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Physicochemical Variability of Shea Butter (*Vitellaria paradoxa*) from the Regions of Chad

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Abstract Shea seeds were collected in 8 regions of Chad and the butters of their almonds were extracted by refluxing with hexane. The quality index (acid, peroxide, iodine and saponification index), the acylglycerol and fatty acid compositions and the proportions of phenolic compounds and chlorophylls of these various butters were evaluated by standardized conventional methods. Chad Shea almonds are very rich in butters (average of 54.24 ± 4.89%), especially that of Mandoul (61.18%). These Shea butters have excellent quality index and contain high proportions of triacylglycerols (TAG: 76.15 ± 7.33%). The major TAGs are distearylolylglycerol (SOS: 49.17-54.43%), dioleylstearylglycerol (SOO: 32.29-35.70%), and dioleylpalmitylglycerol (POO: 3.57-4.66%). This profile revealed a minor content of Chad Shea butter in arachidic, gadoleic, and linolenic acid. However, Mandoul Region Shea butter has the highest proportion of phenolic compounds (7.24 mg GAE/100 g), relatively no chlorophyll was found.

Keywords: *Shea butter, quality index, triacylglycerols, fatty acids, phenolic compounds*

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1. Introduction

In Africa, the forest is a diverse richness of Non-Timber Forest Products (NTFP). These contribute to the population's food and economic balance. Thus, the Non-Timber Forest Products are traded extensively in local and international markets [1].

Shea butter (*Vitellaria paradoxa* C. F. Gaertn., or *Butyrospermum paradoxum* C. F. *Gaertn or Butyrospermum parkii* G. Don) is a Non-Timber Forest Products of the Sapotaceae family, known for its butter extracted from almonds. It exists under two subspecies: V. *paradoxa Nilotica Kotschy* (usually found between Sudan and Uganda, via the Democratic Republic of Congo) and V. paradoxa Paradoxa (C.F. Gaertner) Hepper. (Found in West Africa and in the southern reaches of Central Africa) [2].

The subspecies *Vitellaria paradoxa paradoxa* is widespread in Chad, where it plays a very significant socio-economic and nutritional role [3]. The transformation of Shea fruits into butter is mainly done through traditional methods and remains the main activity of women. This butter has a fatty acid profile identical to that of *Pentadesma butyracea* butter but different from the latter in unsaponifiables [4].

Given its physicochemical qualities sought in the fields of agri-food, the parapharmaceutical industry, cosmetics and soap, Shea butter are increasingly sought on the international market [5]. For this purpose, buyers' requirements in terms of quality are based on certain parameters that make it possible to define their use [6,7]. As a result, the characterization of Shea butters and their functionality has attracted interest in scientific and technical research in many countries [8]. But, very few studies are done on Shea butter produced in Chad. To meet the requirements of the markets, it becomes imperative to conduct the study of the physico-chemical quality of Shea butter in this country. It is for this reason that the present study has set the overall objective of contributing to a better knowledge of the quality of Shea butter extracted from kernels from different regions of Chad.

2. Material and Methods

2.1. Plant Material

Shea fruits were collected in 8 regions in the southern part of Chad. These are Tandjile (Tan), Mandoul (Man), Logone Oriental (Lor), Logone Occidental (Loc), Mayo Kebbi West (Mao), Mayo Kebbi East (Mae), Moyen Chari (Moc) and N'Djamena (Chari-Baguirmi) (Ndj).

2.2. Methods

2.2.1. Oil Extraction and Quality Index

Samples of ground kernels (50g) were weighed and extracted four times with hexane (7 h) using a continuous Soxhlet extractor. The fat content was gravimetrically measured after removal of the solvent by rotary evaporation under vacuum. Extraction was run in triplicate (three times on 50g sample each) on the original iso kernels. For determination of acid, peroxide, iodine and saponification index, standard IUPAC methods were used.

2.2.2. Fatty Acid Analysis and Tryaclglycerols Profiles

Fatty acids and tryaclglycerols profiles were determined by the methods described by [9].

2.2.3. Acylglycerol Profile Determination

The acylglycerols were determined by the method described by [10] and using an automatic depositor (ATS4 Camag, Muttenz, Switzerland). Several standard concentrations of mono, di, triacylglycerols and free fatty acids were used for quantification.

The samples were deposited on silica plates (HPTLC, 20 × 10 cm, silica gel 60F). Elution was done with hexane/diethyl ether / acetic acid 70: 30: 1 (v/v/v) and developed using copper sulfate / acid / methanol / water solution (10: 1). 8: 5: 78, v/v/v/v) and heating the plate at 180 ° C for 10 min. The different compounds have been quantified at 550 nm with a TLC3 scanner (CAMAG, Muttenz, Switzerland).

2.2.4. Phenolic Content

To extract the phenolic compounds, 1 g of the oil was introduced into a tube, supplemented with 2 ml of n-hexane and 2 ml of 60% ethanol-water mixture. After homogenization, the mixture was centrifuged for 5 min at 3000 rpm. The hydroalcoholic phase containing the polyphenols was recovered. This procedure was repeated twice to exhaust the oil.

Total phenolic compounds were determined according to method used by [11] and gallic acid as a standard.

2.2.5. Determination of Chlorophyll Content

The chlorophyll pigments were determined by the method described by [12]. Thus, 7.5 g of the oil was weighed and dissolved in 25 ml of cyclohexane. Then the reading was made spectrophotometer at 670 nm.

3. Results and Discussion

3.1. Butter Extraction Yield and Their Quality Index of Butters

Table 1 shows the extraction yield, the quality index (acid, peroxide, iodine and saponification index) of the different Shea kernels of Chad.

The Shea kernels of the Chad regions have oil contents ranging from 44.42% (N'Djamena kernels) to 61.18% (Mandoul kernels) with an average of 54.24%. This value is higher than that reported by [13] for kernels (43.86%) from parts of Chad between 14º 19'34 "East, 9º 36'30" North and 18º 2'19 "East, 9º 3 '56" North. It is also higher than that of kernels from Cameroon (29.7%) [14]. These variations in butter content may depend on factors such as the morphological characteristics of the kernels and their drying time [15].

The acid and peroxide index provided information on the degradation and conservation qualities of vegetable oils. If the acid number indicates the degree of degradation of the triglycerides during their storage, the peroxide index reflects their auto-oxidation and therefore their ability to preserve. The acid values of Shea butter from all eight regions of Chad are all low and below 0.25 mg KOH/g of butter. The highest value of these index was obtained with the Mayo Kebbi West sample (0.52 ± 0.00 meq O2/kg) and the lowest with the Logone Occidental sample (0.13 ± 0.02 meq O2/kg).

These Shea butters in Chad have acid and peroxide levels that are in line with the WAEMU standards for unrefined Shea butter [15].

The saponification index of butters varies from 144.85±1.39 (Moyen Chari) to 228.87±1.40 mg KOH/g (Mandoul). With the exception of the values of Moyen Chari (144.85), Tandjile (208.56), Mandoul (228.87) and Logone Occidental (228.67), all the others are close to the values obtained from butters. Marketed in Benin (186.43 to 193.74 mg KOH/g), and in Uganda (192.15 ± 1.99 mg KOH/g) [17].

The butters of Chad is therefore low in free fatty acids and can be used as raw material for the manufacture of foaming soaps as the oils of copra (max = 264) and palm kernel (max = 254) commonly used for these uses. The iodine index of Shea butter range from 29.73 ± 0.43mg I_2/100g (N'Djamena) to 30.64 ± 0.44g mgI_2/100g (Mayo Kebbi East).

Table 1. Extraction yield and quality index of Shea butter from the regions of Chad

Samples	Butter yield (%, g/g)	Iodine index (mgI_2/100g)	Acid index (mg KOH/g)	Peroxide index (meq O_2/kg)	Saponification index (mg KOH/g)
Standards		**30–75**	**<1**	**<10**	**160–190**
Tan	54.63	29.84±0.44 a	0.24±0.00 a	0.35±0.00 a	208.56±0.19 a
Man	61.18	30.14±0.44 a	0.14±0.00 b	0.27±0.04 b	228.87±1.40 b
Lor	54.43	30.14±0.45 a	0.14±0.00 b	0.34±0.01 a	198.37±0.60 c
Loc	51.35	30.14±0.45 a	0.15±0.00 c	0.13±0.02 c	228.67±0.71 b
Mae	54.33	30.64±0.44 a	0.08±0.00 d	0.44±0.00 d	172.36±1.39 d
Mao	57.76	30.35±0.43 a	0.07±0.00 d	0.52±0.00 e	170.93±1.40 e
Ndj	44.42	29.73±0.43 a	0.15±0.00 c	0.51±0.00 f	166.83±0.39 e
Moc	55.79	30.02±0.44 a	0.06±0.00 e	0.40±0.00 a,d	144.85±1.39 f

Tan: Tandjilé; Man: Mandoul, **Lor**: Logone oriental, **Loc**: Logone occidental, **Mae**: Mayo Kebbi Est, Mao: Mayo Kebbi Ouest, **Ndj**: N'djamena, **Moc**: Moyen Chari

**Values with the same letters on the same column are not significantly different at the 5% threshold.

Compared to commercialized Shea butters in Benin (48.07 to 50.26mg I_2/100g) [18] and those obtained by "Tchabal" manufacturing processes (71.9 mgI_2/100g) in Cameroon (58.8 mgI_2/100g), iodine levels of Shea butters in Chad are low and very close to those of cocoa butters (36.1 mgI_2/100g), Shea butter from Uganda (36, 6 ± 1.15 mgI_2/100g) and shea butter marketed in Ivory Coast (28.53 to 31.78 mgI_2/100g). They further show that Shea butters in Chad is highly saturated [17].

3.2. Acylglycerol Compounds, Triacylglycerols and Fatty Acid Profiles

The proportions of fatty acids (FA), monoacylglycerols (MG), diacylglycerols (DG) and triacylglycerols (TG) of the various butters samples were made by elution on TLC and the results obtained are shown in Table 2. Shea butters from Chad contain a high proportion of triacylglycerols TG (63.6-86.1%). The proportions of fatty acids vary from 6.2 (Moyen Chari) to 22.8% (Logone Oriental). Monoacylglycerols (3.4-8.0%) and diacylglycerols (0.4-3.6%) are present in relatively low proportions. The strong presence of TGs confirms the good conservation qualities previously observed for these butters based on their quality index.

Table 2. Proportion of fatty acids (FA), monoacylglycerols (MG), diacylglycerols (DG) and triacylglycerols (TG)

Regions	FA (%)	MG (%)	DG (%)	TG (%)
Mao	8.7	4.9	2.7	78.1
Tan	17.1	5.3	3.6	63.6
Moc	6.2	3.4	2.8	84.6
Mae	11.6	4.3	3.0	75.7
Man	10.3	5.0	3.4	72.7
Ndj	19.8	6.0	0.4	77.7
Loc	22.8	8.0	0.8	70.7
Lor	10.5	6.2	0.5	86.1

∗Tan: Tandjilé; Man: Mandoul, Lor: Logone oriental, Loc: Logone occidental, Mae: Mayo Kebbi Est, Mao: Mayo Kebbi Ouest, Ndj: N'djamena, Moc: Moyen Chari

The compositions of these TAGs are defined in Table 3. It is observed that the Shea butters of the different regions studied contain ten molecular species of TAG (SLL, OOO, SLO, POO, POP, SOO, OOS, POS, SOS, SSO). In order of quantitative importance, we find the distearylolylglycerol whose rate is very high (SOS, Mayo Kebbi East: 49.17 at Moyen Chari: 54.43% with an average of 52.75±2.00%), the dioleylstearylglycerol (SOO, average of 34.12±1.20%) and dioleylpalmitylglycerol (OOP, average of 4.03 ± 0.39%).

Gunstone, [19] reported the proportions of SOS (42%) and SOO (26%) of lower Shea butter but the proportions of POP (3%), POS (6%), SOL (5%), and OOO. (6%) are higher. Similarly, Di-Vincenzo et al., 2005 mentioned that the proportions of SOS (Mali: 35.51-45.78%, Burkina Faso: 38.78-43.82%, Nigeria: 42.97-44, 59% and Uganda: 19.87%) and SOO (Mali: 23.74-29.07%, Burkina Faso: 26.02-29.32%, Nigeria: 24.18-26.02 % and Uganda: 33.39%) were still lower than those of Shea butter in this study.

There is evidence that the most important feature of cocoa butter use in chocolate is its important TG composition such as POP, POS, SOS [20]. Considering their rather diversified composition in TG, a study of a use of Shea butters of Chad as equivalents of cocoa butter in chocolate; could be initiated. Since the TG proportions of these Shea butter are close to those of P. butyracea butters "SOO" (35 and 45%), "SOS" (30.5-61.4%), "OOP" (0.2 -2.5%) [4].

This composition of TG prefigures a composition of Shea butter rich in oleic acids. This is evidenced by the results in Table 4

Table 3. Triacylglycerol (TAG) profiles of various Shea butter

	Tan	Moc	Mao	Mae	Man	Ndj	Loc	Lor
SOS	54.45	55.02	51.94	49.17	52.05	54.43	51.24	53.74
SOO	32.29	33.8	34.9	35.64	33.88	33.12	35.7	33.66
POO	3.83	3.57	4.08	4.66	4.47	3.72	4.19	3.71
SLO	2.8	2.56	3.25	3.85	2.97	2.98	2.75	2.4
OOS	2.58	1.8	2.04	2.1	2.61	2.32	1.72	2.34
POS	1.52	1.51	1.8	2.34	1.31	1.33	2.32	2.2
SSO	0.96	0.53	0.67	0.68	1.03	0.89	0.7	0.69
POP	0.37	0.29	0.36	0.37	0.35	0.28	0.43	0.31
SLL	0.33	0.3	0.31	0.43	0.43	0.34	0.27	0.21
OOO	0.29	0.28	0.27	0.37	0.35	0.2	0.31	0.34

∗Tan: Tandjilé; Man: Mandoul, Lor: Logone oriental, Loc: Logone occidental, Mae: Mayo Kebbi Est, Mao: Mayo Kebbi Ouest, Ndj: N'djamena, Moc: Moyen Chari.

Table 4 presents the proportions of 8 Shea Butters harvested in Chad in fatty acids. Shea butters from Chad is indeed rich in oleic acids (47.25%-55.21%), stearic (29.74%-39.48%), linoleic (6.01-8.64%) and palmitic (4.47% - 6.44%). Minor proportions of arachidic acids (1.03% - 1.54), gadoleic (N'Djamena 0.22% - 0.44%) and linolenic (0.10% - 0.19%) were also reported. The proportions of fatty acids <0.10% is considered as traces. These are unusual fatty acids in Shea butter like the heptadecanoic fatty acid (C17). Their proportion could be confirmed by complementary analyzes.

This fatty acid profile (mainly oleic-stearic and palmitic) of Shea butter from southern Chad is typical of this plant species harvested in Africa. However, the oleic acid content of the butters samples from Chad is lower than that of the samples extracted in Uganda (57.76%), but higher than those of the Shea butter of Mali, Burkina Faso and Nigeria which vary from 42 and 46.2% [21]. According to Derya, [22], these variations are due to the degree of maturity, genetic variation, climatic conditions, soil type and chemical compositions by Shea fruits.

Table 4. Fatty acid composition of shea butter from the Chad Regions

	C16:0	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1
Mao	4.95	33.50	52.96	6.75	0.14	1.20	0.31
Mae	4.90	30.61	55.21	7.32	0.15	1.17	0.40
Tan	4.47	39.48	47.25	6.54	0.15	1.54	0.34
Moc	6.44	33.17	52.75	6.01	0.11	1.03	0.22
Man	5.12	32.25	53.59	7.13	0.15	1.11	0.40
Ndj	5.20	29.74	54.24	8.64	0.19	1.22	0.44
Loc	4.66	34.65	51.47	6.92	0.13	1.49	0.39
Lor	5.03	31.02	55.03	6.97	0.14	1.17	0.36

∗Tan: Tandjilé; Man: Mandoul, Lor: Logone oriental, Loc: Logone occidental, Mae: Mayo Kebbi Est, Mao: Mayo Kebbi Ouest, Ndj: N'djamena, Moc: Moyen Chari.

3.3. Levels of Phenolic Compounds and Chlorophylls

Phenolic compounds pass into butters during extraction [23]. Their presence is considered as natural antioxidants that protect the butters against oxidation since they give them a better stability during storage [24].

The content of phenolic compounds (Figure 1) expressed as a percentage of gallic acid (R2 = 0.9999, y = 0.0075x + 6E-05) of Shea butter varies from 1.62 to 7.24 mg. 100 g. The variations observed at these levels vary from 1.62 ± 0.00 to 7.24 ± 0.00 mg GAE/100g.

This phenolic content of Shea butter is similar to that found in some seeds [25].

3.4. Chlorophyll Content

The color of butters comes from natural substances such as carotene, xanthophyll and chlorophyll. These play an important role in determining the physical quality of the butter. They make it possible to characterize and estimate the level of purity of butters. Chlorophylls specifically are pigments related to oxidative phenomena by their catalytic actions, pro-oxidant (in the presence of light) and antioxidant (in the dark) [26]. The chlorophyll content of the butter samples from Chad is shown in Figure 2.

Unlike the higher proportion of this butter in phenolic compounds, Mandoul Shea butter has relatively no chlorophyll. The chlorophyll content therefore varies from 00 ± 0.00 to 0.12 ± 0 mg/kg (Logone occidental). There is a great variability of this chlorophyll composition from one region to another. This variation would depend on the stage of maturity of the seeds before harvest [22]. Because the concentration of pigments of the seeds would decrease with the ripening of the fruits [27].

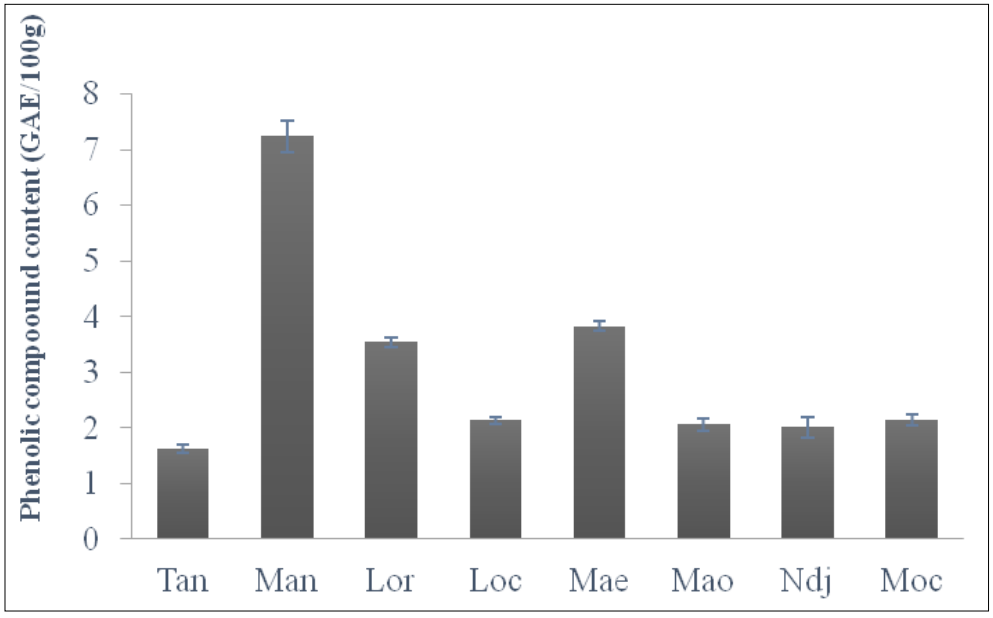

Figure 1. Phenolic compound content of Shea butters (Tan: Tandjilé; Man: Mandoul, Lor: Logone oriental, Loc: Logone occidental, Mae: Mayo Kebbi Est, Mao: Mayo Kebbi Ouest, Ndj: N'djamena, Moc: Moyen Chari)

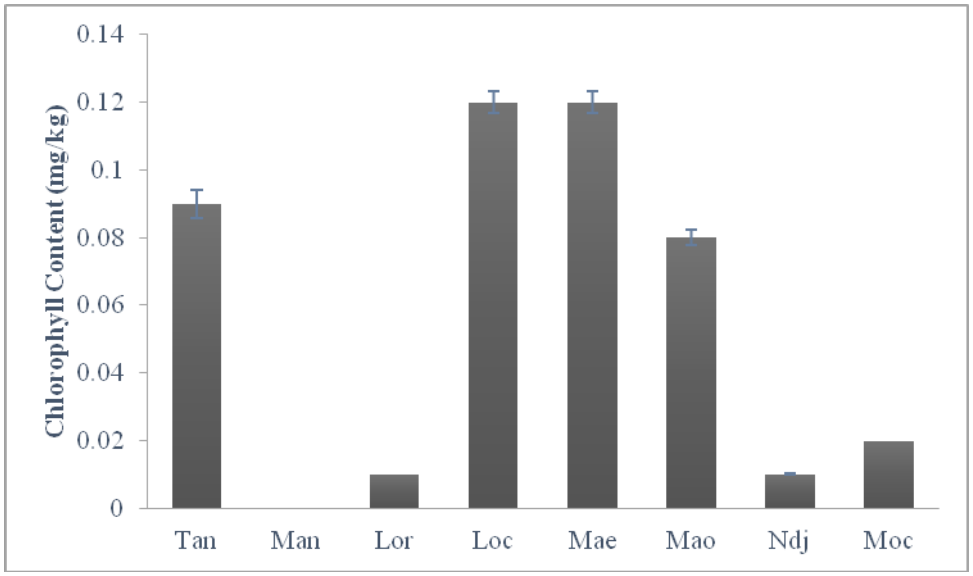

Figure 2. Chlorophyll content of Shea butter extracted from kernels harvested in Chad (Tan: Tandjilé; Man: Mandoul, Lor: Logone oriental, Loc: Logone occidental, Mae: Mayo Kebbi Est, Mao: Mayo Kebbi Ouest, Ndj: N'djamena, Moc: Moyen Chari)

4. Conclusion

Shea butter is a vegetable fat extracted from the fruit kernels of *Vitellaria paradoxa*, an oilseed that grows wild in the semi-arid areas of sub-Sahelian Africa. It is of great socio-economic and nutritional importance linked to its many virtues widely exploited locally and globally in the fields of agribusiness, cosmetics and traditional medicine. The evaluation of the physicochemical quality of butters from *Vitellaria paradoxa* seeds collected in Chad allowed us to characterize these different butters in order to meet the requirements of the markets and to solve the problem of lack of awareness of the quality potential of Shea butter in this country.

In view of the results, Chad's Shea butter extracted by solvent has acid, peroxide and saponification iodine index in accordance with the standards of the West African Economic and Monetary Union (WAEMU) for non-Shea butters refined. These Shea butters from the point of view of fatty acid content, triacylglycerols, phenolic compounds, chlorophylls, unsaponifiables are very rich. Their presence in the Shea butters of Chad determines their stability and their antioxidant properties. From these results it can be concluded that Shea butters from Chad can be classified in the first quality that is to say, they are better able to meet the needs of the cosmetics, pharmaceutical and agribusiness industries and also be consumed directly.

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