J. Chem. Eng. Chem. Res.
Vol. 3, No. 1, 2016, pp. 953-961
Received: August 3, 2015; Published: January 25, 2016

Journal of
Chemical Engineering
and Chemistry Research

Chemical Analyses of Shea Butter from Northern Ghana: Assessment of Six Industrially Useful Chemical Properties

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Abstract: Shea butter from Northern Ghana was collected for analyses in order to improve its visibility and commercial placement. Analyses were carried out to determine unsaponifiable matter, moisture, insoluble impurities, free fatty acids, peroxide value, catechins and total phenol content. The samples had high impurities, free fatty acids and moisture content but low peroxide content. The mechanically extracted samples contained less moisture, 0.177 ± 0.04% and 0.218 ± 0.02%, and also low amount of impurities. The highest mean moisture content, 0.542 ± 0.19%, was found in samples from the Upper East region, while manually extracted samples from the Northern region had the highest mean level of impurity (1.1996 ± 0.55%). Least mean amount of free fatty acid, 3.383 ± 0.05%, was in samples from the Upper East region and the highest, 6.334 ± 0.01%, was found in the manually extracted samples from the Northern region. Unsaponifiable matter was least (5.04 ± 0.04%) in the mechanically extracted sample from the Northern region and the corresponding highest mean amount (7.89 ± 0.02%) was also from the Upper West region. Generally, all the samples had low total phenol and peroxide levels, respectively ranging from 0.0575 ± 0.002 mg/g of phenolics in samples from the Upper East to 0.0255 ± 0.000 mg/g in the manually extracted samples from Northern region. 7.08 ± 0.13 meq/kg peroxide content was also found in samples from Upper West and 3.96 ± 0.06 meq/kg from the Northern region. Most of the Shea butter samples analysed was good for the chocolate, confectionery, pharmaceutical and cosmetics industries.

Key words: Shea butter, fatty acids, peroxides, moisture, impurities, phenols, catechins.

1. Introduction

The Shea tree, *Vitellariaparadoxa*, belongs to the family *Sapoteceae* with subspecies, *paradoxa* from West Africa and *nilotica* from East Africa. Different varieties of the plant are known to occur throughout Africa [1]. The tree has become known globally, and in Africa its importance cannot be over looked. It is the second most important oil crop in Africa after oil palm [2]. The Shea tree can be found growing naturally in the southern region of the Sahel and the northern regions of the Guinea Zone. It thrives in Savannah areas where oil palm cannot grow due to low rainfall [3]. Using remote sensing imaging in Mali, 18 million Shea butter trees were counted over a distance of 20 km [4]. The crop is ellipsoidal in shape and has a white scar at one side. It has a uniform shell of about 1mm thick [5]. The nut is thin-shelled and enclosed with the oil bearing kernel [6]. Harvesting of Shea nuts generally takes place between June and August, peaking during July.

Shea butter is a natural fat extracted from the fruit of the *African Magnifolia* (Karite) tree. It is yellowish white in colour and has a strong smell [7]. The

fat/butter is solid but due to its low melting point it is easily found in the liquid state [8]. The major producing countries are West African countries namely; Mali, Burkina Faso, Benin, Senegal, Ivory Coast, Ghana and Nigeria [9]. In some of these countries Shea butter processing centres produce the butter in large quantities [10, 11]. There is increasing global demand for Shea oil and the tree has been included in the priority list of African Genetic Resources by the FAO [12]. It has been suggested that the Shea industry will continue expanding forever and could pick up speed over time [13]. According to some reports, the use of Shea butter alone for cosmetics in USA has been growing at annual rate of more than 25% [14].

A large group of chemicals are found in Shea butter that gives the butter its therapeutic properties. Some examples are antioxidants such as the oil-soluble tocopherols and water-soluble catechins, triterpenes such as butyrospermol, phenols, sterols and other substances such as karitene and allantoin. The fat can be used in soap and cosmetic making, and traditional medicine in many rural areas [15-17]. Moisture content above 1% promotes bacterial growth, peroxide formation and facilitates triglyceride breakdown thereby increasing the level of free fatty acid. Therefore low moisture content in Shea butter is preferred.

Due to its richness in food nutrients, Shea oil has become marketable to industry in Europe, Asia and North America for manufacture of a large range of products [18].

As a cosmetic, it is used as a moisturizer, for dressing hair [19, 20]. Shea butter also has healing properties [14, 21] and is used for protection against the weather and sun. It is used as a rub to relieve rheumatic and joint pains and is applied to activate healing in wounds and in cases of dislocation, swelling and bruising, and widely used to massage pregnant women and small children [22].

The vegetable fat of Shea nut according to Hall et al. [23] is used by the indigenous people who trade with it, eat it and rub their bodies with it. They also burn it to make light and; it is used as a beneficial remedy against aches, pains, sores and wounds for which it is applied as an unguent [23]. However, it loses popularity in urban areas due to the strong odour it emits, when it becomes rancid [24].

Consumption of Shea oil is believed to be beneficial in lowering the risk of coronary heart diseases now on the increase among urban populations in developing countries [25]. Poor quality butter is applied to earthen walls, doors, windows, and even beehives as a waterproofing agent [22]. In a traditional setting, Shea butter of poor quality is used as an illuminant (or fuel, in lamps or as candles). In Burkina Faso, Shea butter has also been used as a protection against insect (*Callosobruchusmaculatus*) damage to cowpeas (*Vigna sp.*) [26, 27].

With the authorization to use up to 5 percent of other vegetable fats in the manufacture of chocolate and confectioneries, Shea hold a particular esteem for its functional properties due to its stearic content which contributes to a higher melting point than that of cocoa butter [8]. Majority of raw Shea butter in international trade, comes from Ghana, Benin, and Burkina, where the supply is constant. Butter products are in increasing demand in various food, cosmetic, and pharmacological industries internationally [8]. The butter is sometimes used in the chocolate industry as a substitute for cocoa butter. It is used to produce cocoa butter equivalent (CBEs) and cocoa butter improver (CBIs) used in chocolate factories. Also, due to growth in the demand for vegetable fat in the western marketplace, Shea butter (approximately 95%) provides an important raw material for CBRs. This segment is the largest by far in terms of quantity and added value.

Shea trees growing at different places could have serious variation in the chemical components of the butter due to environmental factors such as rainfall, soil fertility, maturation period, agronomic practices and genetic substitution [16, 28]. Only about half of the

60,000 t of crude Shea butter processed in Ghana, Burkina Faso, Benin, Cote d'Ivoire, Nigeria, Mali and Togo is exported [9]. The inefficiency in extraction of Shea butter oil contributes to its inability to compare well with other common vegetable oils [6], most Shea exports in West Africa consist of raw nuts and crude butter, as virtually no significant refining is done. Characterization of Shea oil for nutritional, pharmaceutical and cosmetic purposes is therefore very important to its marketing. Acid value, peroxide value, saponification value and iodine value are also indicators of edible oils that are suitable for food, cosmetic, soap making and lubricants.

In the current work, we determined some quality parameters of extracted Shea butter from the three northern regions of Ghana. Unsaponifiable matter, moisture, insoluble impurities, free fatty acids, peroxide value, catechins and total phenol concentration were measured. Results of this work are expected to give further commercial placement of Shea nuts and butter from Ghana both in local and international business.

2. Materials and Methods

Materials used in this work were Shea butter, various apparatus and glassware. Reagents used were of analytical grade.

2.1 Sample Collection

Twenty four samples of Shea butter were collected, across Northern Ghana (Northern, Upper East and Upper West regions). The samples were collected from two Shea butter processing groups in each region. Manual as well as mechanically extracted samples were collected for analyses. Sample collection was done in triplicates: Three manually extracted samples from each of the two sampling sites (samples 1-6) in each of the three regions. Three mechanically extracted samples were also collected from each of the two sampling sites (sample 7 and 8) in the Northern region. The samples were stored in plastic containers under cold temperature in a fridge until they were used.

Following the triplicate analyses, mean (M) levels and standard error (SE) of the means were calculated. The results were then presented as mean measured value ± standard error (ie. M ± SE).

The parameters of analyses included the determination of moisture, insoluble impurities, free fatty acids, peroxide value, unsaponifiable matter, total phenolic content and levels of catechins.

2.2 Determination of Moisture

This was done using the air oven method [29]. Percentage moisture was determined using the formula:

$$\text{Percentage moisture} = \left|\frac{B-C}{A}\right| \times 100\% \quad (1)$$

where: A is the sample weight (g); B is the weight of dish + sample prior to drying (g);

C is the weight of dish + sample after drying (g); (B−C) is the loss in weight of sample after drying (g).

2.3 Insoluble Impurities

Impurities were determined as insoluble in petroleum ether [30]. Percentage impurities were calculated using the formula:

$$\text{Percentage impurities} = \left|\frac{A}{B}\right| \times 100\% \quad (2)$$

where: A = (final weight of filter paper (g)-initial weight of filter paper); B is the weight of sample (g).

2.4 Determination of Unsaponifiable Matter

Working according to Bauer et al. [31], the samples were dried and processed for determination of unsaponifiable matter calculated as:

$$\text{Unsaponifiable matter} = \left|\frac{100.a}{P}\right| \quad (3)$$

where a = Weight of corrected residue and P = Weight of sample.

2.5 Free Fatty Acids

Determination of free fatty acid was done using titrimetric methods according to procedures of AOCS [32]. The acid value was determined and used

for the calculation of percentage free fatty acids according to Eqs. (4) and (5).

$$\text{Acid value} = \left|\frac{(V.N)56.1}{\text{Weight of sample}}\right| \quad (4)$$

Where V = Volume of KOH and N is normality of KOH.

$$\%\ \text{Free Fatty Acids} = \left|\frac{(V.N)2.82}{\text{Weight of sample}}\right| \quad (5)$$

Where V is the titre value (volume of KOH) and N is normality of KOH

2.6 Total Phenolic Content

This determination was carried out using the spectrophotometric method [33] using a Beckman Coulter spectrophotometer.

2.7 Peroxide Value

Samples of melted butter were dissolved in a solvent consisting of 60% of glacial acetic acid and 40% of chloroform. It was prepared for titration with Sodium thiosulphate solution using starch solution as indicator according to procedures in Lovaas [34].

The peroxide value was calculated as follows:

$$\text{Peroxide value} = \left|\frac{(NV)1000}{\text{Weight of oil used}}\right| \quad (6)$$

Where V = Volume of thiosulphate solution and N is normality of thiosulphate solution.

3. Results and Discussion

3.1 Results

Details of all the results have been presented in Tables 1 and 2. Among the samples, there was variation of moisture content but the levels were close to each other. The mechanically extracted samples had the lowest mean moisture content of 0.177 ± 0.04% and 0.218 ± 0.02%. One of the samples from Upper East region had the highest average moisture content of 0.542 ± 0.19% (Table 1).

Most of the samples were of the third grade because of their average percent insoluble impurities, (ranging from 0.1496 ± 0.03%-1.1996 ± 0.55%). The two mechanically processed samples, 7 and 8 from the Northern region, were however of the second grade having lower impurity levels of 0.1997 ± 0.03% and 0.1496 ± 0.03% respectively (Table 1).

Also, all the samples analysed had quite high levels of free fatty acids, higher amounts being 6.334 ± 0.01% and 6.174 ± 0.02% in the samples from Northern region and the least being 3.383 ± 0.05% in sample 4 from the Upper East region (Table 1).

The levels of unsaponifiable matter obtained from the analyses were all close to each other. The highest level present was 7.89 ± 0.02% in sample 5 from the Upper West region and the least was 5.04 ± 0.04% in sample 7 from the Northern region. The percent unsaponifiable matter of the manually processed samples from the Northern and Upper East regions was similar to those of the mechanically processed samples from Northern region. The samples from Upper West region were slightly higher in unsaponifiable matter compared to all the others (Table 1).

Peroxide levels of all the samples were generally low. The highest was 7.08 ± 0.13 meq/kg in sample 6 from the Upper West region, the lowest being 3.96 ± 0.06 meq/kg in sample 1 from the Northern region which is also the same as that of the mechanically extracted sample 7 (Table 2).

From the results, the total phenol content was generally low. Higher phenol amounts were 0.0575 ± 0.002 mg/g in sample 4 from the Upper East region and 0.0550 ± 0.000 mg/g in sample 1 from the Northern region, while the least was 0.0255 ± 0.000 mg/g in sample 2 from the Northern region (Table 2).

The various characteristics determined were compared to two standards (appendix Tables 1 and 2).

3.2 Discussion

3.2.1 Percentage Moisture

Moisture content of a food sample indicates the shelf life property of that sample. Hence from the results obtained, the mechanically extracted samples, having the least percentage moisture content, should have the longest shelf life whiles sample 4 from the

Table 1 Levels of unsaponifiable matter, moisture, insoluble impurities and free fatty acids.

Sample source region	Sample	Mean content ± Se (%)			
		Unsaponifiable matter	Moisture	Pet ether insoluble impurities	Free fatty acid
Northern	1	5.46 ± 0.00	0.233 ± 0.00	0.6996 ± 0.05	6.174 ± 0.02
	2	6.12 ± 0.02	0.320 ± 0.00	1.1996 ± 0.55	6.334 ± 0.01
Upper East	3	5.85 ± 0.03	0.355 ± 0.02	1.1735 ± 0.03	5.278 ± 0.18
	4	6.38 ± 0.01	0.542 ± 0.19	1.1485 ± 0.05	3.383 ± 0.05
Upper West	5	7.89 ± 0.02	0.273 ± 0.03	0.6488 ± 0.05	6.050 ± 0.02
	6	6.62 ± 0.01	0.293 ± 0.02	0.6982 ± 0.05	5.240 ± 0.01
Northern	7	5.04 ± 0.04	0.177 ± 0.04	0.1997 ± 0.03	5.360 ± 0.04
	8	6.12 ± 0.02	0.218 ± 0.02	0.1496 ± 0.03	5.307 ± 0.04

Table 2 Levels of peroxide, total phenols and catechins.

Sample source region	Sample	Peroxide value (meq/kg)	Total phenol concentration (mg/G)	Relative proportion of catechins in samples
Northern	1	3.96 ± 0.06	0.0550 ± 0.000	0.275 ± 0.005
	2	4.12 ± 0.10	0.0255 ± 0.000	0.125 ± 0.003
Upper East	3	4.06 ± 0.05	0.0285 ± 0.000	0.139 ± 0.001
	4	4.60 ± 0.02	0.0575 ± 0.002	0.138 ± 0.001
Upper West	5	4.61 ± 0.07	0.0285 ± 0.000	0.265 ± 0.005
	6	7.08 ± 0.13	0.0530 ± 0.001	0.292 ± 0.006
Northern	7	3.99 ± 0.05	0.0350 ± 0.000	0.174 ± 0.001
	8	4.02 ± 0.08	0.0355 ± 0.000	0.176 ± 0.000

Upper East region is expected to have the shortest shelf life among the samples. Comparing these values to the Ghana standards for unrefined Shea butter [35] and those of the Union Economique Monetaire Ouest Africaine (UEMOA) [36], it was found that all the butter samples fell within the grades for useful Shea butter. According to both standards, the samples are classified with average percentage moisture content (Appendix Table 1) since the observed moisture contents were either within narrow limits (0.177 ± 0.04%) to or above the lower limit of 0.2 for average moisture as indicated by the standards. None of the samples had moisture level in excess of the maximum values of both standards [35, 36]. The standards therefore indicated that except sample 7, all the samples were of the third grade and thus met the requirement of soap making industries and can also be refined for direct consumption. Sample 7was of second grade [36] and met the requirement of the food industry (confectionery, chocolate, edible oil or as a basis for margarines).

The moisture content of Shea butter depends on how well the butter is stored and has nothing to do with the environment in which the Shea tree grows and the tree's individual genetic makeup [36].

3.2.2 Percentage Insoluble Impurities

From both Ghana and UEMOA standards on levels of impurities present in a Shea butter [35, 36], the samples could be useful to food and pharmaceutical companies.

Based on the levels of impurities (0.1496 ± 0.03%-1.1996 ± 0.55%), all the manually processed samples of butter met requirements of soap making industries and the samples could also be refined for direct consumption. Additionally, samples 7 and 8 from the Northern region met requirements of the food industry [35, 36].

3.2.3 Percentage Free Fatty Acid

According to the standards used in this work [35, 36] all the Shea butter samples analysed were of the third grade with respect to Free Fatty Acids (FFA). FFA are produced from the hydrolytic rancidity of triglycerides

due to unsuitable processing and preservation. FFA may be indicative of degradation of the oil. Some factors that also affect buildup of free fatty acids include length of time between fruit maturation, harvesting and heat treatment. If Shea nuts are dried without a heating stage, FFA levels can be very high.

3.2.4 Peroxide Value

Comparing the current results with the available standards, all the samples were found to be of high quality since the levels of peroxides obtained were below ten and hence places the samples in the first grade [35, 36]. From the perspective of peroxide content, the samples were all suitable for the pharmaceutical and cosmetics industries and also for direct consumption.

Peroxide value is also an indicator of degradation. Long fatty chains may degrade through auto-oxidation into peroxides that later break down into other chemicals and produce malodorous ketones and aldehydes. However, low peroxide values do not necessarily indicate that the butter samples were appropriately stored since their FFA contents were quite high. Other factors such as moderate heat and absence of certain metals such as iron, copper, aluminium could have prevented the formation of peroxides and hence maintaining the quality of the butter.

3.2.5 Percent Unsaponifiable Matter

Acceptable level of unsaponifiable matter for unrefined Shea butter falls between 1-19%. Higher content of unsaponifiables is of particular relevance to buyers of Shea butter especially those in the cosmetic industries due to its therapeutic capacity [35, 36]. In the current work, the unsaponifiable matter of all the samples was within the acceptable range. Unsaponifiable matter is not dependent on extraction procedure, but rather on the environment in which the Shea tree grew and the individual genetic makeup of the trees.

3.2.6 Total Phenol Content

The amount of phenols depends on tree variety, climate, location, degree of maturation and oil extraction procedures. Due to these variations, especially with nut selection and extraction procedures, every batch of Shea butter could have different level of phenol concentration. Phenolic compounds have a host of beneficial effects ranging from healing sunburn to lowering cholesterol, blood pressure and risk of coronary diseases and cancers [14].

Generally, acid, peroxide, saponification and iodine values are all indicators of edible oils that are suitable for cosmetics, soap making and lubricants making. From literature, chemical characteristics of Shea oil such as acid, peroxide, saponification and iodine values range between 2.3 and 12.59 mgKOH/kg, 2.10 and 2.50 meq/kg, 160 and 184 mgKOH/g and 39.21 and 41.37 [I.sub.2]g/100, respectively. Also, values of fatty acids in Shea oil in Uganda were reported to range between 0.65% and 57.72% [25]. Similarly, earlier analyses of physical and chemical properties of crude Shea butter in Ghana reported Fatty Acids (as oleic acid) (6.8 wt%), saponification number (179.6-190.0), and unsaponifiable matter (7.3-9.0%) [37]. Also, a report by Salunkhe and Desai [38] gave a mean fatty acids range of 3.6%-44.4% in oil seeds. In the current work, free fatty acids were found to range from 0.383 ± 0.05% to 6.334 ± 0.01% and unsaponifiable matter from 5.04 ± 0.04% to 7.89 ± 0.02%. These results both compare well with the results of Okullo et al. [25], Adomako [37] and Salunkhe and Desai [38]. However, the 3.96 ± 0.06 to 7.08 ± 0.13 meq/kg range of peroxide value in this work was higher than that reported by Okullo et al. [25] in Shea butter from Uganda. Research results report 1 and 20% free fatty acids of Shea oil, and peroxide value of less than 10 obtained in Ugandan Shea butter [25]. These are also reported as obtainable characteristics of majority of edible vegetable oils [39, 40]. These recommended values also fall within the ranges reported by Kornsteiner et al. [41]. Therefore the values obtained in the current work show that the butter compares well with others from other producer countries.

The preferred requirement in butter quality for the cosmetic industry include low FFA, reduced impurities, low water content, and high unsaponifiable fraction among others [36]. It has been stated that current Shea market prefer FFA < 6%, kernel fat content of 45-55%, water content < 7% and impurities < 1%. In the current work, moisture content and insoluble impurities fall within the preferred market requirements. The moisture content of the butter ranged from 0.177 ± 0.04 to 0.542 ± 0.19, and insoluble impurities were from 0.1496 ± 0.03 to 1.1996 ± 0.55. Shea butter from northern Ghana therefore is of adequate quality for current applications in the manufacturing industry.

5. Conclusion

From the results obtained, it can be concluded that all the Shea butter samples analysed from Ghana have acceptable levels of moisture, impurities, free fatty acids, phenolic content and peroxide values. The butter can be used in cosmetic and pharmaceutical industries, and in making soaps and confectionery. Two samples from the Northern region had lower mean percent moisture, 0.177 ± 0.04% and 0.218 ± 0.02% respectively, giving an expectation of a longer shelf life than all the other samples. Sample 4 from the Upper East region had the highest mean percent moisture content, 0.542 ± 0.19%, indicating that the sample will have the least shelf life. The least percent free fatty acids of 3.383 ± 0.05% was found in sample 4, an indication of low level of rancidity. The highest levels of mean percentage free fatty acid were found in samples 1 and 2, thus 6.174 ± 0.02% and 6.334 ± 0.01% respectively.

Also, the two mechanically extracted samples were found to have the least mean level of impurities. 0.1997 ± 0.03% and 0.1496 ± 0.03% were found in sample 7 and 8 respectively thus indicating that the butter is of high quality. Sample 2 had the highest mean impurity level of 1.1996 ± 0.55%.

Least amount of unsaponifiable matter, 5.04 ± 0.04%, was also realised in sample 7 whilst the highest was in sample 5 (7.89 ± 0.02%). Most of the unsaponifiable contents were above 6.0% making the butter excellent for use in the personal care industry. However, all the samples recorded low total phenol content and peroxide values. The highest peroxide value was 7.08 ± 0.13 meq/kg in sample 6and the lowest was 3.96 ± 0.06 meq/kg. The highest amount of total phenols (0.0575 ± 0.002 mg/g) was found in sample 4 and the lowest (0.0255 ± 0.00 mg/g) was recorded in sample 2. Proportion of catechins was higher in the samples from Upper West and Northern regions compared to the others.

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Appendix

Table 1 Ghanastandards (unrefined shea butter).

Parameter	Grade 1[a]		Grade 2[b]		Grade 3[c]	
	Min	Max	Min	Max	Min	Max
% Moisture	-	0.05	> 0.05	0.2	> 0.2	2.0
% Insoluble impurities	-	0.09	> 0.09	0.2	> 0.2	2.0
Peroxide value (meq/kg)	-	10.0	> 10.0	15.0	> 15.0	50.0
% Free fatty acid	-	1.0	> 1.0	3.0	> 3.0	8.0

Source: [35].

Table 2 Union Economique Monetaire Ouest Africaine Standards (UEMOA), (Shea butter export guide).

Parameter	1st Grade	2nd Grade	3rd Grade
% Moisture	-To 0.05	0.06-0.2	0.3-2
% Insoluble impurities	-To 0.09	0.1-0.2	0.3-2
% Free fatty acid	-To 1.00	1.1-3.0	3.1-8
Peroxide value (meq/Kg)	-To 10	11-15	15.1-50

Source: [36].