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Morpho-chemical divergence and fatty acid profile of shea tree seeds (*Vitellaria paradoxa*) collected from different locations in Kwara State, Nigeria

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Abstract – The present study characterizes seed-related traits, phytochemical, physiochemical parameters and fatty acid profile of shea (*Vitellaria paradoxa*) seeds collected from the Kosubosu, Fufu and Sare areas of Kwara State, Nigeria to determine the effects of microclimate on seed morphology, biochemical and oil constituents. Seed morphological data were analyzed for variability. Seed oil was extracted for phytochemical constituents, physicochemical properties, and fatty acid profiling by gas chromatography equipped with mass spectrometry (GC/MS). Results showed intra and inter-locational variations in seed characters. Most fruits had 1–2 seeds. Seeds were predominantly brown and very few were dark brown. Phytochemicals and physicochemical parameters of the seed oil varied with place of collection. Alkaloid, saponin, tannin and phytate contents ranged between 0.79–0.84, 1.20–1.26, 1.48–1.56 and 0.15–0.18 mg g^{-1} respectively. The density of the oil was less than that of water, acid value ranged from 10.58–13.56 mg KOH g^{-1} and iodine values were between 36.63 to 40.32 g I_2 $(100\ g)^{-1}$. Saponification values lie between 160.39 and 184.14 mg KOH g^{-1}; and free fatty acid was within 5.32–6.81 %. Peroxide, α-tocopherol, total phenol and oxalate values as well as viscosity of the oil also varied; however, refractive index was similar. Ethyl oleate and octadecanoic acids were present and most abundance in all the locations, while glycidol stearate was only found in Fufu samples with three other fatty acids. Five fatty acids were present in Kosubosu, while Sare had only two. The results obtained in the present study indicate that shea oil could be used for medicinal, nutritional and industrial purposes. Since seed characters, phytochemical, physicochemical and fatty acid compositions varied with the microclimate, environmental and micro-ecological conditions should be considered when collecting seeds for oil utilization.

Keywords: fatty acids, phytochemical analysis, physicochemical parameters, shea butter, *Vitellaria paradoxa*

Introduction

Vitellaria paradoxa Gaertn. F., commonly known as the shea tree is a tree of the Sapotaceae family indigenous to Sub-Sahara Africa where it grows in the wild and has huge economic and ecological potentials (Ademola et al. 2012). The tree occurs in West African and is popular among the local dwellers for its numerous social and economic utilizations (Kobomoje et al. 2013). The shea tree grows wild across a wide belt of savanna including West African countries of Senegal, Mali, Cote d' Ivoire, Burkina Faso, Togo, Ghana, Benin, Nigeria, Niger and Cameroon. The tree is also found further to the east, in Uganda, Sudan and Ethiopia (Maranz et al. 2004, Goreja 2004, Masters et al. 2010). Among these countries, Ghana and Burkina Faso are the main Shea net exporters (Walter et al. 2003). In Nigeria, the shea tree is known as "Emi" among the Yoruba people of the western part. The shea grows up to 9–12 m in height with profuse branches. Commercial fruiting quantity usually commences at approximately 20 years and the tree can continuously produce shea fruit for many more years (Alander 2004). Late maturity of the tree has been the bane of its commercial plantation and shea butter related industries depend on nuts collected from scattered, naturally growing shea trees. In Nigeria, the

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shea is found in the Guinea savanna with high tree concentrations in Niger, Kwara, Kebbi and Kaduna states (Warra 2011). Shea trees blossom between February to March, and the fruit matures and falls in May-June. The fruit is ellipitic, yellow green or light green, about 5–8 cm in circumference and similar to the fig (Chalfin 2004). The fruit has a butter-like, mucous pericarp covering an oval brown or light brown seed surrounded by a fragile shining shell with a large hilum on a broad base (Olaniyan et al. 2007). Usually, a shea fruit contains one seed but occasionally has two to three oil-rich nuts (Alander 2004).

The shea tree has the potential to improve nutrition, boost healthcare, reduce rural poverty and support sustainable land care (Moore, 2008). The fruit pulpy pericarp can be eaten while the nut is discarded or crushed for shea butter extraction. The fat obtained from the shea nut known as shea butter (Ori: Yoruba; Nigeria), which contains 40–60% oil, is the most valued product from the shea tree (Warra and Komo, 2014). Shea butter is used for local domestic purposes such as cooking, lightning, soap making, skin moisturizer and cosmetics as well as traditional medicine among the local population where the tree grows in abundance in Nigeria. Also, it is used to treat wounds, suppress inflammation, relieve rheumatic and joint pains and other health conditions (Kraft and Lynde 2005, Soro et al. 2011, Warra and Komo 2014). The potential of shea oil to protect the skin from damaging ultra violet rays was demonstrated by Velasco et al. (2008). On a global scale, the importance of the shea tree is related to the usefulness of its seed fat in food and cosmetic industries. Decolourised shea butter could be used as a cheaper alternative to cocoa butter due to their similar physical and chemical properties (Lipp et al. 2001, Alander 2004). The high levels of unsaponifiable matter in shea nut oil compared to other vegetable fats could be exploited for the development of more shea butter products (Rogers and Lenick 2009). Shea oil finds applications in traditional and social rituals such as marriages, funerals, coronations and rainmaking (Ferris et al. 2004, Gwali et al. 2011, Hall et al. 1996, Moore 2008). Also, high grade charcoal and furniture are made from the wood while the latex yields a considerable amount of glue (Lovett and Haq 2000). Consequently, the shea tree could generate significant incomes for the rural households.

However, despite the enormous economic and healthcare potentials, shea butter and its products are underutilised in Nigeria and only little information is available on the seed variability. In particular, not much work has been done on locational variation of seed characters in relation to the nut phytochemicals and fatty acid characterization of seeds from different locations. The present work was carried out to characterize seed related traits, quantify phytochemical constituents of the nut and profile the fatty acids of the shea seed collected from different locations in Kwara State, Nigeria. This study hopes to identify existing variations in the shea seeds from different locations using seed and oil characteristics to throw more light on how microclimate affects seed morphology and chemical constituents in shea tree.

Materials and methods

Fruit and seed collection

Vitellaria paradoxa fruits were collected from three locations in Kwara State, Nigeria, because of the abundance of shea trees, the folkloric processing and utilization of shea butter for socio-economic purposes. Kwara State is located in the Southern Guinea savanna belt of Nigeria, which is dominated by grasses interspersed mainly with tree species such as *Daniellia oliveri*, *Vitellaria paradoxa*, *Prosopis africana* and *Parkia biglobosa*. The state is within the coordinates 8°30'0.00"N and 4°32'32"E and at an elevation of 303 m above sea level (NGIA, 2016). The names and coordinates of the three locations from where shea fruits and seeds are collected are shown in Table 1. The soil was mainly sandy, lateritic or ferralitic, mean annual rainfall is 640–1350 mm. Usually, the rainy season lasts from May to October and dry season from November to April. Relative humidity is 75–80% in the wet season and about 65% during the dry season (Ajadi et al. 2011). The average monthly temperature is 31.4–33.5 °C, but fluctuates between 33 and 34 °C from November to January and 34–35 °C (February to April) (Ilorin Atlas, 1982; NIMET, 2016).

Tab. 1. Names, local division, coordinates and elevations of the locations from where shea fruits and seeds were collected for the study in Kwara State of Nigeria.

Location name	Local government area	Coordinates	Altitude (m)
Kosubosu	Baruten	9°35'N, 3°15'E	273-364
Fufu	Ilorin West	8°30'N, 4°32'E	300-310
Sare	Ifelodun	9°40'N, 3°22'E	370-418

Fruit and seed morphological studies

Ten mature fruit bearing trees were selected at each location (Kosubosu, Fufu and Sare) from May to July, 2016. Each location has five sites from which two fruiting trees were selected. Thirty ripe fruits were randomly plucked from each tree for characterization. Epicarp thickness and seed diameter were determined using an electronic vernier calliper (ATD-8656). Number of seed per fruit, seed dimension and seed coat colour were also recorded; the mean values of ten readings were used for the seed characters.

Shea nuts oil extraction

The pulpy pericarp of the fruits were removed, the seeds cleaned and sun dried for two weeks. The dried seeds were deshelled, the kernels were ground and kept in airtight containers prior to oil extraction. Oil extraction was carried out in Soxhlet apparatus using n-hexane as solvent. 50 g of the ground material was transferred to a 30 mm × 200 mm cellulose thimble placed in the extraction chamber of a 250 mL Soxhlet apparatus fitted with a condenser on a 500-mL distillation flask containing 250 mL of n-hexane solvent. Shea nut oil was extracted under reflux with n-hexane following

the procedure described by Ali et al. (2015). After extraction, hexane was removed by using a heated rotary evaporator (Stuart, England), under vacuum conditions to recover the oil. Extractions of oil from seeds of different locations were performed in triplicate, and the mean values were reported. Oil yield was expressed as percentage weight of oil obtained relative to the weight of shea butter used for extraction according to Warra et al. (2011).

Phytochemical and physicochemical properties determination

Methanolic extracts of the shea nut were screened for presence or otherwise of bioactive compounds using standard procedures (Sofowora 1993, Kokate 1999, Kumaran and Karunakaran 2006). The amount of tannin was estimated using the method described by Hagerman et al. (2000), saponin, and alkaloid present in the shea nut extract were determined according to procedure of Obadoni and Ochuko (2001). Total phenol, oxalate and phytate contents in the extract were quantified according to the methods of Yadav et al. (2011) and Falana et al. (2016), while the amount of α-tocopherol was determined by the standard procedure of he Association of Official Analytical Chemists (2010).

Iodine values (IV) of the shea oil were estimated using the method of Gafar et al. (2012). The value was calculated from fatty acid methyl ester compositions of oil. Saponification value was calculated from fatty acid methyl ester compositions of oil using the equation of Kalayasiri et al. (1996). Determination of the acid value, which is the amount of carboxylic acid groups in the oil, was carried out based on a titration method using the AOAC (2010) procedure. Viscosity of the shea butter oil was recorded using an Ostwald viscometer (DV-III ultra, UK). The free fatty acid of the oil was estimated by placing 0.2 g of oil into 250 cm^3 Erlenmeyer flask, 100 cm^3 of ethanol was added and followed by 2 cm^3 of phenolphthalein indicator. The mixture was titrated against 0.1 M NaOH till endpoint (slight pink colour that persists for 30seconds), the free fatty acid was calculated according to Chopra and Kanwar (1991). To determine the peroxide value of the oil, 2.0 g of oil was added to 22 cm^3 of a solution containing 12 cm^3 chloroform and 10 cm^3 acetic acid. 0.5 cm^3 saturated potassium iodide was added and allowed to stay with intermittent agitation for 1 minute before 30 cm^3 distilled water was added. The mixture was titrated against 0.1 M of $Na_2S_2O_3$ in the presence of starch indicator until the blue colour had just disappeared. The peroxide value determination was carried out in accordance with Neilson (2003). Refractive index of the oil with reference to air was measured with the Abbe Refractometer (Mettler-Toledo, USA). The specific gravity of the oil relative to water was measured by hydrometer.

Fatty acid profiling

Fatty acid composition of the oil was determined at the Chemical Engineering Laboratory, University of Ilorin, Nigeria by a gas chromatograph equipped with a mass spectrometer (GC/MS; Agilent Technologies; Model: 7890A) with HP column, 30 cm long × 0.32 mm ID × 0.25 μm thickness film (SGE, Australia). The GC is fitted with Hewlett Packard (USA) flame ionization detector (FID) and 99.9% helium was used as carrier gas. The oil triacylglycerides (TG) was converted to fatty acid methyl ester (FAME) to decrease the boiling point. 0.2 mL of biodiesel was added to a 1 mL mixture consisting of hexane and 2-propanol (4/5 volume ratio). Before charging the oil, the samples were purified by filtration using 0.2 μm polytetrafluoroethylene syringe micro filter, then 1 μL of the sample was injected into the GC/MS using a 5 μL micro syringe (SGE, Australia). The gas chromatography condition was continuous flow mode. The inlet temperature was 250 °C while the oven temperature was 250 °C. The injection volume was 1 μL and the split ratio 1:50. The procedure was run for 20 minutes with an average velocity of 37.789 cm s^{-1} at 17.04 psi pressure. On the other hand, the mass spectrometry was run under transfer line temperature of 240 °C, source temperature at 220 °C. The solvent delay was for 2 minutes while the scan mass range was 45–500. Data analysis was conducted with GC/MSD ChemStation Integrator software.

Results

The fruits and seeds of the shea tree collected from three selected local government areas of Kwara State, Nigeria varied in number of seed/fruit, pericarp thickness, seed coat colour and seed dimension as well as phytochemical and fatty acid constituents. Among the 300 shea fruits (30/tree) collected from Kosubosu, Baruten Local Government Area, 265 (88.33%) had 1 seed/fruit, 34 were 2-seeded and only one fruit had 3 seeds (Tab. 2). The average ratios of seeds to fruit were 26.5, 3.4 and 0.1 for 1-seed, 2-seed and 3-seed fruits respectively. In addition, 164 of the seeds had brown seed coats, 112 were light brown while 24 were dark brown. The fruits collected from Fufu (Ilorin West Local Govt Area) are predominantly one seeded. 254 (84.66%) of the fruits were 1-seed, 42 had 2 seeds per fruit and 4 fruits were found with 3 seeds each (Tab. 2). The seed colour distribution showed 129 light brown seeds, 121 brown and 50 dark brown seed coats. Similarly, 1-seed fruits occurred most among the fruits collected from Sare (Ifelodun Local Govt Area). 252 out of the 300 sampled fruits had 1 seed, 2 seeds per fruit were found in 44 and 3 seeds occurred in 5 fruits. Brown seeds were the most frequent (160) followed by light brown (119) and the few (21) dark brown seeds were from Sare samples.

The mean epicarp thickness ranged from 2.77–3.48 mm in fruits collected from Kosubosu (Fig. 1a). Mean seed diameter and circumference ranged between 2.41 to 3.95 cm and 6.44 to 7.46 cm, respectively. Similarly, seed lengths among the Kosubosu seed population were alike. Considering fruit and seed characters, Fufu fruits had mean pericarp thickness between 2.88–3.36 mm (Fig. 1b). The seed diameter and circumference were smaller than those of Kosubosu and ranged between 2.41 and 87 cm and 5.66 and 7.10 cm respectively. The greatest seed length was 4.96 cm while the least was 3.88 cm. Seed diam-

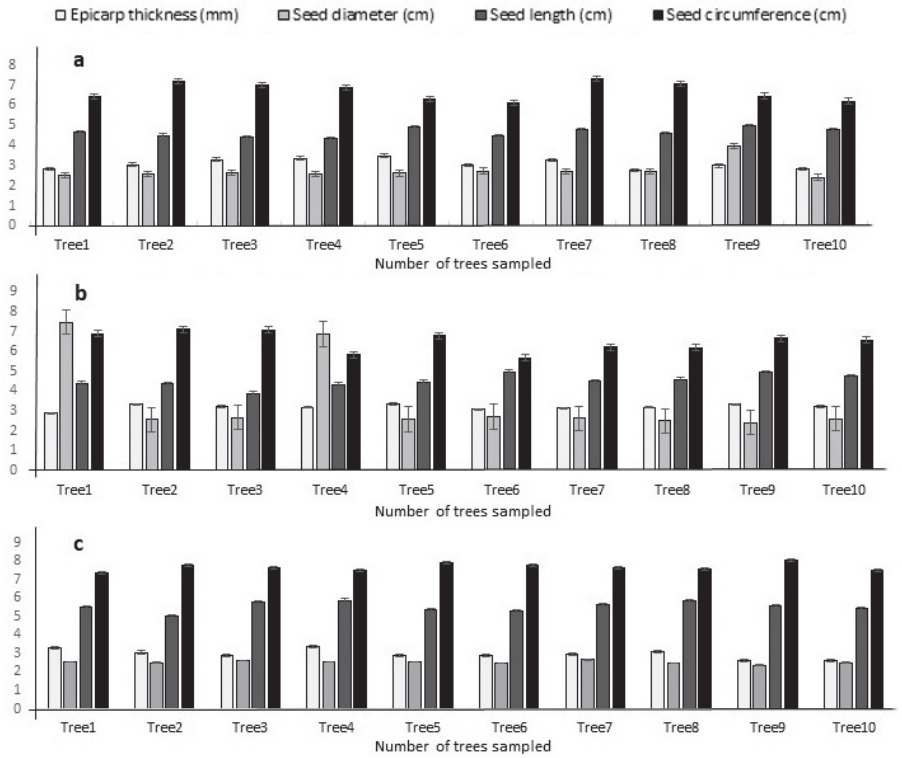

Fig. 1. Morphological seed related characters of shea tree seeds collected from different locations in Kwara State, Nigeria: (a) Kosubosu, Baruten, (b) Fufu, Ilorin West, (c) Sare, Ifelodun.

Tab. 2. Morphological characteristics of shea tree seeds collected from selected locations in three local government areas of Kwara State, Nigeria. TN – number of tree, NFS – number of seeds collected, DB- dark brown, LB- light brown, B – brown.

TN	NFS	Kosubosu						Fufu						Sare					
		No of seed/fruit			Seed colour			No of seed/fruit			Seed colour			No of seed/fruit			Seed colour		
		1	2	3	DB	LB	B	1	2	3	DB	LB	B	1	2	3	DB	LB	B
1	30	29	1	0		13	17	22	7	1	6	13	11	13	16	2	1	13	16
2	30	24	6	0	7	11	12	26	3	1	0	22	8	29	1	0	3	10	17
3	30	30	0	0	3	3	24	28	2	0	0	14	16	28	2	0	3	7	20
4	30	30	0	0	4	9	17	30	0	0	25	4	1	29	0	1	4	9	17
5	30	30	0	0	0	15	15	23	7	0	3	10	17	25	5	0	0	14	16
6	30	14	15	1	10	5	15	26	4	0	1	4	25	28	2	0	3	8	19
7	30	29	1	0	0	21	9	28	2	0	0	19	11	21	8	1	1	21	8
8	30	28	2	0	0	19	11	24	5	1	4	18	8	26	3	1	2	18	10
9	30	22	8	0	0	3	27	28	2	0	7	14	9	23	7	0	0	8	22
10	30	29	1	0	0	13	17	19	10	1	4	11	15	30	0	0	4	11	15
Σ	300	265	34	1	24	112	164	254	42	4	50	129	121	252	44	5	21	119	160
mean	30	26.5	3.4	0.1	2.4	11.2	16.4	25.4	4.2	0.4	5.0	12.9	12.1	25.2	4.4	0.5	2.1	11.9	16.0

eter and circumference were similar for the fruits collected from 10 different trees in Sare, but pericarp thickness and seed length varied (Fig. 1c). The fruits and seeds are smaller than those of Kosubosu and Fufu areas. The average pericarp thickness, seed diameter and length were between 2.61 and 3.37 mm, 2.47 and 2.66 cm, 5.02 and 5.82 cm respectively, however, seed circumference varied from 7.02–7.70 cm.

The phytochemical compositions of the shea nut are presented in Table 3. Highest phytate, tannin, total phenol and alkaloids were found in nuts from Kosubosu which invariably had the least amount of α-tocopherol. The order of the amount of α-tocopherol in the samples was Sare>Fufu>Kosubosu while saponin content was highest (1.26 mg g^{-1}) in samples from Sare, followed by Kosubosu (1.21 mg g^{-1}) and the least (1.20 mg g^{-1}) in Fufu. In contrast, Fufu samples produced the highest amount of oxalate (0.82 mg g^{-1}) as against 0.80 mg g^{-1} from Kosubosu and 0.78 mg g^{-1} obtained from Sare samples.

Tab. 3. Phytochemical composition of shea butter from different locations in Kwara State, Nigeria.

Phytochemical constituent	Location		
	Kosubosu	Fufu	Sare
Phytate (mg g^{-1})	0.18	0.15	0.16
Tannins (mg g^{-1})	1.56	1.50	1.48
Oxalate (mg g^{-1})	0.80	0.82	0.78
Total phenol (mg g^{-1})	0.52	0.50	0.49
α-Tocopherol (mg g^{-1})	26.38	28.60	34.42
Alkaloid (mg g^{-1})	0.84	0.79	0.80
Saponin (mg g^{-1})	1.21	1.20	1.26

Percentage oil yield of the shea nut was highest (53.06%) for Kosubosu, followed by Sare (49.26%) and the least in Fufu (47.31%) (Tab. 4). The specific gravity and refractive index of the oil from the different locations were similar, but the least acid value, iodine value and free fatty acid were recorded for Kosubosu samples. Saponification value was higher (184.14 mg KOH g^{-1}) in the Sare sample than in the Kosubosu (182.15 mg KOH g^{-1}) but a much lower value was obtained for Fufu (160.39 mg KOH g^{-1}) which invariably had the highest viscosity. Furthermore, the order of peroxide values in the shea oil was Kosubosu>Sare>Fufu (Tab. 4).

Table 5 shows the retention time, types and percentage composition of the fatty acids present in shea nut oils. Five fatty acids were found in Kosubosu samples, four in Fufu and only two in Sare. 2-hydroxyl-1(hydroxymethyl) ethyl ester with percentage compositions of 38.89 and 47.43% was the most abundant fatty acid in Kosubosu and Fufu samples respectively; it was however not found in Sare samples. Ethyl oleate constituted 59.96% of the total fatty acids in the Sare sample and octadecanoic acid accounted for 40.04%. While ethyl oleate and octadecanoic acids were common to all the locations, hexadecanoic acid was present in a trace amount (1.36%) only in Kosubosu.

Discussion

Analysis of seed/fruit revealed that fruits from different locations are predominantly one-seeded, a few had 2 seeds per fruit, and 3 seeds per fruit are rare. Although, shea fruit is a berry, occurrence of more than two seeds in a fruit is a rare phenomenon. The higher frequency of one-seeded fruit in Kosubosu than in other locations may be due to environmental and/or edaphic variations. This observation aligned with the seed number variation among fruits from the same tree as reported by Abbiw (1990) and Djekota et al. (2014) who claimed that 2–3 seeds were found in some shea

Tab. 4. Oil yield and physicochemical parameters of extracted shea butter oil from different locations of Kwara State, Nigeria.

Physicochemical property	Location		
	Kosubosu	Fufu	Sare
Oil yield (%)	54.60±2.71	46.35±2.18	49.25±2.63
Specific Gravity (g cm^{-3})	0.90±0.01	0.90±0.01	0.90±0.01
Acid value (mg KOH g^{-1})	10.58±0.70	13.56±0.94	13.16±0.91
Iodine value (g I_2 (100 g)$^{-1}$)	36.63±2.67	40.32±3.52	39.28±2.91
Free fatty acid (% oleic acid)	5.32±0.49	6.81±0.53	6.60±0.56
Reflective index	1.46±0.09	1.46±0.09	1.46±0.09
Saponification value (mg KOH g^{-1})	182.15±3.18	160.39±2.90	184.14±3.14
Peroxide value (mEq kg^{-1})	5.20±0.07	4.10±0.08	4.82±0.04
Viscosity	2.60±0.02	2.70±0.01	2.61±0.02

Tab. 5. Chemical composition of the extracted shea nut oil from different locations in Kwara State, Nigeria.

Location	Compound name	Retention time (min)	% composition
Kosubosu	Hexadecanoic acid, ethyl ester	33.175	1.36
	Ethyl oleate	36.267	20.89
	Octadecanoic acid, ethyl ester	36.768	15.78
	2-hydroxyl-1(hydroxymethyl) ethyl ester	41.262	38.80
	2-hydroxyl-1,3-propanediyl ester	41.685	23.18
Fufu	Ethyl oleate	36.267	7.21
	Octadecanoic acid ethyl ester	36.768	4.25
	2-hydroxyl-1(hydroxymethyl) ethyl ester	44.306	47.43
	Glycidol stearate	41.729	41.13
Sare	Ethyl oleate	36.278	59.96
	Octadecanoic acid ethyl ester	36.796	40.04

fruits collected from different locations of Mondoul in the Chad Republic. Fruit and seed morphological parameters such as pericarp thickness, petiole length, seed dimensions were used to partition populations of shea tree (Djekota et al. 2014). Seed coat colours were mainly in three categories (dark brown, light brown and brown), but while light brown and brown seeds occurred frequently, only very few seeds had dark brown coat for fruits obtained from same tree in a location. Variation in seed colour observed in the present study matched previous findings on shea nut seed coat (Nafan et al. 2007, Lamien et al. 2007). Since seed formation involves meiosis, coat colouration in this case is most likely genetic and can be caused by mutation or recombination of genes. Also, these variations can be explained by natural and/or human selection and gene flow mediated from genetic drift (Tremblay et al. 2010, Abasse et al. 2011). Differences recorded in quantitative seed characters intra and inter-locational in the present study concurred with the findings on *Tamarindus indica* (Soloviev et al. 2004). Furthermore, significant intra and inter-locality variations have been demonstrated in shea tree and seed characters (Mbaiguinam et al. 2007, Gwali et al. 2011).

The phytochemical constituents varied with locations, the variations could be accounted for by environmental stress, rainfall regimes and soil characteristics as opined by Sanou et al. (2005). Amount of phytochemicals were less than those obtained by Falana et al. (2016) who worked on *V. paradoxa* collected from Onipako village, Ilorin and this could be due to locational differences. The presence of similar phytochemicals has been reported in other tropical plants in Nigeria and some of them exhibit varying biological activities (Sofowora 1993, Onwuliri 2004).

The oil yield varied with locations, and the higher amount of oil obtained from the Kosubosu seeds could be explained by the same factors that account for the morphological and biochemical compositions. The yield of the oil from the study locations were in accordance to the values earlier reported (Warra and Komo 2014). The present study revealed that in terms of oil yield, Kosubosu samples are the best. Physicochemical parameters are of great importance in determination of oil quality. Pure oils have marked ranges of specific gravity and refractive index; thus the degree of variation of typical oil from its true values may indicate its relative purity. The specific gravity of the extracted shea nut oil was less than 1.0 g cm^{-3}, which implies the oil is less dense than water. The specific gravity of 0.902 g cm^{-3} obtained in this study correlates with the 0.90 g cm^{-3} documented by Raimi et al. (2014) and is congruent with those of *Persea macrophylla* (0.89 g cm^{-3}) and *Persea gratesima* (0.90 g cm^{-3}) (Akubugwo et al. 2008). Furthermore, the refractive index (1.468), which was the same for the locations, was also the same as the value reported by Raimi et al. (2014) and similar to *Anacandium occidentlis* oil (1.458) (Akinhanmi et al. 2008) and walnut kernel oil (1.534) (Ozcan et al. 2010). The iodine value of the oil suggests it is a typical nondrying oil containing saturated and a low level of unsaturated fatty acid. Hence, the oil may be utilized for vegetable oil-based ice cream manufacturing, but, the non-drying nature of the oil makes it not applicable for paint and varnish production. Shea oil from Fufu has low saponification value compared with the other two locations. The range of saponification indicates that the oil may be useful in making soap and shampoo (Ugbogu et al. 2013). Low acid value of the shea nut oil although higher than value reported by Raimi et al. (2014) was far less than of *Livistona. chinensis* (Nwosu et al. 2012) and this signify it could be used as an edible oil. The free fatty acid which is also an indicator of oil edibility was low and close to the range reported by Ugbogu et al. (2013). This suggests a low level of hydrolytic and lipolytic activities in the oil, thus, the extracted oil could be used as raw materials for industries (Obasi et al. 2012).

Analysis of the fatty acid profile of shea nut oil revealed the presence of 6 fatty acids in varying quantities. It is of interest to note that while five fatty acids were found in Kosubosu samples, four were present in Fufu and only two in Sare samples. Ethyl oleate and octadecanoic acids were present in all the samples irrespective of their locations. This result buttresses an earlier report that variation exists in fatty acid composition of same seed oil from different locations (Wara, 2015). Ethyl oleate acid which is the most abundant in the extracted shea nut oil is an unsaturated fatty acid, naturally present in most seed oil and can be used for lotion and pharmaceutical solvents (PubChem, 2014). The variation in chemical constituents and fatty acid composition of the studied samples may be accounted for by environmental variations (Sanou et al. 2005, Mbaiguinam et al. 2007). This explains why 2-hydroxyl,3-propanediyl ester, was only present in Kosubosu samples while glycidol stearate occurred only in Fufu samples. Hexadecanoic acid ethylester (palmitic acid), used mainly for soaps, cosmetics and release agent production, was present only in Kosubosu shea nut oil. Thus, considering the fatty acid composition of the shea nut oil, its industrial and domestic application potentials, locational variation should be taken into consideration in collecting seeds for oil production. The present study revealed that shea tree seeds from Kosubosu had a higher yield in term of quantity and quality of shea nut oil than the other two locations.

Conclusion

The present study showed that morphological variations exist within and among locations in the seed characters of *V. paradoxa* from different areas of Kwara State in Central Nigeria. Also, from the results, shea nut oil phytochemical constituents and physicochemical parameters varied with locations of seed collection. The fatty acid also varied with locations and the presence of vital fatty acids in a large percentage in the oil enhances the potential of shea oil as a candidate oil for industrial revolution and rural economy development. However, in sourcing for shea seed for butter and oil production, locational variations should be taken into consideration as important factors that could affect oil quantity and quality. The present study can be extended to other regions where the

trees are endemic and the molecular approach could be used for a better understanding of the existing variability among the shea tree and nut populations.

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