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Effect of Frying, Toasting, Boiling and Parboiling of Sheanuts on Percentage Yield, Sensory Attributes, Some Physical and Chemical Properties of Shea Butter

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ABSTRACT

Shea butter contributes minimally to edible fat supply due to variations in product quality, low yield and acceptability. Research reports have not related these to processing methods which vary from place to place. Effect of heat treatment methods on yield, sensory quality and some properties of manually extracted shea butters from fried, toasted, boiled and parboiled sheanuts pastes were evaluated using standard methods. Yield, sensory attributes and characteristics of shea butter from same sheanuts varied depending on method of heat treatment. Fried sheanuts had highest % shea butter yield (40.80±0.84) and saponification value (197.14±0.03). Boiled sheanuts butter was organoleptically preferred.

Introduction

Edible fats and oils are increasingly becoming important in nutrition and commerce for domestic and industrial uses because they are sources of dietary energy, antioxidants, bio fuels and raw materials for the manufacture of industrial products [1]. Palm fruit and its kernels, groundnut, cotton seed and soybeans are conventional oilseeds in Nigeria. They account for 80% of natural edible oil and fat supply [2]. Oils are obtained from oilseeds by manual, solvent or mechanical extraction and are locally used in soap production, cooking and as body cream.

Sheanut from the shea tree, Vitellaria paradoxa, is an under-utilized economic oil crop with great potentials for Nigerian economy. The current contribution of shea butter to the world edible fat/oil supply is minimal. According to [2] it is a potential asset for national economic development. Its adequate exploitation could make a significant contribution to the country's Gross Domestic Production. The shea butter plant (Vitellaria paradoxa C.F Gaertn), a perennial tropical oil-yielding tree belonging to the family Sapotaceae has been reported as the second most important oil yielding tree in Africa after oil palm [3]. In some Northern parts of Nigeria, shea butter tree replaces the oil palm tree as a source of edible oil among many ethnic groups [4]. It is called "Kadanya" in Hausa, "Karaje" in Fulani, "Emi" in Yoruba, "Osisi Okuma" in Igbo and Kwara in Bussa and Kambari languages of Nigeria [5,6].

Shea butter tree grows naturally throughout the Guinea Savannah region. The members of the family could be shrubs or trees with alternate leaves which are always simple and have entire margins. The fruit is always a berry and could contain more than one seed but not more than three.

The brown to orange colour seed coat is hard, bony and shinning and has a small or large scar at the base or on one side [7]. Though, a promising multi-functional fat, shea butter is generally unacceptable as edible oil/fat outside the producing areas [6]. Manually extracted (handcrafted) shea butter has been reported to be preferred to solvent extracted shea butter in the international markets [8, 9]. The elites especially civil servants and students look down on it as inferior to groundnut and other vegetable oils mainly because of its unpleasant odour, poor packaging and presentation [6].

Shea butter is cheap and available in the areas of production and potentially, can complement and compete with groundnut and other vegetable oils which have become too expensive for regular household use. According to [10] sheanuts contain up to 50% shea butter.

Traditional processing methods differ and give low yield with great variations in product quality and characteristics [11, 12]. The nuts could be fried, toasted, roasted, boiled or parboiled before oil extraction [6, 13, 14, and 15]. Most of the reported works on shea butter center on solvent extraction from raw sheanuts [16, 10, and 17]. Solvent extraction of fat and oils for consumption is expensive for adoption and could be health hazardous.

There is paucity of information on the characteristics of shea butter from differently heat treated sheanuts as practiced in different areas of shea butter production. Most of the available research reports also have not related the yield, , sensory qualities and acceptability of manually extracted shea butter to the method of heat treatment of the sheanuts.

This research was therefore designed to investigate and provide empirical data on the effect of different pre extraction heat treatment methods of sheanuts and manual (hand crafted) extraction, a non solvent method of extraction on shea butter yield,quality and characteristics.

This information will add to the knowledge base of shea butter and aid proper processing that would increase utilization of the butter as an edible fat. More so, the information from this study will be useful to researchers, producers, manufacturers, consumers and would be consumers of shea butter.

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Materials and methods

Preparation of samples for processing

Ripe fresh shea fruits were handpicked, left to ferment for 3 days at ambient temperature (26 ± 2^{0}C) washed, parboiled, sundried, weighed, cracked, winnowed and further dried to approximately 10 - 11% moisture content. The dried kernals were stored in sacks at ambient temperature (26 ± 2^{0}C) till required for processing. Five kilograms sheanuts paste were used to manually produce shea butter from four heating methods (frying, toasting, boiling and parboiling). Before use, the stored, dried, dehusked sheanuts were washed and sun dried for 4 to 5 hours.

Heat Treatment Methods:

Frying method

Six kilograms of clean, dehusked dried sheanuts were fried with approximately 530ml of previous shea butter oil (from the natives) for about 30 minutes in a metallic pot. The initial frying temperature of 180^{0}C was gradually reduced to 85±5^{0}C after 5 minutes to avoid burning [18]. The fried sheanuts were size reduced using crack ing machine, mortar and pestle. The semi pounded shea paste was ground to a chocolate brown paste using a locally fabricated electric motor grinder.

Toasting method

Clean sheanuts were toasted at 180^{0}C for 5 minutes and continued at 85±5^{0}C for 25minutes modified from [13] village method) in a metallic pot without oil. The toasted sheanuts were cracked using hammer mill and the size further reduced with mortar and pestle before grinding and extraction.

Boiling method

A modified method [15] was used. The clean sheanuts were boiled at 100^{0}C for 30 minutes and sundried for four hours. The sizes were reduced using cracking machine, mortar and pestle before grinding and shea butter extraction.

Parboiling method

The stored parboiled sheanuts were washed and sun dried for four hours before size reduction, grinding and oil extraction (adopted from a village after the survey [19, 14]. This served as the control. All the sheanuts were parboiled before further treatment. All the extractions were carried out in triplicates.

Manual (Hand-churning) extraction method

Five kilograms each of the shea pastes were placed in a strong Fulani calabash and was slowly hand-mixed and churned with gradual addition of warm water and later vigorously churned till a brownish white shea fat separated from the brownish water solution. The shea fat was scooped out and washed several times using potable water to remove the brownish colour. The fat was heated to melt and water dried off. The shea oil in the pot was allowed to cool and settle overnight before filtration through muslin cloth, measured and packaged into clean plastic sample bottles and one liter plastic containers before solidification. The packaged solidified shea butter samples were stored in the freezer till required. The processing flow charts are as shown in Figures 1 and 2.

Determination of percentage oil yields

These were determined from the ratio of the volume of oil extracted and the weight of the shea paste used for oil extraction as shown in equation 1. (It is worth noting that the shea butter used to fry sheanuts were subtracted from the mean total oil yield of 2676ml before the calculation of the percentage oil yield for fried sheanuts butter).

$$\% \text{ yield} = \frac{volume\ of\ oil\ extracted}{weight\ of\ shea\ paste\ used} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

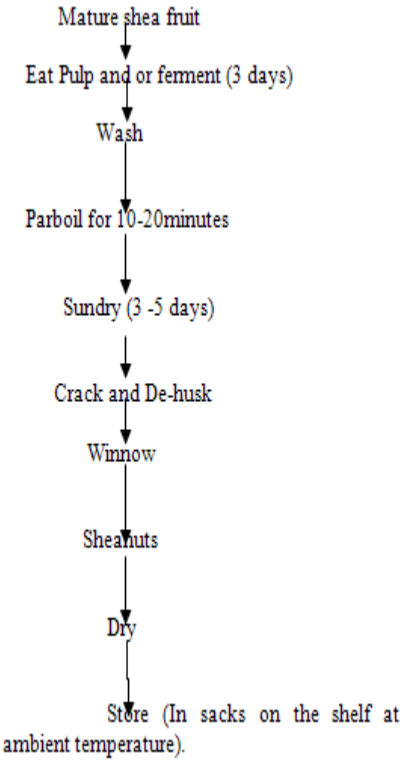

Figure 1.Preparation of shea fruits before sheabutter extraction

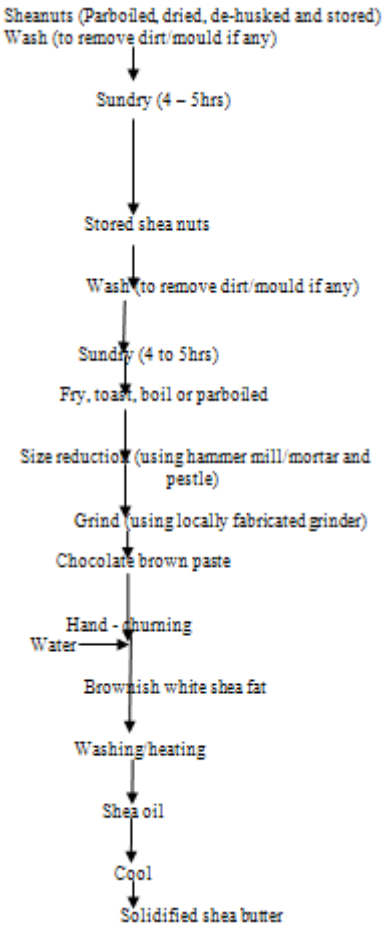

Figure 2. Manual processing of Shea butter from (fried, toasted, boiled and parboiled) Sheanuts

Moisture content determination

The moisture content of the samples was determined by drying 5g of the sample at 150^{0}C in an oven for four hours. The dried samples were put in a dessicator for five minutes before

weighing. The samples were transferred again into the oven for 30 minutes. The process is repeated till a constant weight is obtained. The moisture content (MC) is calculated thus:

MC = weight of sample before drying – weight of sample after drying × 100/ initial weight of the sample.

Determination of Fat content

As reported by [20] 50g of the various sheapaste were put in a thimble and extracted with 200ml of hexane for 6hours using soxhlet apparatus. Chloroform was added after extraction to dissolve the extracted oil in a round bottom flask. The solvent was evaporated at a temperature of 80-85^{0}C for 1 hour in a rotary evaporator.

$$\% \text{ oil content} = W\frac{Volume\ of\ oil}{weight\ of\ shea\ paste} \times 100 \quad \ldots\ldots\ldots\ldots (2)$$

Specific gravity

The sample was homogenized and 40ml of it was poured into the clean 500ml measuring cylinder, air bubbles were avoided during pouring. The temperature was controlled to avoid drifting in the temperature value. Hydrometer was lowered gently into the cylinder and care was taken to prevent the hydrometer from leaning on the wall of the cylinder. The reading was taken when the hydrometer had rested [21].

Melting Point ^{o}C

This was determined in triplicates using Fisher – John melting apparatus. A little smear of the frozen oil was made on the heating plate of the instrument and covered with the observation lens. The apparatus was switched on and the temperatures at which the oil began to melt and melted were observed and recorded [22].

Determination of chemical properties

Iodine Value

Apparatus and reagents used include carborn tetrachloride, potassium iodide, sodium thiosulphate, oil sample, starch indicator, burette, conical flasks, beaker and pipette. According to Pearson (1999), 0.25g of the oil sample was dissolved in the 20ml carbon tetrachloride in 100ml volumetric capacity flask. The Wiji's solution was added to the content of the flask. It was stoppered and allowed to stand for two hours in darkness at room temperature. 20ml of the potassium iodide solution was added and the mixture was titrated against sodium thiosulphate solution using the starch indicator. The same procedure was repeated for the blank. Iodine value was calculated.

$$\text{Iodine value} = \frac{12.69\ N\ (V2-V1)}{W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

N = Normality of thiosulphate
V1= Volume of thiosulphate used in the test
V2 = Volume of thiosulphate used in the blank
W = Weight of sample

Saponification Value

Apparatus and reagents used include ethanoic potassium hydroxide, phenolphthalein, oil sample burette, conical flasks. According to [22], the flask with its content was refluxed for 30minutes. 2ml of the phenolphthalein indicator was added and the hot soap solution formed was titrated against the hydrochloric acid.

The same procedure was repeated for the blank. The saponification number was calculated

$$\text{Saponification value} = \frac{56.1N\ (V1-V2)}{W} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

N = Normality of hydrochloric acid
V1 = Volume of hydrochloric acid used in the test
V2 = Volume of hydrochloric acid used in the blank
W =Weight of sample

Unsaponifiable Matter Analysis

After saponification, 300ml of the mixed solvent of ethanol (70%), toluene (25%) oil were added to the packed column. It was allowed to run through the column at the rate of 12ml/minute. The column was

washed with 150ml of the solvent mixture at the rate. It was concentrated to 25ml and transferred to the tarred dish for evaporation in oven at 105^{o}C for 15minutes. The dried sample was weighed and titrated for the remaining acids; the weight was corrected for the unsaponifiable matter.

Acid Value

Approximately 0.40g of the oil sample was dissolved in the 5.0ml in 1:1 mixture of ethanol diethyl either in100ml volumetric capacity flask. The mixer was homogenized and allowed to stay on the bench until the indicator was added.

The acid value was calculated as in equation 5

$$\text{Acid Value} = \frac{56.1 \times N \times V}{W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

N = Normality of sodium hydroxide
V = Volume of sodium hydroxide used in the test
W = Weight of sample

Sensory evaluation of shea butter

The shea butter samples were evaluated by a panel of 20 persons. They consisted of males and females drawn from the staff and students of the Federal college of freshwater Fisheries Technology, New Bussa Nigeria and few others from outside. The samples were melted, cooled and poured into transparent plastic sample bottles and served. The panelists assessed the shea butter oil samples on a 9-point hedonic scale (9-1) for taste, colour, mouthfeel, aroma and overall acceptability. They rinsed their mouths after evaluation of each sample.

Results and discussions

Moisture and Lipid Content of Sheanuts

The effect of heat treatment method on moisture and lipid content of parboiled, boiled, fried and toasted shea paste or powder are as shown on Table 1. There are significant differences ($p \leq 0.05$) among the samples. The more the moisture content, the lower the fat content of the paste and this agrees with [23] that oil content of oil seeds decreases with increase in moisture content. Sheanuts for oil processing should be adequately dried to very low moisture content before oil extraction.

Legend

PSP = Parboiled sheanuts sheapaste
FSP = Fried sheanuts sheapaste
BSP = Boiled sheanuts sheapaste
TSP = Toasted sheanut sheapaste
±: Standard Deviation

The values are means and standard deviation (SD) of triplicate analysis Values with different letters in a column are not significantly different ($p \leq 0.05$).

Shea butter yield

Effect of heat treatment method on % shea butter yield is as shown on Table 2. Shea butter yield (%) from hand – churned shea paste were 20.29 ± 0.88 for parboiled sheanuts; 40.80 ± 0.84, for fried sheanuts; 34.82 ± 0.42 for toasted sheanuts and 22.97 ± 0.31; 22.90±1.6 for boiled sheanuts respectively. There are great variations and significant differences ($p \leq 0.05$) in the percentage oil yield. Methods of heat treatment therefore are factors that affect percentage shea butter yield. The maximum oil yield of 40.80 ± 0.84% was recorded at 3.62 ± 0.13% moisture content of fried sheanuts shea paste. Frying of sheanuts reduced the moisture content and thus favoured the extraction of

shea butter. At higher moisture content, the cell mucilage swells and produces a cushion effect on the seed or paste during oil extraction which impedes the flow of oil during extraction. Thus on wet basis extraction there is reduction of oil yield.

The difference between the 20% yield of traditionally processed shea butter among the natives and that obtained in this work from hand - churned fried sheanuts paste could be due to the reduced frying time (30 minutes) and temperature (85 ± 5^0C) used to fry the sheanuts. From a survey conducted by [24] the local women fry sheanuts for over two hours at temperatures above 180^oC. The percentage yield of shea butter from fried and toasted sheanuts using the modified traditional method are improvement on the 27.2% and 24% yield reported by [25] for traditional and screw pressed extraction methods of shea butter from sheanuts toasted at 180^oC and the 30 % yield obtained by [13]. [14] reported 30% shea butter yield by manual extraction while [26] reported a shea oil yield of 34 to 29% at a beater speed of 85 to 115 rpm.

The higher percentage yield of shea butter from fried and toasted sheanuts (Table 2) indicates that oil yield increases with increase in temperature and decrease in moisture content of sheanuts. Frying of oilseeds aids moisture loss; breaks down oil cell walls, coagulate proteins and reduces oil viscosity, thus promoting easy flow of oil. However, extensive heat treatment can lead to production of non – volatile oxidized derivatives [27]. Shea butter yield from boiled sheanut was low though its butter was more attractive in colour than others. [17] reported variations in shea kernels oil yield content in different shea districts of Uganda and attributed these variations to environmental influence, geographical location, agronomic practices and genetic variations.

In this study the different heat treatments methods of sheanuts are also factors that affect shea oil yield. Early fruit shea trees in higher elevation and cool temperature are also associated with higher shea oil content [17]. [19] noted that new shea nuts give more viscous and higher shea butter yield than the older nuts.

Legend

PSP = Parboiled sheanuts sheapaste
FSP = Fried sheanuts sheapaste
BSP = Boiled sheanuts sheapaste
TSP = Toasted sheanut sheapaste
±: Standard Deviation
The values are means and standard deviation (SD) of triplicate analysis Values with different letters in a column are not significantly different ($p \leq 0.05$).

Legend

A –Manual (hand churned) extraction of shea butter method.
±: standard deviation
The values are mean and standard deviation (SD) of triplicate analysis
Means with same letters on a row are not significantly different at $p \geq 0.05$

Sensory quality and acceptability of shea butter

Table 3 shows the effect of heat treatment methods on sensory scores and acceptability of shea butter. Acceptable shea butters having overall acceptability scores of (7.05± 1.05, 7.10± 1.12, 7.15± 1.18 and 7.65± 1.14) on a 9 – point hedonic scale were manually extracted from the fried, toasted, boiled and parboiled sheanuts. There were significant differences ($p \leq 0.05$) with respect to overall acceptability. Shea butter from boiled sheanuts had was preferred to others. The colour of shea butter from the different heat - treated samples varied. This is because parboilng, frying, toasting and boiling heat treatments affect the colouring pigment of shea buter differently.

Over heating of sheanuts as in the native processing method leads to a grey coloured product with decreased acceptability. None of the samples had an objectionable or rancid odour. Apart from shea butter from fried sheanuts, there were no significant differences ($p \geq 0.05$) in the aroma of the shea butter samples produced.

Though shea butter has been consumed as a vegetable fat for thousands of years in Africa there is a wide variability in shea butter qualities due to the numerous and uncontrolled traditional techniques [11,12]. [28] reported that blanching of sheanuts improved shea butter sensory qualities. In order to improve the quality of shea butter, several countries in Africa such as Burkina Faso, Coted' Ivoire, Mali and Senegal have tried to establish standards for traditonal processing of shea butter [29].

Legend

A. Manually extracted fried sheanuts shea butter
B. Manually extracted toasted sheanuts shea butter
C. Manually extracted parboiled sheanuts shea butter (control)
D. Manually extracted boiled sheanuts shea butter ±: standard deviation
The values are mean and standard deviation (SD) of triplicate analysis Values with similar letter on a column are not significantly different ($p \geq 0.05$).

Effect of heating and extraction methods on physical and chemical properties of shea butter

Specific Gravity

The method of heating sheanuts (frying, toasting, boiling and parboiling) did not significantly ($p \geq 0.05$) affect the specific gravity of shea butter as shown on Table 4. The specific gravities of shea butter samples were less than that of water ($1g/cm^3$) and were within the range of 0.91± 0.00 to 0.91± $0.03g/cm^3$. Specific gravity is the ratio of the density of a substance compared to the density (mass of the same unit volume) of a reference substance or the ratio of weight of a given volume of liquid to pure water($1g/cm^3$). Unsaturation of fatty acids or increase in chain length of fatty acid residues tends to increase specific gravity [30]. The specific gravity of shea butter samples examined in this study were within the range of 0.90 to $0.91g/cm^3$ as reported by [25], higher than the 0.84±0.01g/cm3 reported by [31] and lower than the $0.92g/cm^3$ reported by [32]. [18] reported a decrease in specific gravity of shea butter from 0.917 to 0.870 as the temperature of dry extraction increased from 50 to 110^0C. This is attributable to increase in viscosity and volume as the temperature increases.

Melting points

Heat treatment method of sheanuts influenced the melting point of the shea butter examined in this study. The mean melting point of the various shea butter samples examined ranged from from 42.33±6.21for parboiled sheanuts shea butter to 51.33 ± 1.53^oC for fried sheanuts shea butter. They differed significantly ($p \leq 0.05$) from each other. The differences could be due to alterations in the fatty acid composition and profile during the various heat treatment methods. The melting point of shea butter is the temperature at which it changes state from solid to liquid at atmospheric pressure and it is also called liquifaction point. Like most fats, shea butter gradually softens over a range of temperature on heating and do not therefore have sharp melting points but a range of values. The mean melting point examined in this work (Table 4) agrees with some of the observation of [25].

Table 1. Effect of heat treatment method on moisture and lipid contents of sheanut paste before oil extraction

Sample	Moisture content (%)	lipid (%)
PSB	13.10 ± 0.17^{d}	46.67 ± 1.20^{d}
BSP	7.10 ± 0.19^{c}	50.60 ± 1.01^{c}
FSP	3.62 ± 0.13^{a}	64.12 ± 0.13^{a}
TSP	5.36 ± 0.15^{b}	59.27 ± 0.07^{b}

Table 2. Effect of heating and extraction methods on percentage yield of shea butter

	Parboiling(%)	Frying(%)	Toasting(%)	Boiling(%)
A.	20.29 ± 0.88^{d}	40.80 ± 0.84^{a}	34.82 ± 0.42^{b}	22.97 ± 0.31^{c}

Table 3. Effects of heat treatment methods on the sensory scores and acceptability of manually extracted shea butter

Samples	Colour	Mouth feel	Taste	Aroma	Over acceptability
A.	6.80 ± 1.44^{bc}	6.65 ± 1.42^{bc}	6.80 ± 1.40^{ab}	6.65 ± 1.31^{bc}	7.05 ± 1.05^{bc}
B.	6.80 ± 1.20^{bc}	6.75 ± 1.29^{abc}	6.80 ± 1.24^{ab}	7.15 ± 1.31^{abc}	7.10 ± 1.18^{abc}
C.	6.60 ± 1.50^{c}	6.85 ± 1.35^{abc}	6.90 ± 1.21^{ab}	7.12 ± 1.23^{abc}	7.15 ± 1.18^{abc}
D.	6.70 ± 1.26^{c}	6.50 ± 1.73^{bc}	7.00 ± 1.26^{ab}	7.60 ± 1.10^{ab}	7.65 ± 0.93^{ab}

Table 4. Effects of heating and extraction methods on some physical and chemical properties of sheabuter

Samples	Moisture%	Specificgravity g/cm^3	Mean Melting point (^{o}C)	Iodine No mgI^2/100g fat	Unsaponifiable matter (%)	Acid Value mgOH/100g	Saponification value (mgKOH/g)
A	4.54 ± 0.04^{d}	0.91 ± 0.03^{ab}	48.68 ± 2.08^{c}	51.28 ± 0.21^{g}	2.82 ± 0.02^{c}	4.72 ± 0.08^{a}	191.52 ± 0.20^{d}
B	4.77 ± 0.03^{e}	0.91 ± 0.00^{ab}	42.33 ± 6.21^{b}	49.15 ± 0.05^{de}	2.80 ± 0.02^{cd}	5.10 ± 0.01^{d}	194.75 ± 0.14^{g}
C	4.96 ± 0.05^{f}	0.91 ± 0.00^{ab}	51.16 ± 0.07^{c}	49.29 ± 0.32^{c}	2.92 ± 0.02^{b}	5.01 ± 0.01^{cd}	192.69 ± 0.03^{f}
D	4.35 ± 0.02^{c}	0.91 ± 0.00^{ab}	51.33 ± 1.53^{c}	49.32 ± 0.33^{f}	2.84 ± 0.02^{d}	4.89 ± 0.01^{b}	197.14 ± 0.05^{i}
N	2.13 ± 0.19^{a}	0.91 ± 0.00^{ab}	39.66 ± 2.52^{b}	51.83 ± 0.21^{h}	3.02 ± 0.02^{a}	5.30 ± 0.10^{f}	199.38 ± 0.16^{j}
K	2.90 ± 0.04^{bc}	0.91 ± 0.00^{b}	27.50 ± 0.71^{a}	40.75 ± 0.05^{a}	1.02 ± 0.01^{f}	5.25 ± 0.05^{f}	188.71 ± 0.28

Mean melting points of shea butter from fried and boiled sheanuts are within the range for n-hexane solvent extracted shea butter reported by [32] but higher than the 35 – 38^{o}C reported by [18] and the 33.0 ± 01 to 35.9 ± 0.50^{o}C range reported by [33] for shea butter from Cote d'Ivoire. [30] reported that melting point of fats are often influenced by the type and quality of triglycerides in it. Since the shea butter samples are from same raw sheanuts, the observed differences are attributable to the effect of heat treatment methods.

Moisture content

The moisture content of the shea butter samples ranged from 2.13 ± 0.09 to 4.96 ± 0.25%. The fried sheanuts butter has the lowest moisture values. The moisture content, though less than 5% differed significantly ($p \leq 0.05$) as shown on Table 4. Moisture content is the quantity of water in a food material and it is an index of food stability during storage. The values from this work are lower than the 14.5 ± 0.01% reported by [33] for grey coloured shea butter marketed in Cote d'Ivoire and the 10% moisture content reported by [32].Some of the moisture contents of shea butter in this work are within the range of 3.36 ± 0.02 to 8.36 ± 0.02 reported for beige and yellow shea butter and are higher than the 0.15 ± 0.01% for optimized shea butter [33].They are higher than 0.56 to 0.10% moisture content reported by [18] for shea butter extracted using dry extraction method. The differences in moisture content could be due to processing treatments, variety of sheanuts, method of extraction and analysis. Adequate dehydration through heat treatment of foods decreases moisture content and low moisture content is indication of good quality. Fats and oils with high moisture are susceptible to recontamination and rancidity and fat and oils of lower moisture content have longer shelf life [34].

Saponification value(mg KOH/gfat)

As shown on Table 4, saponification values of the shea butter samples ranged from approximately 191.52 to 197.14 (mg KOH/g fat) for sheanuts from toasted and fried sheanuts. Native shea butter has the highest value of 199 (mg/KOH/g fat) and the commercial vegetable oil has the lowest number of 188.71 (mg/KOH/g fat). Low molecular weight fatty acids are known to have higher saponification number [30]. Heat treatment and extraction method can cleaved some long fatty acids to lower molecular weight fatty acid differently and thus may affect saponification number of fats and oils. Saponification value also known as the Koettstorfer number is the amount of potassium hydroxide (mg) needed to neutralize the acids in an oil sample and saponify the esters in 1gram of a lipid [30]. It is thus the number of milligram of KOH required to saponify 1gram of a given ester and the value helps to determine the acid and saponifiable esters contained in 1g of lipid.

Most of the saponification value of shea butter examined in this work are within the range of 189 – 195 (mg/KOH/g fat) reported for soybean oil by [35]. [17] noted a saponification number of 193 mgKOH/g for soya beans oil. The saponification values from this work are higher than the 185.20mg KOH/g fat reported by [32], lower than the 220 (mg KOH/g fat) by [10].[33] reported that the saponification values for optimized beige coloured, market yellow and yellow coloured sheabutter were 196.01 ± 0.15, 197.13 ± 0.05 and 168.80 ± 1.10 mg/KOH/g fat respectively. [18] observed that extraction temperatures affected the saponification values of shea oils recovered through dry process. The authors reported saponification values of 261.3, 258.1, 244.7 and 237.7 mgKOH/g fat for shea butter samples extracted at 50, 70, 90,and 110^{0}C respectively showing that the temperature at which sheanuts are heated affects the saponification number. The higher the saponification number of oil, the higher the lauric acid content of the oil which is an indicator of suitability in soap making [36].

The saponification values of 160 -192 mgKOH/g fat of n-hexane extracted shea butter by [17] shows that there are great variations in the saponifcation values of shea butter. Thus the methods of seed heat treatment and extraction among other factors affect the saponification numbers of shea butter. The mechanism and reasons may not be easy to explain but different ways of sheanuts heat treatment and extraction could alter some physical, chemical and structural compositions of sheanuts during processing. The saponification value of samples examined in this work are within the acceptable range for edible fat/oils stated by the Regional Technical Committee comments on Draft African Regional Standards for unrefined shea butter [37].

Unsaponifiable matter (%)

The unsaponifiable matter of the shea butter samples are as shown on Table 4. Heat treatment methods significantly ($p \leq 0.05$) affected the unsaponifiable matter which ranged from 2.65 ± 0.02 to 3.02 ± 0.02. The values from this work varied from those reported by [16, 25 ,33, 38 and 10] respectively.[14] reported unsaponifiable matter of 10.07 and 10.00 for hexane and manually extracted shea butter from boiled sheanuts and 10.03 and 9.92 for sun dried sheanuts. These values are higher than the unsaponifiable matter of the shea butter samples obtained from this study.

Unsaponifiable matter (%) is the non - soap forming unit or the fraction of the substance of an oil or fat which is not saponified by NaOH but dissolves in ordinary fat solvent. It is the wax mixture that fails to form soap when blended with lye. The unsaponifiable values of shea butters from this work are lower than the 5.68% reported by [32]. Most of the antioxidants constituents of crude fats and oils are present as unsaponifiable component. [39]) noted that unsaponifiables are concentrate in the liquid portion of shea butter and are rich in cinnamic acids, esters of triterpene alcohols and sterols and these components make shea butter ideal in the formulation of sunscreen emollient. Shea butter unsaponifiables are thus promising active components for new functional cosmetics. The authors also reported that the triterpene alcohol of shea butter is rich in butyrosperol, lupeol and alpha and beta amyrin while [38] noted that α- amyrin (57.26 – 64. 37%) with anti- inflammatory property is a major unsaponifiable matter. The differences in the unsaponifiable values could be due to the processing and analysis.

Iodine value

Iodine value is an expression of the level of unsaturation of fats/ oils. It determines the stability of oils to oxidation and is the number of grams of iodine compound absorbed by 100g of fat [30]. The higher the iodine value, the greater the unsaturation/liquidity and the more its susceptibility to oxidation. The native sheabutter has the highest iodine value (51.83±0.21mgI_2/100g) followed by the shea butter from toasted sheanuts (51.28±0.21mgI_2/100g) and this shows that native shea butter due its prolonged processing temperature and time would be more prone to oxidation. Generally, heating and extraction methods significantly ($p \leq 0.05$) affected the iodine value of the shea butters which ranged from 47.80± 0.01 to 51.83± 0.21(g$I/1_2$00g fat) as shown on Table 4.

The iodine values of the shea butter samples are however higher than the values reported by [10, 33, 17] and lower than the 62 (mgI_2/100g) noted [14]; 52-66 mgI_2/100g mgI_2/100g by [40]. [18] reported iodine values of 85.4, 83.3 81.7 and 78.8 mgI_2/100g for shea butter extracted by dry extraction method at 50. 70, 90 and 110^{0}C respectively thus indicate that iodine number decreases as temperature of extraction increases.[12] reported an iodine number of 86.6 gI^2/100g for a parboiled sheanuts butter and 63.3 g I^2/100g fat for a sun dried one. It thus appears that parboiling of sheanuts increases the iodine number.This is not in agreement with findings of this study. Iodine values of parboiled sheanut shea butter was 49.15±0.05 mgI_2/100g. [30] reported that linolenic acid, an 18 carbon fatty acid with three bonds has higher iodine number than oleic acid, another 18 carbon fatty acids with a double bond. All these variations in iodine value show that there is no fixed iodine value for shea butter. The soil fertility, geographical location, type of fatty acids, degree of unsaturation, variety of sheanut, heat treatment methods affect iodine values of shea butter. The moderate iodine value of shea butter is an indiction of the presence of saturated fatty acid which ensures stability against oxidation and rancidity.

Acid value

Acid values of shea butters from toasted, parboiled, boiled and fried sheanuts (4.72± 0.08, 5.10± 0.01, 5.01± 0.01 and 4.89± 0.01 mgOH/100g) Acid value is an index of hydrolytic rancidity and contribute to the development of off flavours and off odours in fats and oils. Acid value corresponds to the amount of potassium hydroxide needed to neutralize a free fatty acid [30].The acid values obtained from this work are higher than the 2.30± 0.66 mgOH/100g reported by [17]and lower than the 12.59 ± 0.17 mgOH/100g reported by [31].The acid values are close to the range of 5.12 ± 0.59 and 5.52 ± 0.30 mgOH/100g) of n- hexane and manually extracted shea butter from parboiled sheanuts but lower than the higher values of 10.28 mgOH/100g and 10.58 mgOH/100g) for manually and hexane extracted shea butter from sun dried sheanuts reported by [14] but greater than 1.79 mgOH/100g reported by [32]. Acid values are naturally low in fresh nuts and increases rapidly through hydrolysis under poor storage due to the activities of of lipolytic enzymes and microorganisms. Sun drying of raw sheanuts could allow the enzymes to release more free fatty acids while parboiling or boiling kills or halts the seed growth enymes which hydrolyse triglycerides and reduces the moisture content thus prevent microbial activities.

The acid value of a fat/oil is half of its free fatty acid (FFA) and FFA of fat/oil and increases as the age of sheanuts increases if poorly stored or due to germination of sheanuts before processing [17].The lower the acid value of an oil, the fewer free fatty acid it contains which makes it less prone to rancidity and vice versa. Free fatty acid is a carboxylic acid with long aliphatic tail which could be saturated or unsaturated. The calculated free fatty acid values of shea butter samples examined in this work are within the range of 1 to 20% reported by [17]. [17] also reported that acid value of shea butter from various district of Uganda vary. Low acid values of fats and oils are an indication of high quality.

Prolonged fermentation of shea fruits before processing or inadequate blanching as well as extracting the oil from sprouted seeds could result to higher acid value of shea butter. The acid value of fresh nuts are naturally low but increases rapidly under poor storage conditions. Boiling of sheanuts for an hour shortly after collection and subsequent sun or solar drying to reduce post handling mould infestation and lower free ftty acids was recommended by [28].

There are similarities between the work of [14] and the present study. Both works noted differences in physical and chemical properties of shea butter extracted from differently treated sheanuts and extraction methods. The physical and

chemical properties of edible oils influence their suitability for use in food and other process industries as reported by [16].

Conclusion

Hand-churning manual method of extraction was used to extract shea butter from fried, toasted, boiled and parboiled sheanuts. Methods of pre-extraction heat treatment of sheanuts affected the yield, properties and acceptability of shea butter. Frying of sheanuts before oil extraction increased the oil yield than other heat treatment methods during extraction and shea butter from boiled sheanuts had the highest acceptability.

Legend

A = hand – churned shea butter from toasted sheanuts
B = hand – churned shea butter from parboiled sheanuts
C = Hand – churned shea butter from boiled sheanuts
D = Hand – churned shea butter from fried sheanuts
N = Native shea butter
K = Commercial vegetable oil (Kings)
±: Standard deviation
Values are mean and standard deviation of triplicate analysis.
Values with same letter within a column are not significantly different at P ≥0.05

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