Quality Characteristics and Alpha-Tocopherol Content of Shea Butter Samples from Selected Markets Within Three Southwestern States of Nigeria

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(Received: March 17, 2022; Accepted: August 14, 2022; Published (Web): December 20, 2022)

ABSTRACT: Shea (*Vitellaria paradoxa*) butter samples from selected markets in Nigeria were analyzed for AOAC quality characteristics and α-tocopherol content. The α-tocopherol was determined by RP-HPLC and mg per serving and % daily values (% DV) were estimated. The ranges of acid value (AV) [mgKOH/kg], free fatty acid (FFA) [%], peroxide value (PV) [meqO_2/Kg], iodine value (IV) [gI_2/100g] and saponification value (SV) [mgKOH/g] were 2.20-2.59, 1.15-1.30, 0.75-0.95, 44.43-47.85 and 170.08-259.30, respectively. The α-tocopherol had a retention time of 3.561 minutes and its content ranged from 1.15-2.60 mg/100 g in the samples, but 5.25 mg/100 g for the laboratory sample. Milligram (mg) per serving and percentage dietary value were 0.16-0.74 and 1.07-4.93, respectively. Quality characteristics varied significantly ($p < 0.05$) both within and across different markets. Based on the PV and IV results, the marketed shea butter samples may be both food and industry-grade but failed the FFA test. Similarly, 40% of samples did not qualify for domestic consumption and food industry applications. Hence, the samples with <5% DV values cannot serve as dietary sources of α-tocopherol.

Key words: Quality evaluation, α-tocopherol, shea butter, *Vitellaria paradoxa*, HPLC, southwest Nigeria.

INTRODUCTION

Many oils of plant origin like shea butter, cocoa butter, avocado, palm, coconut, jojoba, olive and illipe are involved in many applications ranging from culinary, industrial, cosmetic or pharmaceutical products depending on their relevant characteristics.[1-3] In sub-Saharan Africa, shea (*Vitellaria paradoxa*, family-Sapotaceae) butter is an important socio-economical agro-resource in its producing countries, due to its usage in several industrial, medicinal, culinary, and other applications.[3,4] Shea butter has good water-binding properties and is rapidly absorbed by the skin. Based on these, it is used for skin care where it acts as a refatting agent.[5] Shea butter is known as *kade* or *kadanya* in Hausa, while it is called *karite* in the Wolof language of Senegal.[6] In some parts of West Africa, it is known as *Ori* and has been used for treating dermatitis and as a nighttime moisturizer for hands and feet.[7]

Nigeria is the leading producer of shea nut, with 355,000 MT and 414,000 MT produced in 1999 and 2005 respectively.[8] The shea sector of the Nigeria economy has the capacity to generate 3.8 million US dollar per annum for the country, in addition to providing employment for a myriad of people.[9] Unfortunately, due to many problems including inadequate capital, poor packaging & marketing, black-mould & insect infestations, non-standardization and lack of quality control of shea products[10-12] the shea industry is currently underexploited in Nigeria. Thus, these challenges affect the whole shea value chain from gatherers of the nuts up to the manufacturers and end-users of shea products.

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Dhaka Univ. J. Pharm. Sci. **21**(2): 105-115, 2022 (December)
DOI: https://doi.org/10.3329/dujps.v21i2.63112

The shea butter is normally extracted from the shea nut using either a traditional or mechanical method. However, Carette[13] stated that in West Africa, shea butter processing utilizes minimal mechanical input, heavy drudgery and firewood. These have a direct negative effect on the quality of shea butter. A lot of wastages is associated with the traditional method of shea butter production. Though there is a huge and wide usage of shea butter in Nigeria, the Nigerian processed shea butter is characterized by low quality and quantity.[14] Studies have also shown that the tropical conditions of the Nigerian market could lead to increased microbial proliferation in vegetable oils and light-induced oxidation.[2,15,16] Additionally, the hydrolytic and oxidative rancidity of fats has been positively correlated with moisture, light, heat, microorganisms, enzymes, unsaturated fatty acid, polyunsaturation, chemical structure of oils & fats, temperature and pH.[17] Hence, considering the tropical temperature, poor handling and packaging of shea butter which are prevalent in many Nigerian local markets, it is possible that the precarious state of the low quality of Nigerian shea butter is further worsened.

Tocopherols act principally as antioxidants that protect food from the oxidation of oils and fats.[18,19] Consequently, their presence in shea butter will decrease its oxidation and thus enhance utilization of shea butter as an important source of fat in food and the food industries.[1,2] Tocols are stable under HPLC conditions, they dissolve easily in appropriate solvents and there are many detectors that are combinable with HPLC to detect tocols.[20,21] Alpha-tocopherol is the most studied and dominant biological potent tocopherol isomer.[22] To the best of our knowledge, a report on the quality of shea butter under Nigerian market conditions has not been documented. Therefore, this study evaluated the quality characteristics and α- tocopherol content in locally produced shea butter samples marketed in the southwestern states of Nigeria.

MATERIALS AND METHODS

Sampling. Samples of shea butter were purchased from open markets in Bodija 200132 (Ibadan) located in Ibadan North Local Government of Oyo State, Oke Arin 100272 (Lagos) located at Sanusi Olusi Rd, Lagos, Lagos Island, Nigeria and Falawo (Sagamu) located at RJXX+MG9,121102, in three south-western states of Nigeria: Oyo, Lagos, and Ogun. The seeds of *Vitellaria paradoxa* (Shea nut) were also purchased from Ago-Are, Oyo state, Nigeria for the laboratory-produced shea butter. Information about the Shea butter samples is provided in table 1.

Table 1. Detailed information on shea butter samples obtained from selected markets in southwest Nigeria.

Sample number	Place of purchase	State of purchase	Place of purchase
1.	Ibadan 01	Oyo	Bodija market
2	Ibadan 02	Oyo	Bodija market
3	Ibadan 03	Oyo	Bodija market
4	Ibadan 04	Oyo	Bodija market
5	Lagos 01	Lagos	Oke-arin market
6	Lagos 02	Lagos	Oke-arin market
7	Lagos 03	Lagos	Oke-arin market
8	Lagos 04	Lagos	Oke-arin market
9	Lagos 05	Lagos	Oke-arin market
10	Sagamu 01	Ogun	Falawo market
11	Sagamu 02	Ogun	Falawo market
12	Sagamu 03	Ogun	Falawo market
13	Sagamu 04	Ogun	Falawo market
14	Sagamu 05	Ogun	Falawo market
15	Refined shea butter	Ogun	Laboratory produced

Chemicals and equipment. Chemicals used in this study include DL-alpha-tocopherol (Supelco), HPLC grade methanol (Sigma-Aldrich), potassium hydroxide, sodium thiosulphate, potassium iodide, hydrochloric acid, phenolphthalein, chloroform, n-hexane, Wijs solution, carbon tetrachloride, glacial acetic acid, ethanol and water.

Extraction of traditional shea butter from shea nuts. The shea shell was cracked by hand to release the shea nut, after which extractors washed the nuts and left them for drying to remove moisture. Then, extractors pounded the nuts and crushed them into smaller pieces which were roasted and transformed into a dark chocolate coloured paste. The paste which was purified by washing with pure water several times was heated and the fat portion raised to the top while the oil remained at the bottom. In the final step, fat was skimmed off and the oil was left to settle at the bottom. The oil becomes hard and was used as shea butter.

Extraction of refined shea butter from shea nuts. The collected shea nuts were crushed with mortar and pestle to remove the seed. The seeds were further crushed into smaller fragments and oven-dried at 45°C for about 3 hours. The dried seeds were ground and extracted in a soxhlet extractor with n-hexane. After three hours of extraction, the extract (n-hexane and shea oil) was concentrated on a rotatory evaporator to remove the n-hexane leaving the shea butter oil. The resulting shea oil was then left overnight in a beaker to solidify, producing the refined shea butter.[23] These samples were subjected to analysis for quality characteristics: acid value [AV], free fatty acid [FFA], peroxide value [PV], iodine value [IV] and saponification value [SV].

Acid value determination. Acid values were quantitated using the method described by Paquot[24] and reported by Adejumo.[25] A melted and filtered shea butter sample (2.5 g) was placed in a 250 mL Erlenmeyer flask and 150 mL of a neutralized mixture of ethanol and diethyl ether solution (1:1) was added. Ethanolic potassium hydroxide (0.1 N) solution was then used to titrate the mixture to a pink color which lasted for at least 10 seconds. Acid value and free fatty acid value were estimated using the following formula: Acid value = F x a x 5.61/ weight (in g) of the sample.

Where: F = normality of standardized potassium hydroxide solution; a = volume of 0.1M KOH required (titre value). The acidity which is expressed as free fatty acid is calculated as; free fatty acid = acid value x 0.503.

Peroxide value determination. Peroxide value was measured as described by previously reported methods.[24,25] Three (3) grams (weighed to 0.001 g accuracy) of melted and filtered shea butter sample were placed in a 250 mL capacity Erlenmeyer flask and the following reagents were added to it: 10 mL of chloroform, 15 mL of glacial acetic acid, 1 mL of potassium iodide saturated solution, 2 mL of starch solution, and 75 ml of distilled water. The resultant mixture showing dark purple to dark brown was titrated with standardized 0.01 N sodium thiosulfate solution until the color of the mixture turned ivory to white color. The peroxide value was calculated by the following formula: Peroxide value (mEq/kg) = V x T x 1000/g

Where, V is the number of mL of standardized sodium thiosulfate solution used for the test corrected to consider the blank test, T is the exact normality of the sodium thiosulfate solution used and g is the mass in grams of the test portion.

Iodine value determination. The iodine value was measured as previously described by Paquot[24] in accordance with AOAC[26] and AOCS.[27] Shea butter (0.3 g) was weighed, dissolved with heat and poured into a dry 500 ml iodine flask and 10 ml of carbon tetrachloride was added. After the complete dissolution of the oil, 25 ml of iodine monochloride (Wijs solution) was added from a burette and the stopper previously moistened with KI solution was inserted.

The whole set-up was then allowed to stand in the dark for 30 minutes at a temperature of 25^{o}C. At the end of 30 minutes, 10% KI solution (15 ml) and water (100 ml) were poured into the flask. The iodine liberated was titrated with 0.1 M Na_2SO_3 with starch

mucilage serving as the indicator. A blank titration was also carried out in which the shea butter was not added.

Iodine value = F x (b-a) x 1.269/ weight (in g) of substance

Where: F = factor of 0.1M Na_2SO_3; a = titre value for sample (ml); b = titre value for blank (ml)

Saponification value determination. Saponification value was measured using the method described by Paquot.[24] Two grams of shea butter sample were placed in a 250 ml Quickfit flask and 1 M alcoholic KOH (25 ml) was added. With a reflux condenser attached, the mixture was refluxed for 1h on a water bath, with a frequent swirling of the content. Thereafter, the water bath was removed from under the flask and phenolphthalein solution (5 ml) was poured down the condenser. The flask was subsequently cooled under a running tap for five minutes followed by titration with 0.5 M HCl. A blank titration was carried out without the shea butter sample.

Saponification value = F x (b-a) x 28.05/weight (in g) of substance

Where, F = factor of 0.5M HCl; a = titer value of sample (ml); b = titer value of blank (ml); and 28.05 = mg of KOH equivalent to1ml of 0.5 M HCl

Analysis of alpha-tocopherol by RP-HPLC. The reversed-phase high-performance liquid chromatography (RP-HPLC) (Agilent 1100 HPLC series) equipped with a main controlling unit, quaternary pump, online degasser and water x-bridge C8 column (100 x 4.6 mm ID, 5µm particle size), with 20µl injector was used. An existing RP-HPLC method[28] was used with specifications described as modified,[25] for the determination of alpha-tocopherol content of the shea butter samples. Injection volume was 20 µL while methanol: water (96:4% v/v) was the mobile phase.

The elution flow rate was 1.00 mL/min and the analytical column was kept at 35°C. The separation was done in an isocratic mode. Three injections of each concentration of the reference standard were analyzed and the peak areas (the mean of the peak area of each concentration) were used for calculations. Detection was performed at 292 nm as each run lasted about 5.0 minutes. The column temperature was adjusted to 35°C for better peak separation instead of 45^0C, while the flow rate of 1 ml/min which lasted for 5 minutes was used rather than the 2 ml/min flow rate which lasted for 6 minutes. The dilution factor was adjusted to 60. The concentration of alpha-tocopherol in each sample was calculated using the alpha-tocopherol calibration curve (each shea butter sample was run twice and the mean was used). Data was collected by Agilent chromatograph automated chem. station software and the method was fully validated.[29] The regression equation for the calibration curve was y = 7.7398x + 1.3394, r^2=1

Preparation of standards and validation measurements. DL-alpha tocopherol PHR1031 Supelco (0.010 g) (Merck, Germany) was weighed into a 100 ml volumetric flask. Sixty (60) milliliters of the mobile phase comprising methanol: water (96 : 4 v/v) was added and stirred until dissolved using a magnetic stirrer. The solution was made up to 100 ml mark with the mobile phase and mixed properly. Standard solutions of 1.3, 2.5, 5.0, 10.0., and 20.0 µg/ml concentrations were prepared from this stock solution with the mobile phase. Validation measurements carried out include linearity, recovery rates, ruggedness, the limit of detection (LOD) and the limit of quantification (LOQ).

Extraction of α-tocopherol from shea butter samples. One (1) gram of shea butter sample was placed in a separating funnel (125 ml) and 10 ml of n-hexane was added and mixed properly for 5 minutes. Two hundred microliter of diluted shea butter was mixed with methanol (800 µL). The mixture was centrifuged and the supernatant was filtered (0.45 µm pore size). Chromatography analysis was performed according to the previous method.[28]

Estimation of α-tocopherol (mg) per serving and % daily value. A serving of shea butter is one table spoon, and it contains fourteen grams of total fat in a serving. About six grams of fat in shea butter is monounsaturated healthy form of fat. Furthermore,

about six grams is saturated fat while almost 1 gram of polyunsaturated fat is present in shea butter.[30] The α-tocopherol (mg) per serving was estimated using the following formula: mg/serving = concentration (mg/100 g) of shea butter x serving size/ 100. The Recommended Dietary Allowance (RDA) for both men and women are 15 mg (35 μmol)/day of α-tocopherol.[31] The percentage daily value (% DV) was estimated using the following formula: %DV = mg/serving x 100/ RDA

Statistical analysis. In this study, triplicate determinations were carried out on the sample for each test. Data were expressed as mean ± standard deviation (SD). A one-way ANOVA was used to analyze the differences between means using SPSS for Windows Version 17.0 statistical package. A p-value of < 0.05 was considered statistically significant.

RESULTS AND DISCUSSION

The chemical characteristics of shea butter samples obtained from selected markets in three southwestern Nigeria are shown in table 2. All the characteristics exhibited significant differences ($p < 0.05$) between the evaluated samples.

Table 2. Chemical characteristics of shea butter samples obtained from selected markets in three states in southwestern Nigeria.

Sample number	Acid value mgKOH/Kg	Free fatty acid (%)	Peroxide value (mEq/kg)	Iodine value (g/100g)	Saponification value (mgKOH/g)
1.	2.49±0.03^{a}	1.25±0.03^{a}	0.81±0.02^{b}	46.57±1.23^{a}	179.84±0.21^{d}
2	2.51±0.02^{a}	1.26±0.02^{a}	0.87±0.01^{b}	46.57±1.13^{a}	172.87±1.27^{e}
3	2.48±0.02^{a}	1.25±0.02^{a}	0.82±0.00^{b}	44.86±2.32^{b}	170.08±1.25^{e}
4	2.51±0.01^{a}	1.26±0.01^{a}	0.87±0.02$^{a\,b}$	44.43±1.30^{b}	174.26±1.13^{e}
5	2.55±0.02^{a}	1.28±0.02^{a}	0.91±0.01^{a}	46.14±1.03^{a}	197.96±1.23^{c}
6	2.53±0.00^{a}	1.27±0.00^{a}	0.89±0.00^{a}	45.29±1.11^{b}	204.93±2.01^{b}
7	2.53±0.01^{a}	1.28±0.01^{a}	0.89±0.03^{a}	46.14±1.45^{a}	203.54±1.11^{b}
8	2.53±0.03^{a}	1.27±0.03^{a}	0.90±0.01^{a}	46.14±0.91^{a}	196.57±1.23^{c}
9	2.52±0.02^{a}	1.27±0.02^{a}	0.88±0.02^{asb}	45.71±1.16^{a}	199.35±1.20^{c}
10	2.20±0.01^{b}	1.11±0.01^{b}	0.73±0.02^{c}	44.43±2.00^{b}	186.81±1.01^{d}
11	2.24±0.01^{b}	1.13±0.01^{b}	0.79±0.01^{c}	46.14±1.15^{a}	184.02±1.21^{d}
12	2.21±0.02^{b}	1.11±0.02^{b}	0.76±0.01^{c}	47.85±2.23^{a}	181.23±0.37^{d}
13	2.23±0.01^{b}	1.12±0.01^{b}	0.77±0.00^{c}	47.10±1.45^{a}	184.02±2.12^{d}
14	2.20±0.01^{b}	1.15±0.01^{b}	0.75±0.01^{c}	47.85±1.03^{a}	182.63±1.99^{d}
15	2.59±0.02^{a}	1.30±0.02^{a}	0.95±0.01^{a}	46.14±1.07^{a}	259.30±1.21^{a}

Values are means of triplicate determinations. Within the column of each treatment values with different superscripts are significantly different ($p < 0.05$).

The acid value reflects the number of fatty acids hydrolysed from triacylglycerides and indexes its quality. Acid values (AV) ranged in this study from 2.20-2.59 mgKOH/Kg and free fatty acid values (FFA) (%) were between 1.11-1.30%. The values of the two parameters varied significantly across different markets. A previous study submitted that non-standardization and lack of quality control are hallmarks of shea products that are locally processed in Nigeria.[11]

The absence of standard practice in the shea products value chain might be responsible for the observed variation of the acid value qualities. The AV obtained in the present study is lower than those (3.00 – 12.59) obtained in different Ugandan shea zones.[1] The FFA values obtained in the present study are lower than those (2.1-6.2 %) reported by Mbaiguinam[32] on shea butter of Southern Chad origin. However, it is evident that the values obtained from the present study are relatively higher than the

FFA values commonly reported in the literature: <0.05 %,[33] and 0.77 %.[34] The acceptable limit of FFA in grade 1 unrefined shea butter for direct consumption is 1% while the second grade is destined for the food industry (confectionery, chocolate, edible oil or the base for margarines), and is permitted to contain up to 3% FFA.[35]

The present result implies that the examined marketed shea butter samples in these three states are not fit for direct consumption but for the food industry. However, it should be noted that these samples were obtained from markets where they were to be purchased for direct consumption. The unusually high level of FFA in both market samples and laboratory-produced samples assayed in the present study is an indication that rancidity has taken place in these shea products, thus suggesting that the rancidity problem in shea products is more endemic in the Shea value chain rather than at the marketing stage only.

Peroxide value is a measure of oil quality as it indicates the oxidative stability of the oil and the level of rancidity and deterioration of fats. The range of peroxide values (PV) in the shea butter sample is 0.73-0.95 mEqO_2/Kg. In a trend that is like those of acid values and FFA, the PV varied significantly ($p < 0.05$) across different markets and the laboratory-produced sample was not significantly different ($p > 0.05$) from some of the market samples. The values of the present study are lower than 2.1 - 2.5 mEq O_2/kg reported in Uganda,[1] but agree with 0.96–1.01 mEq O_2/kg reported for optimized shea butter in Ivory Coast.[3] PV obtained in the present study is much lower than the maximally acceptable value of 10 mEqO_2/kg) in grade 1 unrefined shea butter destined for direct consumption.[35] The low PV of the examined shea butter is indicating that there would be a resistance of the butter to rancidity via peroxidation during storage and that rancidity was less likely to be due to oxidation than hydrolysis.[35,36]

Iodine value measures and indicates the degree of unsaturation in oils, hence, an identity characteristic of native oil. The iodine values of the evaluated shea butter samples ranged between 44.43 and 47.85 gI_2/100g. Iodine values ranged between 44.43-46.57 for Ibadan markets, 45.29-46.14 for Lagos markets, and 44.43-47.85 for the Sagamu markets, while the laboratory-produced shea butter sample had an IV of 46.14 respectively. They varied significantly ($p < 0.05$) across the different markets. The saponification value of the laboratory-produced samples was significantly ($p < 0.05$) highest. The iodine value of the samples in the present study is higher than 39-41 I2 gI_2/100g reported for Ugandan shea butter[1] but lower than 52.64-53.06 reported for optimized shea butter in Ivory Coast.[3] It has been officially stated that the acceptable range for iodine value in unrefined shea butter is 30–75 gI_2/100g.[34] This indicates that the evaluated shea butter samples are both food and food industry grade.

The saponification value is the number of milligrams of potassium hydroxide required to neutralize the fatty acid present via a hydrolysis reaction. The saponification values of the evaluated shea butter samples ranged between 170.08 and 259.30 mgKOH/g. Okullo[1] reported a saponification value of 160-192 which is lower than the values obtained in the present study. Considerable ranges for the saponification values have been documented, but most are between 132 mg KOH/g and 207.5 mg KOH/g and the average is 180.9 mg KOH/g.[36,37] Codex Alimentarius[34] recommended 160-195 mgKOH/g saponification values for unrefined shea butter. In this connection, sample numbers 5, 6, 7, 8, 9 and 15 are not within this acceptable limit and do not qualify for domestic consumption and food industry application.

The calibration curves showed good linearity ($r^2=1$) as displayed above in figure 1 while figures 2 and 3 display chromatograms of a sample and a standard respectively. HPLC validation results are as follows: mean recovery at two levels of spiking was 98.9% and 97.2% respectively while ruggedness value (% RSD) was 0.48 %. Precision gave a relative standard deviation (RSD) of 0.4% and a % content of 99.67±1.49 with a % RSD of 1.5% calculated showing the repeatability of the method. The method displayed good specificity and selectivity as diluents

and placebo did not show any interference at the retention time of alpha-tocopherol. All the validation parameters fell within the acceptance criteria as stipulated in the analytical methods validation protocol.[26] The limit of detection and limit of quantification values were 0.5 and 5 µg/ml, respectively.

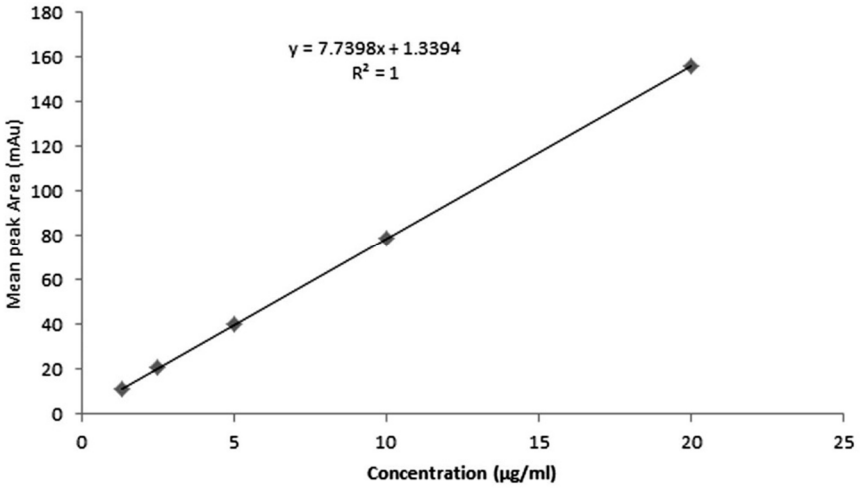

Figure 1. HPLC calibration curve for alpha-tocopherol standard.

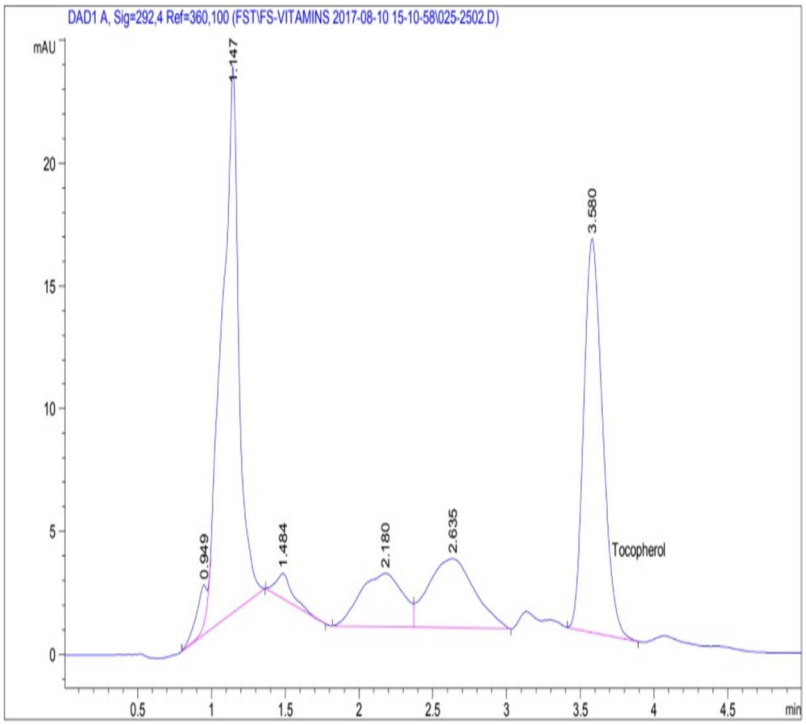

Figure 2. HPLC chromatograph for alpha-tocopherol in shea butter sample (Sagamu 05).

The α-tocopherol content of the market samples of shea butter differed significantly ($p<0.05$) from that of laboratory-produced samples as indicated in table 3. There were also significant variations

($p<0.05$) within and between different market samples. The range of α-tocopherol content of the market samples was 1.15–2.60 mg/100g while that of the laboratory sample was 5.25 mg/100g.

These values are much lower than the value of 26.3-44.4 mg/100g reported for Ugandan shea butter.[1] Similarly, higher values of between 54.4 and 55.0 mg/100mg have been reported in Ivory Coast[3], while 41.4 mg/100g has been documented for Chadian shea butter.[38]

The same study in Chadian shea butter also reported that tocopherols isomers detected in shea butter include α, β, γ, and δ-tocopherols, among which α-tocopherol was found to be the major tocopherol (64% of the total tocopherols).[38] These

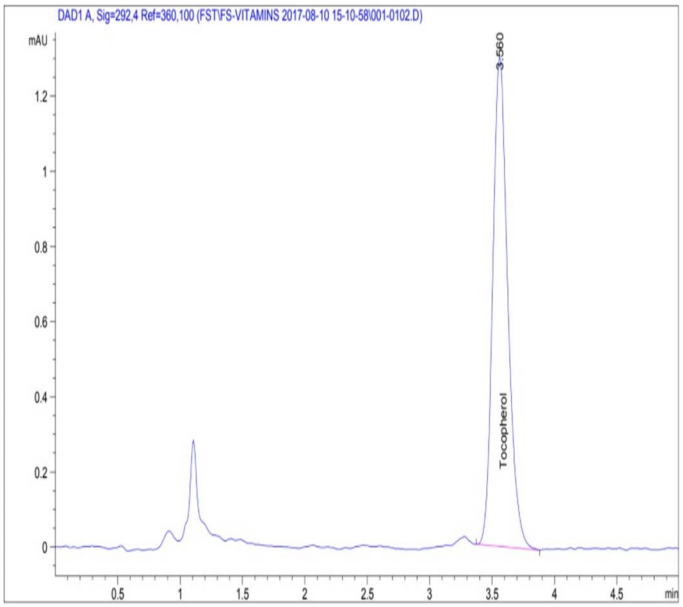

Figure 3. Calibration curve for standard DL-alpha-tocopherol.

Table 3. Alpha-tocopherol contents of shea butter samples obtained from selected markets in three southwestern Nigeria and their corresponding per serving and percentage dietary value.

Sample number	α-tocopherols content (mg/100g)	α-tocopherol (mg) /serving	Percentage dietary value
1.	1.51 ± 0.03^{d}	0.21 ± 0.03^{d}	1.40 ± 0.03^{d}
2	2.06 ± 0.10^{c}	0.29 ± 0.10^{c}	1.93 ± 0.10^{c}
3	2.60 ± 0.08^{b}	0.36 ± 0.08^{b}	2.40 ± 0.08^{b}
4	2.13 ± 0.05^{bc}	0.30 ± 0.05^{bc}	2.00 ± 0.05^{bc}
5	2.32 ± 0.08^{bc}	0.33 ± 0.08^{bc}	2.20 ± 0.08^{bc}
6	2.24 ± 0.04^{bc}	0.31 ± 0.04^{bc}	2.07 ± 0.04^{bc}
7	1.97 ± 0.07^{c}	0.28 ± 0.07^{c}	1.87 ± 0.07^{c}
8	2.52 ± 0.11^{b}	0.35 ± 0.11^{b}	2.33 ± 0.11^{b}
9	1.36 ± 0.05^{d}	0.19 ± 0.05^{d}	1.27 ± 0.05^{d}
10	2.15 ± 0.08^{bc}	0.30 ± 0.08^{bc}	2.00 ± 0.08^{bc}
11	1.88 ± 0.02^{c}	0.26 ± 0.02^{c}	1.73 ± 0.02^{c}
12	1.15 ± 0.01^{d}	0.16 ± 0.01^{d}	1.07 ± 0.01^{d}
13	1.38 ± 0.05^{d}	0.19 ± 0.05^{d}	1.27 ± 0.05^{d}
14	1.83 ± 0.09^{c}	0.26 ± 0.09^{c}	1.73 ± 0.09^{c}
15	5.25 ± 0.14^{a}	0.74 ± 0.14^{a}	4.93 ± 0.14^{a}

Values are means of triplicate determinations. Within the column of each treatment values with different superscripts are significantly different ($p < 0.05$).

authors further reported that tocopherol content, especially α-tocopherol, was directly correlated with temperature; with shea butter from hot, dry areas containing higher amounts than the butter which originated from cooler areas. Other factors linked to variation in α-tocopherols are the storage period of the oil and genetic influence.[38,39] The three southwestern cities of Nigeria from which the examined shea butter was collected are situated within the rainforest belt of Nigeria with the following climatic conditions: Ibadan (temperature, 26.5°C; mean annual rainfall, 1311 mm), Sagamu (temperature, 27.1°C; mean annual rainfall, 1514 mm), and Lagos (temperature, 27.0°C; mean annual rainfall, 1693 mm).[40] The effect of these prevalent climatic conditions might be responsible for the low α-tocopherol contents of the investigated butter samples compared with those from other regions in Africa.

Alpha (α)-tocopherol (mg) per serving and percentage dietary value of the investigated shea butter samples were 0.16–0.74 mg/serving and 1.07 – 4.93% respectively (Table 3). The general guide to the interpretation of % DV stipulates that DV of ≤ 5% is considered low while ≥ 20% DV is considered high.[41] It is not uncommon for shea butter to be taunted as a dietary source of α-tocopherols. Though this may be true for shea butter obtained from regions with dry conditions and high temperatures, however, results of the present investigation suggest a somewhat different position for Nigerian shea butter, with all the samples having less than 5% DV values.

CONCLUSION

The quality of shea butter samples selected from markets in three southwestern states of Nigeria varied significantly both within and across different markets. The FFA content obtained suggest that the examined market shea butter samples in these three states are not fit for direct consumption but may be useful in food industry such as confectionery, chocolate, edible oil or as a base for margarine industries. Peroxide values and iodine values from this investigation also suggest that they are both food and food-industry grade. However, the saponification values suggest that 40% of the investigated samples did not qualify for domestic consumption and food industry applications. Similarly, all the examined shea butter cannot serve as a dietary source of α-tocopherols as all the samples had less than 5% DV values. A low % DV could be because of many factors (fruit quality or seeds, extraction systems and refining procedures) which could have influenced the concentration of alpha-tocopherol in the fats. Consequently, it is important that good manufacturing and handling standards, along the shea butter value chain be adhered to in Nigeria if the great socio-economic, health and food potentials of shea butter are to be maximized.

Declaration of competing interest

The authors declare no known personal or financial competing interest.

ACKNOWLEDGEMENTS

The authors appreciate the laboratory support and contributions of Mr. B E Ndimele and Mr. Taiwo for running the HPLC method.

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