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Impact of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Physicochemical Properties of Shea Butter

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Abstract: *To preserve the inherent characteristics of Shea butter during processing and enssure quality during harvesting, storage and drying of the Shea Kernel for better competitive advantage, this study seeks to determine the effects of picking period, boiling time, cooking temperature and drying methods on the physicochemical properties of shea butter. The shea fruits for the shea butter production were picked from the ground as they fell off the shea tree on the first day, third day and ninth day. The fruits were pretreated to remove the sprouted, disease infected and the pulp to get shea nuts. The nuts were subjected to different treatment conditions of drying (sun, traditional oven and rotary dryer drying), boiling (for 30 minutes) and cooking/roasting (at 60 ^{0}C). The shea butter obtained from each of the treatment (Drying method) was analysed for the following physicochemical parameters; saponification value, free fatty acid, iodine value, peroxide value, unsaponifiable fraction, Density, refractive index, cetane number and oil content. Picking at the 3rd and 9th day gives a higher saponification values of 171.8 – 208.8 mgKOH/g. Free Fatty Acid is only affected by mechanical drying which is lowest at 0.17 – 0.35, compared to other methods (0.63 – 1.33). Iodine values in the range of 40.1 – 49.0 g/kg are slightly affected by picking period than by boiling time and cooking temperature. Peroxide value was in the range of 10.2 – 13.3mEq/kg. Unsaponifiable fraction varied from 7 g/kg – 11.5 g/kg.The lowest density of 0.88 g/cm^{3}was obtained from shea nuts picked on the third day and mechanically dried, while the highest density of 0.95 g/cm^3 was obtained from shea nuts both the oven dried and mechanically dried and picked on 9th day.shea nuts picked on day 1, without boiling and cooking has the highest refractive index of 1.463 – 1.47, while those picked on the 3rd day for all the drying method has the lowest refractive index of 1.38 – 1.43. As the picking period increases the cetane number decreases. shea nuts mechanically dried gave the highest yield of between 58.3 – 60.8%.*

Keywords: *picking period, boiling time, roasting temperature, drying methods, shear butter.*

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I. Introduction

Pure unrefined Shea butter has nutritional, medicinal and cosmetic properties leading to its increased demand locally and internationally for use in the confectionary, cosmetic and pharmaceutical industry (Alander, 2004). It is important that the inherent characteristics of unrefined Shea Butter such as high levels of total fat, antioxidants, unsaponifiables are maintained and the aspects related to quality deterioration such as high moisture content leading to free fatty acids, peroxide value, odouretc are critically addressed to realize the competitive advantage of this important commodity/product (Lovett, 2004). However, some processing methods have negative effects on these important inherent properties. The handling practices during harvesting, storage and drying also have negative effect on the product quality(Maranz, Kpikpi, Wiesman, de Saint Sauveur and Chapagain, 2004).

The very first steps of collection of the fresh fruit to drying of the nuts are of critical importance to the final quality of the Shea butter. If the Shea kernels are of low quality, particularly as defined by high Free Fatty Acid (FFA) and the presence of fungal contamination and/or other impurities, the quality of the Shea butter extracted from them will require chemical refining to remove products resulting from lipid degradation in the kernel(Masters, 2004 and Lovett, 2004).

When collecting or picking Shea fruit from the ground beneath the tree, the fruit should be fully mature, yet un-germinated fruit (Lovett, 205 and Harris, 1998). The time between fruit drop and the heating and/or drying stages will have a major influence on both total available lipids (fat content of the kernel) and oil quality parameters (such as Free Fatty Acid, Peroxide Value, Moisture and Insoluble Impurities). While the seed is alive and healthy, chemical processes associated with germination will occur (metabolism of the seed's stores of oils and fats starting with hydrolysis by lipases that will increase Free Fatty Acid (FFA) levels in the germinating seed). Due to the presence of lipase enzymes in the living shea seed, the primary quality objective in post-harvest processing is to quickly kill and dry the seed in a controlled manner and produce a dry kernel that is chemically stable and can be stored without further chemical processes affecting the lipid content (Harris, 1998 and Hyman, 1991).

The process of stopping enzymatic browning can be done either by heating/ boiling or drying. Boiling of washed nuts should be done with clean water using stainless steel or clay pots for between 30 – 40 minutes (from when it starts to boil). Boiling of the fresh nuts denatures the proteins binding the fiber and holding the moisture and lipids, thus making the fresh nuts easier to dry, and increasing the availability (yield) of total fat content in extraction. In denaturing the lipase enzymes which may cause oxidation of kernel lipids during germination of the living seed, boiling can also reduce Free Fatty Acid (FFA), but can increase susceptibility to development of peroxides, possibly through inhibition and/or reduction of phenolic antioxidant compounds in the kernel (Lovett, 2005; Harris, 1998 and Hyman, 1991).

Drying boiled Shea nuts during the rainy season (under ambient temperatures which can exceed 30^{o}C, and humidity greater than 65%) can cause fungal problems. Since the nuts are now dead - with both natural fungicides as well as lipases activated - they quickly become infected with a range of moulds and fungi (Lovett, 2005). This can result in a range of chemical quality issues - notably increased levels of Free Fatty Acid (FFA), other volatile chemicals with unpleasant odours as well as the potential formation of aflatoxins from the Aspergillus fungus. The only way to reduce these fungal problems is to ensure boiled nuts are dried quickly and efficiently e.g. on wooden drying racks or inside solar – dryers (Maranz et al., 2004).

However, in this study, effects of picking period, boiling time, cooking temperature and drying method on physicochemical properties of shea butter will be determined.

II. Methodology

The methodology in this work includes obtaining the shea nuts for shea butter production. Fresh and matured shea fruits that have fallen to the ground from the shea tree were picked on the first from Sonmajigi (N09^{o} 11$^{'}$ 56$^{''}$; E05^{o} 35$^{'}$ 45$^{''}$), Pati- Ndeji (N09^{o} 23$^{'}$ 38$^{''}$; E06^{o} 36$^{'}$ 25$^{''}$), and Chengudu (N09^{o} 07$^{'}$ 40$^{''}$; E05^{o} 32$^{'}$ 34$^{''}$) villages in Lavun, Gbako and Edati Local Government Areas of Niger State respectively. The picking was continued on the third day, and finally the 9th day. Shea fruit of 500 kg was obtained for each of these days. The sprouted or diseased ones were manually sorted out and discarded. The pulp was manually removed to obtain shea nut, then followed by boiling of the shea nuts (for 30 minutes). The fresh shea nuts were subjected to different treatment conditions of drying (sun, traditional oven and rotary dryer drying). The dried nuts were then cracked to obtain the kernels, then roasted/cooked (at60 ^{0}C). This was followed by milling the kernels severally to obtain the shea paste, kneading the paste to obtain the curd, boiling the curd and collection of shea oil.

The shea butter obtained from each of the treatment (Drying method) was analysed for the following physicochemical parameters; saponification value, free fatty acid, iodine value, peroxide value, unsaponifiable fraction, Density, refractive index, cetane number and oil content.

III. Results and Discussion

The result obtained was compared using bar chart (Figures 1 - 9).

Saponification Value:The saponification value was observed to increase almost proportionately as the picking period increases from day 1 to day 9 as shown in Figure 1.

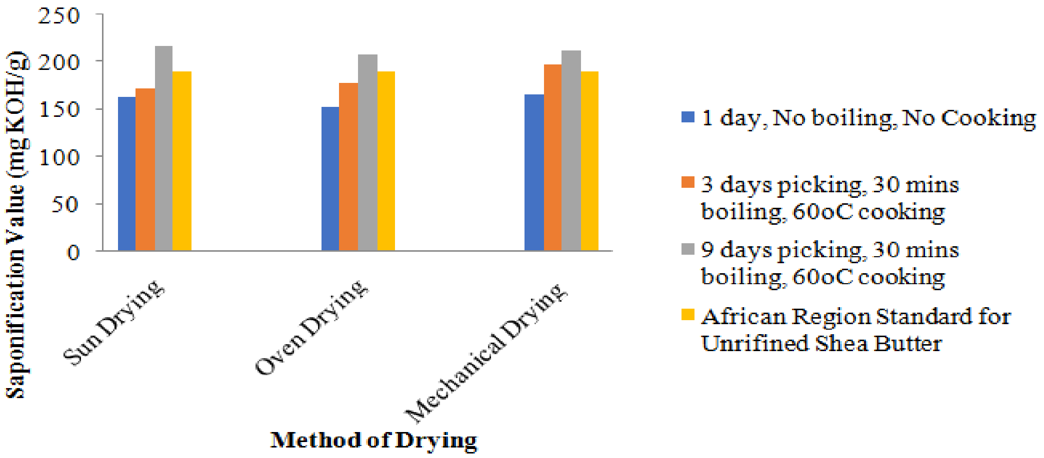

Figure 1: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Saponification Value (mg KOH/g) of Shea Butter

The effects of boiling and cooking were not significant on the saponification value as can be seen from figure 1. The saponification value obtained on the 9th day is similar to values obtained by Obibuzor*et al*. (2014) and Chibor*et al*. (2017) while those obtained for 3 days picking period were similar to Chukwu and Adgidzi (2008), Okullo*et al*. (2010), ARSUSB (2011) and Ouattara *et al*. (2015) suggesting that the shea nuts used for extraction of shea butter by Obibuzor*et al*. (2014) were picked between 8th – 9th day while those for ARSUSB (2011), Ouattara *et al*. (2015) were picked between day 1 – day 3. The seemingly high saponification value obtained for all the treatments on the 9th day picking shows that the mean weight of fatty acids presents in the shea butter is higher than those obtained by Okullo*et al*. (2010), ARSUSB (2011), Obibuzor*et al*. (2014) and Tame *et al*. (2015). This implies that more caustic potash shall be required in saponification reaction using these samples of shea butter.

Free Fatty Acid:One of the major methods of characterizing commercial shea butter is by determining its Free Fatty Acid (FFA). The lower the free fatty acid, the more preferred the shea butter and hence its premium. From the three treatments in this study, the values of FFA obtained are as shown in Figure 2. These figures were observed to be lower than the values obtained by Chukwu and Adgidzi (2008), Okullo*et al*. (2010), ARSUSB (2011) and Obibuzor*et al*. (2014) except for shea nuts picked on the 9th day and oven dried.

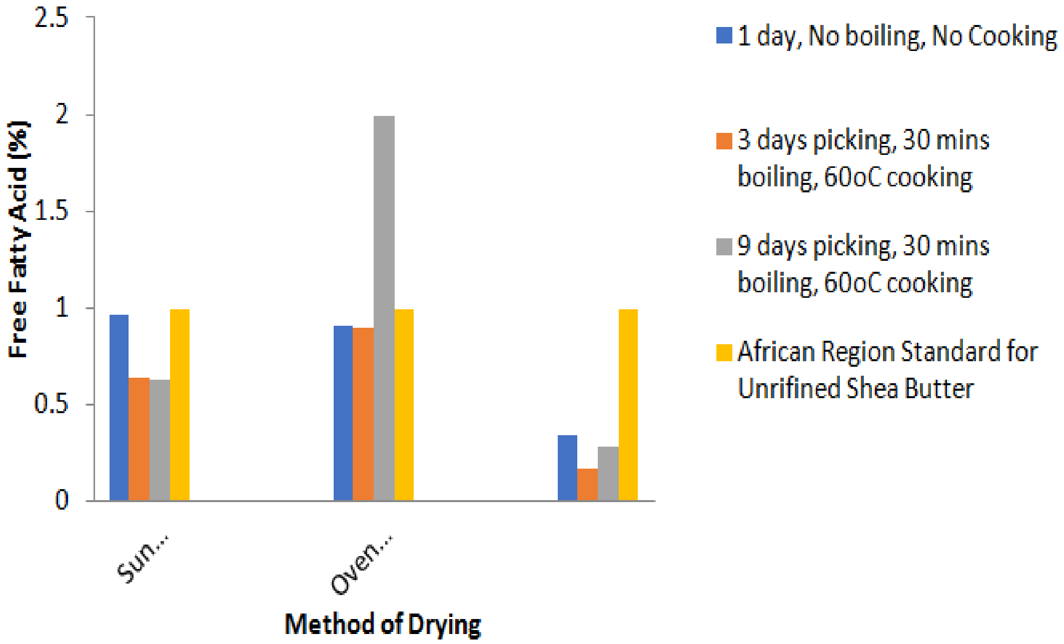

Figure 2: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Free Fatty Acid of Shea Butter

This striking observation is consistent with discoveries of Lovett (2004). Also, the lower values of the FFA obtained from this study, compared to the literature figures, Obibuzor*et al*. (2014) and Ouattara *et al*. (2015) shows that control of these process conditions are necessary for the production of grade A shea butter. The high value obtained in the literature figure may be due to exposure of the kernels to high temperature heating, time of shea kernel storage before processing and possibly the length of time shea pastes were exposed to before kneading.

Iodine Value:The iodine values of all the shea butter samples produced ranged from 40 – 50 g/kg as shown in Figure 3.

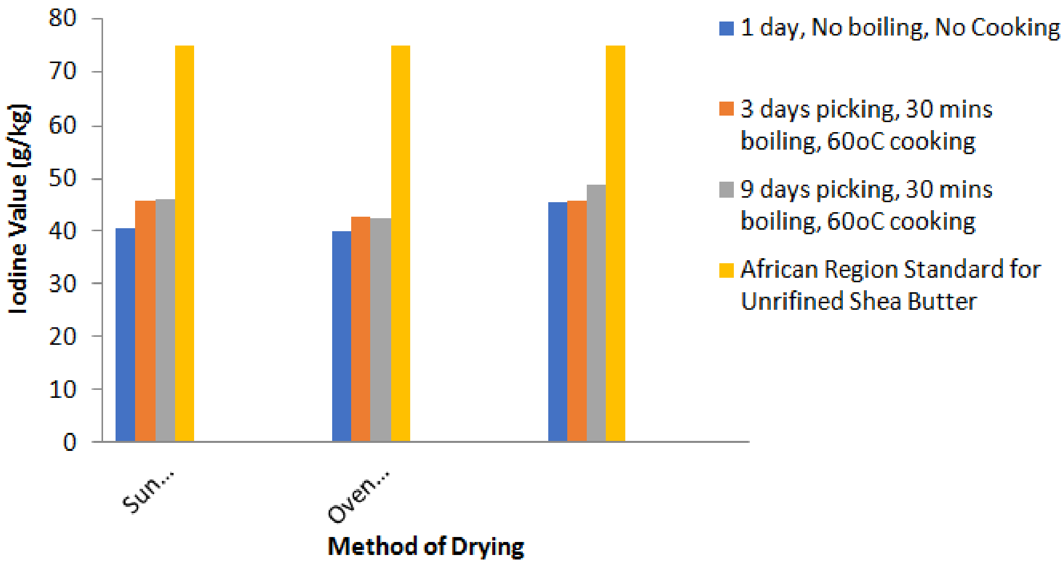

Figure 3: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Iodine Value (g/kg) of Shea Butter

All the values were observed to be similar to those obtained by Chukwu and Adgidzi (2008) and Obibuzor*et al*, (2014) but significantly lower than the ARSUSB (2011), and the values obtained by Ouattara *et al*. (2015) and Chibor*et al*. (2017). These lower values indicate fewer double bonds in the shea butter as compared to the ARSUSB (2011). The iodine values obtained for all the treatments are only slightly affected by picking period than by boiling time and cooking temperature studied. The iodine value for oil is supposed to be a property of the oil and constant at any given condition

Peroxide Value:The higher the peroxides in oil, the higher or faster the oil gets oxidised or rancid. The results of peroxide values obtained are as shown in Figure 4.

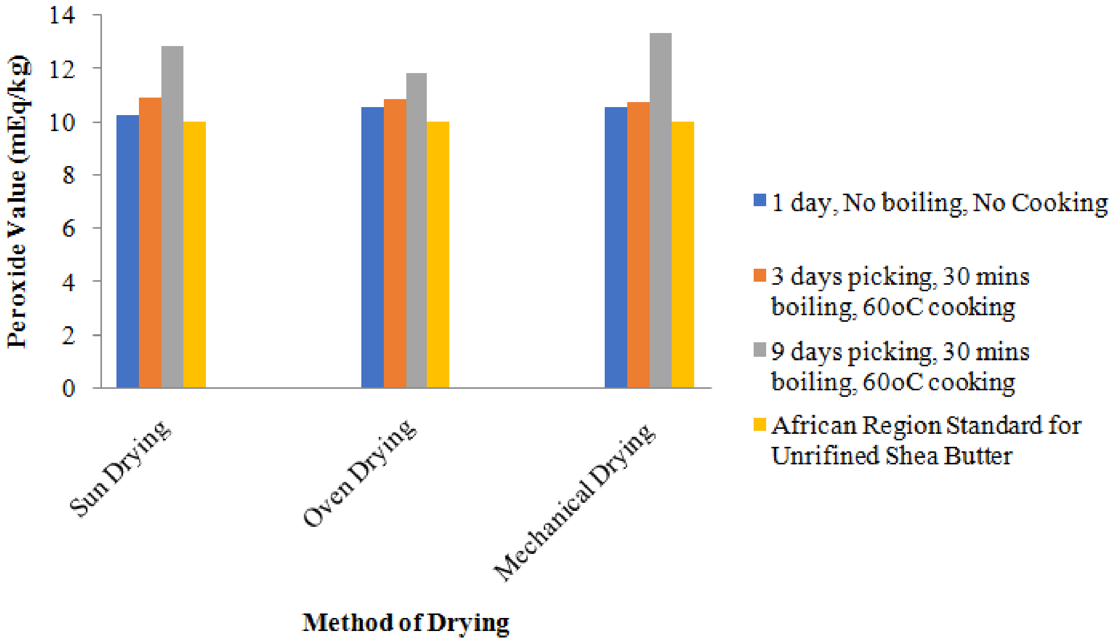

Figure 4: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Peroxide Value (mEq/kg) of Shea Butter

As the shea nuts picking period increases from day 1 to day 9, the peroxide value increases proportionally. Mechanically dried shea nuts picked on the 9th day recorded the highest value of peroxide while shea nuts picked on day one and sun dried gave the lowest value of peroxide. This suggests that the more the time taken for the shea nuts to be picked and processed the higher the peroxide. Also, the effect of drying methods was observed not to be significant on the peroxide value of shea butter produced. The results obtained were also observed to be higher than the figures obtained by Chukwu and Adgidzi (2008), Okullo*et al*. (2010), Obibuzor*et al*. (2014), Ouattara *et al*. (2015), Chibor*et al*. (2017) and also ARSUSB (2011). This may probably be due to lack of adequate refrigeration and delay in conducting the Peroxide Value analysis.

Unsaponifiable Fraction:The unsaponifiable fractions of shea butter even though small compared to the triglycerine component of shea butter is responsible for the healing properties of shea butter. They dissolve in fat and are insoluble in aqueous solution but soluble in organic solvent after saponification as reported by Halmiton and Rossell (1986). Figure 5 shows the variations of unsaponifiable fraction of the various shea butter produced in relation to ARSUSB (2011), Chukwu and Adgidzi (2008), Obibuzor*et al*. (2014). And Chibor*et al*. (2017). The healing property of oil depends on the species of the seeds but can be influenced by the processing method as shown in Figure 5.

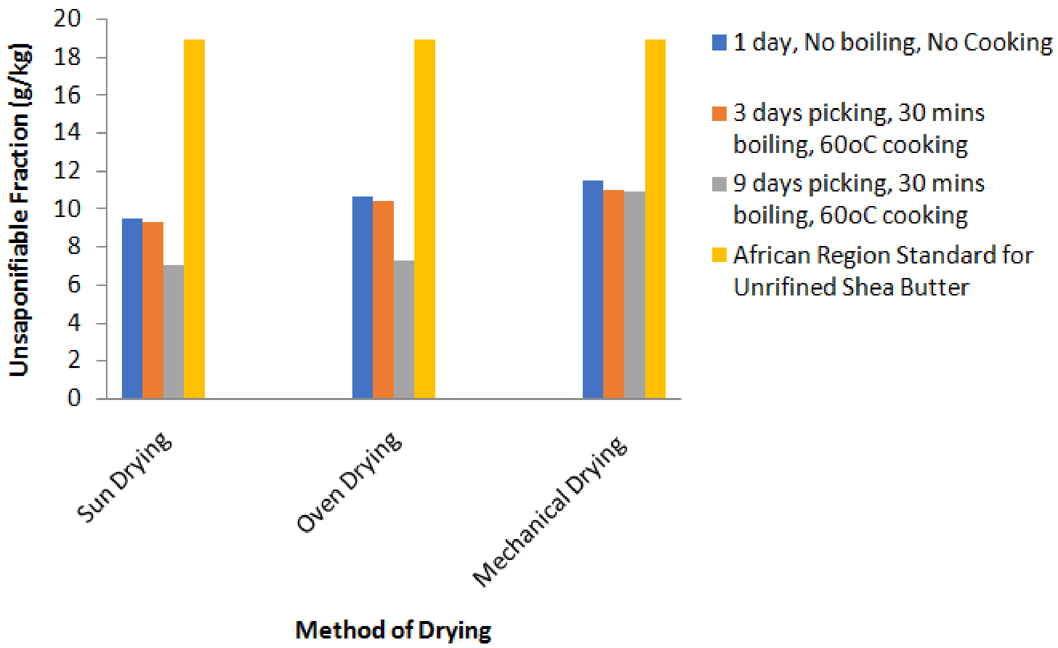

Figure 5: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Unsaponifiable Fraction (g/kg) of Shea Butter

The unsaponifiable fraction for all the samples produced varied from 7 g/kg – 11.5 g/kg. These figures fell within the ARSUSB (2011) of 0 – 19 g/kg. The result also shows that as the picking period increases the healing index decreases for all the treatment, this may be as a result of degradation the nuts must have suffered as a result of microbial activity. This implies that for higher healing index, the earlier the nuts are picked and processed the better. The potentials for higher healing index were more observed from shea nuts mechanically dried.

Density:The density (g/cm^3) of the shea butter samples produced was observed not to follow any particular trend, suggesting that all the variables studied, that is, picking period, boiling time, cooking temperature and drying method may not have direct influence on density of the shea butter as shown in Figure 6.

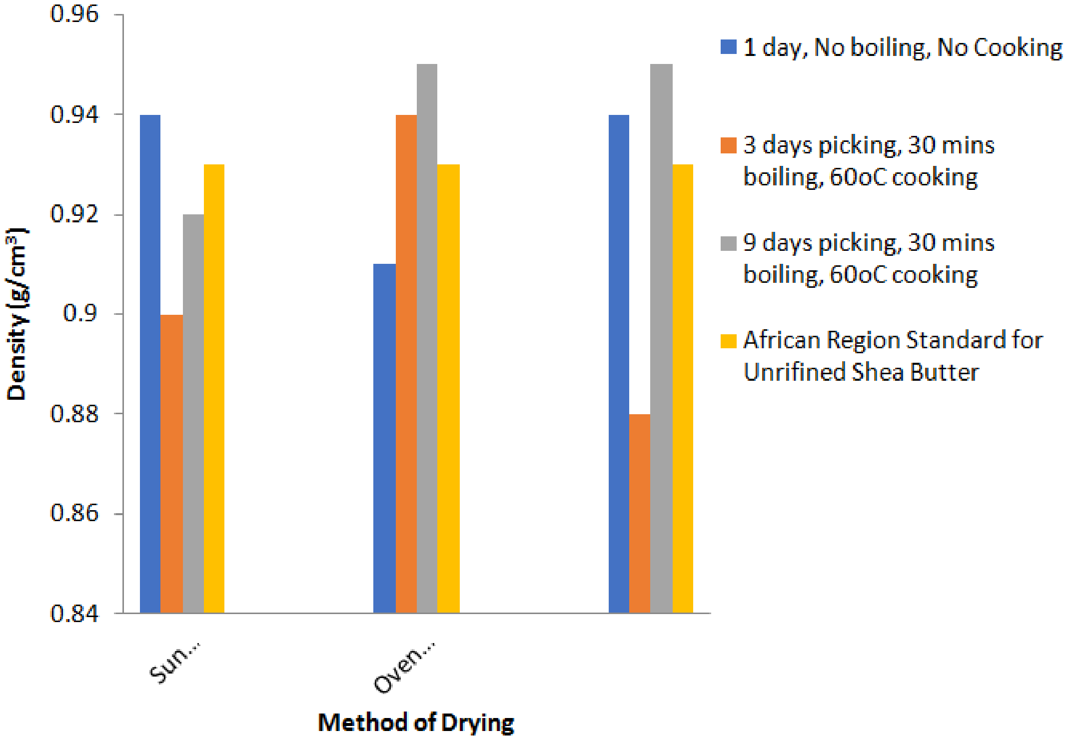

Figure 6: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Density (g/cm^3) of Shea Butter

The values of density obtained were also observed to be lower than the figure obtained by Obibuzor*et al* (2014), but clustered around ARSUSB (2011), Chukwu and Adgidzi (2008) and Chibor*et al*. (2017). This suggests that samples produced are remarkably unadulterated.
The lowest density of 0.88 $g/cm^3$was obtained from shea nuts picked on the third day and mechanically dried, while the highest density of 0.95 g/cm^3 was obtained from shea nuts both the oven dried and mechanically dried and picked on 9th day. This suggests that longer picking period and heating as in the case of oven drying and mechanical drying favours higher shea butter density.

Refractive Index:The refractive index for all the shea butter samples obtained as shown in Figure 7 reveals that for all the drying methods in this study, shea nuts picked on day 1, without boiling and cooking has the highest refractive index of 1.463 – 1.47, while those picked on the 3rd day for all the drying method has the lowest refractive index of 1.38 – 1.43. This observation may suggest that boiling and cooking has more positive effect on the refractive index than picking period.

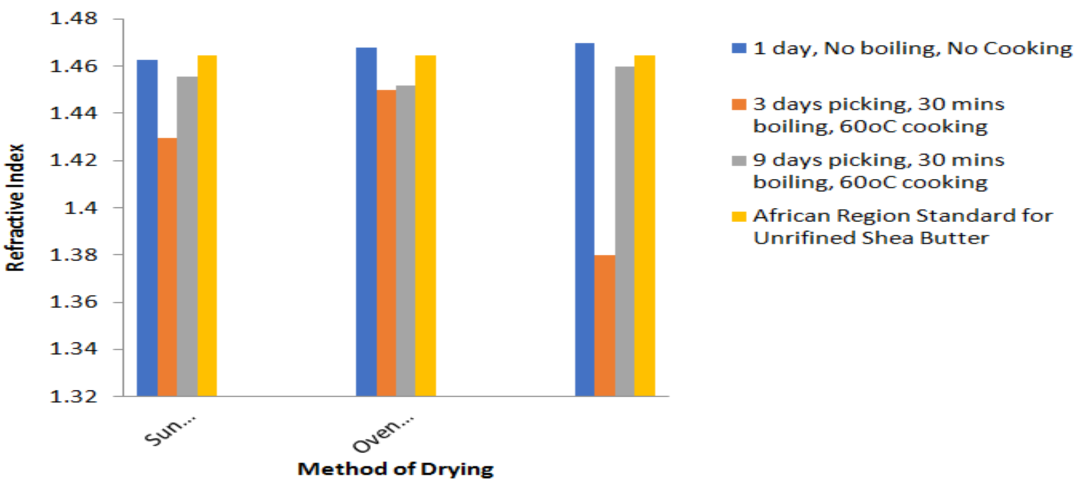

Figure 7: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Refractive Index of Shea Butter

The values of the refractive index obtained in this study favourable compares with the values obtained by Chukwu and Adgidzi (2008), Chibor*et al*. (2017) and ARSUSB (2011).

Cetane Number:Figure 8 shows the influence of variables studied on cetane number for all the shea butter samples produced. The result shows that as the picking period increases the cetane number decreases.

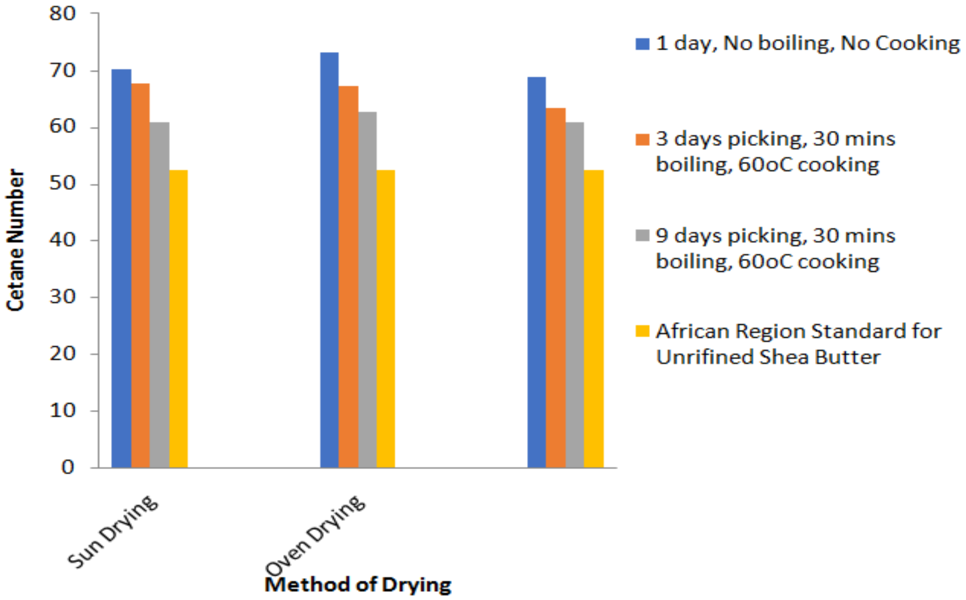

Figure 8: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Cetane Number of Shea Butter

It also shows that boiling cooking and drying method has no significant effect on the cetane number of shea butter. The higher values of cetane number obtained suggests that shea butter can be used for biodiesel production especially from nuts picked on day 1 without cooking and boiling. The values of cetane number obtained for all the shea butter sample are higher than the standard proposed by ASTM-D613.

Oil Content:Figure 9 shows the maximum oil content (shea butter) contained by each of the shea nuts treated in this study. For all the condition studied, shea nuts mechanically dried gave the highest yield of between 58.3 – 60.8%. These figures are slightly higher than 55% reported by Okullo*et al*. (2010).

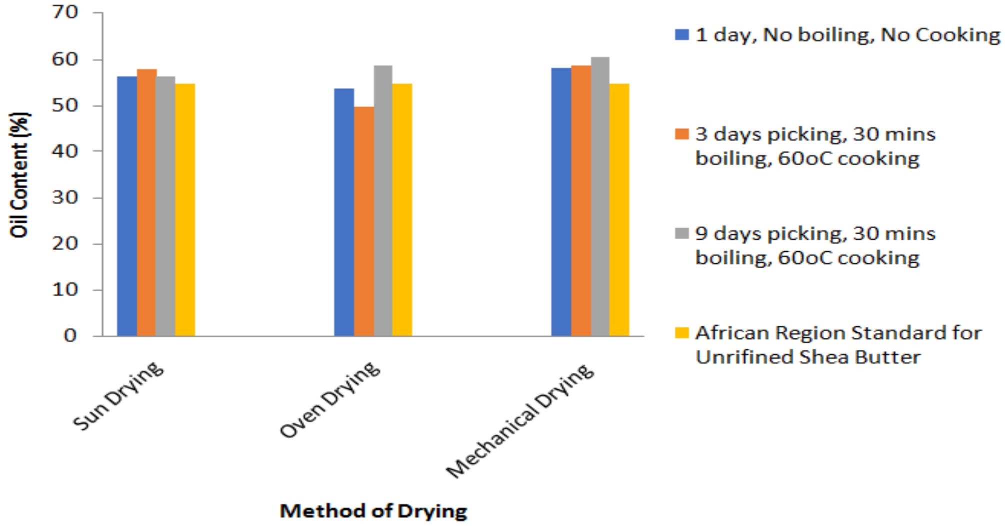

Figure 9: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Oil Content (%) of Shea Butter

This may be as a result of this novel drying process, which gives kernel of even properties.

IV. Conclusion

Effects of picking period, boiling time, cooking temperature and drying method on physicochemical properties of shea butter has been determined. The saponification value was observed to increase almost proportionately as the picking period increases from day 1 to day 9. The effects of boiling and cooking were not significant on the saponification value. The values of FFA obtained are significantly low for in each of the picking days when mechanical means was used for drying. The iodine values obtained for all the treatments are only slightly affected by picking period than by boiling time and cooking temperature studied. The more the time taken for the shea nuts to be picked and processed the higher the peroxide. Also, the effect of drying methods does not significantly affect the peroxide value of shea butter produced. As the picking period increases the healing index decreases for all the treatment, this may be as a result of degradation the nuts must have suffered as a result of microbial activity. This implies that for higher healing index, the earlier the nuts are picked and processed the better. The density (g/cm^3) of the shea butter produced does not have direct influence of picking period, boiling time, cooking temperature and drying method. Boiling and cooking has more positive effect on the refractive index than picking period. As the picking period increases the cetane number decreases. Mechanically dried shear nut gave the highest oil yield.

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V. Appendix

Tables of Physicochemical Analysis

Table 1: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Saponification Value (mg KOH/g) of Shea Butter

	Sun Drying	**Oven Drying**	**Mechanical Drying**
1 day, No boiling, No Cooking	163.4	152.2	165.5
3 days picking, 30 mins boiling, 60^oC cooking, Sun drying	171.8	177.7	198.2
9 days picking, 30 mins boiling, 60^oC cooking, Sun drying	217.2	208.8	212
African Region Standard for Unrifined Shea Butter	190	190	190

Table 2: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Free Fatty Acid of Shea Butter

	Sun Drying	**Oven Drying**	**Mechanical Drying**
1 day, No boiling, No Cooking	0.97	0.91	0.35
3 days picking, 30 mins boiling, 60°C cooking, Sun drying	0.64	0.9	0.17
9 days picking, 30 mins boiling, 60°C cooking, Sun drying	0.63	1.33	0.29
African Region Standard for Unrifined Shea Butter	1.0	1.0	1.0

1Table 3: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Iodine Value (g/kg) of Shea Butter

	Sun Drying	**Oven Drying**	**Mechanical Drying**
1 day, No boiling, No Cooking	40.8	40.1	45.7
3 days picking, 30 mins boiling, 60°C cooking, Sun drying	45.8	42.8	46
9 days picking, 30 mins boiling, 60°C cooking, Sun drying	46.3	42.6	49
African Region Standard for Unrifined Shea Butter	75	75	75

Table 4: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Peroxide Value (mEq/kg) of Shea Butter

	Sun Drying	**Oven Drying**	**Mechanical Drying**
1 day, No boiling, No Cooking	10.2	10.5	10.5
3 days picking, 30 mins boiling, 60°C cooking, Sun drying	10.9	10.8	10.7
9 days picking, 30 mins boiling, 60°C cooking, Sun drying	12.8	11.8	13.3
African Region Standard for Unrifined Shea Butter	10	10	10

Table 5: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Unsaponifiable Fraction (g/kg) of Shea Butter

	Sun Drying	**Oven Drying**	**Mechanical Drying**
1 day, No boiling, No Cooking	9.5	10.7	11.5
3 days picking, 30 mins boiling, 60°C cooking, Sun drying	9.3	10.4	11
9 days picking, 30 mins boiling, 60°C cooking, Sun drying	7	7.3	10.9
African Region Standard for Unrifined Shea Butter	19	19	19

Table 6: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Density (g/cm3) of Shea Butter

	Sun Drying	**Oven Drying**	**Mechanical Drying**
1 day, No boiling, No Cooking	0.94	0.91	0.94
3 days picking, 30 mins boiling, 60°C cooking, Sun drying	0.9	0.94	0.88
9 days picking, 30 mins boiling, 60°C cooking, Sun drying	0.92	0.95	0.95
African Region Standard for Unrifined Shea Butter	0.93	0.93	0.93

2Table 7: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Refractive Index of Shea Butter

	Sun Drying	**Oven Drying**	**Mechanical Drying**
1 day, No boiling, No Cooking	1.463	1.468	1.449
3 days picking, 30 mins boiling, 60°C cooking, Sun drying	1.43	1.45	1.38
9 days picking, 30 mins boiling, 60°C cooking, Sun drying	1.456	1.452	1.46
African Region Standard for Unrifined Shea	1.4650	1.4650	1.4650

Butter			

Table 8: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Cetane Number of Shea Butter

	Sun Drying	**Oven Drying**	**Mechanical Drying**
1 day, No boiling, No Cooking	70.5	73.2	69
3 days picking, 30 mins boiling, 60°C cooking, Sun drying	67.8	67.4	64.8
9 days picking, 30 mins boiling, 60°C cooking, Sun drying	61	62.9	61
Unrifined Shea Butter	52.6	52.6	52.6

Table 9: Effects of Picking Period, Boiling Time, Cooking Temperature and Drying Method on Oil Content (%) of Shea Butter

	Sun Drying	**Oven Drying**	**Mechanical Drying**
1 day, No boiling, No Cooking	56.5	53.9	58.3
3 days picking, 30 mins boiling, 60°C cooking, Sun drying	58	49.9	59
9 days picking, 30 mins boiling, 60°C cooking, Sun drying	56.4	59	60.8
Unrifined Shea Butter	55	55	55

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