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Nutritional and Biochemical Quality Assessment of Commonly Consumed Jujube (*Zizyphus mauritiana* L.) Varieties Available in Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author NRP collected samples, performed analysis and collect data. Author SM helped in data analysis and wrote the first draft of the manuscript. Author HMZ designed the study, collect fund, supervise the work, and corrected the final draft of the manuscript. Authors AR and QFQ helped to design the study and corrected the final draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted to determine major biochemical and mineral constituents in commonly consumed jujube varieties of Bangladesh. A total of 15 (4 local/deshi and 11 exotic) varieties of matured jujube fruits were collected from the different markets and local areas of Mymensingh district, Bangladesh, and analyzed for this study. The study results revealed that all studied physical properties were lower in local/deshi sour varieties of jujube, and *BAU kul* contained the maximum amount of flesh (edible part of fruits) along with flesh and seed ratio. Among the biochemical properties- titratable acidity, vitamin C, chlorophyll-a, chlorophyll-b, total sugar and reducing sugar content varied from 0.178-2.769%, 33.28-98.63 mg/100 g flesh, 0.0019-0.0174 mg/g tissue, 0.0007-0.0148 mg/g tissue, 2.50-9.83% and 0.135-4.150%, respectively. The study results revealed that local/deshi varieties contained a comparatively higher amount of vitamin C and lower total sugar. However, *BARI kuls* contained significantly higher amounts of vitamin C and chlorophylls compared to other exotic varieties. The content of Ca, Mg, Na, K, P, and S in jujube varieties ranged from

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0.040-0.233%, 0.071-0.164%, 0.054-0.189%, 0.490-2.602%, 0.062-0.234% and 0.079-0.359%, respectively. Regarding major nutrients studied, Ca, Na, K, P, and S contents were higher in local/deshi sour varieties while Mg content was higher in exotic varieties. The study results concluded that most of the biochemical and mineral contents in local/deshi sour jujube fruits were higher, allowing breeders to develop new varieties and improve the quality of existing exotic cultivars.

Keywords: Local variety; exotic variety; physicochemical properties; vitamin C; sugar; mineral elements.

1. INTRODUCTION

The jujube fruit is popularly known as *kul* or *boroi* in Bangladesh, *tsao* in China, and jujube or ber in India. It is extensively grown in southern Asia, Syria, northern India, southern central China, and southeastern Europe. Indian jujube (*Zizyphus mauritiana* L.) is indigenous to India and grows under varying climate conditions all over the Indian subcontinent [1]. According to Islam and Simmons [2], the genus *Ziziphus* has 135 to 170 species, and among those, 17 are native of India [3]. The species belongs to the *Rhamnaceae* family, widely used as medicine predominantly in Asian countries, particularly in Taiwan and China [4].

Jujube is one of the most nutritious fruits available in Bangladesh. This fruit is cultivated in most of the districts of the country, but good quality fruits are produced mainly in Rajshahi, Comilla, Khulna, Barisal, and Mymensingh. The total area of jujube cultivation in 2016-17 was 7.06 thousand acres, and production was 89.88 thousand metric tons [5]. Jujube saplings are usually planted twice a year (viz. June-July and September-October) in Bangladesh. High land with proper drainage is suitable for jujube cultivation. It can be cultivated successfully in a wide variety of soils (such as saline and alkaline) and it can tolerate climatic stress conditions (such as drought and waterlogged conditions). However, loamy to sandy loam soil with pH 6.5 to 7.5 is the best for jujube cultivation [6].

Many factors impact jujube fruits' quality, including appearance, color, texture, and flavor; an equally important quality that is invisible is the nutritional value of the fruits. An increasingly important aspect of nutritional quality is the content of phytochemicals, which are responsible for health protection and disease prevention [7]. Jujube has gained much attention in the food and nutritional sciences due to its nutritional and medicinal properties [8,9]. The jujube fruit known has been already described as a rich source of vital functional components such as polysaccharides, phenolics, flavonoids, and saponins, which are responsible for various biological activities, including inhibition of cancer cell development, alleviation of brain nerve disorder, regulation of immune function and reduction of blood triglyceride [10,11]. Primarily, phenolics serve as powerful antioxidants by their hydrogen-donating properties and by donating electrons to stop free radical chain reactions developing from different oxidative stresses [12]. Several scientific publications on phenolics strongly advocate consuming phenolic-rich food to manage degenerative diseases, particularly cardiovascular, cancer, Alzheimer's, diabetes, and neurodegenerative diseases [13-15]. Moreover, according to Koley et al. [13], Indian jujube is a good source of ascorbic acid and total phenolics ranging from 19.54 to 99.49 mg/ 100 g and 172.0 to 328.6 mg (gallic acid equivalent)/ 100 g, respectively.

Literature survey results revealed that most of the information reported in the works had been restricted to Chinese jujube and Indian genotypes remain under-researched, mainly available in Bangladesh. Despite a cheap fruit, jujube remains an underutilized fruit in our average diet compared to other popular fruits such as mango, apple, and orange. This is mainly due to a lack of information about its health-promoting effects on familiar consumers. Bangladesh has enormous biodiversity of *Z. mauritiana* L., but unfortunately, no systematic research report is available on their nutritional quality yet. Considering the fact stated above, this study was planned to assess the major physicochemical and nutritional composition of commonly consumed jujube varieties available in Bangladesh, allowing breeders to select cultivars with higher levels of nutrients and enable increasing dietary intake by consumers.

2. MATERIALS AND METHODS

2.1 Collection of Jujube Fruits

A total of 15 varieties (4 local/deshi and 11 exotic) of matured jujube fruits were collected from different markets and local areas of Mymensingh, Bangladesh and analyzed for this study. Among the exotic varieties, 4 were released by the Bangladesh Agricultural Research Institute (BARI) (*BARI kul*-1, *BARI kul*-2, *BARI kul*-4, and *BARI kul*-5) and all of those were collected from BARI, Joydebpur, Bangladesh. However, among the others, 1 variety is released from BAU (*BAU kul*), and the rest 6 exotic varieties were: *Apple kul*, *Narkeli kul*, *China kul*, *Thai kul*, *Kashmiri kul,* and *Shoira kul*. On the other hand, 4 local/deshi sour varieties were categorized based on their size as- *Deshi kul*-1 (very small; <5.0 g), *Deshi kul*-2 (small; 5.0-7.0 g), *Deshi kul*-3 (medium; 7.0-10.0 g) and *Deshi kul*-4 (large; >10.0 g).

2.2 Determination of Physical Properties of Jujube Fruits

Among the physical properties, moisture content, fresh and dry weight of fruit without seed, seed weight, and flesh seed ratio were measured. For this purpose, 5-10 jujube fruits were selected randomly. Moisture content in jujube fruits was measured using the following equation. After removing the seed, the jujube fruits were homogenized using a blender, and then the resultant homogenate was kept in an electric oven at 70°C temperature. When the fruit weight was constant in the oven, the weight difference of the homogenate before and after the drying process was used to determine the moisture content.

$$\%\,Moisture = \frac{[\text{Fresh weight (g)} - \text{Dry weight (g)}] \times 100}{\text{Fresh weight (g)}}$$

2.3 Processing of Jujube Fruits for Chemical Analyses

Collected jujube fruit samples were sorted, cleaned with distilled water, and air-dried first. After sorting and cleaning, the samples were stored in polythene bags with appropriate marking and leveling. Finally, samples were stored in the refrigerator of the laboratory of the Department of Agricultural Chemistry of Bangladesh Agricultural University, Mymensingh. At the same time, about 100 g flesh was separated from the seed and oven-dried for 72 hrs at 50^0C temperature until a constant weight was obtained. After drying, ground the samples by grinding mill. Then the powdered samples were preserved in polythene bags with the appropriate marking for further chemical analyses.

2.4 Extraction of Jujube Fruits for Chemical Analyses

For the determination of different mineral constituents, precisely 1.00 g of powdered sample was digested with 10 mL of the di-acid mixture (HNO_3:$HClO_4$=2:1) as described by Singh et al. [16]. Finally, the volume of extract was made 100 mL with distilled water. Then the collected extract was transferred into a plastic container and preserved in a refrigerator to determine the total major mineral elements.

2.5 Measurement of Titratable Acidity of Jujube Fruits

In order to measure acidity, some fruits were peeled in each experiment and cut into small pieces. About 10 g of the fruit samples with 10 mL of distilled water was filtered and centrifuged for 10 minutes at 5,000 g; the supernatant was brought to 50 mL with distilled water. Then 10 mL of prepared solution titrated with 0.1 N sodium hydroxide. Titratable acidity was calculated as the percentage of citric acid by the following formula-

$$\%\,Titratable\ acidity = \frac{\text{N} \times V \times 0.064 \times 100}{\text{Weight of sample in g}}$$

Where,

N = normality of titrant, usually NaOH (0.1 N), V = volume of titrant (mL).

2.6 Determination of Vitamin C Content of Jujube Fruits

About 10 g jujube flesh was ground with 4% oxalic acid. The slurry was filtered, and the final volume of the filtrate was brought up to 50 mL with 4% oxalic acid. Ascorbic acid (AA) content was determined using 2, 6-dichlorophenol indophenols by visual titration outlined by Sadasivam and Manickam [17]. Results of AA content were expressed as milligrams of ascorbic acid per 100 g of fresh weight. Measurements were done using the following equation-

$$mg\ of\ vitamin\ C\ in\ 100g\ sample = \frac{\text{I} \times S \times D \times 100}{\text{A} \times W}$$

Where,

I = mL of indophenol reagent used in the titration; S = mg of ascorbic acid reacting with 1 mL of the dye; D = Volume of the extract in mL; A = the aliquot titrated in mL and W = the weight of sample in g.

2.7 Determination of Sugar Content of Jujube Fruits

The sugar content in a food sample is estimated by determining the volume of the unknown sugar solution required to reduce a measured volume of Fehling's solution completely. For this purpose, 2-6 fruits of each jujube cultivar were randomly selected. After the seed was removed, the resultant fruits were immediately extracted with 10 mL ethanol, and finally, the volume was made 50 mL with distilled water (Extract-A). Then 1.0 mL of resultant extract was evaporated near to dryness in a water bath. The content was diluted into 50 mL with distilled water. 1.0 mL of this solution was taken in a test tube, and 4 mL anthrone reagent was added to it. The content was heated for 5 minutes in a boiling water bath. Then absorbance reading was taken at 620 nm wavelength. Glucose was used as the external standard, and the total sugar content was expressed as gram glucose equivalents per 100 g of fresh fruit weight (g/100 g FW).

To determine the amount of reducing sugar, 5 mL of Extract-A was taken in a test tube and evaporated near 3.0 mL using a water bath. Then the content was diluted into 50 mL with distilled water. 3.0 mL of this solution was taken in a test tube, and 3 mL of DNS reagent was added to it. The content was heated for 5-10 minutes in a boiling water bath. Then 1.0 mL of Rochelle salt solution was added to the warm solution, and the content was cooled at room temperature. Finally, the absorbance reading was taken at 575 nm wavelength. Glucose was used as the external standard, and the reducing sugar content was also expressed as gram glucose equivalents per 100 g of fresh fruit weight (g/100 g FW).

2.8 Measurement of Chlorophyll Content of Jujube Fruits

The photosynthetic pigment chlorophyll present in jujube fruits was measured by spectrophotometry, as Sadasivam and Manickam [17] mentioned. The fruits were ground using a ceramic mortar and pestle containing 90% acetone. The extract was filtered through Whatman No. 1 filter paper into a volumetric flask and made up to a volume of 50 mL. The extract was stored in aliquots in the dark until required. Then absorbance reading was taken using the clear extract at 663 and 645 nm wavelength. Then the amount of chlorophyll-a and chlorophyll-b was calculated using the following equation-

$$Chlorophyll - a\ (mg\ g^{-1}\ tissue) = \frac{(12.7 \times A_{663} - 2.69 \times A_{645}) \times V}{1000\ \times \mathrm{W}}$$

$$Chlorophyll - b\ (mg\ g^{-1}\ tissue) = \frac{(22.9 \times A_{645} - 4.68 \times A_{663}) \times V}{1000\ \times \mathrm{W}}$$

Where, V = total volume of extract in mL and W = fresh weight of tissue in g.

2.9 Determination of Major Mineral Contents of Jujube Fruits

Among the major mineral nutrient elements, Ca and Mg were determined by the complexometric method of titration using Na_2-EDTA as a complexing agent at specific pH and using ion-selective indicators [16]. The phosphorus content in the aqueous extract of jujube fruits was determined by developing a phosphomolybdate blue complex with stannous chloride ($SnCl_2.2H_2O$) and measuring the absorbance of color with the help of a spectrophotometer (T60 UV-Visible Spectrophotometer, PG Instrument, UK) at 660 nm wavelength. Sulphur content in the extract was determined turbidimetrically with the help of a spectrophotometer at 425 nm absorbance wavelength using $BaCl_2$ as turbidimetric agent [18]. The content of Na and K in jujube fruit extract was determined with the help of a flame emission spectrophotometer (Model- Jenway PFP7, UK) using an appropriate filter [16]. Finally, the content was expressed as gram per 100 g of dry fruit weight.

2.10 Statistical Analysis

Data on major biochemical and mineral constituents in commonly consumed jujube varieties of Bangladesh were measured thrice, and the mean value was recorded for presentation. Finally, obtained data were analysed statistically with the help of the computer package M-STAT. Single-factor ANOVA at $P \leq 0.05$ significant level was applied to compare concentrations of different biochemical and minerals constituents in jujube varieties.

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Jujube Fruits

The fruit shape and size development has been confirmed to be essentially determined by the fruit genotype [19]. Climate, soil type, and management strategy also play important roles in altering the shape of fruits. Typically, fruits cultivated under high-temperature conditions exhibit a long fruit shape, whereas low-temperature conditions could result in a round shape [20]. Physical properties of commonly consumed jujube varieties of Bangladesh are presented in Table 1.

Moisture content has been considered a critical parameter to evaluate the quality of jujube fruits, and it can be significantly affected by genotype and cultivation conditions [21]. Among the jujube fruit cultivars, moisture content varied from 79.82 to 89.87%, with a mean value of 85.97%. The highest amount of moisture was obtained from *China kul* followed by *Thai kul* and *BAU kul*. On the other hand, the lowest amount of moisture was obtained from *Deshi kul*-1. The highest average fresh weight, both with and without seed, and the maximum mean dry weight were obtained from *BAU kul* followed by *Thai kul, BARI kul-2* and *Kashmiri kul* (Table 1). Similar to moisture content, the lowest average fresh weight, both with and without seed, and the minimum mean dry weight were obtained from *Deshi kul*-2. The study results revealed that all studied physical properties were lower in local/deshi sour varieties of jujube. In contrast, while the exotic varieties contained the maximum amount of flesh (edible part of fruits) and flesh and seed ratio (Table 1).

3.2 Biochemical Properties of Jujube Fruits

3.2.1 Vitamin C content

Ascorbic acid (vitamin C) content was determined using 2, 6-dichlorophenol indophenols by visual titration, and values are presented in Fig. 1. The content of vitamin C ranged from 33.28 to 98.63 mg/100 g flesh depicting three-fold variations. The vitamin C in increasing order was: *Kashmiri kul* < *China kul* < *Deshi kul-2* < *Deshi kul-4* < *BAU kul* < *Narkeli kul* < *Thai kul* < *Apple kul* < *BARI kul-5* < *Shoira kul* < *BARI kul-1* < *Deshi kul-1* < *BARI kul-2* < *BARI kul-4* < *Deshi kul-3*. High variation in vitamin C content among genotypes could be due to the existing differences in growing conditions, climatic factors, maturity levels, size, and fruit positioning on the tree. Furthermore, vitamin C content in fruits is also influenced by the temperature of the production site/area; as we know, higher temperature reduced the amount of vitamin C due to chemical, enzymatic and thermal decay of naturally active compounds. However, the values are in agreement with the previous reports of Zhang et al. [22]. The extent of vitamin C in jujube fruits was found very high compared to other fruit crops commonly consumed in the Indian diet such, as mango, papaya, and guava. The range of vitamin C (mg/100 g) was 60.5 in mango, 92.9 in papaya and 72.2 in guava [23-24]. Ascorbic acid acts as a reducing and chelating agent and has been shown to scavenge free radicals, and is an important component of the antioxidative defense mechanism in cells and tissues. Increased levels of ascorbate also protect the lungs against the oxidizing agents present in cigarette smoke [25]. It also helps to detoxify the hazardous effects of stannous chloride, commonly used as a preservative in soft drinks [26].

3.2.2 Titratable acidity and sugar content

Acid has been reported to be accumulated in fruits during the development, and its level tends to be decreased along with the maturation of fruits [27]. Titratable acidity among the collected varieties ranged from 0.178 to 2.769% (Fig. 2). It is evident from Fig. 2 that acidity in local/deshi sour varieties was several times higher than the other commonly consumed jujube varieties of Bangladesh. BARI released varieties also contained a comparatively higher amount of acid than the others. On the other hand, the lowest amount of acid was obtained from *BAU kul* followed by *Thai kul*, *Kashmiri kul*, *China kul*, *Narkeli kul,* and *Apple kul*. It has been accepted that the sugar-to-acid ratio is an important indicator to evaluate the quality of fruits, and fruits with a high sugar-to-acid ratio tend to be preferred by consumers [28].

Sugar is another vital component in jujube fruits, and its content directly determines the sweetness of jujube fruits. Total sugar content in fruits of different jujube varieties varied from 2.50 to 9.83%, and the results are presented in Fig. 2. According to Gao et al. [28], the sugar-to-acid ratio is an important indicator for evaluating the quality of jujube fruits, and fruits with a high sugar-to-acid ratio tend to be preferred consumers all over the world. Thus, one objective to the breeders to develop varieties that contained a higher amount of total sugar. Total sugar content of collected jujube varieties was decreasing in the order as: *Shoira kul* > *Deshi kul-1* > *BARI kul-1* > *BARI kul-4* > *BAU kul* > *Apple kul* > *Kashmiri kul* > *Narkeli kul* > *China kul* > *BARI kul-5* > *BARI kul-2* > *Deshi kul-3* > *Thai kul* > *Deshi kul-2* > *Deshi kul-4.* Ling et al. [29]

reported that soluble sugar mainly consisted of sucrose, glucose, and fructose. The rate of increase in sucrose accumulation was the highest during the mid-late growth period to ripening in all cultivars studied. According to Kudachikar et al. [30], sucrose and fructose continued to increase, whereas glucose decreased slightly with the advancement of ripening of jujube. Furthermore, the stages of harvest had a significant effect on total sugar content.

Table 1. Physical properties of fruits of commonly consumed jujube varieties of Bangladesh

Name of varieties	Moisture (%)	Average fresh wt. with seed (g)	Average fresh wt. without seed (g)	Average wt. of seed (g)	Average dry wt. without seed (g)	Fresh flesh and seed ratio
BARI kul-1	87.65	27.46	25.59	1.87	3.16	13.68
BARI kul-2	85.73	34.86	32.40	2.46	4.63	13.17
BARI kul-4	84.12	14.36	12.79	1.57	2.03	8.15
BARI kul-5	85.66	15.25	13.39	1.86	1.92	7.20
BAU kul	88.30	62.77	59.45	3.32	6.95	17.91
Apple kul	84.78	14.07	12.87	1.20	1.96	10.73
Narkeli kul	87.11	24.25	22.78	1.47	2.94	15.50
Thai kul	89.50	44.11	41.41	2.70	4.35	15.34
China kul	89.87	18.80	17.43	1.37	1.77	12.72
Kashmiri kul	86.49	30.55	28.87	1.68	3.90	17.18
Shoira kul	85.34	18.71	17.14	1.57	2.51	10.92
Deshi kul-1	79.82	4.50	3.84	0.66	0.78	5.82
Deshi kul-2	86.57	6.01	4.86	1.15	0.65	4.23
Deshi kul-3	80.70	8.97	7.73	1.24	1.49	6.23
Deshi kul-4	87.98	11.06	9.56	1.50	1.15	6.37
Mean	**85.97**	**22.38**	**20.67**	**1.71**	**2.68**	**11.01**
Min.	79.82	4.50	3.84	0.66	0.65	4.23
Max.	89.87	62.77	59.45	3.32	6.95	17.91

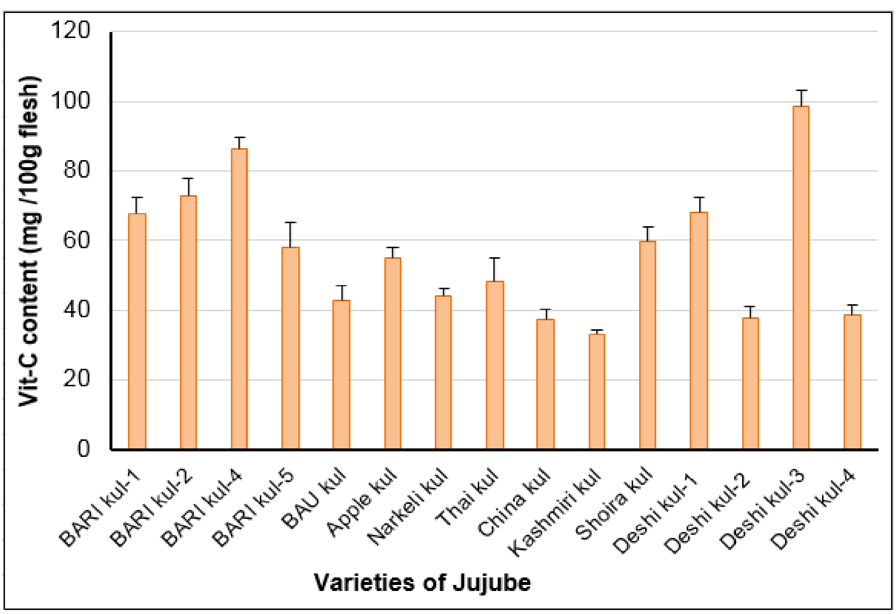

Fig. 1. Vitamin C content in fruits of commonly consumed jujube varieties of Bangladesh

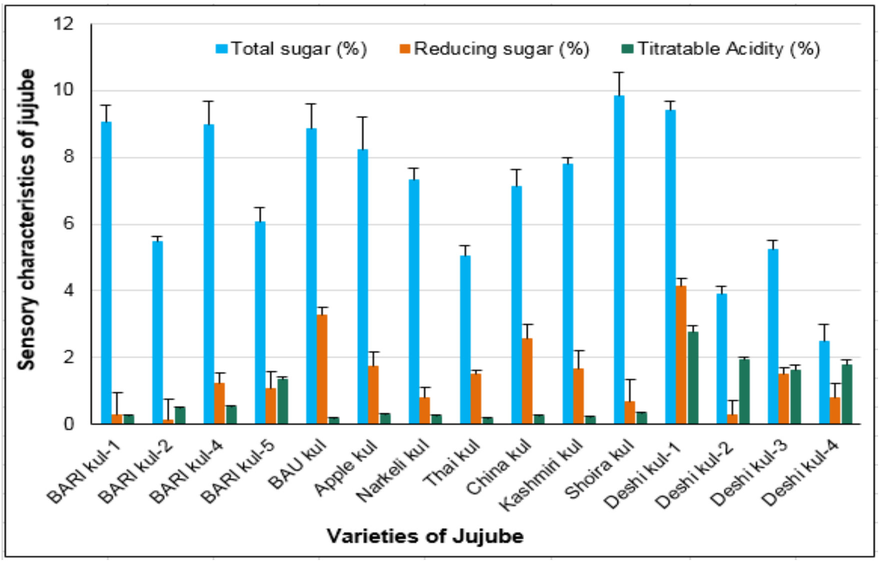

Fig. 2. Titratable acidity, total and reducing sugar contents in fruits of commonly consumed jujube varieties of Bangladesh

Reducing sugar in jujube fruits was increased from 40 days to 72 days after petal fall and then decreased until maturity and ripening [31]. It has been reported that sucrose (non-reducing sugar) is initially accumulated in the leaves of fruits, and it can be transferred from the fruit leaves to the fruit flesh. Afterward, the fruit development process can further hydrolyze sucrose into glucose and fructose in fruit flesh, which results in the accumulation of the sweetness in jujube fruits [32]. Non-reducing sugar (i.e., sucrose) appeared to be the dominant soluble sugar in all the samples. This result was similar to the previous study conducted by Chen et al. [33]. Among the jujube fruit cultivars, reducing sugar (particularly glucose and fructose) content varied from 0.135-4.150% (Fig. 2). The highest amount of reducing sugar obtained from *Deshi kul*-1 followed by *BAU kul*, *China kul*, *Apple kul*, *Kashmiri kul*, *Thai kul,* and *Deshi kul*-3. On the other hand, the lowest amount of reducing sugar was found in *BARI kul*-2, *BARI kul*-1, and *Deshi kul*-2. Soluble sugar content continuously increased throughout the growth and development of fruit, and the highest increase was noticed between 40 and 48 days and 80 to 88 days after petal fall. The soluble sugars content in ripe jujube fruit was 121.58 mg/g [31].

3.2.3 Chlorophyll content

Chlorophyll is known to possess numerous health benefits ranging from the body's circulatory, digestive, immune, and detoxification systems. Chlorophyll counteracts toxins and inhibits the activities of cancer-causing elements [34]. Chlorophyll increases iron levels in human blood, which is especially useful for pregnant or nursing women. Chlorophyll also helps to purify the liver. Chlorophyll regulates blood sugar levels in the human body, which is good for general health and wellness. Chlorophyllin (E141) is a green-colored derivative of chlorophyll pigment used as a food additive and alternative medicine [35]. Recent research shows that chlorophyll has promising medicinal and health benefits [34-36]. Among the commonly consumed jujube fruits of Bangladesh, chlorophyll-a and chlorophyll-b content varied from 0.0019-0.0174 mg/g tissue, 0.0007-0.0148 mg/g tissue, respectively (Fig. 3). The highest amount of total chlorophyll was recorded from the variety *BARI kul*-1 followed by *BARI kul*-5, *Deshi kul*-1, *Deshi kul*-2, *Deshi kul*-3, *Deshi kul*-4, and *BARI kul*-2. On the other hand, the lowest amount of total chlorophyll was obtained from *Apple kul* and *Kashmiri kul*. However, the amount of chlorophyll in jujube was significantly lower when compared with different green vegetables, as mentioned by Vivek et al. [37].

3.3 Mineral Contents in Commonly Consumed Jujube Fruits

3.3.1 Calcium

Calcium is an essential macronutrient element. Calcium is vital for bone formation and prevention of osteoporosis, along with beneficial effects on serum lipids [38]. The highest amount of Ca was found in *Deshi kul*-2 and *Deshi kul*-4 (0.233%), followed by *Deshi kul*-3, *China kul*, and *BARI kul*-4. On the other hand, the lowest amount of Ca was obtained from the *Thai kul* (0.040%) (Table 2). So, it can be inferred from this study that local/deshi sour varieties contained a comparatively higher amount of Ca. Paul and Shaha [39] stated that citrus fruits are not considered to be good sources of Ca, but some fruits may contain an appreciable amount of Ca. According to Pareek [1], on average, five cultivars of Chinese jujube contained 79.3 mg/100 g Ca on a dry weight basis (i.e., 0.079% on a dry weight basis). The mean concentration of Ca obtained by the present study was 0.173%, which was almost twice the result reported by Pareek [1]. However, the present study average of Ca was almost similar to the Indian jujube as reported by Pareek et al. [40].

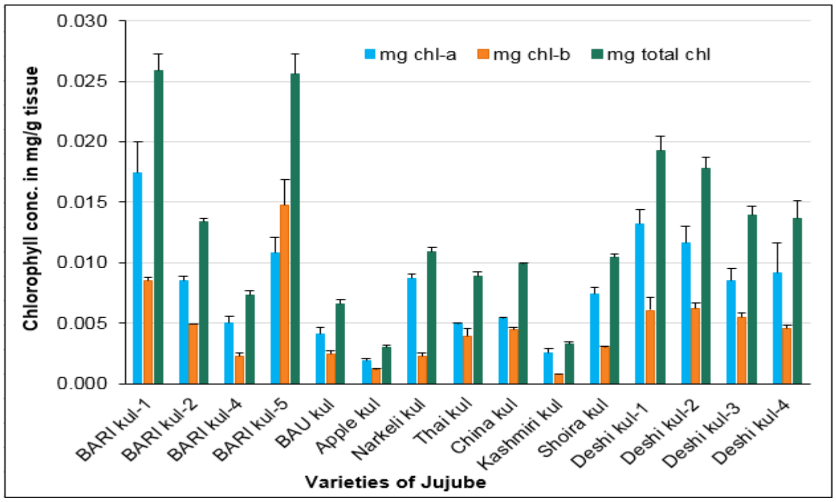

Fig. 3. Chlorophyll-a, chlorophyll-b and total chlorophyll contents in fruits of commonly consumed jujube varieties of Bangladesh

Table 2. Major mineral constituents in fruits of commonly consumed jujube varieties of Bangladesh

Name of varieties	Major mineral constituents in % (dry weight basis ±SD)					
	Ca	**Mg**	**Na**	**K**	**P**	**S**
BARI kul-1	0.192±0.008	0.164±0.002	0.143±0.009	1.58±0.022	0.159±0.013	0.241±0.007
BARI kul-2	0.195±0.005	0.118±0.003	0.118±0.003	1.09±0.009	0.107±0.007	0.224±0.015
BARI kul-4	0.200±0.005	0.073±0.004	0.072±0.003	0.77±0.021	0.062±0.002	0.079±0.002
BARI kul-5	0.156±0.004	0.118±0.011	0.130±0.003	1.35±0.019	0.086±0.003	0.260±0.004
BAU kul	0.120±0.002	0.073±0.004	0.092±0.004	0.73±0.010	0.075±0.005	0.128±0.004
Apple kul	0.154±0.003	0.140±0.002	0.107±0.009	0.97±0.014	0.066±0.002	0.126±0.003
Narkeli kul	0.197±0.008	0.144±0.004	0.104±0.004	0.82±0.010	0.075±0.003	0.151±0.002
Thai kul	0.040±0.001	0.146±0.013	0.095±0.006	0.71±0.003	0.076±0.006	0.177±0.004
China kul	0.203±0.002	0.124±0.005	0.116±0.003	1.13±0.014	0.097±0.004	0.160±0.003
Kashmiri kul	0.194±0.002	0.118±0.010	0.054±0.002	0.49±0.012	0.108±0.007	0.132±0.008
Shoira kul	0.157±0.006	0.119±0.001	0.085±0.007	0.59±0.009	0.068±0.002	0.130±0.002
Deshi kul-1	0.120±0.006	0.121±0.009	0.099±0.003	1.15±0.014	0.072±0.002	0.142±0.012
Deshi kul-2	0.233±0.009	0.094±0.002	0.166±0.004	1.70±0.009	0.085±0.004	0.189±0.010
Deshi kul-3	0.203±0.008	0.099±0.006	0.094±0.005	1.13±0.007	0.077±0.003	0.105±0.004
Deshi kul-4	0.233±0.012	0.071±0.002	0.189±0.010	2.60±0.021	0.234±0.014	0.359±0.013
Mean	**0.173**	**0.115**	**0.111**	**1.121**	**0.096**	**0.173**
Min.	0.040	0.071	0.054	0.490	0.062	0.079
Max.	0.233	0.164	0.189	2.602	0.234	0.359
SD	0.051	0.028	0.035	0.537	0.045	0.072

SD= Standard deviation

3.3.2 Magnesium

Magnesium is the second most abundant element inside human cells and the fourth most abundant positively charged ion in the human body [41]. The Mg content in commonly consumed jujube fruits available in Bangladesh ranged from 0.071-0.164%, with a mean value of 0.115% (Table 2). The highest amount of Mg was found in *BARI kul*-1 followed by *Thai kul, Narkeli kul*, and *Apple kul*. On the other hand, the lowest amount of Mg was obtained from the *Deshi kul*-4, followed by *BARI kul*-4 and *BAU kul* (Table 2). So, it can be inferred from this study that local/deshi sour varieties contained a lower amount of Mg compared to exotic varieties. According to San et al. [42], the average Mg content in fruits of 4 promising jujube genotypes was 18.8 mg/100 g on a dry weight basis (i.e., 0.019% on a dry weight basis), which was lower than the present study average. Al-Kindy et al. [43] also reported a higher amount of Mg in jujube fruits, which was almost at par with the present study result.

3.3.3 Sodium

Sodium is suitable for muscle functions and electrolyte balancing, but it is not usually a problem in mineral deficiencies as it is frequently used to salt food. The Na content in commonly consumed jujube fruits available in Bangladesh ranged from 0.054-0.189%, with a mean value of 0.111% (Table 2). The highest Na was found in *Deshi kul*-4 followed by *Deshi kul*-2*, BARI kul*-1, and *BARI kul*-5. On the other hand, the lowest Na was obtained from the *Kashmiri kul* (Table 2). So, it can be inferred from this study that local/deshi sour varieties contained a comparatively higher amount of Na. According to San et al. [42], the Na concentration of jujube fruits ranged from 6.07 to 9.50 mg/100 g on a dry weight basis (i.e., 0.006 to 0.01% on a dry weight basis) which was lower than the present study range. Pareek [1] also reported a lower amount of Na in five cultivars of Chinese jujube, and the range was 3.22 to 7.61 mg/100 g on a dry weight basis.

3.3.4 Potassium

Potassium has many biological functions. It is a co-factor for many enzymes, and it is required for insulin secretion, creatine phosphorylation, carbohydrate metabolism, and protein synthesis [44]. The K content in commonly consumed jujube fruits available in Bangladesh ranged from 0.49-2.60%, with a mean value of 1.121% (Table 2). The highest amount of K was found in *Deshi kul*-4 followed by *Deshi kul*-2, *BARI kul*-1, and *BARI kul*-5. On the other hand, the lowest amount of Mg was obtained from the *Kashmiri kul* (Table 2). So, similar to Na, it can be inferred from the study that local/deshi sour varieties contained a comparatively higher amount of K. Pareek [1] reported that the amount of K in five cultivars of Chinese jujube ranged from 79.2 to 458.0 mg/100 g (average 291.4 mg/100 g) on a dry weight basis. Similarly, San et al. [42] reported that the K content of jujube fruits ranged from 314.7 to 420 mg/100 g (average 372.1 mg/100 g) on a dry weight basis, which was almost one-third of the present study result.

3.3.5 Phosphorus

Phosphorus as phosphate is an essential nutrient involved in many physiological processes, such as the cell's energy cycle, regulation of the whole body acid-base balance, as a component of the cell structure (as phospholipids), in cell regulation and signaling, and as a principal constituent of bones and teeth [45]. The highest amount of P was found in *Deshi kul*-4 (0.234%), followed by *BARI kul*-1*, Kashmiri kul*, and *BARI kul*-2. On the other hand, the lowest amount of P was obtained from the *BARI kul*-4 (0.062%), followed by *Apple kul* and *Shoira kul* (Table 2). According to San et al. [42], the P content in fruits of 4 promising jujube genotypes ranged from 27.13 to 30.20 mg/100 g on a dry weight basis, which was relatively lower than the present study range. However, Pareek [1] reported that the amount of P in five cultivars of Chinese jujube ranged from 69.3 to 110.0 mg/100 g on a dry weight basis, which was almost close to the present study average (96 mg/100 g on a dry weight basis).

3.3.6 Sulfur

Sulfur is the sixth most abundant macromineral in breast milk and the third most abundant mineral based on total body weight. The sulfur-containing amino acids are methionine, cysteine, cystine, homocysteine, homocysteine, and taurine [46]. The S content in commonly consumed jujube fruits available in Bangladesh ranged from 0.079-0.359%, with a mean value of 0.173% (Table 2). The highest amount of S was found in *Deshi kul*-4 followed by *BARI kul*-5, *BARI kul*-1, and *BARI kul*-2. On the other hand, the lowest amount of S was obtained from the *BARI kul*-4 (Table 2). The study results revealed that like Ca and K, jujube varieties are also a good source of S.

4. CONCLUSION

Jujube is a prevalent fruit all over the country, and it has lots of biodiversity in Bangladesh. Furthermore, it carries nutritional and health benefits for human beings. The present study results revealed that local/deshi sour varieties of jujube contained a comparatively higher amount of vitamin C and most mineral elements. However, the physical properties were inferior in those local varieties. Among the exotic varieties studied, *BARI kuls* contained higher amounts of vitamin C and chlorophylls than others. The present study recommends measuring proximate composition, vitamins, carotenoids, minerals, amino acids, volatiles, etc., in details of other jujube varieties available in the whole country. Furthermore, nutritional changes with the advancement of growth, maturation, and ripening should also be studied in the future. Such information will allow breeders to improve the quality of different existing exotic cultivars and develop new varieties, which ultimately carrying numerous health benefits.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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