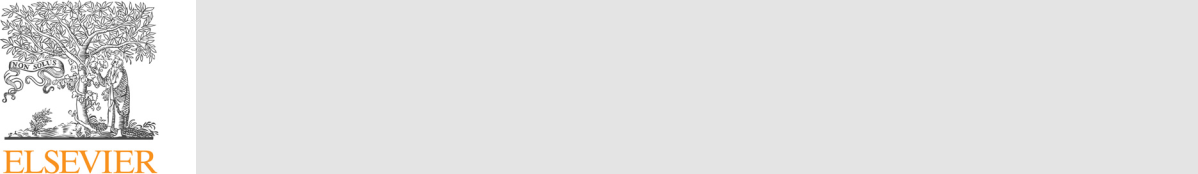
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Comparative assessment of nutritional composition, polyphenol profile, antidiabetic and antioxidative properties of selected edible wild plant species of Bangladesh

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ABSTRACT

Wild edible plants are recently recognized as an important source of acquiring macro and micro nutrients beneficial for human health. Hence, the present study was undertaken to assess the antidiabetic and antioxidant potentials, polyphenolic profile, – as well as the ascorbic acid, proximate and mineral compositions of five selected Bangladeshi wild plants. The studied samples were rich in ash, fiber, protein, vitamin C and low in fat. The undertaken plant samples were found to have good amounts of total phenolic, total flavonoid, and anti-oxidant capacities, documented by DPPH, FRAP, and TEAC assays. They also exhibited varying spectrum of polyphenols estimated by HPLC. Significant inhibition of α-amylase activity by plant extracts was also observed. Evaluation by principal component analysis revealed clear separation among the wild plant varieties. The study findings would enrich the food composition table of Bangladesh and allow the population to consume more wild plants and increase their production.

1. Introduction

For thousands of years, traditional or wild plants have been playing an important role in many cultures for vital nutrients and primary health care. According to World Health Organization (WHO), > 80% of the rural inhabitants around the world rely on traditional plants as a source of nutrients and primary health care. They advise and promote the use of wild plants due to their local availability, eﬀectiveness, and the fact that they are less expensive alternatives to modern medicines ([World Health Organization. (2013), 2013](#page1)).

Nowadays, people are increasingly leaning towards the utilization of wild plants for their superior nutritional composition and therapeutic activity with no adverse eﬀects ([Afolayan & Jimoh, 2009; Alam, Rana,](#page1) [Islam, & Akhtaruzzaman, 2019; Rana, Alam, & Akhtaruzzaman, 2019](#page1)). These wild plants are claimed to be an excellent dietary source of vital nutrients such as minerals, vitamins, proteins, dietary fibers ([Afolayan](#page1)

* [Jimoh, 2009; Gupta, Jyothi Lakshmi, Manjunath, & Prakash, 2005](#page1)) as well as antioxidant molecules such as flavonoids, and other poly-phenolic components, such as tannins and resveratrol ([Afolayan &](#page1) [Jimoh, 2009; Dasgupta & De, 2007](#page1)). One of the most studied functions of wild plants is their potential role in scavenging free radicals, such as

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superoxide (O−2), hydroxyl radical (OH•), nitric oxide (NO) and perox-ynitrite (ONOO−), which may lead to many chronic degenerative dis-eases (atherosclerosis, diabetes, alzheimer’s disease, coronary heart diseases, aging, and cancer) ([Afolayan & Jimoh, 2009; Gupta et al.,](#page1) [2005; Rana et al., 2019](#page1)). The antioxidants from these plants are the preferred one over the synthetic ones in developing new therapeutic drugs. It has been stated that higher intake of antioxidants is associated with lower occurrence of human diseases ([Afolayan & Jimoh, 2009;](#page1) [Dasgupta & De, 2007](#page1)).

Moreover, in recent years, studies of wild plants on antidiabetic activity have gained much attention because of their high eﬀectivity as natural antidiabetic agents ([Ajayi et al., 2012](#page1)). The aging population, consumption of high calorie diets, obesity and inactive lifestyles have led to a remarkable increase in the number of individuals with type-2 diabetes mellitus (T2DM) worldwide. According to the WHO, by the year of 2025 the number of diabetic aﬀected individual is likely to cross 300 million ([Ajayi et al., 2012](#page1)). As the mechanism of this disorder is quite complex, the rates of response of commercially available synthetic anti-diabetic drugs is low and often associated with severe adverse ef-fects. Along with side eﬀects, high cost of synthetic drugs and the un-availability in remote areas are still a major challenge for the

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management of diabetes ([Sun et al., 2008](#page1)). Thus, it is necessary to screen and identify plants with potent anti-diabetic activity having no adverse eﬀects ([Ajayi et al., 2012](#page1)).

Wild plants containing antidiabetic activity have diﬀerent modes of action, such as insulin mimicking activity, acting on beta cells to pro-duce insulin, and/or alter glucose utilization ([Oboh, Agunloye,](#page1) [Adefegha, Akinyemi, & Ademiluyi, 2015](#page1)). One of the strategies in treating T2DM is to decrease the glucose absorption by lowering the starch digestion rate. This can be achieved by inhibiting the salivary α-amylase and intestinal α-glucosidase enzymes which will delay the production of monosaccharides resulting from the breakdown of starch and oligosaccharides, thus resulting in the reduction of both the glucose absorption and postprandial blood glucose level ([Oboh et al., 2015](#page1)). Therefore, wild plants with potent α-amylase inhibitory activity need to be screened.

Bangladesh is a land of vast numbers of wild plants which possess therapeutic potential and these plants have a long history of traditional uses in the treatment of diﬀerent kind of diseases ([Ghani, 2003; Yusuf,](#page1) [Chowdhury, Hoque, & Begum, 2009](#page1)). To date, thousands of the wild plant species of Bangladesh are recognized to possess medicinal values ([Ghani, 2003; Yusuf et al., 2009](#page1)). However, antidiabetic potentials of many of these traditional wild plants of Bangladesh are still unknown. Therefore, the aim of the current study is to determine the in vitro an-tidiabetic and antioxidant activities, nutritional composition - as well as total phenolic contents (TPC), total flavonoid contents (TFC) and polyphenol composition of the selected native wild plant samples of Bangladesh (Blumea lacera (Kukurshunga), Berberis aristata (Daruhar-udra), Hygrophilla schulli (Kulakhara), Sesbania sesban (Dhoinche), and Erythrina variegata (Mandar gach)).

2. Materials and methods

2.1. Reagents

HPLC grade acetonitrile (ACN), methanol, Na2CO3, Folin-Ciocalteu reagent, and acetic acid were purchased from Merck, Germany. ABTS was obtained from Wako Pure Chemical Industries, Ltd., Osaka, Japan. α-amylase, DPPH radical, TPTZ, Trolox, potassium persulfate, gallic acid, catechin hydrate, vanillic acid, caﬀeic acid, epicatechin, p-cou-maric acid, rutin hydrate, ellagic acid, myricetin, kaempferol and quercetin were bought from Sigma Aldrich (St. Louis, MO, USA). All the chemicals used in the analysis were of analytical grade.

2.2. Collection and preparation of wild plant materials

The studied samples were Blumea lacera (Kukurshunga), Berberis aristata (Daruharudra), Hygrophilla schulli (Kulakhara), Sesbania sesban (Dhoinche), and Erythrina variegata (Mandar gach). Multi-region sam-pling plan was employed for the wild plant sampling. In order to con-form the representative sample principle, “what the mass people con-sume’ and from where they collect it”? ([Rana et al., 2019](#page1)), the wild plants were collected on several occasions from diﬀerent locations in Bangladesh and local market near Dhaka, Bangladesh, where the plants are arrived from diﬀerent geographical regions of the country. It was, thus, ensured the representative sample. The multi-regional sampling plan are presented in [supplementary Fig. 1](#page1). A taxonomist of the De-partment of Botany, University of Dhaka, who also accompanied the collection team, confirmed the sample identity after examining the morphological characteristics. Sample characteristics are presented in [supplementary Table 1](#page1) and photographs of the studied wild plants are also of given in the [Fig. 1](#page1). After the collection of above mentioned samples, they were processed, leaves separated from the stems, im-mediately as described earlier ([Rana et al., 2019](#page1)) to evaluate their proximate, mineral, and ascorbic acid content, TPC, TFC, polyphenol composition, antioxidant potentials (DPPH, FRAP, ABTS), and α-amy-lase inhibitory activity.

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2.3. Evaluation of proximate composition

Previously described procedure was followed for the estimation of proximate nutrients in the wild plants ([Alam, Rana, & Islam, 2016;](#page1) [Rana et al., 2019](#page1)). Moisture and ash contents of the sample were cal-culated by the weight diﬀerence method, whereas the total fat content of the samples was estimated by using petroleum ether as solvent. The total protein content was determined by using the micro-Kjeldhal method (nitrogen content of the samples × 6.25). The gravimetric method was utilized for the estimation of total dietary fiber (soluble and insoluble). Total available carbohydrate contents were calculated by diﬀerence.

2.4. Evaluation of mineral profile

Previously described method was followed for the estimation of mineral profile in the wild plants ([Rana et al., 2019](#page1)). Briefly, ap-proximately 500 mg of plant samples after drying were subjected to wet digestion with nitric acid and perchloric acid (2:1 ratio) in an auto-digestor at 325 °C to accelerate the discharge of mineral in the plant matrix. After digestion and appropriate dilution, the digested sample was aspirated into an air–acetylene flame to burn the elements into atomic components, which were then detected in a spectrophotometer at their relevant wavelengths. Proportions of calcium, magnesium, so-dium, zinc, copper and iron were evaluated by atomic absorption spectrophotometry (Model-AA-7000S, Shimadzu, Tokyo, Japan). The amount of potassium was determined by flame photometry (Jenway flame photometer model PFP7, Origin UK). A standard calibration curve was plotted for each of the minerals using the respective mineral standard obtained from Sigma Chemical Co., USA.

2.5. Evaluation of ascorbic acid

Ascorbic acid (Vitamin C) content was determined by the spectro-photometric method followed by [Shajib et al. (2013)](#page1) without any modifications. Briefly, freshly processed plant (1 g) was homogenized with a pestle and mortar using metaphosphoric acid (5% metapho-sphoric acid in 10% acetic acid solution in water). Homogenates were filtered, treated with 85% sulphuric acid solution and 2,4-din-trophenylhydrazine and incubated at 60 ˚C for 60 min in water bath. The absorbance was read at 520 nm in spectrophotometer (UV-1601, UV–Visible, Shimadzu, Tokyo, Japan) for the calculation of Ascorbic acid content in the sample.

2.6. Extraction of wild plant

The leaves of the selected wild plants were subjected to extraction by methanol as stated previously ([Alam et al., 2019; Rana et al., 2019](#page1)). Approximately two grams of freeze-dried powdered sample was taken into a 250 mL conical flask and 42.5 mL methanol and 7.5 mL 1 N hydrochloric acid were added. It was soaked for 24 h at room tem-perature with intermittent shaking. Extracts were filtered through No. 1 Whitman filter paper and the filtrate was concentrated using a rotary evaporator at low temperature under reduced pressure. Methanol was added to make a final concentration of 1 mg/mL to be used as stock solution.

2.7. Evaluation of total phenolic and flavonoid contents

The methods described previously were followed for the quantifi-cation of TPC and TFC in the wild plants ([Alam et al., 2019; Rana et al.,](#page1) [2019](#page1)). To quantify TPC, 150 μL of plant extracts were taken in test tubes. To this, 900 μL distilled water was added. 225 μL of diluted Folin–Ciocalteu reagent (2-fold) was added to the solution and allowed to stand for 5 min at room temperature. Then, 1.125 mL of 2% Na2CO3 solution was added, mixed well and left for 15 min at room

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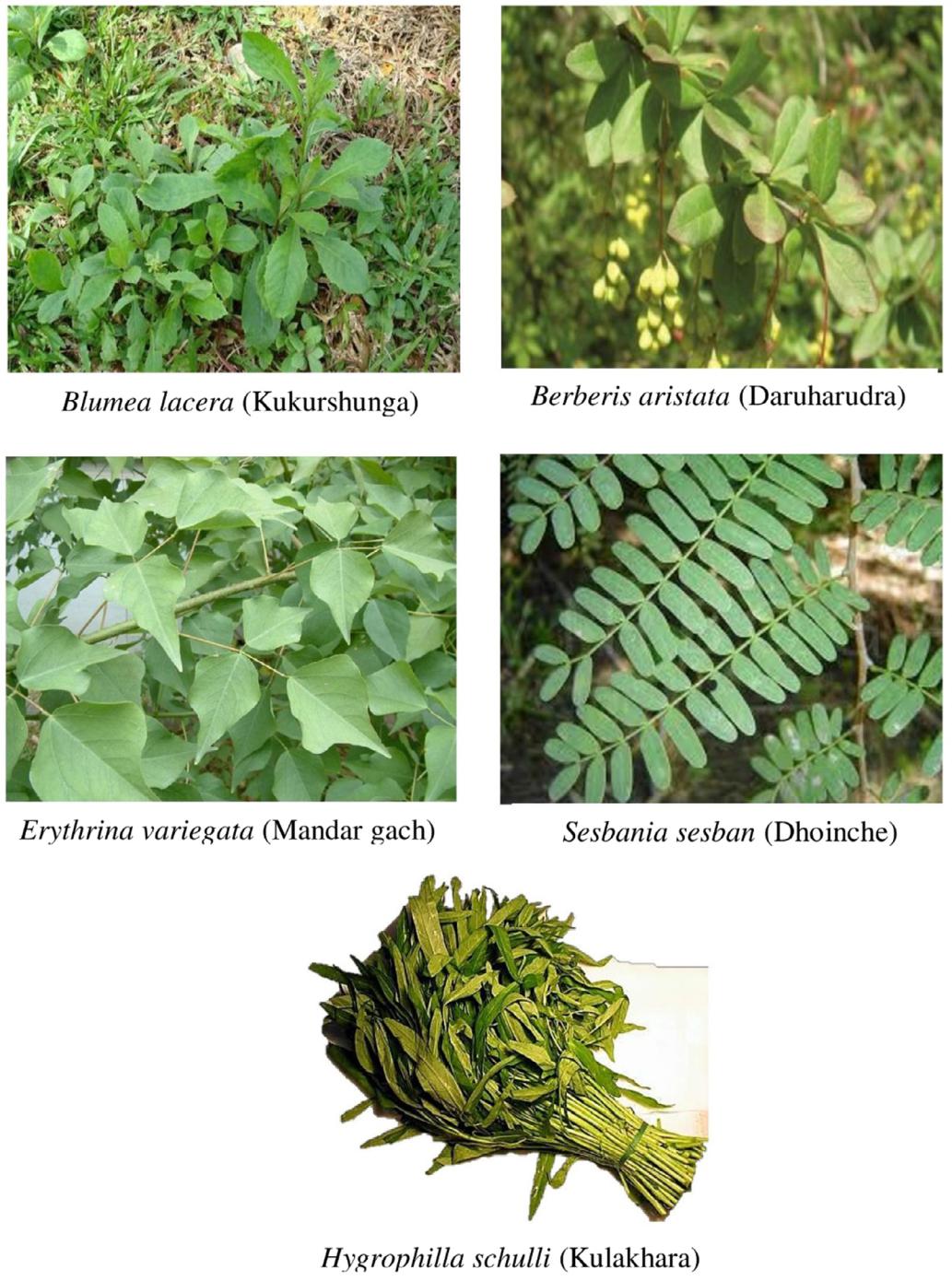


Fig. 1. Photograph of selected wild plants of Bangladesh.

temperature. Finally, the absorbance was measured at 750 nm by a UV–VIS spectrophotometer (UV-1800, Shimadzu, Kyoto, Japan). The TPC was calculated using a standard curve based on gallic acid. Results were expressed as milligrams of gallic acid equivalent (GAE) per gram dry weight (DW) (mg GAE/g DW).

For quantification of TFC, 250 µL of the extract was mixed with 1.125 mL of distilled water in a test tube. To these, 75 µL of 5% NaNO2 solution was added. After 6 min, 150 µL of 10% AlCl3·6H2O solution was added. The solution was left to stand for another 5 min, and 500 µL of 1 M NaOH was added. Finally, the mixture was vortexed, and the absorbance was measured immediately at 510 nm by a UV–VIS spec-trophotometer (UV-1800, Shimadzu, Kyoto, Japan). The TFC in the plant extract was calculated using a standard curve based on quercetin

and results were expressed as milligrams quercetin equivalent (QE) per gram of dry weight (mg QE/g DW).

2.8. Analysis of polyphenol profile

The phenolic standards used in this study were gallic acid (GA), catechin hydrate (CH), vanillic acid (VA), caﬀeic acid (CfA), epica-techin (ECA), p-coumaric acid (PCouA), rutin hydrate (RH), ellagic acid (EA), myricetin (Myr), kaempferol (Kaem), and quercetin (QH).

2.8.1. Preparation of standard and sample

5 mg of each phenolic compound was taken into 50 mL volumetric flask to prepare the stock standard solution at a concentration of

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Table 1

Proximate composition (g/100 g DW), macro and micro minerals (DW basis) and ascorbic acid content of selected wild plants.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wild Plants | Blumea lacera (Burm. f.) DC. | | Erythrina variegata L. | | Berberis aristata | | Sesbania sesban L. Merr | | Hygrophilla schulli | |
|  | (Kukurshunga) | | (Mandar gach) | | (Daruharudra) | | (Dhoinche) | | (Kulakhara) | |
|  | | |  |  |  |  |  |  |  |  |
| Proximate composition (g/100 g sample) | | |  |  |  |  |  |  |  |  |
| Moisture[1](#page1) | 77.78 | ± 2.68c | 85.71 | ± 1.33b | 87.44 | ± 2.22ab | 90.13 | ± 1.55ab | 91.23 | ± 1.01a |
| Protein | 22.52 | ± 0.97a | 21.12 | ± 1.58ab | 19.11 | ± 0.78bc | 15.65 | ± 1.10d | 17.19 | ± 1.49 cd |
| Fat | 0.93 ± 0.09c | | 1.55 ± 0.15b | | 2.14 ± 0.32a | | 0.97 ± 0.05c | | 1.92 ± 0.18ab | |
| Fiber | 20.68 | ± 2.55a | 17.55 | ± 1.98ab | 18.10 | ± 2.03ab | 15.19 | ± 1.79b | 14.07 | ± 1.21b |
| Ash | 24.05 | ± 0.69a | 20.15 | ± 0.53b | 15.46 | ± 0.35d | 18.68 | ± 0.22c | 23.36 | ± 0.66a |
| Carbohydrate (CHO) | 31.82 | ± 1.26d | 39.63 | ± 1.11c | 45.19 | ± 0.56b | 49.51 | ± 0.72a | 43.46 | ± 0.42b |
| Mineral Composition |  |  |  |  |  |  |  |  |  |  |
| Macro minerals (mg/100 g sample) | | |  |  |  |  |  |  |  |  |
| Sodium (Na) | 1097.98 ± 2.10a | | 351.09 ± 1.87d | | 335.10 ± 0.92e | | 465.45 ± 0.55c | | 988.79 ± 2.67b | |
| Potassium (K) | 3185.25 ± 1.15a | | 2266.56 ± 3.12c | | 1189.91 ± 1.57e | | 1259.33 ± 1.49d | | 2845.61 ± 3.71b | |
| Magnesium (Mg) | 445.37 ± 0.90a | | 218.67 ± 0.83d | | 162.88 ± 0.50e | | 290.25 ± 0.85c | | 398.59 ± 1.11b | |
| Calcium (Ca) | 890.05 ± 2.55a | | 292.11 ± 1.71d | | 234.29 ± 1.23e | | 383.15 ± 1.55c | | 642.20 ± 2.02b | |
| Micro minerals (mg/100 g sample) | | |  |  |  |  |  |  |  |  |
| Iron (Fe) | 51.05 | ± 1.01a | 22.19 | ± 1.23d | 19.25 | ± 1.10d | 28.57 | ± 1.31c | 39.65 | ± 0.99b |
| Zinc (Zn) | 6.70 ± 0.50b | | 4.15 ± 0.45c | | 3.71 ± 0.19c | | 10.33 | ± 0.49a | 5.77 ± 0.33b | |
| Copper (Cu) | 0.78 ± 0.02c | | 0.49 ± 0.01d | | 0.37 ± 0.01e | | 1.41 ± 0.05a | | 0.92 ± 0.03b | |
| Ascorbic Acid (mg/ | 127.23 ± 1.51a | | 70.43 | ± 0.87d | 85.55 | ± 1.01c | 49.21 | ± 0.41e | 98.54 | ± 0.92b |
| 100 g) |  |  |  |  |  |  |  |  |  |  |

Means that do not share a superscript letter across rows are significantly diﬀerent.

1. Fresh weight basis.

100 μg/mL. Then, the mixture of standard solution was prepared by diluting the individual stock standard solutions in methanol to have a final concentration of 5 μg/mL for each polyphenol, except for CH, CA, RH (4 μg/mL) and QH (3 μg/mL). After preparation, all standard so-lutions including the mixed were stored and kept in the dark at 5 °C.

The calibration curves of the standard were prepared by diluting each stock solution of standard with methanol. The concentration for preparing the calibration curves was as follows: 1.0–5.0 μg/mL for GA, VA, ECA, PCouA, EA, Myr, Kaem; 0.5–4.0 μg/mL for CH, CfA, RH, and 0.25–3.0 μg/mL for QH. The calibration graphs were obtained by plotting the concentration of standard against the peak area of chro-matogram (R2 > 0.995). All solutions were first filtered through syr-inge filter (0.45 μm) and then degassed in an ultrasonic bath for 5 min before injecting into the HPLC for analysis.

2.8.2. Chromatographic analysis

The phenolic compounds in the wild plants were identified, sepa-rated and quantified as described previously by [Uddin, Ahmed,](#page1) [Rahman, Akter, and Akter (2016)](#page1) employing same mobile phase con-ditions, ACN:Acetic Acid:Methanol, and wavelength program using the Reversed-phase HPLC system (Thermo Scientific Dionex UltiMate 3000) coupling with a Diode Array Detector (DAD-3000RS) and Accalaim® C18 (4.6 internal diameter, 250 mm length and 5 μm particle size) column (Dionex, USA). The column was maintained at 30 °C throughout analysis. The results were expressed in mg per 100 freeze dried weight (fdw) of wild plants of triplicate analytes.

2.9. Antioxidant capacity assays

Three diﬀerent in vitro antioxidant methods, namely, DPPH• radical inhibition (DPPH assay), ferric reducing antioxidant power (FRAP) assay, and trolox equivalent antioxidant capacity (TEAC) assay were performed in this study as described previously by [Alam et al. (2019)](#page1) [and Rana et al. (2019)](#page1). The results from the DPPH free radical inhibi-tion assay were expressed as % DPPH inhibition by plant extracts. For the FRAP and TEAC assays, a standard curve of various concentrations of Fe(2+) solution and trolox solution was prepared for the equivalent quantification of antioxidant potential with respect to Fe(2+) solution

and trolox solution, respectively. The results were expressed as µmol Fe(2+) per gram of dry weight (µmol Fe(2+)/g DW) for the FRAP assay

and µmol trolox per gram of dry weight plant extract (µmol Trolox/g

DW) for the TEAC assay.

2.10. Evaluation of α-amylase inhibitory activity

To evaluate the potential of plant extracts on α-amylase inhibition, procedure from our previous study was followed ([Rana et al., 2019](#page1)). Acarbose, a known α-amylase inhibitor, was used as a standard in this assay. The α-amylase inhibitory activity was calculated and expressed as percentage inhibition using the following formula:

(%)*α* - amylase Inhibition = (1 − (Abssample /Abscontrol)) × 100

where, Abscontrol is the absorbance of the control reaction (containing all reagents minus plant extracts or acarbose) and Abssample is the ab-sorbance of the plant extracts or acarbose.

2.11. Statistical analysis

Each experiment was repeated three times. For each experiment analysis, analytes were replicated in thrice and thus twenty-seven (n = 27) replications were performed in total and the values were presented as mean ± standard deviation. One-way analysis of variance (ANOVA) and Principal Component Analysis (PCA) were employed to evaluate the diﬀerences and identify the plants with similar char-acteristics in relation to their nutritional composition, biological ac-tivities, total - and individual - polyphenol contents. The diﬀerence was considered statistically significant when p < 0.05 at 5% level of sig-nificance. The Dunnett test was used to compare the α-amylase activity of plants with control (Acarbose). Pearson correlation (r) were also calculated. The data analysis was performed in Minitab version 18.0. (Minitab Inc., State College, PA, USA). For the analysis of HPLC data, Dionex Chromeleon Chromatography Data System Version 6.80 was used.

3. Results and discussion

3.1. Proximate profile

[Table 1](#page1) summarize the proximate profile consisting of moisture, protein, total fat, total fiber, ash and total carbohydrate in the studied wild plants. The analyzed wild plants exhibited the moisture content from 77.78 ± 2.68 to 91.23 ± 1.01 g/100 g fresh weight ([Table 1](#page1)).

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Moisture of food is the most frequently measured properties of food materials. These obtained values were in accordance with the results reported by [Rana et al. (2019) and Satter et al. (2016)](#page1) where they analyzed some other wild plants of Bangladesh. On the other hand, lower contents of moisture were reported in wild and commonly con-sumed leafy vegetables of South Africa, India and Pakistan ([Afolayan &](#page1) [Jimoh, 2009; Gupta et al., 2005; Hussain et al., 2011; Imran, Talpur,](#page1) [Jan, Khan, & Khan, 2007](#page1)).

The Table 1 showed that the crude protein ranged from

15.65 ± 1.10 g/100 g dry weight (DW) (Sesbania sesban) to

22.52 ± 0.97 g/100 g DW (Blumea lacera) and the value obtained in this study was comparable to other reported values of South African, Bangladeshi, and Indian wild plants ([Afolayan & Jimoh, 2009; Rana](#page1) [et al., 2019; Satter et al., 2016; Seal, 2018](#page1)). On the other hand, protein content were found to be higher in this study than some previously reported wild and commonly consumed vegetables in India and Paki-stan ([Gupta et al., 2005; Hussain et al., 2011; Imran et al., 2007](#page1)).

The contents of fat in this study were recorded from 0.93 ± 0.09 to 2.14 ± 0.32 g/100 g DW. The investigated wild plants exhibited little contents of fat with Berberis aristata showed the highest fat content (2.14 g/100 g DW). Higher fat content in wild plants, opposite to present study findings, have been reported in previous studies by some investigators ([Afolayan & Jimoh, 2009; Rana et al., 2019; Satter et al.,](#page1) [2016; Seal, 2018](#page1)). However, compared to the findings of [Gupta et al.](#page1) [(2005)](#page1), our reported values were found similar to the values obtained by them.

The ash contents in the wild plants were noted from 15.46 ± 0.35 to 24.05 ± 0.69 g/100 g DW. From [Table 1](#page1), it is evident that the selected wild plants contained high amount of minerals and thus could provide a considerable amount of mineral elements in our diet. Similar content was reported previously ([Afolayan & Jimoh, 2009; Rana et al.,](#page1) [2019](#page1)) and lower content was observed for some edible and commonly used vegetables than ours ([Gupta et al., 2005; Hussain et al., 2011;](#page1) [Satter et al., 2016](#page1)).

The amounts of total dietary fiber were recorded from

14.07 ± 1.21 to 20.68 ± 2.55 g/100 g DW. The values of crude fiber found in this study ([Table 1](#page1)) are close to the values observed in our previous study ([Rana et al., 2019](#page1)) and also by other authors ([Afolayan](#page1)

* [Jimoh, 2009](#page1)) whereas [Satter et al. (2016) and Hussain et al. (2011)](#page1) found lower content of crude fibers. Dietary fiber is essential for ef-fective digestion and bowel movement. Our selected plants could be used as vegetables, and as a source of high fiber content can prevent obesity, constipation, diabetes, lower the serum cholesterol, the risk of coronary heart disease, hypertension, colon, and breast cancer ([Koca,](#page1) [Hasbay, Bostanci, Yilmaz, & Koca, 2015](#page1)).

Total available carbohydrate (CHO) content was in the range of

31.82 ± 1.26 g/100 g (Blumea lacera) to 49.51 ± 0.72 g/100 g (Sesbania sesban). The values observed in this study are lower than the values reported by [Imran et al. (2007) and Satter et al. (2016)](#page1) whereas [Afolayan and Jimoh (2009)](#page1), [Rana et al. (2019) and Seal (2018)](#page1) stated similar value to our findings. Thus, there exists a diﬀerence in terms of proximate nutrients between wild plants grown in Bangladesh and other global regions. As stated previously, geographical, climatic, and/ or other factors could contribute to these diﬀerences in proximate composition ([Alam et al., 2016; Rana et al., 2019](#page1)).

3.2. Mineral profile and ascorbic acid content

[Table 1](#page1) depicts the profile of minerals in the investigated wild plants and the results indicated that these wild plants contained abundant amount of diverse variety of minerals including sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), iron (Fe), zinc (Zn), and copper (Cu). High variations among the investigated species regarding to their mineral concentrations were observed. Blumea lacera was found to contain the highest mineral concentrations whereas the lowest con-centration was recorded in Berberis aristata. Blumea lacera was also

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found to contain the most minerals; except Zn and Cu, while these contents were higher in Sesbania sesban. Blumea lacera was found to be a good source of iron (51.05 ± 1.01 mg/100 g) and calcium (890.05 ± 2.55 mg/100 g) than others ([Table 1](#page1)).

These diﬀerences in mineral contents could be due to species, quality of soil, environmental and climatic conditions ([Rana et al.,](#page1) [2019](#page1)). Among the seven quantified minerals, Na and K were found to be the most abundant. Their concentrations in the plant samples were between 335.10 and 1097.98 mg/100 g and 1189.91–3185.25 mg/ 100 g, respectively. Similar findings were also reported by other au-thors ([Afolayan & Jimoh, 2009; Satter et al., 2016](#page1)), however [Rana et al.](#page1) [(2019)](#page1) reported higher content of these minerals in their study. Mg, Fe, and Ca values in the plant samples were found to be comparable to the values as reported by [Satter et al. (2016)](#page1) whereas [Afolayan and Jimoh](#page1) [(2009)](#page1) and [Rana et al. (2019)](#page1) found higher content of these minerals in South African and other Bangladeshi wild plants, respectively. [Rana](#page1) [et al. (2019), Satter et al. (2016) and Seal (2018)](#page1) reported higher amounts of Cu in wild plants than what have been observed in this study, whereas some values (Zn, Cu) were found to be higher than those observed by [Afolayan and Jimoh (2009)](#page1). Compared to common popular vegetables, such as spinach, red amaranth, cauliflower, cabbage, and other leafy and non-leafy vegetables, the wild plants under investiga-tion contain similar or even higher amounts of specific minerals ([Saikia](#page1)

* [Deka, 2013](#page1)). Therefore, consumption of these wild plants could provide substantial micronutrients required for the proper body func-tion and maintenance.

The mean content of ascorbic acid in the wild plants analyzed are given in [Table 1](#page1). Ascorbic acid (vitamin C) content of wild plants varied significantly from 49.21 ± 0.41 to 127.23 ± 1.51 mg/100 g. As-corbic acid (vitamin C) is a potent free radical scavenger and plays a vital role in maintaining a healthy life by acting as anti-carcinogenic and anti-atherogenic agents ([Gupta et al., 2005](#page1)). The highest level was found in Blumea lacera (127.23 ± 1.51 mg/100 g) followed by Hy-grophilla schulli (98.54 ± 0.92 mg/100 g) while the lowest level was observed in Sesbania sesban (49.21 ± 0.41 mg/100 g). Similar or even higher contents of vitamin C were also reported for some underutilized green leafy vegetables ([Gupta et al., 2005](#page1)). Blumea lacera (127.23 ± 1.51 mg/100 g) and Hygrophilla schulli (98.54 ± 0.92 mg/ 100 g) were found to have considerably high content of ascorbic acid than commonly consumed locally available vegetables, such as spinach (36.8 mg/100 g) and cauliflower (42.4 mg/100 g) ([Singh, Kawatra, &](#page1) [Sehgal, 2001](#page1)). High variations were observed in the studied wild edible plants in regard to their ascorbic acid content which could be attributed to diﬀerent species from diﬀerent geographical locations, diﬀerent cli-matic conditions and also may be due to diﬀerent stage of maturity of the plants. Thus, these plants could be incorporated into our daily diet as a rich source of vitamin C for the local people.

3.3. Total phenolic- and flavonoid- contents of the selected wild plants

The TPC and TFC of the investigated wild plants are presented in [Table 2](#page1). Generally, the TPC and TFC in the plant samples under study were high. TPC in the samples ranged from 95.23 ± 1.35 to 170.33 ± 2.18 mg GAE/g and TFC in the samples ranged from 53.42 ± 1.23 to 97.16 ± 1.38 mg QE/g. The highest TPC was found in Erythrina variegata (170.33 ± 2.18 mg GAE/g) while Blumea lacera contained the lowest (95.23 ± 1.35 mg GAE/g). On the other hand, Sesbania sesban and Erythrina variegata had the highest (97.16 ± 1.38 mg QE/g) and lowest (53.42 ± 1.23 mg QE/g) TFC, respectively. These values are in accordance with the values reported by [Dasgupta and De (2007)](#page1), where they studied several widely con-sumed leafy vegetables of Asian origin.

Phenolic compounds are a large, diverse group of secondary plant metabolites and have been claimed to possess various biological ac-tivities such as anti-inflammatory, anti-carcinogenic, antidiabetic and anti-atherosclerotic activities. The antioxidant potential of the phenolic

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Table 2

Total phenolic, total flavonoid, DPPH, TEAC and FRAP values of the selected wild plants.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name of wild plants | Family | TPC[1](#page1) (mg GAE/g DW) | | TFC[2](#page1) (mg QE/g DW) | | DPPH radical inhibition | | TEAC[3](#page1) (µmol Trolox/g | | FRAP[4](#page1) (µmol Fe(2+)/g | |  |
|  |  |  |  |  |  | (%) |  | DW) |  | DW) |  |  |
|  |  |  | |  |  |  |  |  |  |  |  |  |
| Blumea lacera (Burm. f.) | Asteraceae | 95.23 ± 1.35d | | 59.87 | ± 0.93d | 75.11 | ± 1.30e | 240.17 | ± 3.26e | 262.91 | ± 2.35e |  |
| DC. |  |  | ± 2.18a |  | ± 1.23e |  | ± 1.49a |  | ± 4.38a |  | ± 5.37a |  |
| Erythrina variegata L. | Fabaceae | 170.33 | 53.42 | 89.27 | 738.41 | 845.87 |  |
| Berberis aristata | Berberidaceae | 135.56 | ± 3.26c | 82.05 | ± 0.78a | 78.03 | ± 1.26d | 355.67 | ± 2.42d | 413.25 | ± 4.28d |  |
| Sesbania sesban (L.) Merr | Fabaceae | 167.66 | ± 2.37a | 97.16 | ± 1.38c | 86.13 | ± 1.53b | 650.76 | ± 5.40b | 705.47 | ± 6.24b |  |
| Hygrophilla schulli | Acanthaceae | 148.05 | ± 3.21b | 87.12 | ± 0.86b | 80.10 | ± 2.13c | 436.58 | ± 2.32c | 565.23 | ± 4.87c |  |

Means that do not share a superscript letter across columns are significantly diﬀerent.

1. Total phenolic content.
2. Total flavonoid content.
3. Trolox equivalent antioxidant capacity.
4. Ferric reducing antioxidant power.

compounds could attributed for these activities ([Afolayan & Jimoh,](#page1) [2009; Alam et al., 2019; Rana et al., 2019](#page1)). Free radicals are unstable compounds in the body responsible for tissue damage. Antioxidants play a key role in maintaining good health either by counteracting or by preventing these free radicals. As a rich source of antioxidants, as well as for the therapeutic uses, wild plants have recently received much interest by researchers in order to find an alternative source of synthetic antioxidants due to the health risk they possesses.

To the best of our knowledge, no scientific data sources were available to compare the TPC and TFC in the investigated plants. So, this study’s findings supply preliminary information for discovering novel antioxidants rich wild plants. Compared to regularly consumed local fruits and vegetables, our study samples had higher TPC ([Hossain,](#page1) [Shaheen, Mohiduzzaman, & Banu, 2011; Mamun et al., 2012; Rahman,](#page1) [Khan, Das, & Hossain, 2016](#page1)). However, in relation to other Asian fruits and vegetables, this study reported lower content of TPC ([Dasgupta &](#page1) [De, 2007; Kaur & Kapoor, 2002](#page1)). Nonetheless, the geographical loca-tion, growing conditions and extraction methods can significantly in-fluence the TPC ([Alam et al., 2016, 2019; Rana et al., 2019](#page1)).

3.4. Polyphenol profile

An attempt has also been taken to identify and quantify the most frequently occurring polyphenols in the wild plants ([Table 3](#page1)). A wide variation in spectrum and content of polyphenolics was obtained among the studied plants. GA, CH, VA, and RH were present in all of the tested plants. Most of the samples contained seven to ten phenolic compounds. Quantity of phenolic compounds ranged from 0.85 ± 0.03 to 480.27 ± 15.50 mg/100 g fdw. The highest amount of CH (76.54 ± 3.42 mg/100 g fdw), CfA (9.28 ± 1.50 mg/100 g fdw), ECA (8.67 ± 0.94 mg/100 g fdw), EA (480.27 ± 15.50 mg/100 g fdw), Kaem (1.51 ± 0.11 mg/100 g fdw) and QH (10.15 ± 1.05 mg/ 100 g fdw) were present in the Erythrina variegata. Moreover, the highest amount of GA (6.83 ± 1.14 mg/100 g fdw) and VA (9.40 ± 0.70 mg/100 g fdw) were detected in Hygrophilla schulli and Blumea lacera, respectively. Berberis aristata was found to contain the

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| most | PcouA | (18.41 ± | 0.31 mg/100 | g fdw) | and | RH |
| (64.23 | ± | 2.87 mg/100 | g fdw) than | others | while | Myr |

(40.75 ± 2.45 mg/100 g fdw) was highest in Sesbania sesban.

Erythrina variegata was found to be a good source of ECA and EA. Erythrina variegata contained the most of the phenolics and was also indicated a very good source of polyphenols. Blumea lacera and Hygrophilla schulli also contained a high amount of CA, which has a wide spectrum of medicinal values and is eﬀective in prevention of diabetes, cell proliferation, cardiovascular diseases, and cancers ([Lin,](#page1) [Wu, Jian, & Shih, 2017](#page1)). RH, which was present in all of the vegetables, has vasoprotectives action in hemorrhoids, varicose and capillary sta-bilization. VA also have been claimed to possess hepatoprotective ef-fects ([Janel & Noll, 2014](#page1)).

Unlike total phenolic, reports on polyphenolic composition are very scarce in Bangladesh. The Food Composition Tables (FCTs) for Bangladesh ([Islam, Khan, & Akhtaruzzaman, 2012; Shaheen et al.,](#page1) [2014](#page1)) did not have any phenolics or polyphenolics data. However, a few studies reported polyphenolic profile for some Asian vegetables and fruits ([Andarwulan et al., 2012; Khanam, Oba, Yanase, & Murakami,](#page1) [2012](#page1)). [Muthukrishnan et al. (2016)](#page1) reported that the Erythrina variegata contain little or no amount of GA, CfA, rutin, or QH, which is in contrast to the findings of the present study. Absence or undetectable content of polyphenolics such as PcouA, EA, Myr, and Kaem in some vegetables was also reported ([Khanam et al., 2012](#page1)).

Despite the promising health benefit of polyphenols, particularly, in prevention of chronic diseases, data on dietary intake of phenolic foods are scant. It was documented that polyphenolic intake is significantly associated with 46% reduction in risk for cardiovascular diseases ([Andarwulan et al., 2012](#page1)). Suggested polyphenolics intake was re-ported to be 1756.5 ± 695.8 mg per day, but energy adjusted poly-phenol intake was 854.3 ± 331.3 mg per day per 1000 kcal. Further, fruits and vegetable intake account for about 28% of daily polyphenolic need ([Brat et al., 2006](#page1)). However, it was also pointed that excess intake of polyphenolics might have adverse health eﬀects. In animal studies, it was noted that high dose of certain polyphenolic caused kidney da-mage, even led to tumour development and also alter thyroid hormone production ([Brat et al., 2006](#page1)). Some polyphenol-rich foods may also aﬀect absorption of certain nutrient. Also, people with food allergies or certain medical conditions may need to avoid some polyphenolic rich foods. Therefore, database on phenolic and polyphenolics for local ve-getables and fruits needs to be generated and the people need to be informed to consume vegetables and fruits and also to avoid certain foods.

3.5. Antioxidant capacities of selected wild plants

It is somewhat complicated to distinctly analyze each antioxidant component due to the presence of various antioxidant molecules in the plant tissues. The solvents used for extraction and settings of the ex-traction procedure can markedly aﬀect the antioxidant potential of the plant extracts. Several aspects can influence the antioxidant abilities of plant extracts, which cannot be fully defined by based on one particular method. The antioxidant activity of plant extracts is believed to be mediated through phenolics which can act as a reducing agents, elec-tron donors, and singlet or triplet oxygen scavengers due to their redox properties. Thus, more than one kind of antioxidant capacity assay is essential to carry out with a view to the several mechanisms of anti-oxidant activity ([Rana et al., 2019](#page1)). In this study, the extracts of the selected wild plants were assessed for the antioxidant potential by utilizing the DPPH, FRAP, and TEAC assays. As stated, this was the first study to evaluate the antioxidant capacities of the undertaken wild plants, no reference data was available to compare.

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|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Quercetin | nd | a | 1.±0.0319 | 4.±0.8016 | nd |  |  |
|  | 10.±1.0515 |  |  |
|  |  |  |  | c | b |  |  |  |
|  |  |  | a |  | a |  |  |  |
|  | Kaempferol | nd | 1. ± 0.1151 | nd1. ± 0.3119 | | nd |  |  |
|  | Myricetin | 1.±0.1824 | 4.±0.2857 | nd | a | nd |  |  |
|  | 40.±2.4575 |  |  |
|  |  | c | b |  |  |  |  |  |
|  | Ellagicacid | nd | a | nd83.±4.2239 | | nd |  |  |
|  | 480.±15.5027 |  |  |
|  |  |  |  |  | b |  |  |  |
|  | Rutinhydrate | b | b | a | 0.±0.0385 | 4.±0.6423 |  |  |
|  | 26.±0.7733 | 24.±1.1067 | 64.±2.8723 |  |  |
|  |  |  |  |  | c | c |  |  |
|  | p-coumaricacid | 3.±0.1809 | nd | 18.±0.3141nd | | 8.±0.8969 |  |  |
|  |  | c |  | a |  | b |  |  |
|  |  |  |  |  |  |  |
|  |  | b | a | c | c | a |  |  |
|  | Epicatechin | 5. ± 0.6045 | 8. ± 0.9467 | 0. ± 0.01951.±0.1059 | | 8. ± 1.0325 |  |  |
|  |  | b | a |  | d | c |  |  |
|  | ﬀCa eic acid | 5. ± 0.3156 | 9. ± 1.5028 | nd | 1. ± 0.0550 | 3. ± 0.0363 | erent. |  |
|  |  |  |  |  |  |  | ﬀ |  |
|  |  | a | a | c | c | b | di |  |
| Table3Polyphenolcontent(mgper100gfreezeDW)inthewildplantstested. | NameofwildplantsGallicacidCatechinhydrateVanillicacid | 0.70 | 0.82 | 0.05 | 0.32 | 0.92 |  |
| Blumealacera(Burm.f.)DC.1.±0.1289 | ErythrinavariegataL.3.±0.7525 | Berberisaristata2.±0.0285 | Sesbaniasesban(L.)Merr4.±0.5212 | Hygrophillaschulli6.±1.1483 | dw:dryweight.nd:notdetected.fiMeansthatdonotshareasuperscriptletteracrosscolumnsaresignicantly |  |
|  |  | 9.±408.±060.±892.±224.±86 | | | | |  |  |
|  |  | cd | a |  | c | b |  |  |
|  |  | 12.±1.2276 | 76.±3.4254 | 7.±1.187815.±2.2555 | | 53.±4.4505 |  |  |
|  |  |  |  | d |  |  |  |  |
|  |  | c | bc | bc | b | a |  |  |
|  |  |  |  |  |  |  |  |  |

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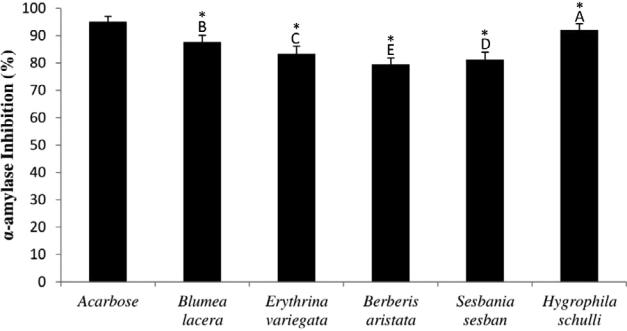


Fig. 2. α-Amylase inhibitory (%) activity of the selected samples and acarbose. Means that do not share a letter among samples are significantly diﬀerent. \* indicates significant diﬀerence compared to Acarbose.

3.5.1. DPPH scavenging activity

DPPH• radical scavenging abilities of the studied wild plants are presented in [Table 2](#page1). Erythrina variegata showed the highest DPPH in-hibition capacity (89.28% inhibition) while the lowest antioxidant ca-pacity (75.34% inhibition) was observed in Blumea lacera. Our study findings demonstrated that the samples under study exhibited good DPPH radical scavenging capacity. Previous study also reported similar results ([Afolayan & Jimoh, 2009; Alam et al., 2019; Gupta et al., 2005;](#page1) [Hossain et al., 2011; Kaur & Kapoor, 2002; Mamun et al., 2012; Rana](#page1) [et al., 2019](#page1)).

3.5.2. FRAP and TEAC assays

FRAP and TEAC values of the plant extracts under study are pre-

sented in [Table 2](#page1). For the FRAP assay, the antioxidant ability varied from 262.91 ± 2.35 to 845.87 ± 5.37 µmol Fe(2+)/g. The FRAP assay

is a simple method which provides rapid and reproducible results. In this assay, the antioxidant potential is determined according to the ability to convert ferric(3+) ions to ferrous(2+) ions. Among the tested

samples, Erythrina variegata was found to demonstrate the highest an-tioxidant capacity (845.87 ± 5.37 µmol Fe(2+)/g), followed by Ses-bania sesban (705.47 ± 6.24 µmol Fe(2+)/g) while Blumea lacera ex-

hibited the lowest antioxidant capacity (262.91 ± 2.35 µmol Fe(2+)/ g).

The TEAC was determined by means of the advanced ABTS·+ radical scavenging assay ([Rana et al., 2019](#page1)). For the TEAC assay, the anti-oxidant potential was in the range of 240.17 ± 3.26 to 738.41 ± 4.38 µmol Trolox/g. Like FRAP assay, Erythrina variegata was found to possess the highest antioxidant capacity (738.41 ± 4.38 µmol Trolox/g), followed by Sesbania sesban

(650.76 ± 5.40 µmol Trolox/g) while Blumea lacera showed the lowest value (240.17 ± 3.26 µmol Trolox/g).

Since both TEAC and FRAP are a quantification of the eﬃcient antioxidant capacity of the extract, a higher TEAC and FRAP values would generally imply superior antioxidant capacity of the samples. From low to high, the following order was observed among the samples, Blumea lacera < Berberis aristata < Hygrophilla schulli < Sesbania sesban < Erythrina variegata, in relation to both FRAP and TEAC va-lues. A strong correlation (r = 0.9866) was seen between the FRAP and TEAC antioxidant abilities, which signifies the eﬃciency of these plants

both in scavenging free radicals (ABTS·+) and reducing oxidants (ferric(3+)).

3.6. Correlation between antioxidant capacity assays and total phenolic content

The Pearson correlation coeﬃ cient between DPPH and TPC, TEAC and TPC, and FRAP and TPC of tested plants were r = 0.9101, r = 0.9271, and r = 0.9475, respectively. Thus, the correlation results indicate that at least 90% of antioxidant potential is considered to be

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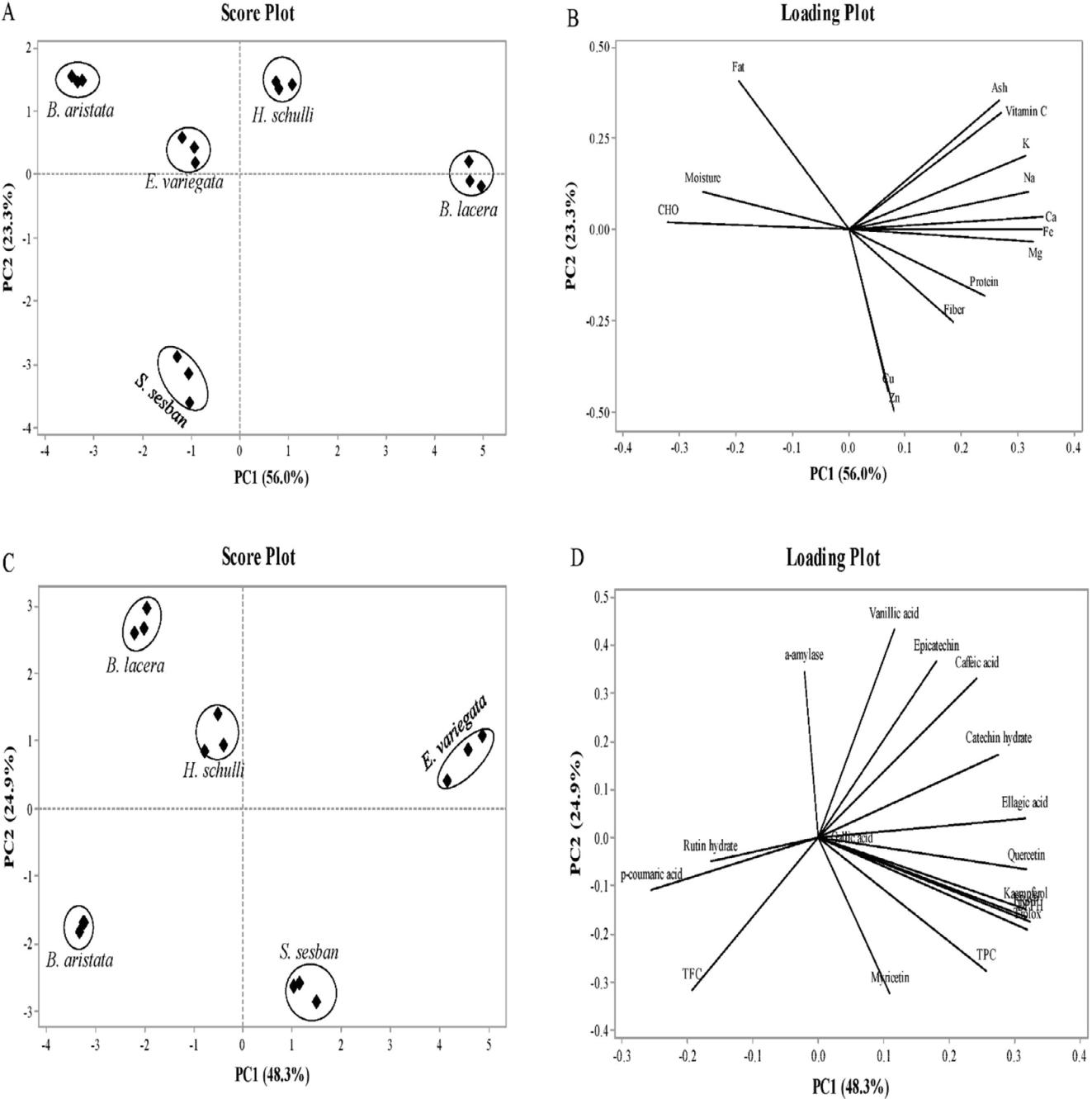


Fig. 3. Principal component analysis using variables listed in [Tables 1–3](#page1). Score plot (A and C) and loading plot (B and D) of first two principal components for clustering of plant samples. Variables: 11 polyphenols, TPC, TFC, DPPH, ABTS, FRAP, α-amylase inhibition activity, 6 proximate nutrients, 7 minerals, and ascorbic acid.

exerted through the high phenolic content of the plants. The linear correlation between TPC and antioxidant capacities as observed in our study are in accordance with previous reports ([Afolayan & Jimoh, 2009;](#page1) [Gupta et al., 2005; Hossain et al., 2011; Kaur & Kapoor, 2002; Mamun](#page1) [et al., 2012; Rana et al., 2019; Uddin et al., 2016](#page1)). From the data ob-tained by antioxidant activity assay methods, it was found that the tested plants showed good antioxidant capacities. Thus, as a natural rich source of antioxidants, these wild plants could be utilized for the preparation of crude extracts and also for further isolation and pur-ification of antioxidant molecules.

3.7. α-amylase inhibitory activity

Controlling or constraining the response of carbohydrate hydro-lyzing enzymes (α-amylase and α-glucosidase) is considered to be ef-fective strategy in tackling and/or managing of T2DM. Restricting the activity of α-amylase slows down the carbohydrate digestion after meal intake and thus generation of glucose declines and inevitably brings down the circulatory glucose levels ([Oboh et al., 2015](#page1)). The ability of the selected plant extracts to restrict α-amylase ([Fig. 2](#page1)) activity was evaluated. The findings revealed that the extract of Hygrophilla schulli exhibited potent inhibitory activity on α-amylase reaching to 92.11% inhibition. Compared to other samples, Berberis aristata inhibited the activity of α-amylase least (79.45% inhibition). In this study, all the

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plant extracts demonstrated considerable and significant α-amylase activity when compared with known potent α-amylase inhibitor (acarbose) ([Fig. 2](#page1)) and this anti-diabetic eﬀect may be attributed to the occurrence of phenolic compounds. Few other studies also reported similar findings by using some Bangladeshi wild plants ([Rana et al.,](#page1) [2019; Uddin et al., 2014](#page1)), Indian medicinal plants ([Sudha, Zinjarde,](#page1) [Bhargava, & Kumar, 2011](#page1)) and Egyptian wild plants ([Hossain, El-Sayed,](#page1)

* [Aoshima, 2009](#page1)). Phenolic compounds have been reported to lower the risk of type-2 diabetes which could be linked to their inhibitory activity on α-amylase ([Hossain et al., 2009; Oboh et al., 2015; Rana](#page1) [et al., 2019; Sudha et al., 2011; Uddin et al., 2014](#page1)). Thus, the selected plants could serve as a potential candidate for making anti-diabetic medicines and/or functional foods to treat type-2 diabetes.

3.8. Principal component analysis

To better discriminate among the samples under investigation, principal component analysis (PCA) was performed separately on the combined proximate, ascorbic acid and mineral data and combined TPC, TFC, biological activities and polyphenol profile ([Fig. 3](#page1)). The PCA score plots of all of the plant samples are shown in [Fig. 3](#page1)A (based on all proximate, ascorbic acid and mineral variables) and [Fig. 3](#page1)C (based on TPC, TFC, antioxidant activities, α-amylase inhibition activity, and polyphenol profile), and their corresponding loading plots are pre-sented in [Fig. 3](#page1)B and [Fig. 3](#page1)D. Though the PCA results yielded three or four principal components (PC) with eigenvalues > 1, only first two PCs were kept to simplify the analysis of results. The first two PCs ac-counted for 79.3% ([Fig. 3](#page1)A and B) of the total variance based on the pooled proximate, ascorbic acid and mineral values, with PC1 (56.0%) explaining ~ 2.5 times as much as PC2 (23.3%) while the first two PCs accounted for 73.2% ([Fig. 3](#page1)C and D) of the total variance based on the pooled TPC, TFC, antioxidant activities, α-amylase inhibition activity, and polyphenol profile, with PC1 (48.3%) explaining almost two times as much as PC2 (24.9%). In [Fig. 3](#page1)B, PC1 was negatively associated with moisture, carbohydrate and fat and positively associated with the as-corbic acid, all mineral elements and other proximate variables. PC2 was negatively correlated with Mg, Cu, Zn, protein, and fiber, while positively correlated with the others. In [Fig. 3](#page1)D, PC1 was correlated negatively with α-amylase, RH, PCouA and TFC, and positively with the rest of the phenolic compounds and TPC. PC2 was correlated positively with α-amylase, VA, ECA, CA, CH and EA and negatively with the rest of the phenolic compounds. Erythrina variegata and Blumea lacera were clearly separated and were distant from all other samples on the right side as a result of the high contents of DPPH, ABTS, FRAP, total poly-phenols, VA, ECA, and EA and protein, fiber, ash, vitamin C, Na, K, Ca, Fe, and Mg, respectively.

4. Conclusions

This was the first comprehensive evaluation of proximate and mi-neral composition, vitamin C content, antioxidant capacities, total phenolic- and flavonoid- contents, polyphenol profile and antidiabetic potential of five selected wild plants of Bangladesh. The results suggest that the plants undertaken in the current study are promising sources of essential nutrients and could be exploited as ingredient for preparation of functional foods. The current study also justifies and provides the preliminary result of eﬀectiveness in inhibiting α-amylase enzyme by the selected wild plants. Thus, the consumption of the studied wild plant species may contribute to health benefits due to their potential α-amylase enzyme inhibition activity as well as their high antioxidant and nutritional values. Therefore, increased utilization and production of these wild plants are suggested to meet the nutritional requirement in addition to staple food and to maintain and promote diversity.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influ-ence the work reported in this paper.

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Author contributions

M. K. Alam and Z. H. Rana prepared the manuscript. S. N. Islam and M. Akhtaruzzaman reviewed and corrected the manuscript. S. N. Islam and M. Akhtaruzzaman designed and guided the study and M. K. Alam and Z. H. Rana conducted the experimental work. Data interpretation and analysis was done by M. K. Alam and Z. H. Rana. All authors re-viewed and approved the manuscript.

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Ethics approval and consent to participate

Not applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at [https://](https://doi.org/10.1016/j.foodchem.2020.126646) [doi.org/10.1016/j.foodchem.2020.126646](https://doi.org/10.1016/j.foodchem.2020.126646).

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