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Physical and Chemical Characteristics of Fruits, Pulps, Kernels and Butter of Shea *Butyrospermum parkii* (Sapotaceae) from Mandoul, Southern Chad

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Abstract: This research determines physico-chemical characteristics of shea fruit, pulp, kernel and butter from Mandoul region, southern Chad. The results show that shea pulp is a rich source of carbohydrates, protein and some minerals. Fat contains of the kernels is over 50% by solvent extraction and 30% by manual methods. The fatty acids profile shows that the butter contains more oleic acid (over 50%) than stearic acid. The butter composition ressemble more those of east African provenances.

Key words: *Butyrospermum parkii,* shea butter, pulp, characteristics, Chad, composition

Introduction

The shea tree, *Butyrospermum parkii* syn *Butyrospermum paradoxum*, *Vitellaria paradoxa* or *Bassia parkii is* an African savana tree of 10 to 25 m high and average 1 m wide. It grows from Senegal in the west to Ethiopia at the east within a soudano-sahelien landscape known as shea belt. It's divided into 2 subspecies: *nilotica* and *paradoxa*. The subspecies *nilotica* is more located in Sudan and Uganda with some occurrence in Ethiopia and Democratic Republic of Congo. The subspecies *paradoxa* is found more in West Africa (Mali, Burkina Faso, Senegal and Nigeria) (Hall *et al*., 1996).

Shea fruit resembles a small avocado with delicious and flavourful pulp when it is ripe.

The fruit production is from 15 to 30 kg per tree and the fruit weights from 10 to 57 g (Chevalier, 1943; Amin, 1990).

The pulp is eaten by people when the fruit is slightly overripe and fall down from trees generally from the beginning of June to the end of August.

This period corresponds the rainy and hungry season. Pearson (1976) found shea pulp containing ascorbic acid (196 mg/100 g), iron (2 mg/100 g) and calcium (36.4 mg/100 g). Maranz *et al*. (2004) found also that the shea pulp is a rich source of sugars, proteins, calcium and potassium. They suggested taking into consideration the role of shea pulp in development programs.

The kernel represents 50 to 70% of the fruit and contains up to 66% of fat according regions. Kernels of Ghana, Guinea and Uganda contain average 43% of fat (Wiesman and Maranz, 2001). Delolme (1947) found that shea kernels from Ivory Coast contains from 29 to 51% of fat. The use of organic solvents like hexane or methylene chloride yields better extraction of fat up to 70%. The fatty acids and unsaponifiable matter in shea butter show high variability. After screening 150 samples from different origins, Di Vincenzo *et al*. (2005) found that oleic acid is dominant in butters from Uganda whereas stearic acid is dominant in samples of West Africa provenances. The difference of the two provenances butters occurs first in their consistency (Boffa, 1999). Shea butter from Uganda which is oleic acid rich presents an oil aspect while that from Mali, Burkina Faso, Senegal and Nigeria which

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contains more stearic acid is solid at ambient temperature. There is also a great variability in physico-chemical properties. The density range from 0.91 to 0.98, freeze point from 32 to 40, iodine value from 50 to 80, saponification value from 170 to 190 and unsaponifiable matter from 2 to 17% (Gunstone *et al*., 1986; Renard, 1990; Pontillon, 1992).

The mandoul region (Southern Chad) is the part of the country where shea trees grow the most. The density of this tree in Koumra parkland reaches 50 per ha in some areas (Djekota *et al*., unpublished data). The production of shea fruits occurs early at the beginning of June and finish at the end of August. The pulp is eaten and the kernel yields butter for cooking, cosmetic, pharmacological use and soapmaking. Kapseu *et al*. (2000) have studied the chemical characteristics of shea butter of northern Cameroon including 2 samples from Chad. These 2 samples, which origins are unknown (the authors have mentioned them from N'djamena but shea tree doesn't grow at N'djamena area) are the only ones from Chad which have been studied.

The purpose of this study is the determination of physical and chemical characteristics of shea from Koumra (Mandoul region) including:

- Fruits Weight, pulp and kernels ;
- Total carbohydrates, moisture content, proteins, amino acids profile, total ash and some minerals of the pulp;
- Moisture and fat content of the kernels;
- Chemicals characteristics of fat extracted by hexane and by 3 manual methods (Moisture content, acidity, iodine value, saponification value, unsaponifiable matter and fatty acids profiles namely stearic and oleic acid).

Materials and Methods

The fruits have been harvested randomly in the parkland of Koumra (Mandoul region, Southern Chad) along July to August 2005. They were identified in varieties with the farmers who have recognized 6, according the trees aspect, the form, the size and the firmness of the fruit and the taste of the pulp (Table 1). At each collection the fruits are classified and brought at laboratory in hermetic cooler within one day for analysis. Fat content have been extracted using soxtherm method with hexane as solvent and using also the 3 local manual extracting methods (Fig. 1).

Fruit Weight, Pulp and Kernel%

Thirty fruits per variety were weighted on a precision balance. After removing the pulp, the seed and the kernel were weighted again. The% of each is than calculated.

Pulp Analysis

All analysis have been carried with dry pulp after moisture determination.

Total protein was determined according to the Kjeldhal method after nitrogen determination.

For amino acid analysis, powdered pulp was hydrolysed, under nitrogen, in HCl vapour at 120°C for 24 h using a Pico-Tag work station (Waters). Along with 2-β-mercaptoethanol (4%), to preserve

Table 1: Varieties and characteristics as recognized by farmers

Varieties	Fruit form	Fruit color	Fruit size	Fruit firmness when ripe	Pulp taste when ripe
Komane	Ovoid	Green	Big	Soft	Sweet
Mbabéte	Elliptical	Brown green	Big	Firm	Very sweet
Ngoïtokro	Ovoid	Yellow green	Middle	Soft	Very sweet
Bogrombaye	Ovoid	Brown green	Middle	Soft	Sweet
Kiankos	Ovoid	Yellow green	Middle	Firm	Sweet
Méingré (Koryengré)	Ovoid	Green	Small	Soft	Tasteless

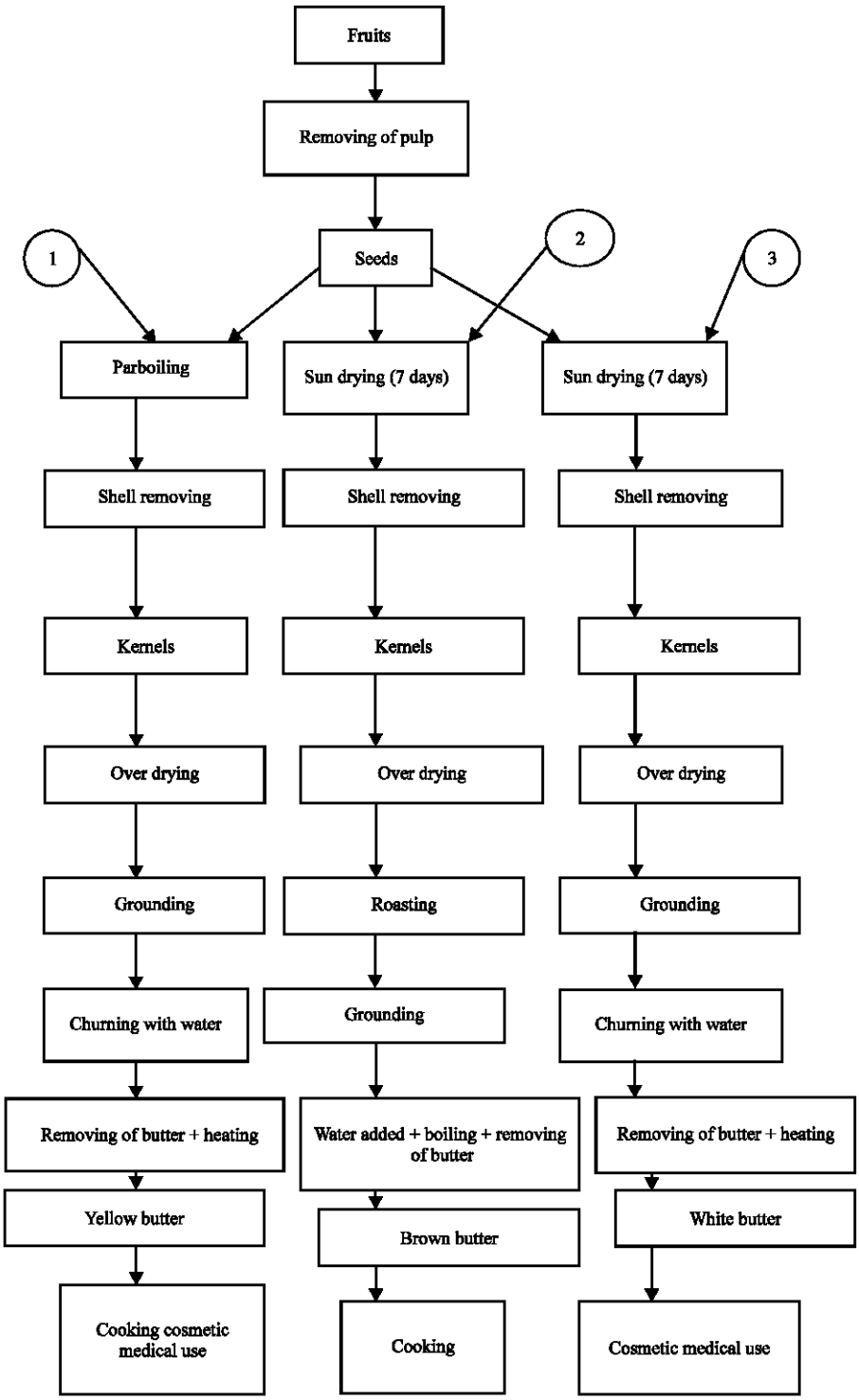

Fig. 1: The 3 manual processes of shea butter extraction

sulphur-containing amino acids, 200 µL of 6 N HCl were placed in the hydrolysis tank. After hydrolysis, 10 nmol of glocosamic acid per mg of sample were added as an internal standard. The samples were dried under vacuum in a Speedvac apparatus (Savant Instrument Inc., Farmingdale) and taken up with 0.05 M lithium citrate buffer, pH 2.2. The samples were submitted to ion exchange chromatography on an automatic amino acid analyser (Beckman 3600). Amino acids were detected by the ninhydrin reaction, identified by their retention time and wavelength ratio and quantified by their absorption at 570 nm (440 nm for proline).

The total carbohydrates was estimated using the method of Dubois *et al*. (1956).

For minerals, 10 g of dried and ground to fine powder pulp were incinerated at 550°C according to the processing previously described (AFNOR, 1981). The ash (1 g) was then dissolved in 1 L of water acidified with H_2SO_4 15%. Potassium was determined with a 410 flame spectrophotometer using butane under the pressure of 2.1 kg cm^{-2}, the debit was 0.4 L^{-1} min. Calcium and magnesium were determined with an atomic absorption spectrophotometer (Spectro Varian 20BQ). Colorimeter method was used for the determination of phosphorus (Buoso *et al*., 2002).

Kernels Analysis

The moisture content of 30 kernels of each variety was determined by drying in an oven at 100-105°C to constant weight (AOAC, 1980).

Dry kernels of each variety were ground in Warring Blender grinder type and than reduced to fine paste in a laboratory mortar. Total lipids were determined by continuous extraction in a Soxhterm, 2000 apparatus using hexane as solvent. One hundred grams of each variety were used in the manual extraction processes (Fig. 1).

Butter Analysis

For the acidity, 2 g of the extracted butter were dissolved in ethanol 95%/methylene chloride (V/V) containing 1% of phenolphthalein. The solution was than titrated with potassium chloride 0.1M. The total acidity of the butter was expressed as the quantity (milligrams) of potassium chloride needed to titrate one gram of butter.

Iodine and saponification values were determined according the AFNOR methods (1981). The unsaponifiable matter is extracted with hexane after total saponification of 10 g of butter and than expressed in% after removing the solvent in rotavapor.

For fatty acids profile determination, samples were dissolved in dry chloroform/methanol (19:1, v/v). A 0.1 mL aliquot was withdrawn for transmethylation using 0.3 mL of 14% BF_3 in methanol in a 2 mL Teflon lined screw-cap vial which was heated in a boiling water bath for 15 min. After cooling and addition of 0.3 mL of water, the transmethylated fatty acids were extracted into hexane. A calibration mixture of fatty acid standards was processed in parallel. Aliquots of the hexane phase were analyzed by GC. A Hewlett-Packard Gas Chromatograph (5890 Series II) with the Mass Selective Detector 5972A in scan mode was used to separate and quantify fatty acids. Aliquots (1 to 2 µL) of the hexane extract were injected in splitless mode onto a DB-225 column (30 m×0.25 mm indoor diameter, 0.24 µm thikness film). The injector temperature was 250°C, detector at 250°C, oven at 70°C for 1 min, then 70-180°C at 20°C per min, 180-220°C at 3°C per min, 220°C for 15 min. The carrier gas was nitrogen and the flow rate was 30 mL min^{-1}. The identification and quantisation of the fatty acids through their esters in the extracts was realized by means of the comparison of their retention times with standards.

Statistical Analysis

Means were compared using student t-test and the level of significant difference was determined at $p<0.05$.

Results and Discussion

Fruit, Pulp and Kernel Weights

The biggest fruits are that of Komane and Mbabete varieties. They are significantly different of that of Ngoitokro, Bogrombaye and Kiankos. The smallest fruits are from the Meingré variety. Bogrombaye and Meingré are the varieties with have the highest% of kernel. The pulp of Mbabete and Ngoitokro varieties (respectively 74 and 83%) are very appreciated by the farmers at the rainy season when dietary is insufficient and the agriculture works are hard. Kiankos and Komane varieties are slightly appreciated but their pulp are less sweet. Fruits of Bogrombaye and Meingré are generally ghatered only for their kernel (Table 2). Shea fruits from Mandoul have similar weighs compared to that of other provenances. Ruyssen (1957) found the fruits of West Africa weights from 10 to 45 g, Person (1986) found weight range from 10 to 57 g and Boffa *et al*. (1996) found the fruit weights 9 to 44 g.

Chemical Characteristics of Pulp

The moisture content of the different pulps is not significantly different. All these pulps have average moisture of 79%. Komane, Mbabéte and Ngoïtokro contain more carbohydrates than the 3 others. Mbabéte and Ngoïtokro have a very sweet pulp and are the most appreciated. Their carbohydrates content probably explains this preference (Table 3).

The shea pulp contains average 4% protein with all amino acids. It's rich in Asx and Glx but limited in Met (Table 4). The works presented in base de données VITELLARIA show average 4.13% of dry shea pulp from Uganda and 6.52% of dry pulp from Burkina Faso. According these results, protein content of dry shea pulp from Mandoul is nearest that of Uganda. This is not in agreement with Glew *et al*. (1997), which in a study of 24 indigenous plants from Burkina Faso including *Butyrospermum parkii*, found 4.2% of protein with well equilibrated amino acids. They found Aspartic acid, glutamic acid and proline had the highest values and the smallest was that of met like the present results. The shea pulp contains average 4.67% ash and is a rich source of Ca, K and Mg (Table 5). These results confirm the works of Maranz *et al*. (2004) and Glew *et al*. (1997).

Shea constitute a dietary contribution for farmers during the hungry season (July to August) when generally the food stores become low and the energy is much needed for planting.

Table 2: Mean±SD of fruit weight, pulp and kernel percents within varieties

Varieties	Fruit weight (g)	Pulp (%)	Kernel (%)
Komane	33.6659±6.1528	68.5081±3.0798	22.8667±3.9405
Mbabéte	32.8091±4.1278	74.7490±2.9385	23.4590±0.5179
Ngoïtokro	26.1572±6.2532	83.3257±4.0337	12.4852±1.8364
Bogrombaye	27.8187±6.2532	58.4452±6.3866	39.3278±3.6068
Kiankos	23.1199±11.6430	76.9648±3.1952	7.4286±2.2438
Méingré (Koryengré)	17.6679±3.3267	53.9871±0.8126	37.5500±0.6844

Levels of significant (Student t-test) $p<0.05$

Table 3: Chemical characteristics of shea pulp

Varieties	Moisture (%)	Carbohydrates (%)	Protein (%)	Ash (%)
Komane	77.42±1.96	8.16±0.21	4.22±1.03	5.97±0.28
Mbabéte	78.45±1.86	9.35±0.18	4.45±1.32	3.66±1.02
Ngoïtokro	79.12±2.19	8.96±0.24	4.28±1.14	4.40±0.92
Bogrombaye	80.21±2.11	7.56±0.24	4.56±2.01	4.63±0.26
Kiankos	77.92±1.80	7.54±0.14	4.62±0.94	5.40±0.55
Méingré (Koryengré)	81.11±2.65	6.52±0.25	4.19±1.52	3.97±1.57
Average	79.03±1.28	8.01±0.94	4.38±0.16	4.67±0.79

Results are the mean of three replicates. Levels of significant (Student t-test) $p<0.05$

Table 4: Total protein and amino acids profile within varieties. Amino acids are in mg/g dry matter

Varieties	Komane	Mbabéte	Ngoïtokro	Bogrombaye	Kiankos	Méingré (Koryengré)	Average
Protein (%)	4.22	4.45	4.28	4.56	4.62	4.19	4.38±0.16
Asx	6.63	6.93	6.81	6.55	6.77	6.03	6.62±0.29
Thr	1.75	1.62	1.53	2.01	1.88	1.67	1.74±0.16
Ser	1.96	2.28	2.01	2.41	1.71	2.12	2.08±0.22
Glx	5.07	6.12	4.98	5.94	6.28	5.16	5.59±0.53
Pro	3.92	3.86	3.56	4.03	4.12	3.72	3.86±0.18
Gly	1.93	2.13	2.44	2.06	2.32	2.24	2.18±0.16
Ala	2.21	2.31	2.52	2.63	2.51	2.41	2.43±0.14
Val	2.52	2.68	2.46	2.25	2.62	2.33	2.47±0.15
Cys	1.12	0.97	1.11	1.28	1.14	1.15	1.12±0.09
Met	0.09	0.07	0.12	0.09	0.11	0.08	0.09±0.01
Ile	1.87	2.19	1.96	2.07	1.99	2.12	2.03±0.10
Leu	2.97	3.17	2.88	3.22	3.06	2.94	3.04±0.12
Tyr	1.41	1.72	1.84	1.61	1.87	1.77	1.70±0.15
Phe	1.38	1.65	1.29	1.47	1.31	1.54	1.44±0.12
Trp	-	-	-	-	-	-	-
Lys	1.75	1.81	1.67	1.91	1.77	1.88	1.79±0.08
His	1.03	1.17	1.32	1.28	1.37	1.22	1.23±0.11
Arg	3.12	2.97	3.27	3.32	3.18	2.93	3.13±0.14

Results are the mean of three replicates. Levels of significant (Student t-test) $p<0.05$

Table 5: Ash content and minerals of dry pulp

		Minerals (mg g^{-1})				
Varieties	Ash (%)	Ca	Fe	P	Mg	K
Komane	5.97	3.76	0.36	0.93	1.23	19.25
Mbabéte	3.66	4.16	0.43	1.06	1.12	23.12
Ngoïtokro	4.40	4.42	0.51	0.87	0.97	21.63
Bogrombaye	4.63	4.83	0.39	0.97	1.17	24.51
Kiankos	5.40	3.97	0.40	1.03	1.26	22.16
Méingré (Koryengré)	3.97	4.12	0.45	0.89	0.91	19.66
Average	4.67±0.79	4.21±0.34	0.42±0.04	0.95±0.06	1.11±0.12	21.72±1.83

Results are the mean of three replicates. Levels of significant (Student t-test) $p<0.05$

Table 6: Moisture content of kernels and fat content using 4 extraction methods

Varieties	Moisture (%)	Fat hexane extract (%)	Fat manual process 1 (%)	Fat manual process 2 (%)	Fat manual process 3 (%)
Komane	29.72±2.24	53.70	34.26	30.25	33.48
Mbabéte	32.92±1.79	52.76	31.42	29.83	30.72
Ngoïtokro	30.32±1.83	63.26	36.17	31.14	33.52
Bogrombaye	27.74±1.66	56.47	32.14	29.62	30.81
Kiankos	30.06±1.38	55.87	30.98	28.92	29.79
Méingré (Koryengré)	29.94±2.07	53.62	33.35	29.74	31.15
Average	30.11±1.51	55.94±3.52	33.05±1.78	29.91±0.67	31.57±1.41

Results are the mean of five replicates. Levels of significant (Student t-test) $p<0.05$

Kernels Characteristics

The moisture content of kernels of the 6 varieties is not significantly different ($p<0.05$) (Table 6). It's average 30%. The fat content of kernels is more extracted with hexane than by manual processes. There remains about 20% of fat in the waste by manual extraction. Ngoïtokro variety contains most fat extracted by solvent. It's significantly different of the 5 others varieties.

Although, solvent permits better extraction, it needs especial material and chemicals which are not suitable in the farms. It's also hazardous treating chemically man food. The 3 manual processes are generally used according the use of the final butter. Process 1 is recently introduced from West Africa and is the most used now in the Mandoul region. Butter obtained this way is used for cooking, cosmetic, medical use and soap making. Process 2 is the oldest extracting method. The butter obtained this way is mainly used for cooking because it smells of burning but well appreciated by people of the region. This kind of butter is generally not used for cosmetic because of its odour. Butter obtained by process 3 is used for cosmetic because it's odourless, for medical use and for soap making.

The total fat content of kernels from Mandoul is almost the same with those of others provenances (Marchand, 1988; Skrechkenberg, 1996; Wiesman and Maranz, 2001).

Butter Analysis

Acidity

Butters from hexane extraction and manual process 1 are less acid than extracts obtained by manual methods 2 and 3. The parboiling of the seeds used in the 2 extractions can explain these low acidities. Parboiling kills seed growth enzymes which hydrolyse triglycerides with free fatty enriching. Shea butter quality is high when its free fatty acid content is low. Free fatty acid content is naturally low in fresh nuts, but it increases rapidly through hydrolysis under poor storage conditions. The shea seed germination begins just 1 to 3 weeks after harvest and this germination starts with enzymes activity. The 2 other processing methods lead to a poor quality of butter. Total acidity of these butters is over 10. Sun drying of seeds and kernels allows the enzymes to release more free fatty acids (Table 7).

Hydrolysis occurs through the lipolytic activity of the fruit lipases and micro- organisms. It is halted by heating and by reducing the moisture content to lower than 8%. Louppe (1994) therefore recommended that nuts be boiled for an hour shortly after collection and then dried in the sun. Solar dryers would reduce the need to handle nuts daily and techniques are also needed to eliminate possibilities of fungal infection when the nuts are stored in their shells.

Iodine and Saponification Values

The iodine value of the different butters is not significantly different. This value is average 62. The iodine value of shea butter obtained in former studies ranged fro 50 to 80. Renard (1990) obtains a value between 50 to 80 effectively (Table 8). Pontillon (1992) measured values from 52 to 66 and Gunstone *et al*. (1986) obtains a value ranging from 53 to 60. Womeni *et al*. (2004) noticed increasing of the iodine value (86.6) of parboiling seeds compared to that of the sun drying ones (68.3). In these results, the iodine values are the same in parboiling and sun drying seeds.

Saponification value is the same in hexane extract and manual process 1. This value increase significantly in the butters obtains by manual processes 2 and 3. The 2 former butters were obtained from boiling seeds whereas the 2 last are obtained from sun drying seeds. It seems that the acidic ends

Table 7: Acidity of different fat extracted within varieties

Varieties	Hexane extract	Manual extract 1	Manual extract 2	Manual extract 3
Komane	5.50	5.83	11.09	10.15
Mbabéte	4.91	5.95	9.98	9.97
Ngoïtokro	4.73	5.63	10.94	10.41
Bogrombaye	4.19	5.61	9.03	9.86
Kiankos	5.36	4.89	10.12	10.09
Méingré (Koryengré)	6.04	5.23	12.32	11.21
Average	5.12±0.59	5.52±0.36	10.58±1.03	10.28±0.44

Results are the mean of five replicates. Levels of significant (Student t-test) $p<0.05$

Table 8: Iodine and saponification values of butters within extracting methods

	Hexane extract		Manual extract 1		Manual extract 2		Manual extract 3	
Varieties	Ii	Is	Ii	Is	Ii	Is	Ii	Is
Komane	62.02	172.89	64.02	176.25	63.11	183.25	61.95	182.16
Mbabéte	63.16	176.05	62.13	177.02	62.91	185.12	63.45	185.51
Ngoïtokro	61.71	177.52	63.42	176.18	63.26	186.27	64.07	183.33
Bogrombaye	63.22	176.22	61.82	173.42	62.28	183.22	62.73	185.07
Kiankos	62.18	177.17	64.09	178.11	62.92	184.41	63.28	184.61
Méingré (Koryengré)	64.13	174.43	62.89	174.73	63.17	187.08	63.47	185.81
Average	62.73±0.83	175.71±1.60	63.06±0.87	176.95±1.51	62.94±032	184.89±1.44	63.15±0.66	184.41±1.28

Results are the mean of five replicates. Levels of significant (Student t-test) $p<0.05$

increased in the sun drying seeds perhaps due to lipoxygenases activity. The lipoxygenases break down fatty acids chains at the double bounds. This created novel acidic ends. In parboiling seeds, these enzymes were destroyed by heat. The saponification values are in agreement with the acidity. They are lower in the butters obtained with the parboiled seeds.

Fatty Acids Profile

There are no significant differences of fatty acids profiles within varieties (Table 9). There is a dominant% of oleic acids in the shea butters from Mandoul. This explains their oil aspect at ambient temperature. The freeze point of oleic acid is less (9°C) than that of stearic acid (69.6°C). Ferris *et al*. (2002) in a review have mentioned that Chemical analysis of Shea butter extracted from nuts samples of four African countries (Uganda, Nigeria, Burkina Faso and Mali) confirmed the considerable variability in Shea oils across Africa. The Ugandan sample had a 59% oleic acid content compared with 47% for Nigeria and only 39% for Burkina Faso. From these studies it was found that Malian Shea closely resembles cocoa butter while Ugandan Shea has more similarities with olive oil. Di Vencenzo *et al*. (2005) confirmed these results after checking fatty acids profiles of 150 samples from the four countries. They found oleic acid dominant in butters from Uganda, whereas stearic acid is dominant in those from west Africa. The base de données VITELLARIA shows that the shea butters from Uganda and Cameroon (northern and west) contains respectively 56.5 and 52% of oleic acid whereas those from Senegal, Gambia, Nigeria and Burkina Faso contain less than 50%.

Table 10 shows that the Mandoul shea butter profile is between those of Cameroon and Uganda. Mandoul region is located nearest east of Africa (Sudan) and far from West Africa. The subspecies found in this region are probably more *nilotica* than *paradoxa*. The subspecies *nilotica* (with oleic acid dominant) is more located in Sudan and Uganda with some occurrence in Ethiopia and Democratic Republic of Congo. The subspecies *paradoxa* with is stearic acid dominant is found more in West Africa (Mali, Burkina Faso, Senegal and Nigeria).

The unsaponifiable matter of the butters are not different within extraction methods (Table 11) It's average 10%. This result is in agreement with those of Gunstone *et al*. (1986) and Pontillon (1992) who found an unsaponifiable fraction of butter range from 7 to 11%. It's more than those of Renard (1990) and Kapseu *et al*. (2000) who found respectively 3.5 to 8% and 5.9%. Shea butter is a rich source of unsaponifiable matter including triterpene alcohols, Kariten, sterols and tocopherols. This explains its use in cosmetic.

Table 9: Fatty acids profile within varieties

Varieties	Palmitic	Stearic	Oleic	Linoleic
Komane	5.2	31.1	53.7	8.1
Mbabéte	5.1	31.3	54.1	7.8
Ngoïtokro	4.9	30.8	53.9	8.0
Bogrombaye	4.7	31.5	54.3	7.9
Kiankos	5.0	30.9	53.6	8.0
Méingré (Koryengré)	5.3	31.3	54.0	8.1
Average	5.03±0.19	31.15±0.24	53.93±0.23	7.98±0.10

Results are the mean of three replicates. Levels of significant (Student t-test) $p<0.05$

Table 10: Summary of fatty acids percent in shea butter within provenance

Provenance	Stearic	Oleic
Uganda (Ferris *et al*., 2002)	26.4	59.3
Uganda (Vitellaria base)	31.2	56.5
Nigeria (Ferris *et al*., 2002)	38.9	47.5
Eastern Senegal through Western Nigeria (Vitellaria base)	42.8	43.3
Burkina Faso (Ferris *et al*., 2002)	42.5	39.3
Burkina Faso-Plateau Mossi (Vitellaria base)	45.1	43.3
Mali (Ferris *et al*., 2002)	31.1	42.6
Cameroon (Vitellaria base)	33.7	52.0
Chad (Presence study)	31.1	53.9

Table 11: Unsaponifiable matter within extraction methods

Varieties	Hexane extract	Manual extract 1	Manual extract 2	Manual extract 3
Komane	10.18	9.88	10.14	10.16
Mbabéte	9.87	10.02	10.18	8.97
Ngoïtokro	10.07	10.11	9. 90	9.88
Bogrombaye	10.22	9.98	10.05	10.08
Kiankos	10.14	10.23	9.92	10.12
Méingré (Koryengré)	9.94	9.78	10.02	10.31
Average	10.07±0.12	10.00±0.14	10.03±0.10	9.92±0.44

Results are the mean of three replicates. Levels of significant (Student t-test) $p<0.05$

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