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Original Paper

Nutritional Composition of Seeds of False Mopane (*Guibourtia coleosperma*) from Shakawe and Kasane Areas, Northern Botswana

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Abstract*— The seeds of *Guibourtia coleosperma* serve as potential source of nutritious food for rural communities in northern Botswana though underutilized. The objective of this study was to determine the proximate and mineral composition of *G. coleosperma* seeds collected from northern Botswana. Seed samples were collected from Shakawe and Kasane areas in northern Botswana. The proximate composition and mineral contents of the seed were determined following standard procedures. The data were analyzed using T-test. Seeds collected from Shakawe had average moisture (%), crude fat (%), crude fiber (%), crude protein (%), ash (%), total carbohydrate (%) and energy (kcal/100g) contents of 8.48 ± 0.29, 9.24 ± 0.31, 4.72 ± 0.60, 15.34 ± 0.48, 2.40 ± 0.02, 59.81 ± 1.00 and 383.80 ± 4.81, respectively. The corresponding values for seeds collected from Kasane were 9.00 ± 0.10, 10.17 ± 0.37, 7.13 ± 0.21, 16.44 ± 0.43, 2.45 ± 0.02, 54.80 ± 0.58 and 376.50 ± 2.22, respectively. Seeds collected from Kasane had significantly higher ($p < 0.05$) crude fat, crude fiber, crude protein and ash contents than seeds collected from Shakawe. However, the total carbohydrates content of seeds collected from Shakawe was significantly higher ($p < 0.05$) than those collected from Kasane. No significant differences ($p > 0.05$) were observed for moisture and energy contents between the seed samples collected from the two locations. The predominate proximate component in the seeds was total carbohydrate followed by crude protein and, therefore, the seeds can serve as good sources of energy and protein. The average zinc, iron, magnesium, potassium, calcium, sodium (mg/100 g) and phosphorus (mg/g) contents of seeds collected from Shakawe were 2.96 ± 0.53, 2.40 ± 0.27, 116.80 ± 2.82, 468.69 ± 19.28, 316.70 ± 21.15, 1.21 ± 0.67 and 1.35 ± 0.04, respectively. The corresponding values for False Mopane seeds collected from Kasane were 2.53 ± 0.31, 3.34 ± 0.18, 173.65 ± 5.83, 460.86 ± 10.53, 367.59 ± 15.37, 3.51 ± 0.44 and 1.45 ± 0.12, respectively. The values for iron, magnesium, calcium and sodium were significantly higher ($p < 0.05$) for seeds collected from Kasane than those collected from Shakawe. However, no significant differences ($p > 0.05$) were observed between the seed samples collected from the two locations for zinc, potassium and phosphorus. Quantitatively, the predominant mineral observed in seed was potassium followed by calcium. The seeds could serve as good source of magnesium, iron, zinc, calcium and potassium since they contribute higher proportions of the recommended daily intake of these minerals. The results showed that location has a significant effect both on the proximate composition and mineral contents of False Mopane seeds.

Keywords*— *Guibourtia coleosperma, Nutritional composition, Wild edible seeds

I. INTRODUCTION

Guibourtia coleosperma (Benth.) J.Leonard is an evergreen tree with a somewhat rounded, drooping crown tree. The tree is native in tropical parts of Africa: Angola, Botswana, Southern Democratic Republic of Congo, Namibia, Zambia and Zimbabwe [1]. In Botswana the species occurs along the northern border of Botswana to Namibia [2]. *Guibourtia coleosperma* has an English common name of False Mopane. According to Palgrave and Drummond [3], the leaves of *G. coleosperma* superficially resemble those of *Colophospermum mopane*, hence, the common name False Mopane, but the silhouette of the two trees are very different. The Mopane is more erect with resin gland characteristic seeds while the False Mopane is more rounded with aril covered seeds [3]. The species has other English common names, such as African Rosewood, Bastard Mopane, Bastard Teak, Large False Mopane, Rhodesian Copalwood, Rhodesian Mahogany and Rhodesian Teak [4, 5]. Locally, the species is known by the following names: *Motsaodi*, *Motsaudi*, *Nsibi*, *Shii*, *Tsaudi* and *Ushi* (Setswana) [5]. The species belongs to the Fabaceae family, therefore, it belongs to the legume, pea, or bean family. The False Mopaneis widely distributed with no apparent conservation threats but in Namibia and Botswana it is legally protected [6].

False Mopane is found in woodlands on deep sandy soils [4]. Unlike many other leguminous species, this species does not fix atmospheric nitrogen [7]. The tree is suitable for light (sandy) and medium (loamy) soils, prefers well-drained, soil and can grow in nutritionally poor soil. The suitable pH of the soil is acidic and neutral, and the tree can grow in very acidic soils, but cannot grow in the shade and prefers moist soil [7]. The tree

occurs in woodland and deserts, often, along rivers at 750-1,400 m altitude, and it is found in areas with a mean annual temperature of 20-28 ℃ and an annual rainfall of 450-1,100 mm [6]. It forms the upper story with *Baikiaea plurijuga* Harms and *Pterocarpus angolensis* DC. It is found on Kalahari sand soils, which have a low water holding capacity. The species is sensitive to fire while it is insensitive to frost [6].

False Mopane tree grows up to 20 m high with rounded drooping crown and slightly buttressed bole [4]. Its bark is greyish, yellowish- or pale reddish-brown to black and fairly smooth or, sometimes, roughish on old trees. The tree slash is blood-red with glabrous young branchlets. Leaves are alternate with a single pair of leaflets [4]. The flowers of False Mopane are in lax terminal heads, creamy white, 1 cm in diameter and are pollinated by insects [8]. The fruits are oval woody pod, brownish with red-brown seeds covered by aril when split open [9]. The pods are 2-3 cm long, dark brown, splitting on one side only, partially releasing a single brown seed with a bright red aril, which is attached to the pod by a narrow stalk [8]. The seeds are edible when cooked [10] and are referred to as Bushman Beans in Namibia [11].

The seeds of *G. coleosperma* are prepared by cooking and, traditionally, they are baked in hot ashes and, then, pounded. Although they can be eaten at this stage, they are commonly mixed with water to form a paste and, then, cooked again [11]. The seed and its aril contain oil, which is used for cooking. In Botswana, the seeds are eaten after roasting and pounding, or can be eaten boiled as beans or mixed with meat [12]. The red dye from the aril has been used for staining furniture [6]. In Namibia, *G. coleosperma* seeds are called *nonsivi*, and the oily arils of the seeds are very good when cooked with cabbage but go rancid before they could be processed [13]. According to Plessis [13], the seeds might be made into an interesting relish, and it was reported that they are used for consumption and some further work on them would be a good research idea. The fruits are also cooked. The fruit, which is completely enclosed by a fleshy red aril, is easily removed from the seed by soaking in warm water for a few minutes, then, the arils are used to make soup or used to make a nourishing drink [11].

The bark is pounded and, then, applied as paste to treat skin ailments and wounds [11]. The reddish-pink heartwood is used for making furniture, knife handles and various other purposes [4]. The wood is used for paneling, parquet flooring, cabinet making and the large burs of old trees are used to make table tops [1].

The seeds of *G. coleosperma* have oil and proteins [6]. The seeds also contain high carbohydrates and calcium, which indicate that they have a high nutritional value [14]. The oil is extracted by pounding and boiling the seeds. People in Botswana and Zambia remove arils with warm water [6]. Flavonoid glycosides have been isolated from the bark [6].

Botswana possesses rich diversity of wild plants, which have been used for food and medicinal purposes. Most wild plants of Botswana have served as sources of nutrition [15]. If properly exploited, wild plants of Botswana can ensure food security. Common trees in Botswana with edible parts include species of *Colophospermum*, *Adansonia*, *Sclerocarya*, *Senegalia* and *Vachellia*, *Boscia*, *Phoenix*, *Cyperus*, *Ficus*, *Hyphaene*, *Garcinia*, and *Kigelia* [16, 33]. The trees grow in areas with ample supply of water, such as Okavango Delta swamps and Chobe River. Wild plants are extremely important in Botswana as principal sources of food and medicines [15]. On average, once in three years, crop failure is experienced in the arable agriculture in Botswana. Hence, some indigenous tree species yield fruits during drought periods, hence, improving food security for local communities [17].

The indigenous fruit tree species, such as the False Mopane available in Botswana, are underutilized due to various factors, such as non-availability of post-harvest processing technologies, poor transportation and lack of knowledge on processing techniques. Information on the nutritional composition of these fruits, seeds and other edible parts of the tree is limited [18]. This study was undertaken to investigate the nutritional values of seeds of False Mopane.

According to Maguire [14], the seeds of False Mopane have a fairly high nutritional value with regard to their energy level, proteins, carbohydrates and calcium content. They also have appreciably low anti-nutrient content; therefore, it is suggested that *G. coleosperma* seeds can contribute significantly to the nutritional requirements of humans [19]. The seeds contain phytochemicals [19] and protein (14.5%) [6]. Although the seeds possess these qualities, their nutritional composition in Botswana has not been fully exploited for human consumption and other benefits. Similar to other native edible wild plants that are extremely useful during times of food shortage for rural communities in Botswana, the nutritional and medicinal importance of seeds of False Mopane is overlooked. Therefore, this study reports the nutritional potential of seeds of False Mopane naturally growing in northern Botswana through the information generated on its nutritional composition.

The objective of this study was to assess and compare the proximate composition and mineral contents of seeds of *Guibourtia coleosperma* naturally growing in Shakawe and Kasane area, northern Botswana.

II. Materials And Methods

A. Description of the Study Area

The seeds of False Mopane used in this study were collected from Shakawe in Ngamiland District and Kasane in Chobe District in northern Botswana. Northern Botswana and the surrounding regions are home to a rich diversity of plants. The region is dominated by *Senegalia nigrescens* (Oliv.) P.J.H.Hurter, *Diospyros mespiliformis* Hochst. ex A. DC. and *Ficus* spp. *Adansonia digitata* L., *Berchemia discolor* (Klotzsch) Hemsl., *Croton megalobotrys* Müll.Arg. and *Colophospermum mopane* (Benth.) J. Léonard occur less frequently. Shakawe is a village located at the beginning of the Okavango Delta, close to Namibia and Angola while Kasane is a town close to where Botswana, Namibia, Zambia and Zimbabwe meet.

In northern Botswana, winter is milder, and the maximum temperature is around 24/26 °C and the minimum temperature is around 8/10 °C. The hottest period in the north occurs from September to November while in the summer, the temperature slightly decreases because of the prevalence of more humid air masses of tropical origin. In the northernmost area, which is the

rainiest of the country, rainfall exceeds 600 mm per year, though the rains are concentrated, as usual, in the summer. In this area, the sun regularly shines in the long dry season, while in the rainy period, the sunshine hours decrease as compared to in the rest of the country.

B. Sampling Plan and Sample Size

The first seed samples were randomly collected by gathering them from the trees naturally growing in Shakawe, Ngamiland District, near a small rural village called Ghani. The second seed samples were collected from trees naturally growing in Kasane, Chobe District. The seeds were collected while still attached to their pods and/or arils. About 20 cups of the False Mopane seeds from the two sampling locations were gathered and collected. One cup of the seeds represented 128 g which is 0.128 kg. The total mass of the seeds was 2 kg per sample. The seeds were, then, transported in a plastic packet to Botswana University of Agriculture and Natural Resources (BUAN) where the analyses were undertaken.

C. Sample Preparation

In the BUAN Food Science and Technology Laboratory, selected sound seeds in the pods and with arils were air dried. The seeds were separated from the pods and arils by mild pounding using mortar and pestle (Fig. 1 and 2). The images were taken after the seed pods and arils were separated from the individual seeds.

Fig. 1. Image of *Guibourtia coleosperma* seeds collected from Shakawe, Botswana

Fig. 2. Image of *Guibourtia coleosperma* seeds collected from Kasane, Botswana

The individual seeds were collected and weighed. The seeds were, then, first crushed to reduce seed sizes manually using mortar and pestle, and, then, ground to a uniform powder in a food processing blender and sieved before use. The samples were stored in zip lock bags until used for the analyses.

D. Proximate Composition

Moisture content

The moisture dishes were cleaned and dried at 130 ˚C for 1 h and kept in a desiccator for about 10 minutes until they were cooled to ambient temperature. Tongs were used to handle the dishes. The masses of the dishes were taken on an analytical balance and recorded as "m_1". The powdered seed sample (5 g) was weighed in triplicate into moisture dishes. The mass was taken as "m_2" (mass of sample + mass of moisture dish before drying). The sample was spread evenly on the dish and weighed rapidly to minimize moisture loss or gain. Then, it was removed and placed in the oven chamber. The sample was dried at 130 ± 1 ˚C for 1 h. Care was exercised not to overload the drying oven that may lead to an insufficient drying or erroneous result. Regular checks of the oven ventilation and temperature were undertaken to monitor the proper functioning of the oven. After drying was completed, the sample from the oven was placed in desiccator to cool the sample to room temperature and weighed accurately, and the results were recorded as "m_3" [20].

$$\text{Moisture \%} = \frac{\text{Minitial} - \text{Mdried}}{M\ initial} * 100$$

where $M_{initial} = m_2 - m_1$ and $M_{dried} = m_3 - m_1$

Crude fat content

The powdered seed sample (3 g) was accurately weighed into a thimble lined with a circle of filter paper. The thimble and contents were placed into 50 ml beaker and dried in an oven for 2 h at 110 ℃. The thimble and the contents were transferred to the extraction apparatus and the beaker was rinsed several times with n-hexane solvent. The sample contained in the thimble was extracted with the solvent in a Soxhlet extraction apparatus for 8 h at a condensation rate of at least 3-6 drops per second. At the completion of the extraction, the fat extract was transferred from the extraction flask into a pre-weighed (Mi) evaporating small beaker (150 ml) with several rinsing with the solvent. The evaporating small beaker was placed in the fume hood and evaporated off the solvent on a steam bath until no odour of the solvent was detectable. The beaker and its contents were dried in an oven for 30 min at 100 ℃. The sample was removed from the oven, cooled in a desiccator and the beaker plus contents (mf) were weighed and calculated to get the percent crude fat as shown below [21].

$$\text{Calculation: Lipid (\%)} = \frac{Mf - Mi}{Sample\ mass\ dry\ basis} * 100$$

where M_f = mass of the flask and lipid extracted and M_i = mass of dried flask.

Crude protein content

Ground sample (0.3 g) was weighed into a Kjeldahl digestion flask. One kjtabs catalyst tablet (consists of 3.5 g K_2SO_4 and 0.105 g $CuSO_45H_2O$) was added into the flask. Then concentrated H_2SO_4 (12 ml) was added, and the digestion flask was placed in the digester and the sample was digested. After

the completion of digestion, the flask was removed from the digester and allowed to cool. The digestion was considered complete when the digested samples were colorless. After it was cooled, the digestion flask was transferred to the distillation unit. Distilled/deionized water was added, and this dilutes the sample, hence, making it easier to detect all the ammonia. Nitrogen was separated from the digested mixture by steam distillation, which extract the ammonia from the alkaline solution. The pH of the digested mixture was raised using sodium hydroxide (40%). This converts NH_4^+ (salt form) into NH_3 (gaseous). The distilled vapors were trapped in a dedicated solution of 4% boric acid (this traps all the nitrogen, eliminating the risk of loss). The distillate was titrated with standard acid (0.1N HCl). The volume of HCl consumed during titration was shown in the titrator. The readings were recorded and the percent N and percent protein calculated using the equation given below [20].

$$\%N = \frac{(\text{V HCl sample} - \text{V HCl blank}) * 0.1\text{N HCl} * 14.00}{\text{Sample weight in dry matter basis}} * 100$$

Percent protein = %N x F (conversion factor 6.25)

Crude fiber content

The powdered seed sample (3 g) was weighed. The sample was transferred into 600 ml beaker and fiber contamination from paper or brush was avoided. Boiling 0.255 N 1.25% H_2SO_4 (200 ml) was added to the sample in the 600 ml beaker. The beaker was placed on a digestion apparatus with pre-adjusted hot plate and boiled for exactly 30 min. The beaker was rotated periodically to keep solids from adhering to sides. The sample was filtered through a 74-75 µm sieve with addition of 50-75 ml boiling distilled water. After the wash was removed, the process was repeated with three 50 ml washings. Then, 200 ml boiling 1.25% NaOH was added and boiled exactly for 30 min rotating periodically. The beaker was removed and filtered as above. The contents were washed with 25 ml boiling 1.25% H_2SO_4 and, then, three 30 ml portions of boiling water. After every wash, there was filtering. The residue, along with the anti-bumping chips, were removed and transferred into the moisture dish and dried at 130 ℃ for 2 h. The residue was cooled in a desiccator and weighed (m1). The residue was transferred into a crucible and, then, to the muffle furnace and ignited for 2 h at 600 ℃ until ashing was complete. The ash was cooled in a desiccator and weighed (m2) [20].

$$\text{Percent crude fiber} = \frac{(m1-m2)}{wt\ of\ sample\ (db)} * 100$$

where *wt* = weight and *db* = dry matter basis.

Ash content

The ash dish was cleaned and, then, dried at 120 °C and ignited at about 550 °C in a muffle furnace for 1 h. The dish was removed and cooled in a desiccator, and the mass of the crucible was recorded as m1. The powdered (3 g) sample (dry basis) was weighed into the ash dish and the mass was recorded as m2 (mass of the sample plus mass of crucible). Then, the sample was dried at 120 °C for 1 h in a drying oven, and, then, the dish was removed from the oven and carbonized by blue flame of Bunsen burner by placing the sample dish on a wire gauze. The contents were heated until they turned black. The dish with its contents were transferred into a muffle furnace and ignited at about 550 °C until free from carbon, and the contents appeared grayish white for about 8 h. The dish was removed from the furnace and dried at 120 °C for 1 h and re-ashed at 550 °C until white ash colour was obtained, and it was removed from the furnace and allowed to cool . The sample was placed in a desiccator until the temperature assumed ambient temperature and weighed (mass was recorded as m^3). Then, percent ash was calculated and the percent ash expressed on dry matter base as follows [20]:

$$\text{Ash (\%)} = \frac{m3-m1}{m2-m2} * 100$$

Total carbohydrate content

The total carbohydrate content of the seeds was determined by estimation of the difference from proximate analyses percentages, i.e., 100 – (percent crude protein + percent moisture + percent crude fat + percent crude fiber + percent total ash). By this difference calculation, available carbohydrate that approximate the starches and soluble sugars were estimated. The method required other food proximate contents to be pre-determined [22, 34].

Gross energy

The gross energy (kcal/100 g) was calculated by multiplying the mean values of crude proteins, crude fat and total carbohydrate by factors of 4, 9 and 4, respectively [23].

E. Mineral Analyses

Calcium, magnesium, zinc, iron, potassium and sodium in the samples were determined by flame atomic absorption spectrometric method, while phosphorous was determined by using UV Visible Spectrophotometer at the Food Chemistry Laboratory of the National Food Technology Research Centre (NFTRC) in Kanye, Botswana.

In analyzing for calcium, magnesium, zinc, iron, potassium and sodium, approximately 0.3 g of each of the samples were weighed into sterilized digestion vessels. In a fume hood, 10 ml of 69% Nitric Acid (HNO_3) was pipetted into all the different samples in triplicate, lyophilized brown bread reference material in triplicate and empty vessels as blank. After waiting for the samples to froth, the vessels were tightly closed. The rotor segment was inserted into the microwave cavity (Berghof Microwave) and the digestion program fully run for 40 minutes. Upon completion of the digestion program, the rotor was cooled with water until the solution reached room temperature. The solutions were filtered into sterilized 50 ml volumetric flasks. To make analyte, the flasks were filled to the mark with ultra-pure water and finally transferred into 100 ml plastic bottles for storage at 4 °C ready for flame atomic absorption spectrometric analysis. The samples, blank and reference material were analyzed for calcium, magnesium, zinc, iron, potassium and sodium using the Spectr AA 220 model Atomic Absorption Spectrometer (AAS) from Varian Manufacturers. The standard concentrations of 0.5, 1, 1.5 and 2 ppm were used. The AAS gave the concentration results in mg/L. Therefore, to obtain the mineral content in mg/100 g the calculation below was followed [24].

$$\text{Mineral} = \frac{[\text{Concentration- blank (mg/L)}] \text{ x V flask (L)}}{\text{Sample weight (g)}} \text{ x } 100$$

For the determination of phosphorus, 0.5 g of the samples and lyophilised brown bread reference material were weighed into the crucibles, including the blank, and the crucibles were placed in a muffle furnace for 5 hours at 525 ℃. The crucibles were, then, removed from the furnace and cooled to room temperature in a desiccator. Distilled water (5 ml) and 5 ml of 12 M HCl were added to the samples, the crucibles were covered with the watch glasses and the contents boiled carefully for 5 minutes on a hot plate. The contents were, then, filtered into 100 ml volumetric flasks. The crucibles and inner surface of the watch glass was rinsed with 5 ml hot distilled water 4 times, and the content was filtered through into the volumetric flask. The flask was cooled to room temperature and the solution neutralized by adding 50% KOH solution until the solution was slightly opalescence. HCl was added dropwise until the opalescence disappeared. The solution was left to cool to room temperature and, then, diluted to 100 ml with distilled water. The treated solutions (1 ml) were pipetted into 50 ml volumetric flasks and diluted to 15 ml with deionised water. Molybdite-ascorbic acid solution (20 ml) was added to test solutions in 50 ml volumetric flasks and also added to phosphorus standard solutions of 0, 0.01, 0.02, 0.04 and 0.06 mg P (with 1 ml 0.01 mg P/ml stock standard solution into 100 ml volumetric flask), and the contents were swirled. The flasks were closed by placing filter paper strips at the stoppers so that they were not tightly closed, and they were placed in a vigorously boiling water bath for exactly 15 minutes. The flasks were, then, cooled and filled to the 50 ml mark with deionised water and mixed. The treated solutions were determined for phosphorus using the Genesys 180 model UV Visible Spectrophotometer from Thermoscientific Manufacturers at 827 nm measurement wavelengths. One beam was used, and the Spectrophotometer ran using the Vision Lite Scan programme. The results were recorded in mg/g [24].

F. Statistical Analyses

All determinations were made in triplicates and the average values and standard deviations were reported for each sample. The data generated through proximate and mineral analyses for the seed samples obtained from the two locations were compared and analysed using the two tailed t-test ($p \leq 0.05$).

III. Results And Discussion

A. Proximate Composition

Moisture content of False Mopane seeds from Kasane was 9% while moisture content of the seeds from Shakawe was 8.48% (Table 1). However, this difference was not statistically significant ($P > 0.05$). Moisture content recorded in this study is in line with the findings of Maguire [14] who reported moisture content of 9.1g/100g for *G. coleosperma* seeds collected from Makapangat, South Africa. Moisture content of any food is an index of its water activity and is used as a measure of stability and susceptibility to microbial contamination hence spoilage [25]. This high moisture content also implies that dehydration would increase the relative concentrations of other food nutrients and, therefore, improve the shelf-life of the seeds. Moisture content determination in seeds is also important because seed moisture content has a major effect on the storage life of the seeds. Therefore, moisture content is used to make a reasonably accurate prediction of the possible storage life of the seeds.

TABLE 1. PROXIMATE COMPOSITION OF *GUIBOURTIA COLEOSPERMA* SEEDS COLLECTED FROM SHAKAWE AND KASANE

Parameter (%)	False Mopane seeds	
	Shakawe	**Kasane**
Moisture	8.48 ± 0.29	9.00 ± 0.10
Crude fat	9.24 ± 0.31[a]	10.17 ± 0.37[b]
Crude fiber	4.72 ± 0.60[a]	7.13 ± 0.21[b]
Crude protein	15.34 ± 0.48[a]	16.44 ± 0.43[b]
Ash content	2.40 ± 0.02[a]	2.45 ± 0.02[b]
Total carbohydrate	59.81 ±1.00[a]	54.80 ± 0.58[b]
Energy (kcal/100g)	383.80 ± 4.81	376.50 ± 2.22

Means that are followed by different superscript letters in the same row are significantly different at 0.05 significance level. The values in the Table are means and standard deviations of triplicate observations.

Proteins function as enzymes, hormones, and antibodies as well as transport and structural components, and they are required for structure and proper functioning of the body. The crude protein contents of the seeds from Shakawe and Kasane were 15.34% and 16.44%, respectively (Table 1). False mopane seeds from Kasane had a significantly higher ($P < 0.05$) protein content than those from Shakawe (Table 1). This might be due to genetic variations (varietal difference) brought about by the adaptations to the geographical locations of the tree species from which the different seed samples were collected. The crude protein content reported by Maguire [14] for False Mopane seeds from South Africa and Mojeremane and Kopong [6] for seeds of the same species were 14.3% and 14.5%, respectively, and are lower than the values observed in the present study. The crude protein content is the second most abundant proximate component of the seeds next to carbohydrates, and this suggests that the seeds are important sources of proteins, which could help alleviate protein deficiencies of rural communities. Pumpkin seeds are considered one of the seeds with high levels of proteins (30.3 g/100 g) [26] and the maximum amount of crude protein recorded in this study is 16.44 g/100 g, which may imply that the False Mopane seeds have a potentially significant amount of protein to be considered as protein-rich seeds.

The crude fat content of seeds collected from Kasane (10.17%) was significantly higher ($P < 0.05$) than those collected from Shakawe (9.24%) (Table 1). These values are higher than the values (8%) reported by Maguire [14] for seeds of False Mopane from South Africa and 6.5% reported by Mojeremane and Kopong [6] for crude fat content of False Mopane seeds. This difference may be due to the differences in the geographical conditions where the False Mopane trees were grown or the differences in the genetic makeup of the seeds. The fat content of the seeds of False Mopane is lower than that of the common high fat content wild seeds of Botswana, i.e. *Tylosema esculentum* (Burch.) A.Schreib. (called *Morama* in Setswana) (24-48%) [27]. The seeds of False Mopane are still potential sources of oil extraction, and they could serve as a viable and

sustainable oil option for rural communities if improvements are made in the oil extraction method from the seed [28].

The crude fiber content of the seeds from Kasane (7.13%) was significantly higher ($P < 0.05$) than seeds obtained from Shakawe (4.72%) (Table 1). Results on the fiber content of seeds from Shakawe agree with the results obtained by Maguire [14] who reported fiber content of 4.4% for False Mopane seeds from South Africa. According to Whitbread [29], sunflower seeds, peanuts and chestnuts have 9%, 8% and 5% fiber content, respectively, and are considered as seeds with the highest fiber content. This implies that False Mopane seeds can also be considered as producing seeds with higher fiber content since 7.13% crude fiber was recorded in this study for seeds collected from Kasane. Seeds are particularly rich in dietary fiber, and these fiber contents are good in the management of diabetes mellitus. Fiber can also help to keep blood sugar levels under control, and it binds to cancer causing chemicals, keeping them away from the cells lining the colon, providing another line of protection from colon cancer [30].

The ash content of the seeds from Kasne (2.45%) was significantly higher ($P < 0.05$) than the that of seeds obtained from Shakawe (2.4%) (Table 1). The difference in the ash content was further analyzed to determine the types and amounts of minerals present in the False Mopane seeds (Table 2). The results of the ash content of False Mopane seeds obtained in the present study are consistent with those of Maguire [14] who reported an ash content of 1.9% for *G. coleosperma* seeds collected from South Africa. The seeds of False Mopane had a significant amount of ash, and the ash content helps in determining the amount and type of minerals present in various food items.

Carbohydrates make up the largest proportion of the False Mopane seed regardless of the differences in the collection localities (Table 1). False Mopane seeds collected from Shakawe had significantly higher ($P < 0.05$) carbohydrate content (59.8%) than those collected from Kasane (54.8%) (Table 1). These results are lower than the carbohydrate content (62.3%) reported by Maguire [14] for seed of False Mopane collected in South Africa. The seeds of False Mopane have, therefore, a high carbohydrate content and, thus, they could, potentially, serve as a good source of energy in human nutrition.

No significant difference ($p > 0.05$) was observed in gross energy content between seeds collected from Shakawe (383.8 kcal/100 g) and Kasane (376.5 kcal/100 g) (Table 1). The results obtained from both seed sources are consistent with the findings of Maguire [14] who reported that False Mopane seeds from South Africa contained 1589 KJ/100 g (379.78 kcal/100 g). The present results indicated that False Mopane seeds can serve as a good source of energy for the human body.

B. Mineral Contents

Except for zinc, potassium and phosphorous, significant differences ($P < 0.05$) were observed for all the other minerals (iron, magnesium, calcium and sodium) between False Mopane seeds collected from Kasane and Shakawe (Table 2). The values for iron, magnesium, calcium and sodium were significantly higher ($P < 0.05$) for seeds collected from Kasane than those collected from Shakawe (Table 2). Potassium was the predominant mineral in the seeds with 468.69 and 460.86 mg/100 g in Shakawe and Kasane seeds, respectively, followed by calcium with 316. 7 and 367.59 mg/100 g in Shakawe and Kasane seeds, respectively, and Magnesium with 116.8 and 173.7 mg/100 g in Shakawe and Kasane seeds, respectively. The least predominant mineral in the seeds was phosphorus with 1.35 and 1.45 mg/g in Shakawe and Kasane seeds, respectively.

Mineral nutrients are usually obtained from the soil through plant roots, but many factors can affect the efficiency of nutrient acquisition, such as the chemistry and composition of certain soils, which can make it harder for plants to absorb nutrients and the nutrients may not be available in certain soils or may be present in forms that the plants cannot use [31]. Therefore, differences in soil properties like water content, pH, and compaction may be the reason for variations in mineral content of the seeds collected from Shakawe and Kasane. The False Mopane seeds collected from Shakawe and Kasane have exhibited significant amounts of minerals that can make them valuable sources of minerals for human nutrition.

Minerals are elements in food that the human body needs to develop and function normally. The minerals analysed in the study (iron, zinc, calcium, potassium, magnesium, phosphorus and sodium) are essential for health. According to the Oria et al. [32], calcium is stored in bones and teeth to make and keep them strong. Iron is a part of hemoglobin protein that transports oxygen from the lungs to the tissues. Magnesium helps the body regulate muscles, nerves, blood sugar and blood pressure. Phosphorus helps keep bones healthy and blood vessels working. Potassium promotes proper functioning of the cells, nerves and muscles. Zinc helps the body fight off invading bacteria and viruses, and sodium also helps with the proper functioning of nerves, muscles and balances body fluids. Each mineral has a daily recommended intake value for individuals to achieve adequate mineral intake and avoid toxicity due to high doses of minerals.

The seeds of False Mopane could serve as good sources of magnesium, iron, zinc, calcium and potassium as their daily recommended intakes are 310, 8, 8, 1000 and 3400 mg/day, respectively [32]. This means that the False Mopane seeds can provide 174.65 mg/100 g Mg, 3.34 mg/100 g Fe, 2.96 mg/100 g Zn, 367.59 mg/100 g Ca and 468.69 mg/100 g K, which contribute 56% Mg, 41.75% Fe, 37.25% Zn, 36.76% Ca and 13.79% K of the daily recommended intake. However, the seeds of False Mopane cannot serve as good sources of sodium and phosphorus as they provide less than 1% of the 1,200 mg/day Na and 700 mg/day P of the daily recommended intakes of sodium and phosphorus.

TABLE 2. MINERAL CONTENT OF FALSE MOPANE SEEDS COLLECTED FROM SHAKAWE AND KASANE

Mineral content	False Mopane seeds	
	Shakawe	Kasane
Zinc (mg/100 g)	2.96 ± 0.53^{a}	2.53 ± 0.31^{a}
Iron (mg/100 g)	2.40 ± 0.27^{a}	3.34 ± 0.18^{b}
Magnesium (mg/100 g)	116.80 ± 2.82^{a}	173.65 ± 5.83^{b}
Potassium (mg/100 g)	468.69 ± 19.28	460.86 ± 10.53
Calcium (mg/100 g)	316.70 ± 21.15^{a}	367.59 ± 15.37^{b}
Sodium (mg/100 g)	1.21 ± 0.67^{a}	3.51 ± 0.44^{b}
Phosphorus (mg/g)	1.35 ± 0.04^{a}	1.45 ± 0.12^{a}

Means that are followed by different superscript letters in the same row are significantly different at 0.05 significance level. The values in the Table are means and standard deviations of triplicate observations.

IV. CONCLUSIONS

The study revealed that the seeds of False Mopane from Kasane and Shakawe showed significant differences in most of the proximate parameters and mineral contents. They had significantly different crude fat, crude protein, crude fiber, total carbohydrate and ash contents. They also significantly differed in their iron, magnesium, calcium and sodium contents, suggesting that the different locations from which the seeds were collected influenced the nutritional composition of the seeds. This study also showed that the seeds of False Mopane collected in Botswana have the potential to contribute significant nutrients to human nutrition and promote good health. Just like many wild edible plants found in Botswana, the seeds of False mopane plant are, often, underutilized and overlooked as potential food rich in nutrients. However, the levels of carbohydrates, crude protein, crude fiber, potassium, calcium, iron and magnesium analyzed in these seeds indicated that False Mopane seeds could be valuable in the diets of the people of Botswana. These seeds would positively contribute essential nutrients in the diet if utilized and, thereby, promote good health of people, especially in rural villages in northern Botswana where False Mopane occurs naturally and also contributes to the diversification of the diets of the people. Future studies on False Mopane seeds could focus on oil production potential of the seeds, quality characteristics of the oil and determination of the amino acid profile.

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