Food Research 6 (5) : 403 - 411 (October 2022)
Journal homepage: https://www.myfoodresearch.com

FULL PAPER

Heavy metals, trace elements, minerals and ascorbic acid content of occasionally consumed eight indigenous fruits in Bangladesh

Motalab, M., Mumtaz, B., Mohajan, S., Saha, B.K. and *Jahan, S.

Institute of Food Science and Technology, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka-1205, Bangladesh

Article history:
Received: 4 August 2021
Received in revised form: 16 September 2021
Accepted: 19 January 2022
Available Online: 31 October 2022

Keywords:
Fruits,
Heavy metals,
Trace elements,
Minerals,
Ascorbic acid,
Bangladesh

DOI:
https://doi.org/10.26656/fr.2017.6(5).584

Abstract

Herein, a study was carried out to assess the nutritional potential of eight indigenous fruits namely sapodilla, stone apple, bilimbi, amla, litchi, strawberry, tamarind, elephant-apple particularly on the basis of heavy metal, mineral and ascorbic acid content along with the physicochemical properties. Inductively coupled plasma mass spectrometer (ICP-MS) and atomic absorption spectrophotometer (AAS) analysis were performed to determine the essential trace elements and heavy metals in the selected fruits, whereas sodium and potassium content was determined by flame-photometer. Even though the essential trace elements such as zinc, copper, manganese, selenium and cobalt were found in all the examined fruits, sapodilla, stone apple and tamarind were observed as a rich source of selenium and cobalt. The current research demonstrated the presence of toxic heavy metals like arsenic, cadmium, lead, and mercury in elephant-apple, sapodilla, stone apple and tamarind in trace levels which are below the Maximum Residue Limits (MRLs). All the selected eight fruits are found as rich sources of macro-minerals for instance sodium, potassium, calcium, magnesium and phosphorous. Ascorbic acid was estimated by HPLC which ranged from 4.10 to 475.0 mg/100 g of edible portion and the highest amount was found in amla. In summary, these fruits could be potential sources of macro and micro-minerals and safe from toxic heavy metal contamination. The nutritional data observed in the present study would be played a promising role in dietary recommendation, nutritional education, training, research, and food supplementation.

1. Introduction

Bangladesh is blessed with a wide range of climates (six seasons in a year) and agricultural ecosystems, both are appropriate for the cultivation of diversified tropical fruits (Shajib *et al.,* 2013). Based on the favorable agro-ecological conditions and better marketing facilities, more than sixty different types of fruit species are grown in Bangladesh with great regional variation and the extent of the cultivation process (Rahman, Khan and Hosain, 2007). These fruits are a good source of vitamins, minerals, carbohydrates, and antioxidants (Sajib *et al.,* 2014; Ara *et al.,* 2014). Minerals (e.g., iron, copper, manganese, selenium, cobalt, and zinc) and antioxidants protect the cell from oxidative damage. For example, zinc, copper, and manganese are required for superoxide dismutases in both cytosol and mitochondria. Additionally, Iron is a constituent of catalase, a hemeprotein, which catalyzes the decomposition of hydrogen peroxide (Machlin and Bendich, 1987). Selenium functions as a cofactor of enzymes such as glutathione peroxidase or thioredoxin reductase. Glutathione peroxidase prevents various diseases by reducing oxidative stress (Bampidis *et al.,* 2018). Selenium is a constituent of more than two dozen selenoproteins that play a vital role in reproduction, thyroid hormone metabolism, DNA synthesis, and protection from oxidative damage and infection (Ross *et al.,* 2012). Antioxidant acts as free-radical scavenger by neutralizing free radical intermediates and inhibiting other oxidation reactions (Sies, 1997). Vitamins and minerals are essential micro-nutrients that act as coenzymes and cofactors of many biosynthetic reactions. These beneficial aspects of fruits have remained unknown to the majority of the people in many communities. In 2007, Nishida and Nocito pronounced that reduced fruit and vegetable intakes especially in developing countries could lead to various diseases, including obesity, type II diabetes, coronary heart disease and some forms of cancer as the fruits possess medicinal value in the basis of FAO/WHO scientific update (Nishida and Nocito, 2007).

*Corresponding author.
Email: *shammy79@gmail.com*

eISSN: 2550-2166
Published by Rynnye Lyan Resources

Numerous indigenous fruits have conventional and Ayurveda medicinal values but are occasionally consumed in Bangladesh. This present study emphasizes fruits that have enormous health benefits however infrequently consumed. In this investigation, eight indigenous low-consumed fruits namely amla, bilimbi, sapodilla, litchi, strawberry, stone apple, elephant apple and tamarind were selected. Firstly, several citrus fruits like amla and bilimbi were chosen for their various properties such as antioxidant, antimicrobial, antidiabetic properties, anti-radiation protection, healing of wounds and applied for the treatment of various ailments of several diseases from the ancient period (Alhassan and Ahmed, 2016; Ikram *et al.,* 2021). In addition, the indigenous variety of sapodilla, litchi, strawberry and stone apple are palatable fruits that were chosen. Previous studies revealed that these fruits have antioxidant, potent anti-inflammatory properties, immune system boosting properties, and beneficial effects on digestive and cardiovascular health as well (Giampieri *et al.,* 2012; Emanuele *et al.,* 2017; Padmavath, 2018; Yadav *et al.,* 2018). Furthermore, minor fruits such as elephant apple and tamarind are rich in phenolic compounds, flavonoids and tannins, which also are used for the treatment of laxative problems, abdominal pain. Both fruits are beneficial for cardiovascular and immunological health as well as have specific roles in antimicrobial and anticancer activities. It also exhibits a defense mechanism as an anti-inflammatory, antidiabetic and antihyperlipidemic agent for the treatment of several human health hazards (Bhagyasri *et al.,* 2017; Nayik and Gull, 2020). Apart from these beneficial health aspects, the cultivation and commercialization of fruits could have a huge impact on the economy.

The purpose of the present study is to prepare new and updated nutritional information about tropical fruits which would be related to our food habits. This nutritional and food compositional information will play a crucial role in the dietary recommendation, nutritional education, training, research, and supplementation of food. For this purpose, eight indigenous occasionally consumed fruits mentioned above were selected for the study of physicochemical properties, minerals, ascorbic acid and trace elements, and heavy metal contents.

2. Materials and methods

2.1 Reagents and standards

Ascorbic acid, mineral and heavy metal standards were acquired from Sigma-Aldrich Company Ltd. (St. Louis, USA). The analytical grade metaphosphoric acid, methanol, acetic acid, sulfuric acid, nitric acid, hydrochloric acid, sodium hydroxide, potassium sodium tartarate, sodium acetate, copper sulphate, potassium sulphate, hydrogen peroxide were purchased from Merck (Darmstadt, Germany). Phenolphthalein and methylene blue indicators were obtained from Thomas Scientific (Swedesboro, New Jersey, USA).

2.2 Sample collection

A total of eight different types of fruits were analyzed in this study. These were sapodilla (*Manilkara zapota*), stone apple (*Aegle marmelos*), bilimbi (*Averrhoa bilimbi*), amla (*Phyllanthus emblica*), litchi (*Litchi chinensis*), strawberry (*Fragaria* x *ananassa*), tamarind (*Tamarindus indica*), and elephant apple (*Dillenia indica*). The sources of these selected fruits are different local markets in Dhaka city, Bangladesh during February to May. These collected samples were fresh, well-shaped, and free from insect bites and other organoleptic deterioration. The biochemical analyses were carried out at the laboratory of the Institute of Food Science and Technology, Bangladesh Council of Scientific and Industrial Research (IFST, BCSIR), Dhaka.

2.3 Sample preparation

Whole fruits were thoroughly washed with deionized water. The edible portion of the fruits was separated carefully and used for all analytical investigation. The analytical data were presented on a raw weight basis. Three replications of each type of fruit were selected for measurement.

2.4 Determination of physico-chemical properties

The pH was determined with a digital pH meter (Type H1 98106 by HANNA) and titratable acidity was estimated with the visual acid-base method (Ranganna, 1986). The moisture content was determined by the digital moisture analyzer (AnD MX50). The total soluble solids (TSS) were determined with a hand refract-meter (Jahan *et al.,* 2011). Crude fibre, total fat and ash were determined by the standard AOAC method (AOAC, 1990) and total protein was estimated according to the method described by the Kjeldahl method (Ronald and Ronald, 1991). Total carbohydrate and energy contents were determined by the proximate analysis method (Osborn and Voogt, 1978). Total sugar and reducing sugar were determined by following the Lane and Eynon method (Ranganna, 1986).

2.5 Analysis of ascorbic acid

Ascorbic acid was determined by HPLC (model: Thermo Scientific Dionex UltiMate 3000 Rapid Separation LC systems (RSLC) from Thermo Fisher Scientific Inc., MA, USA) according to the following described method (Van de Velde *et al.,* 2012). Extraction was carried out by adding 1 g of homogenized sample to a 10 mL solution of metaphosphoric acid (30 g/L) and acetic acid (80 g/L). The mixture was homogenized for 1 min, then sonicated in an ultrasonic bath for 15 mins, and centrifuged at 12.000×*g* for 20 mins at 4°C. The supernatant was separated, and 0.5 mL of it was diluted with mobile phase to achieve a final volume of 5 mL and then filtered through a 0.45-µm Millipore membrane and injected into the HPLC system for quantification. A stock standard solution of ascorbic acid (4.0 g/L) was prepared in an extracting solution of metaphosphoric acid (30 gL^{-1}) and acetic acid (80 g/L).

HPLC Conditions: separations were achieved in a reversed-phase column Thermo 5µC18 110A attached to a guard column (Phenomenex Inc., CA, USA) at room temperature (25°C). The mobile phase, under isocratic conditions, consisted of a 0.03 M sodium acetate/acetic acid buffer, and 5% methanol. Mobile phase pH was adjusted to 5.8 and was filtered through a 0.45-µm nylon membrane filter and degassed under vacuum. The flow rate was 1 mL/min and the reading was taken at a wavelength 270 nm.

2.6 Analysis of minerals and heavy metals

Heavy metals and trace elements (Copper, Manganese, Zinc, Selenium, Cobalt, Cadmium, Chromium, Lead, Mercury and Arsenic) were measured by inductively coupled plasma mass spectrometer (ICP-MS) (Agilent 7700, USA). Other minerals (iron, calcium, magnesium, and phosphorous) were measured by the Graphite Atomic Absorption Spectrometric method using (iCE 3300, Thermo Scientific) (Kirk and Sawyer, 1991). For the analysis samples were prepared by using a microwave digestion system. As a digestion reagent, 5 mL 69% HNO_3 acid and 2 mL 30% H_2O_2 were used. About 0.3 g of samples were placed into the digestion reagent in a Teflon vessel. After digestion, samples were transferred into a Teflon beaker and the total volume was made up to 25 mL with MilliQ water. The digest solution was filtered using a syringe filter (pore size= 0.45 mm) and then stored in a screw cap plastic tube for analysis.

2.7 Analysis of sodium and potassium

About 2.0 g of each fruit powder was weighed in a crucible and burned at 550°C using a muffle furnace for 5.0 hrs to produce ash. The resultant ash was dissolved in 5 N HCl and heated gently on a hot plate until brown fumes disappeared. Subsequently, 5 mL of deionized water was added and heated till the colourless solution was obtained. Next, to determine potassium and sodium by a flame photometer (Jenway PFP7), the final solution was prepared by transferring the ash solution to 100 mL volumetric flask thru filtration with an ashless Whatman filter paper and the volume was made up to the mark with deionized water. The calibration curve was prepared with 1, 2, 4, 8 ppm of sodium and 5, 10, 20, and 40 ppm of potassium solution from the purchased 1000 ppm stock solution. Sodium and Potassium analysis was done at wavelengths 589 nm and 768 nm with air pressure of10 lb/in^2 (Ranganna, 1986).

2.8 Statistical analysis

Statistical analyses were carried out by using Statistical Package for Social Science (SPSS) for Windows version 16.0. The results obtained in the present study are reported as mean values (obtained from the five replications) ± standard deviation (SD). The significant differences between mean values were analyzed by the Duncan multiple range test at a significance level of $p<0.05$.

3. Results and discussion

This study was conducted to evaluate the nutritional quality of selected fruits by studying their ascorbic acid, trace-element, mineral, and heavy metal content, and physicochemical properties. Each value represents the average from five replications and the outcomes are expressed as mean values ± standard deviations (SD).

3.1 Micro-minerals

The micro-mineral contents of the studied fruits are shown in Table 1. In the present study, it was found that the selected fruits are a poor source of copper (0.02-0.41 mg/100 g of edible portion). The highest amount of copper was found in sapodilla (0.41±0.05 mg/100 g of edible portion). Another study showed that fruits contain 0.03-0.23 mg of copper per 100 g of an edible portion (Almeida *et al.,* 2009). Copper content was almost the same as in the study except for sapodilla. It was also mentioned in a study that most fruits contain a small amount of copper 0.39-1.31 mg/100 g (Jahan *et al.,* 2011; Shaheen *et al.,* 2013). As it is an essential trace element, according to the results people may partially fulfil their dietary allowance by consuming sapodilla, bilimbi and litchi.

The amount of iron, zinc, and manganese was found in the studied fruits 0.30±0.02 to 2.69±0.07 mg/100 g, 0.03±0.00 to 0.16±0.03 mg/100 g and 0.03±0.01 to 0.36±0.04 mg/100 g respectively. The highest amount of iron, zinc, and manganese was found in tamarind, sapodilla and strawberry respectively. A previous study showed that fruits contain 0.50-1.00 mg/100 g of iron and 0.04-1.68 mg/100 g of zinc (Shaheen *et al.,* 2013). A study reported that some indigenous fruits available in

eISSN: 2550-2166

Table 1. Trace elements content of studied fruits

Name of Fruits	Scientific name	Copper (mg)	Iron (mg)	Manganese (mg)	Zinc (mg)	Selenium (mg)	Cobalt (mg)
Amla	*Phyllanthus emblica*	0.02±0.00^{f}	0.87±0.03^{d}	0.04±0.01^{ef}	0.09±0.02^{a}	0.62 ±0.05^{d}	2.16±0.02^{f}
Bilimbi	*Averrhoa bilimbi*	0.17 ±0.02^{c}	0.96±0.07^{b}	0.03 ±0.01^{f}	0.12±0.05^{b}	0.52±0.01^{e}	2.80±0.01^{e}
Elephant Apple	*Dillenia indica*	0.08±0.02^{de}	0.49±0.03^{e}	0.10±0.02^{cd}	0.15±0.04^{b}	1.07 ±0.04^{b}	11.20 ±0.05^{a}
Litchi	*Litchi chinensis*	0.16 ±0.01^{cd}	0.45±0.02^{e}	0.07±0.02^{cd}	0.11±0.01^{b}	0.51 ±0.02^{e}	1.80±0.01^{g}
Sapodilla	*Manilkara zapota*	0.41±0.05^{a}	0.97±0.05^{c}	0.16±0.01^{c}	0.16 ±0.03^{a}	0.30±0.02^{g}	9.20±0.06^{c}
Stone apple	*Aegle marmelos*	0.04±0.01^{ef}	0.30±0.02^{f}	0.31±0.03^{b}	0.03 ±0.00^{c}	0.80±0.04^{c}	9.46±0.04^{b}
Strawberry	*Fragaria X ananassa*	0.13±0.03^{d}	0.41±0.04^{e}	0.36±0.04^{a}	0.09±0.01^{a}	0.43 ±0.02^{f}	1.70 ±0.02^{gh}
Tamarind	*Tamarindus indica*	0.07±0.01^{d}	2.69±0.07^{a}	0.11±0.01^{d}	0.13±0.03^{b}	1.32 ±0.05^{a}	6.26 ±0.03^{d}

Values are presented as mean±SD per 100 g of edible portions. Values with different superscript are significantly different (p<0.05).

Bangladesh contain Manganese from 0.15 mg to 0.26 mg per 100 g of the edible portion (Shajib *et al.,* 2013). Other studies in Vietnam and India have reported that manganese content in fruits varies from 0.01 to 0.04 mg/100 g (Trong *et al.,* 2019) and 0.01 to 0.05 mg/100 g (Seal *et al.,* 2014) in edible portions. According to the result of this study, it was noted that the manganese content in fruits was higher than the available fruits of Vietnam and India.

In the present study, the selenium content was found in sapodilla (0.30±0.02 µg/100 g), stone apple (0.80±0.04 µg/100 g), bilimbi (0.52±0.01 µg/100 g), amla (0.62±0.05 µg/100 g), litchi (0.51±0.02 µg/100 g), strawberry (0.43±0.02 µg/100 g), tamarind (1.31±0.05 µg/100 g), and elephant apple (1.07±0.04 µg/100g) that could partially fulfil the daily requirement of the micro-mineral. Another study showed that tropical fruits' selenium content ranges between 0.11-3.13 µg/100 g of edible portion and tamarind contains the highest (Almeida *et al.,* 2009). It was noted that tamarind contains a good amount of selenium.

In this study, cobalt content in the selected fruits was found 1.70±0.02 to 11.20±0.05 µg/100 g. The highest amount of cobalt was found in elephant apples and followed by stone apples, sapodilla, and tamarind. Previous a study has revealed that fruits contain 8.54 to 53.99 µg cobalt per 100 g of the edible portion (Almeida *et al.,* 2009). As cobalt is an essential element for the human body and has a significant role in some biochemical reactions (Miller *et al.* 2005), these fruits may partially contribute to meet the dietary requirement.

3.2 Macro-minerals

Macro-minerals (Na, K, Ca, Mg, P) content of studied fruits is shown in Table 2. In this study, the sodium content in different fruits ranged from 0.91±0.08 to 22.30±0.27 mg/100 g of edible portion. Other studies showed that sodium contain in tamarind was 13.95 mg/100 g (Almeida *et al.,* 2009) and 59.60 -171.30 mg/100g (Okello *et al.,* 2017). Results noted that tamarind (22.30±0.27 mg/100 g), sapodilla (10.19±0.06 mg/100 g) and stone apple (7.04±0.04 mg/100 g) were good sources of sodium and which was very resembled the latest Food Composition Table for Bangladesh (FCTB) prepared by Shaheen *et al*. (2013). Potassium content in the selected fruits ranged from 13.00±0.12 to 606.00±1.01 mg/100 g of edible portion and the highest was in tamarind. An almost similar result was found in tamarind of Brasil for potassium which was 790.11 mg/100 g of an edible portion (Almeida *et al.,* 2009). Whereas potassium content for stone apple in FCTB was five times higher than that of the present study (Shaheen *et al.,* 2013).

Table 2. Macro minerals content of studied fruits

Name of Fruits	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)	Phosphorous (mg)
Amla	1.21±0.02^{f}	156.10±0.72^{e}	26.40±0.13^{c}	76.40±0.26^{b}	25.16±0.07^{b}
Bilimbi	3.30±0.07^{d}	13.00±0.12^{h}	5.80±0.08^{h}	8.80±0.02^{e}	11.80±0.05^{e}
Elephant Apple	0.91±0.08^{g}	42.06±0.21^{g}	13.90±0.09^{f}	7.65±0.03^{g}	24.72 ±0.02^{c}
Litchi	2.22±0.05^{e}	181.00±0.23^{c}	8.79±0.06^{g}	10.92±0.05^{d}	22.40 ±0.02^{d}
Sapodilla	10.19±0.06^{b}	204.00±1.23^{b}	21.10±0.07^{d}	10.61±0.08^{d}	11.68±0.07^{e}
Stone apple	7.04±0.04^{c}	89.00±0.87^{f}	32.60±0.21^{b}	19.80±0.06^{c}	95.12±0.04^{a}
Strawberry	1.16±0.03^{f}	170.00±0.64^{d}	16.16 ±0.11^{e}	8.72±0.09^{f}	25.14±0.03^{b}
Tamarind	22.30±0.27^{a}	606.00±1.01^{a}	78.71±0.91^{a}	93.30±0.12^{a}	95.60 ±0.08^{a}

Values are presented as mean±SD per 100 g of edible portions. Values with different superscript are significantly different (p<0.05).

eISSN: 2550-2166

Calcium levels among the analyzed fruits were 5.80±0.08 to 78.71±0.91 mg/100 g of the edible portion were highest in tamarind and lowest in bilimbi. According to FCTB calcium content was found 11.0 mg, 127.0 mg and 41.0 mg per 100 g of edible portion in litchi, tamarind and stone apple respectively which was nearly similar to our research (Shaheen *et al.,* 2013). Conforming the calcium content of tropical fruits varied from 4-50 mg/100 g (Gopalan *et al.* 1993). Magnesium found in fruits ranged between 7.65±0.03 to 93.30±0.12 mg/100 g of edible portion. It was noted that amla (76.50 mg/100 g) and tamarind (93.30 mg/100 g) contained a much higher amount of magnesium than other selected fruits. Previous research found that amla contained 24.50 mg/100 g of magnesium (Paul *et al.,* 2004) which was almost three times lower than this study while FCTB showed a parallel result (Shaheen *et al.,* 2013). It was observed that selected fruits were rich in calcium and magnesium.

Phosphorus content in selected fruits ranged from 11.68±0.07 to 95.60±0.08 mg/100 g of edible portion. The highest amount of phosphorus was found in tamarind and followed by Stone apple, strawberry, amla and elephant apple, the results were quite alike to FCTB (Shaheen *et al.,* 2013). In addition, other studies showed that phosphorus content in tropical fruits varied from 10.00-98.90 mg/100g (Paul *et al.,* 2004) and 5.36-98.49 mg/100 g (Almeida *et al.,* 2009). The research revealed that tamarind contains a good amount of sodium, potassium, calcium, magnesium and phosphorus than other selected fruits. Minerals content in studied fruits might vary for other agro-ecological zones' fruits as agro -ecological zones may differ in minerals content (Okello *et al.,* 2017).

3.3 Heavy metals

The heavy metals content of the studied fruits is shown in Table 3. The result exposed that the chromium level was from 0.02±0.01 to 0.05±0.01 mg/100 g of edible portion in the fruits. The maximum amount of chromium was found in Amla. Arsenic was found in amla (0.02±0.01 µg/100 g), litchi (0.03±0.01 µg/100 g), and strawberry (0.08 µg/100 g). Most human foods like vegetables, fruits, dairy products, and meats contain less than 0.05 mg/kg and rarely exceed 0.1 mg/kg of arsenic (Dara, 2004). Cadmium was found in sapodilla, stone apple, tamarind, and elephant apple, ranging from 0.02-0.04 mg/100 g. The lead was found in tamarind, stone apple, sapodilla, elephant apple and litchi ranging from 0.01 to 0.04 mg/100 gm of edible portion. The presence of heavy metals may be due to solid waste disposal into the land with a high amount of heavy metals, usage of arsenic-contaminated water during cultivation, as its consequences groundwater may contain heavy metals and it may be utilized by plants and ultimately absorbs in the fruits (Heikens *et al.,* 2007). The heavy metal content of the fruits was lower than the recommended safe value (arsenic max 0.1 mg/kg; chromium max 2.3 mg/kg; cadmium max 0.2 mg/kg, lead max 0.3 mg/kg) by WHO/FAO (CAC, 2001).

3.4 Ascorbic acid

Among the fruits analyzed, ascorbic acid content was found the highest in the amla (475±2.01 mg/100 g), whereas, the lowest amount (4.10±0.07 mg/100 g) was found in tamarind (Table 4). The ascorbic acid content in bilimbi, elephant apple, litchi, sapodilla, stone apple and strawberry were recorded 16.1±0.61 mg/100 g, 6.5±0.09 mg/100 g, 35.0±0.73 mg/100 g, 15.6±0.11 mg/100 g, 8.9±0.20 mg/100 g and 57.0±0.93 mg/100 g of edible portion respectively. Some previous studies revealed that the ascorbic acid content in low-consumed tropical fruits as like sapodilla 21.72 mg/100 g (Rahman *et al.,* 2007), litchi 39±5.5 mg/100 g (Paul *et al.,* 2004) and 11.00 mg/100 g (Shaheen *et al.,* 2013), elephant apple 12.80 mg/100 g (Shaheen *et al.,* 2013), tamarind 11.20 mg/100 g (Shaheen *et al.,* 2013) and bilimbi 182.98 mg/100 g (Yan *et al.,* 2013). This study also exposed that these low -consumed fruits were rich in ascorbic acid content although some of those grow carelessly at homesteads, forests, and roadsides as well as cheaper.

Table 3. Heavy metals and metalloid content of selected fruits

Name of Fruits	Cadmium (mg)	Chromium (mg)	Lead (mg)	Mercury (µg)	Arsenic (µg)
Amla	ND	$0.05±0.01^{a}$	ND	ND	$0.02 ±0.01^{b}$
Bilimbi	ND	$0.04±0.02^{a}$	ND	ND	ND
Elephant Apple	$0.03±0.02^{a}$	$0.03±0.02^{a}$	ND	$0.52±0.06^{a}$	ND
Litchi	ND	$0.04±0.03^{a}$	$0.01 ±0.00^{b}$	$0.24±0.02^{c}$	$0.03±0.01^{b}$
Sapodilla	$0.02±0.01^{a}$	$0.04±0.03^{a}$	ND	$0.44±0.02^{b}$	ND
Stone apple	$0.04±0.01^{a}$	$0.03±0.01^{a}$	$0.03±0.01^{a}$	$0.26±0.04^{c}$	ND
Strawberry	ND	$0.02±0.01^{a}$	ND	ND	$0.08±0.02^{a}$
Tamarind	$0.04±0.02^{a}$	$0.03±0.02^{a}$	$0.04±0.01^{a}$	$0.29±0.03^{c}$	ND

Values are presented as mean±SD per 100 g of edible portions. Values with different superscript are significantly different ($p<0.05$). ND, not detected

eISSN: 2550-2166

Table 4. Physico-chemical properties of studied fruits

Parameter	Amla	Bilimbi	Elephant Apple	Litchi	Sapodilla	Stone apple	Strawberry	Tamarind
Edible portion (%)	89.15 ± 1.93^{c}	99.98 ± 1.45^{a}	68.19 ± 1.98^{e}	59.11 ± 2.32^{f}	77.36 ± 2.12^{d}	60.00 ± 1.21^{f}	95.51 ± 2.15^{b}	29.92 ± 2.63^{g}
Moisture content (%)	79.56 ± 1.32^{d}	94.26 ± 1.53^{a}	83.30 ± 1.98^{c}	79.96 ± 1.67^{d}	73.28 ± 1.23^{e}	63.48 ± 1.25^{f}	89.64 ± 1.21^{b}	14.49 ± 2.12^{g}
pH	3.3 ± 0.06^{d}	2.2 ± 0.01^{f}	3.3 ± 0.05^{d}	3.5 ± 0.03^{c}	5.2 ± 0.10^{a}	5.3 ± 0.04^{a}	3.7 ± 0.09^{b}	2.8 ± 0.07^{e}
Titratable acidity (%)	6.4 ± 0.09^{b}	1.19 ± 0.11^{c}	0.06 ± 0.01^{e}	0.82 ± 0.03^{d}	0.11 ± 0.01^{e}	0.71 ± 0.04^{d}	1.02 ± 0.05^{c}	15.12 ± 0.28^{a}
Total soluble solids (%)	9.17 ± 0.70^{e}	3.0 ± 0.09^{g}	7.25 ± 0.07^{f}	12.70 ± 0.87^{d}	15.92 ± 1.12^{c}	25.80 ± 1.15^{b}	6.0 ± 0.08^{f}	28.06 ± 1.18^{a}
Reducing sugar (%)	0.99 ± 0.02^{f}	1.91 ± 0.03^{e}	0.99 ± 0.03^{f}	6.54 ± 0.21^{d}	11.91 ± 0.09^{b}	8.97 ± 0.11^{c}	2.14 ± 0.06^{e}	17.11 ± 1.02^{a}
Total sugar (TS) (%)	1.61 ± 0.03^{f}	2.41 ± 0.08^{f}	2.52 ± 0.04^{f}	7.97 ± 0.21^{d}	13.06 ± 1.03^{c}	24.36 ± 1.23^{b}	3.95 ± 0.08^{e}	27.07 ± 1.05^{a}
Crude fiber (%)	2.19 ± 0.04^{e}	0.72 ± 0.01^{g}	2.50 ± 0.05^{d}	0.90 ± 0.02^{f}	4.5 ± 0.07^{b}	2.61 ± 0.03^{c}	2.11 ± 0.06^{e}	8.51 ± 0.09^{a}
Total carbohydrate (%)	19.43 ± 0.12^{e}	4.66 ± 0.06^{g}	13.77 ± 0.04^{f}	17.81 ± 0.08^{e}	24.84 ± 0.08^{d}	33.65 ± 0.10^{b}	30.1 ± 0.05^{c}	79.73 ± 0.10^{a}
Energy (kcal/100 g)	80.37 ± 0.18^{c}	22.93 ± 0.32^{g}	60.17 ± 0.12^{e}	78.43 ± 0.34^{d}	111.33 ± 0.12^{c}	148.90 ± 0.62^{b}	126.97 ± 0.52^{f}	335.37 ± 0.36^{a}
Protein (%)	0.19 ± 0.01^{h}	0.55 ± 0.03^{f}	0.71 ± 0.03^{e}	1.01 ± 0.04^{c}	0.45 ± 0.02^{g}	2.62 ± 0.07^{b}	0.81 ± 0.03^{d}	3.10 ± 0.07^{a}
Total fat (%)	0.21 ± 0.02^{ef}	0.16 ± 0.01^{f}	0.25 ± 0.02^{e}	0.35 ± 0.05^{d}	1.13 ± 0.05^{a}	0.43 ± 0.03^{bc}	0.37 ± 0.03^{cd}	0.45 ± 0.06^{b}
Ash content (%)	0.75 ± 0.03^{d}	0.21 ± 0.01^{h}	3.14 ± 0.04^{a}	0.53 ± 0.04^{f}	0.62 ± 0.05^{e}	1.07 ± 0.07^{c}	0.43 ± 0.02^{g}	2.74 ± 0.07^{b}
Ascorbic acid (mg/100 g)	475.0 ± 2.01^{a}	16.1 ± 0.61^{d}	6.5 ± 0.09^{f}	35.0 ± 0.73^{c}	15.6 ± 0.11^{d}	8.9 ± 0.20^{e}	57.0 ± 0.93^{b}	4.1 ± 0.07^{g}

Values are presented as mean±SD. Values with different superscript are significantly different ($p<0.05$).

3.5 Proximate analysis and physicochemical properties

The edible portions of the studied fruits varied from 29.92±2.63 to 99.98±1.45% (Table 4). The results showed that bilimbi has the highest amount of edible portions because it is free from larger seeds and almost the whole fruit body could be eaten. Strawberry also has a good edible portion (95.51±2.15%) due to the lack of big seeds and hard shells. Whereas, tamarind contains the lowest amount of edible portion (29.92±2.63%) owing to its heavy peel weight and proportionally bigger seeds.

The moisture content of the selected fruits was 14.49±2.12 to 94.26±1.53% (Table 4). Bilimbi contains the highest amount of moisture, whereas, tamarind contains the lowest moisture content. Generally, most tropical fruits are composed of 70% to 90% water (Haque *et al.,* 2009). The moisture content has a great impact on energy density as water adds substantial weight to the fruit without adding energy. The variation in moisture content among fruits is due to climate change, soil conditions, and total rainfall (Webster and Wilson, 1966).

The results showed that fruits were poor sources of protein (Max 3.10±0.07%) and fat (Max 1.13±0.05%). In general, the protein and fat content of different fruits are not greater than 3.5% and 1.0% respectively (Potter, 1976). The amount of total ash (mineral) present in the selected fruits ranged from 0.21±0.01 to 3.14±0.04%. The highest amount of ash was found in elephant-apple, followed by tamarind, whereas, the minimum amount of ash was present in bilimbi. Ash content reveals the communal picture of minerals present in the food (Mumtaz *et al.,* 2019) and this study also exposed that the more the ash content, the more the mineral content in fruits.

Among the fruits, the highest amount of fibre was present in tamarind (8.51±0.09%) which was followed by sapodilla, stone apple, and elephant apple (Table 4). A previous study indicated that some tropical fruits in Bangladesh comprise 0.32% to 2.69% fibre (Jahan *et al.,* 2011).

The total carbohydrate content of selected fruits was 4.66±0.06 to 79.73±0.10%. The highest amount of total carbohydrate and energy content were found in tamarind, whereas, the lowest amount was found in bilimbi. From this data, it can be stated that there was a positive correlation between carbohydrates and energy content as fruits contain a very low amount of protein and fat.

The pH of the selected fruits was from 2.20±0.01 to 5.30±0.03 and titratable acidity was from 0.06±0.01-15.12±0.28% (Table 4). Among the fruits, the stone apple showed the highest pH value, whereas, bilimbi showed the lowest. In the case of titratable acidity, tamarind showed the highest amount of titratable acidity whereas; elephant apple showed the lowest.

The highest amount of TSS was present in tamarind 28.06±1.18% and the lowest (3.00±0.09%) in bilimbi (Table 4). The total sugar content is directly proportional to the sweetness of the fruits (Salma *et al.,* 2015). The total sugar and reduced sugar content of the selected fruits were 1.61±0.03% to 27.07±1.05% and 0.99±0.03% to 17.11±1.02% respectively (Table 4). Both total sugar and reducing sugar content were the highest in tamarind.

4. Conclusion

In summary, the investigation of nutritional and physicochemical parameters of the selected fruits suggested that these fruits are an excellent source of ascorbic acid, micro and macro-minerals such as zinc, copper, manganese, iron, potassium, calcium, and magnesium. Contrariwise, Bangladeshi people tend to purchase expensive foreign fruits due to ignorance and unavailability of the data on these fruits. The current study is promising for consumers to choose cost-effective local fruits in their daily diet to fulfil their required dietary allowance for minerals and trace elements. To conclude, further study is needed to find out the sources of the contamination of the heavy metals in quite a few fruits and preventive measures to control such contamination.

Conflict of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

Acknowledgements

This investigation was carried out under the research and development (R&D) project entitled “Studies on the nutritional and qualitative evaluation of fruits, juice, jam, jelly, pickle, and sauces available in the local market” funded and facilitated by the Bangladesh Council of Scientific and Industrial Research (BCSIR).

References

Alhassan, A.M. and Ahmed, Q.U. (2016). *Averrhoa bilimbi* Linn.: A review of its ethnomedicinal uses, phytochemistry, and pharmacology. *Journal of Pharmacy and Bioallied Sciences*, 8(4), 265–271. https://doi.org/10.4103/0975-7406.199342

Almeida, M.M.B., de Sousa, P.H.M., Fonseca, M.L., Magalhães, C.E.C., Lopes, M.F.G. and de Lemos, T.L.G. (2009). Evaluation of macro and micro-mineral content in tropical fruits cultivated in the northeast of Brazil. *Ciência e Technologia de Alimentos*, 29(3), 581-586. https://doi.org/10.1590/S0101-20612009000300020

AOAC. (1990). Official Methods of Analysis, 15th ed. Arlington, Virginia, USA: AOAC.

Ara, R., Motalab, M., Uddin, M.N., Fakhruddin, A.N.M. and Saha, B.K. (2014). Nutritional evaluation of different mango varieties available in Bangladesh. *International Food Research Journal, 21(6),* 2169-2174.

Bampidis, V., Azimonti, G., Bastos, M.L., Christensen, H., Dusemund, B., Kouba, M., Durjava, M.k., López-Alonso, M., Puente, S.L., Marcon, F., Mayo, B., Pechová, A., Petkova, M., Ramos, F., Sanz, Y., Villa, R., Woutersen, R., Cubadda, F., Flachowsky, G., Gropp, J., Leng, L., López-Gálvez, G. and Mantovani, A. (2018). Assessment of the application for renewal of authorisation of selenomethionine produced by *Saccharomyces erevisiae* CNCM I-3060 (selenised yeast inactivated) for all animal species. *EFSA Journal*, 16(7), e05386. https://doi.org/10.2903/j.efsa.2018.5386

Bhagyasri, Y., Goud, D.S., Suvarna, C.M. and Subramanian, N.S. (2017). A pharmacological review on elephant apple. *World Journal of Pharmacy and Pharmaceutical Sciences,* 6(12), 1809-1816. https://doi.org/10.20959/wjpps201712-10678

CAC (Codex Alimentarius Commission). (2001). Food Additives and Contaminants. ALINORM 01/12A, p. 1-289. Rome, Italy: Joint FAO/WHO Food Standards Program.

Dara, S.S. (2004). A text book of Environmental Chemistry and Pollution Control. 6th ed., p. 206 – 209. New Delhi, India: S. Chand and Company Ltd.

Emanuele, S., Lauricella, M., Calvaruso, G., D'Anneo, A. and Giuliano, M. (2017). Litchi chinensis as a functional food and a source of antitumor compounds: An overview and a description of biochemical pathways. *Nutrients*, 9(9), 992. https://doi.org/10.3390/nu9090992

Giampieri, F., Tulipani, S., Alvarez-Suarez, J.M., Quiles, J.L., Mezzetti, B. and Battino, M. (2012). The strawberry: composition, nutritional quality, and impact on human health. *Nutrition*, 28(1), 9-19. https://doi.org/10.1016/j.nut.2011.08.009

Gopalan, C., Rama, S.B.V. and Balasubra, S.C. (1993). Nutritive value of Indian Foods, 2nd ed. Hyderabad, Pakistan: Indian Council of Medical Research.

Haque, M.N., Saha, B.K., Karim, M.R. and Bhuiyan, M.N.H. (2009). Evaluation of nutritional and physico-chemical properties of several selected fruits in Bangladesh. *Bangladesh Journal of Scientific and Industrial Research,* 44(3), 353-358. https://doi.org/10.3329/bjsir.v44i3.4410

Heikens, A., Panaullah, G.M. and Meharg, A.A. (2007). Arsenic behaviour from groundwater and soil to crops: impacts on agriculture and food safety. *Reviews of Environmental Contamination and Toxicology*, 189, 43–87. https://doi.org/10.1007/978-0-387-35368-5_3

Ikram, A., Khalid, W., Aziz, M., Arif, M.A., Jha, R.P., Khalid, M.Z., Fizza, C., Mehmood, M.Z., Haseeb, M., Rahim, M.A., Naeem, S. and Sultana, F. (2021). Nutritional and biochemical composition of amla (*Emblica officinalis*) and its therapeutic impact: A review. *Acta Scientific Nutritional Health*, 5(2), 153-160. https://doi.org/10.31080/ASNH.2020.05.0821

Jahan, S., Gosh, T., Begum, M. and Saha, B.K. (2011). Nutritional profile of some tropical fruits in Bangladesh: specially antioxidant vitamins and minerals. *Bangladesh Journal of Medical Science,* 10(2), 95-103. https://doi.org/10.3329/bjms.v10i2.7804

Kirk, R.S. and Sawyer, R. (1991). Pearson's Composition and Analysis of Foods. 9th ed. England: Addision Wesley Longman Ltd.

Machlin, L.J. and Bendich, A. (1987). Free radical tissue damage: protective role of antioxidant nutrients. *The FASEB Journal*, 1(6), 441-445. https://doi.org/10.1096/fasebj.1.6.3315807

Miller, A., Korem, M., Almog, R. and Galboiz, Y. (2005.) Vitamin B12, demyelination, remyelination and repair in multiple sclerosis. *Journal of the Neurological Sciences,* 233(1–2), 93–97. https://doi.org/10.1016/j.jns.2005.03.009

Mumtaz, B. Mozakkin, M.J.I., Motalab, M., Jahan, S., Ferdous, T. and Saha, B.K. (2019). Nutritional and microbiological evaluation on jams and jellies available in Bangladesh. *American Journal of Food and Nutrition*, 7(4), 113-119. https://doi.org/10.12691/ajfn-7-4-1

Nayik, G.A. and Gull, A. (2020). Antioxidants in Fruits: Properties and health benefits. Singapore: Springer Nature Singapore Pte Ltd. https://doi.org/10.1007/978-981-15-7285-2

Nishida, C. and Martinez Nocito, F. (2007). FAO/WHO scientific update on carbohydrates in human nutrition: introduction. *European Journal of Clinical Nutrition*, 61(1), S1–S4. https://doi.org/10.1038/sj.ejcn.1602935

Okello, J., Okullo, J.B.L., Eilu, G., Nyeko, P. and Obua, J. (2017). Mineral composition of *Tamarindus indica* LINN (tamarind) pulp and seeds from different agro-ecological zones of Uganda. *Food Science and Nutrition*, 5(5), 959-966. https://doi.org/10.1002/fsn3.490

Osborn, D.R. and Voogt, P. (1978). The Analysis Of nutrients in Foods. New York, USA: Academic Press.

Padmavath, D. (2018). A study on nutritional and health importance of “Sapotas”. *International Journal of Food Science and Nutrition*, 3(1), 184-187.

Paul, D.K. and Shaha, R.K. (2004). Nutrients, vitamins and minerals content in common citrus fruits in the northern region of Bangladesh. *Pakistan Journal of Biological Sciences,* 7(2), 238-242. https://doi.org/10.3923/pjbs.2004.238.242

Potter, N.N. (1976). Food Science, 2nd ed., Westport, Connecticut, USA: The Avi publishing company, INC.

Rahman, M., Khan, M. and Hosain, M. (2007). Analysis of vitamin C (ascorbic acid) contents in various fruits and vegetables by UV-spectrophotometry. *Bangladesh Journal of Scientific and Industrial Research*, 42(4), 417-424. https://doi.org/10.3329/bjsir.v42i4.749

Rahman, S.A., Rahman, M.F., Codilan, A.L. and Farhana, K.M. (2007). Analysis of the economic benefits from systematic improvements to shifting cultivation and its evolution towards stable continuous agroforestry in the upland of eastern Bangladesh. *International Forestry Review,* 9(1), 536-547. https://doi.org/10.1505/ifor.9.1.536

Ranganna, S. (1986). Handbook of Analysis and Quality Control for Fruit and Vegetable Products, New Delhi, India: Tata McGraw-Hill Publishing Company Ltd.

Ronald, S.K. and Ronald, S. (1991). Pearson’s Composition and Analysis of Foods. 9th ed. England: Addision Wesley Longman Ltd.

Ross, A.C., Caballero, B.H., Cousins, R.J., Tucker, K.L. and Ziegler, T.R. (2012). Modern nutrition in health and disease. 11th ed. USA: Jones & Bartlett Learning.

Sajib, M.A.M., Jahan, S., Islam, M.Z., Khan, T.A. and Saha, B.K. (2014). Nutritional evaluation and heavy metals content of selected tropical fruits in Bangladesh. *International Food Research Journal*, 21(2), 609-615.

Salma, I.J., Sajib, M.A.M., Motalab, M., Mumtaz, B., Jahan, S., Hoque, M.M. and Saha, B.K. (2015). Comparative evaluation of macro and micro-nutrient element and heavy metal contents of commercial fruit juices available in Bangladesh. *American Journal of Food and Nutrition,* 3(2), 56-63. DOI:10.12691/ajfn-3-2-4

Seal, T., Pillai, B. and Chaudhuri, K. (2014). Nutritional potential of wild edible fruits, traditionally used by the local people of Meghalaya state in India. *Indian Journal of Natural Products and Resources, 5(4),* 359-364.

Shaheen, N., Rahim, A.T.M.A., Mohiduzzaman, M., Banu, C.P., Bari, L., Tukun, A.B., Mannan, M., Bhattacharjee, L. and Stadlmayr, B . (2013). Food Composition Table for Bangladesh. Institute of Nutrition and Food Science. Retrieved from website: http://www.fao.org/fileadmin/templates/food_composition/documents/FCT_10_2_14_final_version.pdf

Shajib, M.T.I., Kawser, M., Miah, M.N., Begum, P., Bhattacharjee, L., Hossain, A., Fomsgaard, I.S. and Islam, S.N. (2013). Nutritional composition of minor indigenous fruits: Cheapest nutritional source for the rural people of Bangladesh. *Food Chemistry*, 140(3), 466–470. https://doi.org/10.1016/j.foodchem.2012.11.035

Sies, S. (1997). Oxidative stress: Oxidants and antioxidants. *Experimental Physiology,* 82(2), 291–295. https://doi.org/10.1113/expphysiol.1997.sp004024

Trong, L.V, Thinh, B.B., Khoi, N.T. and Chung, B.D. (2019). Nutritional composition of some fruits harvested in the ripening period cultivated in Vietnam. *Bioscience Research*, 16(2), 1726-1735.

Van de Velde, F., Pirovani, M.E., Cámara, M.S., Güemes, D.R. and Bernardi, C.M.D.H. (2012). Optimization and validation of a UV–HPLC method for vitamin C determination in strawberries (*Fragaria ananassa* Duch.) using experimental designs. *Food Analytical Methods*, 5, 1097–1104. https://doi.org/10.1007/s12161-011-9347-5

Webster, C.C. and Wilson, P.N. (1966). Agriculture in the Tropics. London, United Kingdom: Longans, Green and Co. Ltd.

Yadav, T., Vishwakarma, D., Saloni, S., Tiwari, S. and Sindhu. (2018). Wood apple-its nutritive value and medicinal benefits. *International Journal of Agricultural Engineering*, 11(Sp. Issue), 159-163. DOI: 10.15740/HAS/IJAE/11.Sp. Issue/159-163.

Yan, S.W., Ramasamy, R., Alitheen, N.B.M. and Rahmat, A. (2013). A Comparative Assessment of Nutritional Composition, Total Phenolic, Total Flavonoid, Antioxidant Capacity, and Antioxidant Vitamins of Two Types of Malaysian Underutilized Fruits (*Averrhoa Bilimbi* and *Averrhoa Carambola*). *International Journal of Food Properties*, 16 (6), 1231-1244. https://doi.org/10.1080/10942912.2011.582975

FULL PAPER