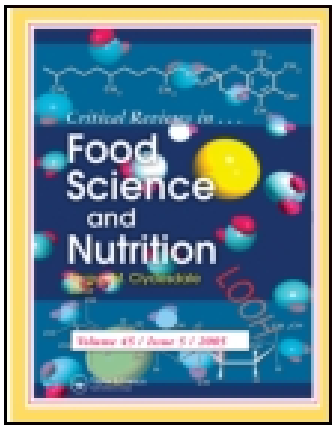

Critical Reviews in Food Science and Nutrition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/bfsn20

Nutritional Composition of Shea Products and Chemical Properties of Shea Butter: A Review

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Accepted author version posted online: 07 Feb 2013.Published online: 21 Nov 2013.

To cite this article: Fernande G. Honfo, Noel Akissoe, Anita R. Linnemann, Mohamed Soumanou & Martinus A. J. S. Van Boekel (2014) Nutritional Composition of Shea Products and Chemical Properties of Shea Butter: A Review, Critical Reviews in Food Science and Nutrition, 54:5, 673-686, DOI: 10.1080/10408398.2011.604142

To link to this article: http://dx.doi.org/10.1080/10408398.2011.604142

Critical Reviews in Food Science and Nutrition, 54:673–686 (2014)

ISSN: 1040-8398 / 1549-7852 online
DOI: 10.1080/10408398.2011.604142

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Nutritional Composition of Shea Products and Chemical Properties of Shea Butter: A Review

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Increasing demand of shea products (kernels and butter) has led to the assessment of the state-of-the-art of these products. In this review, attention has been focused on macronutrients and micronutrients of pulp, kernels, and butter of shea tree and also the physicochemical properties of shea butter. Surveying the literature revealed that the pulp is rich in vitamin C (196.1 mg/100 g); consumption of 50 g covers 332% and 98% of the recommended daily intake (RDI) of children (4–8 years old) and pregnant women, respectively. The kernels contain a high level of fat (17.4–59.1 g/100 g dry weight). Fat extraction is mainly done by traditional methods that involve roasting and pressing of the kernels, churning the obtained liquid with water, boiling, sieving, and cooling. The fat (butter) is used in food preparation and medicinal and cosmetics industries. Its biochemical properties indicate some antioxidant and anti-inflammatory activities. Large variations are observed in the reported values for the composition of shea products. Recommendations for future research are presented to improve the quality and the shelf-life of the butter. In addition, more attention should be given to the accuracy and precision in experimental analyses to obtain more reliable information about biological variation.

Keywords Shea pulp, shea kernels, shea butter, nutrient composition, antioxidant properties

INTRODUCTION

The shea tree (*Vitellaria paradoxa* C.F. Gaertn, also classified as *Butyrospermum paradoxum* or *Butyrospermum parkii*; family Sapotaceae) is indigenous to the savanna belt in sub-Saharan Africa, extending across 19 countries, from Mali in the west to Ethiopia and Uganda in the east, viz. from 16°W to 34°E longitude and 1°N to 15°N latitude (Chevalier, 1943; Masters et al., 2004). The tree is generally found in semi-arid to arid areas north of the humid forest zone and is characterized by its leaves that persist for more than nine months per year and are not used as feed or for food purposes. Its height reaches 15 to 22 m and the trunk diameter varies from 0.5 to 1 m. The shea tree begins to bear fruit after about 15 years and can produce good-quality fruits with a high fat content for up to 30 years (Hall et al., 1996). The fruits are produced from May to August; being subglobose to ovoid in shape and resembling small avocado fruits with delicious pulp when ripe. The fruit weighs from 10 to 57 g and its annual production is from 15 to 30 kg/tree (Agbahungba and Depommier, 1989). The fruit, which is a berry, consists of a thin epicarp and a soft mesocarp enclosing a single seed, sometimes two or more (Ruyssen, 1957).

The importance of the shea tree was recognized centuries ago through the fruit, its kernels, and the butter (Ruyssen, 1957; Boffa et al., 1996; Hall et al., 1996). The sweet pulp of the fruit is widely consumed in areas where the species occurs and is a rich source of sugars, proteins, calcium, ascorbic acid, and iron (Maranz et al., 2004a). An additional benefit is that it becomes available at the beginning of the rainy season, which is a period characterized by general food scarcity in sub-Saharan Africa (Maranz et al., 2004a; Ugese et al., 2008a). The kernels constitute a major commodity on the international market (Hall et al., 1996). The fat extracted from the kernels, also known as karité or shea butter, represents an important export commodity and plays, together with the kernels, a significant role in poverty alleviation (Elias and Carney, 2004). The butter is widely used for cooking and as illuminant in rural areas of the savanna

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zone of West Africa (Chevalier, 1943). Boffa et al. (1996) have reported that despite the cultivation of modern annual oil crops such as groundnut and cotton, and the influx of palm oil from higher rainfall areas, shea butter is still the primary cooking fat of the Sudanian savanna zone.

Shea butter is essentially composed of triglycerides with oleic, stearic, linoleic, and palmitic fatty acids and unsaponifiable matter (Maranz et al., 2004a). Due to its high percentage of unsaponifiables (viz. triterpenes, tocopherol, phenols, sterols), to which anti-inflammatory and antioxidant properties are ascribed, shea butter is highly demanded by international cosmetic industries (Alander, 2004; Maranz and Wiesman, 2004). Some authors have also shown the usefulness of shea butter in European and Japanese food as well as its potential as a cocoa butter replacer in chocolate manufacture (Gasparri et al., 1992; Hall et al., 1996; CNUCED, 2006).

A monograph by Hall et al. (1996) on the shea tree provides extensive information on the taxonomy, distribution, properties, utilization, agronomy, and proximate composition of shea kernels and butter. In addition, there is a database on *Vitellaria* that was compiled by Maranz during 1999–2004, which is available on the website of Prokarité (http://www.prokarite.org/vitellaria-dbase-EN/index-EN.html). It presents information on the fat content, fatty acid profile, triglyceride content, unsaponifiable compounds, shea fruit composition, and the nut quality parameters. All of the data on this website are derived from Maranz' own research on shea products in different locations in Africa. An omission of these two reviews is that they do not take all the existing data on shea products with their different analysis methods into account. Moreover, the data on shea products need to be updated to cover the research done in the past 10 years. The present review investigates the nutritional value of shea products (pulp, kernels, and butter) and the quality properties of the butter based on data from various authors and critically evaluates the similarities and divergences of the values in relation to the research methods used. For each component, the reported values are, as much as possible, converted into the same unit, and their minimum, average, and maximum values are calculated and reported in Table 1. The review ends with recommendations for further research based on the analysis of the present state of knowledge.

NUTRITIONAL COMPOSITION OF SHEA PULP

Macronutrients

The moisture content of shea fruit pulp ranges from 67% (Maranz et al., 2004a) to 80.3% (Mbaiguinam et al., 2007) (Table 1). The energy value has been reported by Ugese et al. (2008a), who found it equal to 179.5 kcal/100 g dry weight (dw). Mbaiguinam et al. (2007) and Ugese et al. (2008a) reported carbohydrate contents of 8.1 and 37.2 g/100 g dw, respectively. Ugese et al. (2008a) have assessed the nutritional composition of shea fruit pulp across its major distribution zones in Nigeria and reported that the carbohydrate content decreased at higher latitudes. They attributed this phenomenon to a more adequate water supply leading to improved photosynthesis at latitudes closer to the equator. The presence of sugars was mentioned by Maranz et al. (2004a), who found a total soluble sugar content of 13.3g/100 g dw and a glucose content of 1.6 g/100 g dw. Dako et al. (1974) reported glucose (1–2 g/100 g), fructose (1–1.9 g/100 g), and sucrose (0.7–1.7 g/100 g) in shea pulp from Ghana. The reported crude protein content varies from 4.4 g/100 g dw (Mbaiguinam et al., 2007) to 5.6 g/100 g dw (Maranz et al., 2004a). Crude lipid and crude fiber content were reported by Ugese et al. (2008a), who found it to be 1.3 and 42.2 g/100 g dw, respectively. Ash content ranges from 4.7 g/100 g dw (Mbaiguinam et al., 2007) to 5.4 g/100 g dw (Ugese et al., 2008a).

The variations in the reported values of the macronutrient composition of shea fruit pulp seem to be large even if the number of authors who investigated the macronutrient composition of shea fruit pulp is limited, although Maranz et al. (2004a) have evaluated the nutritional values and indigenous preferences for shea fruits in various African agroforestry parklands. Variations are more pronounced between data reported by Mbaiguinam et al. (2007), who collected the shea fruit in Tchad (West Africa), and those reported by Ugese et al. (2008a), who collected the shea fruit in Nigeria (West Africa). These differences seem to be primarily due to the methods of analysis used by the authors, specifically with respect to the determination of the carbohydrate content. Ugese et al. (2008a) determined the carbohydrate content by difference after using the methods of the Association of Official Analytical Chemists to assess the fat content (determined by the Soxhlet analysis), protein content (determined by the Kjeldahl method with a conversion factor of 6.25), ash content (determined by incineration), and fiber content. Mbaiguinam et al. (2007) assessed the carbohydrate content by the colorimetric method described by Dubois et al. (1956). In this method, the sample is first treated with a solution of phenol (80%) and concentrated sulfuric acid (95%). Next, the mixture is shaken and placed for 10–20 minutes in a water bath at 25–30°C before readings are taken. The absorbance of the color is measured by a spectrophotometer. To determine crude fiber contnet, Ugese et al. (2008a) used the method of Weende; this method is based on the solubilization of noncellulosic compounds (protein, starch and other digestible carbohydrates, and fat) by sulfuric acid and potassium hydroxide solutions.

Minerals

Shea fruit pulp is particularly rich in potassium (K) according to the literature (Table 1). With an average of 830.4 mg/100 g dw, the highest value (1686 mg/100 g dw) was reported by Maranz et al. (2004a) and the lowest value (21.7 mg/100 g dw) by Mbaiguinam et al. (2007). The calcium (Ca) content of shea fruit pulp varies widely from 2.5 mg/100 g dw (Ugese

Table 1 Composition of shea pulp, kernels, and butter

	Pulp				Kernels				Butter			
	Min.	Average	Max.	Reference	Min.	Average	Max.	References	Min	Average	Max	References
Macronutrients												
Moisture (%)	67.0	74.2	80.3	(Maranz et al., 2004a; Mbaiguinam et al., 2007)	5.0	6.8	8.1	(Busson, 1965; Tallantire and Goode, 1975; GRET, 2007; Mbaiguinam et al., 2007)	0.1	1.4	4.9	(Greenwood, 1929; Megnanou et al., 2007; Olaniyan and Oje, 2007; Chukwu and Adgidzi, 2008; Honfo et al., 2011)
Energy (kcal/100 g dw)		179.5		(Ugese et al., 2008a)								
Carbohydrates (g/100 g dw)	8.1	22.6	37.2	(Mbaiguinam et al., 2007; Ugese et al., 2008a)	25.0	30.9	34.8	(Greenwood, 1929; Busson, 1965; Tallantire and Goode, 1975; Duke and Atchley, 1986; Tano-Debrah and Ohta, 1994; GRET, 2007)		22.3		(Chukwu and Adgidzi, 2008)
Crude protein (g/100 g dw)	4.2	5.2	5.6	(Maranz et al., 2004a Mbaiguinam et al., 2007; Ugese et al., 2008a)	6.8	8.1	9.0	(Greenwood, 1929; Busson, 1965; Tallantire and Goode, 1975; Duke and Atchley, 1986; Tano-Debrah and Ohta, 1994; GRET, 2007)				
Crude lipid (g/100 g dw)		1.3		(Ugese et al., 2008a)	17.4	45.2	59.1	(Greenwood, 1929; Busson, 1965; Tallantire and Goode, 1975; Duke and Atchley, 1986; Tano-Debrah and Ohta, 1994; Maranz and Wiesman, 2003; Di Vincenzo et al., 2005; Mbaiguinam et al., 2007; Nkouam et al., 2007; Akihisa et al., 2010)		75.0		(Chukwu and Adgidzi, 2008)
Crude fiber (g/100 g dw)		42.2		(Ugese et al., 2008a)	3.2	9.1	20.4	(Greenwood, 1929; Ruyssen, 1957; Duke and Atchley, 1986; Tano-Debrah and Ohta, 1994)				
Ash (g/100 g dw)	4.7	5.1	5.4	(Mbaiguinam et al., 2007; Ugese et al., 2008a)	1,8	2.5	3.0	(Greenwood, 1929; Ruyssen, 1957; Duke and Atchley, 1986; Tano-Debrah and Ohta, 1994; GRET, 2007)	1.6	2.3	3.2	(Adomako, 1985; Chukwu and Adgidzi, 2008)

(Continued on next page)

Table 1 Composition of shea pulp, kernels, and butter *(Continued)*

	Pulp				Kernels				Butter			
	Min.	Average	Max.	Reference	Min.	Average	Max.	References	Min	Average	Max	References
Mineral (mg/100 g dw)												
Ca	2.5	117.3	426.0	(Eromosele et al., 1991; Maranz et al., 2004a; Mbaiguinam et al., 2007; ugese et al., 2008b)	0.1	71.8	215.2	(Tallantire and Goode, 1975; Duke and Atchley, 1986; Megnanou et al., 2007; Alhassan et al., 2011)	0.2	9.6	34.1	(Megnanou et al., 2007)
Cu	0	0.1	1.1	(Eromosele et al., 1991; Maranz et al., 2004a)		0.3		Megnanou et al., 2007	0	0.8	1.5	(Megnanou et al., 2007)
Fe	0.4	8.5	16.0	(Eromosele et al., 1991; Maranz et al., 2004a; Mbaiguinam et al., 2007; Ugese et al., 2008b)	0.01	1.6	3.1	(Duke and Atchley, 1986; Megnanou et al., 2007)	0.5	3.6	6.7	(Megnanou et al., 2007)
K	21.7	830.3	1686.0	(Maranz et al., 2004a; Mbaiguinam et al., 2007; Ugese et al., 2008b)	0.1	0.1	0.2	(Alhassan et al., 2011)	0	2.2	4.5	(Megnanou et al., 2007)
Mg	11.1	57.2	129.0	(Eromosele et al., 1991; Maranz et al., 2004a; Mbaiguinam et al., 2007; Ugese et al., 2008b)		142.6		(Megnanou et al., 2007)	0	4.5	8.9	(Megnanou et al., 2007)
Mn	0.3	0.6	0.9	(Eromosele et al., 1991; Maranz et al., 2004a)	0.1	0.4	0.7	(Alhassan et al., 2011)	0	0.006	0.14	(Alhassan et al., 2011)
P	1.0	39.8	71.4	(Eromosele et al., 1991; Maranz et al., 2004a; Mbaiguinam et al., 2007; Ugese et al., 2008b)		0.04		(Tallantire and Goode, 1975; Duke and Atchley, 1986)				
Na		19.3		(Ugese et al., 2008b)	0.9	20.9	73.9	(Megnanou et al., 2007; Alhassan et al., 2011)	1	4.2	9.6	(Megnanou et al., 2007)
Zn	0.5	2.1	4.0	(Eromosele et al., 1991; Maranz et al., 2004a; Ugese et al., 2008b)		0.9		(Megnanou et al., 2007)	1.9	2.7	3.4	(Megnanou et al., 2007)
Vitamin (mg/100 g)												
B		7.0		(Maranz et al., 2004a)								
C		196.1		(Eromosele et al., 1991)								

et al., 2008b) to 426.0 mg/100 g dw (Maranz et al., 2004a), with an average of 117.3 mg/100 g dw. The reported magnesium (Mg) content ranges from 11.1 mg/100 g dw (Mbaiguinam et al., 2007) to 129 mg/100 g dw (Maranz et al., 2004a), with a mean value of 57.2 mg/100 g dw. The phosphorus (P) content ranges greatly from 0.95 mg/100 g dw (Mbaiguinam et al., 2007) to 71.4 mg/100 g dw (Ugese et al., 2008b). Mbaiguinam et al. (2007) and Maranz et al. (2004a) reported an iron (Fe) content of 0.4 and 16 mg/100 g dw, respectively. The zinc (Zn) content varies from 0.5 mg/100 g dw (Eromosele et al., 1991) to 4 mg/100 g dw (Maranz et al., 2004a). Ugese et al. (2008b) reported that the sodium (Na) content is 19.3 mg/100 g dw. Copper (Cu) and manganese (Mn) contents are very low; the highest values were reported by Eromosele et al. (1991): 1.1 and 0.9 mg/100 g dw, respectively, while the lowest values were found by Maranz et al. (2004a): 0 and 0.3 mg/100 g dw, respectively.

Eromosele et al. (1991) and Maranz et al. (2004a) used atomic absorption spectrophotometry to determine all of the mineral elements. Ugese et al. (2008b) used this method too, except for Na and K, which were determined by flame photometry. Mbaiguinam et al. (2007) used a flame spectrophotometer to determine K, while Fe, Ca, and Mg were determined by an atomic spectrophotometer and a colorimeter was used to determine P.

Vitamins

Maranz et al. (2004a) have investigated the vitamin B content of shea fruit pulp and found it to be 7 mg/100 g dw. Eromosele et al. (1991) have investigated the vitamin C content and found that the pulp is particularly rich in vitamin C (196.1 mg/100 g) in comparison with oranges (50 mg/100 g) (Table 1). Vitamin contents were determined by high-performance liquid chromatography (HPLC).

Amino acids

The literature is limited on amino acid contents of the pulp; only Mbaiguinam et al. (2007) investigated the amino acids of shea fruit pulp (Table 2). They found that the pulp contains asparagine/aspartic acid (6.6 g/100 g protein), glutamine/glutamic acid (5.6 g/100 g protein), proline (3.9 g/100 g protein), and leucine (3.1 g/100 g protein), and it is limited in cysteine (1.1 g/100 g protein) and methionine (0.1 g/100 g protein).

Table 2 Amino acids (g/100 g proteins) of shea fruit pulp

Amino acid	Value	Amino acid (*continued*)	Value
Asparagine/aspartic acid	6.6 ± 0.3	Methionine	0.1 ± 0.0
Threonine	1.7 ± 0.2	Isoleucine	2.0 ± 0.1
Serine	2.1 ± 0.2	Leucine	3.1 ± 0.1
Glutamine/glutamic acid	5.6 ± 0.5	Tyrosine	1.7 ± 0.2
Proline	3.9 ± 0.2	Phenylalanine	1.5 ± 0.1
Glycine	2.2 ± 0.2	Lysine	1.8 ± 0.1
Alanine	2.4 ± 0.1	Histidine	1.2 ± 0.1
Valine	2.5 ± 0.2	Arginine	3.1 ± 0.14
Cysteine	1.1 ± 0.1		

Source: Mbaiguinam et al. (2007).

NUTRITIONAL COMPOSITION OF SHEA KERNELS

After gathering/collecting, shea fruits are depulped, boiled for one to two hours and dried for 7–15 days to obtain the nuts. Throughout the shea-butter-producing areas of West Africa, producers employ different traditional methods for drying the shea nuts. Most use exposure to the sun, while some use traditional ovens. After drying, the nuts are shelled by mortar, pestle, or stick and the kernels are sundried for three to seven days. These traditional processes are common practice in the shea tree locations.

Macronutrients

The moisture content of dried shea kernels ranges from 5% (Busson, 1965) to 8.1% (Mbaiguinam et al., 2007), with an average of 6.8% (Table 1). The variation in the reported values for kernels is low compared with the variation in the reported values for the moisture content of the pulp. To our knowledge, no author has investigated the energy content of shea kernels. Reported carbohydrate contents vary from 25 g/100 g dw (Busson, 1965) to 34.8 g/100 g dw (Tano-Debrah and Ohta, 1994). Crude protein values range from 6.8 g/100 g dw (Tallantire and Goode, 1975) to 9 g/100 g dw (GRET, 2007).

Many authors have investigated the fat content of shea kernels. Crude lipid contents of dried kernels vary greatly among the authors (Table 1). With an average of 45.2 g/100 g dw, the highest value (59.1 g/100 g dw) was found by Tano-Debrah and Ohta (1994), who extracted the fat by enzyme-assisted aqueous extraction. The lowest value (17.4 g/100 g dw) was reported by Nkouam et al. (2007) by using supercritical CO_2. They also used hexane to extract the fat from the kernels and found that the extraction yield varied from 44.9 to 53.8 g/100 dw, compared with the yield of 17.4–39.6 g/100 g dw for extraction by supercritical CO_2. Mbaiguinam et al. (2007) used two different methods to extract the butter: hexane extraction and traditional manual extraction, as performed in the rural areas in which sundried kernels were ground, churned with water, and heated to get the butter. They obtained different fat yields, namely 50% by solvent extraction and 30% by manual method, and concluded that a chemical solvent permits far better extraction, but also requires special equipment and chemical reagents, which are not available on the farms. Apart from differences caused by the use of different analytical methods, the variation in the fat content of shea kernels could also be attributed to environmental influences, geographical location, agronomic factors, and genetic variation (Maranz and Wiesman, 2003; Di Vincenzo et al., 2005). High altitudes and cool temperatures (20–25°C) are

associated with high fat contents of shea kernels (Maranz and Wiesman, 2003; Kapseu et al., 2001).

With an average of 9 g/100 g dw, the lowest fiber content (3.2 g/100 g dw) of shea kernels was reported by Greenwood (1929) and the highest value (20.4 g/100 g dw) by Tano-Debrah and Ohta (1994), who have used the method of Lee et al. (1992) with heat-stable α-amylase, α-glucosidase, and a protease. Ash contents range from 1.8 g/100 g dw (Duke and Atchley, 1986) to 3 g/100 g dw (Greenwood, 1929), with an average of 2.5 g/100 g dw.

Minerals

Few authors have investigated the mineral contents of shea kernels (Table 1). The Ca content reported by Megnanou et al. (2007) is equal to 215.2 mg/100 g dw, but Tallantire and Goode (1975), Duke and Atchley (1986), and Alhassan et al. (2011) observed a value of 0.1 mg/100 g dw. This great variation is also observed for the Fe content, for which Megnanou et al. (2007) found a value of 3.1 mg/100 g dw, while Duke and Atchley (1986) reported a value of 0.003 mg/100 g dw. Except Alhassan et al. (2011), who used neutron activation analysis (it consists of the irradiation of the sample in one reactor) to determine the mineral contents, all of these authors used atomic absorption spectrophotometry. The variation in the reported data could be attributed to the environmental and genetic influences and also to the identification method. Megnanou et al. (2007) found a value of 142.6 mg/100g dw for Mg, 73.9 mg/100 g dw for Na, 0.9 mg/100 g dw for Zn, and 0.3 g/100 g dw for Cu, and Alhassan et al. (2011) found 0.1 mg/100 g dw for K and 0.4 mg/100 g dw for Mn.

Vitamins

No author has investigated the vitamin content of shea kernels, to our knowledge.

NUTRITIONAL COMPOSITION OF SHEA BUTTER

The first stage of shea butter extraction by rural women after obtaining the kernels involves roasting and grinding the kernel into a powdery material or flour, which is then mixed with warm or lukewarm water. The resulting semi-solid mixture is then stirred continuously or kneaded by hand until separation of the oily phase occurs. This fat-rich fluid is collected and subsequently boiled until it is clear. The fat is then poured over a sieve into a basin where it is left to solidify.

Macronutrients

The reported moisture contents of shea butter vary from 0.1% (Olaniyan and Oje, 2007) to 4.9% (Honfo et al., 2011) (Table 1). However, exceptional higher values of 8.4% and 14.5% were mentioned by Megnanou et al. (2007), who evaluated the physicochemical and microbiological characteristics of shea butter sold on markets in Côte d'Ivoire. However, the required moisture contents of shea butter destined for cosmetic and food industries are 0.05% and less than 0.2%, respectively (Kassamba, 1997). Carbohydrates and crude lipid contents were reported by Chukwu and Adgidzi (2008), who found them to be 22.3 g/100 g dw and 75.0 g/100 g dw, respectively. Reported ash content ranges from 1.3 g/100 g dw (Chukwu and Adgidzi, 2008) to 3.2 g/100 g dw (Adomako, 1985), with an average of 2.2 g/100 g dw.

All of the authors used the methods of the Association of Official Analytical Chemists to determine the different values.

Minerals

Some mineral contents of shea butter were assessed by Megnanou et al. (2007) by atomic absorption spectroscopy and by Alhassan et al. (2011) by neutron activation analysis (Table 1). Ca value varies from 0.2 to 34.1 mg/100 g dw, Na reported is in the range of 0.7–9.6 mg/100 g dw, Fe level is 0.5–6.7 mg/100 g dw, Mg value is 0–8.9 mg/100 g dw, Mn content range is 0–0.14 mg/100 g dw, Zn level is 1.9–3.4 mg/100 g dw, Cu content is 0–1.5 mg/100 g dw, and K value ranges from 0 to 4.5 mg/100 g dw.

Vitamins

No published reports on the vitamin contents of the shea butter were found, but the tocopherol content of shea butter was investigated by Maranz and Wiesman (2003), and more details are given next. However, shea butter should contain some vitamin A in view of its yellow color.

PHYSICOCHEMICAL PROPERTIES OF SHEA BUTTER

Shea butter is mainly composed of triglycerides and a large fraction of unsaponifiable components, which are promising active ingredients for new functional cosmetic products (Akihisa et al., 2010a). As presented in Table 3, the average unsaponifiable content of shea butter is 8.1%. It ranges from 1.2% (Njoku et al., 2000) to 17.6% (Megnanou et al., 2007). However, Adriaens (1943) found that the riper the fruit is, the lower the quantity of unsaponifiable matter is, while Ruyssen (1957) reported that the amount of unsaponifiable matter varied from year to year and in accordance to the variation in rainfall. The values for unsaponifiable matter reported by different authors are higher than those found in most vegetable oils (Anhwange et al., 2004; Dhellot et al., 2006; Tchobo et al., 2007).

The acid value of shea butter is a measure of the extent to which the glycerides in the butter have been decomposed by lipase or other actions such as heat and light. It is often used

Table 3 Physicochemical properties of shea butter

Parameter	Min.	Average	Max.	References
Unsaponifiable content (%)	1.2	8.1	17.6	(Greenwood, 1929; Peers, 1977; Gasparri et al., 1992; Tano-Debrah and Ohta, 1994; Njoku et al., 2000; Kapseu et al., 2001; Alander and Andersson, 2002; Letchamo et al., 2007; Mbaiguinam et al., 2007; Megnanou et al., 2007; Chukwu and Adgidzi, 2008; Akihisa et al., 2010a)
Acid value (mg KOH/g)	0.0	8.5	21.2	(Mital and Dove, 1971; Renard, 1990; Ezema and Ogujiofor, 1992; Njoku et al., 2000; Womeni et al., 2006; Mbaiguinam et al., 2007; Megnanou et al., 2007; Nkouam et al., 2007; Womeni et al., 2007; Chukwu and Adgidzi, 2008; Dandjouma et al., 2009; Okullo et al., 2010; Honfo et al., 2011)
Peroxide value (meq O_2/kg)	0.5	7.6	29.5	(Renard, 1990; Womeni et al., 2004; Megnanou et al., 2007; Womeni et al., 2007; Chukwu and Adgidzi, 2008; Dandjouma et al., 2009; Okullo et al., 2010; Honfo et al., 2011)
Free fatty acid (%)	1.0	5.3	10.7	(Greenwood, 1929; Badifu, 1989; Renard, 1990; Olaniyan and Oje, 2007)
Iodine value (mg I_2/100 g)	21.68	51.4	89.5	(Mital and Dove, 1971; Renard, 1990; Gasparri et al., 1992; Tano-Debrah and Ohta, 1994; Njoku et al., 2000; Kapseu et al., 2001; Womeni et al., 2004; Mbaiguinam et al., 2007; Megnanou et al., 2007; Nkouam et al., 2007; Chukwu and Adgidzi, 2008; Okullo et al., 2010; Honfo et al., 2011)
Saponification value (mg KOH/g)	132.0	180.9	207.5	(Mital and Dove, 1971; Renard, 1990; Ezema and Ogujiofor, 1992; Gasparri et al., 1992; Tano-Debrah and Ohta, 1994; Njoku et al., 2000; Kapseu et al., 2001; Womeni et al., 2004; Mbaiguinam et al., 2007; Megnanou et al., 2007; Chukwu and Adgidzi, 2008; Okullo et al., 2010; Honfo et al., 2011)
Refractive index (40°C)	1.45	1.5	1.5	(Renard, 1990; Ezema and Ogujiofor, 1992; Gasparri et al., 1992; Megnanou et al., 2007; Chukwu and Adgidzi, 2008; Okullo et al., 2010)
Relative density (40°C)	0.90	0.9	1.0	(Renard, 1990; Kapseu et al., 2001; Chukwu and Adgidzi, 2008)
Melting point (°C)	25	35.9	45	(Mital and Dove, 1971; Renard, 1990; Ezema and Ogujiofor, 1992; Gasparri et al., 1992; Tano-Debrah and Ohta, 1994; Kapseu et al., 2001; Womeni et al., 2006; Megnanou et al., 2007; Chukwu and Adgidzi, 2008)
Impurity (%)	0	0.9	3.5	(Greenwood, 1929; GRET, 2007)
Color	Yellow, yellow-orange, yellow-green, pale-yellow, orange, beige, ivory, gray, white, ivory-white, brown, cream, light gray, white			(Greenwood, 1929; Letchamo et al., 2007; Megnanou et al., 2007; Okullo et al., 2010)

as a general indicator of the condition and edibility of the oil. The reported acid values of shea butter vary from 0 mg KOH/g (Womeni et al., 2006) to 21.2 mg KOH/g (Nkouam et al., 2007), with an average of 8.1 mg KOH/g. However, Nkouam et al. (2007) found the high acid value of 128.2 mg KOH/g in shea oil extracted by supercritical CO_2 in kernels that had been stored for two years. The required acid values for butter that is to be used for cosmetic and food applications are 0.3 mg KOH/g of oil and less than 9 mg KOH/g of oil, respectively (Kassamba, 1997).

The decomposition of triglycerides is also measured by free fatty acid (FFA) percentage. The FFA values reported range from 1% (Badifu, 1989) to 10.7% of oil (Badifu, 1989), with an average of 5.3% of oil. The maximum tolerated amounts of FFA for cosmetic and food uses are 1% and 3%, respectively (Kassamba, 1997). FFA produced irritation on the tongue and in the throat (Kirk and Sawyer, 1991). Kapseu et al. (2001) reported that the acid value and FFA of the butter increase with the duration of the storage of the shea fruits. They explained this increase by the physiological activity of fruits; thus, during storage, the fatty acids are degraded to produce some energy and precursors for the synthesis of new molecules.

Kirk and Sawyer (1991) described peroxide as a first product of oxidation of unsaturated fats and oils. With an average of 7.6 meq O_2/kg, the reported peroxide value ranges from 0.5 meq O_2/kg (Njoku et al., 2000) to 29.5 meq O_2/kg (Dandjouma et al., 2009). Most of the authors found peroxide values below the average value reported here; the high value reported by Dandjouma et al. (2009) is due to the kernels used for the butter extraction, which were fermented before the extraction. For use in the cosmetic and food industries, the required peroxide values of shea butter utilizations are 1 meq O_2/kg and less than 10 meq O_2/kg, respectively (Kassamba, 1997). For this parameter, Kirk and Sawyer (1991) found that during fat storage, peroxide formation is slow at first during an induction period (which may vary from a few weeks to several months), depending on the particular oil and temperature.

The iodine value expresses the degree of saturation of oil. It is an indicator of the storability of the oil; the higher the iodine numbers, the higher the degree of unsaponification, and the shorter the shelf-life (Hui, 1996). As presented in Table 3, the average reported iodine value is 51.4 mg I_2/100 g. It ranges from 21.7 mg KOH/g (Nkouam et al., 2007) to 89.5 mg I_2/100 g (Womeni et al., 2004). The low value reported by Nkouam et al. (2007) was found in butter extracted by supercritical CO_2.

Literature values show a considerable range for the saponification values, but most fall between 132 mg KOH/g (Ezema and Ogujiofor, 1992) and 207.5 mg KOH/g (Womeni et al., 2004), and the average is 180.9 mg KOH/g.

Kirk and Sawyer (1991) defined the refractive index of oil as the ratio of the incident angle to the refracted angle when

Table 4 Composition (%) in triglycerides of shea butter

Polyunsaturated									Di-unsaturated				Mono-unsaturated			
SLiLi*	OOLi	POLi	OOO	SLiO	LiLiLi	OLiO	LiLnLi	PLiP	POO	PLiS	SOO	AOO	PPS	POS	SOS	References
	2	2.6	7.8	10.5	–	–	–	–	2.5	–	35.2	–	0.5	8.5	32.6	Kapseu et al., 2001
0.6	–	–	10.8	5.2	1.7	1.6	0.3	0.1	3.1	1.5	26.7	1.2	–	5.3	40.4	Di Vincenzo et al., 2005

S = stearic, Li = linoleic, O = oleic, P = palmitic, Ln = linolenic, A = arachidic.

light travels through the oil at a given wavelength. Fats/oils have specific refractive indices, which are used as a characteristic for identification and for checking purity. Concerning this parameter, all authors reported values of about 1.46 at 40°C.

The relative density is a measure of the purity of a substance and is the ratio of the density of a substance to the density of water (Kirk and Sawyer, 1991). It changes with temperature. At 40°C, the relative density found by most of the authors was close to the average of 0.93 (Table 3).

The melting point is described by Letchamo et al. (2007) as an important aspect of traditional processing of shea butter. In many West African countries, women boil roots, grasses, or branches, together with shea nuts, during shea butter preparation to enhance the melting point of the butter. Hence, the degree of variation in the melting point might not reflect the actual nature of shea butter. The reported melting points vary between 25°C (Womeni et al., 2006) and 45°C (Gasparri et al., 1992), with an average of 35.9°C, depending on shea origin and processing method. Bonkoungou (1987) stated that a melting point close to body temperature is an attribute that makes the butter particularly suitable as a base for ointments and medicines.

The insoluble impurities of shea butter reflect the presence of unwanted components in the butter. Greenwood (1929) found that the insoluble impurities varied from 0.1 to 0.4%, while the Group of Research Technology Exchange (GRET) reported in their bulletin of 2007 that the insoluble impurities ranged from 0 to 3.5% in shea butter extracted by a centrifugal process. Cosmetic and food industries have set 0% and less than 0.2%, respectively, as maximum limits for insoluble impurities of shea butter (Kassamba, 1997).

The color of shea butter is reported to vary from white to gray with many nuances. Kar and Mital (1981) reported that the final shea butter color is related to the quality of the kernels processed. The presence of fungal infection (visible as black nuts) increases the darkness of the butter; this can be prevented or reduced by more efficient drying and roasting techniques. Chukwu and Adgidzi (2008) found that the color of shea butter varies depending on the processing technique, in particular on the temperature used during processing. Some roots or bark of *Cochlospermum tinctorium* are often used to improve shea butter color.

TRIGLYCERIDES AND FATTY ACIDS IN SHEA BUTTER

Kapseu et al. (2001) and Di Vincenzo et al. (2005) identified three groups of triglycerides in shea butter: polyunsaturated, di-unsaturated, and mono-unsaturated; no saturated triglycerides were reported (Table 4). The main polyunsaturated triglyceride was OOO (10.8%), while the principal di-unsaturated and mono-unsaturated were SOO (35.2%) and SOS (40.4%), respectively. Maranz et al. (2004b) assessed the variations in fat composition across the *Vitellaria* species distribution range and found that the main triglycerides in shea butter were SOS and SOO. SOS ranged from 13% of total triglycerides in Ugandan shea butter to 45% in Burkina Faso shea butter; while SOO was highest (28–30%) in Uganda and some Malian shea butter. The SOS to SOO ratio is an important indicator for the melting point of a plant fat.

Kapseu et al. (2001) and Maranz et al. (2004b) used the equivalent carbon number procedure and HPLC analysis to determine triglyceride composition, while Di Vincenzo et al. (2005) used a gas chromatograph to identify the triglycerides.

Fatty acid analysis shows great variability in shea butter among the reported values (Table 5). After screening 150 samples of shea kernels from different origins, Di Vincenzo et al. (2005) showed that shea butter fat is characterized by 16 saturated and unsaturated fatty acids, but five of them (oleic, stearic, palmitic, linoleic, and arachidic) are the most dominant. The major fatty acid reported by different authors is oleic acid, which ranges from 37.2% (Ugese et al., 2010) to 60.7% (Akihisa et al., 2010a), with an average of 49.3%. The second fatty acid is stearic acid, which varies from 29.5% (Okullo et al., 2010) to 55.7% (Akihisa et al., 2010a). Certain authors (Maranz et al., 2004b; Di Vincenzo et al., 2005; Akihisa et al., 2010a) found that oleic acid is dominant in butters from Uganda, while stearic acid is dominant in samples of West Africa provenances. Concerning the palmitic acid content, the highest content (7.5%) was reported by Okullo et al. (2010) and the lowest (3.4%) by Di Vincenzo et al. (2005), the average is 4.4%. The reported linoleic acid content ranges from 5.5% (Mendez and Lope, 1991) to 7.9% (Mbaiguinam et al., 2007), with an average of 6.6%. Maritz et al. (2006) reported that the linoleic acid is an essential fatty acid that is vital in nutrition because it intervenes in the fabrication of the cell membrane and cannot be synthesized by the body. According to Maranz and Wiesman (2004), the linoleic acid content of 6–8% makes shea oil a moderate source of essential fatty acids in the human diet. As reported in Table 5, the content of arachidic acid varies from 0.6% (Mendez and Lope, 1991) to 1.8% (Akihisa et al., 2010a), and linolenic acid ranges from 0.2% (Tholstrup et al., 1994) to 1.6% (Tano-Debrah and Ohta, 1994). Maranz and Wiesman (2004) reported that the large variability in fatty acid profiles indicates that shea butter is not a single uniform product across the continent. For

Table 5 Main fatty acids content of the shea butter

Fatty acid	Gram fatty acid/100 g fat			References
	Min.	Average	Max.	
Palmitic 16:00	3.3	4.4	7.5	(Tano-Debrah and Ohta, 1994; Tholstrup et al., 1994; Alander and Andersson, 2002; Maranz et al., 2004; Di Vincenzo et al., 2005; Mbaiguinam et al., 2007; Letchamo et al., 2007; Akihisa et al., 2010a; Okullo et al., 2010; Ugese et al., 2010)
Stearic 18:00	29.5	40.4	55.7	(Kershaw and Hardwick, 1981; Tano-Debrah and Ohta, 1994; Tholstrup et al., 1994; Kapseu et al., 2001; Alander and Andersson, 2002; Maranz et al., 2004; Di Vincenzo et al., 2005; Mbaiguinam et al., 2007; Letchamo et al., 2007; Akihisa et al., 2010a; Okullo et al., 2010; Ugese et al., 2010)
Oleic 18:01	37.2	49.3	60.7	(Kershaw and Hardwick, 1981; Tano-Debrah and Ohta, 1994; Tholstrup et al., 1994; Kapseu et al., 2001; Alander and Andersson, 2002; Maranz et al., 2004; Di Vincenzo et al., 2005; Mbaiguinam et al., 2007; Letchamo et al., 2007; Akihisa et al., 2010a; Okullo et al., 2010; Ugese et al., 2010)
Linoleic 18:02	4.3	6.6	8.0	(Mendez and Lope, 1991; Tano-Debrah and Ohta, 1994; Tholstrup et al., 1994; Kapseu et al., 2001; Alander and Andersson, 2002; Maranz et al., 2004; Di Vincenzo et al., 2005; Mbaiguinam et al., 2007; Letchamo et al., 2007; Akihisa et al., 2010a; Okullo et al., 2010; Ugese et al., 2010)
Linolenic 18:03	0.2	0.4	1.7	(Tano-Debrah and Ohta, 1994; Tholstrup et al., 1994; Akihisa et al., 2010a)
Arachidic 20:00	0.8	1.3	1.8	(Kapseu et al., 2001; Maranz et al., 2004; Di Vincenzo et al., 2005; Letchamo et al., 2007; Akihisa et al., 2010a; Okullo et al., 2010)

example, Malian shea butter has more resemblance to cocoa butter, while Ugandan shea butter is more comparable to olive oil, due to its high oleic content.

For all authors, fatty acid methyl esters were prepared by KOH methylation and fatty acid profiles were determined by gas chromatography.

THE UNSAPONIFIABLE FRACTION OF SHEA KERNELS AND BUTTER

Triterpene Alcohol Compounds

The main components of the unsaponifiable fraction are triterpene alcohols. Peers (1977) reported that the most characteristic tritrepene alcohols of the unsaponifiable fraction of shea butter were α-amyrin (26.5%), β-amyrin (10.2%), lupeol (21.7%), and butyrospermol (25%), most of which occur as acetic acid and cinnamic acid ester (Table 6). According to Alander and Andersson (2002), the α-amyrin content was 40–50%, the β-amyrin content 5–10%, the lupeol content 10–20%, and the butyrospermol content 15–25%. Akihisa et al. (2010a) assessed the triterpene alcohols in shea nuts from seven African countries and showed four triterpene acetates (α-amyrin acetate, β-amyrin acetate, lupeol acetate, and butyrospermol acetate) and four triterpene cinnamates (α-amyrin cinnamate, β-amyrin cinnamate, lupeol cinnamate, and butyrospermol cinnamate). Di Vincenzo et al. (2005) analyzed the percentages of acetyl and cinnamyl triterpene esters and showed strong regional affinity, with the highest values found in Nigerian provenances and the lowest values in Ugandan butters. Combination of these data suggests that West African provenances had significantly higher levels of both acetyl and cinnamyl triterpenes than shea butter from East Africa.

Table 6 Main compound of triterpene alcohols of shea butter

α-Amyrin (%)	β-Amyrin (%)	Lupeol (%)	Butyrospermol (%)	References
26.5	10.2	21.7	25	Peers, 1977
40–50	5–10	10–20	15–25	Alander and Andersson, 2002
31.3–41.1	8.2–13.2	17.5–25.1	14.9–26.3	Akihisa et al., 2010b

Tocopherol Content

Maranz and Wiesman (2004) evaluated the tocopherol content of shea butters from 11 African countries by HPLC and found high variability between provenances and a significant effect of climate on the α-tocopherol levels. They found that the tocopherol content (α, β, γ, and δ) ranged from 29 to 805 μg/g, and the main tocopherol was α-tocopherol with 64% (112 μg/g), followed by γ-tocopherol (15%), δ-tocopherol (14%), and β-tocopherol (7%). They stated that the α-tocopherol content appeared to be directly related to the temperature of the climatic zone from which the butter originated. The amount of both α-tocopherol and total tocopherols in shea butter increases with the temperature. Also, several factors linked to environmental conditions, the storage period of the oil, and the genetic profile have been reported to cause variation in α-tocopherol. It has been reported that α-tocopherol always increases with temperature during seed maturation and also with drought (Kornsteiner et al., 2005)

Phenolic Compounds

Maranz et al. (2003) identified and quantified eight catechin compounds in shea kernels from 40 shea tree provenances

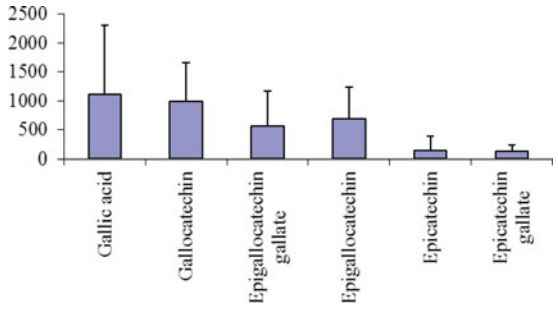

Figure 1 Concentrations (parts per million) of phenolic compounds in shea kernels. Error bars represent standard deviation. *Source*: Maranz et al. (2003) (Color figure available online).

from 10 African countries by liquid chromatography and mass spectrometry. The mean kernel content of the eight catechin compounds was 4000 ppm (0.4% of kernel in dry weight), with a 2100–9500 ppm range. They reported that among the six major phenolic compounds, gallic acid was the major phenolic compound, comprising an average of 27% of the measured total phenols and exceeding 70% in some populations (Fig. 1). They found a wide variation in phenolic compound proportion across the countries, and they also reported that the amount of phenolic compounds followed a parabolic curve, with high content occurring under both cool, wet and hot, dry conditions and low amount under unstressed, mesic growth conditions. Thus, the overall concentration of phenolic compounds in shea kernels may be linked to the level of environmental stress in the source population, with the highest phenolic concentrations occurring in *Vitellaria* trees at the upper and lower temperature limits of the species. This phenomenon has been reported in other species such as olive (Mulinacci et al., 2001; Patumi et al., 2002). However, Shahidi and Alexander (1998) and Yang et al. (2001) reported that the compounds from the catechin family in shea kernels were similar to those found in green tea, which has gained wide attention recently as an antioxidant-rich and healthy beverage.

In the same study, Maranz et al. (2003) have extracted total polyphenol in some samples of shea butter by colorimetric analysis using the Folin–Ciocalteu reagent method of Gutfinger (1981). The different samples of shea butter were extracted by hexane and the authors found an average of 97 ppm of total polyphenols, with the values for different provenances varying between 62 and 135 ppm. These values indicate that 90–98% of the potential phenolic content of shea butter is lost in hexane extraction of shea kernels.

Sterol Content

The unsaponifiable fraction of shea butter contains a small fraction of sterols, and few authors have investigated this aspect. Peers (1977) reported two sterol compounds in shea butter: stigmasterol and Δ7-stigmasterol. In addition to these compounds, Njoku et al. (2000) identified β-sitosterol and cholesterol (Table 7). According to Li and Sinclair (2002) β-sitosterol, campesterol, and stigmasterol are the main sterols in plants and constitute bioactive compounds that can decrease plasma/serum levels of lipids and lipoprotein lipids.

Table 7 Sterol contents of shea butter

Stigmasterol (mg/100 g)	β-Sitosterol (mg/100 g)	Δ7-Stigmasterol (mg/100 g)	Cholesterol (mg/100 g)	References
1.74	–	2.01		Peers, 1977
0.5	0.4	–	0.2	Njoku et al., 2000

DISCUSSION

Variation in Reported Data

This review shows that the reported values of nutrient contents of shea products (pulp, kernels, and butter) vary greatly. The causes of these variations are well known and most authors have worked on them. Variations are first due to the different provenances of the samples, the age of the sample, the climatic conditions, the genetic variation, and the soil structure and its chemical composition. Variation can also be attributed to the methods of analysis such as in the case of the determination of the carbohydrate content, which was determined by difference in one case and by a colorimetric method in the other case. In addition, another cause of variation is linked to shea butter composition and this is due to the distribution range of the shea tree by the fact that the tree is wild, and the different methods to extract the butter.

Antioxidant and Anti-inflammatory Effects of Shea Butter

The most valued product of the shea tree is the shea butter extracted from the kernels. The majority of this fat is consumed directly at home as cooking oil and food accompaniment. This butter has been found to have high levels of tocopherol constituents, with significant regional variation in the content of α-tocopherol. In addition, shea butter contains some polyphenols and its concentration depends on the extraction technique. Then, in order to retain higher levels of phenolic compounds in shea butter, the extraction and refining processes will need to be modified. However, both tocopherol and polyphenol constitute some antioxidants, and consuming antioxidant-rich foods can contribute to the prevention of oxidation in the human cell, and hence of some diseases. In general, antioxidants such as α-tocopherol can be responsible for reducing degenerative diseases and also for mopping up free radicals responsible for oxidative damage of cell membranes and the skin and for causing cancer. Since α-tocopherol is one of the groups of fat-soluble vitamin E compounds that cannot be synthesized by animal cells, it must be obtained from plant sources through the diet (Kornsteiner et al., 2005). Because of their vital role in

nutrition, the presence of α-tocopherol in shea butter makes it an important fat, especially in human diet, nutrition, and health.

The non-glyceride constituents of shea butter permit its use in skin care products and cosmetic product formulations. Most of the non-glyceride constituents are triterpene alcohols of cinnamates, which possess anti-inflammatory effects, especially lupeol and α/β-amyrin in their esterified forms (Alander and Andersson, 2002). Some anti-inflammatory activities against tetradecanoylphorbol acetate (TPA)-induced inflammation in mice were reported by Akihisa et al. (2010a), who also noticed that the triterpene cinnamate isolated from shea fat could be valuable as a chemopreventive agent in chemical carcinogenesis. Although these compounds can be found in other plants, shea kernels are a particularly attractive source due to their high levels of triterpene alcohols (up to 6.2% of unsaponifiable matter in fat). In addition, triterpene alcohol esters are useful in high-performance skin care products such as sunscreen and suncare products because of the combination of its anti-inflammatory action and protease-inhibiting effects (Alander, 2004). According to the findings of Di Vincenzo et al. (2005), the shea butter from West Africa had significantly higher levels of both acetyl and cinnamyl triterpenes than that of East Africa. Vissers et al. (2000) and Maranz et al. (2003) reported that these results should be of significant interest to the cosmetic and pharmaceutical industries. The good stability and the inherently good formulating properties associated with shea butter in general open up a number of possibilities, extended by the variety of derived products that can be obtained from this well-researched raw material.

Analysis of the Main Unit Operations of Shea Butter Processing

The traditional extraction techniques for shea butter have many unit operations that have an impact on the quality of the butter. The boiling of the depulped shea fruit is generally done during 15–60 minutes to inactivate the enzymes responsible for hydrolysis of the fatty acids and to facilitate shelling. If the boiling time is too short, shelling becomes difficult because latex appears on the kernels, binding them to the shells, and enzymes are not inactivated. The direct exposure of the nuts/kernels to the sun for drying is one of the handicaps of shea butter production because it takes several days (7–15 days) and, in the meantime, the nuts are subjected to the prevailing climatic conditions with the risks of pollution and hydrolysis of fatty acids by lipases, which leads to increasing amounts of FFA in the product. Bup et al. (2008) showed that shea kernels dried without direct exposure to the sun yielded butter that was according to the standards for cosmetic and pharmaceutical uses. The storage of the kernels is not included directly in the shea butter extraction process, but considering the annual gathering of the fruits, the storage of nuts/kernels is inevitable for butter extraction around the year. The kernels are usually stored for 1–12 months in bags or a granary before export or further use (Honfo et al., 2011). Most storage conditions that are used at present could lead to germination and infestation by microorganisms and birds. The germination of kernels is due to the bad drying of kernels before storage. According to processors, the roasting of the crushed kernels is generally done for 30–60 minutes to facilitate fat extraction and improve the sensory characteristics of the butter (Honfo et al., 2011). Not controlling this operation could lead to cumbersome volatile compounds in the product. Bail et al. (2009) compared the volatile profile of different shea butters and reported that processing steps, including drying of kernels before producing the fat and additional roasting procedures, influence shea butter volatile compounds significantly. Most these volatile compounds investigated by Bail et al. (2009) are composed of fatty acid degradation products such as acetic and hexanoic acid, carbonyl compounds (hexanal, heptanal, trans-2-heptenal, 2,4-heptadienal), 2-pentylfurane, and processing compounds such as furfural as well as glycerol. Insufficient heating during the roasting may prevent the oil from attaining the maximum flow during extraction and, at too high a temperature, can also reduce the yield of oil. Finally, the storage of the shea butter is done under bad conditions; it is one of the key causes of its quality deterioration by, for example, hydrolysis and oxidation of fatty acids. Some undesirable volatile/aroma compounds could also be produced in shea butter during different storage conditions.

Table 8 Shea pulp composition with the recommended daily intake (RDI) for children (4–8 years old)

Nutrients	Energy	Carbohydrates		Protein		Ca		Fe		Mg		Vit C
RDI for children (g/day)	1710 (kcal/day)	130	130	19	19	0.8	0.8	0.01	0.01	0.13	0.13	0.025
Pulp composition (g/100 g)	kcal/100 g	Highest*	Lowest*	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	
	179.5	37.2	8.1	5.6	4.4	0.43	0.003	0.016	0.0004	0.13	0.01	0.1661
% RDI covered by consumption of 50 g/d	5.2	14.3	3.1	14.7	11.5	26.6	0.2	80.0	2.1	49.6	4.3	332.2
% RDI covered by consumption of 80 g/d	8.4	22.9	4.9	23.6	18.4	42.6	0.3	128.0	3.4	79.4	6.8	531.5
% RDI covered by consumption of 100 g/d	10.5	28.6	6.2	29.5	23.1	53.3	0.3	160.0	4.2	99.2	8.5	664.4

Source: RDIs for individuals for energy: http://www.fnri.dost.gov.ph/reni/renitable1.htm (accessed November 3, 2010).
Source: Other recommended daily intakes for individuals: http://www.iom.edu/Global/News%20Announcements/~/media/Files/Activity%20Files/Nutrition/DRIs/DRISummaryListing2.ashx (accessed November 3, 2010).
*Highest and lowest values reported by different authors for nutrient composition of shea pulp.

Table 9 Shea pulp composition with the recommended daily intake (RDI) for pregnant women (19–30 years old)

Nutrients	Energy	Carbohydrates		Protein		Ca		Fe		Mg		Vit C
RDI for pregnant women (g/day)	(kcal/day) 2240	175	175	71	71	1	1	0.027	0.027	0.350	0.350	0.085
Pulp composition (g/100g)	kcal/100 g	Highest*	Lowest*	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	
	179.5	37.2	8.1	5.6	4.4	0.43	0.003	0.016	0.0004	0.13	0.01	0.1661
% RDI covered by consumption of 50 g/d	4.0	10.6	2.3	3.9	3.1	21.3	0.1	29.6	0.8	18.4	1.6	97.7
% RDI covered by consumption of 80 g/d	6.4	17.0	3.7	6.3	4.9	34.1	0.2	47.4	1.2	29.5	2.5	156.3
% RDI covered by consumption of 100 g/d	8.0	21.3	4.6	7.9	6.2	42.6	0.3	59.3	1.6	36.9	3.2	195.4

Source: RDIs for individuals for energy: http://www.fnri.dost.gov.ph/reni/renitable1.htm (accessed November 3, 2010).
Source: Other recommended daily intakes for individuals: http://www.iom.edu/Global/News%20Announcements/~/media/Files/Activity%20Files/Nutrition/DRIs/DRISummaryListing2.ashx (accessed November 3, 2010).
*Highest and lowest values reported by different authors for nutrient composition of shea pulp.

Contribution of Shea Pulp to Recommended Daily Intake

In the following calculation, digestibility and bioavailability could not be taken into account because of lack of data. Therefore, the values given should be seen as maximum values; in reality, they will be lower.

The vitamin C content (196.1 mg/100 g) of the shea pulp has been reported by Eromosele et al. (1991). A comparison with the recommended daily intake (RDI) for children (4–8 years old) is presented in Table 8. Consumption of 50 g/day of pulp by a child (4–8 years) will cover 332% of the RDI. On the other hand, the consumption of 15 g of shea pulp by children is enough to cover the RDI for vitamin C. Considering the lowest reported values for the macro- and micronutrients, the consumption of 100 g of shea fruit pulp will cover 6.2% of the RDI for carbohydrates, 23.1% of the RDI for protein, 4.2% of the RDI for Fe, 8.5% of the RDI for Mg, and 0.3% of the RDI for Ca.

Similarly, the consumption of 50–100 g of shea pulp by a pregnant woman will cover 97.7–195.4% of her RDI of vitamin C (Table 9). As mentioned for the children, the coverage of the macro- and micronutrients will be possible when the lowest reported values are considered. Then, the consumption of 100 g of the pulp will cover 4.6% of the RDI for carbohydrates, 6.2% of the RDI for protein, 1.6% of the RDI for Fe, 0.3% of the RDI for Ca, and 3.2% of the RDI for Mg.

The energy content is low for the RDI for both children and pregnant women. The consumption of 50 g of shea pulp by children and pregnant women covers 5% and 4%, respectively, of their required energy intake.

CONCLUSIONS AND RECOMMENDATIONS

To date, research on *Vitellaria* products (fruit pulp, kernels, and butter) has been fragmentary and undertaken mostly on a local and national basis. The literature review shows a wide variation of research on shea products, with a fair number of investigations in a certain field such as the macro- and micronutrient composition of shea pulp and butter, tocopherols, and sterols contents of the non-glyceride part of shea butter. Despite this variability, the pulp is very rich in vitamin C and the kernels in fat (butter). The shea butter will have some antioxidant and anti-inflammatory activities even if most of this butter is extracted by traditional methods. Of greater interest is the very active level of research on the uses of shea butter in the medicinal, foods, and cosmetics industries, as evidenced by a steady and current flow of research publications in these fields. Further research is necessary to improve the quality of the butter extracted by traditional techniques. Some of the possible solutions are highlighted below.

Further research is necessary to improve the sun drying and the storage conditions of the nuts/kernels, to enhance the processing and the quality of the butter in order to satisfy the international demand, and to provide more information about the fruit pulp consumption. In addition, more attention should be given to accuracy and precision in analyses in order to get more reliable information about biological variation.

ACKNOWLEDGMENT

The authors thank Nuffic for the PhD scholarship made available through the NPT/BEN/263 project, hosted at the University of Abomey-Calavi in Benin.

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