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Preliminary Study of Process Route for Quality Improvement of Traditionally Produced Shea Butter in Nigeria to Meet Export Requirements

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ABSTRACT: This preliminary study investigates the various routes for the production of improved quality shea butter to meet export requirements (African Standard for Unrefined Shea Butter) ARSUSB. Fresh shea fruit were collected, de-pulped, boiled and dried using three methods viz-a vis; sun drying, traditional oven drying and manually operated rotary drying (MORD). The fresh shea nuts were subjected to boiling times of 0, 15, 30, 45 and 60 minutes. The drying stage was preceded by cooking, milling, kneading and curd boiling to obtain shea oil. Physicochemical properties of the shea oil for example, yield, iodine value, free fatty acid, peroxide value, percentage impurities, refractive index, moisture content, absorbance, saponification value and unsaponifiable fractions were determined. The results for each of the treatment methods i.e for sun drying,(yield, 20-37%), (density, 0.894-0.980g/cm3), (iodine value, 23-34.6g/100g), (free fatty acid, 3.99-6.91%), (peroxide value, 2.42-5.20mEq/100g),(impurity,1.0-2.00%), (refractive index,1.465-1.468), (saponification value, 178.12-293mgKOH/g), (unsaponifiable fractions, 5.07-9.31g/kg), for traditional oven drying, (yield, 21-42%), (density, 0.896-0.991g/cm3), (iodine value,26.6-40.43g/100g), (free fatty acid,4.62-7.51%), (peroxide value, 2.99-4.95mEq/100g), (impurity,0.69-2.0%), (refractive index,1.465-1.469), (saponification value,173.4-287.4mgKOH/g), (unsaponifiable fraction 4.78-9.2g/kg), and for manually operated rotary dryer, (yield,25-32%), (density, 0.898-0.988g/cm3), (iodine value, 22.01-46.020g/100g), (free fatty acid, 3.05-7.32%), (peroxide value,2.99-5.82mEq/100g), (impurity, 1.05-2.00%),(refractive index,1.4650-1.469), (saponification value,154.1-268.5mgKOH/g), (unsaponifiable fractions, 1.15-8.72g/kg). The results of parameters obtained refractive index (1.465-1.468), density (0.896 g/cm^3-0.991g/cm^3) and moisture content (0.211-1.264) are comparable with ARSUSB, however some other parameters for example saponification value 178.12 mgKOH/g -293mgKOH/g), free fatty acid, (4.62%-7.51%), Iodine value (26.6 g/100g - 40.43g/100g), and peroxide value (2.42 mEq/100g -5.20mEq/100g), were found to be at variance with ARSUSB. The percentage impurity (1.05%-2.00%), was found to be high as compared to ARSUSB of percentage impurity figure of 0.09% - 0.2% necessitating further treatment for good industrial application like biodiesel production.

Key words: shea nut, physicochemical, bioactive, tocopherols, refining

INTRODUCTION

Shea butter is a fatty extract obtained from the kernel of shea fruit. It is also a mixture of fatty acids consisting of oleic, stearic, palmitic, linoleic and arachidic acids but oleic and stearic acids predominate and constitute about 85% of the fatty acid content of shea butter (Lovett, 2004). The nuts are obtained from shea tree which are native of Africa and are either called *Vitellaria paradoxa or Butyrospernum parkii* or simply *V. paradoxa* in West Africa or *"nilotica"* in East Africa. Examples of countries where shea trees are found include Senegal, Mali, Ivory Coast, Burkina Faso, Togo, Ghana, Benin, Niger, Nigeria, Cameroon and further east in Uganda, Sudan and Ethiopia (Walter *et al.,* 2003).

Lovett (2004) estimated that 50%-60% of shea trees in West Africa are domiciled in Nigeria. These trees are concentrated in North Central states of Niger, Kwara, Nassarawa, Plateau, Kaduna and some parts of Kebbi, Bauchi, Kogi, FCT and Oyo States (Munir *et al.*,2012) . The tree starts flowering/ fruiting in January and harvest begins between May to June through to august. After the harvest, the pulp is removed, the kernels are dried, the shell is removed and the Shea nuts processed for Shea butter. In Nigeria, all these processes are

done by children and rural women with little or no formal training and hence produce shea butter with attendant low yield, poor quality and inconsistent properties. These limitations are capable of limiting the export potentials of the shea butter because the quality of the shea butter produced does not meet international standards (Williams and Isemede, 2015).

As a result of poor and uncontrolled processing methods, Shea kernels generally undergo hydrolytic and oxidative degradations and are also affected by aflatoxin and other harmful micro-organisms during the post- harvest processing and storage (Esiegbuya *et al.,* 2014). These results in shea butter characterized by high level of iodine number, high percentage of free fatty acid, peroxide value, microbes, and other solid and dissolved impurities. Traditional processing techniques involve numerous uncontrolled and non-scientific practices. These factors lead to low yield, poor and inconsistent quality of shea butter from this method of production and consequently affect the export potentials of Shea butter from Africa and Nigeria in particular (Loveth , 2004; Njoku, 2006; Megananou *et al.,* 2012 and Obibuzor *et al.,* 2014).

Demand for shea butter produced in West Africa has increased by over 1200 % in the last ten years. In 2012, an estimated 350, 000 metric tons of kernels were exported from Africa with a market value of approximately US$120 million (William and Isemede, 2015). In the past 10 years, demand for shea products has grown in both the European Union and the United States of America. The net worth of this demand is about $10 billion and is projected to be worth $30 billion by the year 2020 (William and Isemede, 2015).

Nigeria particularly and other west African countries must key in to this global demand of shea butter by producing good and consistent quality shea butter. The country need to support its diversification efforts in renewable energy plans and biodiesel production. Since shea nut is indigenous to Africa and prices of crude oil are not only declining but the crude oil itself is non-renewable.

Therefore, the focus of this work is to carry out a preliminary study of process routes for the production of shea butter with improved quality to meet export requirements, by investigating the effects of shea nut boiling time, drying methods and cooking/roasting temperature on the yield and quality of shea butter.

MATERIALS AND METHODS

Freshly de-pulped shea nut were collected from Sonmajigi (N09º 11′ 56″; E05º 35′ 45″), Pati- Ndeji (N09º 23′ 38″; E06º 36′ 25″), and Chengudu (N09º 07′ 40″; E05º 32′ 34″) villages in Lavun, Gbako and Edati local government areas of Niger State, Nigeria respectively. The nuts obtained from these locations were mixed and sprouted ones were discarded. From the remaining nuts, 500 kg was weighed using Diamond weighing balance (made in China) and subsequently divided into five groups of 100 kg each. Each group was boiled in water (50 litres) at 95 ºC for 0, 15, 30, 45 and 60 minutes respectively using aluminium pot. Each of the boiled nuts was further divided into three and respectively sun dried for 14 days, oven dried for 3 days and rotary dried for 10 hours on wire mesh bed, traditional oven and manually fabricated rotary dryer respectively. The shell of the dried nuts was then removed to obtain fresh kernel. The fresh kernels were exposed to sunlight to further reduce the moisture content to between 7-8 %. 5 kg of each of the dried kernels from the three methods of drying was respectively subjected to 30 ^{0}C (room temperature, no cooking) and 100 ^{0}C boiling point of water. The cooked kernels were severally milled using 1.5 kW atlas milling machine (made in China) to obtain a fine homogeneous paste. The paste obtained was then kneaded with occasional addition of cold water as kneading progresses to facilitate the separation of the curd with the sludge. The curd which floats on the water was carefully collected and boiled at between 85 ^{0}C and 90 ^{0}C over water for 50 minutes. The oil collected was again washed with water, kept for about 6hrs to separate and the clean oil was collected and allowed to congeal, packaged, refrigerated and then analysed in Central Laboratory, National Cereals Research Institute (NCRI) Badeggi, Nigeria.

Characterisation

The effects of shea nut boiling time, kernel cooking temperature and drying methods on the

physicochemical properties (density, yield, iodine value, free fatty acid, peroxide value, melting point impurities, refractive index, moisture content, absorbance, saponification value and unsaponifiable fractions) on shea butter were determined using AOAC (1990) and (ASAE, 1998).

RESULTS AND DISCUSSION

The shea butter obtained from each of the kernels was analysed for the following parameters: yield, density, iodine value, free fatty acid, peroxide value, melting point, refractive index, absorbance, saponification value, unsaponifiable fraction and acid value and compared with the standard (ARSUSB, 2011).

For both the cooked and the uncooked kernels, the yield fell within the range of 20%-42%, with sun dried, uncooked kernel and village/controlled sample recording the lowest yield (20%) while oven dried, uncooked, 0 min and 15 min boiled ones having the highest yield (42%) as can be seen in Figure 1.

The high yield recorded for the OD sample probably explains why in the study area, this method of drying is the most practiced and even in the shea kernel markets its price is higher than the sun dried ones. The method may introduce high Polycyclic Aromatic Hydrocarbon (PAHs) into the shea butter (Lovett, 2004). Also, the effect of high temperature cooking (100 ^{o}C) and no cooking (room temperature) at all for all the treatment methods (drying methods) of the kernel, showed an inconsistent yield. This may be due to uncontrolled processing variable, especially picking period and cooking temperatures.

The density showed similar trend with the yield of shea butter obtained (Figure 2). Even though for all the treatments here, except for ODC, all samples boiled for 45 minutes and 60 minutes had higher density compared to other members of the group boiled for shorter times.

This may be due to longer heating time which may have led to higher absorption of moisture translating into more interaction between the oil molecules and moisture. With these differences the values of densities obtained for all the shea butter samples boiled above 45 minutes have densities higher than the ARSUSB of 0.89 to 0.93 g/cm^3. It was also observed that samples not boiled at all also have densities above this range. This implies that boiling may not have direct influence on the density of shea butter.

The melting point of all the shea butter samples fell within 28 – 40^{0}C, with ODC nut recording the lowest melting point of 28^{0}C and nut village/controlled samples under RDC had the highest melting point of 40^{0}C. It should be noted that these values are in agreement with ARSUSB values of 30^{0}C -40^{0}C, except for some few samples that have melting point of 28^{0}C and 29^{0}C as shown in Figure 3.

This also shows that there is little or no adulteration in the shea butter samples produced and that heat treatment method has little or no effect on the melting point of shea better. Melting point determination is also one of the methods of determining purity levels in shea butter.

Free fatty acid (FFA) is a very important parameter in characterising shea butter internationally. Shea butter with low free fatty acid attracts higher premium in international markets. Figure 4 shows the distribution of free fatty acid in all the shea butter samples.

Shea nut samples boiled for 15 minutes, RDC had FFA of 7.51% and then closely followed by village/controlled sample ODC with FFA of 7.32%. These two figures are very high when compared with recommended range of 1-3% (ARSUSB, 2011). These high values may be due to the quantity of heat the kernels were exposed to before extraction and possibly the length of time the shea pastes were exposed before kneading (Harris, 1999).

The higher the peroxide value in oil, the higher or faster the oil gets oxidised and hence rancid. The values obtained from the samples showed that shea kernel boiled for 60 minutes especially RDC and SDC had higher peroxide value of 5.21 mEq/100g and 5.2 mEq/100g respectively, even though these values are lower than ARSUSB 10.0 mEq/100g – 15.0 mEq/100g suggesting that longer boiling

times does not favour production of good quality shea butter. This is shown in Figure 5.
The longer the nuts were boiled in water, the more moisture it absorbed and the longer it took to dry, this led to the formation of higher levels of peroxides and subsequently rancidity (Miraliakbari, 2007).

In this preliminary study, the highest impurity levels were observed from village/controlled samples 1.88%-2.00%) while all other treatments fell below 1.63%. This is shown in Figure 6.

Figure 6 shows the impurity level of all the shea butter samples produced. Generally, the impurity levels were higher than the recommended standard of 0.09 - 0.2%. To obtain a purer shea butter, the levels of impurity must be reduced by either filtration, adsorption or refining.

The refractive index of the shea butter samples produced fell between 1.4650-1.4689. This range is closely related with ARSUSB standard of 1.4620-1.4650.

Figure 7 shows that the treatment method had no significant influence on the refractive index of shea butter produced as all the values obtained were very close to the standard the standard (1.4620-1.4650).

The iodine value for the shea butter sample produced ranged from 23 g/100g - 47 g/100g. The values obtained were mostly lower than the ARSUSB (30 g/100g -75g/100g). This shows that the shea butter samples produced had fewer double bonds or are more saturated. The iodine value for oil is supposed to be constant at any given condition, if production parameters are controlled. The result obtained as shown in Figure 8, shows that either of boiling time or drying method have influence on iodine value. The need to regulate and optimize the parameters being studied is necessary.

For the shea butter samples produced, the saponification value fell between 154 mgKOH/g and 293 mgKOH/g as shown in Figure 9. RDC nut 0 mins boiling had the lowest saponification value (154 mgKOH/g) and SDC nut had the highest saponification value (293 mgKOH/g). These values obtained are slightly at variance with ARSUSB (170 mgKOH/g -190 mgKOH/g). The seemingly high saponification value shows that the mean weight of fatty acids present is higher than those obtained by Okullo *et al*., 2010; Obibuzor *et al*., 2014 and Tame, *et al*., 2015. This also means that more potassium hydroxide may be required to produce soap from these samples with higher saponification value.

The unsaponifiable fractions of shea butter even though small compared to the triglyceride component of shea butter is responsible for the healing properties of shea butter (Nahm, 2011). They dissolve in fat and are insoluble in aqueous solution but soluble in organic solvent after saponification as reported by Hamilton and Rosell, (1986). Figure 10 shows the variations of unsaponifiable fractions of the various shea butter samples produced in relation to the standard.

This property of shea butter depends on the sample species but it can be influenced by processing method. The unsaponifiable fraction for all the samples produced varied from 0.53-9.31%. These figures fell within the recommended range of 0-12% (Lovett, 2004). Figure 10 reveals that shea nut samples RDC and boiled for 60, 45, 15 and 0 minutes had very low unsaponifiable fraction showing that the healing index for these sample is low.

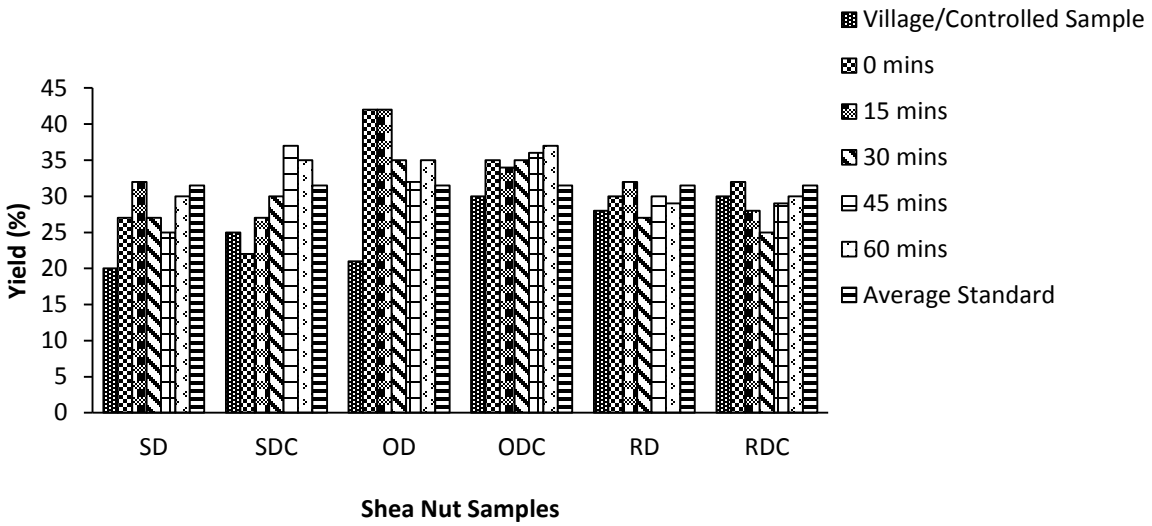

Figure 1: Yield (%) of Shea butter from different shea nut samples at varying boiling times

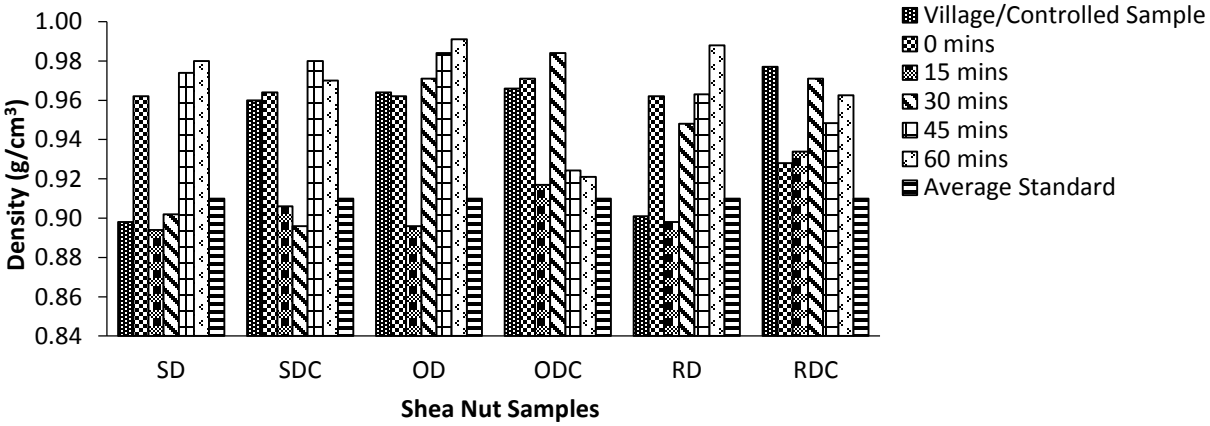

Figure 2: Density (g/cm^3) of Shea butter from different shea nut samples at varying boiling times

SD = Sundried uncooked; SDC = Sundried Cooked; OD = Oven dried uncooked;
ODC = Oven dried Cooked; RD = Rotary dried uncooked; RDC = Rotary dried Cooked

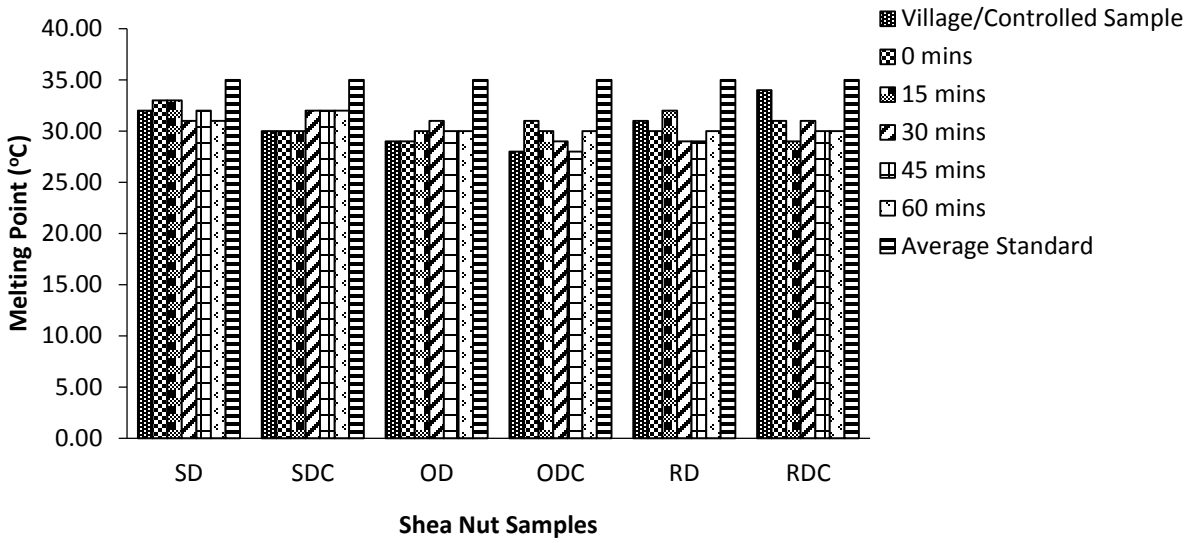

Figure 3: Melting Point (°C) of Shea butter from different shea nut samples at varying boiling times

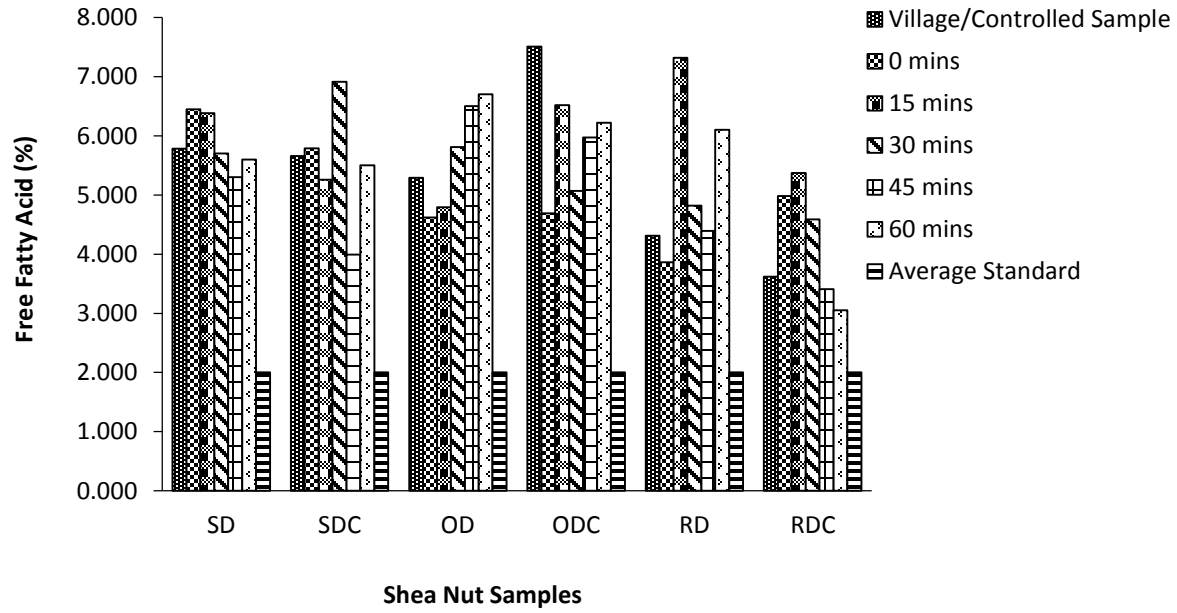

Figure 4: Free Fatty Acid (%) of Shea butter from different shea nut samples at varying boiling time

SD = Sundried uncooked; SDC = Sundried Cooked; OD = Oven dried uncooked;
ODC = Oven dried Cooked; RD = Rotary dried uncooked; RDC = Rotary dried Cooked

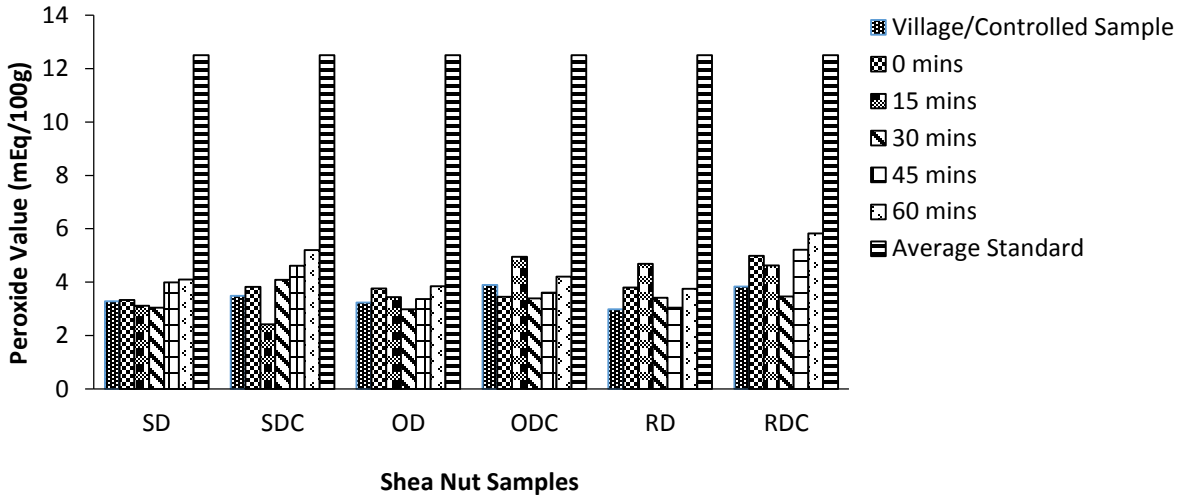

Figure 5: Peroxide Value (mEq/100g) of Shea butter from different shea nut samples at varying boiling times

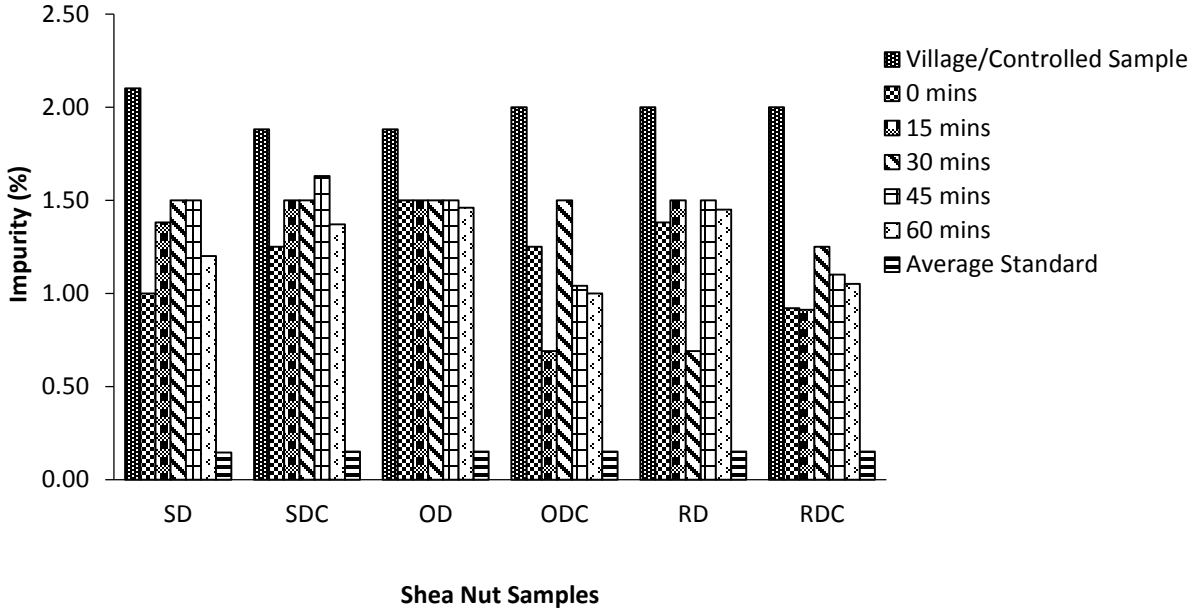

Figure 6: Impurity (%) of Shea butter from different shea nut samples at varying boiling times

SD = Sundried uncooked; SDC = Sundried Cooked; OD = Oven dried uncooked;
ODC = Oven dried Cooked; RD = Rotary dried uncooked; RDC = Rotary dried Cooked

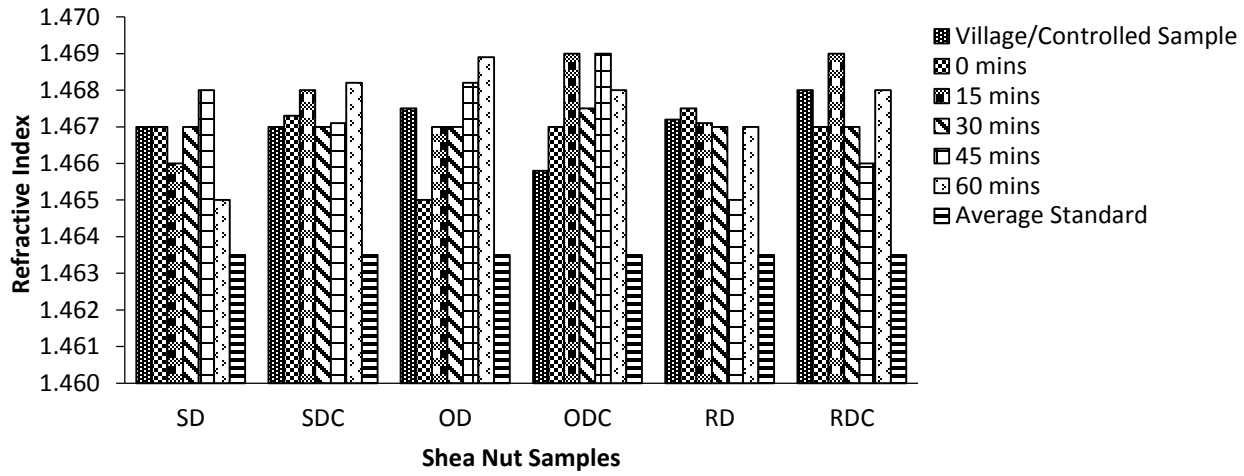

Figure 7: Refractive Index of Shea butter from different shea nut samples at varying boiling times

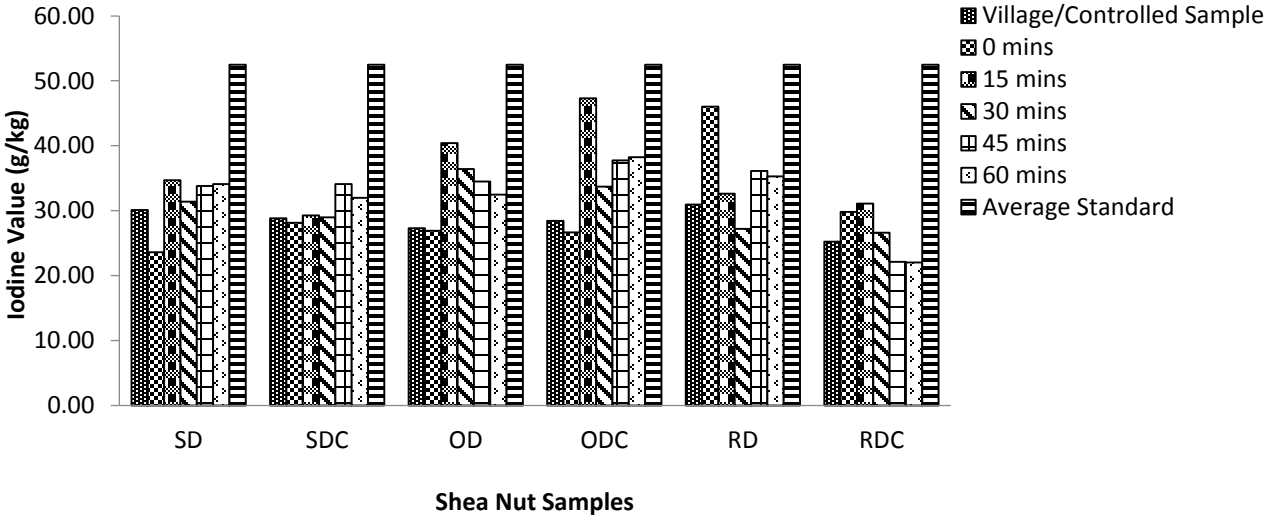

Figure 8: Iodine value (g/kg) of Shea butter from different shea nut samples at varying boiling times

SD = Sundried uncooked; SDC = Sundried Cooked; OD = Oven dried uncooked;
ODC = Oven dried Cooked; RD = Rotary dried uncooked; RDC = Rotary dried Cooked

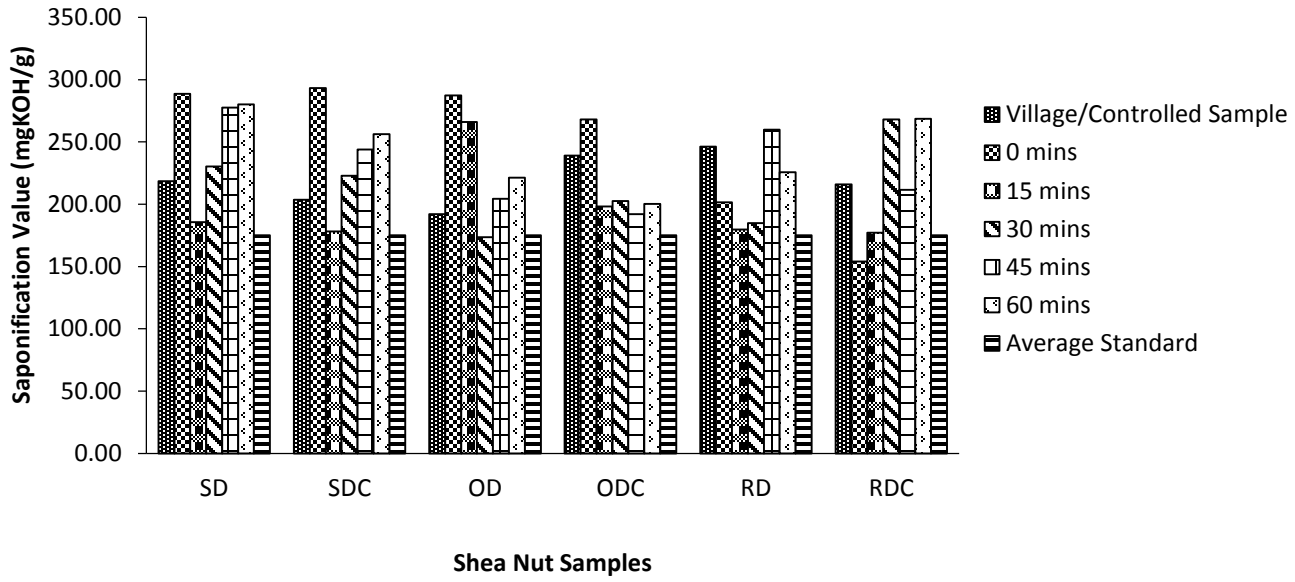

Figure 9: Saponification value (mgKOH/g) of Shea butter from different shea nut samples at varying boiling times

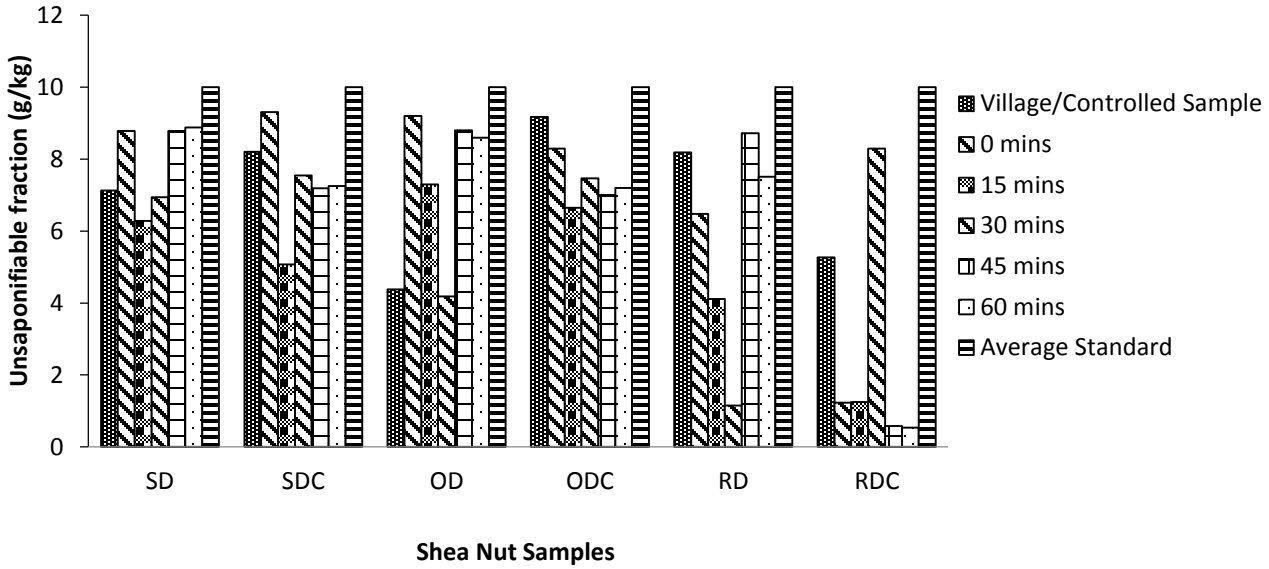

Figure 10: Unsaponifiable Fraction (g/kg) of Shea butter from different shea nut samples at varying boiling times

SD = Sundried uncooked; SDC = Sundried Cooked; OD = Oven dried uncooked;
ODC = Oven dried Cooked; RD = Rotary dried uncooked; RDC = Rotary dried Cooked

CONCLUSION

The results show some consistency in the physical properties like refractive index, density, moisture content. However, properties like saponification value, free fatty acid, iodine value and peroxide value are not consistent. The preliminary study also brings to fore the need to carefully investigate also the effects of shea nut picking period and more cooking temperatures.

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