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MZT, MAFM, and MAS designed the experiments; MZT, MAFM, MDHS, MSAS, and MM conducted the experiments; KKB, MZT, SNI, MZAR, and MAS analyzed the data; MZT, KKB, and MAS wrote the manuscript; MZT and MAFM contributed equally to this work

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ORIGINAL RESEARCH PAPER in HORTICULTURAL PLANTS

Nutritive Value of BJRI Mesta-2 (*Hibiscus sabdariffa* L.) Leaves

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Abstract

The genus *Hibiscus* has more than 300 globally distributed species. This plant is well known for its bast fiber biogenesis, while its nutritional and medicinal values are largely ignored. Consequently, the nutritional properties of the Roselle variety, BJRI mesta-2, are unknown. Therefore, this study was carried out to analyze the nutritional composition of our selected Roselle tissues to support the nutritional requirements for humans in early summer in Bangladesh. Leaves were found to be a good source of calcium (2.7%), magnesium (1.6%), ash (7.34%), vitamin A (165.9%), and vitamin C (94.88%), whereas calyx was the potential source of potassium (1.9%), iron (422%), manganese (126%), and moisture (87.45%). Roselle seeds also have edible oil-producing capabilities, along with their nutritional properties. Our results indicate that BJRI mesta-2 can be an additional source of leafy vegetables, along with its herbal tea and edible oil contents.

Keywords

Hibiscus sabdariffa; minerals; vitamins; ash; moisture

1. Introduction

Roselle or mesta (*Hibiscus* spp.) is native to tropical Africa and has more than 300 species distributed worldwide (Balarabe, 2019; Rao, 1996). This plant is primarily cultivated for bast fiber production (Kalita et al., 2019); however, different parts of Roselle are also used for various purposes. Fresh leaves and calyx are used for making salads, tea, jams, and many other products (Dy Phon, 2000, pp. 343–344; Islam et al., 2016). Hot and cold beverages and food colorants are also prepared from dried calyx, and Roselle calyx tea can be used as a substitute for herbal tea (Maganha et al., 2010; Mollah et al., 2020). Heated leaves are used as medicine for curing foot cracks and as lotion in the treatment of sores and wounds (Morton, 1987). In addition, Roselle seeds are widely used in industries such as bakery, poultry, and edible oil production (Al-Wandawi et al., 1984; Karma & Chavan, 2016).

Roselle contains lipids, proteins, carbohydrates, and vitamins (Choudhary et al., 2013; Grubben & Denton, 2004; Odhav et al., 2007; Steyn et al., 2001) and the leaves contain more moisture than the calyx and seeds (Balarabe, 2019; Karma & Chavan, 2016). The calyx is the most essential part of the Roselle plant and contains valuable components such as malic acids, anthocyanins, ascorbic acids, antioxidants, and minerals (Javadzadeh & Saljooghianpour, 2017; Mollah et al., 2020). Considerable amounts of fat and proteins have been found in Roselle seeds (Shaheen et al., 2012; Tounkara et al., 2013). Major fatty acids such as palmitic, oleic, linoleic, and steric acids have been reported in Roselle seeds (El-Adawy & Khalil, 1994; Rao, 1996).

In Bangladesh, a number of vegetables are cultivated year-round; however, the availability of leafy vegetables is limited during the early summer (March to May)

(Tareq et al., 2019). Moreover, cultivar and geographical location influence the concentration of organic acids, minerals, amino acids, carotene, vitamin C, and total sugar present in the calyx, leaves, and seeds of Roselle (Cisse et al., 2009). Considering the above facts, this study was conducted to determine the nutritional composition of BJRI mesta-2 as a leafy vegetable and to examine the correlation and path coefficient analysis among the nutritional components.

2. Material and Methods

The experiment was conducted at the Jute Agriculture Experimental Station, Bangladesh Jute Research Institute (BJRI), Manikganj, Bangladesh (23.8644° N, 90.0047° E) from August to December 2019.

The altitude of the experimental plot was 4 m high, and the silt loam soil was classified as Old Brahmaputra-Jamuna flood plain (AEZ-8), with pH 6.7. The soil contained 1.6% organic matter, 0.08% total nitrogen, 12.31 mg kg^{-1} available P, 73.71 mg K 100 g^{-1} soil, and 20.93 mg kg^{-1} available S. The soil was prepared by plowing and cross-plowing with laddering. Urea, triple super phosphate, muriate of potash, gypsum, and zinc sulfate were added at 200 kg ha^{-1}, 25 kg ha^{-1}, 30 kg ha^{-1}, 45 kg ha^{-1}, and 12 kg ha^{-1}, respectively, in the experimental field. Half of the urea and all other fertilizers were applied during the final land preparation. The plot size was 4 m × 2 m, and the rows were spaced at 50 cm. Seeds of BJRI mesta-2 were sown in lines on August 10, 2019, with plants spaced at 8–10 cm. The rest of the urea was top-dressed 20 days after seed sowing. All intercultural operations were performed as recommended by Chowdhury and Hassan (2013). The experiment was arranged in a randomized complete block design with three replicates.

Calyx and leaf samples were collected on November 20, 2019, from 100-day-old plants. Seeds were collected 150 days after seed sowing. Calcium, magnesium, potassium, phosphorus, sulfur, sodium, iron, and manganese concentrations were analyzed using a wet digestion protocol (Pequerul et al., 1993). Moisture content was determined using the oven-drying method as described by Ranganna (1986). The ash content of different parts of the BJRI mesta-2 was measured using the procedure described by Association of Official Analytical Chemists (2016) using the following formula:

$$Ash\ content(\%) = \frac{W_3 - W_1}{W_2 - W_1} \times 100,$$

where, W_1 = dried weight of cooled porcelain crucible after oven drying at 105 °C for 10 min; W_2 = weight of porcelain crucible + pulverized plant sample; and W_3 = dried weight of plant samples at 250 °C for 1 hr and 550 °C for 7 hr.

Vitamin C was analyzed by titration using a 2,6-dichlorophenol indophenol dye solution as described by Ranganna (1986). Vitamin A was estimated using a standard protocol where macerated plant samples (0.5 g) were homogenized in 25 mL of acetone containing dimethyl sulfoxide solution and filtered. The filtered solution was made up to 100 mL and measured according to the method of Alasalvar et al. (2005).

Data were subjected to analysis of variance in MSTAT-C (Gomez & Gomez, 1984). The treatment means were separated with the least significant difference. The STAR statistical package (ver. 2.0.1; IRRI, Los Banos, Laguna, Philippines) was used to analyze variance and correlation and for path analysis.

3. Results

Mineral contents in different parts of Roselle plants varied significantly, as shown in Table 1. The highest calcium content was found in leaves and lowest in seeds; however, the calyx had intermediate concentrations. Leaves had the highest magnesium concentration, followed by the calyx and seed. The magnesium concentration of the leaves was twice that of the calyx (Table 1). The highest potassium content was found in the calyx and lowest in the seed; concentrations in the leaves were intermediate. Interestingly, seeds contained higher levels of phosphorus than the leaves and calyx. The sulfur content in leaves and calyxes was

Table 1 Mineral composition of dry BJRI mesta-2 calyx, leaves, and seed (%).

Tissue	Calcium	Magnesium	Potassium	Phosphorus	Sulfur	Sodium	Iron	Manganese
Calyx	1.3 ± 0.06 b	0.8 ± 0.01 b	1.9 ± 0.02 a	0.1 ± 0.01 b	0.6 ± 0.06 a	0.1 ± 0.06 a	422.0 ± 7.2 a	126.0 ± 3.8 a
Leaf	2.7 ± 0.2 a	1.6 ± 0.1 a	0.7 ± 0.1 b	0.7 ± 0.1 a	0.6 ± 0.05 a	0.1 ± 0.01 a	215.2 ± 1.1 b	97.8 ± 1.3 b
Seed	1.1 ± 0.12 b	0.1 ± 0.02 c	0.5 ± 0.1 b	0.9 ± 0.15 a	0.1 ± 0.03 b	0.1 ± 0.01 a	82.8 ± 2.7 c	37.6 ± 3.5 c
%*CV*	8.6	9.6	6.9	20.3	9.7	30.0	5.1	5.6
LSD	0.3	0.2	0.2	0.3	0.1	0.1	27.6	11.1

Values in columns followed by the same letter are not significantly different, $p \leq 0.05$, LSD.

Table 2 Correlation coefficients of minerals of BJRI mesta-2.

	Calcium	Magnesium	Potassium	Phosphorus	Sulfur	Sodium	Iron
Magnesium	0.92***						
Potassium	−0.48***	−0.09***					
Phosphorus	0.23	−0.17***	−0.94***				
Sulfur	0.50*	0.13*	−0.96***	0.90***			
Sodium	−0.36***	−0.14***	0.68**	−0.47	−0.66*		
Iron	−0.02***	0.37*	0.88**	−0.95***	−0.82**	0.55*	
Manganese	0.30*	0.65**	0.69**	−0.84***	−0.62*	0.40	0.94***

Correlation is significant at the * 0.05, ** 0.01, and *** 0.001 level.

Table 3 Path coefficient analysis showing direct and indirect effects of minerals of BJRI mesta-2.

	Calcium	Magnesium	Potassium	Phosphorus	Sulfur	Sodium	Iron	Manganese
Calcium	0.258	0.233	−0.139	−0.104	0.091	−0.033	−0.005	0.30*
Magnesium	0.237	0.253	−0.026	0.077	0.0237	−0.013	0.096	0.65**
Potassium	−0.124	−0.0228	0.290	0.428	−0.175	0.063	0.229	0.69**
Phosphorus	0.059	−0.043	−0.272	−0.455	0.164	−0.044	−0.248	−0.84***
Sulfur	0.129	0.032	−0.278	−0.410	0.182	−0.062	−0.214	−0.62*
Sodium	−0.093	−0.035	0.197	0.214	−0.120	0.094	0.143	0.40
Iron	−0.005	0.093	0.255	0.433	−0.149	0.051	0.261	0.94***

Correlation is significant at the * 0.05, ** 0.01, and *** 0.001 level.

not different and was very low in seeds. Calyx, leaves, and seeds had the same concentrations of sodium. The highest iron content was in the calyx and lowest in the seed; leaves had half the concentration of the calyx and three times that of the seed (Table 1). Similar to iron, manganese had the highest concentration in the calyx and lowest in the seed. These results indicate the importance of Roselle tissues as sources of different minerals.

The correlation coefficient revealed that calcium was significantly and positively correlated with most of the minerals such as magnesium, phosphorus, sulfur, and manganese, but negatively correlated with potassium, sodium, and iron (Table 2). Similarly, potassium, sodium, and iron were negatively correlated with the rest of the nutrients. These results clearly suggest that increasing or decreasing any nutritional component will proportionally change the total nutrient content. Path coefficient analysis indicated that among the minerals, potassium had the highest positive direct effect, followed by iron, calcium, and magnesium (Table 3). Only phosphorus had a direct negative effect on the minerals. This may indicate that the BJRI mesta-2 could provide potassium and iron to the human diet.

Percent moisture, ash, vitamin A, and vitamin C from fresh calyx and leaves varied (Table 4). The moisture content of the fresh calyx was higher than that of fresh leaves. There was more ash in fresh leaves than in fresh calyx (Table 4). The leaves

Table 4 Vitamin composition of fresh BJRI mesta-2 calyxes and leaves (%).

Tissue	Moisture	Ash	Vitamin A	Vitamin C
Fresh calyx	87.44 ± 2.16 a	3.88 ± 0.23 b	38.84 ± 1.1 b	58.30 ± 2.4 b
Fresh leaf	79.32 ± 1.4 b	7.34 ± 0.8 a	165.9 ± 4.2 a	94.88 ± 1.0 a
%*CV*	1.0	3.0	4.91	6.1
LSD	3.04	0.6	17.67	16.28

Values in columns followed by the same letter are not significantly different, $p \leq 0.05$, LSD.

Table 5 Correlation coefficients of vitamins of BJRI mesta-2.

Component	Moisture	Ash	Vitamin A
Ash	-0.99^{***}	1.00	
Vitamin A	-0.98^{***}	0.99^{***}	1.00
Vitamin C	-0.97^{***}	0.98^{**}	0.97^{***}

Correlation is significant at the ** 0.01 and *** 0.001 level.

Table 6 Path coefficient analysis showing direct and indirect effects of minerals of BJRI mesta-2.

Component	Moisture	Ash	Vitamin A
Moisture	0.01010101	−0.99	−0.00989899
Ash	−0.01000000	1.00	−0.01000000
Vitamin A	−0.00989899	0.99	−0.01010101

contained almost 4 times more vitamin A than the calyx (Table 4). Compared to fresh calyx, vitamin C was almost doubled in the leaves (Table 4). From these results, it can be concluded that fresh leaves of Roselle, rather than fresh calyx, may play an important role in the human diet.

There were significant correlations for all the studied characters (Table 5). Moisture content was significantly and negatively correlated with ash, vitamin A, and vitamin C levels. Ash was positively correlated with vitamin A and vitamin C levels. Vitamin A and vitamin C levels were significantly correlated with each other. From these results, it is highly likely that increasing the moisture content will negatively decrease the ash and vitamin content in both leaves and calyxes.
Path coefficient analysis indicated that ash had the highest positive direct effect, followed by moisture (Table 6). Vitamin A had a direct negative effect on moisture and ash.

4. Discussion

Roselle contains several essential minerals, including calcium, magnesium, phosphorus, potassium, iron, zinc, and manganese, which are critical for disease prevention (Cissouma et al., 2013; Nzikou et al., 2011; Rao, 1996). Roselle is unique in its nutritional characteristics as it contains high concentrations of vitamin C and anthocyanins (Islam et al., 2016).

Minerals play a significant role in various physiological processes, including cell division, cell elongation, activation of enzymes, and balancing acid-base concentration to build a strong structure for supporting the body as well as the metabolic activity of living organisms (Adediran et al., 2015; Arasaretnam et al., 2017; Fairbanks, 1999; Nielsen, 1999; Osborne & Voogt, 1978). Leafy vegetables contain most of the macro- and microminerals, along with vitamins (Aletor et al., 2002; Caunii et al., 2010; Krzepiłko et al., 2019). Our analysis found that calcium and magnesium contents were higher in the leaves (Table 1). The concentration of calcium is higher than that of the jute genotypes, however, lower than that of the other Roselle genotypes (Islam 2019; Islam et al., 2016; Nnam & Onyeke, 2003; Tareq et al., 2019). In addition, the magnesium content of BJRI mesta-2 was lower than that of Roselle, jute, and some other leafy vegetables (Butnariu & Butu, 2014; Etiosa et al., 2017; Idris et al., 2010).

Potassium, iron, and manganese contents were higher in the calyx than in the leaves and seeds. Iron was the most abundant, followed by manganese and potassium (Table 1). Most of the leaves of different jute genotypes contained lower concentrations of potassium than the BJRI mesta-2, except for the Birol red genotype (Tareq et al., 2019). However, Roselle leaves and calyx were previously found to contain higher amount of potassium: 208 mg 100 g^{-1} in leaves and 49.35 mg 100 g^{-1} in fresh calyxes, respectively, comparable to our result (Adanlawo & Ajibade, 2006; Islam, 2019). Iron content was lower than that of the different jute genotypes and much higher than that of the Roselle leaves, calyxes, and seeds (Islam, 2019; Islam et al., 2016). Similar to iron content, manganese content in our study was much higher in Roselle calyxes and leaves (Adanlawo & Ajibade, 2006; Ansari et al., 2013). Interestingly, phosphorus concentration alone was found to be higher in seeds than in leaves and calyxes (Table 1); however, this concentration was much lower than that reported in other studies (Adanlawo & Ajibade, 2006; Ansari et al., 2013).

Vitamins are necessary for the regulation of different functions, including maintenance of skin, mucosal membranes, bones, vision, and reproduction (An et al., 2020; Chatterjea & Shinde, 1998; Natesh et al., 2017; Rahman et al., 2006). Moreover, vitamins can absorb different types of minerals (Bangash et al., 2011). Percent moisture, ash, vitamin A, and vitamin C from fresh calyx and leaves varied (Table 4). There was higher moisture content in fresh calyx than in fresh leaves; however, ash, vitamin A, and vitamin C contents were higher in Roselle leaves. Reports have shown that the moisture content of Roselle leaves is higher than that of calyx and calyx contains higher levels of ash (Adanlawo & Ajibade, 2006; Ansari et al., 2013; Islam et al., 2016). Our experiment found higher moisture and ash contents in calyxes and leaves, respectively, which vary with previous results. Vitamin A and vitamin C contents were higher in leaves, and similar results were also reported in earlier studies (Shoosh, 1993; Singh et al., 2017).

The concentrations of different minerals, vitamins, moisture, and ash differed greatly from previously reported values. One possibility for the variation of contents is the use of different Roselle varieties for our experiment. Several reports also suggested that the Roselle genotype, along with agro-climatic conditions and soil type, is involved in changing vitamin and mineral contents (Atta et al., 2013; Islam 2019; Luke, 1984). Another reason for this variation might be related to the procedure of analyzing the contents in this study.

5. Conclusion

Vitamins and minerals are essential for human health and are taken from different sources, including leafy vegetables. Leafy vegetables are comparatively cheaper than other sources, and people can easily afford them. The enrichment of minerals, ash, vitamin A, and vitamin C in different parts of BJRI mesta-2 may play important roles during normal growth and development of the human body. Thus, BJRI mesta-2 could be treated not only as an alternative source of leafy vegetable during early summer but also be used in the industrial preparation of herbal tea and edible oil for human consumption.

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