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Evaluation of the physicochemical properties of Northern Ghana *Sclerocarya birrea* seed oil and proximate analysis of the process waste

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Physicochemical properties and proximate composition of *Sclerocarya birrea* was studied by n-hexane extraction of its oil. The oil contents of raw and roasted kernel were determined to be 46.4 and 44.1% respectively, and their specific gravity to be 0.88 and 0.91 with acid values of 4.20 and 2.52, respectively. Saponification values were also calculated to be 12.48 and 11.36 in raw and roasted kernel respectively. Regarding the proximate compositions of the raw seed powder and its residue, moisture contents of 4.17 and 4.00%, respectively, were calculated. Respective fibre, fat, and carbohydrate contents were also determined. Of interest were the high lipid contents of 57.25 and 26.50%, respectively. This suggests that the oil from marula seeds can be extracted commercially. Also, the high protein content indicates that both the raw powder and its residue can contribute to the nutritional needs of the local population.

Key words: *Sclerocarya birrea*, physicochemical properties, proximate analysis, nutrient, oil.

INTRODUCTION

The *Sclerocarya birrea* tree, known as marula tree, is indigenous to most parts of the Northern regions of Ghana and often referred to as the “tree of life” due to its ability to provide two fundamental human needs; that is, food and medicine. The marula tree is taxonomically derived from the Anacardiaceae plant family to which belong the mango, cashew and pistachio nut, and it is an indigenous, fruit- bearing tree of sub-Saharan Africa at low altitudes and can reach up to 20 m in height and 1.2 m in diameter (Russo et al., 2013).

The marula tree has gained attention in numerous chemical, biological and environmental investigations since 1906 and has been identified as one of five fruit tree species that should be integrated in the domestication process in African farming system (Russo et al., 2013), for its usage as source of food and medicine and its potential to increase income in rural communities. The barks, leaves and roots of *S. birrea*

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Figure 1. *Sclerocarya birrea* fruit.

Figure 2. Raw powdered seed kernel.

have been traditionally used to treat some human ailments such as dysentery, fevers, malaria, diarrhea, stomach problems, rheumatism, sore eyes, infertility, headaches, toothache and body pains. Extractions from parts of this plant have been reported to possess antioxidant, antibacterial, antifungal, astringent, anticonvulsant,antihyperglycaemic, anti-inflammatory and antiatherogenic properties (Russo et al., 2013). Several of these properties could be attributed to the high content of polyphenols and its antioxidant activity. Unsaturated lipids in foods generally results in deterioration in flavour, colour as well as lower nutritional value. The antioxidant properties of the extractions from marula tree can be used in a case like this to control oxidation of the unsaturated lipids in foods.

Marula oil has a clear, pale, yellowish-brown colour and a pleasant nutty aroma. The oil is classified as medium rich and is silky to the touch with an excellent slip factor making it ideal as massage oil. Like many other fixed oils (e.g. baobab seed oil; olive oil), marula oil is rich in monounsaturated fatty acids which makes the oil very stable (Hore, 2004; Mariod et al., 2004; Zimba et al., 2005; Kleiman et al., 2008). The oxidative stability of marula oil is much higher (induction period of 34.2 h) when compared to other fixed oils such as olive oil (4.6 h), sunflower oil (1.9 h), palmolein oil (8.5) and cottonseed oil (3.1 h) (Glew et al., 2004). Marula oil is contains saturated fatty acids palmitic (9.0 - 12.0%) and stearic (5.0 - 8.0%) and unsaturated fatty, such as oleic acid (70.0 - 78.0%), α linoleic (0.1 - 0.7%) and arachidonic acid (0.3 - 0.7%) (Glew et al., 2004). The oil is particularly rich in oleic acid and can be considered an excellent source of natural oleic acid. A study conducted by Ogbobe (1992) revealed that the oil was rich in stearic and palmitic acids (50.8 and 22.6%) respectively. Mariod et al. (2004) investigated the composition of selected Sudanese oils and found that the marula oil contains tocopherols, sterols, procyanidine and gallotannin in addition to saturated and unsaturated fatty acids. Marula oil is similar to olive oil in terms of the high content of oleic acid. Therefore it can be used as starting material for the production of pomade equivalents that can be used in the food and cosmetic industries (Zimba et al., 2005).

It is a worldwide trend to explore wild oil plants to augment the existing sources of oil. The evaluation of marula nut oil as a potential oil source had to be included (Gandure et al., 2013). The marula nut oil is used as a base oil for soap and as nose- drops for infants (Zimba et al., 2005). In some rural areas, it is also used to treat leather and preserve meat, due to its high moisturizing capacity (Mariod et al., 2004). Moreover, it was found that the seed kernel of marula had high nutritional value which could serve as supplement to diet when mixed with vegetable or meat (Shone, 1979). The utilization of marula fruits can help to improve the economic growth of individuals and people living around where it is grown for the oil is listed as a possible ingredient in cosmetic and personal care application (Hein et al., 2009).

However, the marula fruits found in the Northern regions of Ghana are not being utilized effectively and most of marula fruits are consumed by livestocks and birds.

In the present study, the evaluation of selected physicochemical properties, proximate composition and nutritional value of marula seed oil was performed, which would help to identify its potential uses.

MATERIALS AND METHODS

Sample collection and preparation

Ripened fresh fruits (Figure 1) were collected from marula trees grown at “Bonia” village in the Upper East Region of Ghana and around the University for Development Studies, Navrongo Campus which were the study areas. Five trees were randomly selected and the fruits were collected from different branches of the trees. The juice, peels and the seeds were separated by squeezing ripened fruits. The seeds were air dried and the kernel was removed manually using sizable stone, pulverized to fine powder (Figure 2) using pestle and mortar. The powdered kernel was stored in a closed glass container to be used for various analyses. Liquid-liquid extraction method was used to establish actual oil yield levels of the selected wild fruit nuts. The

Figure 3. Raw sample of marula oil.

Figure 4. Roasted sample of marula oil.

Figure 5. Raw seed residue of *S. birrea* kernel.

process involved hard seed cracking of nuts to remove oil seeds, grinding, maceration, filtration and distillation.

Oil extraction

Marula fruit oil was extracted from the ground seed kernel using n-hexane in a mass to volume ratio of 1:3. The solvent for the extraction was evaporated under the influence of direct sunlight after decantation leaving the extracted oil. Figures 3 and 4 show the sample oils obtained from the raw and the roasted kernel. The solid residue of the raw sample left after extraction (Figure 5) was used for proximate analysis and the roasted sample was discarded.

Physicochemical properties of the oil

The selected physicochemical properties, that is, specific gravity, pH, refractive index, acid value, peroxide value, saponification value and iodine value of the *S. birrea* seed oil were determined using the methods specified in the Official Methods of Analysis of Association of Official Analytic Chemistry (AOAC) International, 19th Edition. However, colour and odour of the oil were determined using visual observation and sense of smell.

Proximate analysis of *S. birrea* raw seed kernel (nuts)

The moisture, ash, fat, fibre, crude protein and carbohydrate contents of the raw seed kernel (cake) after the oil extraction were determined using the methods describe in Official Methods of Analysis of AOAC International, 19th Edition.

RESULTS AND DISCUSSION

The physicochemical properties of crude oil extracted from the raw and roasted seed of *S. birrea* were shown in Table 1.

The results indicate that the acid value of the raw sample of *S. birrea* seed oil (4.20) which is an index of free fatty acid content due to enzymatic activity in the samples was found to be higher than the minimum acceptable value of 4.0 for Sesame recommended by the Codex Alimentarius Commission for oil seeds (Abayeh et al., 1998) but low in the roasted sample of *S. birrea* seed oil. The saponification values of raw and roasted sample of *S. birrea* seed oil were found to be (12.48 and 11.36) mg KOH/g respectively, having lower saponification value than the range 188 to 199 mg KOH/g suitable for soap making. According to Ezeagu et al. (1998), a saponification value of 200 mg KOH/g indicates high proportion of fatty acids of low molecular weight. Saponification values of virgin marula oil outside the range mentioned does not have a potential for use in soap making industry. Peroxide value is an index of rancidity, thus the high peroxide value of oil indicates a poor resistance of the oil to peroxidation during storage. The peroxide values of both raw and roasted sample birrea seed oil are below the maximum acceptable value of 10 meq KOH/g set by the Codex Alimentarius Commission for groundnut seed oils (Abayeh et al., 1998). The quantity of crude oil in both raw and roasted sample of *S. birrea* seed oil (46.4 and 44.1%) respectively are comparable to the values reported in seeds of linseed 40%, cotton seed 24% and groundnut 46% (Abdullahi et al., 1991). This indicated that *S. birrea* seed oil is good source of oil. The oils were shown to

Table 1. Physicochemical properties of *Sclerocarya birrea* seed oil*.

Parameter	Raw sample of *S. birrea* seed oil (Figure 3)	Roasted sample of *S. birrea* seed oil (Figure 4)
Colour	Light yellow	Brownish
Odour	Nutty aroma	Coconut oil flavor
Oil yield (%)	46.40 ± 0.07	44.10 ± 0.04
Specific gravity	0.88 ± 0.01	0.91 ± 0.01
Refractive index (20°)	1.37 ± 0.01	1.38 ± 0.02
Peroxide value (meq O_2/kg)	1.30 ± 0.02	1.80 ± 0.03
Iodine value (g I_2/100 g)	19.56 ± 0.02	23.88 ± 0.01
Acid value (mg KOH/g)	4.20 ± 0.01	2.52 ± 0.02
Free fatty acid	2.11 ± 0.01	1.27 ± 0.02
pH (at 35.2°C)	4.06 ± 0.01	4.47 ± 0.01
Saponification value (mg KOH/g)	12.48 ± 0.02	11.36 ± 0.01

*The values are average of three replicates.

Table 2. Proximate composition of raw seed kernel of *Sclerocarya birrea* fruit (before and after oil extraction).

Parameter	*S. birrea raw* seed powder	*S. birrea* raw seed residue (After oil extract)
Moisture content (%)	4.17 ± 0.23	4.00 ± 0.47
Fibre content (%)	2.47 ± 0.02	6.77 ± 0.69
Ash content (%)	4.63 ± 0.08	7.31 ± 0.08
Lipid content (%)	57.25± 0.35	26.50 ± 0.24
Protein content (%)	28.36± 0.49	53.04 ± 0.38
Carbohydrate content (%)	7.29 ± 0.04	6.38 ± 1.09

have specific gravities of 0.884 (raw sample) and 0.914 (roasted sample) g/cm^3, which is comparable to the values reported in seeds of *Balanite aegyptiacae* (0.895) and *Lophira lanceolata* (0.8867) (Eromosele and Pascal, 2003). Minzangi et al. (2011) summarized that seed oils containing specific gravity within the range of 0.880 to 0.9400 are more suitable for edible purposes whereas those with values 0.8114 to 1.0714 which include edibles have more potential for biofuels. The specific gravities 0.884 (raw sample) and 0.914 (roasted sample) g/cm^3 of these oils put it within the edible range. The iodine values of the crude oils were 19.56 and 23.88 gI_2/100 g for raw and roasted samples respectively, which is high, indicating that it is non-dry oil and has an appreciable degree of unsaturation and hence could be liable to oxidative degradation (Dangarembizi et al., 2015). Thus, the oil will attract high interest in the paint and coatings industry (Abayeh et al., 1998). On the other hand, the values obtained are lower than 53.4 to 101.5 reported as iodine values for some selected vegetable oils such as cotton seed, melon seed and shea (Fernando and Akujobi, 1987) and other wild seed oil grown in Bauchi, Nigeria (Abayeh et al., 1998), but lower than 178.8 reported in palm oil (Oshinowo, 1987). The results of proximate composition of both raw seed powder and raw seed residue are presented in Table 2.

The moisture content of both *S. birrea* raw seed powder and *S. birrea* raw seed residue are relatively low (4.17 and 4.00%) respectively. The value recorded was smaller than 7.50% w/w recorded in *Lophira lanceelata* seed kernel (Ighodalo and Catherine, 1991). Similarly, the moisture content in the raw seed powder and raw seed residue of *S. birrea was* smaller as compared to 5.5% w/w in the seed kernel of *Zizyphus sonorensis* (Marcelino et al., *2005*). Higher moisture content is associated with a rise in microbial activities during storage (Hassan and Umar, 2004). Therefore seed kernel with high amount of moisture content should be properly dried before storing. The ash content of both *S. birrea* raw seed powder and *S. birrea* raw seed residue was recorded to be 4.63 and 6.77%, respectively, which is an indication that, the seed contains nutritionally important mineral elements. These ash content values of both raw seed powder and raw seed residue (4.63 and

6.77%) respectively were higher than 2.0% dry weight (DW) in the seed kernel of *Zizyphus sonorensis* (Marcelino et al., 2005) and also the *S. birrea* raw seed residue is a little bit higher than 6.5% dry weight (DW) in the kernel of baobab seed reported by Chadare et al. (2009). Both the raw seed powder and raw seed residue have a crude protein content of 28.36 and 53.04%, respectively. These values of crude protein content were higher than 27.0% dry weight (DW) observed in the kernel of *L. lanceelata* seed (Ighodalo and Catherine, 1991), the value of *S. birrea* raw seed powder was relatively lower than 32.7% dry weight (DW) recorded in the kernel of baobab seed, but higher in the *S. birrea* raw seed residue (Chadare et al., 2009). When compared with 19 g set as recommended daily intakes for children 4 to 8 years (Chadare et al., 2009), the kernel can supply a significant proportion of the daily protein requirements. The crude lipid content of both *S. birrea* raw seed powder and *S. birrea* raw seed residue was 57.25 and 26.50% respectively. The value observed in the raw seed powder is within the range of 53.50 to 60% DW in the raw seed powder of *S. birrea* but higher than 40.0% dry weight (DW) recorded in the raw seed powder of *L. lanceelata* seed (Ighodalo and Catherine, 1991). The value recorded in the raw seed powder was higher than 27.80% dry weight (DW) recorded in the raw seed powder of baobab seed reported by (Chadare et al., 2009), also higher than 44.0% dry weight (DW) observed in the seed of sugar apple (*Annona squamosa*) reported by Hassan et al. (2008). Lipids are the principal sources of energy but should not exceed the daily recommended dose of not more than 30 calories so as to avoid obesity (Hassan et al., 2008).

The crude fibre content of both *S. birrea* kernel and *Sclerocarya birrea* kernel residue were 2.47% and 6.77% respectively. The value were low compared to 21.20% dry weight (DW) in the kernel of baobab seed (Chadare et al., 2009) also lower than 36.33% dry weight (DW) in the seed of sugar apple (*Annona squamosa*) reported by (Hassan et al., 2008). Hassan and Umar (2004) reported that consumption of vegetable fiber can reduce serum cholesterol level; risk of coronary heart disease, hypertension, and it enhances glucose tolerance and increase insulin sensitivity.

Thus, the fruit could be a good source of dietary fiber and could have potential of providing some human body requirements. The available carbohydrate content of both *S. birrea* raw seed powder and *S. birrea* raw seed residue was (7.29% and 6.28%) respectively. The values observed in both raw seed powder and raw seed residue was lower than 17.32% dry weight (DW) and 24.05% dry weight (DW) of *L. lonceelata* respectively (Ighodalo and Catherine, 1991), but high compared to 34.52% dry weight (DW) in baobab seed (Chadare et al., 2009).

The main function of carbohydrate is for energy supply, therefore; the raw seeds could be used to supplement carbohydrate especially to rural populace.

Conclusion

The results of the oil content, iodine value, specific gravity determinations and other physicochemical analysis of the oil extracted from the *S. birrea* seed compared favourably with those reported by other researchers. The high percentage oil content of the seeds makes them viable for commercial extraction. The oil was also found to be suitable for human consumption. The results obtained in the study show that *S. birrea* raw seed powder and raw seed residue has a great potential as source of important nutrition. It was found to be rich in fat, protein and carbohydrate which are important in human diet. This is an indication that the fruit can contribute to nutritional needs of the communities where it grows and also as raw materials to support local fruit processing industries.

Conflict of Interests

The authors have not declared any conflict of interests.

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