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RESEARCH ARTICLE

Nutritional and Phytochemical Properties of Morula (*Sclerocarya birrea*), Moretologa (*Ximenia americana*), Mowana (*Adansonia digitata* L.) and Mogose (*Bauhinia petersiana*): Indigenous Plants in Botswana

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ABSTRACT

Sub-Saharan Africa continues to struggle with food insecurity, which has been made worse by issues like the COVID-19 pandemic and climate change. In the African continent, plants have been used for food and medicine for many generations. Morula (*Sclerocarya birrea*), Moretologa (*Ximenia americana*), Mowana (*Adansonia digitata* L.), and Mogose (*Bauhinia petersiana*) are among the most consumed indigenous plants in Botswana. The objective of this study was to analyse nutritional and phytochemical profiles of these indigenous plants. The results showed that protein content ranged between 1.80% (Morula) and 25.54% (Mogose). The highest fat content of 14.29% was observed in Mogose seeds. Mowana proved to be rich in calcium compared to other plants. Manganese was detected only in Mogose samples. Phytochemical screening showed the presence of various phytochemicals. Moretologa proved to be a good source of beta carotene (419.33 μg/100 g). The plants contained different amounts of ascorbic acid; 163.83, 141.59, 24.78, and 3.00 mg/100 g were recorded in Mowana, morula, Moretologa, and Mogose, respectively. Total phenols ranged between 7.98 mg/100 g (Moretologa) to 14.3 mg/100 g (Mowana). The four indigenous plants proved to have good nutritional qualities and their increased consumption may contribute positively towards efforts to attain food security in Botswana. Additionally, the plants are good sources of phytochemicals, and they may aid in the discovery of novel drugs and medicines and be useful in formulation of functional foods.

Keywords: Food security, Indigenous plants in Botswana, Nutrition, Phytochemicals.

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1. Introduction

Food insecurity remains to be a challenge in developing nations in Sub-Saharan Africa, especially after the Covid-19 pandemic, which has resulted in economic downturns [1]. Furthermore, [2] emphasised how the agriculture sector has been impacted by climate change, leading to an increase in malnutrition in certain African nations, particularly among women and children. It is widely acknowledged that indigenous plants play a significant role in reducing food and nutrition insecurity, especially in Sub-Saharan Africa. These plants contribute towards the diversification of food sources and food intake options, thus improving human nutrition at household level [3]. In most African countries including Botswana traditional medicine obtained from native plants is essential in the health care delivery in terms of diagnosis, prevention, and treatment of various ailments [4]. Reference [5] reported that consumption of edible indigenous plants is linked to reduced risk of non-communicable diseases such as cancer, diabetes, stroke, and hypertension. This may be attributed

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to their inherent natural antioxidants, which may remedy the damage caused by oxidative stress.

Indigenous plants like Morula (*Sclerocarya birrea (*A. Rich.) Hochst*.)*, Moretologa (*Ximenia americana L.*), Mowana (*Adansonia digitata* L.) and Mogose (*Bauhinia petersiana* Bolle) are some of the important plants to the rural communities in Botswana. Morula is a rich source of Vitamin C and possesses high antioxidant activity [6]. Various products can be processed from Morula, including jam, jelly, juice, and alcoholic beverages [7]. Moretologa bears yellowish, oval edible fruits [8], which can be used in the treatment of constipation [9]. Mowana, commonly known as baobab, bears woody shell fruits containing brown seeds covered in whitish acidulous pulp [10]. The fruit pulp can be used to process various edible products, and it is also utilised as a fermenting agent in traditional brews [11]. Mogose is a wild legume which has received considerable attention in recent years because of its of socio-economic importance to rural communities. Roasted seed powder is used to make porridge, and the seeds are eaten as relish since they are a good source of protein [12].

In Botswana and other developing nations, indigenous plants are vital food sources for rural communities, especially during times of food scarcity. Understanding the nutritional composition of these significant native plant resources is essential because it could lead to a rise in the local communities' use of them. Increased consumption of indigenous plants may contribute positively to Botswana's efforts to attain food security. Moreover, both rural and urban dwellers use some parts of indigenous plants as sources of traditional medicine. Understanding their photochemical composition could facilitate the identification of new pharmaceuticals and medications as well as their use in the development of functional foods. Thus, the objective of this study was to examine the photochemical and nutritional characteristics of local woody plant species.

2. Materials and Methods

2.1. Sample Collection and Preparation

Moretologa, Mowana, Morula and Mogose were collected from Shakawe (18.3673° S, 21.8390° E), Mosu (21.2177° S, 26.0196° E), Kopong (24.4771° S, 25.8906° E) and Malwelwe (23.9871° S, 25.2487° E) in Botswana, respectively.

Mature Mogose seeds were removed from the pods and cleaned. The seeds were milled with an industrial blender to obtain a powder, which was packed in polyethylene bags and kept in refrigerated storage until use. Moretologa pulp was obtained by using a fruit pulper after skin removal. The pulp was packed and sealed in polyethylene bags and stored in frozen (−20 °C) conditions. Ripe Morula fruits were collected and washed. The pulp was extracted using a fruit pulper, poured and sealed in polyethylene bags, and stored in frozen conditions. Baobab pulp was obtained by breaking the baobab fruit to remove the outer cover. Pestle and mortar were used to separate the dry pulp from the seeds. The pulp was passed through a sieve to obtain a fine powder, which was packed in polyethylene bags and stored in refrigerated conditions.

2.2. Proximate Composition

Moisture, fat, protein, and ash content were determined following the methods described by reference [13] (methods 925.10, 920.39, 920.87, and 923.03, respectively). Carbohydrates were calculated by difference using the following formula:

$$100 - moisture\,(g) + fat\,(g) + protein\,(g) + ash\,(g) \qquad (1)$$

Results were expressed as g/100 g on dry matter basis. The Atwater conversion factor was used to calculate energy content of the samples as:

$$Energy\,(kcal/100\,g) = 4 \times protein\,(g) + 4 \times carbohydrates\,(g) + 9 \times fat\,(g) \qquad (2)$$

2.3. Mineral Analysis

Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer Analyst 800, Shelton, USA) was used for the determination of minerals. The procedure described by reference [14] was followed. The samples (1 g) were weighed into porcelain crucibles and ashed at 550 °C for 6 hours. 10 ml of 3N HCl was added to dissolve the obtained ash. The mixture was then filtered using a 0.45 μm filter, and the filtrate was made up to 400 ml with deionised water. Minerals (Fe, Ca, Mn, Zn, and Na) were determined by spraying the solution into the flame with the AAS having a flame atomiser unit and recommended conditions were regulated for each element determined. At least five external standards of different concentrations for each mineral were used to plot the calibration curve used for the quantification of the minerals. Flame was produced by acetylene (2 L/minute) as fuel gas and air (7 L/minute) as the oxidant. To prevent ionic interferences in sodium and calcium analysis, 1 g/100 ml $LaCl_3$ was added to the sample solutions in pursuit of the device producer. The wavelengths used for the analysis were 213.9 nm (Zn), 248.3 nm (Fe), 279.5 nm (Mn), 422.7 nm (Ca), and 589.0 nm (Na).

2.4. Phytochemical Screening

Samples were extracted for qualitative analysis following the methods described by [15]. Samples were extracted in five organic solvents (water, ethanol, methanol, acetone and n-hexane). A 5 g sample of each indigenous plant was mixed with each of the five solvents, and the mixture was left to stand at room temperature for 2 hours. The mixture was then put in a water bath at 60 °C for 30 minutes. The mixture was then filtered with a Whatman filter paper number 1, and the filtrate was centrifuged at 2500 rpm for 15 minutes, and the resultant filtrates were used for phytochemical screening. The various phytochemical tests were conducted as follows:

- *Coumarins:* 2 ml of extract was mixed with 3 ml of 10% sodium hydroxide. Yellow colour formation indicated the presence of coumarins [16].
- *Oxalates:* A few drops of glacial ethanoic acid were added to 3 ml of extract. Presence of oxalates will be shown by a greenish black colouration.

- *Steroids:* Chloroform (10 ml) was used to dissolve 1 ml of extract. 10 ml of concentrated sulphuric acid was added by the sides of the test tube. Presence of steroids was depicted by a reddish upper layer while the lower sulphuric acid layer turned yellow with green fluorescence [17].
- *Saponins (Foam test):* The foam test was conducted according to reference [18]. 5 ml of distilled water was added to a 2 ml extract in a test tube, and the mixture was shaken vigorously. Foam persistence indicates the presence of saponins.
- *Terpernoids (Salkowski's test):* 2 ml of chloroform was added to 5 ml of extract, and 3 ml concentrated sulphuric acid was further added carefully to form a layer. A positive result was depicted by a reddish-brown colouration at the mixture interface [19].
- *Tannins:* Three drops of 1% lead acetate were added to a 2 ml extract, and the formation of a yellowish precipitate indicated the presence of tannins [16].
- *Phenolic compounds:* Ferric chloride test was conducted according to reference [13] to determine the presence of phenolic compounds. 2 ml of extract was mixed with 5% aqueous ferric chloride. Formation of a deep blue or black colour was taken as a positive result for presence of phenolic compounds.
- *Flavonoids:* 2 ml of sample was initially filtered, and to the filtrate, 5 ml of dilute ammonia was added, followed by 1 ml of concentrated sulphuric acid. The presence of flavonoids was indicated by the development of a yellow colour that disappears on standing [20].

2.5. *Total Phenols*

Phenolic extracts were prepared by taking 0.5 g sample and mixing it with ethanol water (50:50). The mixture was then put in a shaking water bath for 20 minutes and then centrifuged (Heraeus biofuge Primo R centrifuge model no. 7590) at 4200 rpm for ten minutes and the obtained supernatant was used for analysis.

Total phenols were analysed following the method described by [21]. A sample of 0.4 ml was taken and mixed with 1.6 ml of 7.5% sodium carbonate solution, followed by 2 ml of Folin-Ciocalteu reagent diluted 10 times (1:10). The mixture was then incubated for an hour at room temperature and absorbance was taken at 765 nm. Gallic acid was used for the standard calibration curve, and results were expressed as gallic acid equivalent (GAE)/g.

2.6. *Vitamin C Analysis*

Vitamin C was estimated by 2,6 dichlrophenol-indophenol method as described by reference [22]. The samples were extracted in 3% metaphosphoric acid solution and titrated against a dye solution till a pinkish colour persisted for a few seconds, and ascorbic acid was expressed as mg of ascorbic acid per 100 g sample.

2.7. *Beta-Carotene*

Beta carotene was analysed following methods described by [22]. Samples (5 g) were extracted in acetone and the mixture transferred to a separating funnel to separate the coloured portion after adding petroleum ether and 5% sodium sulphate solution. The optical density was taken at 452 nm and Beta-carotene standard was used to make the calibration curve.

2.8. *Statistical Analyses*

All analysis was conducted in triplicate. The data was subjected to one-way Analysis of Variance (ANOVA) using IBM SPSS 2022. LSD test was used to compare means at 95% confidence interval and the results presented as mean ± standard deviation. The qualitative phytochemical screening results were presented by indicating the presence or absence of a phytochemical extracted in a specific solvent.

3. Results and Discussion

Results shown in Table I depict that there was a significant difference in all the nutritional parameters under study for all the indigenous plants. The highest moisture

TABLE I: Proximate Composition of Mogose (Bauhinia Petersiana), Morula (Sclerocarya Birrea), Moretologa (Ximenia Americana) and Mowana (Adansonia Digitata) Per 100 G on Dry Matter Basis

Plant	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrates (%)	Energy (kcal/100 g)
Mogose	8.30 ± 0.18^{c}	3.22 ± 0.15^{a}	14.29 ± 0.03^{d}	25.64 ± 0.32^{d}	48.54 ± 0.56^{a}	424.61 ± 0.68^{d}
Morula	11.92 ± 0.03^{d}	3.53 ± 0.25^{a}	1.39 ± 0.04^{b}	5.78 ± 0.19^{b}	77.38 ± 0.29^{c}	345.18 ± 0.86^{a}
Moretologa	7.59 ± 0.07^{b}	4.17 ± 0.14^{b}	0.87 ± 0.02^{a}	12.62 ± 0.10^{c}	74.74 ± 0.12^{b}	357.27 ± 0.21^{b}
Mowana	5.22 ± 0.17^{a}	4.79 ± 0.05^{c}	1.77 ± 0.03^{c}	1.80 ± 0.09^{a}	86.43 ± 0.22^{d}	368.84 ± 0.87^{c}

Note: All values are mean ± SD and means with different superscripts within a column are significantly different ($p < 0.05$).

TABLE II: Mineral Composition of Mogose (Bauhinia Petersiana), Morula (Sclerocarya Birrea), Moretologa (Ximenia Americana) and Mowana (Adansonia Digitata)

Plant	Fe (mg/kg)	Zn (mg/kg)	Na (mg/kg)	Ca (mg/kg)	Mn (mg/kg)
Mowana	10.92 ± 0.06^{a}	4.61 ± 0.71^{a}	185.31 ± 53.29^{b}	1870.58 ± 94.51^{b}	*ND
Mogose	37.29 ± 6.03^{b}	35.32 ± 0.53^{b}	226.49 ± 1.07^{b}	1050.66 ± 4.72^{ab}	3.57 ± 0.52^{a}
Morula	22.46 ± 3.31^{a}	5.73 ± 0.66^{a}	96.94 ± 3.04^{a}	345.84 ± 2.11^{a}	ND
Moretologa	15.21 ± 0.69^{a}	6.98 ± 0.37^{a}	109.41 ± 8.68^{b}	62.58 ± 1.22^{a}	ND

Note: *Not detected. All values are mean ± SD and means with different superscripts within a column are significantly different ($p < 0.05$).

TABLE III: Phytochemical Screening of Mogose (Bauhinia Petersiana), Morula (Sclerocarya Birrea), Moretologa (Ximenia Americana) and Mowana (Adansonia Digitata)

Mowana (n = 3) Phytochemicals	Water	Methanol	Ethanol	Acetone	n-hexane
Terpernoids	+	+	+	–	–
Steroids	+	+	+	+	–
Tannins	–	+	–	–	–
Oxalate	–	–	–	–	–
Coumarins	+	–	–	–	–
Phenols	–	+	+	–	–
Saponins	+	–	–	–	–
Flavonoids	+	+	+	+	–
Mogose (n = 3) Phytochemicals	Water	Methanol	Ethanol	Acetone	n-hexane
Terpernoids	+	+	+	+	+
Steroids	+	–	–	+	+
Tannins	–	+	–	+	–
Oxalates	–	–	–	–	–
Coumarins	+	+	–	+	–
Phenols	+	+	+	–	–
Saponins	+	+		–	–
Flavonoids	+	+	+	–	–
Moretologa (n = 3) Phytochemicals	Water	Methanol	Ethanol	Acetone	n-hexane
Terpernoids	+	+	+	+	–
Steroids	–	–	–	–	–
Tannins	–	+	–	–	–
Oxalate	–	–	–	–	–
Coumarins	–	–	+	+	–
Phenols	–	+	+	+	–
Saponins	–	–	–	–	–
Flavonoids	–	+	+	–	–
Morula (n = 3) Phytochemicals	Water	Methanol	Ethanol	Acetone	n-hexane
Terpernoids	–	+	+	+	–
Steroids	+	–	+	–	–
Tannins	–	–	–	–	–
Oxalates	–	–	–	–	–
Coumarins	–	–	–	–	–
Phenols	+	+	+	–	–
Saponins	+	+	–	–	+
Flavonoids	–	+	+	+	–

Note: + = present; − = absent; n = number of samples used in each test.

content (11.92%) was recorded for Morula, and Mowana had the lowest moisture content (5.22%). The fat content of the samples ranged between 0.87% (Moretologa) to 14.79% (Mogose). This also explains the high energy value of 424.61 kcal/100 g recorded for Mogose compared to the other plants. Mowana contained 4.79% ash which is slightly higher than 4.33% ash content reported in Sudanese baobab samples by [23].

There has been an increased interest in plant proteins especially as sources of bioactive peptides as various studies have recognised their role in disease prevention and health promotion [24]. Additionally, plant proteins may be a sustainable solution compared to animal proteins, which have a noticeable carbon footprint [25]. Mogose with a high protein (25.64%) makes it a good candidate for extraction of bioactive peptides.

Table II shows that Mogose has the highest zinc and iron contents and its significantly different from other indigenous plants. Sodium content ranges from 96.94 mg/kg (morula) and 226.49 mg/kg (Mogose). Manganese was only detected in Mogose, and the recorded value (3.57 mg/kg) was lower than that of 1.9 mg/100 g reported by [26]. Inclusion of fruits and vegetables in the diet has positive effects including disease prevention due to their inherent fibre, protein and micronutrients including minerals [27]. If manganese is deficient in the diet it may result in bone demineralisation and hypocholestrolemia [28].

Calcium is essential for bone formation and muscle movement [29]. Mowana had the highest calcium content of 1870.58 mg/kg. Mowana is a rich source of calcium compared to commonly consumed fruits like banana

TABLE IV: Total Phenols, Beta Carotene and Ascorbic Acid Contents of Mogose (Bauhinia Petersiana), Morula (Sclerocarya Birrea), Moretologa (Ximenia Americana) and Mowana (Adansonia Digitata)

Plant	Total phenols (mg/100 g) GAE	B-carotene (µg/100 g)	Ascorbic acid (mg/100 g)
Mogose	10.1 ± 0.01^{b}	287.10 ± 3.9^{b}	3.00 ± 1.41^{a}
Mowana	14.3 ± 0.35^{d}	38.78 ± 1.57^{a}	163.83 ± 2.43^{d}
Moretologa	7.98 ± 0.28^{a}	419.33 ± 2.36^{c}	24.78 ± 1.40^{b}
Morula	12.0 ± 0.14^{c}	29.33 ± 0.79^{a}	141.59 ± 2.81^{c}

Note: All values are mean ± SD and means with different superscripts within a column are significantly different ($p < 0.05$).

(4.64 mg/100 g), apple (506.52 mg/kg) and mango (11.0 mg/100 g) according to [30]–[32].

Plants provide medicines with various biological effects. Phytochemicals like polyphenols, saponins, carotenoids and flavonoids are present in plant sources making plants a cheaper and important source for therapeutic compounds [33], [34]. The phytochemical screening results (Table III) show that mowana tested positive for all the phytochemicals extracted in various solvents except for oxalates. Saponins, oxalates and steroids were not detected in any of Moretologa fruit extracts. Reference [35] however noted the presence of saponins in aqueous and ethanolic extracts of *X. americana* stem bark and steroids were only detected in the ethanolic extract. Tannins were detected in the other three plant samples except for Morula. Tannins can be used in the treatment of burns and other wounds and promote vascular health [36].

Ascorbic acid, or Vitamin C, is water soluble and possesses various biochemical roles [37]. As an antioxidant, it has the capacity to hinder oxidative degradation due to reactive oxygen species [38]. Results (Table IV) show that Mowana pulp contained the highest amount of Vitamin C (16.83 mg/100 g) while Mogose contained the lowest of 3.0 mg/100 g. Morula pulp contained 141.59 mg/100 g, which is almost similar to 141.29 mg/100 g reported by [39].

A lower Vitamin C content was reported in *X. americana* by reference [40] compared to the 141.5 mg/100 g reported in this study. Humans cannot synthesise Vitamin C due to the absence of L-glucono-1,4-lactone oxidase and as such they need to get Vitamin C from diet. Therefore Morula, Mowana and Moretologa are good sources of Vitamin C which may be included in the diet [41], [42]. Samples under study contain beta carotene in varying amounts ranging from 38.37 µg/100 g (Mowana) and 419.33 µg/100 g (Moretologa). Carotenoids are brightly coloured (red, orange, and yellow) pigments though some are colourless (phytoene and phytofluene). Carotenoids have various benefits when included in the diet such as being anti-cancer and cardiovascular disease prevention [43]. Polyphenols are produced as secondary metabolites in plants and are classified as flavonoids, phenolic acids, lignin, and stilbene [44]. There was a significant difference in the total phenols among all the other samples. Comparatively to the Mogose sample under study reference [45] recorded a lower total phenol content of 0.08 mg/g.

4. Conclusion

The four indigenous plants under study have good nutritional qualities and possess various phytochemicals. Some of these plants are still underutilised, especially their inclusion as sources of phytochemicals in the formulation of functional foods. As such, this is a gap to be bridged.

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Conflict of Interest

There is no conflict of interest declared by the authors.

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