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Full Length Research Paper

The value of *Vitellaria* fruit pulp beyond energy and heat generation

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The shea nut pulp (SNP) has been used minimally for energy and heat generation. There is increased generation of SNP as waste during the processing of the shea nut fruit (SNF) to butter. Although the pulp is sweet and eaten by human and birds, there is paucity of information on the composition and potential uses of the SNP. This study investigated *Vitellaria* fruit pulp for their total solids and biochemical components. The fresh shea nut fruit weighs 32.33 g, the pulp is 24.61 g or 75.45% of the total fresh fruit weight and the dry weight is about 26.25%. The total solids are about 88.91 ± 0.15%. The moisture and ash contents are respectively 11.09±0.15 and 4.08±0.22%. The rest are 2.16±0.25% fat, 19.56±2.38% Fiber, 6.28±0.07% protein, and 56.83±2.09% carbohydrates. The shea nut pulp has enormous total solids and is a valuable source of proteins, fiber, lipids, and carbohydrates. The material can thus be used as raw material for animal feed production. The protein and carbohydrate concentrations make shea nut pulp suitable substrate for bio-ethanol production-beyond just energy and heat generation.

Key words: *Vitellaria paradoxa*, composition, biochemical, shea nut pulp, protein, proximate.

INTRODUCTION

Waste generation is unavoidable in many production processes such as industrial, agricultural and food processing. Industrial waste is especially released in large quantities in most developing countries and has become threat to safe human habitation in urban centres for instance. There are few innovation technologies to convert such waste to useful substances. In the northern

regions of Ghana, myriad of local and mechanized shea nut industries are being established (Abdul-Mumeen, 2013) due largely to the value placed on shea butter across the world's markets. The phenomenon has led to an increase in enormous generation of waste of various forms: shea nut pulp, shea nut cake and the shells. The shea nut pulp alone constitute about 60 to 80% of the

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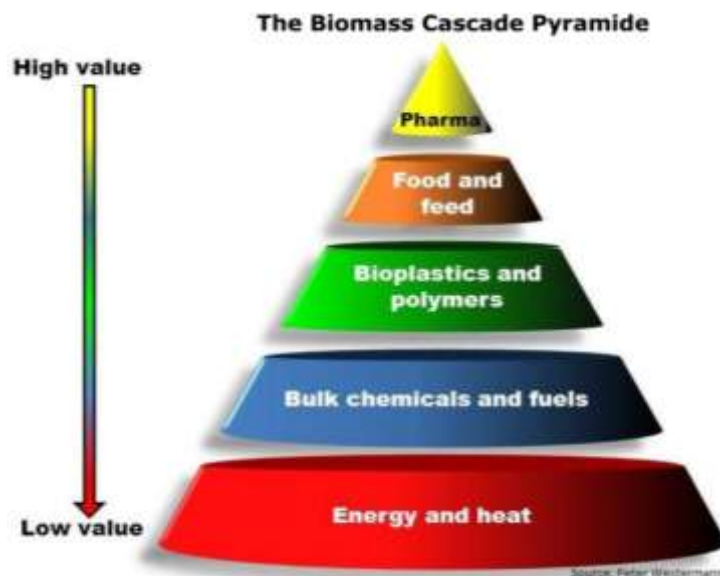


Figure 1. The biomass cascade pyramid.
Source: Lange (2010).

total fruit weight and this is a huge volume of waste to deal with resulting from SB processing.

The potential number of *Vitellaria* species in Africa's shea zone is estimated around a billion trees (Naughton et al., 2014) with 9.4 million shea nut trees found in Ghana (Dogbevi, 2008). The shea nut tree is the largest tree population size among the economic tree species in the region. Approximately, 1.76 million MT of raw shea nuts are produced annually in Africa (Mohammed et al., 2013) with Ghana estimated to produce about 75,000 equivalent tons of shea nuts per annum locally (Ghana TechnoServe, 2018).

Ghana has the potential to produce 90% of the world's shea nuts (Ghana TechnoServe, 2004) from its thickest shea nut trees in the Northern Savannah areas covering over 80% of the woody vegetation (Lovett and Haq, 2000). The shea nut pulp (SNP) constitutes about 60 to 80% of fruit weight of the shea nut fruit. During the processing of the shea nut fruit for its butter, the SNP is generated in mass quantities (Abdulai et al., 2015). For instance, for every 1000 kg of wet mass of shea fruits picked, about 600 to 800 kg of wet mass of SNP is generated. The quantum of waste generated is thus huge and, therefore, the SNP is best described as an industrial residue. Fruit rinds remain one of the most abundant and affordable raw material source for bio-ethanol production. There has not been any quantitative studies on the biochemical and total solids of the *Vitellaria paradoxa* pulp across all the shea zones of Ghana. The purpose of this study is to examine the biochemical composition and the total solids embedded in the shea nut pulp.

There has been several attempts at dealing with waste by conversion to useful substances employing bio-

technological processes. Some traditional use of waste has been mainly energy and heat generation in Ghana as shown on the biomass cascade pyramid in Figure 1. The processing and conversion of some categories of waste has been tried at the laboratory scale in Ghana. However, most industrial waste and agricultural residues have found use in biofuel generation, fertilizer formulation and food and feed production.

Recent studies have revealed that extensive research has been carried out on the proximate traits of the shea nut pulp. There is however limited information on the biochemical characteristics and the potentiation of the shea nut pulp. The current study examined the total solids (wet and dry) embedded in the shea nut pulp - the proportions of the shea nut pulp that represent total solids and the biochemical composition of the shea nut pulp and whether these qualities are the same across the five shea regional zones of Ghana.

MATERIALS AND METHODS

Sample collection

Samples of fresh *Vitellaria* fruits were collected by hand-picking of fallen fruits from under shea nut trees from different locations across each of the five regions of northern Ghana (Northern, Upper East, Upper West, Volta and Brong-Ahafo). The samples were quickly transported to the laboratory for storage at -4°C until needed. From the stored samples, composite samples were prepared. Table 1 shows the details of the samples collected.

Wet and dry weight determination

V. paradoxa fruit samples were rinsed with distilled water. Each

Table 1. SNP collection time, location and fermentation history.

Region	Local name	Harvest date	Coordinates
Brong-Ahafo	Nku (Ngu)	2020 - May - 20	8.44N;1.56W
Volta	Ku (yokuti)	2020 - May - 28	8.41N;0.04W
Northern	Tama	2020 - June - 12	8.85N;0.06E
Upper East	Taama	2020 - June - 19	10.89N;1.09W
Upper West	Taama	2020 - July - 03	10.06N;2.50W

Source: Authors

sample was wiped dry and weighed, de-pulped with the pulp and nut weighed separately. The nut and pulp were sundried for seven days and the weighed retaken separately. For dry weight, triplicate samples of 5 g of each sample were placed in pre-weighed aluminium pans and weighed using the Mettler AB-104S balance. Thereafter, the samples were kept in an incubator and maintained at 70°C until the weight of each sample became stable. Subsequent analyses were carried out on dry matter bases.

Total solids (TS) determination

The method recommended by Sluiter et al. (2008) was used in the analysis of TS. Approximately, 0.5 g (500 mg) of *V. paradoxa* fruit pulp samples were weighed into pre-weighed oven dried aluminium weighing-dishes and placed in an oven at 105 ± 3°C overnight. The dishes together with the samples were cooled in a desiccator and weighed. Percentage Total Solids content were calculated and the moisture content determined.

Ash content determination

The Ash Content analysis was determined by heating 1 g of dried sample in an oven at 550 ± 5°C for 3 h, followed by cooling and weighing. The percentage ash content was then computed (Sluiter et al., 2008).

Determination of lipid content

The Soxhlet extraction technique adopted by Abdul-Mumeen et al. (2013) was used. Thirty grams (30 g) of each sample was weighed and carefully placed inside a fat free thimble. This was covered with cotton wool to avoid loss of the sample. The loaded thimble was put in the Soxhlet extractor and about 200 mL of petroleum ether poured into a weighed fat free Soxhlet flask with the flask attached to the extractor. The flask was placed on a heating mantle such that the petroleum ether in the flask refluxed. Cooling was achieved by a running tap connected to the extractor for 8 h after which the solvent was completely siphoned into the flask. Rotary vacuum evaporator was used to evaporate the solvent leaving behind the extracted lipids in the Soxhlet. The flask was removed from the evaporator and dried to a constant weight in the oven at 60°C. The flask was then cooled in a desiccator and weighed. Each determination was done in triplicate.

Crude protein determination

Total protein was determined by the Kjeldahl method and in accordance with the modifications used by Abdul-Mumeen et al. (2013). The analysis of protein content in a compound by Kjeldahl

method is based upon the determination of the amount of reduced nitrogen present and then multiplying by a 6.25 factor. 30 g of each sample was weighed into a filter paper and put into a Kjeldahl flask with 10 tablets of Na₂SO₄ and 1 g of CuSO₄ also added to the flask. 20 mL of concentrated H₂SO₄ was added and then digested in a fume cupboard until the solution became colourless. It was cooled overnight and transferred into a 500 mL flat bottom flask with 200 mL of distilled water added. This was then cooled with the aid of packs of ice block. About 60 to 70 mL of 40% NaOH was poured into the conical flask which was used as the receiver containing 50 mL of 4% boric acid with methyl red as indicator. The ammonia gas was then distilled into the receiver until the all gas evaporated. Titration was done with 0.1 N H₂SO₄ until the solution became colourless. The percentage N content was calculated and then multiplied by a 6.25 factor.

Crude fiber determination

Crude fibre content was determined according to methods adopted by Pousga et al. (2007). 30 g of each SNP sample was defatted, separately, with diethyl ether for 8 h, and boiled under reflux for exactly 30 min with 200 mL of 1.25% H₂SO₄. It was then filtered through a cheese cloth on a fluted funnel. This was later washed with boiling water to completely remove the acid. The residue was then boiled in a round bottom flask for 30 min with 200 mL of 1.25% sodium hydroxide (NaOH), and filtered through previously weighed couch crucible. The crucible was then dried, with samples, in an oven at 100°C, left to cool in a desiccator and later weighed. This was later incinerated in a muffle furnace at 600°C for 2 to 3 h and which later was cooled in a desiccator, and weighed. The fibre content was then determined.

Carbohydrates determination

Carbohydrates were calculated by the difference according to Pousga et al. (2007):

$$\% \text{ CHO} = (100\% - (\% \text{ moisture} + \% \text{ ash} + \% \text{ crude protein} + \% \text{ crude fat} + \% \text{ crude fibre}))$$

Mineral analysis

The mineral content of SNP was determined according to Cunniff and Washington D (1997) procedure. Each of the SNP samples was digested in a di-acid mixture (HNO₃:HClO₄) in the ratio of 7:3 on hot plate at a temperature of 180°C for 2 h. The contents were diluted to the volume of 100 mL with double-distilled (de-ionized) water. The mineral contents: K, Na, Mg, and Ca in the digested samples were estimated by using atomic absorption spectrophotometer (Model Varian Spectra AA 250 plus).

Table 2. Relative percentage weight analysis of SNP in five regions of Ghana.

Sample	FW (g)	NW (g)	WWP (g)	WDP (g)	WWP%	WDP%	%Water
BA	32.29	6.60	25.69	6.40	79.56	24.91	75.09
VR	26.18	9.10	17.08	5.07	65.24	29.68	70.32
NR	33.57	7.50	26.07	7.00	77.66	26.85	73.15
UER	28.46	7.20	21.26	4.20	74.70	19.76	80.24
UWR	41.15	8.20	32.95	9.90	80.07	30.05	69.95
Mean value	32.33 ^S	7.72 ^S	24.61 ^S	6.51 ^S	75.45 ^S	26.25 ^S	73.75

FW: Weight of Fruit; NW: Weight of Nut; WWP: weight of wet pulp; WDP: Weight of Dried Pulp; S: Significantly different, BA: Brong Ahafo, VR: Volta Region, NR: Northern Region, UER: Upper East Region, UWR: Upper West Region.
Source: Authors

Table 3. Relative percentage total solids, moisture and ash contents of SNP from five shea nut producer regions of Ghana.

Sample	Total solids (%)	Moisture (%)	Ash (%)
BA	90.77±0.21**	9.23±0.21*	3.61±0.65*
VR	88.50±0.10*	11.50±0.10**	3.37±0.22*
NR	87.01±0.01*	12.99±0.01**	3.92±0.03*
UER	91.07±0.11**	8.93±0.11*	3.87±0.02*
UWR	87.21±0.34*	12.79±0.34**	5.61±0.17**
Mean	88.91±0.15 ^S	11.09±0.15 ^S	4.08±0.22 ^{NS}

S, Significantly different; NS, not significantly different. BA: Brong Ahafo, VR: Volta Region, NR: Northern Region, UER: Upper East Region, UWR: Upper West Region.
Source: Authors

Statistical analysis

All measurements involving chemical compositional analysis of SNP biomass were carried out in triplicates. All reported values in this study were means of replicate values.

RESULTS AND DISCUSSION

The relative weight of a Shea Nut Fruit (SNF) and a SNP from five regions of Ghana were investigated and the results are presented in Table 2. The average fruit contained significantly 32.95 g of fresh pulp and a dried pulp weight of 9.90 g in the Upper West Region of Ghana (Table 2). The fresh pulp weight was, however, generally higher (65.24 to 80.07%) across the five regions of Ghana. Even though the weights differed significantly across the five regions, the high values observed were of significant interest since fermentation processes are dependent on substrate availability.

SNP predominantly had high amounts of total solids (88.91%) and ash content (4.08%) (Table 3). The SNP total solids were highest in samples from BA (90.77%) and lowest in samples from NR (87.01%) and the values were significantly different across the regions of shea nut tree existence. The total solids of SNP from the BA (**) and the UER (**) were not significantly different; the rest of the three regions (VR, NR and UWR)* were also not

significantly different from one another, but SNP from the two groups of regions (** and *) differed significantly (*).

The moisture content of sundried SNP is 11% on the average and significantly different across the five shea nut regions of Ghana. The moisture content was highest in NR and UWR. The finding could be attributed to the size of the fruit. The NR and the UWR regions had bigger fruits (33 and 41 g, respectively) and fatter pulps (26 and 32 g, respectively), a factor accounting for their respective moisture contents of 12.79 and 12.99%.

It was observed from the pulp analysis that fresh SNP constitutes about 65 to 80% of the total weight of the shea nut fruit which weighs about 75% on the average. Water alone constitutes about 70 to 80% of the total weight of the fresh pulp. The fresh weight is about three times the dry weight (20-30%) of the total fruit pulp weight. Similarly, a report by Mbaiguinam et al. (2007), recorded fresh SNP values of 53.9 to 83.3% for the *Vitellaria paradoxa* species in Chad. The observation of the values during this research for the fresh weight of SNP was higher than what Ugese et al. (2010) discovered in three ecological zones of Nigeria where about 54.5 to 68.1% of fresh SNP weight were detected. Maranz and Wiseman (2003), note that the shea nut (shell + kernel) is 50% by weight of the shea nut fruit; the pulp will be 50% too but that will be lower than that of the findings of the current research. These differences in the

Table 4. Comparison of selected Mineral element content in SNP based on dry weight discovered from the five shea nut regions of Ghana.

Sample	K	Ca	Mg	Na
	g/100 g			
BA	0.258±0.001 ^a	0.284±0.004 ^a	0.118±0.001 ^a	0.057±0.001 ^a
VR	0.263±0.005 ^a	0.296±0.002 ^a	0.162±0.003 ^b	0.070±0.002 ^a
NR	0.258±0.000 ^a	0.278±0.002 ^a	0.195±0.002 ^c	0.061±0.001 ^a
UER	0.258±0.001 ^a	0.406±0.002 ^b	0.154±0.006 ^b	0.055±0.000 ^a
UWR	0.288±0.002 ^a	0.341±0.002 ^a	0.153±0.002 ^b	0.071±0.002 ^a
Mean	0.265±0.012	0.321±0.050	0.156±0.026	0.063±0.007

Columns with similar superscripts are statistically not different, otherwise they are significantly different. BA: Brong Ahafo, VR: Volta Region, NR: Northern Region, UER: Upper East Region, UWR: Upper West Region.

Source: Authors

SNP weight could be attributed to the variation in soil type and humus cover since the shea nut trees triumph under sandy soils with higher soil nutrients (Hall et al., 1996; Adam, 2015). The difference in weight could be due to significant and substantial effects of both environmental conditions and genetic traits. The SNP has about 87 to 91% total solids as was observed in pulp of *V. paradoxa* across the shea tree zones of Ghana. An average of 88.9% total solids in the SNP makes it a suitable substrate for use in many industries. Total solids are determinant of substrate concentration and substrate concentration is known to have a significant effect on the growth and fermentation capacity of a microorganism (Edwards, 1970). The observation of the 11% SNP moisture content is lower than 15% discovery by Enaberue et al. (2014) but higher than 9% average from oven dried samples estimation by Ugese et al. (2010) and 4.5% findings by Aguzue et al. (2013). Maranz et al. (2004) and Mbaiguinam et al. (2007) have described the moisture content as, “the difference between the fresh pulp and the dried pulp irrespective of the temperature at which it was dried”. They estimated the moisture content to be within 67 to 80.3%. In this study, the difference between fresh pulp and sundried pulp has been described as “percentage water.” This ranges between 69.95 and 80.24% (Table 2) which is very similar to that detected by Maranz et al. (2004) and Mbaiguinam et al. (2007).

Experiments were performed purposely to determine the Ash content of the SNP and the subsequent analysis of its elemental composition. The Ash content of SNP was observed to be about 4% although there was a demonstration of variability in the results for the Upper West Region (5.61%) and the rest of the regions (3.37 - 3.87%).

Potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) in their elemental forms were all detected in different quantities in samples across the five regions (Table 4). The calcium content of the SNP was generally high (0.27 – 0.40) g/100 g but highest (0.406 g/100 g) in samples from the Upper East Region of Ghana. There

was no difference in calcium levels of SNP samples from the five regions except in the Upper East region. The least detected mineral composition was sodium (Na); its detection levels were uniform ($p > 0.05$) in all five regions. Like sodium, potassium was not significantly different in its detection levels in SNP in all the regions (Table 4). However, the detection levels of potassium were quite higher and comparable to calcium levels across the regions. Magnesium levels in the Volta region, the Upper East and West regions were similar ($p > 0.05$); that of Volta and Northern regions were individually different.

The difference in the Ash content of pulp from the UWR and the rest of the regions could be attributed to genetic or environmental reasons that characterize plant material makeup of the regional divide (Bensah et al., 2012). The detection of elemental magnesium (0.156 g/100 g), sodium (0.063 g/100 g), calcium (0.321 g/100 g) and potassium (0.265 g/100 g) in the SNP was a plus for the use of the Pulp as animal feed. Honfo et al. (2013), made similar findings about the SNP when 0.13 and 0.43 g/100 g were, respectively, detected for Mg and Ca at maximum levels. Other researchers found lower elemental composition for SNP. For instance, Aguzue et al. (2013) made an estimation of 2.3 mg/100 g of Ca and 0.5 mg/100 g of Mg while Dakora and Naab (2014) found 1.93 mg/kg Ca, 0.98 mg/kg Mg, 52.3 mg/kg Na and 13.99 mg/kg K with Mbaiguinam et al. (2007) reporting 4.67 mg/g Ca, 1.11 mg/g Mg and 21.72 mg/g K. The SNP have some health benefits because of its mineral content. According to Amao (2018), most fruits are good for weight management, cholesterol level regulation and prevention of constipation. In the biorefinery industry, the presence of sodium ion in the fermentation medium increases the ionic strength of the medium. Sodium concentration beyond 125 mM is a major concern for the growth and activity of *Saccharomyces cerevisiae* although yeast cells show a great deal of tolerance with regard to growth in the presence of high sodium chloride concentrations (Paul, 2010). However, 0.063 g/100 g discovered of the sodium ion concentration was quite low to be a concern for the growth of the yeast. Potassium,

Table 5. Concentration of biochemical composition of SNP.

Sample	Crude Fat	Fibre	g/100 g	
			Crude Protein	Carbohydrates
BA	2.57±0.34 ^a	13.71±1.48 ^b	7.26±0.17 ^e	63.61±0.90 ^f
VR	1.86±0.03 ^a	21.05±2.61 ^d	4.95±0.04 ^e	57.27±2.31 ^g
NR	1.65±0.42 ^a	25.22±3.94 ^c	6.10±0.01 ^e	50.12±3.55 ^h
UER	2.96±0.07 ^a	18.04±2.32 ^d	5.58±0.02 ^e	60.61±2.13 ^f
UWR	1.74±0.37 ^a	19.78±1.57 ^d	7.52±0.10 ^e	52.55±1.58 ^h
Mean	2.16±0.25	19.56±2.38	6.28±0.07	56.83±2.09

Columns with similar superscripts are statistically not different, otherwise they are significantly different. BA: Brong Ahafo, VR: Volta Region, NR: Northern Region, UER: Upper East Region, UWR: Upper West Region.
Source: Authors

calcium and magnesium are important components of nutrient supplements for the growth of *S. cerevisiae*.

The total crude fat, fibre, crude protein and carbohydrate content of the SNP are presented in Table 5. The fat content of the SNP was highest in samples from the Upper East Region of Ghana and least in the Northern Region; 2.96 and 1.65 g/100 g, respectively. The variation was, however, not significant across the five regions constituting the shea nut zones of Ghana (Table 5). The difference in total crude protein content was equally insignificant in all the regions.

SNP from the Upper West region had the highest amount of protein (7.52 g/100 g) compared to the other regions. The lowest shea pulp crude protein (4.95 g/100 g) was detected in samples from the Volta Region of Ghana where shea nut trees are sparsely and scarcely distributed towards the Northern parts of the Volta Region. The fiber and carbohydrate portions of the SNP showed significant difference ($p < 0.05$) in all five regions. The fibre content was quite high in the Northern Region (25.22 g/100 g) and the least of 13.71 g/100 g detected in pulp samples from the Brong Ahafo Region. The amount of fiber determined in pulp samples from the rest of the regions did not differ ($p > 0.05$) significantly. That of carbohydrates was determined by difference. The highest amount (63.61 g/100 g) of carbohydrates was detected in SNP samples from the Brong Ahafo Region. The Northern Region had the least carbohydrate content of 50.12 g/100 g. Further statistical analysis did not show any difference in the carbohydrate content between the Northern and Upper West regions, and between the Brong Ahafo and the Upper East regions (Table 5).

When individual regional SNP samples were analyzed for their biochemical components, the fat content with a concentration range of 1.65 to 2.96 g/100 g was found with 2.16 g/100 g calculated average. This measured concentration of fat in the SNP in the current study is higher than 1.35% (w/w) as determined by Aguzue et al. (2013) and 1.3 g/100 g determined by Ugese et al. (2008). Enaberue et al. (2014), measured a higher crude fat value of SNP (16.37%), about eight times higher than the findings of this research. The mean fibre content of

the SNP measured 19.56 g/100 g in this study is about half the findings (43%) of Ugese et al. (2008). Many researchers (Omujal, 2009; Okullo et al., 2010; Aguzue et al., 2013; Ojo and Adebayo, 2013; Enaberue et al., 2014) have all detected lower amount of 9.6 to 13.1% SNP fibre contents. SNP has 6.28 g/100 g crude protein across the five shea zones of Ghana. Maranz et al. (2004) observed that the sweet pulp of the shea nut fruit is a rich source of sugars, proteins, and calcium. Report on the protein content of the SNP varied significantly from 7.5% by Enaberue et al. (2014), 5.6 g/100 g by Honfo et al. (2013), 4.8% by Ugese et al. (2008), 4.35% by Mabaiguinam et al. (2007), 3.6 g/100 g by Omujal (2009), Okullo et al. (2010), 3.5% by Aguzue et al. (2013) to 1.6 g/100 g by Ojo and Adebayo (2013). Only few of these findings fell outside the range of values of protein detection (4.95-7.52 g/100 g) in this study. Shea nut fruit quality is influenced by the organic matter content, the organic carbon content, the organic nitrogen content of the soil where the shea tree is located as well as the soil Carbon Exchange Capacity (CEC) (Adam, 2015). The SNP composed of 56.83 g/100 g carbohydrates levels although it can go as high as 63.61 g/100 g in some of the shea zones of Ghana. Some researchers (Aguzue et al., 2013; Omujal, 2009) have recorded carbohydrate content of SNP to range between 62 – 72 g/100 g. This is higher than the findings of this research; however, many other researchers (Mabaiguinam et al., 2007; Okullo et al., 2010; Ojo and Adebayo, 2013; Honfo et al., 2013) have detected lower carbohydrates contents (7.5 - 43%) than our findings. This green shea nut fruit with fleshy, soft sweet edible layer called the pulp contains 41.2 g of carbohydrate according to Fobil (2002). Only Enaberue et al. (2014), discovered similar carbohydrate content (57%) of the SNP. Maanikuu and Peker (2017) have suggested that there is a decrease in the carbohydrate content of the SNP at higher latitudes since more moisture is found at the equator, leading to improved photosynthesis. Ojo and Adebayo (2013), however, claim the decrease in carbohydrate content of SNP stored at room temperature is due to fermentation caused by microbes (fungi) and the corresponding loss of sugars (glucose and fructose),

especially, as carbon (IV) oxide. The fermentation is largely as a result of the activities of the fungi *Aspergillus niger* which causes an intensive deterioration of the SNP at a rate of 2.7% within a week from harvest (Ojo and Adebayo, 2013). This assertion is backed by earlier research work by Parkison (1984), who reported that fermented SNP was low in carbohydrate content.

Conclusion

Fresh shea nut pulp weight ranges from 65.24 to 80.07% across the five regions of Ghana with 88.91% total solids and 4.08% ash content. Shea nut pulp is minerals rich and calcium content is generally highest 0.40 g/100 g Region of Ghana with sodium (Na) being the least, 0.063 g/100 g, detected mineral in shea nut pulp. The concentration of the fats ranged between 1.65 and 2.96 g/100 g with an average of 2.16 g/100 g. SNP has 6.28 g/100 g crude protein and it is composed of 56.83 g/100 g carbohydrates concentration.

The shea nut pulp has myriad potential in the biorefinery industry, fertilizer production industry, and feed industry and as a potential source of useful minerals and amino acids due to its relatively high protein content. SNP is composed of 56.83 g/100 g carbohydrates. Carbohydrates are the main source of reducing sugars from which bioethanol can be generated. The shea nut pulp is thus a potential source of bioethanol.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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