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Original Article

Comparative sunscreen and stability studies of shea butter from Nigeria

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ABSTRACT

Shea butter extracted from the nuts of Vitellaria paradoxa is utilized as food, medicine and a significant source of income especially, in rural communities. The butter is reported to vary in their physicochemical compositions which may affect the sunscreen and stability of it, thus, the need for the present study. Shea nuts were collected from Ngaski (A), Bosso (B) and Yamaltu-Deba (C) of northern Nigeria. The in-vitro sunscreen activity was determined using UV-spectrophotometer and the stability study using plastic, clear and amber bottles stored in different conditions. The shea butter samples showed high SPF values at 1.00 % with shea butter C having the highest value at 37.49 % while shea butter A had the least value at 25.17. All the butter had sunscreen values less than 1 % at 0.50%. Samples stored in plastic, colourless and amber bottles in the refrigerator had higher moisture content. In comparison, those stored at room temperature had lower moisture content, although samples in amber bottles stored in the refrigerator were found to have fewer peroxide values.

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1. Introduction

Shea tree (Vitellaria paradoxa) produces fruits that are an important source of food for man and livestock. The kernels also called shea nuts have been reported to contain oil ranging from 45-60% that is usually obtained by drying, cracking and crushing of the nuts which when solidified forms a solid, fatty, butter-like substance [1, 2]. The butter is utilized in cooking and as a skin and body moisturizer by the local communities. It is also used by the traditional medical practitioners to treat rheumatism, bone dislocation, nasal congestion and cough. The butter is utilized in the pharmaceutical and cosmetic industries in formulation of ointments and creams. It is also used as raw materials for the production of margarine, soap, detergents and candles. It is reported to have anti-inflammatory, anti-ageing and sunscreen activity [3, 4].

Rancidity forms the basis used in determining the shelf-life of all vegetable fats and oils. The development of this process is observed by determining the moisture content and peroxide value of the fat or oil [5, 6].

Studies have shown variations in the physicochemical composition of the shea butter [7, 8], but little or no studies have

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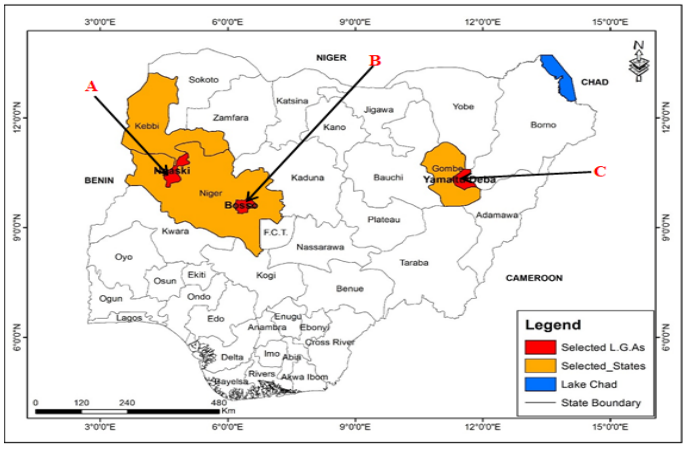
reported the effect of these physicochemical variations on the sunscreen activity and stability of the shea butter, thus the need for the present study.

2. Materials and Methods

2.1. Study area and plant collection

The shea fruits were collected randomly from twenty (20) trees in farmland population with the circumference of the trunk between 1 to 1.2 m in diameter in the months of August-September, 2018 from three locations namely; Ngaski (Latitude 10o 24' 26" North; Longitude 4o 43' 4" East), Bosso (Latitude 9o 36' 53" North; Longitude 6o 21' 57" East) and Yamaltu-Deba (Latitude 10o 14' 18" North; Longitude 11o 26' 30" East) local government areas of Kebbi, Niger and Gombe states of northern Nigeria respectively (Plate 1). The shea fruits collected were identified as A for Ngaski, B for Bosso and C for Yamaltu-Deba respectively. The shea tree was identified in the field using taxonomic characters and transported to the Herbarium unit of the Department of Botany, Ahmadu Bello University; Zaria-Nigeria for authentication and a voucher number ABU900148 was assigned



. **Fig. 1.** Nigerian Map Showing the Three Study Areas

2.2. Extraction of Shea Butter

The dried Shea kernel collected was handpicked to remove the rotten ones and oven dried for 48 hours. Crushing of the kernel to collect the nuts and milling with mortar and pestle was carried out. The milled Shea nuts (1600g) were extracted using hexane (2.5 litres) in a soxhlet apparatus (Konte USA) for 6 hours at 60°C. The oil was obtained after evaporating over water bath at 70°C to remove excess solvent, dried in an oven and cooled in the desiccators and then re-weighed to determine the amount of oil extracted [9].

2.3. Determination of Sunscreen Properties of Shea Butter

The initial stock was prepared for each of the shea butter by dissolving 1 g of the butter in ethanol: distilled water (20:80). Serial dilution to prepare 0.1 %, 0.5 % and 0.05 % was prepared and thereafter, the absorbance of each aliquot was determined using Shimadzu UV-Spectrophotometer at 290, 295, 300, 305, 310, 315 and 320 nm respectively taking ethanol: distilled water (20:80) as the blank solution [10, 11]. Determinations were made in triplicate and the sun protection factor (SPF) was determined using the formula below;

Sun Protection Factor (SPF) =CF $\sum_{290}^{320} EE(\lambda) \times I(\lambda) \times Abs(\lambda)$----------(14)

Where,

CF is the correction factor (= 10),

EE (λ) is the erythemal effect of the radiation with wavelength λ determined (Table 1)

I (λ) is the solar intensity of radiation with wavelength λ,

Abs (λ) is the absorbance of the sunscreen product at wavelength λ.

Table 1. Relationship between Erythemal Effect (EE) and Radiation Intensity (I) at each Wavelength (λ)

S/No	Λ	EE × I
1	290	0.0150
2	295	0.0817
3	300	0.2874
4	305	0.3278
5	310	0.1864
6	315	0.0839
7	320	0.0180
	Total	1

2.4. Determination of the Effects of Three Storage Conditions on Shea Butter

The Schaal accelerated oven storage test

with slight modification was used to test the storage properties of the Shea butter samples. The Shea butter samples were transferred into clear colourless bottles (CCB), amber coloured clear bottles (ACB), in opaque plastic bottles (OPB) and each of the containers was stored in a dark cupboard, refrigerator and at room temperature for 28 days and subsequently analysed for moisture content and peroxide value at 7-day intervals. The Shea butter was further evaluated for moisture content and peroxide values at 3 months and 6 months respectively [12, 13].

2.4.1. Determination of Moisture Content of the Shea Butter

Shea butter (5 g) was weighed in a dried tared dish and dried in an oven at 105°C. After 1 h, the sample was removed from the oven and placed in the desiccator for 30 min to cool. It was then be removed and re-weighed. This process was repeated until the change in the weight between the two successive observations did not exceed 1 mg [14]. The percentage moisture in the butter was calculated as follows;

Moisture Content (%) = 100 (W1-W2)/W1

Where; W1 = Original weight of sample before drying (g), and W2 = Weight of sample after drying (g)

2.4.2. Determination of Peroxide Values of the Shea Butter

Shea butter (2 g) was weighed in a 250 ml conical flask with a glass stopper. 30 mL of 3:2 v/v glacial acetic acid-chloroform solvent was added, and swirled to dissolve the sample and 0.5 mL of saturated KI solution was added. The solution was left to stand in the dark with occasional shaking for exactly 1 min, and 30 mL of distilled water was added immediately. The mixture was titrated with 0.1N sodium thiosulphate using 0.5 mL of starch indicator solution. A blank was prepared using the same procedure at the same time in triplicate [10]. The peroxide value was calculated as follows;

Peroxide value= b-a N/W (meq/Kg)

Where; N = normality of Na2S2O3 solution,

b = volume (ml) of Na2S2O3 solution used in test,

a = volume (ml) of Na2S2O3 solution used in blank,

W = weight of oil sample.

2.5. Statistical Analysis

One-way Analysis of variance (ANOVA) was used to compare the variation between the moisture content and peroxide values of shea butter by generating the data using SPSS software version 17. Means and standard deviation were computed. Duncan multiple range test was used to compare the mean variance with significance level at $p< 0.05$

3. Results and Discussion

3.1 Sun Protection Factor (SPF) Values of the Shea Butter

Vegetable fats and oils from Helianthus annuus, Glycine max and Vitellaria paradoxa have been reported for their photoprotective properties, with the activity mainly attributed to the presence of tocopherols, flavonoids, and phenolic acids [15]. Shea butter has been reported to have strong UV-radiation absorbance in wavelength range of 250-300 nm [3] as observed in the present study. The butter samples showed high sunscreen values at 1.00 % with shea butter C having the highest value at 37.49 %. This was followed by shea butter B at 33.84 % while shea butter A had the least value at 25.17 %. All the butter samples had low sunscreen values at 0.50 % but there was an increase at 0.10 % with shea butter A having a high value of 11.72 %, shea butter B at 11.13 %, while shea butter C had the least value at 11.07 %. Shea butter C also had a high value at the least concentration of 0.05 % with a value of 4.17 %, and the least value was obtained from shea butter B at 3.72 % while shea butter A had an average value of 4.13 % (Table 2).

The photoprotective properties of the butter have been attributed to the presence of tocopherols and cinnamate esters of triterpenes [4, 7], with variations in both the tocopherol and triterpenes esters reported in shea butter due to the influence of climate and geographical locations [16, 17].

The variations in the sunscreen properties of the shea butter in the presence study can be attributed to the variations in the tocopherol and triterpenes contents. This is because studies have shown that variations in the phytochemical and physico-chemical composition of plants influence its medicinal properties [18, 19].

Table 2. SPF of the Shea Butter (A, B and C)

S/no	Ethanol solution	1.00%	0.50%	0.10%	0.05%
1	Shea butter A	25.17	0.70	11.72	4.13
2	Shea butter B	33.84	0.67	11.13	3.72
3	Shea butter C	37.49	0.64	11.07	4.17

Keys : Shea butter from Ngaski (A), Shea butter from Bosso (B), Shea butter from Yamaltu-Deba (C)

3.2. Stability Studies of the Shea Butter

Fats and oils oxidation is one of the major process by which food deteriorates due to rancidity resulting in unpleasants flavors and tastes. This process results in the generation of reactive oxygen reported to be linked with cancer, inflammation, cardiovascular disorders and aging. This oxidation has been found to occur in the presence of catalytic systems such as light, heat, moisture, atmospheric oxygen, temperature, enzymes and metals producing unwanted monomers and free radicals [20, 22]. The moisture content of all the butter samples stored in different containers and temperatures were significantly different. It was found that the samples stored in plastic, colourless and amber bottles in the refrigerator (Tables 3-5) had higher moisture content while those stored at room temperature had lower moisture content.

Although, refrigerators have been reported to be better in terms of the effects of temperature on peroxide values which increase with an increase in temperature, the percentage moisture content values for all the samples at 6 months stored in the refrigerator and cupboard were higher than the international standard of 0.05 % to 2.0 %. Therefore, the shea butter stored in the refrigerator is exposed to oxidative rancidity, microbial growth and infestation [21, 23].

Table 3. Moisture Content of Shea Butter A

S/No	Sample	Moisture content (%) 7 days	14 days	21 days	28 days	3 months	6 months
1	AP1	11.5 ± 0.003^{g}	11.0 ± 0.001^{e}	8.9 ± 0.001^{c}	5.6 ± 0.003^{a}	4.8 ± 0.003^{a}	2.0 ± 0.01^{a}
2	AC1	12.8 ± 0.001^{i}	12.9 ± 0.0001^{g}	12.5 ± 0.006^{e}	11.6 ± 0.21^{de}	6.9 ± 0.006^{d}	4.0 ± 0.06^{e}
3	AA1	12.0 ± 0.001^{h}	11.8 ± 0.001^{e}	10.3 ± 0.001^{d}	10.0 ± 0.01^{b}	5.6 ± 0.003^{b}	3.5 ± 0.03^{d}
4	AP2	2.0 ± 0.001^{c}	5.0 ± 0.001^{a}	7.2 ± 0.001^{a}	11.8 ± 0.06^{e}	14.1 ± 0.01^{h}	6.4 ± 0.03^{h}
5	AC2	3.2 ± 0.003^{f}	12.4 ± 0.001^{f}	15.0 ± 0.001^{g}	14.2 ± 0.06^{f}	7.3 ± 0.006^{e}	5.2 ± 0.03^{g}
6	AA2	2.5 ± 0.001^{e}	13.3 ± 0.001^{g}	14.4 ± 0.001^{f}	14.8 ± 0.06^{g}	11.0 ± 0.08^{g}	8.0 ± 0.03^{i}
7	AP3	1.8 ± 0.001^{a}	6.6 ± 0.001^{c}	8.2 ± 0.001^{b}	10.5 ± 0.03^{c}	6.3 ± 0.003^{c}	4.9 ± 0.03^{f}
8	AC3	2.0 ± 0.003^{c}	7.6 ± 0.001^{d}	9.4 ± 0.006^{c}	11.5 ± 0.03^{d}	6.3 ± 0.006^{c}	2.2 ± 0.03^{b}
9	AA3	1.9 ± 0.001^{b}	5.9 ± 0.001^{b}	7.3 ± 0.006^{a}	10.6 ± 0.06^{c}	8.4 ± 0.03^{f}	3.0 ± 0.08^{c}

Keys: A-Shea butter from Ngaski, P-Plastic Bottles, C-Clear Glass Bottles, A-Amber Glass bottles, 1-Room temperature, 2-Cupboard, 3-Refrigerator. *SEM with same superscripts along columns is not significantly different

Table 4. Moisture Content of Shea Butter B

S/No	Sample	Moisture content (%) 7 days	14 days	21 days	28 days	3 months	6 months
1	BP1	2.6 ± 0.001^{a}	2.8 ± 0.001^{f}	3.8 ± 0.001^{a}	5.5 ± 0.003^{b}	4.3 ± 0.06^{c}	1.7 ± 0.03^{c}
2	BC1	2.2 ± 0.001^{a}	4.6 ± 0.0001^{i}	5.6 ± 0.001^{b}	6.0 ± 0.03^{f}	2.6 ± 0.003^{a}	1.2 ± 0.06^{a}
3	BA1	2.4 ± 0.001^{a}	3.9 ± 0.001^{h}	4.2 ± 0.001^{a}	5.6 ± 0.03^{c}	4.2 ± 0.003^{f}	2.0 ± 0.03^{d}
4	BP2	1.0 ± 0.001^{a}	2.3 ± 0.001^{c}	4.2 ± 0.001^{a}	5.7 ± 0.03^{d}	9.7 ± 0.03^{h}	5.0 ± 0.06^{g}
5	BC2	1.9 ± 0.001^{a}	2.5 ± 0.001^{d}	3.9 ± 0.001^{a}	5.2 ± 0.03^{a}	8.3 ± 0.03^{g}	4.1 ± 0.03^{f}
6	BA2	1.3 ± 0.001^{a}	3.0 ± 0.001^{g}	5.1 ± 0.001^{b}	5.9 ± 0.03^{e}	10.0 ± 0.01^{i}	5.4 ± 0.06^{h}
7	BP3	1.2 ± 0.001^{a}	2.7 ± 0.001^{e}	4.5 ± 0.001^{a}	8.6 ± 0.03^{i}	5.4 ± 0.03^{e}	3.9 ± 0.03^{e}
8	BC3	1.5 ± 0.001^{a}	2.0 ± 0.001^{a}	7.3 ± 0.001^{c}	7.3 ± 0.03^{g}	4.2 ± 0.03^{b}	1.6 ± 0.03^{b}

9	BA3	1.3±0.001[a]	2.1±0.001[b]	4.6±0.006[a]	8.4±0.003[h]	4.7±0.06[d]	2.0±0.03[ab]

Keys: B-Shea butter from Bosso, P-Plastic Bottles, C-Clear Glass Bottles, A-Amber Glass bottles, 1-Room temperature, 2-Cupboard, 3-Refrigerator. *SEM with same superscripts along columns is not significantly different

Table 5. Moisture Content of Shea Butter C

		Moisture content (%)					
S/No	**Sample**	**7 days**	**14 days**	**21 days**	**28 days**	**3 months**	**6 months**
1	CP1	1.3±0.001[c]	2.7±0.001[bc]	3.6±0.001[b]	5.0±0.001[a]	3.2±0.01[a]	1.2±0.01[b]
2	CC1	0.5±0.001[a]	1.3±0.0001[a]	2.5±0.001[a]	4.7±0.01[a]	2.6±0.001[a]	1.1±0.01[a]
3	CA1	1.5±0.003[d]	2.9±0.001[b]	4.1±0.001[c]	6.2±0.01[b]	3.9±0.001[a]	1.7±0.03[c]
4	CP2	1.0±0.001[b]	2.5±0.001[b]	4.7±0.001[c]	7.1±0.01[c]	10.1±0.01[a]	6.1±0.03[h]
5	CC2	3.5±0.003[g]	4.2±0.001[e]	6.6±0.001[f]	6.2±0.01[b]	11.2±0.01[a]	7.2±0.01[i]
6	CA2	1.5±0.001[d]	3.5±0.001[d]	5.3±0.001[d]	10.2±0.01[f]	10.5±0.01[a]	5.9±0.03[g]
7	CP3	2.0±0.001[e]	3.5±0.001[d]	5.1±0.001[d]	8.4±0.01[d]	7.6±0.001[a]	4.6±0.03[f]
8	CC3	2.5±0.001[f]	3.2±0.001[d]	5.5±0.001[e]	9.1±0.01[e]	6.1±0.001[a]	2.2±0.01[d]
9	CA3	2.3±0.001[e]	3.3±0.001[d]	5.2±0.001[d]	10.0±0.01[f]	7.0±0.001[a]	3.1±0.03[e]

Keys: C-Shea butter from Yamaltu-Deba, P-Plastic Bottles, C-Clear Glass Bottles, A-Amber Glass bottles, 1-Room temperature, 2-Cupboard, 3-Refrigerator. *SEM with same superscripts along columns is not significantly different

Although, the shea butter samples stored under all the conditions (Tables 6-8) for the duration of the 6 months did not have peroxide value above the Codex 210 of 2013 standards at 15 meqO2/mg, the shea butter stored in amber bottles at the different temperatures were found to have lower peroxide values for all the shea butter samples. This can be supported by the report of (24) that brown bottles have more resistance to oil deterioration as it acts as a shield from light source. This result is also similar to the report of [25] that reported dark bottles although, stored at room temperature had a low peroxide value. The shea butter in the plastics and colourless bottles had more peroxide values when compared with the amber bottles which differ from the study that revealed plastic bags and containers were better in the storage of shea butter [21], and supported by the claim that plastic bags undergo more hydrolytic processes than glass bottles [25].

Table 6. Peroxide Value of Shea Butter A

		Peroxide Value ($meqO_2/mg$)					
S/No	**Sample**	**7 days**	**14 days**	**21 days**	**28 days**	**3 months**	**6 months**
1	AP1	0.98±0.001[a]	1.4±0.006[d]	3.1±0.003[f]	4.0±0.006[g]	5.2±0.003[h]	6.3±0.03[h]
2	AC1	1.0±0.006[b]	2.5±0.0003[i]	2.9±0.03[e]	3.1±0.003[d]	6.0±0.001[i]	6.8±0.06[i]
3	AA1	1.5±0.006[b].	2.0±0.003[h]	3.2±0.003[g]	3.9±0.008[f]	4.4±0.003	4.7±0.03[e]
4	AP2	1.1±0.001[d]	1.5±0.006[e]	2.5±0.006[d]	3.2±0.03[e]	3.7±0.03[d]	4.5±0.03[c]
5	AC2	1.0±0.003[e]	1.1±0.003[c]	2.0±0.003[c]	2.5±0.003[c]	3.8±0.003[e]	6.0±0.06[f]
6	AA2	1.2±0.006[c]	1.6±0.003[f]	2.0±0.006[c]	2.2±0.003[b]	3.5±0.03[b]	4.2±0.03[d]
7	AP3	1.5±0.003[b]	1.9±0.009[g]	2.0±0.003[c]	2.2±0.003[b]	3.6±0.003[c]	4.7±0.03[d]
8	AC3	1.0±0.009[b]	1.2±0.001[b]	1.8±0.003[b]	2.0±0.001[a]	3.9±0.003[f]	6.1±0.03[g]
9	AA3	1.0±0.001[b]	0.9±0.03[a]	1.5±0.003[b]	2.0±0.003[a]	2.5±0.003[a]	3.3±0.006[a]

Keys: A-Shea butter from Ngaski, P-Plastic Bottles, C-Clear Glass Bottles, A-Amber Glass bottles, 1-Room temperature, 2-Cupboard, 3-Refrigerator. *SEM with same superscripts along columns is not significantly different

Table 7. Peroxide Value of Shea Butter B

		Peroxide Value (meqO_2/mg)					
S/No	**Sample**	**7 days**	**14 days**	**21 days**	**28 days**	**3 months**	**6 months**
1	BP1	0.9±0.003^{b}	1.0±0.003^{a}	2.5±0.006^{f}	3.6±0.009^{a}	4.7±0.006^{g}	5.5±0.06^{f}
2	BC1	1.3±0.003^{b}	1.9±0.0006^{e}	2.0±0.006^{d}	2.9±0.03^{d}	4.2±0.006^{e}	5.9±0.03^{h}
3	BA1	0.8±0.006^{a}.	1.4±0.006^{d}	2.0±0.003^{d}	2.9±0.003^{d}	3.6±0.00g^{c}	4.5±0.03^{c}
4	BP2	0.9±0.001^{b}	1.0±0.003^{a}	1.4±0.003^{a}	2.6±0.006^{b}	3.2±0.04^{a}	4.2±0.06^{b}
5	BC2	1.0±0.003^{b}	1.2±0.001^{b}	2.4±0.003^{e}	3.0±0.003^{e}	4.2±0.006^{e}	5.2±0.15^{e}
6	BA2	1.0±0.003^{b}	1.3±0.003^{c}	1.9±0.003^{c}	2.7±0.006^{c}	3.5±0.03^{b}	4.0±0.06^{a}
7	BP3	0.8±0.001^{a}	1.3±0.003^{c}	2.0±0.003^{d}	3.0±0.007^{e}	4.3±0.003^{e}	5.6±0.06^{g}
8	BC3	0.8±0.001^{a}	1.9±0.009^{e}	2.4±0.006^{e}	3.4±0.001^{f}	4.2±0.006^{e}	5.9±0.04^{h}
9	BA3	0.8±0.003^{b}	1.2±0.006^{b}	1.8±0.003^{b}	2.4±0.003^{a}	3.9±0.006^{d}	4.2±0.06^{d}

Keys: B-Shea butter from Bosso, P-Plastic Bottles, C-Clear Glass Bottles, A-Amber Glass bottles, 1-Room temperature, 2-Cupboard, 3-Refrigerator. *SEM with same superscripts along columns is not significantly different

Table 8. Peroxide Value of Shea Butter C

		Peroxide Value (meqO_2/mg)					
S/No	**Sample**	**7 days**	**14 days**	**21 days**	**28 days**	**3 months**	**6 months**
1	CP1	0.9±0.01^{c}	1.4±0.003^{c}	3.6±0.003^{f}	4.2±0.001^{h}	5.4±0.001^{g}	6.3±0.03^{h}
2	CC1	1.2±0.001^{d}	1.6±0.0003^{d}	3.7±0.01^{g}	4.5±0.003^{i}	5.6±0.001^{h}	7.0±0.06^{i}
3	CA1	0.9±0.001^{c}.	1.2±0.001^{b}	2.6±0.003^{e}	3.8±0.006^{g}	4.2±0.001^{f}	5.0±0.03^{f}
4	CP2	0.9±0.003^{a}	1.2±0.001^{b}	1.9±0.003^{b}	2.6±0.001^{d}	3.1±0.001^{c}	4.8±0.03^{c}
5	CC2	1.0±0.001^{b}	1.4±0.003^{c}	2.0±0.001^{c}	2.9±0.003^{e}	3.9±0.003^{d}	5.8±0.01^{b}
6	CA2	0.9±0.001^{b}	1.3±0.003^{c}	1.7±0.003^{a}	2.0±0.003^{a}	3.0±0.001^{b}	4.0±0.03^{a}
7	CP3	1.0±0.001^{b}	1.4±0.003^{c}	2.0±0.001^{c}	2.5±0.003^{c}	3.0±0.001^{b}	5.1±0.03^{d}
8	CC3	1.0±0.001^{b}	1.9±0.003^{e}	2.3±0.003^{d}	3.1±0.001^{f}	4.2±0.001^{e}	6.0±0.03^{g}
9	CA3	0.9±0.001^{c}	1.0±0.01^{a}	1.7±0.001^{a}	2.2±0.001^{b}	2.9±0.003^{a}	3.9±0.03^{d}

Keys: C-Shea butter from Yamaltu-Deba, P-Plastic Bottles, C-Clear Glass Bottles, A-Amber Glass bottles, 1-Room temperature, 2-Cupboard, 3-Refrigerator. *SEM with same superscripts along columns is not significantly different

4. Conclusion

There was variation in the Sun Protection Factor (SPF) values for the shea butter from the three study areas. Also, there was variation in the moisture content and peroxide values of the shea butter depending on the source of the shea butter, storage containers and condition of storage. From the present study, amber bottles are more suitable for storage of shea butter as they retained less moisture with less peroxide values regardless of the conditions they are stored when compared with the other storage containers.

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Conflict of Interest

The authors declare there is no conflict of interest that could be perceived as prejudice regarding the research reported.

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