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Quality Characteristics and Volatile Compounds of Shea Butter Under Different Storage Conditions

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Abstract
Proper storage of shea butter is crucial to maintain quality and ensure availability of the product over time, particularly in the production zones where refrigeration is not an option. The present study investigated several quality characteristics of shea butter under different storage conditions. Three packaging materials (*i.e.* calabash, black plastic, and transparent plastic), often used to store shea butter in the production zones, were used to store the butter for six months at ambient conditions (28-30ºC) and at low temperatures (4-7ºC). After 6 months of storage, all parameters investigated were significantly affected by storage conditions and storage duration while the effects of the packaging materials were less pronounced. At ambient conditions, changes were more pronounced than at low temperatures. For instance, after 6 months of storage, the increase of free fatty acid of butter stored in a calabash was three times higher than that stored in refrigerator (1.9 % at ambient conditions against 0.53 % in refrigerator). Also, the rate of oxidation reaction was two times higher at ambient temperature than at refrigerator temperature. After 6 months of butter storage, the number of volatile compounds increased from 42 to 54 at room temperature and from 42 to 47 at refrigerator. The increase in rate of chemical reactions at ambient conditions is in accordance with the hypothesis that the quality changes of shea butter are caused by chemical reactions influenced by the temperature of storage. Black plastic containers seemed to be the better packaging materials for a long storage period.

Keywords: Black plastic, Free fatty acid, Shea butter, Storage temperature, Volatile compounds

Caractéristiques de qualité et composés volatils du beurre de karité dans différentes conditions de stockage

Résumé
Un stockage approprié du beurre de karité est crucial pour maintenir la qualité et assurer la disponibilité du produit dans le temps, en particulier dans les zones de production où la réfrigération n'est pas une option. La présente étude a evalué plusieurs caractéristiques de qualité du beurre de karité dans différentes conditions de stockage. Trois matériaux d'emballage (calebasse, plastique noir et plastique transparent), souvent utilisés pour stocker le beurre de karité dans les zones de production, ont été utilisés pour stocker le beurre pendant six mois dans des conditions ambiantes (28-30ºC) et à basse température (4-7ºC). Après 6 mois de stockage,

tous les paramètres étudiés ont été significativement affectés par les conditions et la durée de stockage, tandis que les effets des matériaux d'emballage étaient moins prononcés. Dans les conditions ambiantes, les changements étaient plus prononcés qu'à basse température. Par exemple, après 6 mois de stockage, l'augmentation de l'acide gras libre du beurre stocké dans de calebasse était trois fois plus élevée que celle du beurre stocké au réfrigérateur dans le même matériel (1,9 % à température ambiante contre 0,53 % au réfrigérateur). De même, le taux de réaction d'oxydation était deux fois plus élevé à la température ambiante qu'à celle du réfrigérateur. Après 6 mois de stockage du beurre, le nombre de composés volatils a augmenté de 42 à 54 à température ambiante et de 42 à 47 au réfrigérateur. L'augmentation du taux de réactions chimiques à température ambiante est conforme à l'hypothèse selon laquelle les changements de qualité du beurre de karité sont causés par des réactions chimiques influencées par la température de stockage. Les récipients en plastique noir semblent être les meilleurs matériaux d'emballage pour une longue période de stockage.

Mots clés: Plastique noir, Acide gras libre, Beurre de karité, Température de stockage, Composés volatils.

Introduction

Vitellaria paradoxa, commonly known as the shea butter tree, is indigenous to the dry savannah woodlands of Africa (Boffa, 1999; Aleza, 2018). Shea fruit pulp is rich in carbohydrates (41.14% dw), protein (10.34% dw), and essential minerals such as Ca (587 mg /100 g dw), Na (138.30 mg /100 g dw), Mg (1358 mg /100 g dw), K (771.5 mg /100 g dw), Fe (29.88 mg/100 g dw), and Zn (40.31 mg/100 g dw) (Donkor, *et al*. 2021). Its nuts contain up to 57 % of fat, which is traditionally extracted by local populations for purposes ranging from cooking to traditional pharmacology (Hall, *et al.* 1996; Choungo Nguekeng, *et al.* 2021). Shea butter is also much appreciated for cosmetic and pharmaceutical purposes as well as being a fat replacer in chocolate production at international level (Tano-Debrah & Ohta, 1994; Hall, *et al.* 1996; Alander, 2004). Shea nuts are a seasonal product, which is generally available for 3 to 5 months annually, depending on the location. The dried nuts or kernels are stored for several months during which butter processing is performed regularly (Honfo, *et al.* 2012). Storage of the butter after processing is also common practice; for a few days at processors' level before it is sold, up to several months at consumers' level during utilization (Honfo, *et al.* 2012). At local conditions, shea butter is generally stored in a relatively cool area (28-30 ºC) to avoid melting. Different packaging materials are used to store the butter, and the most frequently used ones are calabashes, plastic containers, plastic bags, and aluminium containers (Honfo, *et al.* 2012). All these packaging materials are always available in various sizes in the production zones. Calabashes are locally produced from the dry shells of the gourd plant. It is the cheapest packaging solution among the available packaging materials and the most popular.

Proper storage conditions are essential to maintain the quality of shea butter for prolonged periods of time. Indeed, packaging material, storage environment (*viz.* temperature, light, oxygen, relative humidity) and storage duration are critical factors in preserving the quality of foods (Gunstone, 2002).Water activity (a_w) is an important parameter in predicting and controlling the shelf life of food products. Water acts in two

ways in this respect: i) it can influence deteriorative chemical reaction rates because it acts as a reagent, ii) it is also a solvent for reactants and products; and microbiological activity depends on water activity (van Boekel, 2009). Several changes caused by the different factors or chemical reactions during storage are reflected in many quality characteristics of fat e.g., rancid flavour, changes in colour, texture, changes in functional properties, a high percentage of free fatty acid (FFA) (Nawar, 1998). A rancid flavour in fat is due to the presence of some volatile compounds, which are derived from peroxide and hydroperoxide formation during fat oxidation reactions (Frankel, 1985). FFA is produced during hydrolytic reactions in which mono-, di- or triglyceride molecules react with water (Kiritsakis & Tsipeli, 1992). Lipases speed up this reaction enormously and are therefore generally responsible for fat hydrolysis if present **(**De Man, 1999**)**.

Some research on shea products, *viz.* kernels and butter, have been done to improve local processing (Olaniyan, 2002; Womeni, *et al.* 2006; Kapseu, et al. 2007; Bup, et al. 2011; Honfo, *et al.* 2017); some research focused on the storage of the fresh nuts (Koloche, *et al.* 2021). Several researchers have also investigated changes in fat and shelf life (Aremu, *et al.* 2019). However, specific studies on storage of shea butter are limited. Thus, keeping in mind that shea butter has to be stored and handled with care after its production for further use, it is necessary to test packaging materials used for their suitability to assure quality during storage in different environments. In addition, shea butter for export has to meet the requirements for different uses. The aim of this work was to investigate the effect of (1) traditional packaging materials, (2) storage duration and (3) storage temperature on relevant quality characteristics of shea butter, namely FFA percentage, peroxide value and volatile compounds responsible for butter flavour. The hypothesis underlying this objective was that quality changes of shea butter during storage are due to chemical reactions influenced by storage temperature and packaging.

Materials and Methods

Sample preparation and storage

Shea kernels were bought at the local market of Bassila (9°00 N and 1°40 E), located in Donga Department, in the north-western part of Benin. The kernels were processed into butter by local processors as follows: kernels were cleaned, sun-dried for 4 h on a cement platform, sorted and crushed. The sorting consisted of selecting the intact kernels from the broken and damaged kernels. The crushed kernels were roasted for 20 min at 130 °C in an oven, milled, mixed with four volumes of water and churned manually. Next, the cream was transferred to a cooking pot, heated for 45-60 min around 100 ºC and left for 20-30 min. An equal volume of water was added to the crude oil and subsequently the top layer was separated and dehydrated by heating around 100 ºC. The resulting oil was filtered and cooled for 24 hours to obtain the shea butter. The butter was packed in three packaging materials, namely black plastic containers with a lid, transparent plastic containers with a lid, and calabashes with a cover made from calabashes as well, and stored for 6 months at either ambient conditions (28-30 °C, relative humidity: 81 ± 3 %) with exposure to daylight, or at cool and dark conditions in a refrigerator (4-7 ºC). A butter sample was taken at the start of the storage period. Thereafter, monthly samples were taken from each packaging material in duplicate.

Physico-chemical parameters and volatile compounds characterization of shea butter

The most important colour parameter for shea butter is its yellowness value (b*), thus, this

was measured using a chromameter (Minolta CR210b). The FFA percentage was determined by titration and calculated as oleic acid percentage (NB ISO 660, 2006). Titration was also used to determine peroxide values (NB ISO 3960, 2006). Water activity (a_w) was assessed for each sample by a thermo-hygrometer recorder (hygrolab 2 rotronic 8303 Bassersdorf, USA). Each parameter was measured in triplicate.

Volatile compounds in shea butter were assessed by Solid-Phase Micro-Extraction Gas-Chromatography and Mass-Spectrometry (SPME GC-MS) according to Bail, et al. (2009) and Krist, et al. (2006). SPME sampling was done by putting two grams of shea butter in vials that were tightly closed with a septum by using a GC crimper and extracted isothermally for 10 h at room temperature using a preconditioned Supelco 57348 2 cm, 50/30 mm DVB/Carboxen/PDMS Stable-Flex fibre for analysing volatile compounds. After sampling, the SPME device was immediately placed into a splitless-mode injection port of a GC-MS instrument (Thermo Scientific DSQ II). Volatile compounds were separated using an Rxi-5ms GC column (60 m length x 0.25 mm inner diameter, 0.25 µm film thickness). The initial temperature of the oven was held for 1 min at 38 °C and then increased by 2.5 °C/min to 175 °C. From that point, the temperature was increased by 50 °C/min to a temperature of 220 °C, which was held for 2 min. The injector port temperature was 250 °C. After using splitless mode for 2 min, a split ratio of 1:40 was used to expurgate the system. A constant carrier gas (helium: 5.0) flow of 1 mL/min was applied. The transfer line temperature was 250 °C, which resulted in an ion source temperature of approximately 225 °C. The mass spectrometer was operated in electron impact (EI) mode with the ionization voltage set at 70 eV. The scan range was 32-250 amu. Compounds were identified by matching mass spectra with AMDIS and Xcalibur Qual Browser library of standard compounds. Relative quantification of compounds was done as % peak area using integration data. However, data of volatile compounds were described qualitatively and quantitatively.

Statistical analysis

Analysis of variance was used to determine the effect of the three factors (*viz.* storage duration, packaging material and storage temperature) on the quality characteristics (b*, FFA percentage, and peroxide value). Correlations between the three factors and different variables were also established. *p*-Values < 0.05 were considered significant. All of these analyses were performed using SAS 9.1 software package (SAS Institute Inc., Cary, NC, USA).

Results and Discussion

Effect of storage conditions on quality characteristics of shea butter

The values of the colour characteristic - (b*), of butter were found to be significantly affected by storage duration, storage temperature and packaging material (Table 1). As storage time increased, butter lost its yellowness with decreasing b* values and became paler, irrespective of the packaging material. These observations were confirmed by negative correlations between b* with storage duration (r=-0.653, *p=0.000*) and between b* with storage temperature (r=-0.497, *p=0.000*). Significant differences were also noticed between the two storage temperatures, irrespective of the packaging material and the storage duration. The higher the storage temperature, the faster the colour of the butter changed; thus, the rate of the decrease of b* values was less pronounced during storage at low temperatures (Figure 1b). At ambient conditions, some differences were also noticed among the tested packaging materials. For example, the colour of butter

Table 1: Quality parameters of shea butter samples before and after 6 months of storage

Packaging materials		Quality parameters		
		Luminance (b*)	Free fatty acid (%)	Peroxide value (mEq O_2/kg)
Before storage	Black plastic	28.4 ± 0.1[a]	0.4±0.2[c]	2.6±0.1[c]
After storage at	Transparent plastic	26.3 ± 0.4[c]	1.5 ± 0.3[b]	4.5 ± 0.4[ab]
28-30 ºC	Calabash	25.2 ± 0.2[d]	1.7 ± 0.3[a]	4.9 ± 0.3[a]
		26.4 ± 0.4[b]	1.9 ± 0.3[a]	5.0 ± 0.3[a]
After storage at	Black plastic	27.8 ± 0.3[a]	0.5 ± 0.4[c]	3.4 ± 0.3[b]
4-7 ºC	Transparent plastic	27.8 ± 0.2[a]	0.6 ± 0.3[c]	3.6 ± 0.2[bc]
	Calabash	27.7 ± 0.3[ab]	0.5 ± 0.4[c]	3.5 ± 0.2[b]

Mean ± standard error of mean; means with different letters in a column are statistically different at 5% significance level

stored in transparent plastic was more affected than the butters stored in the other types of packaging; the mean values of b* ranged from 28.4 at the beginning of the storage period to 25.2 after 6 months of storage. This observation can be explained by the fact that light can enter the product in the case of transparent material, and that colour changes of fat during storage are initiated or accelerated by light (Kim, *et al.* 2002). Additionally, the yellow colour of shea butter is caused by carotenoids and the main cause of the degradation of carotenoids is oxidation, which is also accelerated by light (Clydesdale, 1998). Thus, plastic packaging for shea butter ought to be opaque or at least yellow coloured in order to ensure protection from the pro-oxidative action of light.

Significant effects of storage duration (r = 0.635, *p=0.000*) and storage temperature (r = 0.509, *p=0.000*) on FFA percentage were observed while no significant effect was observed for packaging materials.These effects, however, were more pronounced at ambient conditions (28-30 °C) (Table 1). In fact, the FFA percentage increased from 0.36 % to 1.48 % in butter packaged in black plastic after 6 months of storage at room temperature while the increase was less pronounced (from 0.36 % to 0.53 %) for butter packaged in the same container and kept in the refrigerator (Figure 2). The same trend was also observed for butter packaged in transparent plastic and in calabashes. At room temperature, butter stored in calabashes had the highest percentage (1.91 %) of FFA after 6 months of storage. Considering the FFA requirements for cosmetic purposes (less than 1 %) and for food utilization (less than 3 %), butter stored in the refrigerator could still be used for cosmetic purposes, while butter stored at room conditions was still suitable for food purposes after six months of storage (USAID/WATH, 2005; NB 04.02.001, 2006). Regarding the FFA percentages in samples stored at different temperatures, it can be concluded that the rate of hydrolysis is 2-3 times higher at ambient conditions (28-30 °C) than refrigerator conditions (4-7 °C). This observation could be due to the hydrolysis that occurred at ambient temperatures during

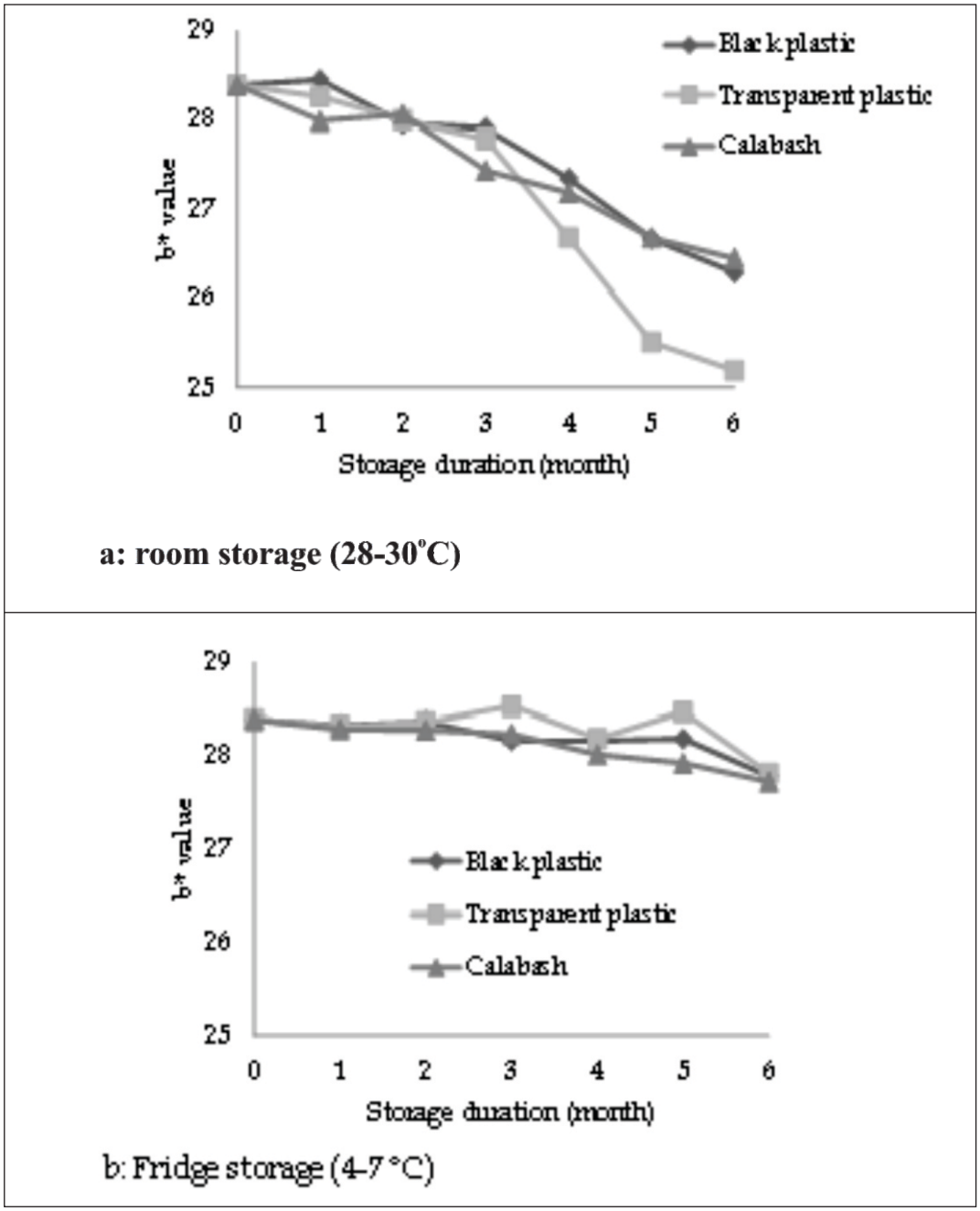

Figure 1: Yellowness (b* value) of shea butter during storage in different packaging materials at ambient (a) and refrigerator (b) temperature

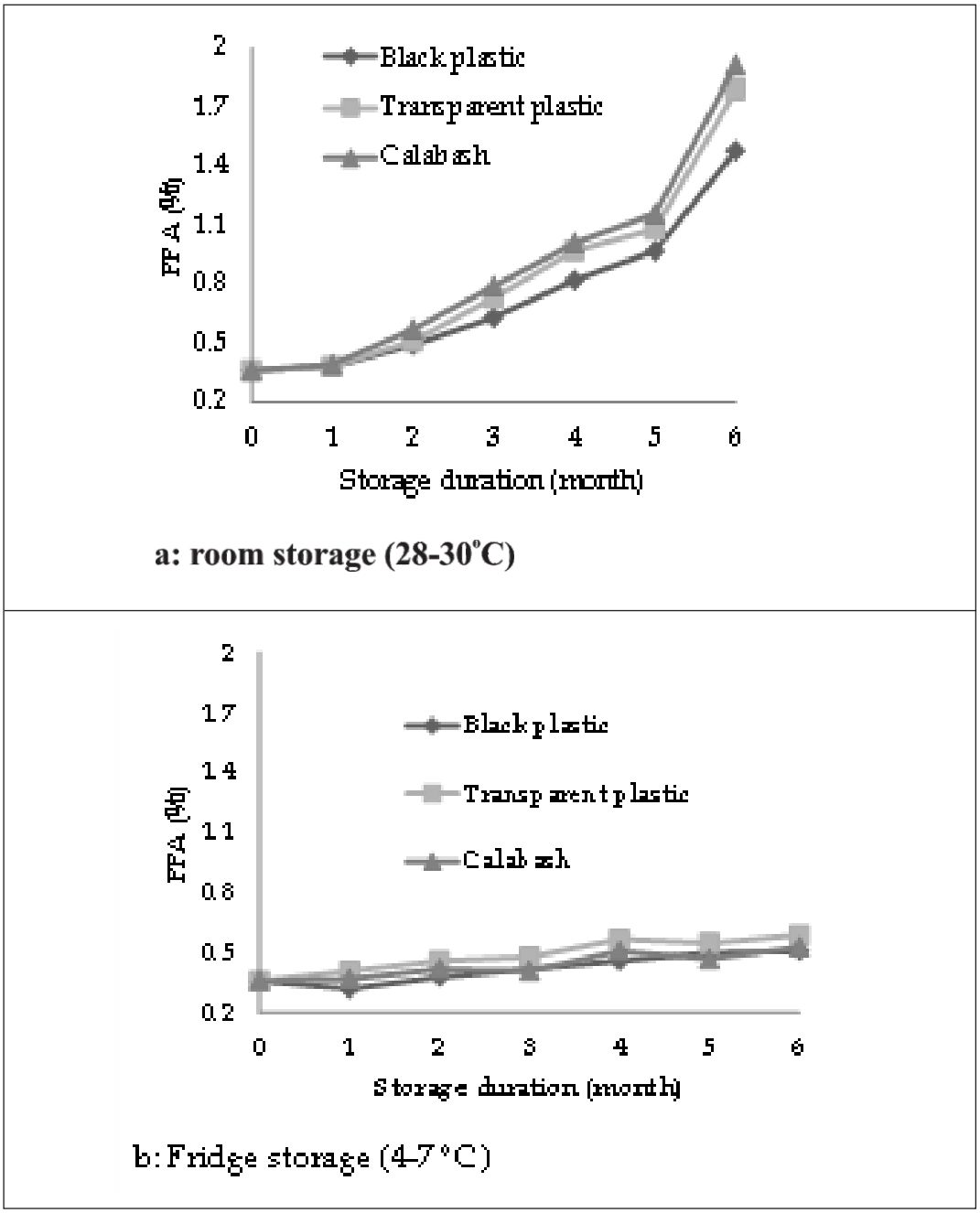

Figure 2: Free fatty acid (FFA) percentage of shea butter during storage in different packaging materials at ambient (a) and refrigerator (b) temperature

the storage which may generate more FFA and the accompanying mono- and di-glycerides. Thus, continual increase in FFA percentage is expected over storage which may present comparatively low pH conditions that can support bleaching of carotenoids and subsequent fading of oil colour. These explain the negative correlation between FFA percentage and b* (r=-0.903, *p=0.000*) indicates a relation between the FFA percentage and the colour change of the butter. This observation was also noticed in cocoa butter in addition to the low acidity which was related to butter with desired yellowness (Akaki, *et al.,* 2013).

Significant and positive effects of storage duration (r=0.697, *p=0.000*) and storage temperature (r=-0.483, *p=0.000*) were found on peroxide values. The rate of this reaction was two times higher at room temperature than at refrigerator temperature, giving peroxide values ranging from 2.6 to 5.4 meq O_2/kg at room temperature and from 2.6 to 3.5 meq O_2/kg at refrigerator temperature (Figure 3). With respect to peroxide formation, Berger & Hamilton (1995) noticed that during storage peroxide formation is slow at first during a period called induction period, which may vary from a few weeks to several months depending upon the type of fat or oil. However, the type of packaging material used also influenced the peroxide value during storage. Relatively higher peroxide values were found for the samples packaged in calabashes. Butter in calabashes appeared to be more susceptible to oxidation than butter in the other packaging materials, probably since the cover did not fit the container properly, allowing air to get into contact with the sample. Kirk & Sawyer (1991) reported that the rancid state of fats begins to be noticeable when the peroxide value is between 20 and 40 meq O_2/kg. Thus, even though peroxide values increased in butter kept at room temperature, the increase was probably not that high to cause noticeable rancidity. In addition, peroxide values of all butter samples were lower than the thresholds of 10 meq/kg and 15 meq/kg tolerated for cosmetic and food purposes, respectively (NBF 01-005. 2006). However, a low peroxide value does not necessarily indicate that fat or oil is not oxidized. As reported in the literature (Frankel, 1985; Choe & Min, 2006; Kim & Min, 2008), a combined index of primary and secondary oxidation products may indicate the state of oxidation of products better. A positive correlation (r=0.842, *p=0.000*) was found between the peroxide value and the FFA percentage, showing the free fatty acids are more susceptible to oxidation than bound fatty acids.

However, chemical reaction rates concerning oxidation and hydrolysis may be influenced by water activity. For instance, lipid oxidation is strongly promoted at very low water activity and decreases with increasing water activity, while hydrolysis increases with water activity as water is a reagent in hydrolysis (van Boekel, 2009). During the 6 months of storage, a_w varied from 0.5 to 0.6 in the samples of shea butter (Figure 4); thus, water activity did not change drastically and thus would not have substantially influenced chemical reactions in shea butter. Lipid oxidation occurs at a minimum a_w rate of 0.2 to 0.3 (Rockland & Nishi, 1980); therefore, the rate of this reaction in shea butter may not have been noticeably influenced by the water activity. Water activity is a function of temperature; thus, storage temperature can change the effect of a_w on the microbial, chemical, and physical properties of foods (Le Meste, *et al.* 2001). Yet in this case, a similar trend in a_w was noticed during storage under the two conditions, so it is not likely that the storage temperature had an effect on reaction rates via the a_w. Another important conclusion to be drawn from the water activity results is that microbial spoilage can

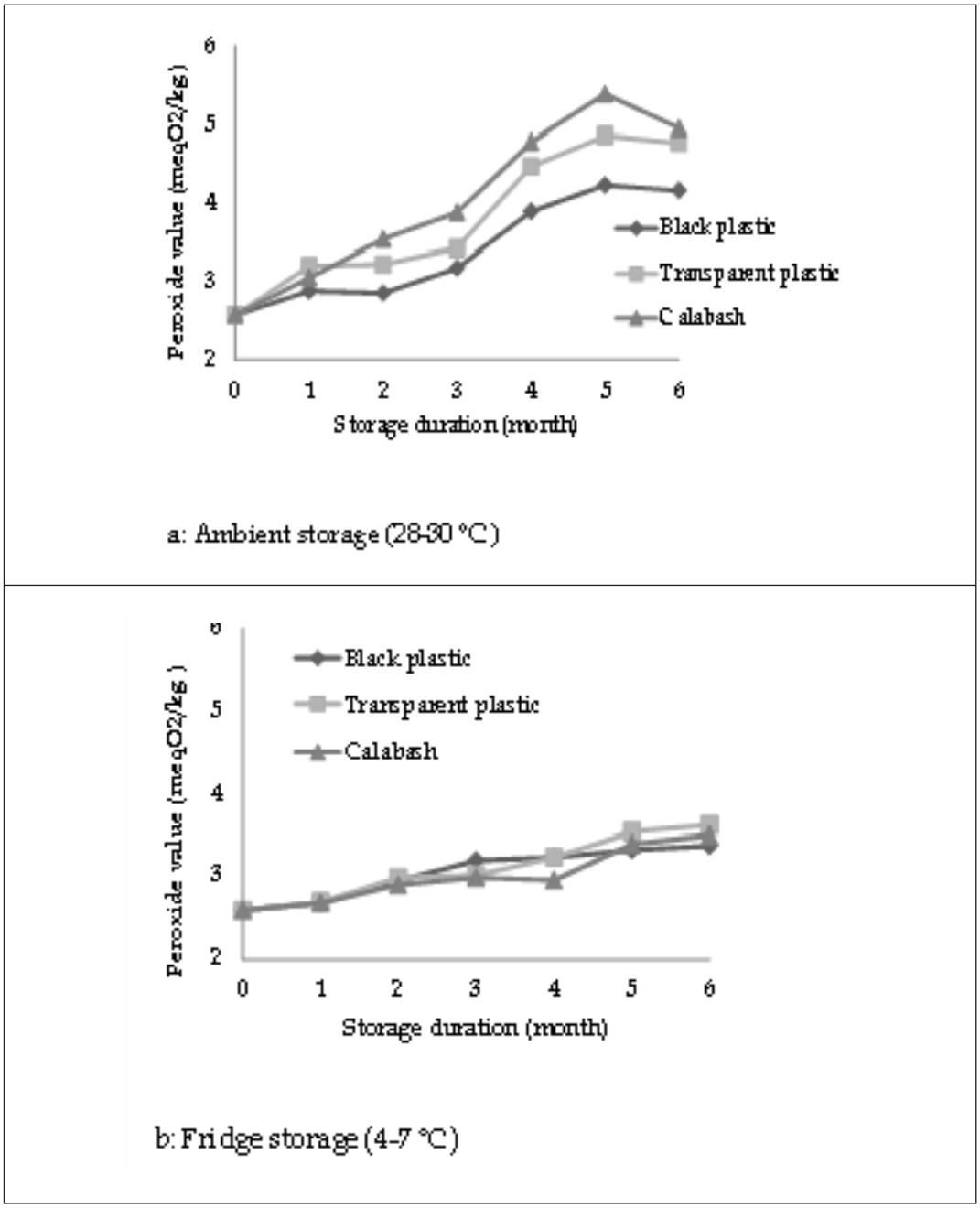

Figure 3: Peroxide values of shea butter during storage in different packaging materials at ambient (a) and refrigerator (b) temperature

be excluded at a water activity between 0.5 and 0.6. Compared to butter made from cow's milk and margarine, the water activity of shea butter is much lower. Unsalted butter and margarine have an a_w of about 0.99 while salted butter or margarine has an a_w of about 0.91 (Welti-Chanes, *et al.* 2007). In this respect, shea butter is similar to cocoa butter. Due to many similarities, shea butter is used as a cocoa butter substitute in chocolate in others areas of Africa and at the international level (Official Journal of the European Community, 2000; Lipp & Adam, 1998).

Effects of storage conditions on volatile compounds of shea butter

After 6 months of storage, the number of volatile compounds in shea butter increased from 42 to 54 at room temperature and from 44 to 49 compounds at refrigerator temperature (Table 2). Apparently, the number of compounds increases with the storage duration, whatever the storage temperature and packaging material. The production rate of volatile compounds increased with increasing storage temperature and this observation is understood as most of the volatile compounds are generated by oxidation reactions, which were two times faster in ambient conditions than in refrigerator conditions. Most of the comp-ounds found were identified by Krist, *et al.* (2006) and Bail, *et al.* (2009) in shea butter from different regions. Independent of the processing steps, the composition of volatile compounds in shea butter mainly results from degradation of long chain fatty acids by hydrolysis due to enzymatic activity (probably due to the possible contamination during the processing) as well as oxidation (Bail, *et al.* 2009). For instance, a variety of compounds, such as hydrocarbons, alcohols, furans, aldehydes, ketones, and acid compounds, are formed during oxidation as peroxide or hydroperoxide degradation products. Volatile compounds might also result from the Maillard reaction as shea butter is derived from a roasted product. Most of these volatile compounds are responsible for the off-flavour in oxidized edible oils (Min & Bradley, 1992). Comparing the results for the different packaging materials, a similar number of compounds was identified at the same storage temperature, but different compounds were detected (Table 2). Most of the volatile compounds occurred in small quantities, but this observation does not mean that they were not important. The 10-15 quantitatively most dominant compounds in the different packaging materials are discussed next.

The dominant volatile compounds of samples stored in black plastic at ambient temperature were dodecane, pentanal, decane, furan 2-pentyl and phenylethyl alcohol (Figure 5a). A gradual increase of dodecane (1-21 % of total amount) and decane (1-18 %) was observed throughout the storage period. Both compounds are hydrocarbons with an undesired petrolic or tarry odour (Umano & Shibamoto, 1987); their increase during storage may affect the butter flavour. A sharp decrease of furan 2-pentyl (from 21 % to 1 %) was observed after 2 months of storage till the end of storage. In terms of odour profile, this corresponds with a shift from a fruity, flowery and sweet odour (Fors, 1983) to a more tarry/oily, fruity odour (Umano & Shibamoto, 1987; Chung, *et al.* 1994; Adams, 2007). During storage in the refrigerator, the dominant compounds of samples packed in black plastic were pentanal, furan 2-pentyl, phenylethyl alcohol, limonene, and acid acetic (Figure 5b). A gradual increase (3-28 % of total amount) of pentanal was noticed throughout storage. Furan 2-pentyl showed a peak (41 %) at 2 months of storage before its rapid decrease (4 %) from the third month onwards until the end of storage. Acetic acid was the main free acid dominant in shea butter; its content was higher during

Table 2: Number of identified volatile compounds in shea butter before and after storagesamples before and after 6 months of storage

Volatile compounds	Before storage	After storage at 28-30 ºC			After storage at 4-7 ºC		
		Black plastic	Trans-parent plastic	Calabash	Black plastic	Trans-parent plastic	Calabash
Carbonyls	10	12	12	12	11	11	12
Hydrocarbons	7	9	9	9	8	8	9
Benzenoid hydrocarbons	7	8	10	10	6	7	7
Furans	2	3	2	2	2	2	1
Acids	5	5	5	5	5	5	5
Alcohols	4	6	6	6	5	5	6
Ketones	5	5	5	5	5	4	5
Monoterpene hydrocarbons	1	1	1	1	1	1	1
Esters	1	1	1	1	1	1	0
Phenols	2	2	3	3	2	2	3
Total	42	52	54	54	46	47	47

refrigerator storage, ranging from 2 % to 12 %. Thus, during refrigerated storage, the flavour of butter changed towards compounds with a more pungent, green, and fruity profile (Sumitami, *et al.* 1994; Qian & Reineccius, 2003).

At storage under ambient conditions, dodecane, pentanal, naphthalene, decane, acetic acid, and hexanal were dominant (Figure 6a). Among them, naphthalene was the main compound (25-35 %) during the first two months. Gradual increases of the relative contents of dodecane (1-21 %), pentanal (4-23 %), and decane (2-18 %) were noticed throughout the storage period. These compounds, as well as naphthalene, belong to hydrocarbons group and are generally generated by oxidation in this case. Based on the odour profiles of these compounds, the butter odour may change from a coal tar and fatty green citrus profile to a tarrier oil and fruity profile during storage (Umano & Shibamoto, 1987; Gasser & Grosch, 1988; Chung, *et al.* 1994). During refrigerated storage, the amounts of decane (1-16%) and dodecane (1-17 %) increased, changing the odour to a more tarry and oily profile (Figure 6b).

During the first two months of ambient storage, furan 2-pentyl was the dominant volatile (45 %) among the major compounds found in butter packed in calabashes (Figure 7a). A gradual increase (14 to 52 %) of pentanal was noticed throughout the storage period. After 6 months, the odour profile was dominated by pentanal and furan 2-pentyl,

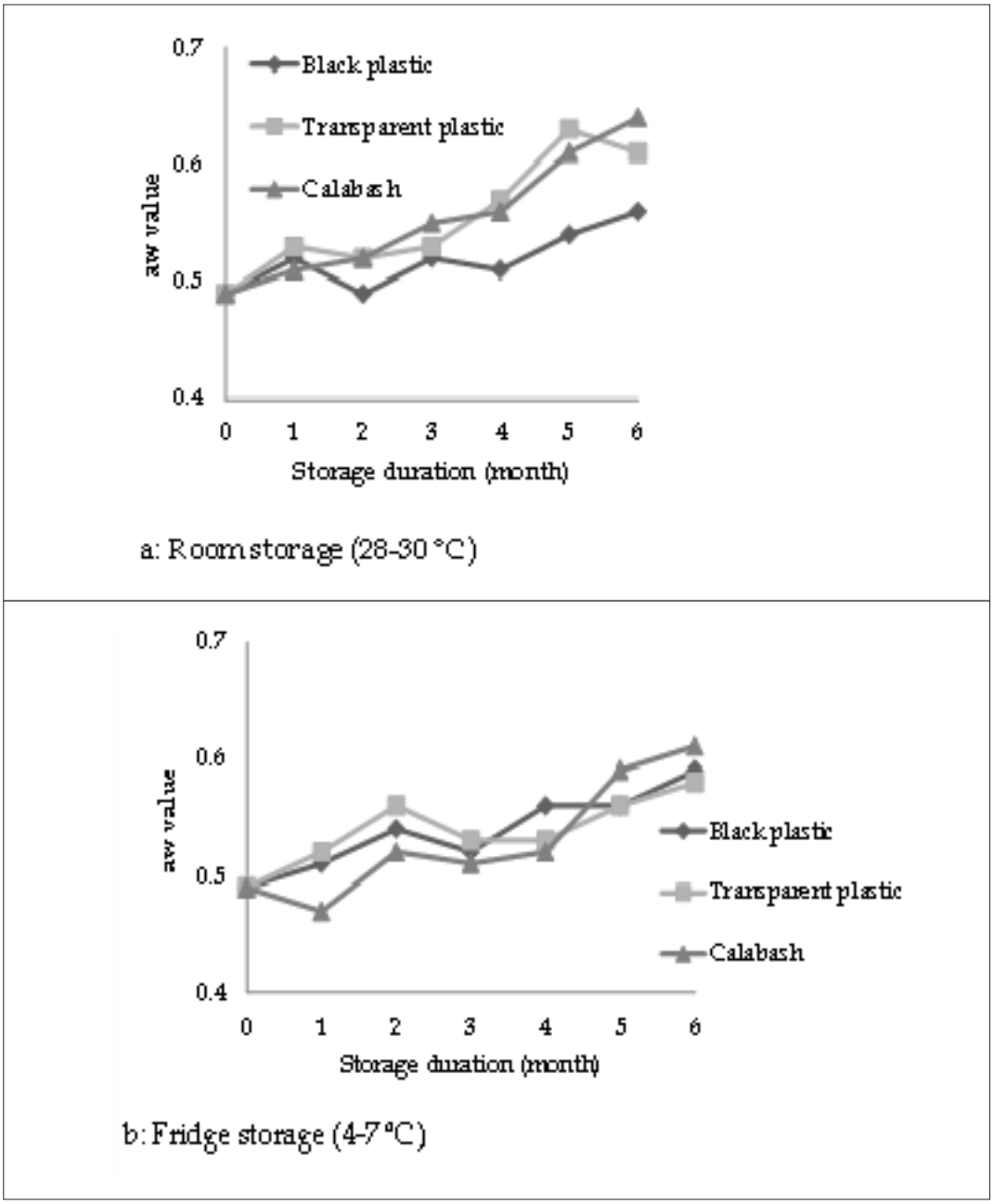

Figure 4: Water activity of shea butter during storage in different packaging materials at ambient (a) and refrigerator (b) temperature

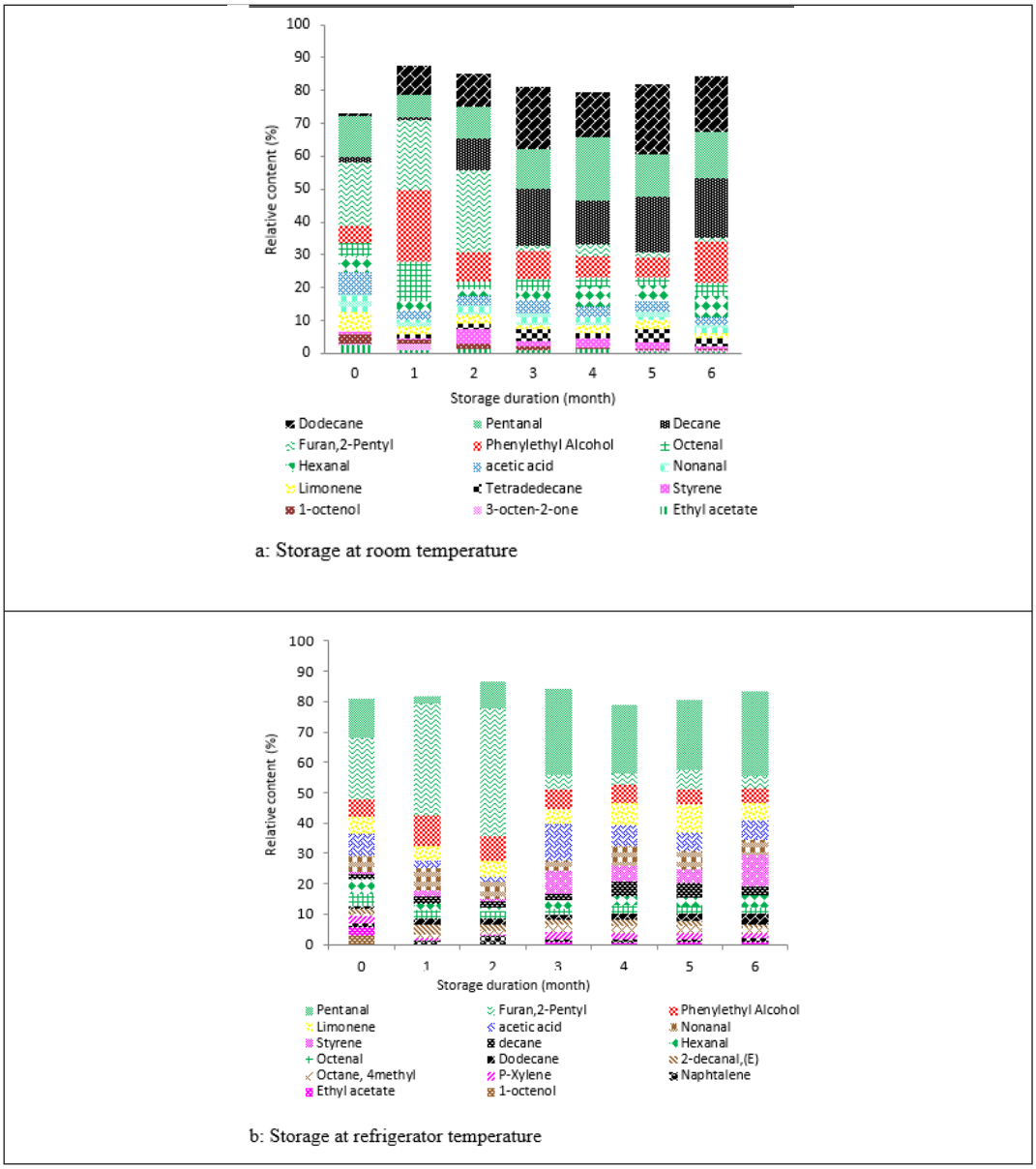

Figure 5: Most abundant volatile compounds in shea butter packaged in black plastic during 6 months of storage

The colour black represents tarry oily odours, green: fruity green odours, red: floral odours, brown: meaty mushroom-like odours, pink: sweet turquoise: fatty, nutty, cucumber (http://www.flavornet.org/flavornet.html / http://www.odour.org.uk/cgi-bin/)

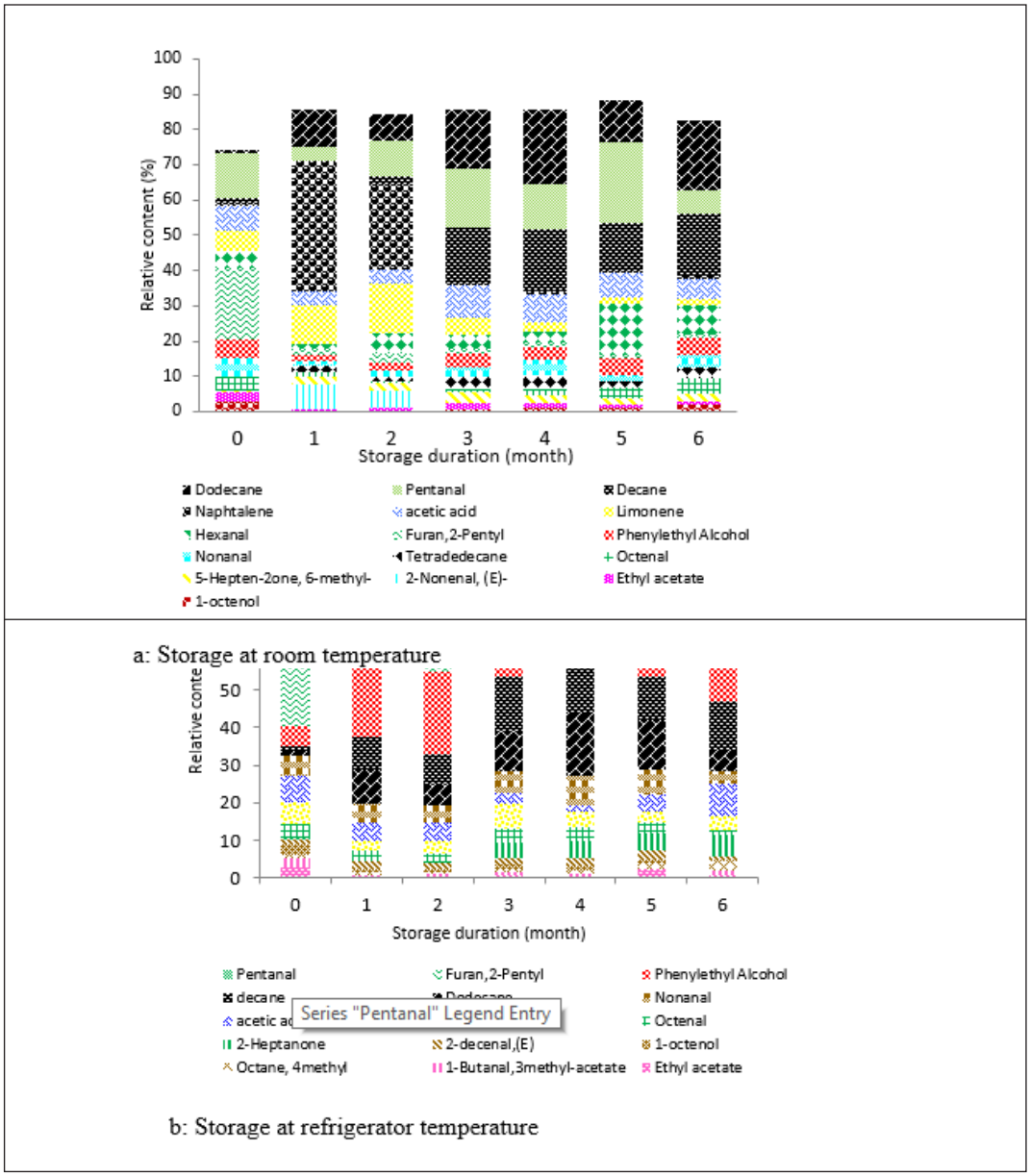

Figure 6: Most abundant volatile compounds in shea butter packaged in transparent plastic during 6 months of storage

The colour black represents tarry oily odours, green: fruity green odours, red: floral odours, brown: meaty mushroom-like odours, pink: sweet turquoise: fatty, nutty, cucumber (http://www.flavornet.org/flavornet.html / http://www.odour.org.uk/cgi-bin/)

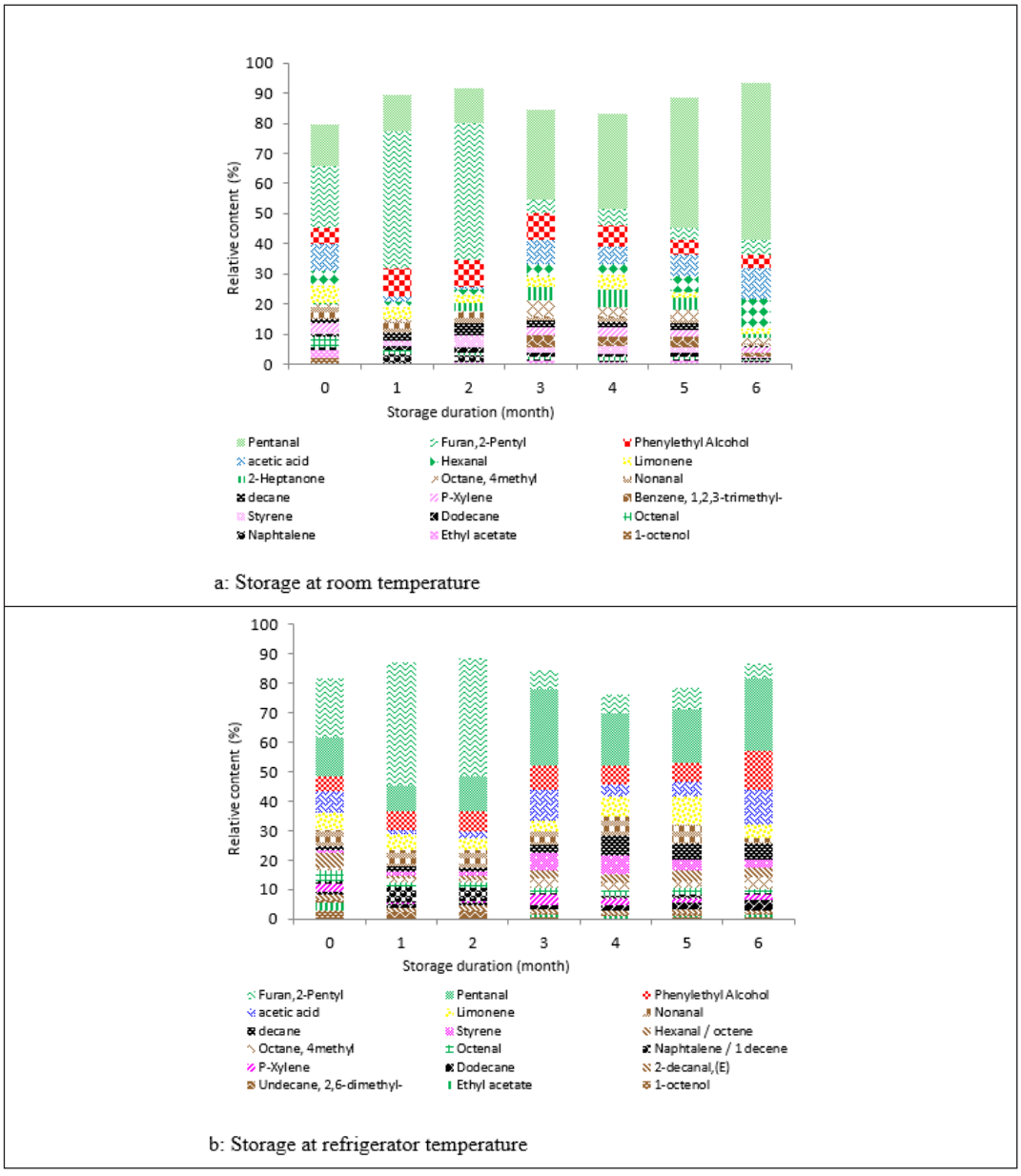

Figure 7: Most abundant volatile compounds in shea butter packaged in calabash during 6 months of storage

The colour black represents tarry oily odours, green: fruity green odours, red: floral odours, brown: meaty mushroom-like odours, pink: sweet turquoise: fatty, nutty, cucumber (http://www.flavornet.org/flavornet.html / http://www.odour.org.uk/cgi-bin/)

which could give a pungent, fruity and green odour (Sumitami, *et al.* 1994; Qian and Reineccius, 2003). Apart from these two compounds, phenylethyl alcohol, acetic acid, and hexanal were also dominant with relative contents of about 10 % for each of them. A similar trend, but less pronounced, was observed during refrigerated storage (Figure 7b). Additionally, the content of each compound changed during storage. Furan 2-pentyl was dominant at the beginning, while pentanal was present in a larger proportion at the end of the storage. Another noticeable change was the absence of hexanal during refrigerated storage and the occurrence of new compounds, *viz.* limonene and decane, which may impact the odour profile of the butter.

Conclusion

Shea butter stored at ambient conditions for a period of six months showed a change of colour, an increase in the FFA percentage, peroxide value and number of volatile compounds. Storage temperature and storage duration significantly affected the quality attributes of shea butter, essentially the chemical properties, with impact on colour and odour. Shea butter stored at ambient conditions was most affected during storage, even though the changes observed would not hinder its use for food purposes. Butter stored in the refrigerator after six months can still be used in the cosmetic and pharmaceutic industries. For shorter periods (1-3 months), all of the three packaging materials studied can be used. However, the plastic containers, notably the black ones were the best option as demonstrated by the small changes during storage. In the absence of possibilities to store butter at low temperatures, it is recommended to keep shea butter in a relatively cool area to maintain the quality of the product. However, as plastic containers vary in their permeability to oxygen, light and water due to their composition, further studies could focus on assessing the plastic packaging material that will be most appropriate for shea butter storage.

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