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RESEARCH PAPER

PHYSICOCHEMICAL EVALUATION OF SHEA BUTTER TREATED WITH BORUTUTU (*COCHLOSPERMUM ANGOLENSIS*) BARK

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ABSTRACT

Borututu (Cochlospermum angolensis) bark has long been used in the preparation of 'yellow shea butter with claims of improving its aesthetic appeal and quality than its 'ivory' counterpart. The objective of this study was to investigate the impact of 'borututu' bark on the physicochemical and antioxidant characteristics of shea butter. The shea butter samples were treated with borututu bark (shredded and milled) at varying levels of 10–70 g per 100 g of butter. The resulting butter samples were analysed for pH, acid value, free fatty acid, saponification value, ester value, iodine value total polyphenols and % radical scavenging activity using standard methods. The results indicate that 'borututu' influenced the physicochemical properties positively and improved the total polyphenol content and radical scavenging properties of the treated shea butter samples. The findings suggest that borututu could be explored as natural food additive/colourant to improve the quality attributes of shea butter.

Keywords: Borututu, Shea Butter, Physicochemical Properties, Total Polyphenols, Radical Scavenging Activity

INTRODUCTION

In recent times, a lot of attention has been drawn to the consumption of fats and oils. However, excessive consumption of these lipids, particularly saturated fats as found in butter and margarine, coupled with poor eating habits and lifestyles have been associated with several adverse health conditions such as obesity, hypertension and cardiovascular diseases like congestive heart failure and stroke (Israel, 2015; Nelson and Cox, 2017). This has resulted in the sensitization of the general public on healthy nutrition and lifestyles. One front of such sensitization has been the advocacy of plant-based fats and oils rather than their chemically synthesized and animal-based counterparts (Israel, 2015).

Shea butter is an edible fat that is obtained from the kernels of the shea tree (*Vitellaria paradoxa*). It may be ivory or yellow/amber in colour. The plant is part of the *Sapoteceae* family with subspecies *paradoxa* being predominant in the West African subregion, and *nilotica* mainly in East Africa (Abagale *et al.*, 2016). The *paradoxa* subspecies thrive in the dry savannah belts of West African countries like Ghana, Nigeria, Cote d'ivoire, Senegal, Benin, Togo, Burkina Faso, Niger and Cameroon, whereas *nilotica* thrives in Eastern Africa countries like Uganda, Sudan and Ethiopia (Israel, 2015). In Ghana, the plant is cultivated in the five northern regions namely; Savannah, Northern, North East, Upper West and Upper East regions. Several seeds and nuts are used for oil production. Shea tree, however, ranks as the second most important oil crop after palm tree (Kyari, 2008; Abagale *et al.*, 2016).

Shea butter has applications in cosmetic, pharmaceutical and food industries and hence the economic potential of the crop. Shea butter is used extensively in the five northern regions in Ghana in varied ways, including medicine; as balms and ointment, cosmetics; as body and hair creams, and food; as oils and butter for frying and cooking (Honfo *et al.*, 2014; Akpambang, 2015; Megnanou and Niamke, 2015; Mohagir *et al.*, 2015). The plant is indigenous to Africa, yet the oil and fat are used internationally in the food, cosmetics and pharmaceuticals industries for various products consumed worldwide (Nde *et al*., 2016). Shea butter is a good source of essential fatty acid like linoleic acid which nourishes the body as well as antioxidants (vitamins A, E and K) which mitigates the effects of aging on the skin (Nde *et al*., 2016). It also contains several phytonutrients such as polyphenols, tocopherols, triterpene, phytosterols, etc. that confer several medicinal attributes like antioxidant and anti-inflammatory properties on the butter (Abagale *et al.*, 2016).

Cochlospermum angolensis commonly called 'borututu', is a plant that is used in traditional folk medicine in Africa. The borututu plant is native to Central African states like Angola and The Democratic Republic of Congo. The bark of borututu is used in the preparation of local beverages consumed as treatment for several ailments (Abourashed and Fu, 2017). An earlier study by Ferreres *et al*. (2013), showed that *C. angolensis* extracts had great antioxidant potential and capacity to be used in drug discovery. In addition to its antioxidant capacity, the plant has been reported to be effective in the treatment of malaria by inhibiting DNA replication by *Plasmodium falciparum* and *P. berghei* (Abourashed and Fu, 2017).

In the northern regions of Ghana, the ivory shea butter is treated with borututu bark to obtain the yellow-coloured shea butter. The yellow shea butter has been suggested to be aesthetically pleasing and of higher quality, hence preferred by consumers to its natural ivory counterpart, thereby improving sales of the yellow product.

Borututu bark has been used to treat shea butter since antiquity, yet to the best of our

knowledge, no research has been done to ascertain its impact on the physicochemical and antioxidant characteristics of the resultant butter. The current use of shredded 'borututu' bark to impart colour to the butter during preparation of 'yellow shea butter' results in yellow-coloured products with inconsistent characteristics such as appearance/colour, aroma, insoluble impurities and compositional properties including free fatty acids and peroxide value among others. There is the need to ascertain the effect of 'borututu' bark on the physicochemical and antioxidant properties of the resultant yellow shea butter. It is hypothesized that the use of milled 'borututu' bark in the preparation of yellow shea butter can give yellow shea butter products with consistent characteristics.

The objective of this study was to investigate the effect of borututu bark on the physicochemical properties of the shea butter treated with burututu bark.

MATERIALS AND METHODS

Materials

Random samples of *Cochlospermum angolensis* (borututu) bark together with locally prepared shea butter 'nkuto' (as called in the akan language) samples were collected from sellers in Tamale market. Two freshly prepared samples of shea butter namely; 'ivory coloured' and 'yellow coloured' samples were also purchased from the Tamale market by random selection. Samples were kept in plastic containers, sealed, and transported by road to the lab for analysis. The 'borututu' bark samples were identified at the Agroforestry Department of KNUST. All chemicals used were analytical grade reagents.

Sample preparation

'Borututu' bark samples were sorted from debris and dried using a solar dryer (made in Ghana) for 4 h during the cool hours of the day at temperatures between 30-36°C from 8 am to 12 noon, for three consecutive days. Drying was done in the early hours of the day to avoid excessive heat which can destroy the pigment molecules in the sample. This was to remove as much moisture as possible to reduce the growth of molds to the barest minimum, since that will facilitate spoilage of the samples during storage. Solar dried 'borututu' samples were stored in a cool dry place at room temperature of ~28 °C. The samples were then divided into two portions. The first portion was bagged and used as it was bought whilst the second portion was milled by pulse grinding into powder (1.0 mm particle size) using Crompton mix grinder (Model: ACGMTD71; Crompton Greeves Consumer Electricals Ltd; India) as shown in Figure 1. Pulse grinding was done to ensure that heat generated during milling was minimum to avoid degradation of pigment molecules in the samples.

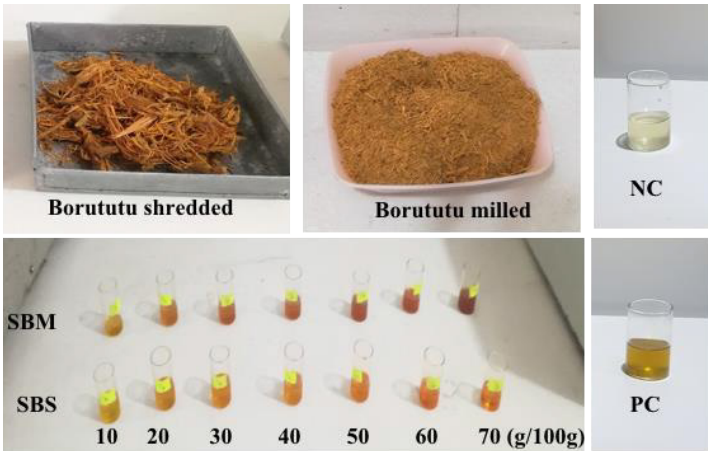

Figure 1. Experimental samples

SBS**:** *Shea butter treated with shredded borututu; SBM: Shea butter treated with milled borututu; NC:negative control (ivory shea butter sold on the market), PC: positive control (yellow shea butter sold on the market)*

Preparation of yellow shea butter samples

The ivory shea butter sample was divided into two parts, one part was further divided into seven glass jars, each with 100 g of shea butter serving as an experimental batch. Each experimental batch had one replicate. In a batch, each 100 g of shea butter sample was treated with shredded samples of 'borututu' bark sample as it was purchased from Tamale market; as done by local processors in increasing quantities from 10 – 70 g per 100 g of butter (borututu : shea butter ratio). This was set up in an incubator at 60°C to keep the shea butter in a molten state for pigment and phytochemical extraction for 24 h. Since this batch contained shea butter samples treated with the shredded plant matter, it was denoted as SBS experimental group. The other set up was done as described above, but in this case the shea butter samples were treated with milled 'borututu' bark samples. Since this batch contained shea butter samples treated with milled 'borututu' samples, it was denoted as SBM experimental group (Figure 1).

In addition to the shea butter samples treated with 'borututu', two more samples were added to the experimental batches as controls. A quantity of 100 g of raw ivory shea butter as purchased from the Northern region, with its replicate was used as negative control (NC) since it was not treated with any 'borututu' sample whilst another 100 g of already prepared yellow shea butter as sold on the market was set up with its replicate as positive control (PC).

Determination of physicochemical properties

Shea butter samples were incubated at 60°C to melt, 5 mL of melted butter was delivered into a petri dish. This was then covered and allowed to cover the entire base of the bottom piece, then the colour of the various samples was determined by means of a handheld chroma meter (Konica Minolta CR -400; Konica Minolta Inc; Japan) which measures 'L', 'a', 'b' colour space. This is a three-dimensional method of colour assessment where 'L' measures the lightness of the sample on a scale of 0 – 100, with black measuring 0, white 100 and

grey 50. Saturation of cyan (-) to magenta (+) pigments is determined as 'a', from -100 to +100 with 0 as neutral. Saturation of blue (-) to yellow (+) pigments is determined as 'b' from -100 to +100 again with 0 as neutral. Values obtained by this measurement are absolute, the – and + signs of 'a' and 'b' only indicate the degree of saturation of a particular colour beyond the neutral 0 (Margulis, 2005).

pH of the samples was determined according to a method described by Megnanou *et a*l. (2014) using pH meter (HI5221; Hanna Instruments; Singapore). About 2 mL of shea butter samples melted at 60 °C were dissolved in 15 mL of n-hexane at room temperature and the pH determined by means of a pH meter for both SBS and SBM experimental groups including control samples.

Acid value (AV), percentage free fatty acid (% FFA), Iodine value (IV), Percentage unsaponifiable matter (% USM) and were determined according to the method described in the '*Manual for Analysis of Oils and Fats'* (FSSAI, 2015).

Determination of saponification value (SV) of shea butter samples was done according to method previously reported (Munir *et al.*, 2012) whereas Peroxide value (PV) was determined according to a modified method described by Abagale *et al.* (2016).

The Ester values (EV) of the shea butter samples were calculated using the formula (Nielsen, 2010):

$$EV = \text{Saponification value (SV)} - \text{Acid value(AV)} \quad (1)$$

Determination of total polyphenols content

Total polyphenols content was determined using a modified method as described by Malacrida and Jorge (2012). In a clean and dried test tube, 0.5 g of melted shea butter sample was weighed and dissolved in 3 mL of methanol solvent. The content of the test tube was vortexed to mix and then centrifuged at 2500 rpm for 10 min and the supernatant collected.

The procedure above was repeated twice, the combined fractions was topped to 10 mL with methanol and labelled as phenol extract (P.E) for that particular sample. An aliquot of 1 mL was delivered into a fresh labelled test tube, 50 µL of Folin-Ciocalteu reagent was added and vortexed to mix. This was allowed to stand for 3 min after which 1.5 mL of saturated sodium carbonate (Na2CO3) solution was added. The solution was further diluted to a final volume of 10 mL and the reaction was allowed to proceed in the dark for two hours at 28 °C. The absorbance at 765 nm was determined using a UV-Vis spectrophotometer (GmbH; Mettler Toledo; Switzerland). The procedure was repeated for all samples and controls used in this investigation. A calibration curve was prepared using gallic acid as standard ranging from 0.00 to 100 ppm.

Total polyphenols content (TPC) in gallic acid equivalents (GAE) was calculated as;

$$TPC = (C \times V)/(m(g)) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where: TPC is Total phenolic acid content in mg GAE/g; C is Concentration of Gallic acid in the sample from the standard curve (mg/mL); V is volume of extract in mL; m is mass of the extract.

Determination of DPPH Radical Scavenging Activity

Radical scavenging activity was determined according to the method by Kiran *et al.* (2012). An aliquot of 3 mL of melted dried shea butter was delivered into cleaned, dried test tube. To this, 1 mL of 50 µM stock 2'2-diphenyl-1-pycrylhydrazyl (DPPH) solution dissolved in methanol was added. The reaction mixture was incubated at 37 °C for 30 mins in the dark, after which the absorbance at 517 nm was

determined using a UV-Vis spectrophotometer (GmbH; Mettler Toledo; Switzerland). The absorbance of the stock DPPH solution was used as a control whilst that of pure methanol was used as a blank. This procedure was repeated for all other samples and controls used in this investigation.

DPPH Radical Scavenging activity (%) was calculated as:

$$\text{DPPH Radical Scavenging activity (\%)} = ((A1-A2))/A1 \times 100 \quad \text{.....(3)}$$

Where: A1 is absorbance of oxidized DPPH solution and A2 is absorbance of the sample with DPPH solution.

Statistical analysis

The data reported are averages of duplicate determinations. One-way Analysis of variance was performed with IBM SPSS Statistics 20 (IBM Corp., 2011, US) and interpreted using Tukey's test at 5 % level of significance ($p < 0.05$).

Colour is a very important attribute in this experiment because it provides a rapid evidence for the efficiency of pigment extraction within the two experimental groups. By observation, colour was found to increase with increasing quantities of plant sample in both experimental groups (Figure 1). As presented in Table 1; 'L', 'a', and 'b' ranged from 62.52 - 60.61, 3.21 – 7.20 (in the cyan region) and 10.13 – 26.33 (in the yellow region), respectively for SBS experimental group. In the SBM experimental group, L', 'a' and 'b' were observed to range from 62.69 - 55.95, 3.55 - 6.80 (in the cyan region) and 10.19 - 29.51 (in the yellow region), respectively. Values obtained for 'L' generally show that there was a gradual increase in darkness of the shea butter samples in both SBS and SBM experimental groups as the quantity of 'borututu' bark used as treatment increased per 100 g of fat as evident in Figure 1. NC recorded the highest 'L' value of 72.17 ± 0.08, closest to 100 (white) showing it was the lightest in colour as expected.

In the SBS group, all 'L' values with the exception of shea butter treated with 10 g, were not statistically different ($p > 0.05$) from one another and also from the positive control (PC). In the SBM group with the exception of 40 g it was observed that increasing quantity of 'borututu' bark per 100 g of fat resulted in a corresponding increase in darkness of the resultant butters, as milling significantly improved the surface area for pigment extraction. With the exception of 10 g of milled plant bark, all quantities per 100 g of fat, used in this group resulted in butters with 'L' values significantly lower than 'L' values recorded for shea butter treated with same quantity of shredded 'borututu' in the SBS group ($p < 0.05$). PC recorded an 'L' value that can be located between values of shea butters treated with 30g and 40 g in the SBM group, though values obtained for 40 g/100g of fat and PC were found not to be statistically different ($p > 0.05$).

The degree of cyan to magenta as measured by 'a', was less than 8% for the highest quantity of plant bark per 100 g of fat (70 g) in both experimental groups, as values obtained were less than 8. This suggests that, saturation of cyan pigments in the 'borututu' sample is generally minute. Generally, it was observed that the saturation of cyan in samples in both SBS and SBM experimental groups increased with increasing quantity of plant bark per 100 g butter, though this was very minimal. Negative control (NC) recorded the least saturation of cyan (-) 0.24 ± 0.01 and was found to be statistically different ($p < 0.05$) from values obtained for treated samples in both SBS and SBM groups and that of PC as expected, since it was not treated with any burututu bark.

RESULTS AND DISCUSSION

Physicochemical properties

Table 1. Colour of shea butter samples treated with 'borututu' bark

	SBS			SBM		
Treatment	**L**	**a (-)**	**b**	**L**	**a (-)**	**b**
10	62.46 ± 0.06^{b}	3.49 ± 0.28^{b}	10.97 ± 0.84^{b}	62.65 ± 0.04^{f}	3.81 ± 0.26^{d}	10.91± 0.72^{b}
20	61.21 ± 0.02^{a}	6.62 ± 0.09^{a}	22.97 ± 0.46^{c}	61.95 ± 0.03^{e}	5.72 ± 0.30^{bc}	17.65 ± 0.78^{c}
30	60.91 ± 0.05^{a}	6.48 ± 0.17^{a}	23.62 ± 0.71^{cd}	60.28 ± 0.03^{c}	6.75 ± 0.05^{a}	26.53 ± 0.15^{d}
40	60.62 ± 0.01^{a}	6.72 ± 0.04^{a}	26.45 ± 0.11^{de}	61.09 ± 0.04^{d}	6.63 ± 0.24^{ab}	27.30 ± 0.28^{d}
50	60.65 ± 0.02^{a}	6.76 ± 0.03^{a}	27.17 ± 0.17^{e}	59.66 ± 0.01^{bc}	5.33 ± 0.04^{c}	27.51 ± 0.15d^{e}
60	60.75 ± 0.11^{a}	6.68 ± 0.08^{a}	26.02 ± 0.72^{cde}	59.46 ± 0.12^{b}	4.92 ± 0.27^{c}	27.81 ± 0.10d^{e}
70	60.94 ± 0.15^{a}	7.14 ± 0.06^{a}	25.46 ± 0.87^{cde}	56.01 ± 0.06^{a}	5.88 ± 0.03^{abc}	29.41 ± 0.10^{e}
NC	72.17 ± 0.08^{c}	0.24 ± 0.01^{c}	2.59 ± 0.02^{a}	72.17 ± 0.08^{g}	0.24 ± 0.01^{e}	2.59 ± 0.02^{a}
PC	61.06 ± 0.32^{a}	6.64 ± 0.11^{a}	26.51 ± 0.05^{de}	61.06 ± 0.32^{d}	6.64 ± 0.11^{ab}	26.51 ± 0.05^{d}

Values are Mean± SEM of duplicate *determinations,*

Values within a column with different superscript letters are significantly different at p < 0.05.

*SBS -shea butter treated with shredded '*borututu*', SBM- shea butter treated with milled '*borututu*', NC-negative control (ivory shea butter sold on the market), PC- positive control (yellow shea butter sold on the market)*

In the SBS experimental group, with the exception of 10 g, increasing quantities of shredded 'borututu' bark from 20 – 70 (g) per 100 g butter, resulted in butters with saturation of cyan pigments not statistically different ($p > 0.05$) from each other and also from that of PC. In the SBM group, saturation of cyan (-) of PC; 6.64 ± 0.11 was found not to be statistically different from butter treated with 40 g of milled 'borututu' bark per 100 g butter. However, no vivid trend was observed with levels of cyan (-) as was the case in the SBS group.

Values obtained for 'b' showed that the least quantity of burututu bark (i.e., 10 g) per 100 g of fat resulted in more than 10 % development of yellow colour, showing capacity of the plant bark to impart yellow pigments to treated shea butter samples. Values as high as 27.17 ± 0.17 and 29.41 ± 0.10 were recorded for 40 and 70 (g/100 g) of fat in the SBS and SBM experimental groups, respectively. NC recorded the least saturation of yellow (+) pigments with a value of 2.59 ± 0.02, which was statistically different ($p < 0.05$) from values obtained for shea samples treated with 'borututu' bark in both experimental groups and PC. Values obtained for 'b' showed that, with the exception of 10 g, each quantity of milled plant bark, imparted more yellow pigments than same quantity of shredded plant bark in the SBS group per 100g of fat.

In the SBS group, value of 'b' obtained for PC could be located among 'b' values of shea butters treated with 40 – 60 (g) 'borututu' bark per 100 g butter. In the SBM group, however, PCs' 'b' value, could be located among 'b' values of shea butters treated with quantities of 20 - 40 (g) of milled plant bark to 100 g butter; lower than quantities of shredded plant bark as stated above. However, it was observed that 30 - 50 (g) of milled plant bark per 100 g butter, recorded 'b' values that were not statistically different ($p > 0.05$) from 'b' value of PC though higher quantities of 60 and 70 (g/100 g of fat) gave 'b' values significantly different from that of PC ($p < 0.05$). This phenomenon could be due to the fact that, in the range of 30 – 50 (g) of milled 'borututu' bark, the amounts of yellow pigments might be nearing their saturation points per the 100 g of shea butter used, and hence only significantly higher quantities of plant sample could have resulted in significantly higher amounts of pigments being extracted.

The ability of shredded *C. angolensis* bark to significantly impart yellow colour to the shea butter could be attributed to the presence of pigment molecules such as tocopherols and apocarotenes in 'borututu' (Maranz and Wiesman 2004; Abourashed and Fu, 2017). Samples in both experimental groups as shown in Figure 1, were yellow to dark orange in colour as observed by Okullo *et al.* (2010). The present study ascertains that the colour of shea butter sample depends on the quantity of pigment molecules extracted from the given plant bark.

Table 2. pH, acid value and percent free fatty acid of shea butter samples treated with 'borututu' bark

	pH		Acid value (mg KOH/g)		Free fatty acid (%)	
Treatment	**SBS**	**SBM**	**SBS**	**SBM**	**SBS**	**SBM**
10	5.77 ± 0.01^{g}	4.93 ± 0.01^{d}	4.87 ± 0.03^{b}	5.67 ± 0.01^{b}	2.45 ± 0.02^{b}	2.85 ± 0.00^{b}
20	5.55 ± 0.05^{f}	4.63 ± 0.05^{c}	5.24 ± 0.09^{b}	7.45 ± 0.05^{c}	2.63 ± 0.05^{b}	3.75 ± 0.02^{c}
30	5.41 ± 0.05^{ef}	4.49 ± 0.05^{c}	6.13 ± 0.04^{c}	7.88 ± 0.05^{de}	3.08 ± 0.02^{c}	3.96 ± 0.03^{de}
40	5.33 ± 0.02^{de}	4.32 ± 0.01^{b}	7.11 ± 0.05^{d}	8.01 ± 0.02^{e}	3.57 ± 0.03^{d}	4.03 ± 0.01^{e}
50	5.18 ± 0.03^{cd}	4.29 ± 0.01^{b}	7.26 ± 0.11^{d}	7.91 ± 0.01^{de}	3.65 ± 0.05^{d}	3.98 ± 0.00^{de}
60	5.00 ± 0.02^{bc}	4.24 ± 0.02^{b}	7.85 ± 0.04^{e}	8.60 ± 0.01^{f}	3.95 ± 0.02^{e}	4.32 ± 0.00^{f}
70	4.83 ± 0.07^{b}	4.07 ± 0.01^{a}	7.70 ± 0.02^{e}	8.81 ± 0.10^{f}	3.87 ± 0.01^{e}	4.43 ± 0.05^{f}
NC	5.94 ± 0.03^{g}	5.94 ± 0.03^{e}	4.43 ± 0.10^{a}	4.43 ± 0.10^{a}	2.23 ± 0.05^{a}	2.23 ± 0.05^{a}
PC	4.58 ± 0.04^{a}	4.58 ± 0.04^{c}	7.67 ± 0.08^{e}	7.67 ± 0.08^{cd}	3.86 ± 0.04^{e}	3.86 ± 0.04^{cd}

Values are Mean± SEM of duplicate *determinations.*

Values within a column with different superscripts letters are significantly different at $p < 0.05$

*SBS -shea butter treated with shredded '*borututu*', SBM- shea butter treated with milled '*borututu*', NC-negative control (ivory shea butter sold on the market), PC- positive control (yellow shea butter sold on the market)*

The pH values recorded were in the range of 4.83-5.77 and 4.07 -4.93 for SBS and SBM experimental groups, respectively (Table 2). There was a general decrease in pH values (i.e. increasing acidity) in both experimental groups with increasing quantity of plant bark from 10–70 (g) per 100 g butter, however, pH value of shea butter treated with each quantity of milled 'borututu' bark in the SBM experimental groups was lower than butter treated with same quantity of plant bark in the SBS experimental group and were found to be statistically different ($p < 0.05$). Following the observed trend, the negative control sample (NC) recorded the highest pH value of 5.94 ± 0.03 compared with both experimental groups and PC. The increase in surface area of the milled plant bark, could have enhanced the extraction of more acidic compounds into resultant shea butter samples in the SBM experimental group compared to resultant butter samples in the SBS group, hence the trend observed. pH value of NC and shea butter treated with 10 g per 100 g butter in SBS group were not statistically different ($p > 0.05$), whilst pH of PC was closest to 100 g butter treated with 70 g shredded 'borututu', in the SBS group but the two values were statistically different ($p < 0.05$). However, within the SBM experimental group the pH value of PC was between, values recorded for butters treated with 20 g and 30 g of milled 'borututu' samples per 100 g butter; all three values were not statistically different ($p > 0.05$).

Hydroxybenzoic acids particularly gallic and protocatechuic acids together with ascorbic acid are major acidic compounds present in 'borututu' (Barreira *et al.*, 2013; Abourashed and Fu, 2017). Ellagic acid is also another acidic compound that has been suggested to be present in 'borututu'; all of which could have possibly leached from the plant bark into the resultant butters to lower their pH (Pereira *et al.*, 2015).

pH values for crude and refined shea butter as 4.38 and 4.58, respectively has been previously reported (Munir *et al.*, 2012), which fall within the range of pH values obtained for SBM experimental group. Megnanou and Niamke (2015), also reported pH values of 6.50 ± 0.30 and 6.78 ± 0.30 for beige (ivory) shea butter samples and yellow shea butter samples, respectively. Although these values were different from the values obtained in the present research, the differences may have resulted from differences in soil pH of the geographical locations and varietal differences in shea trees both of which can affect shea butter pH as suggested by Honfo *et al.* (2014).

Acid value (AV)

The acid value (mg KOH/g) of shea butter samples increased gradually upon treatment with 'borututu' bark from 10 – 70 (g) per 100 g butter in both SBS and SBM experimental groups (Table 2). Shea butters treated with each quantity of 'borututu' bark used in the SBM group had higher acid values than butters treated with same quantity used in the SBS group. Acid values (AV) obtained ranged from 4.84 - 7.89 (mg KOH/g) and 5.66 - 8.91 (mg KOH/g) for SBS and SBM experimental groups, respectively.

Within SBM experimental group, there was a consistent increase in acid value of resultant butters as quantities of plant bark increased with the exception of 50 g, however, same was not observed with acid values of resultant butters in the SBS group. NC recorded the least acid value of 4.43 ± 0.10 (mg KOH/g), whereas acid value for PC was determined as 7.67 ± 0.08 (mg KOH/g). Acid value of PC was found to be between acid values for shea butters treated with 60 g and 70 g of plant bark per 100 g butter in the SBS group, though all three values were not statistically significant ($p > 0.05$), but in the SBM group, it was between acid values for shea butters treated with 20

and 30 (g) of plant bark per 100 g butter. Likewise, all three values were not statistically different ($p > 0.05$).

A study by Leonardi *et al.* (2012) reported the presence of essential oils in 'borututu' as sesquiterpene hydrocarbons and monoterpene hydrocarbons. These essential and other potentially non-essential oils present in 'borututu' could be suggested as the sources of additional fatty acids which are extracted upon treatment of shea butter samples with 'borututu' bark; increasing the acid values of resultant butters in both experimental groups as observed in the present study.

Munir *et al.* (2012) reported 8.42 mg KOH/g and 3.36 mg KOH/g for crude and refined shea butter samples, respectively. Due to the variability in reported data, several researchers have reported acid values of shea butter to range from 1.0 – 21.2 (mg KOH/g) with an average of 8.1 mg KOH/g (Chukwu and Adgidzi, 2008; Okullo *et al.*, 2010; Honfo *et al.*, 2014; Megnanou and Niamke, 2015). Values obtained in the present study were within values reported by the above authors. Also, the reported average of 8.1 mg KOH/g by these authors can be located between the recorded values for shea butters treated with 30 g and 40 g of 'borututu' bark per 100 g butter for the SBM experimental group.

Percentage Free Fatty Acid (% FFA)

Values of % FFA recorded ranged from 2.43 - 3.88 (%) and 2.85 - 4.48 (%) for SBS and SBM experimental groups, respectively as shown in Table 2. Values of % FFA of resultant butters were observed to increase with increasing quantities of 'borututu' bark per 100 g butter in both experimental groups (i.e. SBS and SBM); however, like acid value, shea butters treated with 60 g and 70 g of plant bark in the SBS group were not statistically different ($p > 0.05$). Again, each quantity of 'borututu' bark per 100 g of butter in the SBM experimental group resulted in butters with higher % FFA values than butters obtained from same quantities of plant bark in the SBS group. This could be due to increased surface area of milled 'borututu' used for pigment and phytochemical extraction in the SBM samples. In the SBM experimental group increasing quantity of 'borututu' treatment resulted in butters with increasing % FFA values, except for those treated 40 g and 50 g of milled 'borututu' bark which were not significantly different ($p > 0.05$). Shea butters treated with 60 g and 70 g milled 'borututu' were also not significantly different ($p > 0.05$) from each other but were significant different ($p < 0.05$) from values obtained for shea butters treated with 40 and 50 g of milled 'borututu' bark. NC recorded the least value of 2.23 ± 0.05 % and was statistically different ($p < 0.05$) from acid values of resultant butters in both experimental groups and PC. PC recorded a value of 3.86 ± 0.04 %. Within the range recorded for SBS group, PC value falls between values recorded for butters treated with 50 and 60 (g) of 'borututu' bark per 100 g butter, though all three values were not statistically different ($p > 0.05$). In the SBM group, % FFA value of PC falls between recorded values for shea butters treated with 20 and 30 (g) of 'borututu' bark per 100 g butter. However, values recorded for shea butter treated with 30 g and PC were not statistically different ($p > 0.05$).

Shea butter has been reported to have percentage free fatty acid (% FFA) within the range of 1.1 – 3.0 (%) (Munir *et al.*, 2012). Values of 1.68 % and 4.21 % have been reported for refined and crude shea butter samples, respectively (Munir *et al.*, 2012). Also, shea butter samples with % FFA value in the ranges of 0.0 – 1.0 (%), 1.0 – 3.0 (%) and 3.0 – 8.0 are classified as grade 1, grade 2 and grade 3 respectively (Munir *et al.*, 2012). The range of % FFA recorded in the present study fall within the range of 1.0 – 10.7 (%) reported by Honfo *et al.* (2014). Since % FFA

is one parameter used as an indicator for early onset of rancidity, values obtained suggested, resultant butters were in better storage conditions than reported average of 5.3 % by Honfo *et al*. (2014). This could be attributed to the fact that samples used in the present study were freshly extracted shea butter samples.

Saponification Value (SV)

Saponification values (SV) recorded ranged from 301.55 - 251.39 (mg KOH/g) and 262.05 - 189.68 (mg KOH/g) for SBS and SBM experimental groups, respectively, as shown in Table 3.

Table 3. Saponification value and ester value of shea butter samples treated with 'borututu' bark

	Saponification value (mg KOH/g)		Ester value (mg KOH/g)	
Treatment	**SBS**	**SBM**	**SBS**	**SBM**
10	301.01 ± 0.54^{e}	260.99 ± 1.06^{h}	296.15 ± 0.57^{f}	255.31 ± 1.05^{h}
20	304.74 ± 1.11^{e}	241.54 ± 1.37^{g}	299.51 ± 1.20^{f}	234.09 ± 1.41^{g}
30	295.00 ± 0.44^{d}	224.06 ± 1.04^{e}	288.87 ± 0.40^{e}	216.15 ± 0.96^{e}
40	290.07 ± 0.38^{d}	212.18 ± 0.23^{d}	282.96 ± 0.43^{d}	204.18 ± 0.21^{d}
50	303.22 ± 0.95^{e}	206.64 ± 0.39^{c}	295.96 ± 1.05^{f}	198.73 ± 0.38^{c}
60	277.53 ± 0.36^{c}	199.88 ± 0.75^{b}	269.68 ± 0.39^{c}	191.29 ± 0.75^{b}
70	252.77 ± 1.38^{b}	189.85 ± 0.17^{a}	245.07 ± 1.36^{b}	181.04 ± 0.07^{a}
NC	317.71 ± 1.04^{f}	317.71 ± 1.04^{i}	313.27 ± 0.94^{h}	313.27 ± 0.94^{i}
PC	233.51 ± 1.64^{a}	233.51 ± 1.64^{f}	225.84 ± 1.56^{a}	225.84± 1.56^{f}

Values are Mean± SEM of duplicate *determinations.*

Values within a column with different superscript letters are significantly different at p < 0.05.

*SBS -shea butter treated with shredded '*borututu*', SBM- shea butter treated with milled '*borututu*', NC-negative control (ivory shea butter sold on the market), PC- positive control (yellow shea butter sold on the market)*

However, the resultant butters obtained with increasing quantity of 'borututu' bark per each 100 g of butter recorded decreasing saponification values in both experimental groups, hence establishing an inverse relation between saponification value and quantity of plant bark used. Treatment with 50 g of 'borututu' bark per 100 g of butter in the SBS group, however, recorded a value higher than that of 40 g ($p < 0.05$). Also, saponification values of resultant butter for each quantity of plant bark in SBS group was higher than value of resultant butter obtained with same quantity of plant sample in the SBM group. NC recorded the highest value of 317.71 ± 1.04 (mg KOH/g) compared to both experimental samples and PC, whereas PC recorded a value of 233.51 ± 1.64 (mg KOH/g). The value obtained for PC was closest to that of shea butter treated with 70 g of plant bark in the SBS group, but both values were statistically different ($p < 0.05$; Table 3).

In the SBM group, SV of PC could be located between SV of resultant butters obtained with 20 g and 30 g plant bark per 100 g butter but all three values were statistically different ($p < 0.05$). The trend observed may have resulted from the presence of basic compounds which

neutralize some of the fatty acids, reducing the quantity of fatty acids that were eventually saponified to form soap upon reacting with KOH in the saponification reaction. Varied SV have been reported in literature for shea butter from different countries and geographical locations, however, Munir *et al.* (2012) reported a range of 180 – 360 (mg KOH/g). SV recorded in the present study were all within this range. SV of shea butter oil, palm oil and pumpkin seed oil have been reported as 226.17, 193.18 and 177.63 (mg KOH/g), respectively emphasizing that high SV are characteristic of both shea butter and shea oils (Chibor *et al.*, 2017). High SV of shea butter and oils imply that they are very good for soap making and this was confirmed in a study by Boadu *et al.,* (2017).

Ester Value (EV)

EV ranged from 296.72 – 243.71 and 256.36 – 180.97 (mg KOH/g) for the SBS and SBM experimental groups, respectively (Table 3). Each 100 g of shea butter obtained with each quantity of 'burututu' bark in the SBS group recorded higher ester values than values recorded for shea butters treated with same quantity of plant bark in the SBM group. NC recorded the highest value of 313.27 ± 0.94 (mg KOH/g). Like saponification value, increasing quantities of 'burututu' bark resulted in decreasing ester values per 100 g of the resultant butters. Again 50 (g) of plant bark per 100 g butter in the SBS group, resulted in butter with a value higher than 40 g. Ester value of PC was calculated as 225.84± 1.56 (mg KOH/g), and it was closest to E.V recorded for shea butter treated with 70 g plant bark per 100 g butter in the SBS group but both values were statistically different ($p < 0.05$).

In the SBM group, ester value of PC fell between values recorded for shea butters treated with 20 g and 30 g plant bark per 100 g butter, but all three values were statistically different ($p < 0.05$).

The presence of phytochemical constituents with basic properties like alkaloids and saponins shared in the *Cochlospermaceae* family of *C. angolensis* has been suggested to neutralize some of the triglycerides in the shea samples before reaction with KOH in the saponification process, resulting in reduced ester values as seen in both SBS and SBM experimental groups as 'burututu' bark increases (Magaji *et al.*, 2010).

The ester value of shea oil has been reported as 226.17 ± 0.38 (mg KOH/g) (Chibor *et al.*, 2017). Although, the article failed to clarify if this value is for crude shea oil or refined shea oil, the interesting observation is that it falls in the ranges obtained for both SBS and SBM experimental groups as shown in the present study. Ester value of NC; 313.27 ± 0.94 (mg KOH/g) was far higher than the reported value of 226.17 ± 0.38. However, the ester value of PC; 225.84 ± 1.56 (mg KOH/g) is very comparable to the reported value.

Iodine Value (IV)

Iodine value (I.) determined ranged from 28.99 - 28.16 (mg I2/100g) and 26.59 – 24.70 (mg I2/100g) for SBS and SBM experimental groups, respectively (Table 4). Values obtained for shea butters treated with increasing quantities of 'burututu' bark (i.e. 10 – 70 g) per 100 g butter in the SBS experimental group were all not statistically different ($p > 0.05$) from each other and the value recorded for NC. However, iodine value of PC; 25.83 ± 0.10 (mg I2/100g), was statistically different ($p < 0.05$) from values recorded for resultant butters in the SBS group. No consistent trend was observed with regards to values obtained for the SBS experimental group.

Table 4. Iodine value and peroxide value of shea butter samples treated with 'borututu' bark

	Iodine value (mg I_2/100g)		Peroxide value (meq O_2/kg)	
Treatment	**SBS**	**SBM**	**SBS**	**SBM**
10	28.70 ± 0.27^{b}	26.57 ± 0.02^{e}	21.79 ± 0.08^{f}	19.86 ± 0.04^{g}
20	28.60 ± 0.42^{b}	26.11 ± 0.07^{de}	20.84 ± 0.19^{e}	19.07 ± 0.04^{f}
30	28.77 ± 0.12^{b}	25.62 ± 0.17^{cd}	22.29 ± 0.34^{f}	17.92 ± 0.02^{e}
40	28.66 ± 0.23^{b}	26.02 ± 0.06^{de}	19.74 ± 0.15^{d}	16.06 ± 0.04^{d}
50	28.64 ± 0.16^{b}	25.27 ± 0.06^{bc}	15.87 ± 0.03^{b}	15.22 ± 0.05^{c}
60	28.98 ± 0.01^{b}	24.62 ± 0.17^{a}	13.94 ± 0.03^{a}	14.59 ± 0.08^{b}
70	28.52 ± 0.36^{b}	24.82 ± 0.12^{ab}	15.87 ± 0.04^{b}	11.99 ± 0.01^{a}
NC	27.82 ± 0.07^{b}	27.82 ± 0.07^{f}	19.90 ± 0.10^{d}	19.90 ± 0.10^{g}
PC	25.83 ± 0.10^{a}	25.83 ± 0.10^{cd}	17.95 ± 0.05^{c}	17.95 ± 0.05^{e}

Values are Mean± SEM of duplicate *determinations*

Values within a column with different superscript letters are significantly different at p < 0.05

*SBS -shea butter treated with shredded '*borututu*', SBM- shea butter treated with milled '*borututu*', NC-negative control (ivory shea butter sold on the market), PC- positive control (yellow shea butter sold on the market)*

In the SBM experimental group, each 100 g of shea butter sample treated with increasing quantity of 'borututu' bark resulted in butters with decreasing iodine values which were statistically different ($p < 0.05$). Iodine value for PC; 25.83 ± 0.10 (mg I2/100g) was observed to fall between values of shea butters treated with 30 g and 40 g of 'borututu' bark per 100 g butter in the SBM experimental group. The value of PC was closer to that of shea butter treated with 30 g of milled 'borututu' bark, whilst NC recorded the highest iodine value of 27.82 ± 0.07 (mg I2/100g) in both experimental groups as expected (Table 4). In the SBS experimental group, 70 g of 'borututu' bark resulted in a butter with the closest iodine value to that of PC, but the two values were statistically different ($p < 0.05$). Iodine value for shea butter has been reported to range from 21.68 - 89.5 (mg I2/100g) with an average of 51.4 (mg I2/100g) (Honfo *et al.*, 2014).

The I.V for SBM experimental groups were lower than those obtained for the SBS experimental group (Table 4). This could be attributed to the leaching of chemical constituents that can possibly reduce double bonds in unsaturated fatty acids of the shea butter upon treatment with 'borututu' bark. Acidic components of the 'borututu' like gallic, protocatechuic, ellagic and ascorbic acids could possibly release electron deficient protons (H+) capable of attacking electron 'rich' nucleophilic double bonds of unsaturated fatty acids resulting in their reduction, hence the trend observed in the present study (Ferreres *et al.*, 2013; Pereira *et al.*, 2015; Abourashed and Fu 2017).

Iodine values recorded in the present study as compared to the reported average of 51.4 (mg I2/100g), could be attributed to the fact that local preparation procedures might have exposed the butter to rancidity (Nahm *et al.*, 2013).

Peroxide Value (PV)

Peroxide values (PV) were estimated to range from 22.63 - 13.91 (meq O2/kg) and 19.90 - 11.98 (meq O2/kg) for both SBS and SBM experimental groups, respectively (Table 4). Generally, treatment of shea samples with increasing quantities of plant bark per 100 g butter resulted in butters with decreasing peroxide values in both experimental groups. However, in the SBS group, 20 g recorded lower peroxide value than 30 g, similarly 60 g also recorded lower a value than that of 70g. Due to inadequate extraction as a result of reduced surface areas of shredded plant samples, resultant butters obtained from 10 – 30 (g) plant bark per 100 g butter in the SBS experimental group, recorded peroxide values higher than the value of NC, implying that more shredded plant sample was needed to mop up peroxides present in the butter samples. Also, peroxide value of PC could be located between values obtained for shea butters treated with 40 g and 50 g plant bark per 100 g butter in the SBS group.

In the SBM experimental group, treatment of each 100g of shea samples with increasing quantities of 'borututu' bark consistently yielded resultant butters with reducing peroxide values. Treatment with 10 g of 'borututu' resulted in a butter with peroxide value of 19.86 ± 0.04 (meq O2/kg), which was the closest peroxide value to that of the negative control (NC); 19.90 ± 0.10 (meq O2/kg). Both values were not statistically different ($p > 0.05$, Table 4).

Within the SBM experimental group, peroxide value of PC could be located between values for butters treated with 30 g and 40 g of 'borututu' bark per 100 g butter; butter treated with 30 g and that of PC were not statistically significant ($p > 0.05$).

Peroxide values between 3.90 – 7.21 (meq O2/kg) have been reported previously for shea butter samples from the Northern regions of Ghana by Abagale *et al.* (2016). In another report by Nahm *et al.* (2013), peroxide values of shea butter samples used ranged from 2.15 – 15.32 (meq O2/kg). In a review by Honfo *et al.* (2014), peroxide values of shea butter were reported to range from 0.5 – 29.5 (meq O2/kg), with an average of 7.6 meq O2/kg. Peroxide values as reported in the present study fall within the range previously reported. The observations/results suggest the antioxidant potential of the borututu as hypothesized.

Percentage Unsaponifiable Matter (% USM)

Percentage unsaponifiable matter (% USM) was estimated to range from 2.70 - 8.16 (%) and 6.08 – 29.50 (%) for SBS and SBM experimental groups (Table 5). Generally, % USM of resultant butter was observed to increase with increasing quantities of 'borututu' bark per 100 g butter in both SBS and SBM experimental groups. % USM values recorded for resultant butter upon treatment with each quantity of 'borututu' bark per 100 g butter in the SBM group was higher than values obtained for butter treated with same quantities of 'borututu' in the SBS group. In the SBS experimental group, shea butters treated with 10 g and 20 g of 'borututu' bark per 100 g butter recorded % USM values statistically different ($p < 0.05$) from each other. However, in the same group 30 g – 70 g plant bark per 100 g butter, all recorded % USM values which were not statistically different ($p > 0.05$) from one another, though a gradual increase in values was observed. In the SBS group, 10 g of shredded 'borututu' bark per 100 g butter resulted in butter with % USM value of 2.83 ± 0.13 (%) statistically different ($p < 0.05$) from negative control (NC) of 2.16 ± 0.02 %. Likewise, 10 g of milled 'borututu' bark per 100 g butter in the SBM group, resulted in butter with % USM value of 6.15 ± 0.07 % also significantly different ($p < 0.05$) from that of NC.

Table 5. Unsaponifiable matter, total polyphenols content and antioxidant activity of shea butter samples treated with 'borututu' bark

	Unsaponifiable matter (%)		Total polyphenols (mg GAE/g)		Radical scavenging activity (%)	
Treatment	**SBS**	**SBM**	**SBS**	**SBM**	**SBS**	**SBM**
10	2.83 ± 0.13^{b}	6.15 ± 0.07^{b}	0.08 ± 0.01^{ab}	0.12 ± 0.00^{ab}	24.39 ± 0.40^{ab}	46.68 ± 2.40^{b}
20	3.93 ± 0.05^{c}	7.38 ± 0.08^{bc}	0.13 ± 0.01^{b}	0.14 ± 0.01^{b}	35.69 ± 1.65^{bcd}	61.56 ± 4.96^{c}
30	5.08 ± 0.08^{d}	10.68 ± 0.09^{c}	0.12 ± 0.01^{b}	0.22 ± 0.00^{b}	32.33 ± 2.64^{bc}	80.96 ± 0.05^{d}
40	5.06 ± 0.04^{d}	15.39 ± 0.42^{d}	0.20 ± 0.02^{c}	0.40 ± 0.02^{c}	46.74 ± 1.66^{d}	84.24 ± 0.32^{d}
50	5.06 ± 0.06^{d}	17.68 ± 0.03^{de}	0.23 ± 0.00^{ce}	0.62 ± 0.00^{d}	37.73 ± 1.37^{cd}	84.74 ± 0.11^{d}
60	5.09 ± 0.05^{d}	20.86 ± 1.09^{e}	0.27 ± 0.01^{e}	1.47 ± 0.04^{e}	71.92 ± 3.35^{ef}	86.32 ± 0.25^{d}
70	8.12 ± 0.04^{e}	28.16 ± 1.34^{f}	0.29 ± 0.02^{e}	1.97 ± 0.02^{f}	66.35 ± 4.70^{e}	87.11 ± 0.04^{d}
NC	2.16 ± 0.02^{a}	2.16 ± 0.02^{a}	0.04 ± 0.00^{a}	0.04 ± 0.00^{a}	17.28 ± 0.59^{a}	17.28 ± 0.59^{a}
PC	10.42 ± 0.02^{f}	10.42 ± 0.02^{c}	0.21 ± 0.00^{c}	0.21 ± 0.00^{b}	81.80 ± 0.20^{f}	81.80 ± 0.20^{d}

Values are Mean± SEM of duplicate results

Values within a column with different superscript letters are significantly different at $p < 0.05$

*SBS -shea butter treated with shredded '*borututu*', SBM- shea butter treated with milled '*borututu*', NC-negative control (ivory shea butter sold on the market), PC- positive control (yellow shea butter sold on the market)*

% USM value for PC was determined as 10.42 ± 0.02 %, much higher than % USM of butter obtained upon treatment with each quantity of 'borututu' bark per 100 g butter in the SBS experimental group (Table 5). Percentage unsaponifiable matter has been reported to range from 2.21 – 4.18 (%), 1.2 – 17.6 (%) and 5.00 – 7.91 (%) as reported by Nahm *et al.* (2013), Honfo *et al.* (2014), and Abagale *et al.* (2016), respectively. % USM values obtained in the SBS experimental group falls in the range as reviewed by Honfo *et al.* (2014). Values obtained for SBM experimental group falls outside this range particularly for 60 g and 70 g of milled 'borututu' bark per 100 g butter. This variation could be due to the use of milled plant samples in the treatment of shea butter in the present study. Also, increase in surface area by milling could have resulted in the high % USM values of samples in the SBM experimental group due to adequate extraction.

The values recorded for butters in the SBM experimental group, suggests that milling enhanced the extraction of unsaponifiable constistituents like tocopherols, sterols, antioxidants etc. which could have influenced the % USM of the treated samples. Unsaponifiable matter contains the bioactive molecules of fat samples, which influence the medicinal potential of the fat (Segman *et al.*, 2012; Nahm *et al.*, 2013).

The unusually high % USM could be due to the fact that, raw shea butter is characterized by high amounts of unsaponifiable matter, hence the additional treatment with increasing quantities of plant matter, resulted in the cummulatively higher % USM reported in the present study.

Total polyphenols content

The total polyphenols (TP) content ranged 0.07 – 0.31 (mg GAE/g) and 0.12 – 1.99 (mg GAE/g) for SBS and SBM experimental groups, respectively (Table 5). It was observed that GAE of resultant butters increased as each 100 g shea butter samples was treated with increasing quantities of 'borututu' bark. TP of resultant butters obtained upon treatment with each quantity of 'borututu' bark per 100 g butter in the SBS experimental group were lower than values obtained for butters treated with same quantities in the SBM experimental groups. Values recorded for both experimental groups were higher than that of the negative control (NC); 0.04 ± 0.00 (mg GAE/g) and were statistically significant ($p < 0.05$). The presence of Gallic acids in the negative control (NC) as bioactive compounds have been suggested to give the profound medicinal properties of shea butter (Nahm *et al.*, 2013).

Several reports have been cited in literature suggesting the antioxidant potential of 'borututu' due to the presence of phenolic compounds such as Gallic acids, protocatechuic acids, ascorbic acids and methyl ellagic acids (Barreira *et al.* 2013; Pereira *et al.* 2014, 2015; Abourashed and Fu, 2017).

Pereira *et al.* (2013) reported 132.26 mg GAE/g for *Cochlospermum angolensis* infusion, the highest phenolic content among three medicinal plants studied; 'borututu', 'milk thistle' and 'artichoke' justifying its use in traditional medicine and as dietary supplement.

Radical Scavenging Activity (% RSA)

Percentage DPPH radical scavenging activity (% RSA) ranged from 23.99 – 75.27 (%) and 44.28 - 87.15 (%) for SBS and SBM experimental groups, respectively (Table 5). Generally, it was observed that shea butter samples treated with increasing quantity of 'borututu' bark resulted in butters with increasing % RSA in both experimental groups as observed with the results of total polyphenols content. Each quantity of shredded 'borututu' bark per 100 g butter in the SBS experimental group had lower % RSA than same quantity used to

treat butter samples in the SBM experimental group.

NC recorded the least % RSA of 17.28 ± 0.59 % among both experimental groups and PC. With the exception of shea butters treated with 10 – 30 (g) of 'borututu' bark per 100 g butter in the SBS experimental group, % RSA value of NC was statistically different ($p < 0.05$), from those of both experimental groups and PC.

An important determinant of % RSA is the IC50 value, defined as the concentration of antioxidant at which a minimum of 50% of generated free radicals are effectively scavenged by the antioxidant molecules in a reaction medium (Pereira *et al.*, 2013). In the SBS experimental group 10 - 50 (g) of 'borututu' bark per 100 g butter, including the negative control (NC) recorded % RSA below 50%, hence each concentration of radical scavenging molecules within this range was less than 1.30 mg/mL.

PC recorded % RSA of 81.80 ± 0.20 %, higher than values obtained for resultant butters in the SBS group, though it was closest to the value recorded for 60 g rather than of 70 g of plant bark per 100 g butter. In the SBM experimental group, like the SBS group, treatment of shea butter with increasing quantities of 'borututu' bark per 100 g butter had increasing % RSA. Values of % RSA recorded for butters treated with quantities in the range of 10–30 (g) of plant bark per 100 g butter in the SBM group were statistically different ($p < 0.05$). However, butters treated subsequently with 'borututu' bark ranging from 40–70 (g) per 100 g butter in the SBM group were all not statistically different ($p > 0.05$) from one another. This could possibly be due to the fact that 30 g of milled plant bark was able to saturate the 100 g of shea butter used in the study with enough antioxidant molecules such that further increment in plant matter did not yield significant quantities of antioxidants extracted.

With the exception of butter treated with 10 g of 'borututu' bark which was the smallest quantity of plant bark used, butters treated with higher quantities of 'borututu' bark per 100 g butter in SBM group yielded % RSA above 50%, implying that each concentration of extracted antioxidant for any given quantity from 20 g was significantly higher ($p < 0.05$) than the IC50 value of 1.30 mg/mL. in the SBS group, shea butter treated with 60 g and 70 g of shredded 'borututu' recorded % RSA above 50 %.

Percentage radical scavenging activity (% RSA) of PC; 81.80 ± 0.20 % could be located between % RSA values of butters treated with 20 g and 30 g 'borututu' bark per 100 g butter in the SBM experimental group. % RSA values recorded for PC and shea butter treated with 30 g of milled 'borututu' were not significantly different ($p > 0.05$).

The antioxidant potential of 'borututu' bark has been attributed to its phenolic contents (Gallic acids, ascorbic acids, protocatechuic) as well as antioxidant compounds such as sterol and tocopherols (Barreira *et al.*, 2013; Pereira *et al.*, 2014, 2015; Abourashed and Fu, 2017, Leonardi *et al.* 2012; Nahm *et al.*, 2013; Pereira *et al.* 2013).

CONCLUSION

Treatment of shea butter with 'borututu' bark improved the physicochemical qualities, total polyphenols content and radical scavenging activities of the resultant shea butter samples. The milled 'borututu' bark had a greater positive influence on the quality attributes studied than the shredded 'borututu' counterpart. The findings indicate that borututu could be explored as natural food colourant to improve the quality attributes of shea butter.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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