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PHYSICOCHEMICAL AND FATTY ACID PROFILE OF SHEA BUTTER AS INFLUENCED BY STORAGE ENVIRONMENTS AND TIME OF SHEA (*VITELLARIA PARADOXA* C.F.GAERTN.) NUTS IN YOLA, ADAMAWA STATE, NIGERIA

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ABSTRACT

The effects of storage environments (open space and laboratory, under ambient condition) and time (0, 1.5, 3, 4.5, 6, 7.5 and 9 months) on shea nuts as it affects the quality of shea butter was investigated, from September 2009 to June 2010 at Modibbo Adama University of Technology, Yola. The experimental set up was a Factorial in Randomized Complete Block Design. The physico-chemical parameters and fatty acid composition determined were oil yield, oil density, refractive index, specific gravity, iodine value, saponification value, unsaponifiable matter, free fatty acid, stearic acid, oleic acid, linoleic acid, linolenic acid and palmitic acid. The results showed that storage time significantly ($p<0.01$) affected oil density, refractive index, specific gravity, saponification value, unsaponifiable matter, free fatty acid, stearic acid, linoleic acid, oleic acid and palmitic acid. Storage environments significantly ($p<0.01$) affected refractive index, iodine value, saponification value, free fatty acid, stearic acid, oleic acid, linoleic acid and linolenic acid. The interaction between storage time and environments significantly ($p<0.01$) affected oil density, refractive index, specific gravity, iodine value, saponification value, unsaponifiable matter, free fatty acid, stearic acid, oleic acid, linoleic acid and palmitic acid. Based on the parameters measured, storage of nuts for 9 months was found to be promising in terms of oil yield, linoleic acid, linolenic acid, free fatty acids and the saponification value. On the other hand, laboratory storage environment happened to perform very well in terms of oil yield, oil density, free fatty acid, iodine value, linoleic acid and palmitic acid as compared to open space storage environment. It is, therefore, concluded that storage for 9 months and laboratory storage environment were the best storage conditions respectively.

Key words: Shea butter, Storage, fatty acids profile, time, environments, Quality.

INTRODUCTION

Shea nuts are obtained from the fruits of shea tree (Olaniyan and Oje, 2007). The butter extracted from it (Rajeev, 2011) is highly appreciated for its multi-uses Mohagir *et al*., 2009).

Shea butter is becoming more popular be-

cause of its unsaturated fatty acid composition as well as the potential utility of its unsaponifiable fraction now being used in cosmeceutical, pharmaceutical and nutraceutical applications (Moharram *et al*., 2006). Traditionally, shea butter is used as a decongestant, an anti-inflammatory for sprains and arthritis, a healing salve for babies' umbilical cords, a lotion for hair and skin care, as cooking oil and for lamp fuel (Agbanga Karite, 2010).

How shea kernels are stored or the environment in which they are stored, have a great effect on the quality of shea butter that will be extracted from the kernels. As pointed out by Kordylas (1990), dried kernels of shea have to be kept with care in a well ventilated area; careless storage reduces the percentage of oil obtained, and the fat breaks down and decomposes.

As pointed out by FAO (2004), the value of shea butter depends very much on the market in which it is sold. It is however, pitiful today that most of the developing countries do not meet the international standard as regards to marketing of agricultural products. This is mostly as a result of low quality products, which is in line with poor storage techniques. A better solution needs to be sought for, in order to meet the international standard for marketing of agricultural products. The objectives of this research work were to determine the: (i) effects of storage environments of shea nuts on the quality of shea butter (ii) effects of storage time of shea nuts before oil extraction on the quality of shea butter.

MATERIALS AND METHODS

Experimental site

The research work was carried out at the Crop Production and Horticulture Departmental laboratory, Modibbo Adama University of Technology, Yola, Adamawa State. Yola is situated at 9^0 16' N, $12^0$35' E and is 152 m above sea level, with an average rainfall of 910.8 mm (Adebayo and Tukur, 1999).

Sample collection and preparation

Physiologically matured shea butter fruits were harvested from the bush from August to September, 2009 for this research work. The fruits were de-pulped and kernels were dried for about 5 to 10 days before storage as described by Fobil (2010).

Shea butter extraction

For each treatment, the dried kernels were de-husked manually, by cracking them between two stones as described by Salunhe *et al*. (1992) cited by Fobil (2010). The nuts were then roasted, milled into powder before oil extraction. Oil from the milled nuts was extracted with n-hexane solvent using Soxhlet apparatus (Pomeranz and Meloan, 2004; Jacobs, 1999).

Experimental design and layout

A Factorial in Randomized Block Design (RCBD) was used, consisting of two factors:
Factor 1: Storage environment. This consisted of two storage environment which were open space where the nuts were exposed to the effects of weather elements like rainfall, wind etc. The other environment was the cool room environment where the nuts were kept in the laboratory with cross ventilation. In each of the storage environment, there were seven treatments replicated three times.

Factor 2: Storage time. Oil from some of the nuts were extracted and analyzed immediately after harvest and subsequent extracted oil were analyzed for the period of one and the half months interval for the period of nine

months. This factor had seven levels. Thus, the experiment consisted of 2 X 7 treatment combinations and was replicated three times.

Data collection

Physico-chemical properties

Oil yield, density, specific gravity, refractive index, free fatty acids, iodine value, saponification value, unsaponifiable matter were determined as described by Onwuka (2005).

Fatty acids profile

Fatty acids profile was assayed using High Performance Liquid Chromatography (HPLC) (BLC-10.254 nm flow cell), 15 cm c/8 column, by employing methanol-water (70: 30 v/v) solvent system (mobile phase). The amount of each fatty acid in the sample was expressed as percentage of the sum of all fatty acids in the sample as indicated below:

$$\% \text{ fatty acid} = \left[\frac{\text{fatty acid peak area}}{\Sigma \text{total fatty acid peak areas}}\right] x100$$

Statistical analysis

Data collected were subjected to Analysis of Variance (ANOVA) using Genstat Statistical package. Means were separated using the Least Significant Difference (LSD) at 5 % probability level.

RESULTS AND DISCUSSION

Effects of the treatments on the physical properties of shea butter

Storage of nuts in the laboratory significantly ($p<0.05$) gave higher oil yield as compared to open space (Table 1). The significant differences observed for the different storage environments, might be attributed to harsh weather conditions the shea nuts stored in open space had been exposed to, such a high temperatures from the sun aided in the loss of oil during the prolonged time of storage. Similar report was given by Ferris *et al*. (2001) that when shea nuts are over dried or over heated, oil is lost.

Table 1 revealed that extracting the oil after the nuts have been stored for 3, 4.5, 6 and 7.5 months significantly ($p<0.01$) gave higher oil density, while storage of nuts for 0, 1.5 and 9 months significantly gave low oil density. No significant ($p<0.05$) difference was observed in terms of storage environment. The interaction significantly ($p<0.01$) gave higher oil density for nuts stored in the laboratory at 1.5, 3.0, 7.5 and 9 months. However, low values of oil density were obtained at 4.5 and 6 months of storage (Table 2). The differences observed for oil density, could be due to variations in temperatures during the period of storage and also due to the two storage environment of the nuts. It was reported by Abramovic and Abram (2005) that as storage temperature increases, the density of the oil decreases. The variations may also be due to the differences in the degree of unsaturation of the nuts over time. Ohlson (1983) as cited by Abramovic and Abram (2005) reported that density of oil increases as the degree of unsaturation increases.

Refractive index was significantly ($p<0.01$) higher for storage of nuts for 0, 4.5 and 6 months. However, storage of nuts for 1.5, 3, 7.5 and 9 months before oil extraction gave low refractive index (Table 1). Open space storage significantly ($p<0.01$) gave higher refractive index as compared to laboratory storage. With respect to the interaction, refractive index of nuts stored in the laboratory was in all cases higher than the nuts stored in the open space, except for storage for 3 months and 7.5 months in the open space storage that gave higher and equal values respectively (Table 2). Differences in storage temperatures due to the different storage environment might have caused the

differences observed in refractive index among the various storage time and environment. Cheronis *et al*. (1983) reported that the refractive index varies significantly with the temperature. The value of the refractive index decreases from 0.00035 to 0.00055 for each degree rise in temperature. According to Fashina and Ajibola (1989) as cited by Olaniyan and Oje (2007), the refractive index is used for rapid sorting of fats and oils for suspected adulterations. Shea butter continues to be adulterated as heating temperature increases beyond 90 ^{0}C.

Storage of nuts for 0, 1.5, 3, 4.5 and 9 months significantly ($p<0.01$) gave oil of high specific gravity, while storage of nuts for 6 and 7.5 months gave oil of low specific gravity (Table 1).

Table 1: - Effect of treatments on the physical properties of shea butter

Treatment Storage time (months)	Oil yield (%)	Oil density (g/cm^3)	Refractive index	Specific gravity
0	46.41	0.903	1.465	0.915
1.5	40.37	0.932	1.464	0.908
3.0	38.08	0.960	1.462	0.913
4.5	39.84	0.959	1.466	0.909
6.0	39.83	0.952	1.465	0.905
7.5	36.81	0.952	1.464	0.904
9.0	44.44	0.898	1.464	0.909
SE	4.25	0.00095	0.0004	0.0006
LSD	9.255	0.0019	0.0008	0.0013
Prob. of F	0.330	<0.001	<0.001	<0.001
Storage Environment				
Open space	39.41	0.936	1.465	0.909
Laboratory	42.24	0.937	1.464	0.909
SE	1.117	0.0005	0.0002	0.0003
LSD	2.397	0.0010	0.0004	0.0006
Prob. of F	0.024	0.434	<0.001	0.015
Interaction				
SE	4.734	0.0012	0.0005	0.0008
LSD	9.961	0.0021	0.0010	0.0016
Prob. of F	0.292	<0.0001	<0.001	<0.001

Table 2: - Interaction of storage time and environment on the oil density, refractive Index and specific gravity of shea butter

Storage time (months)	Density (g/cm^3) E1 E2 (open space)	(Lab.)	Refractive index E1 E2 (open space)	(Lab.)	Specific gravity E1 E2 (open space)	(Lab.)
0	0.904	0.902	1.463	1.466	0.916	0.913
1.5	0.929	0.934	1.463	1.465	0.905	0.910
3.0	0.958	0.961	1.468	1.456	0.911	0.914
4.5	0.963	0.955	1.465	1.466	0.912	0.906
6.0	0.954	0.949	1.464	1.465	0.907	0.902
7.5	0.946	0.957	1.464	1.464	0.898	0.911
9.0	0.898	0.897	1.463	1.464	0.909	0.908

Laboratory storage happened to have higher mean in terms of specific gravity as compared to open space storage ($p<0.05$). The interaction revealed that extracting the oil after 1.5 and 3 months of storage gave higher specific gravity from nuts that were stored in the laboratory environment ($p<0.01$). As storage time increased beyond three months, nuts stored in open space gave higher specific gravity (Table 2).

Effects of the treatments on the chemical properties of shea butter

Storage of nuts for 0, 3, 4.5 and 7.5 months significantly ($p<0.01$) gave high saponification value, while storage of nuts for 1.5, 6 and 9 months significantly gave low saponification value (Table 3). In terms of storage environments, storage in the laboratory significantly ($p<0.01$) gave high saponification value as compared to open space storage (Table 3). The interaction between the two factors on saponification value shows that extracting the oil after 3, 4.5, 6 and 7.5 months of storage significantly ($p<0.01$) gave higher saponification value from nuts that were stored in the laboratory. However, at 0, 1.5 and 9 months open space storage gave higher saponification values (Table 4). The differences noticed might be linked to temperature variations during extraction, which is inversely proportional to the saponification value. The high saponification value noticed in storage of nuts for 0, 3.0, 4.5 and 7.5 months as well as noticed in storage in the laboratory indicates the presence of high percentage of fatty acids in the oil (Omolara and Dosumu, 2009) as cited by Okoye *et al*. (2011). High saponification value may suggest possible use of the oil in the soap industry.

Storage of nuts for 3 months before butter extraction significantly ($p<0.01$) gave the

highest mean in terms of unsaponifiable matter, followed closely by storage of nuts for 9, 6, 1.5 and 7.5 months (Table 3). Storage of nuts for 0 and 4.5 months had significantly given low unsaponifiable matter. No significant ($p<0.05$) effect was observed for unsaponifiable matter with respect to storage environments. The interaction clearly reveals that extracting the butter after 1.5 and 3 months of storage gave higher unsaponifiable matter contents. However, as storage time increased beyond three.

Table 3: - Effects of treatments on the chemical properties of shea butter

Storage time (Months)	Iodine value (I_2g/100g)	Saponification value (mgKOH/g)	Unsaponifiable matter (%)	Free fatty acid (%)
0	49.97	176.00	6.35	2.29
1.5	50.50	173.83	6.53	2.27
3.0	50.55	175.00	6.75	8.24
4.5	49.73	175.33	6.40	4.54
6.0	50.32	174.33	6.55	4.36
7.5	50.10	175.83	6.52	2.73
9.0	49.97	172.00	6.65	0.57
SE	0.199	0.333	0.0215	0.444
LSD	0.434	0.726	0.047	0.968
Prob. of F	0.012	<0.001	<0.001	<0.001
Storage Environment				
Open space	49.43	173.48	6.55	4.61
Laboratory	50.89	175.76	6.52	2.53
SE	0.087	0.172	0.024	0.16
LSD	0.187	0.368	0.052	0.343
Prob. of F	<0.001	<0.001	0.343	<0.001
Interaction				
SE	0.2574	0.4629	0.050	0.535
LSD	0.531	0.9521	0.105	1.112
Prob. of F	<0.001	<0.001	<0.001	<0.001

Table 4:- Interactive effect of storage time and environment on the iodine value and saponification value of shea butter

Storage time (months)	Iodine value (I_2g/100g) E1 (open space)	E2 (Lab.)	Saponification value (mgKOH/g) E1 (open space)	E2 (Lab.)
0	49.07	50.87	177.67	174.33
1.5	49.77	51.23	176.33	171.33
3.0	48.77	52.33	171.33	178.67
4.5	49.07	50.40	175.33	175.33
6.0	50.13	50.50	170.00	178.67
7.5	50.07	50.13	171.33	180.33
9.0	49.17	50.77	172.33	171.67

Table 5: - Interactive effect of storage time and environment on the unsaponifiable matter and free fatty acid of shea butter

Storage time (months)	Unsaponifiable matter (%) E1 (open space)	(Lab.) E2	Free fatty acid (%) E1 (open space)	(Lab.) E2
0	6.23	6.47	2.36	2.21
1.5	6.40	6.67	3.02	1.52
3.0	6.70	6.80	10.35	6.13
4.5	6.43	6.37	7.01	2.06
6.0	6.77	6.33	6.45	2.28
7.5	6.67	6.37	2.47	2.99
9.0	6.63	6.67	0.59	0.55

months, nuts stored in the open space gave higher unsaponifiable matter up to 7.5 months of storage (Table 5). The significant variation that existed could be attributed to the different sources the shea fruits were obtained from which normally affects the level of the healing fractions. It could also be due to the age of the shea butter and the storage conditions of the products before analysis, which could have affected the healing properties within the shea butter. Similar information was given by Squidoo (2011).

Storage of nuts for 3 months significantly ($p<0.01$) gave the highest free fatty acid contents, followed by 4.5 and 6 months of storage. Storage for 0, 1.5 7.5 and 9 months gave low free fatty acid contents (Table 3). Storage in the laboratory had significantly ($p<0.01$) gave low free fatty acid as compared to open space. For the interaction between the two factors, it shows that storage period of nuts in the open space gave higher FFA than nuts stored in the laboratory from the beginning of the storage to the end, except for storage for 7.5 months in the laboratory which gave higher FFA value (Table 5). The variations observed could either be due to seasonal effect on kernels, or poor storage conditions at source after fat extraction due to oxidation (Dei *et al*., 2008). It may also be attributed to the recalcitrant nature of shea fruits; early germination may increase the free fatty acid of shea oil (Okullo *et al*., 2010).

Iodine value was significantly ($p<0.05$) higher for storage of nuts for 1.5, 3, 6 and 7.5 months, while storage for 0, 4.5 and 9 months gave low values. Storage in the laboratory had significantly ($p<0.01$) gave high iodine values than the open space storage (Table 3). The interaction shows that iodine value was higher for the nuts stored in the laboratory than those that were stored in open space from the beginning of storage period up to 9 months of storage (Table 4). The variations observed might be due to differences in heating temperatures during oil extraction. Olaniyan and Oje (2007) mentioned that iodine value decreases with increase in heating temperatures of shea butter. It may also be due to the differences in the storage environment of the shea nuts as shade affects the iodine value (James, 1961).

Effects of the treatments on the fatty acid profiles of the shea butter

From the result in Table 6, storage of nuts for 4.5, 7.5 and 9 months significantly ($p<0.01$) gave high stearic acid contents, while storage for 0, 1.5, 3 and 6 months gave low stearic acid contents. Storage in the laboratory significantly ($p<0.01$) gave high stearic acid contents as compared to open space storage. The interaction shows that extracting the oil from nuts after 3, 6 and 7.5 months storage in open space significantly ($p<0.01$) gave higher stearic acid contents. Also, at 0, 1.5, 4.5 and 9 months of storage, nuts that were stored in the laboratory gave higher stearic acid contents (Table 7) .The differences observed might have been due to the genetic variability (Okullo *et al*., 2010) among the nuts collected from different sources or it might be due to the differences in the storage environment; warm climate favour the formation of unsaturated acids (James, 1961).

Storage for 6 and 7.5 months significantly ($p<0.01$) gave high oleic contents, while storage for 0, 1.5, 3, 4.5 and 9 months gave low oleic contents. Open space storage significantly ($p<0.01$) gave high oleic contents (Table 6). For the interaction, oleic acid composition was high under open space

storage for the first 4.5 months from the beginning of the storage of the nuts. As the storage time increased beyond 4.5 months, nuts stored in the laboratory gave higher oleic acid contents up to 9 months of storage (Table 7). Variations observed in terms of oleic acid contents may be due to the differences in time (age) of storage of the nuts; shea nuts that have been stored for long is softer in terms of butter than the one that have been stored for a short time. Similar record was given by Maranz *et al*. (2004) that shea butter that is produced from nuts that are three months old or less will be much harder than shea butter produced from older nuts. It could also be attributed to high temperature in the open space environments where the nuts were stored, as warm climates favour the formation of unsaturated acids.

Storage for 0,3, 7.5 and 9 months gave high linoleic acid contents ($p<0.01$), while storage for 1.5, 4.5, 6 and 9 months had significantly gave low linoleic acid contents (Table 6). Laboratory storage gave high linoleic acid as compared to open space. Interaction between the two factors revealed that the linoleic acid contents was significantly ($p<0.01$) high at 0, 1.5, 4.5, 6 and 9 months of storage in the laboratory, however, it was low at 3 and 7.5 months of storage for nuts stored in open space. The differences observed may be due to genetic variability among the shea nuts.

As for palmitic acid, storage for 0 and 7.5 months significantly ($p<0.01$) gave higher mean, followed by storage for 9 and 3 months. Storage for 1.5, 4.5 and 6 months were low (Table 6). For the interaction, it was noticed that extracting the oil after 7.5 and 9 months of storage significantly ($p<0.01$) gave higher palmitic acid contents from nuts that were stored in open space. However, laboratory storage environment gave higher values at 1.5 and 6 months of storage of shea nuts (Table 8). The differences that existed could have been due to the age of the nuts during storage and also due to genetic variability that existed among the nuts, as age variation and genetic variability affect the degree of saturation of shea butter.

Linolenic acid gave high mean for storage of nuts for 0, 7.5 and 9 months ,followed by storage of nuts for 4.5 and 6 months ($p<0.05$); storage of nuts for 1.5 and 3 months were the lowest (Table 6). Storage in the open space significantly ($p<0.01$) gave high linolenic acid contents. The interaction reveals that the linolenic acid was higher under open space storage environment at 3, 4.5 and 6 months of storage except for 1.5 months of storage where laboratory storage environment was higher (Table 8). The variations observed could be due to genetic variability of the nuts from the different trees they had been obtained (Okullo *et al*., 2010). It may also be due to the differences in environmental conditions; warm climates favour the formation of unsaturated fatty acid (James, 1961).

Table 6: - Effects of treatments on the fatty acid profiles of shea butter

Treatment Storage time (months)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Palmitic acid (%)
0	27.28	49.57	5.22	0.40	6.32
1.5	27.35	49.77	4.88	0.30	6.08
3.0	27.62	48.95	5.10	0.25	6.12
4.5	29.05	49.57	4.57	0.35	6.03
6.0	27.55	50.25	4.82	0.35	6.07
7.5	28.38	50.18	5.15	0.40	6.30
9.0	28.07	49.55	5.25	0.40	6.13
SE	0.03	0.036	0.035	0.000	0.033
LSD	0.065	0.078	0.075	0.00	0.071
Prob. of F	<0.001	<0.001	<0.001	0.02	<0.001
Storage Environment					
Open space	27.81	49.77	4. 94	0.36	6.17
Laboratory	28.00	49.61	5.05	0.34	6.13
SE	0.02	0.021	0.016	0.00	0.02
LSD	0.043	0.046	0.034	0.000	0.043
Prob. of F	<0.001	<0.001	<0.001	0.002	0.12
Interaction					
SE	0.048	0.054	0.045	0.000	0.0500
LSD	0.099	0.110	0.093	0.000	0.1028
Prob. of F	<0.001	<0.001	<0.001	0.017	0.003

Table 7: - Interactive effect of storage time and environment on the stearic and oleic acids of shea butter

Storage time (months)	Stearic acid (%) E1 (open space)	E2 (Lab.)	Oleic acid (%) E1 (open space)	E2 (Lab.)
0	27.23	27.33	50.10	49.03
1.5	26.40	28.30	50.33	49.20
3.0	28.00	27.23	49.03	48.87
4.5	29.03	29.07	49.77	49.37
6.0	27.87	27.23	50.03	50.47
7.5	30.03	26.73	50.03	50.33
9.0	26.07	30.07	49.07	50.03

Table 8: - Interactive effect of storage time and environment on the linoleic, linolenic and palmitic acids of shea butter

Storage time	Linoleic acid (%) E1 (open space)	E2 (Lab.)	linolenic acid (%) E1 (open space)	E2 (Lab.)	Palmitic acid (%) E1 (open space)	E2 (Lab.)
0	5.03	5.40	0.40	0.40	6.27	6.37
1.5	4.77	5.00	0.20	0.40	6.03	6.13
3.0	5.17	5.03	0.30	0.20	6.20	6.03
4.5	4.37	4.77	0.40	0.30	6.03	6.03
6.0	4.77	4.87	0.40	0.30	6.03	6.10
7.5	5.27	5.03	0.40	0.40	6.37	6.23
9.0	5.23	5.27	0.40	0.40	6.23	6.03

CONCLUSION AND RECOMMENDATION

Storage of nuts for 9 months before butter extraction happened to be the suitable time for storage before oil extraction. On the other hand, laboratory storage environment was found to be very suitable for storage of shea nuts before shea butter extraction.

Based on the findings of this research, it may be recommended that for a high quality shea butter to be extracted from shea nuts the nuts must be stored in well ventilated area ,void of any weather element (like rainfall, high temperatures, etc.) that may lead to low quality shea butter. The nuts can be kept for long before butter extraction provided that they are well stored.

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