± 0.00[a]	2.77 ± 0.03[a]	1.5
Methionine + Cysteine	2.14 ± 0.06[a]	2.35 ± 0.36[a]	1.14 ± 0.22[b]	2.2
Total essential amino acids	39.57 ± 2.23[a]	39.13 ± 0.57[a]	40.90 ± 2.78[a]	27.1
Glutamic acid and glutamine	21.93 ± 0.05[a]	20.76 ± 0.04[b]	21.76 ± 3.73[a]	
Aspartic acid and asparagine	8.56 ± 0.23[a]	8.96 ± 0.05[a]	8.67 ± 1.73[a]	
Serine	6.42 ± 0.17[b]	6.13 ± 0.18[b]	7.83 ± 0.37[a]	
Glycine	6.95 ± 0.35[a]	7.07 ± 0.14[a]	7.33 ± 0.84[a]	
Arginine	6.42 ± 0.17[a]	6.61 ± 0.31[a]	6.19 ± 0.62[a]	
Proline	5.35 ± 0.14[b]	6.61 ± 0.31[a]	5.05 ± 0.41[b]	
Alanine	4.81 ± 0.41[a]	4.72 ± 0.22[a]	2.28 ± 0.44[b]	
Total nonessential amino acids	60.42 ± 2.89[a]	60.86 ± 2.46[a]	59.10 ± 2.81[a]	3.8

Values are the mean ± SD (n=3). Different letters in the same row indicate significant differences ($p < 0.05$) according to Tukey's test. Amino acid requirements for adults over 18 years old (FAO/WHO/UNU, 2007).

3.4. Fatty acid composition of *C. adenogonium*, *C. glutinosum*, and *C. paniculatum* seed fats.

The FA compositions of *C. adenogonium, C. glutinosum,* and *C. paniculatum* seed fats are presented in Table 4. The three species of seed fat were characterized by high contents of saturated (52.97- 42.70 %) and monounsaturated (39.55 - 30.16 %) fatty acids and low ranges of polyunsaturated fatty acids (19.41-8.71 %). The fatty acid compositions of *C. adenogonium, C. glutinosum,* and *C. paniculatum* differed significantly. C. *adenogonium* and *C. glutinosum* had oleic (38.31 - 29.51 %), palmitic (27.52 - 22.48 %), linoleic (19.15 - 17.45 %), and myristic (18.95 - 11.04 %) acids as major fatty acids, representing 88.9 and 95.13 % of the total oil, respectively. The seed fat of *C. paniculatum* had palmitic (24.32 %), myristic (23.82 %), palmitoleic acid (23.33 %), oleic (8.16 %), linoleic (8.46 %) and vaccenic (5.76 %) acids as predominant ones, amounting to 88.09 % of the total oil. Lauric, vaccenic, and myristoleic acids were only found in the seed fat of *C. paniculatum*.

TABLE 4. Fatty acid composition (%) of *Combretum adenogonium , Combretum glutinosum, and Combretum paniculatum seed fats*.

Proximal composition	*C. adenogonium*	*C. glutinosum*	*C. paniculatum*
C12:0	-	-	0.31 ± 0.01a
C14:0	11.04 ± 0.04[c]	18.95 ± 0.05[b]	23.82 ± 0.08[a]
C14:1n5	-	-	0.57 ± 0.01[a]
C16:0	22.48 ± 0.19[c]	27.52 ± 0.07[a]	24.32 ± 0.10[b]
C16:1n7	0.36 ± 0.00[b]	0.32 ± 0.01[c]	23.33 ± 0.12[a]
C17:0	0.44 ± 0.01[a]	0.09 ± 0.00[c]	0.18 ± 0.00[b]
C18:0	6.00 ± 0.09[a]	2.89 ± 0.01[b]	2.42 ± 0.00c
C18:1 n9 trans	0.43 ± 0.02[a]	0.08 ± 0.00c	0.17 ± 0.00b
C18:1 n9 cis	38.31 ± 0.13[a]	29.51 ± 0.02[a]	8.16 ± 0.02[c]
C18:1 n7 cis	-	-	5.76 ± 0.00[a]
C18:2 n6	17.45 ± 0.07[b]	19.15 ± 0.03[a]	8.46 ± 0.03[c]
C19:0	0.39 ± 0.00[a]	-	0.16 ± 0.01[b]
C18:3 n3	0.3 ± 0.01[a]	0.26 ± 0.07[ab]	0.25 ± 0.02b
C20:0	1.51 ± 0.01[a]	0.68 ± 0.02[b]	0.19 ± 0.00[c]
C20:1 n9 cis	0.46 ± 0.01[a]	0.29 ± 0.00[c]	0.35 ± 0.00[b]
C24:0	0.86 ± 0.03[b]	0.3 ± 0.00[c]	1.58 ± 0.33[a]
SFA	42.70 ± 0.03[c]	50.43 ± 0.11[b]	52.97 ± 0.12[a]
MUFA	39.55 ± 0.12[a]	30.16 ± 0.07[c]	38.32 ± 0.14[b]
PUFA	17.75 ± 0.08[b]	19.41 ± 0.04[a]	8.71 ± 0.01[c]
UFA	57.3 ± 0.04[a]	49.57 ± 0.12[b]	47.03 ± 0.15[c]
TOTAL	100.00	100.00	100.00

Values are the mean ± SD (n=3). Different letters in the same row indicate significant differences ($p < 0.05$) according to Tukey's test. SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids; UFA: Unsaturated Fatty Acids

3.5. Triacylglycerol composition of *C. adenogonium*, *C. glutinosum*, and C. *paniculatum* seed fats.

The composition of the triacylglycerols of the seed fats of *C. adenogonium, C. glutinosum,* and *C. paniculatum* are presented in Table 5. The seed fats contained a complex mixture of trisaturated, monosaturated, disaturated, and triunsaturated triacylglycerols. Monosaturated triacylglycerols (46.84 - 40.62) were predominant in the seed fats of *C. glutinosum* and *C. paniculatum*, whereas the seed fat of *C. adenogonium* had both triunsaturated (33.33 %) and monosaturated (30.38 %) triacylglycerols as the major ones.

A total of 16 triacylglycerols were identified in the seed fat of *C. adenogonium* with LOP (17.17 %), OOL (16.06 %), OOO (14.42 %), OOP (13.21 %), and LMP (9.26 %) as the predominant ones, accounting for 70.12 % of the total triacylglycerols. The seed fat of *C. glutinosum* contained 16 triacylglycerols, among which LOP (20.48 %), OOL (16.15 %), OOP (13.83 %), PPP (13.18 %), and MMM (9.22 %) were predominant, representing 72.86 % of the total triacylglycerols. 22 triacylglycerols were found in the seed fat of *C. paniculatum* with MOP (14.97 %), PoPoS (13.21 %), OLM (11.05 %), MMP (10.62 %), and PPP (9.11 %) as the dominant triacylglycerols, representing 58.96 % of the triacylglycerols in the fat.

TABLE 5. Triglyceride (TAG) profile of *Combretum adenogonium, Combretum glutinosum,* and *Combretum paniculatum seed fats.*

TAG	ECN	*C. adenogonium*	*C. glutinosum*	*C. paniculatum*
LLaMo	41	-	-	1.76 ± 0.04[a]
LMM	42	5.58 ± 0.03[b]	6.72 ± 0.04[a]	-
LLL	42	1.80 ± 0.00[a]	1.56 ± 0.14[b]	1.21 ± 0.03[c]
MMM	42	-	9.22 ± 0.01[a]	4.71 ± 0.24[b]
PoPoPo	42	-	-	2.21 ± 0.14[a]
LMP	44	9.26 ± 0.18[a]		-
OMM	44	3.91 ± 0.15[a]	-	-
MMP	44	-	-	10.62 ± 0.66[a]
OLM	44	-	3.71 ± 0.07[b]	11.05 ± 0.78[a]
OPoPo	44	-	-	3.67 ± 0.26[a]
PoPoP	45	-	-	6.04 ± 0.41[a]
LPP	46	4.75 ± 0.21[a]	-	-
OOPo	46	1.05 ± 0.00[a]	0.93± 0.01[a]	-
POL	46	17.17 ± 0.07[b]	20.48 ± 0.04[a]	-
OPM	46	-	-	14.97 ± 2.08[a]
OOL	46	16.06 ± 0.08[b]	16.15 ± 0.07[a]	-
OOM	46	-	-	4.27 ± 0.32[a]
OPPo	46	-	-	2.28 ± 0.17[a]
PoPoS	46	-	-	13.21 ± 1.00[a]
PPPo	46	-	-	2.00 ± 0.28[a]
PPMa	47	1.22 ± 0,12[a]		
ALL	48	-	-	1.93 ± 0.18a
OOO	48	14.42 ± 0.09[a]	4.54 ± 0.05[b]	1.41 ± 0.80[c]
OOP	48	13.21 ± 0.03[b]	13.83 ± 0.07[a]	-
OPP	48	-		-
PPP	48	5.58 ± 0.03[c]	13.18 ± 0.03[a]	9.11±0,15 [b]
OPL		1.80 ± 0.00[b]		5.27 ± 0.49[a]
LiLnLa	49	-	-	1.83 ± 0.04[a]
MPS		-	0.67 ± 0.03 [a]	
SPP	50	9.26 ± 0.18[a]	1.59 ± 0.04[b]	-
PSS	50	3.91 ± 0.15[a]	-	-
MMS	50	-	3.67 ± 0.00[a]	-
APoPo	51	-	-	1.03 ± 0.31[a]
EiSS	52	1.19 ± 0.04[a]	-	-
ALL	52	-	2.60 ± 0.05[a]	-
LLiM	52	-	-	1.41 ± 0.06[a]
LiMaMa	54	1.02 ± 0.01[a]		-

TAG	ECN	*C. adenogonium*	*C. glutinosum*	*C. paniculatum*
SSS			0.66 ± 0.02[a]	
LnEiLi	56	-	0.48 ± 0.03[a]	-
∑SUU		**30.38[c]**	**40.62[b]**	**46.84[a]**
∑SSU		**25.08[a]**	**6.72[c]**	**20.21[b]**
∑SSS		**11.18[c]**	**28.99[a]**	**24.44[b]**
∑UUU		**33.33[a]**	**23.66[b]**	**8.50[c]**
∑ TAG	**52**	**99.97**	**99.99**	**99.99**

Values are the mean ± SD (n=3). Different letters in the same row indicate significant differences ($p < 0.05$) according to Tukey's test. ECN=Equivalent Carbon number [CN-(2×ND), S=saturated, U=unsaturated, ∑SUU: Monosaturated TAG, ∑SSU: Disaturated TAG, ∑SSS: Trisaturated TAG, ∑UUU: Triunsaturated TAG.
M: Myristic acid (C14:0); **Mo**: Myristoleic acid (C14:1n5); **P**: Palmitic acid (C16:0); **Po**: Palmitoleic acid (C16:1n7); **Ma**: Margaric acid (C17:0); **S**: Stéaric acid (C18:0); **O**: Oleic acid (C18:1); **L**: Linoleic acid (C18:2n6); **A**: Arachidic acid (C20:0); **Ei**: Eicosenoic acid (C20:1n9**cis**); **Li**: Lignoceric acid (C24:0).

3.6. Physicochemical characteristics and Total Phenolic Content (TPC) of *C. adenogonium, C. glutinosum*, and *C. paniculatum* seed fats.

The physicochemical characteristics of *C. adenogonium*, *C. glutinosum,* and *C. paniculatum* seed fats are presented in Table 6. The melting points were 32.47, 33.90, and 34.57 °C for *C. adenogonium*, *C. glutinosum,* and *C. paniculatum* seed fats, respectively. The saponification value of the three seed fats comprised 208.19 and 219.09 mg KOH/g (Table 6). The highest and the lowest values were obtained for *C. paniculatum and C. adenogonium*, respectively. Both *C. adenogonium* and *C. glutinosum* had similar iodine values of 68.12 and 68.56 gI_2/100 g of fat, respectively, which were higher than that of *C. paniculatum* (61.53 gI_2/100 g) (Table 6).

The seed fat of *C. paniculatum* exhibited the highest index of oxidative thermal stability of 3.78 h at 160 °C, followed by *C. adenogonium* (1.66 h) and *C. glutinosum* (1.13 h).

C. paniculatum and *C. adenogonium* seed fats had the highest and lowest total phenolic contents with values of 15.78 and 12.79 mg GAE/100 g, respectively.

TABLE 6. Physicochemical characteristics and Total Phenolic Content (TPC) of *Combretum adenogonium, Combretum glutinosum,* and *Combretum paniculatum* seed fats.

Parameters	*C. adenogonium*	*C. glutinosum*	*C. paniculatum*
Melting point (°C)	32.47 ± 0.12[c]	33.90 ± 0.10[b]	34.57 ± 0.06[a]
Saponification Value (mgKOH/g of fat)	208.19 ± 0.02[c]	213.43 ± 0.03[b]	219.09 ± 0.26[a]
Iodine Value (gI_2/ 100 g of fat)	68.12 ± 0.08[a]	68.56 ± 0.26[b]	61.53 ± 0.33[c]
Index of Oxidative Stability 160 °C (h)	1.66 ± 0.02[b]	1.13 ± 0.00[c]	3.78 ± 0.17[a]
Acid Value (mg KOH/ g of fat)	1.74 ± 0.16[a]	1.28 ± 0.06[c]	1.42 ± 0.10[b]
Peroxide Value (meq O_2/Kg of fat)	1.06 ± 0.01[a]	0.66 ± 0.01[c]	0.69 ± 0.02[b]
TPC (mg GAE/100 g of fat)	12.79 ± 0.50[b]	15.45 ± 0.37[a]	15.78 ± 0.94[a]

Values are the mean ± SD (n=3). Different letters in the same row indicate significant differences ($p < 0.05$) according to Tukey's test. TPC: Total Phenolic Content.

4. DISCUSSION

The carbohydrate content in *C. adenogonium* and *C. glutinosum* (54.73-49.98 %) was lower than the 64.20–57.35% reported for the other species of the same genus (Bougma *et al.,* 2021). The fat content in *C. paniculatum* seeds was similar to the value reported for the shea tree (45.2–59.1 %), *Pentadesma butyracea* (41.9 %), coconut (37.00–59.8 %), and palm kernels (32.6–49.4 %) (Appaiah *et al.,* 2014; Chibor *et al.*, 2017; Tanwar and Goyal, 2021; Tchobo *et al.,* 2013). The results of the fat content highlighted the oleaginous potential of the three plant seeds for industrial applications.

Both *C. glutinosum* and *C. paniculatum* had protein contents higher than those reported for *Combretum collinum, Combretum micranthum, Combretum nigricans,* and *Combretum niorense* but lower than the values reported for *Moringa oleifera* seeds (34.51–36.53 %) palm kernel (7.5–10.9 %), copra (10.20 %) and coconut kernel (6.20 %) (Erwa *et al.,* 2019; Liang *et al.,* 2019; Tanwar and Goyal, 2021). The ash content in the three seeds was in the range of those of *Adansonia digitate* and *Moringa oleifera* seeds (Erwa *et al.,* 2019; Liang *et al.,* 2019).

The Ca, Mg, Fe, and Zn contents of the three seed species were in the range of that reported for *Adansonia digitate* and *Moringa oleifera,* which have been described as potential sources of these minerals (Erwa *et al.,* 2019; Liang *et al.,* 2019). Therefore, the *C. adenogonium, C. glutinosum,* and *C. paniculatum* seeds can be considered good sources of Ca, Mg, Fe, and Zn.

Phenylalanine + tyrosine, leucine, threonine, valine, isoleucine, and histidine contents in 100 g of the seeds of the three species met the levels of requirements recommended by FAO/WHO/UNU for adults over 18 years old (FAO/WHO/UNU, 2007). In contrast, that of the lysine did not meet it. Methionine + cysteine was also limited for C. *adenogonium* and *C. paniculatum* seeds.

The seed fat composition of *C. adenogonium* and *C. glutinosum* were close to those of *C. collinum, C. micranthum, C. nigricans,* and *C. niorense* as previously described by Bougma *et al.* (2021) but different from that of *C. paniculatum*. The fatty acid and triglyceride compositions differed from those already reported for the tropical vegetable fats, which usually contain POP, POS, and SOS as dominant triglycerides (Norazlina *et al.,* 2021).

The melting points of the three species of seed fat were in the range of those of shea (32.2 to 35.8 °C) (Honfo *et al.,* 2014). The highest melting point of *C. paniculatum* (34.57 °C) could be a consequence of its highest contents of saturated fatty acids (52.97%) and trisaturated triglycerides (24.44 %) (Devi and Khatkar, 2016). The length of the hydrocarbon chains of the fatty acids on the glycerol backbone influences the saponification value. The higher the saponification value, the shorter the chains on the glycerol backbone (O'Brien, 2009). Both *C. adenogonium* and *C. glutinosum* saponification values were lower and higher than that of *C. paniculatum* and shea butter, respectively, but similar to that of palm oil (200.06-209 mgKOH/g). The highest saponification value of *C. paniculatum* could be related to its high myristic acid content, which has been reported to possess a high saponification value (Dijkstra, 2016). The saponification value of *C. paniculatum* seed oil makes it suitable for soap making.

Oxidation stability is influenced by both fatty acid composition and the presence of some secondary metabolites, such as phytosterols and phenolic compounds. The higher the saturated fatty acid content, the higher the fat stability (Abril *et al.,* 2019). The higher content of saturated fatty acids in *C. paniculatum* than those of *C. glutinosum* and *C. adenogonium* could be explained partly by their higher stability. It could also be related to its higher phenolic compound content (Abril *et al.,* 2019). The high oxidation stability of the three seed oils indicated that they can be used as frying oils.

5. CONCLUSIONS

This study characterized the composition of seeds and seed fats of *C. adenogonium, C. glutinosum, and C. paniculatum*. The three seeds were good sources of proteins, lipids, ashes, and amino acids. The seed fats mainly contained oleic, palmitoleic, myristic, and linoleic acids. Moreover, they had high saponification value, oxidative stability, and polyphenol content. *C. paniculatum* seed fat had the highest saponification

value, oxidative stability index, and phenolic content, which makes it the most suitable for applications in cosmetics and as a frying oil in food industries.

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RESEARCH DATA POLICY

DATA AVAILABILITY

Seed samples and seed oils are available at the Plant Biology and Ecology Laboratory at Joseph KI-ZERBO University of Ouagadougou.

The datasets generated and/or analyzed during the current study are available from the corresponding author upon request.

DECLARATION OF COMPETING INTEREST

The authors of this article declare that they have no financial, professional, or personal conflicts of interest that could have inappropriately influenced this work.

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A BOUGMA: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

RSB BAZIE: Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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IHN BASSOLE: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

REFERENCES

Abril D, Mirabal-Gallardo Y, González A, Marican A, Durán-Lara EF, Santos LS, Valdés O. 2019. Comparison of the oxidative stability and antioxidant activity of extra-virgin olive oil and oils extracted from seeds of Colliguaya integerrima and Cynara cardunculus under normal conditions and after thermal treatment. *Antioxidants* **8** (10), 470. https://doi.org/10.3390/antiox8100470

Al-Hooti S, Sidhu JS, Qabazard H. 1998. Chemical composition of seeds date fruit cultivars of United Arab Emirates. *Food Sci. Technol.* **35**, 44–46.

AOAC. 2019. Official Methods and Recommended Practice of Analysis of Association of Analytical Chemists, 21st ed, *AOAC International*, Rockville, MD.

AOCS. 2017. Official methods and recommended practices of the American Oil Chemist' Society, 7th ed., *AOCS Press,* Urbana, IL.

Appaiah P, Sunil L, Prasanth Kumar PK, Gopala Krishna AG. 2014. Composition of coconut testa, coconut kernel, and its oil. *J. Am. Oil Chem. Soc.* **91**, 917–924. https://doi.org/10.1007/s11746-014-2447-9

Assouma A F, Koffi K, William D, Emmanuel B, Atèhèzi T, Kosi NM, Kudzo GA, Jacques D, Amégnona A, Sodokè TK, Messanvi G. 2018. Enquête Ethnobotanique Sur La Prise En Charge Traditionnelle De L'infertilité Féminine Dans La Région Sanitaire Des Savanes Au Togo. *Eur. Sci. J.* **14** (3), 358.

Bazongo P, Bassolé IHN, Nielsen S, Hilou A, Dicko MH, Shukla VKS. 2014. Studies in the Evaluation of Unconventional Oils from Burkina Faso Rich in Linoleic Acid, Oleic Acid or Other Unusual Fatty Acids. *J. Food Process. Technol.* **5**, 1–5. https://doi.org/10.4172/2157-7110.1000303

Bougma A, Sere A, Bazie BSR, Sangare H, Ouilly JT, Bassole IHN. 2021. Composition and physicochemical properties of *Combretum collinum, Combretum micranthum, Combretum nigricans,* and *Combretum niorense* seeds and seed oils from Burkina Faso. *J. Am. Oil Chem. Soc.* **98**, 1083–1092. https://doi.org/10.1002/AOCS.12540

Chibor BS, Kiin-Kabari DB, Eke-Ejiofor J. 2017. Physicochemical properties and fatty acid profile of shea butter and fluted pumpkin seed oil, a suitable blend in bakery Fat Production. *Int. J. Nutr. Food Sci.* **6**, 122–128. https://doi.org/10.11648/j.ijnfs.20170603.12

Daulatabad CD, Ankalgi R. 1983. Component Fatty Acids of Some Indian Seed Oils Name of seed oil. *Fette Seifen Anstrichm.* **85**, 404–406. https://doi.org/https://doi.org/10.1002/lipi.19830851007

Devi A, Khatkar BS. 2016. Physicochemical, rheological and functional properties of fats and oils in relation to cookie quality: a review. *J. Food Sci. Technol.* **53** (10), 3633–3641. https://doi.org/10.1007/s13197-016-2355-0

Dijkstra AJ. 2016. Encyclopedia of Food and Health || Lauric Oils. in *Encyclopedia of Food and Health, 1st Edition, Academic Press, eBook ISBN: 9780123849533*. Elsevier, pp. 517–522. https://doi.org/10.1016/B978-0-12-384947-2.00513-4

Erwa IY, Ali AM, Khalid EA, Omer AB, Ishag OA. 2019. Proximate composition, mineral elements content, and physicochemical characteristics of *Adansonia digitata L*. seed oil. *Int. J. Pharma Bio Sci.* **10**, 119–126. https://doi.org/10.22376/ijpbs.2019.10.4.p119-126

FAO/WHO/UNU. 2007. Protein and amino acid requirements in human nutrition. *ISBN 978 92 4 120935 9* Press W, (Ed.), Geneva.

Fyhrquist P, Mwasumbi L, Hæggström C, Vuorela H, Hiltunen R, Vuorela P. 2002. Ethnobotanical and antimicrobial investigation on some species of *Terminalia* and *Combretum* (Combretaceae) growing in Tanzania. *J. Ethnopharmacol.* **79,** 169–177. https://doi.org/10.1016/S0378-8741(01)00375-0

Gunstone FD, Steward SR, Cornelius JA. 1972. New Tropical Seed Oils : Component Acids of Leguminous and other Seed Oils, including Useful Sources of Crepenynic and Dehydrocrepenynic Acid. *J. Sci. Food Agric.* **23**, 53–60. https://doi.org/https://doi.org/10.1002/jsfa.2740230108

Honfo FG, Akissoe N, Linnemann AR, Van Soumanou M, Boekel MA. 2014. Nutritional composition of shea products and chemical properties of shea butter: a review. Critical Rev. *Food Sci. Nutr.* 54 (5), 673–686. 10.1080/10408398.2011.604142

Jordaan M, Van Wyk AE, Maurin O. 2011. A conspectus of Combretum (Combretaceae) in southern Africa, with taxonomic and nomenclatural notes on species and sections. *Bothalia* **160**, 135–160. https://doi.org/DOI:10.4102/abc.v41i1.36

Khan AI. 2013. A GC-FID method for the comparison of acid-and base-catalyzed derivatization of Fatty acids to FAMEs in three edible oils. Application Note 20733, *Thermo Fisher Scientific*, Runcorn, UK; 1–8.

Liang L, Wang C, Li S, Chu X, Sun K. 2019. Nutritional compositions of Indian *Moringa oleifera* seed and antioxidant activity of its polypeptides. *Food Sci. Nutr.* **7**, 1754–1760. https://doi.org/10.1002/fsn3.1015

Lima GR de M, Praxedes de Sales IR, Filho MRDC, Taveira de Jesus NZ, Falcão H de S, Barbosa-Filho JM, Cabral A nalúcia GS, Souto AL, Tavares JF, Batista LM. 2012. Bioactivities of the Genus *Combretum* (Combretaceae): A Review. *Molecules* **17**, 9142–9206. https://doi.org/10.3390/molecules17089142

Norazlina MR, Jahurul MHA, Hasmadi M, Mansoor AH, Norliza J, Patricia M, Ramlah George MR, Noorakmar AW, Lee JS, Fan HY**,** 2021. Trends in blending vegetable fats and oils for cocoa butter alternative application: A review. *Trends Food Sci. Technol.* **116**, 102–114. https://doi.org/10.1016/j.tifs.2021.07.016

O'Brien RD. 2010. Fats & Oils: Formulating and Processing for Applications (3rd ed.). *Boca Raton, Florida: CRC Press*.

Pinheiro C, Baeta JP, Pereira AM, Domingues H, Ricardo CP. 2010. Diversity of seed mineral composition of Phaseolus vulgaris L. germplasm. *J. Food Compos. Anal.* **23**, 319–325. https://doi.org/https://doi.org/10.1016/j.jfca.2010.01.005

Podlaha O, Toregard B. 1989. Some new observations on the equivalent carbon numbers of triglycerides and the relationship between changes in equivalent carbon number and molecular structure. *J. Chromatogr.* **482**, 215–226. https://doi.org/10.1016/S0021-9673(01)93222-4

Singleton VL, Orthofer R, Lamuela-Ravent RM. 1999. Analysis of Total Phenols and Other Oxidation Substrates and Antioxidants by Means of Folin-Ciocalteu Reagent. *Methods Enzymol.* **299**, 152–178. https://doi.org/10.1016/S0076-6879(99)99017-1

Tanwar B, Goyal A. 2021. Oilseeds: Health Attributes and Food Applications, In *Springer Nature Singapore Pte Ltd* . https://doi.org/10.1007/978-981-15-4194-0_21

Tchobo FP, Alitonou GA, Noudogbessi J, Laguerre M, Barea B, Piombo G, Natta AK, Villeneuve P, Soumanou MM, Souhounhloue DKC. 2013. Evaluation of the chemical composition of *Pentadesma butyracea* butter and defatted kernels. *Int. J. Biosci.* **3**, 101–108.

Thiombiano A, Schmidt M, Dressler S, Hahn K, Zizka G. 2012. Catalogue des plantes vasculaires du Burkina Faso*. Boissiera* **65***,* 1–391.

Thiombiano A, Dorothea K (eds). 2010. Atlas de la Biodiversité de l'Afrique de l'Ouest, Tome *II : Burkina Faso. Ouagadougou & Frankfurt/Main. 625p*.