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Effects of storage conditions on the fatty acid composition of the butter of tallow tree *(Pentadesma butyracea)*

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ABSTRACT

Objective: In this study, the effect of various storage conditions of the kernel of *P. butyracea* on the fatty acid profile of the derived butter was evaluated.
Methodology and results: An experimental design was set up to assess the effects of kernel boiling, the packaging material and the storage duration on the kernel butter yield and water activity; and on the fatty acid composition of derived butter. The fatty acid composition of the butter varied significantly according to the storage conditions of the kernels. The palmitic, stearic and linoleic acids content of the butter tend to increase because of the storage duration while the oleic acid decreases during storage.
Conclusions and Application of results The kernels dried without boiling, stored in jute bag for a duration of less than 6 months provided a butter with optimum yield and less modifications in its fatty acid composition. *Pentadesma butyracea* butter from kernels stored in jute bags maintains its physicochemical quality, thus these packaging materials should be recommended.
Key words: *Pentadesma butyracea*, oil seed, storage, butter, fatty acid

INTRODUCTION

Forest products contribute significantly to the food security of millions of people in Africa. Their use also contributes to biological diversity of forest resources (Vantomme, 1999). *Pentadesma butyracea Sabine* (Clusiaceae) (Photo 1) is a ligneous forest species of multipurpose uses. It is widely distributed in Africa from Guinea-Bissau to the West of the Democratic Republic of Congo. The plant is known as "tallow tree" or "butter tree" in English, "arbre à suif" or "arbre à beurre" in French, "Krinda" in Côte d'Ivoire, "Abotoasebie" in Ghana, "Agnuhé" in Gabon and "Kpangnan" or

"Sesseido" in Benin. *Pentadesma butyracea* is found in the centre and northern part of Benin in forest galleries and along waterways (Avocèvou-Ayisso 2011; Natta *et al*., 2010). The fresh kernels consumed like kola (Sinsin & Sinadouwirou 2003) are rich in edible butter similar to Shea butter (Tchobo *et al*., 2007). The *Pentadesma butyracea* butter is used in traditional medicine as massage oil, in skin and hair care and in the manufacturing of soap because of its softening, lubricating and healing qualities (Dencausse *et al*., 1995). In Central Africa, notably in Gabon, the sweet mesocarp of mature fruits is used to make fruit juice (White & Albernethy, 1996). In spite of its potential application in food and cosmetic industries, very little is known on the quality attributes of the *Pentadesma butyracea* butter. Previous studies showed that the compositions in fatty acids and in triglycerides of *Pentadesma butyracea* butter are similar to that of Shea butter ((Dencausse *et al*. 1995). Tchobo *et al*. (2013) evaluated the physicochemical characteristics of the butter of *Pentadesma butyracea* and reported that oil content is 41.90%, crude proteins content is 44.0%, lysine content is 3.2% DM; methionine content is 1.6% and cysteine is 1.5%. Evrard *et al*. (2005) reported that the oil cakes of *Pentadesma butyracea* kernels are very poor in proteins; particularly in essential amino acids. The colour characteristics of the butter of *Pentadesma butyracea* kernel are reported to be L*=53.07; a*= 11.77; and b * = 7.76 (Aïssi *et al*., 2011). Moreover, the technical itinerary of the traditional processing of the kernels from *Vitellaria paradoxa* and *Pentadesma butyracea* is nearly the same (Aïssi *et al*., 2011). Lipid oxidation is one of the major causes of quality deterioration in many oil rich food systems. *Pentadesma butyracea* nut contain approximatively 48.66% of oil (Aïssi *et al*., 2012). 52.81 % of the *Pentadesma butyracea* nut oil is composed of unsaturated fatty acids of which 49.86% of saturated fatty acids. This fatty acid profile makes the *Pentadesma butyracea* butter and derived products susceptible to deterioration due to rancid development and off-flavours through lipid oxidation. Oxidation of lipids may occur during long term exposure to oxidative agents during process like storage. In the present study, kernels of *Pentadesma* were subjected to various treatments including boiling, drying, packaging prior to storage. The change in the fatty acid composition of the derived butter was monitored every three month of the storage of 9 months.

Fruits of *Pentadesma butyracea*

Butter of *Pentadesma butyracea*

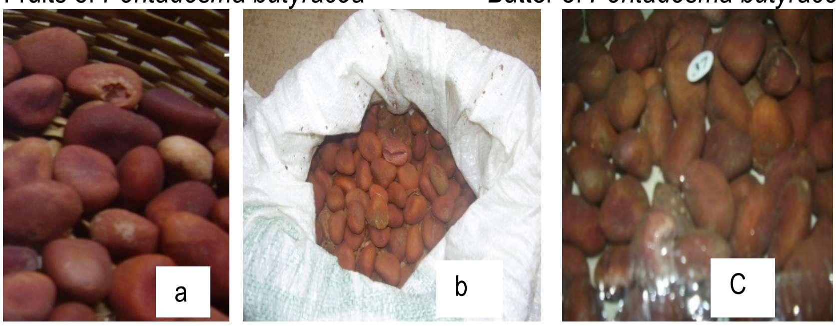

Photo1: Kernels boiled and dried stored in basket (a), Kernels boiled and dried stored in jute bag (b), kernels dried without boiling stored in basket (C), kernels dried without boiling stored in jute bag

MATERIAL AND METHODS

Plant material: Fresh fruits of *Pentadesma butyracea* were collected from May to June 2013 in the forest galleries of Péperkou village in the community of Toucountouna (10°20' - 10°45' N and 1°10' - 1°40' E) located in the Northwest of Benin. Forty kilograms of *P butyracea* fruits were randomly collected from different trees. The fruits were transported to the laboratory where the kernels were extracted, cleaned and subjected to various treatments prior to storage.

Experimental design: An experimental design with 3 factors including storage duration, the pre-treatment and the packaging materials was used to study the effects of storage conditions on the fatty acid profile, the oil yield, the ash content and the water activity of the kernel of the *P. butyracea* and derived butter. The storage duration varied from 0 to 12 months and the kernel pre-treatments includes the fresh kernel without any treatment, the boiled and dried kernel and the dried kernel. The packaging materials included the jute bag and the basket container. Boiling was performed at a temperature of 90-100°C during 60 min and kernel drying was done at a temperature of 45°C during 72 hours. Samples were stored at ambient temperature (temperature: 29.5°C; relative humidity 65±3%) (Figure 1).

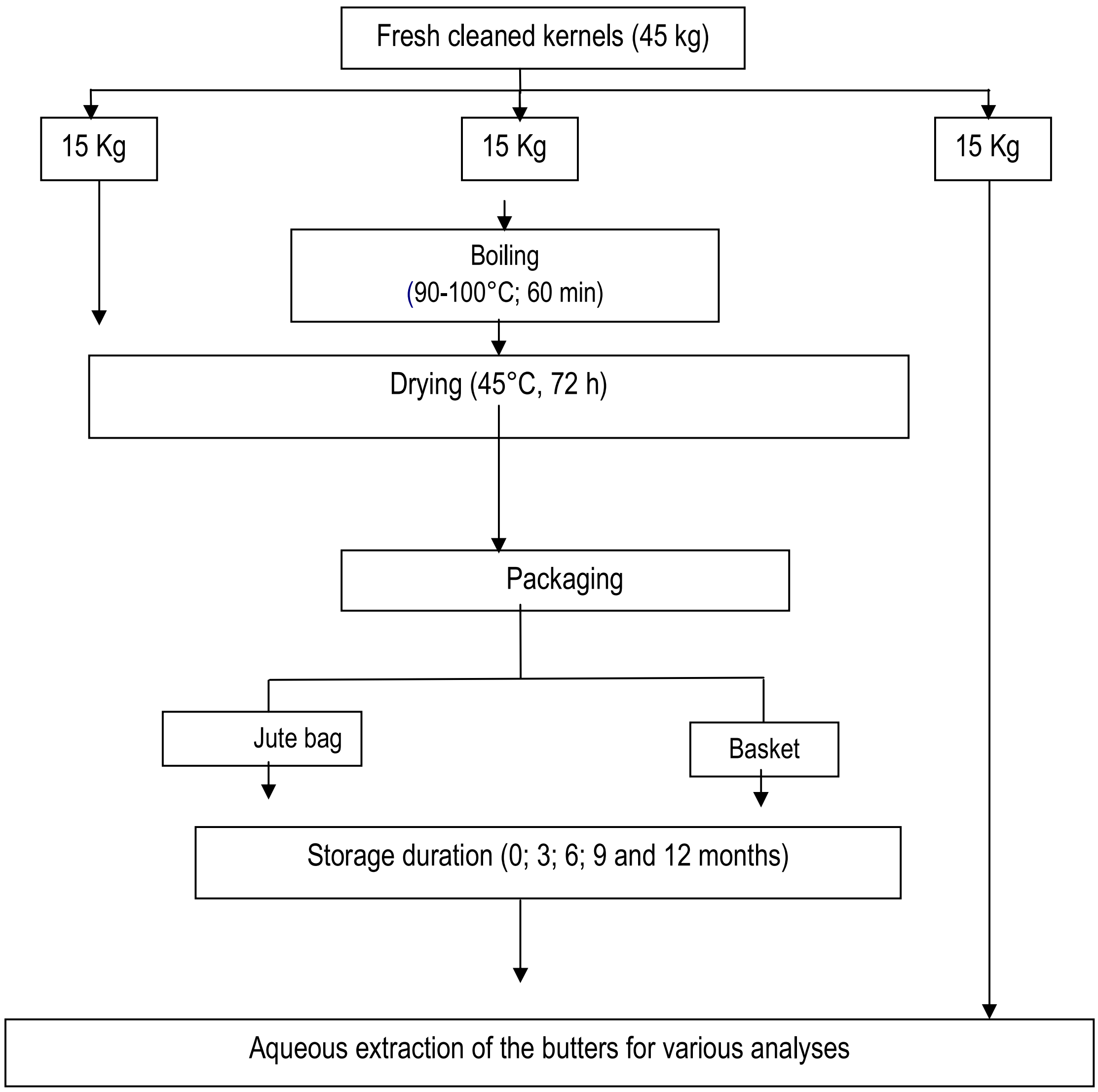

Figure 1: Experimental design

Determination of water activity, oil yield and ash content of the kernels: Samples of *P. butyracea* kernels were drawn at different storage duration and analyzed for their Water activity (a_w), ash and oil contents. The Water activity (Aw) was measured according to the method described by Anihouvi *et al.* (2006), using a thermo-hygrometer recorder (Rotronic HygroLab 2, 8303 Bassersdorf). About 2 g of sample were put into the instrument and the a_w was measured automatically after starting the program. The ash content was determined following the AOAC standard methods (AOAC, 2002). Values were calculated in percentage of dry matter. The yield of *Pentadesma butyracea* butter was expressed on wet weight as the percentage of mass of clear oil after filtering on the mass of the kernels used.

$$\text{Butter yield } (\%) = \frac{\text{Weight of butter obtained}}{\text{Weight of kernel processed}} \text{x } 100$$

Oil extraction : Butter was extracted from the kernels using the traditional procedure (Ayegnon *et al.* 2015).The kernels were sorted, crushed and approximately 300 grams (g) of crushed kernels were roasted for 120°C during 30 minutes. The roasted kernels were ground into fine powder. Tepid water was added to the fine powder, which was churned for 2 hours using a mixer to generate a cream. The cream is recovered and washed with water. The derived raw butter was heated at a temperature of 120-130°C to obtain an oil, which is filtered and cooled to give the butter. The butter obtained was preserved in the refrigerator at 4-7°C for various laboratory analyses.

Fatty acid analysis: The fatty acid composition of *P. butyracea* butters was analyzed with a gas chromatography following the method described by Tchobo *et al.* (2007). In a 25-ml round bottom flask, oil samples (10 mg) were added to sodium methylate solution (3 mL) containing phenolphthalein. The mixture was refluxed for 10 min and 3 mL methanolic HCl were added until phenolphthalein discoloration occurred. The mixture was refluxed again for 10 min and cooled to room temperature. Hexane (8 mL) and water (10 mL) were added and the organicphase recovered, dried over anhydrous sodium sulfate and filtered for subsequent GC analysis. An Agilent 6890series GC apparatus provided with a Supelcowax 10capillary column (SGE, Courtaboeuf, France) with the following characteristics: length, 30 m; internal diameter,0.32 mm, film thickness 0.25 µm, was used. Fatty acid methyl esters were directly injected into the GC. The carrier gas was helium with a flow rate of 1 mL/min, and a splitting ratio of 1/80. The injector temperature was 250 °C and that of the FID was 270 °C. The temperature settings were as follows: 150–225 °C at 5 °C /min, and then held at 225 °C for 2 min. Fatty acids were identified by comparison with commercially available fatty acids standards.

Statistical analysis: Statistical analysis were performed using the statistical program SPSS16.00 (SPSS, Chicago, IL, USA) and the one-way ANOVA model was used applying the Tukey's post-hoc test to evaluate significant difference among means at $p < 0.05$.

RESULTS AND DISCUSSION

Effects of the storage conditions on the kernel oil yield and water activity: The result of ANOVA showing the effect of factors i.e. kernel pre-treatments, packaging material and the storage duration on the kernel water activity, the oil yield and the fatty acid profile of the derived butter is presented in Table 1. There is a significant effect of the 3 factors studied on the oil yield of the kernel. The interactions of the factors are not significant on the kernel water activity while they significantly affect the kernel oil yield. Particularly the interactions between the pre-treatments and the packaging material (Pre-treatment *Packaging) and between the storage duration and the packaging material (Storage duration*Packaging) were significant with respect to oil yield ($p \leq 0.05$). Figure 2 showed the trend in the kernel oil yield as function of the storage duration with respect to various pre-treatment and packaging materials. Under the investigated storage conditions, the kernel oil yield varied from 9.73 % to 31.2 %. The highest oil yield was obtained from the kernels directly dried and stored in jute bags after 12 months of storage. The lower value of oil yield was obtained in the fresh kernels without any treatment. For all samples, the oil yield tended to increase because of the storage duration. Oil yield from kernels directly dried was significant higher ($P \leq 0.05$) than the oil yield from the kernels boiled and dried. Likewise, kernels pre-treated (boiled and/or dried) yield more oil than (P

≤ 0.001) untreated kernel (fresh). It is most likely that pre-treatments such as boiling/drying facilitate the bursting of the oleiferous cells and subsequently allowed the oil release.

Table 1: Analyze of variance showing the effect of the kernel pre-treatments, the packaging material and the storage duration on kernel water activity and oil yield and on the fatty acid composition of the derived butter

		Fischer value (F)					
Factors	**DL**	**Oil yield**	**Water activity**	**Palmitic acid**	**Stearic acid**	**Oleic acid**	**Linoleic acid**
Pre-treatment	2	306.005**	854.771**	10.771*	102.478**	101.098**	0.104
Storage duration	3	211.396**	210.115**	24.375**	457.849**	29.196**	0.104
Packaging material	1	96.848**	12.217*	25.208**	0.618	232.232**	0.000
Storage duration*Packaging	3	10.671**	1.201	6.458*	214.727**	13.125**	0.313
Packaging*Pre-treatment	1	4.554*	0.445	1.875	53.175**	122.232**	0.000
Duration*Packaging*Pre-treatment	3	2.17	0.27	1.875	6.967*	12.411*	0.313

*:Significant with the threshold of 2%, **:Significant with the threshold of 1‰.

This study data are similar to findings by Aïssi *et al*. (2011) who reported an oil yield of 25% for roasted kernels and 33.5% for the kernels boiled and dried. With respect to the packaging materials, kernels stored in jute bag yield more oil than those stored in basket (P ≤ 0.05). All the studied factors affected the water activity (a_w) of the kernels, but their interactive effects are not significant on these parameters (Table1). Before storage, the a_w of the fresh kernels was 0.93. In the kernels boiled and dried it varied from 0.57 to 0.69 (Figure 3).The highest value was observed in the kernels stored in basket bag for 3 months; while the lowest value was obtained in the kernels stored in jute bag after 12 months of storage. Compared to butter made from cow's milk and margarine, the a_w of *P. butyracea* 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 *P., butyracea* butter is similar to cocoa butter. Overall, kernels stored in jute bag exhibited low level of a_w compared to those in basket while the boiled and dried kernels seem to possess relatively high a_w in comparison to the dried kernel. An implication of this result is that kernels with high level of water activity are more subject to deteriorations such as microbial, enzymatic and oxidative degradations. Thus, modifications in the fatty acid profile of the kernel butter could be expected.

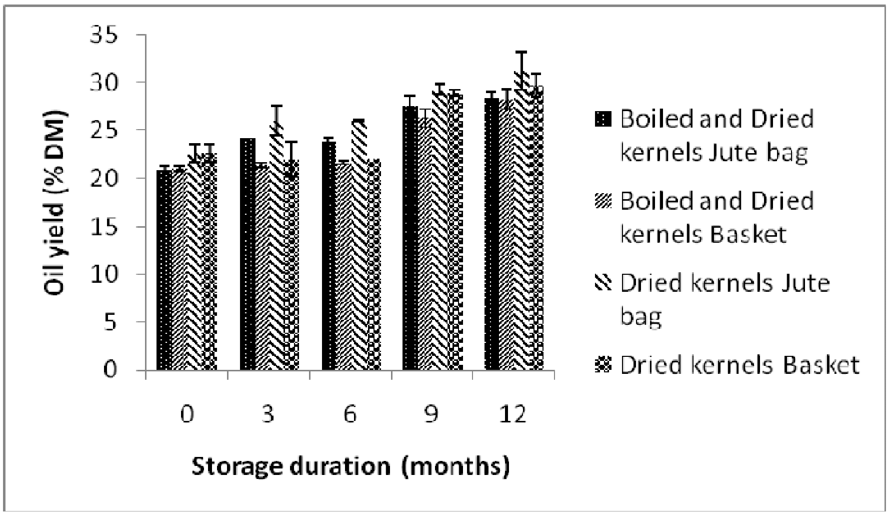

Figure 2: Effect of storage duration, pre-treatment and packaging materials on oil yield of the kernels

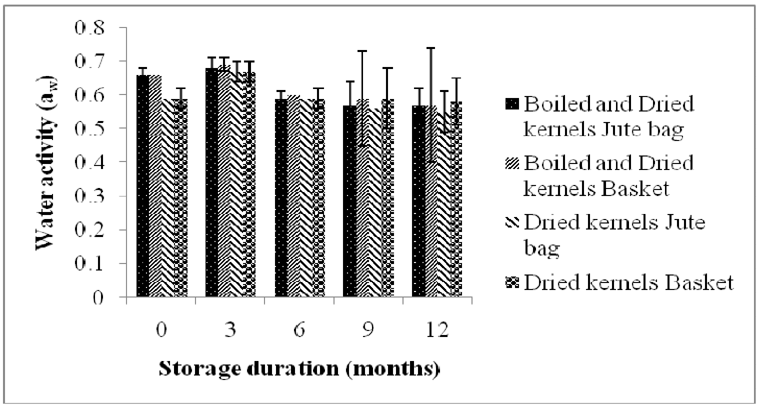

Figure 3: Effect of storage duration, pre-treatment and packaging materials on water activity of the kernels

Effects of the storage conditions on the fatty acid profile of the butter extracted from *Pentadesma* kernels : The analysis of variance revealed significant ($P \leq 0.05$) effects of kernel boiling, packaging materials and storage duration on the palmitic acid (C16:0), stearic acid (C18:0) and oleic acid (C18:1) contents of the derived butter while the level of linoleic acid (C18:2) was not significantly affected. More specifically, the linear and the interactive effects of these factors were significant with respect to the three fatty acids mentioned above (Table 1). Figure 4 showed the trend in the palmitic acid content of the butter as function of the storage duration with respect to various pre-treatment and packaging materials. Under the investigated storage conditions, the palmitic acid content of the butter varied from 2.2 to 2.6%. The highest value was obtained from the kernels dried without boiling and the lower value was obtained in the boiled and dried kernels. The palmitic acid content of the butter tends to increase during the first six month of storage of the kernels irrespective to the other storage conditions. Higher amounts of palmitic acid were found in the kernels stored for duration longer than 6 months. With respect to the packaging materials, kernels stored in baskets yield butter with higher amount of palmitic acid compared to those stored in jute bags ($P < 0.05$). As far as the pre-treatment is concerned, no significant difference ($P < 0.05$) was detected in the palmitic acid content of butters from fresh kernels, boiled and dried kernels and directly dried kernels. The effect of the storage duration on the stearic acid content of the butter was significant only after 3 months of storage (Figure 5). The highest amounts of stearic acid were found in butters extracted from kernels of 9 months of storage. With respect to packaging materials, the highest concentration of stearic acid was recorded in butter from kernels stored in baskets. There is a significant difference ($P \leq 0.001$) in the stearic acid content of butters from fresh kernels, from boiled and dried kernels and butter from directly dried kernels. The highest value of stearic acid was obtained from butters extracted from directly dried kernels and the low level in boiled and dried kernels stored in jute bag. The low level of stearic acid recorded in the butters from boiled kernels could be explained by leaching of the fatty acids (dissolution of fatty acids) in the cooking medium. This phenomenon of dissolution was also observed by Aïssi *et al*. (2011) in a study on butter extraction from *Pentadesma* kernels. Overall, the oleic acid concentration in all samples is significantly affected by the storage duration (Figure 6). Longer storage duration of kernels results in the reduction of the oleic acid concentration in the derived butters. A decrease in oleic acid content could be expected in accelerated oxidation conditions with storage duration (Beltrán *et al*., 2009). Nuernberg *et al*. (2006) reported that storage of plant oils for 144 h caused significant decrease in the concentration of linoleic acid (18:2n-6), arachidonic acid (20:4n-6) and docosapentaenoic acid (22:5n-3). Nkouam *et al*. (2007) also observed an increase of the proportion of the palmitic acid and the decrease of the proportion of the linoleic acid throughout storage of aiélé seeds (*Canarium schweinfurthii Engl.*) to 18°C. About the packaging materials, the lowest level of oleic acid was obtained in butter from kernels stored in jute bags. Higher amounts of oleic acid ($P \leq 0,001$) were found in butters from boiled and dried kernels, while butters from kernels directly dried exhibited lower amounts of oleic acid. There is no significant effect of the storage conditions on the linoleic acid concentration of the butters extracted from the difference kernels ($p > 0.05$). Thus, the linoleic acid appears to be stable during the storage of the kernels of *Pentadesma*. It also suggests, as regards to the conservation, the butter of *Pentadesma butyracea* would grow rancid less quickly than other vegetable oils. On the nutritional plan, it represents good information because the linoleic acid is an essential fatty acid. Thus, Maritz *et al*. (2006) reported that the linoleic acid is an essential fatty acid that is vital in nutrition because it intervenes in the fabrication of the cell membrane and cannot be synthesized by the body. According to Maranz and Wiesman (2004), the linoleic acid content of 6-8%, makes Shea oil a moderate source of essential fatty acids in the human diet. Modifications of fatty acids during cooking could be related to 2 mechanisms: oxidation, loss of fatty acids by diffusion in cooking medium. In studies on cooking beef, Ono *et al*. (1985) and Scheeder *et al*. (2001) reported a significant decrease in total saturated fatty acids and an increase in total unsaturated fatty acids as the result of cooking. The increase of unsaturated fatty acids suggests that the hydrogenation reaction is limited at warmer temperature. This observation is in agreement with the result obtained by Honfo *et al*. (2013) in Shea butter, who reported that higher amounts of linoleic acid were found for butter from boiled kernels.

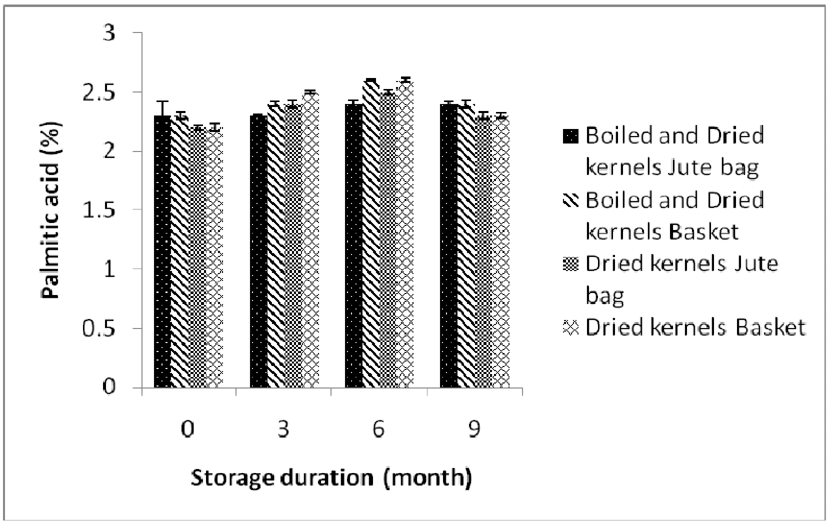

Figure 4: Effect of storage duration, pre-treatment and packaging materials on palmitic acid content of *P. butyracea* butter

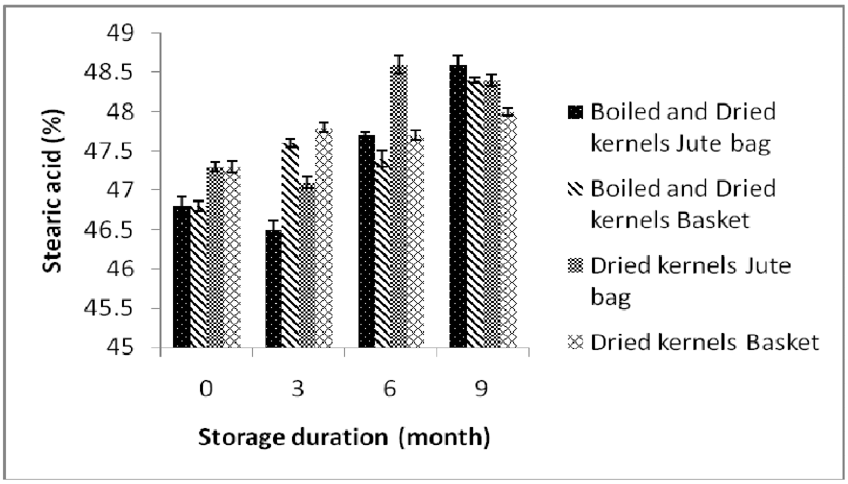

Figure 5: Effect of storage duration, pre-treatment and packaging materials on stearic acid content of *P. butyracea* butter

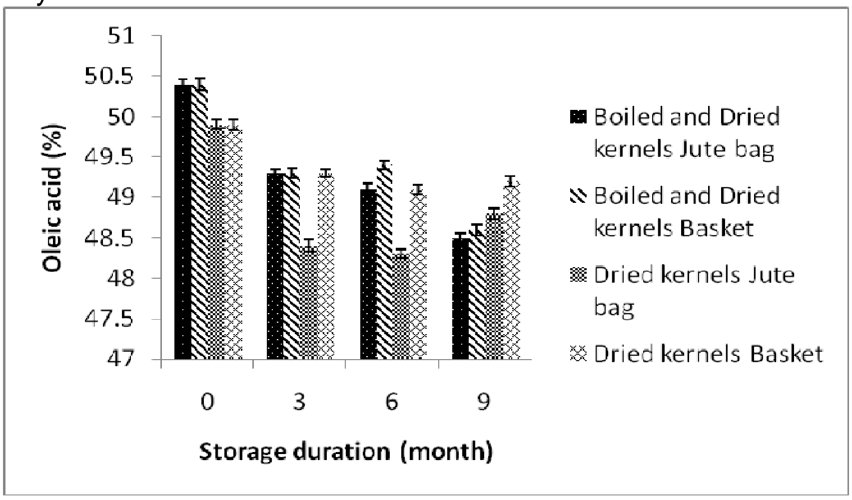

Figure 6: Effect of storage duration, pre-treatment and packaging materials on oleic acid content of *P. butyracea* butter

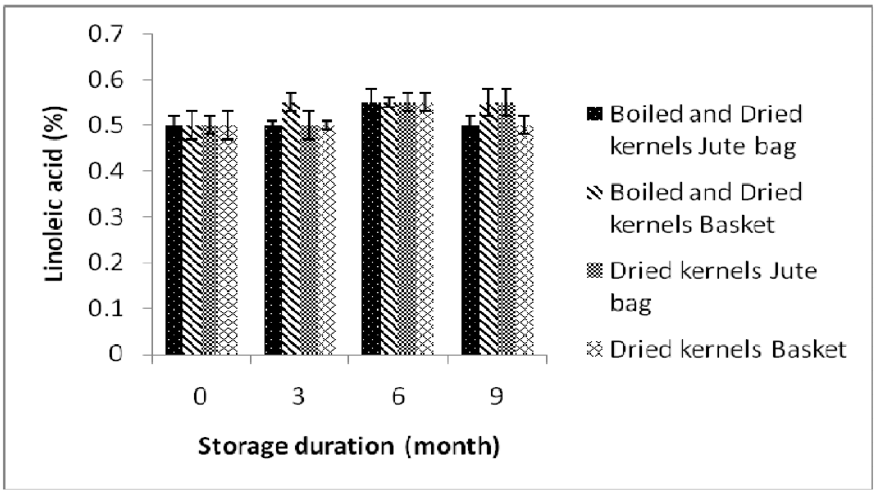

Figure 7: Effect of storage duration, pre-treatment and packaging materials on linoleic acid content of *P. butyracea* butter

CONCLUSION

The storage duration, the kernel boiling and the packaging materials significantly affected the oil yield of kernel of *P. butyracea* and the fatty acid profile of derived butter. The storage duration had a significant effect on the water content, the water activity of the kernels. Overall, the butter yield and quality were better before six months of storage. The basket is less effective in preserving the quality of *Pentadesma butyracea* butter during storage. *Pentadesma butyracea* butter from kernels stored in jute bags maintains its physicochemical quality. The storage duration of the kernels should not exceed 6 months.

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