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ORIGINAL ARTICLE

Effect of storage conditions on microbiological and physicochemical quality of shea butter

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Abstract Storage conditions are key constraints for quality assurance of the shea (Vitellaria paradoxa Gaertner) butter. In the Sudan savannah Africa, storage conditions of butter produced by women vary across and among processors, traders and consumers. These conditions could impact the quality of the products and reduced their access to international market. The present study attempted to investigate the effect of storage duration and packaging materials on microbiological and physicochemical characteristics of shea butter under tropical climatic conditions. Five packaging materials traditionally used in shea butter value chain were tested for their efficacy in storing shea butter freshly produced. Total germs, yeasts and mould varied with packaging materials and storage duration. After 2 months of storage, moisture content of butter remained constant (5%) whereas acid value increased from 3.3 to 5.4 mg KOH/g, peroxide value from 8.1 to 10.1 meq O_2/kg and iodine value dropped from 48.8 to 46.2 mg I_2/100 g in shea butter irrespectively to the storage materials used. The basket papered with jute bag was the less effective in ensuring the quality of butter during storage while plastic containers and plastic bags seemed to be the best packaging materials.

Keywords Shea butter · Packaging material · Acid value · Peroxide value · Iodine value

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Introduction

Shea tree, *Vitellaria paradoxa*, Sapotaceae is the main indigenous oil-producing plant spontaneously grown in Africa, native to the dry savannah zones from Senegal to Uganda (Hall et al. 1996). In shea growing countries, such as Benin, shea butter is generally extracted by traditional processing methods that involve roasting, churning and boiling of kernels. The resulted crude butter is then marketed in local markets or larger secondary markets and used for dietary and medicinal purposes. Shea products contribute to 40%–50% of the income for the population in the production zone and the butter provides fat for more than 80% of this population, thus being the most important source of fatty acids and glycerol in their diet (Letchamo et al. 2007).

Shea butter is highly demanded in national level where it's also used in soap making, cosmetic and traditional medicine in many rural areas (Ernest 2001; Maranz et al. 2004); and in international markets due to its richness in food nutrients, it's used as baking fat, margarine and other fatty spreads, confectionery and chocolate industry in Europe and Asia (Alander 2004; CNUCED 2006).

Several studies were undertaken throughout the world to increase the efficacy of shea butter extraction and improve both shea nut and butter qualities (Louppe 1995; Hall et al. 1996). Attempts were made to introduce appropriate technologies, with aim at improving efficiency and reducing the drudgery of labor, as well as the process impact on the

environment (Elias and Carney 2004; Schreckenberg 2004; Maranz et al. 2004; Kapseu et al. 2005; Womeni et al. 2006).

To date, numerous quality problems persist that are associated with the production, the processing and the packaging of shea products despite the results obtained so far. On the other hand, the consumption of shea butter is increasing, especially in the production zones due to the high cost of imported oils. It's therefore necessary to assess the sanitary and physicochemical quality of stored shea butter in order to define the best conditions of handling and storage shea butter. This study assessed the effects of storage packaging materials and duration on the microbiological and physicochemical characteristics of shea butter.

Materials and methods

Field data collection

An appraisal survey was conducted in the production zones (Banikoara and Ndali) at the north of Benin. Shea butter processors (38), butter traders (43) and consumers (41) were reasonably selected and individually interviewed on the storage conditions of shea butter (packaging materials, storage duration and storage structures). This survey gave information on the main packaging materials used by the three actors to store shea butter.

Experimental design

Shea kernels were bought at the local market of Ndali, a location of Borgou Department, North-Benin. The kernels were processed into butter by three selected processors as follows; kernels were cleaned, sun-dried for 1 day, sorted, roasted for 45 min, ground and churned. The cream was then boiled for 1 h and water was added in equal volume to the crude oil obtained. The mixture was leaved out for 1 h and the layer separated was boiled during 30 min. The resulted oil was cooled to get shea butter. The extracted butter was packed in the five packaging materials identified (traditional woven basket papered with jute bags, plastic container with its lid, aluminium container covered by plastic sachet, plastic bag and calabash with its cover) during the appraisal survey, and stored for 2 months in the laboratory at ambient temperature (temperature: 30±1 °C; relative humidity: 81±3%). A butter sample was taken from each packaging materials at 0, 30 and 60 days of storage.

Determination of the microbiological characteristics of shea butter

Aerobic mesophilic bacteria (on Plate Count Agar at 30 °C for 72 h), total coliforms (on Violet Red Bile Agar at 30 °C for 24 h), faecal or thermotolerant coliforms (on Violet Red Bile Agar at 44 °C for 24 h), yeast and moulds (on Malt Extract Agar at 25 °C for 72 h) were determined in each butter sample during storage according to the methods described by the French quality standards NF V 08-052 (1997), NF V 08-051 (1999), NF V 08-050 (1999), NF V 08-060 (1996) and NF V 08-059 (2002), respectively.

Determination of the physicochemical characteristics of shea butter

Moisture content was determined according to AOAC (2002). Colour characteristics were performed using the chromameter (Minolta (CR210b). Colour results were expressed as L* (brightness), b* (yellowness), and ΔE (gap of color in relation to the white reference ceramic). Acid, peroxide, iodine and saponification values were determined according to the methods of the Beninese shea butter characterization standards (2006) using ISO 660, ISO 3960, ISO 3961, and ISO 3657, respectively.

Statistical analysis

Statistical analyses were performed using SAS 9.1 software. A one-way analysis of variance (ANOVA) with two factors (packaging materials, storage duration) was used to identify differences among treatments and the interactions between the two factors. Tests of conformity using Student *t*-test was used to compare the microbiological characteristics of the shea butter and the international standards threshold.

Results and discussion

Changes in microbial counts during the storage of shea butter in different packaging materials

Initial aerobic mesophilic bacteria count was 2 $\log_{10}$ CFU/g; no yeasts and moulds were initially detectable (Table 1). The presence of the microbial in the shea butter could be probably due to the use of contaminated water during the butter extraction. Significant differences were observed on the microbial contamination for the different packaging materials (p=0.0001), the storage duration (p=0.0001) and their interaction (p=0.0001) after 2 months of storage of butter. Overall, microbial counts increased during storage. The mean number of aerobic mesophilic germs increased by ten-fold after 30 days of storage. Yeasts and moulds were detected after 30 days in all the stored butter samples indicating the development of their spores or ultimate contamination during storage. After 60 days of storage, the level of both yeasts and moulds in the butter stored in plastic bags and in baskets papered with jute bag was high,

Table 1 Changes in microbial viable counts ($\log_{10}$ CFU/g^{-1}) during the storage of shea butter in different packaging materials

Germs identified	Storage duration (days)	Plastic container	Calabash container	Basket papered with bag of jute	Plastic bag	Aluminium container	Norms[a]
Aerobic mesophilic bacteria	0	2.0±0.03^{b}	2.0±0.0^{b}	2.0±0.03^{b}	2.0±0.03^{b}	2.0±0.03^{b}	4.0^{a}
	30	3.6±0.11^{c}	3.0±0.14^{d}	3.6±0.09^{c}	3.0±0.12^{d}	3.8±0.11^{b}	4.0^{a}
	60	4.2±0.08^{c}	4.6±0.12^{a}	4.3±0.13^{b}	4.0±0.15^{d}	4.0±0.16^{d}	4.0^{d}
Yeast and mould	0	ND	ND	ND	ND	ND	1.0
	30	0.8±0.02^{b}	0.8±0.06^{b}	1.0±0.02^{a}	0.5±0.08^{d}	0.6±0.07^{c}	1.0^{a}
	60	0.8±0.04^{d}	1.3±0.09^{b}	3.5±0.10^{a}	1.2±0.06^{b}	0.6±0.09^{e}	1.0^{c}

[a] Codex Alimentarius 1992; NBF 01-005 2006; *ND* not detected; n=3; For each parameter and for each row (each duration), means with the same letter are not significantly different at 5% significant level

significantly higher than the international standards threshold (1 $\log_{10}$ CFU/g). The processors watered jute bags prior to use. This practice could lead to favourable environmental conditions for the development of yeasts and moulds. In short, except the butter stored in the aluminium containers, the counts of aerobic mesophilic germs and yeasts and moulds were higher for all samples at the end of storage than the international standards threshold of 4 $\log_{10}$ CFU/g and 1 $\log_{10}$ CFU/g for aerobic mesophilic germs and yeasts and moulds respectively.

No coliform was detected in all the stored samples during storage, probably due to the non exposure of the shea butter to the atmospheric air.

Effect of storage duration and packaging materials on physicochemical characteristics of shea butter

Moisture content Before storage, the shea butter moisture content was 4.9% (Table 2). No significant change was observed during storage whatever the packaging materials used. Irrespective of the storage duration and the packaging materials used, the moisture content in all samples were very higher than those obtained in Côte d'Ivoire (0.15%) by Megnanou et al. (2007) and in Nigeria (1.37%) by Chukwu and Adgidzi (2008); they are also higher than the international standards (0.05%–2%) for non refined shea butters (NBF 01-005 2006). The relative low moisture is desirable in fat and oil to preserve the shelf-life because oxidative rancidity, microbial growth and infestation are prevented or reduced by moisture removal (Mittal and Paul 1997).

Table 2 Effect of the duration and packaging material on the moisture content (%) of shea butter

Packaging material	Storage duration (day)		
	0	30	60
Plastic container	4.9±0.32[a]	5.4±0.13	5.1±0.18
Calabash container	4.9±0.32	4.8±0.12	4.7±0.61
Basket papered with jute bag	4.9±0.32	4.9±0.48	5.1±0.23
Plastic bag	4.9±0.32	5.2±0.24	5.0±0.29
Aluminium container	4.9±0.32	4.8±0.31	4.8±0.42

[a] Mean ± Standard deviation; n=3

Characteristics of color Butter color was found to be significantly affected by the storage duration (p=0.0001) and the types of packaging materials used (p=0.0001) (Table 3). Significant interactive effects of both duration and the types of packaging materials used were also observed (p=0.0001). Mean values of L* (brightness) significantly decreased during the storage time in the samples stored in aluminium containers and in baskets papered with jute bags (Table 3). No significant change was detected in the other packaging materials. The ΔE value before shea butter storage was 32.9 (Table 3). Significant variations of ΔE were observed after 30 days and 60 days of storage between the different packaging materials, except for the shea butter stored in plastic containers. The yellowness (b*) of shea butter prepared in the current experiment are conformed to the national and international markets requirements. The color required by these markets for shea butter is the beige color (NBF 01-005 2006; Moharram et al. 2006).

Acid value The acid value was 3.3 mg KOH/g at the beginning of storage (Table 4). This value slightly increased, not significantly, in most of the samples during storage. This increase was significant in shea butter stored in baskets papered with jute bags ranging from 3.3 to 5.4 mg KOH/g (Table 4). Oil is considered acidic if its acid value is greater than 2 mg KOH/g oil (FAO 1979). All of the acid values are fairly higher than the threshold of 2 mg KOH/g oil. Acid value is a measure of the extent to which glyceride in the oil has been decomposed by lipase or other actions such as heat and light. This determination is often used as a general indication of the condition and edibility of the oil (Kirk and Sawyer 1991). Therefore, the increasing of the acid value during the storage of butter specifically observed in basket papered with jute bags could be explained by the triglycerides hydrolysis which occurred

Table 3 Effect of storage duration and packaging materials on colour parameters of shea butter

Parameters	Packaging material	Storage duration (day)		
		0	30	60
Luminance (L*)	Plastic container	72.5 ± 0.11^{a1}	72.3 ± 0.0^{ab1}	72.5 ± 0.09^{a1}
	Calabash container	72.5 ± 0.11^{a1}	72.3 ± 0.0^{ab1}	72.3 ± 0.0^{ab1}
	Basket papered with jute bag	72.5 ± 0.11^{a1}	71.8 ± 0.0^{c2}	72.2 ± 0.23^{ab1}
	Plastic bag	72.5 ± 0.11^{a1}	72.5 ± 0.0^{a1}	72.5 ± 0.0^{a1}
	Aluminium container	72.5 ± 0.11^{a1}	72.1 ± 0.0^{b1}	72.1 ± 0.12^{b1}
Yellow saturation index (b*)	Plastic container	14.9 ± 0.12^{a1}	14.9 ± 0.09^{a1}	14.9 ± 0.11^{a1}
	Calabash container	14.9 ± 0.12^{a1}	14.4 ± 0.11^{b2}	14.9 ± 0.09^{a1}
	Basket papered with jute bag	14.9 ± 0.12^{a1}	14.5 ± 0.0^{b2}	14.7 ± 0.23^{a1}
	Plastic bag	14.9 ± 0.12^{a1}	13.9 ± 0.10^{c3}	$14.\ 5\pm0.12^{b2}$
	Aluminium container	14.9 ± 0.12^{a1}	14.4 ± 0.0^{b1}	14.2 ± 0.20^{b1}
Color difference (ΔE)	Plastic container	32.9 ± 0.0^{a1}	33.1 ± 0.12^{a1}	32.9 ± 0.0^{b1}
	Calabash container	32.9 ± 0.0^{a12}	32.8 ± 0.09^{c2}	33.1 ± 0.09^{a1}
	Basket papered with jute bag	32.9 ± 0.0^{a2}	33.2 ± 0.0^{a1}	32.8 ± 0.11^{b2}
	Plastic bag	32.9 ± 0.0^{a2}	32.7 ± 0.0^{c3}	33.2 ± 0.0^{a1}
	Aluminium container	32.9 ± 0.0^{a1}	32.9 ± 0.0^{b1}	32.3 ± 0.0^{c2}

Mean ± Standard deviation; $n=3$; For each parameter **in columns**, means followed with different letters express the meaningful effect of the storage materials. **In rows**, means followed with different figures express the meaningful effect of the storage duration

Table 4 Effect of storage duration and packaging material on quality indices of shea butter

Parameters	Packaging material	Storage duration (day)		
		0	30	60
Acid value (mgKOH/g)	Plastic container	3.3 ± 0.22^{a1}	3.3 ± 0.32^{b1}	3.5 ± 0.0^{c1}
	Calabash container	3.3 ± 0.22^{a2}	3.5 ± 0.0^{b1}	3.9 ± 0.0^{b1}
	Basket papered with jute bag	3.3 ± 0.22^{a3}	4.2 ± 0.21^{a2}	5.4 ± 0.0^{a1}
	Plastic bag	3.3 ± 0.22^{a1}	3.3 ± 0.20^{b1}	3.5 ± 0.0^{c1}
	Aluminium container	3.3 ± 0.22^{a1}	3.7 ± 0.19^{b1}	3.5 ± 0.0^{c1}
Peroxide value ($meqO_2/kg$)	Plastic container	8.1 ± 0.29^{a2}	9.6 ± 0.39^{a1}	9.8 ± 0.40^{a1}
	Calabash container	8.1 ± 0.29^{a2}	8.9 ± 0.23^{b1}	9.1 ± 0.12^{b1}
	Basket papered with jute bag	8.1 ± 0.29^{a2}	9.9 ± 0.11^{a1}	10.1 ± 0.21^{a1}
	Plastic bag	8.1 ± 0.29^{a2}	9.3 ± 0.38^{a1}	9.6 ± 0.52^{ab1}
	Aluminium container	8.1 ± 0.29^{a2}	9.3 ± 0.38^{a1}	9.8 ± 0.32^{a1}
Iodine value ($mgI_2/100$ g)	Plastic container	48.8 ± 0.62^{a1}	48.8 ± 0.11^{a1}	47.8 ± 0.89^{a1}
	Calabash container	48.8 ± 0.62^{a1}	48.8 ± 0.42^{a1}	48.6 ± 0.10^{a1}
	Basket papered with jute bag	48.8 ± 0.62^{a1}	48.3 ± 0.82^{a1}	46.2 ± 0.81^{b2}
	Plastic bag	48.8 ± 0.62^{a1}	48.1 ± 0.09^{b1}	46.9 ± 0.41^{b2}
	Aluminium container	48.8 ± 0.62^{a1}	48.8 ± 0.71^{a1}	47.8 ± 0.42^{a2}
Saponification value (mgKOH/g)	Plastic container	181.7 ± 0.31^{a1}	179.6 ± 0.71^{c2}	179.6 ± 0.71^{b2}
	Calabash container	181.7 ± 0.31^{a1}	180.6 ± 0.42^{bc2}	179.9 ± 0.69^{b2}
	Basket papered with jute bag	181.7 ± 0.3^{a2}	182.0 ± 0.23^{ab2}	183.5 ± 0.39^{ab1}
	Plastic bag	181.7 ± 0.31^{a1}	181.8 ± 0.34^{ab1}	183.2 ± 0.49^{b1}
	Aluminium container	181.7 ± 0.31^{a2}	182.5 ± 0.63^{a2}	184.2 ± 0.09^{a1}

Mean ± Standard deviation; $n=3$; For each parameter **in columns**, means followed with different letters express the meaningful effect of the storage materials. **In rows**, means followed with different figures express the meaningful effect of the storage duration

during the storage; probably enzymatic hydrolysis since the chemical hydrolysis would only be possible in lipids with a high moisture content (>20%) or when fat is used at high temperatures (180–220°) (Hultin 1992). In addition, the high number of yeasts and moulds founded on the sample packed in this material is consistent with the enzymatic hydrolysis since some of these micro organisms could have the capacity to secret the lipase, responsible of the enzymatic hydrolysis in the lipid (Hultin 1992). However, the acid indices observed here are similar to those founded in Nigeria (3.82 mgKOH/g) by Chukwu and Adgidzi (2008) and lower than those (10.51–11.94 mg KOH/g) reported by Megnanou et al. (2007) in Côte d'Ivoire.

Peroxide value The initial peroxide value was around 8.12 meq O_2/kg (Table 4). The analysis of variance revealed significant effect of storage duration (p=0.0001) and packaging materials (p=0.0289) on this index. This result was supported by a positive coefficient of correlation between the peroxide value and storage duration (r= 0.8435, p=0.0001). Shea butter stored in basket papered with jute bags seemed to give higher peroxide index, with a mean value of 10.12 meq O_2/kg after 2 months of storage. Peroxide is the first product of oxidation of unsaturated fats/oils. During storage, peroxide formation is slow at first during an induction period (which may vary from few weeks to several months) depending on the particular oil and temperature (Kirk and Sawyer 1991). When the concentration of peroxide reaches a certain level, complex changes occur with the formation of ketones, aldehydes and hydroxyl groups which are volatile and mainly responsible for the off-flavours (rancidity) and odours (Abdulrahim et al. 2000).

Iodine value The mean of iodine value at the beginning of storage was 48.85 mg I_2/100 g but decreased to 46.21–47.83 mgI_2/100 g after 2 months of storage (Table 4). 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 of oil (Hui 1996). This is consistent with a negative correlation between the iodine value and the storage duration (r=−0.64965, p=0.0001). Iodine values were lower than the maximal value accepted at international level (58–72 mgI_2/100 g) (NBF 01-005 2006).

Saponification value The initial mean value was around 181.67 mg KOH/g (Table 4). The analysis of variance revealed significant effects of the packaging materials (p= 0.0001), storage duration (p=0.0044), and their interaction (p=0.0001) on this index. Saponification value of shea butter samples stored in basket papered with jute bags and in the aluminium containers gave the highest values at 30 and 60 days of storage. This index seemed to increase with the storage duration irrespective of packaging material (r= 0.68141, p=0.0001). The values observed were lower than those founded in most vegetable oils (Anhwange et al. 2004; Dhellot et al. 2006; Tchobo et al. 2007).

Conclusion

The effect of storage duration and packaging materials on microbiological and physicochemical qualities of shea butter revealed the necessity to change some packaging materials used in the production sites. More specifically, the basket papered with jute bags is less effective in ensuring the quality of shea butter after 1 month of the storage. Shea butter stored in plastic containers and plastic bags maintains its microbiological and physicochemical quality, thus these packaging materials should be recommended even if some limited variations of the studied parameters were observed.

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