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Evaluating the proximate compositions, antioxidants, and minerals of brinjal hybrids and their progenitor (*Solanum melongena* L.)

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Abstract
The current study assessed eleven eggplant genotypes—five parent plants and six hybrid populations—for their proximate, antioxidant, and mineral content. Moisture ranged from Akshita (89.90%) to CHT-2 (81.92%), with Akshita having the highest crude protein level (24.11%), whereas genotypes of HVSP-4, CHT-2, and HVSP-5 had statistically comparable crude fat, carbohydrates, and ash content. All genotypes showed greater IC_{50} values than ascorbic acid, indicating lower antioxidants. The hybrid and parent plants exhibit strong TPC, TFC, and TTC. HVSP-1, like its parent CHT-2, has the greatest TFC content (21.58 µg/ml). Neither parents nor hybrids differ much in TTC. Both genotypes had lead (Pb) levels within human tolerance. Furthermore, the present investigation observed considerable amounts of important minerals such as calcium (Ca), zinc (Zn), iron (Fe), and manganese (Mn) on both types of genotypes. Thus, hybrid eggplants contain considerable levels of phytochemicals identical to those found in parent plants while efficiently avoiding BFSB.

Keywords: Hybrid eggplant, proximate composition, Antioxidant activities, Phytochemicals, Mineral composition

Introduction
Eggplant, also known as aubergine or brinjal, is a plant species in the nightshade family Solanaceae. The edible fruit of *Solanum melongena* is grown all over the world. The aubergine is a delicate, tropical perennial plant that is commonly grown as a sensitive or half-hardy annual in temperate areas [1]. Many countries use eggplant in their cuisines [2]. Brinjal is the second most significant vegetable farmed in Bangladesh, with approximately 150,000 resource-poor farmers cultivating it on 50,955 hectares and producing 507,000 metric tonnes [3]. Chronic and extensive infestations of the eggplant fruit and shoot borer are the most significant restrictions to eggplant production [4]. Increased eggplant production is required to ensure social stability and future food security due to disease resistance and rising population and food demands. The hybridization process is utilized for it. Hybridization is the process of breeding two separate individuals of the same or different species to create the desired modifications in the organisms. Hybrids are especially effective in less fertile, more difficult environments since the technology has been utilized to produce features that help the plant resist abiotic stress while also increasing yields. They are also more sensitive to inputs than standard cultivars. Hybrid variants offer more plant vigour, greater resistance to diseases and pests, greater tolerance to temperature conditions, draughts, and so on, as well as larger flowers and fruits than parental types [5]. Eggplants are grown and eaten globally. Its antioxidant and phenolic acid concentrations make it one of the top 10 vegetables. Genotypic variation, production methods, season, maturity level, seed source, and storage conditions affect eggplant composition and attributes. Eggplant varieties filled with carbohydrates, protein, minerals, and antioxidants with low browning are ideal. To meet future demand, brinjal hybrids must be disease-resistant and nutritionally rich.
In addition to this, the hybrid types oftentimes have increased levels of certain biochemical and nutritional factors. Therefore, before the release of a hybrid, it is essential to do comparative research on the hybrids and their parents to examine the proximate components, antioxidant activity and mineral composition of the hybrids and their parents.

Materials and Methods

Plant Materials

The plant materials for this investigation were the 11 brinjal accessions with five parents and six segregating populations of hybrids (Table 1). The hybrid population was created last few years in the field laboratory of the Department of Botany, University of Rajshahi, Bangladesh. The fresh edible fruits were picked in March 2024 from the field laboratory and stored in the laboratory for the present study.

Table 1: List of eggplant accessions used in the present study

Sl. No.	Genotype Code	Accession name	Origin	Fruit type	Source of collection
1.	China	China begun	China	Oblong	Local market
2.	Akshita	Akshita	Bangladesh	Oblong	Local market
3.	Srilanka	Srilanka	Srilanka	Round	Srilanka
4.	CHT-1	CHT-1	Bangladesh	Round	Khagrachori
5.	CHT-2	CHT-2	Bangladesh	Round	Khagrachori
6.	HVSP-1	AKS × SL	Hybrid	Oblong	Field laboratory
7.	HVSP-2	CHT-1 × SL	Hybrid	Round	Field laboratory
8.	HVSP-3	CHT-2 × SL	Hybrid	Round	Field laboratory
9.	HVSP-4	SGO × SL	Hybrid	Oblong	Field laboratory
10.	HVSP-5	SPL × SL	Hybrid	Oblong	Field laboratory
11.	HVSP-6	CHINA × SL	Hybrid	Oblong	Field laboratory

Here, AKS = Akshita, CHT = Chittagong, SL = Srilanka, SGO = Super Green Oblong, SPL = Super Pink Long

Methods

Proximate analysis

The proximate composition such as moisture%, carbohydrate, crude protein, fat and ash% of the eggplant fruits was determined by the following methods:

Estimation of moisture percentage

The moisture content was determined by dehydrating the sample in an oven, and the moisture content was calculated based on the weight difference between the fresh and dry samples.

$$\text{Moisture}(\%) = \frac{(\text{Weight of fresh sample} - \text{Weight of dried sample})}{(\text{Weight of fresh sample})} \times 100$$

Determination of crude carbohydrate

The crude carbohydrate concentration was determined using the enthrone method as modified by Gerhardt *et al.* [6]. In short, the ethanolic extracted sample was thoroughly mixed and then transferred into a 1 ml COD tube. Two (2) ml of pre-chilled 75% sulfuric acid solution were added to the COD tube, followed by vortexing, and then 4 ml of pre-chilled enthrone solution was added. The COD tubes were positioned on the heating block and heated to 100 °C for 15 minutes. The solution's absorbance was measured at 578 nm using a Thermo Spectronic 20, USA UV-vis spectrophotometer after it was cooled to room temperature. The carbohydrate levels were determined using the specified formula.

Determination of soluble protein

The fruit sample's soluble protein concentration was measured using the Lowry *et al.* [7] method. Reagents (i) and (ii) were combined in a 50:1 ratio, consisting of 2% Na_2CO_3 in 0.1 N NaOH and 0.5% $CuSO4.5H_2O$ in 1% Na-K tartrate, respectively. Reagent (iii), Folin-Ciocalteu's Reagent (FCR), was diluted right before use. Standard protein solution was divided into 9 glass test tubes containing varying volumes ranging from 0.0 to 0.8 ml, which were then diluted to 1 ml with distilled water. One (1) ml of the sample was aliquoted into a test tube, and a duplicate was created. 5.0 ml of the mixture (i and ii) was added to each tube, followed by the addition of 0.5 ml of FCR after 10 minutes. The solution's absorbance was measured at 650 nm (Thermo Spectronic 20, USA UV-vis spectrophotometer) after 30 minutes. Protein content was determined by creating a standard curve using bovine serum albumin (BSA).

Determination of ash percentage

Ash content was measured according to the procedure outlined by Anonymous, [8]. Approximately 50 g of fresh eggplant fruit sample was weighed in a porcelain crucible that had been cleaned, heated to 100 °C, cooled and then weighed. The crucible was heated in a muffle furnace at 600 °C for approximately 4 hours. The sample was subsequently cooled in desiccators and then weighed. To ensure the ashing process was completed, the crucible was reheated in the muffle furnace for 30 minutes, allowed to cool and then weighed once more. This process was repeated until two consecutive weights matched and the ash appeared nearly white.

Antioxidant activity

DPPH radical scavenging methods

The extracts' antioxidant activity was assessed by measuring their ability to scavenge the stable 1,1-diphenyl-2-picrylhyorazyl (DPPH) free radical, following the method [9] with minor adjustments. A 1 ml solution of 0.1 mM DPPH in ethanol was combined with 1 ml of eggplant fruit extract solutions at concentrations of 50, 100, 150, 200, and 250 µg/ml. Blank samples were prepared accordingly, and a reference standard of L-ascorbic acid (1–100 µg/ml) was utilised. A mixture of 1 ml ethanol and 1 ml DPPH solution was utilised as a control. The experiment was conducted three times, and the reduction in absorbance was quantified at 517 nm after 30 minutes in the absence of light using a UV-Vis spectrophotometer. The inhibition percentage was determined by the formula: Inhibition (%) $=\frac{(Ac-As)}{Ac} \times 100$, where Ac represents the absorbance of the control and As represents the absorbance of the sample. The sample concentration that provided 50% inhibition (half-maximal inhibitory concentration, IC_{50}) was calculated by plotting inhibition percentages versus sample concentrations.

Total phenolic content (TPC)

The phenolic content of the plant extracts was determined using the Folin-Ciocalteu Reagent (FCR) method [10]. The reaction mixture was prepared by combining 0.5 ml of ethanolic extract with 2.5 ml of 10% FCR in 2.5 ml of water and adding 7.5% $NaHCO_3$. The blank solution consisted of

FCR dissolved in water and 2.5 ml of 7.5% $NaHCO_3$. Gallic acid was used to create a standard curve. Different concentrations of Gallic acid were prepared in 80% ethanol: 20, 40, 60, 80, and 100 µg/ml. Each dilution was transferred into a test tube in 1.0 ml volumes and then diluted with 10 ml of distilled water. Following this step, 2.5 ml of FCR was included. Then, 2.5 ml of 7.5% $NaHCO_3$ was added to each test tube. The mixture was allowed to sit for 30 minutes at room temperature. The standard's absorbance was measured at 765 nm with a UV-Vis spectrophotometer (Thermo Spectronic 20, USA UV-vis spectrophotometer) compared to a blank sample. The phenolics concentration in the extracts was quantified as milligrams of Gallic acid equivalent per gramme. The total phenol content was determined using the following equation. The total phenolic content = $\frac{GAE \times V \times D}{W}$, where, GAE represents the Gallic acid equivalent (mg/g), V is the volume of the extract (ml), D is the dilution factor, and W is the weight (gm) of the pure fruit extract.

Total flavonoids content (TFC)

The flavonoids were determined utilising the spectrophotometric method [11]. In brief, 2% $AlCl_3$ (ethanol) was mixed with 1 ml of the ethanol extract solution (solution concentrations were 1 mg/ml). For one hour, the samples were incubated at ambient temperature. Utilising a UV-Vis spectrophotometer set at 415 nm, the absorption was calculated. Estimation of flavonoids from fruit extracts in terms of quercetin equivalents. Flavonoids content =$\frac{QE \times V \times D}{W}$, where QE = quercetin equivalent (mg QE/g), V = total volume of sample (ml), D = dilution factor, W = samples weight (g).

Total tannin content (TTC)

The tannin levels in eggplant samples were determined using the Folin-Ciocalteau's reagent procedure [12]. 1.0 ml of ethanol extract was combined with 0.5 ml of Folin-Ciocalteau's reagent, then 1.0 ml of saturated sodium carbonate (Na_2CO_3) solution and 8.0 ml of distilled water were added. The reaction mixture was left to stand for 30 minutes at ambient temperature. The supernatant was acquired through centrifugation, and its absorbance was measured at 725 nm with a UV-visible spectrophotometer. Various concentrations of standard tannic acid were prepared and their absorbance was plotted to create a standard graph. The tannin content was quantified as tannic acid equivalent (TAE) per gramme of the extract (mg TAE/g).

Methods for mineral estimation

The mineral composition of various eggplant fruit samples was analysed using the atomic absorption spectrophotometric (AAS) method [13]. Approximately 50 g of sample was collected from each variety and washed with tap water and then deionized distilled water. The samples were sliced into small pieces and left to dry in the sun on a concrete surface for approximately 12 hours. Once dried, the samples were pulverised into powder. Each sample weighing around 0.5 g was placed in duplicate into the digestion tube. To each tube, 5 ml of nitric acid and 2.5 ml of perchloric acid in a 2:1 ratio were added and thoroughly mixed. The test tubes were heated to approximately 100 °C for 10 to 12 hours in a boiling water bath and then cooled. Next, 2.5 ml of nitric acid was added to each tube and heated for approximately 3-4 hours in a boiling water bath until the solution turned transparent. The solutions were cooled, filtered using Whatman No. 1 filter paper, and diluted to 100 ml with deionized distilled water to create the working standard. All glassware, including digestion tubes, was treated with 30% nitric acid (HNO_3) for 8 hours and then rinsed with deionized distilled water. 14 ml of each treatment solution was transferred into test tubes using a pipette. A reagent blank was created by adding 14 ml of deionized distilled water to a test tube. The solution's absorbance and concentrations in parts per million (ppm) were analysed at specific wavelengths using an atomic absorption spectrophotometer (AAS): 422.67 nm for calcium (Ca), 371.99 nm for iron (Fe), 403.08 nm for manganese (Mn), 307.59 nm for zinc (Zn), and 217.0 nm for lead (Pb). The mineral content in the samples was determined based on the concentrations (ppm) of the solutions.

Statistical analysis

The results were calculated as the mean ± SE of three different replications. The means were compared using the Statistical Package for the Social Sciences (IBM SPSS. 23). Graphical presentations were created with Origin Pro 9.1 program. The statistical significance criterion was $P<0.05$.

Results

A detailed result of the present investigation is given under the following subheadings:

Proximate composition

Table 2 shows the proximate composition of the different parents and the segregating population of their hybrids. The moisture was significantly different in different accessions ($P<0.05$). The moisture percentage ranges from 81.92% for CHT-1 to 89.90% for Akshita. The highest moisture% was found in the parent variety Akshita (89.90%) and China (89.54%) and it was followed by Srilanka (84.94%) then in segregating population HVSP-5 (85.76%), HVSP-2 (85.19%), HVSP-3 (83.65%). The lowest moisture% was observed in CHT-2 (84.08%), HVSP-1 (84.35%), HVSP-4 (83.76%), CHT-1 (81.92%) and HVSP-6 (81.93%). Here, China and Akshita; Srilanka and CHT-2, HVSP-1, HVSP-2, HVSP-3, HVSP-4, HVSP-5; CHT-1, CH-2, HVSP-1, HVSP-4 and HVSP-6 have no significant difference according to DMRT at $P< 0.05$.

The crude protein content of different accessions was significantly different. The crude protein content ranges from 10.94% for HVSP-2 to 24.11% for Akshita. The highest crude protein was observed in the parent variety Akshita (24.11%) and it was followed by HVSP-2 (22.69%), Srilanka (22.11%), CHT-1 (19.44%), China (17.31%), HVSP-1 (17.04%), HVSP-5 (15.00%), HVSP-3 (13.23%), HVSP-4 (13.40%) and HVSP-6 (13.22%). The lowest crude protein was observed in CHT-2 (10.94%). Here, in respect to crude protein the accession Srilanka and HVSP-2, China and HVSP-1, HVSP-3, HVSP-4, and HVSP-6 have no significant difference according to DMRT (Table 2).

The crude fat percentage ranges from 0.02% for HVSP-4 to 0.12% for CHT-2. The highest crude fat was observed in CHT-2 (0.12%), China (0.11%), HVSP-6 (0.11%), Srilanka (0.08%), and Akshita (0.07%). All of these accessions have no significant difference according to DMRT. The highest value was followed by HVSP-5 (0.06%), HVSP-2 (0.05%), HVSP-1 (0.03%), and HVSP-3 (0.03%). The lowest was observed in HVSP-4 (0.02%). Here, the accession of Akshita, Srilanka, HVSP-6, and HVSP-2 have no significant difference according to DMRT by the study character crude fat%. Similarly, CHT-1, HVSP-1, HVSP-3, HVSP-4, and HVSP-5 have no significant difference according to DMRT (Table 2).

The carbohydrate content ranges from 5.18% for China to 33.34% for Akshita. The highest crude carbohydrate was observed in CHT-1 (22.5%) and it was followed by HVSP-6 (21.3%), HVSP-5 (18.00%), HVSP-2 (12.9%), CHT-2 (11.9%) and HVSP-3 (10.00%). The lowest crude carbohydrate was found in China (5.18%). Here, Akshita and Srilanka, Srilanka, and HVSP-4 have no significant difference according to DMRT (Table 2).

The ash content ranges from 8.08% for HVSP-3 to 10.3% for HVSP-4. The highest ash% was observed in Akshita (33.34%) and it was followed by HVSP-4 (10.30%), China (10.04%), HVSP-6 (10.03%), Srilanka (10.16%), CHT-2 (10.01%), HVSP-1 (9.35%) respectively. The lowest ash% was found in CHT-1 (8.18%) and HVSP-2 (8.18%), HVSP-3 (8.08%). The genotypes China, Srilanka, CHT-2, HVSP-4, HVSP-5 and HVSP-6; CHT-2, HVSP-1 and HVSP-6; CHT-1, HVSP-2, HVSP-3 and HVSP-5 have no significant difference according to DMRT in respect to ash% (Table 2).

Table 2: Proximate composition of different fruits of eggplant parents and segregating population of their hybrids

Genotypes name	Moisture%	Crude Protein	Crude Fat%	Carbohydrate	Ash%
China	89.54±0.28^{a}	17.31±0.21^{d}	0.11±0.01^{ab}	5.18±0.14^{j}	10.04±0.22^{bc}
Akshita	89.90±0.62^{a}	24.11±0.13^{a}	0.07±0.01^{abcd}	8.44±0.24^{g}	33.34±0.45^{a}
Srilanka	84.94±1.02^{b}	22.11±0.07^{b}	0.08±0.00^{abcd}	8.12±0.16^{gh}	10.16±0.32^{b}
CHT-1	81.92±1.53^{c}	19.44±0.31^{c}	0.04±0.01^{d}	22.5±0.44^{a}	8.18±0.19^{d}
CHT-2	84.08±0.80^{bc}	10.94±0.30^{g}	0.12±0.01^{a}	11.9±0.50^{e}	10.01±0.25^{bc}
HVSP-1	84.35±1.32^{bc}	17.04±0.44^{d}	0.03±0.01^{d}	6.41±0.21^{i}	9.35±0.11^{c}
HVSP-2	85.19±0.61^{b}	22.69±0.35^{b}	0.05±0.01^{cd}	12.9±0.14^{d}	8.18±0.24^{d}
HVSP-3	85.59±0.56^{b}	13.23±0.13^{f}	0.03±0.00^{d}	10.0±0.49^{f}	8.08±0.08^{d}
HVSP-4	83.65±0.57^{bc}	13.40±0.23^{f}	0.02±0.00^{d}	7.36±0.18^{h}	10.3±0.26^{b}
HVSP-5	85.76±0.57^{b}	15.00±0.11^{e}	0.06±0.00^{bcd}	18.0±0.05^{c}	8.20±0.10^{d}
HVSP-6	81.93±0.87^{b}	13.22±0.17^{f}	0.11±0.04^{abc}	21.3±0.28^{b}	10.03±0.11^{bc}
Significance CV%	* 1.77	* 2.55	* 4.45	* 4.31	* 3.61

CV, coefficient of variation; in a column, different letters in mean values ± SE are significantly differed by Duncan Multiple Range Test (*, $p < 0.05$); n = 3.

Antioxidant activity

Figure 1 displays the DPPH radical scavenging activity of different eggplant fruit extracts. The ethanolic extract of eggplant fruit samples was tested against DPPH stable radicals spectrophotometrically, revealing remarkable antioxidant activity as concentration increased. In the case of five completely different concentrations (25, 50, 100, 200, and 400 mg/ml), the causes for the scavenging activity of China, Akshita, Sri Lanka, CHT-1, CHT-2, HVSP-1, HVSP-2, HVSP-3, HVSP-4, HVSP-5, and HVSP-6 were gradually exaggerated. The scavenging percentage of that different concentration (25 to 400 mg/ml) for China is 7.72%, 13.65%, 23.34%, 36.56%, 40.08%; Akshita 12.51%, 16.56%, 23.96%, 26.87%, 32.15%; Sri Lanka 16.87%, 21.92%, 27.08%, 39.35%, 41.05%; CHT-1 6.20%, 9.84%, 11.89%, 21.58%, 33.92%; CHT-2 7.01%, 12.07%, 22.55%, 27.22%, 30.83%; HVSP-1 6.61%, 12.77%, 18.06%, 28.63%, 36.56%; HVSP-2 12.46%, 21.51%, 26.56%, 32.73%, 41.54%; HVSP-3 6.6%, 10.13%, 12.77%, 18.94%, 23.34%; HVSP-4 6.32%, 11.96%, 14.48%, 18.53%, 22.96%; HVSP-5 10.39%, 17.44%, 28.89%, 39.18%, 41.35% and HVSP-6 8.32%, 14.49%, 19.18%, 24.71%, 37.35% respectively. For standard ascorbic acid scavenging activity, the maximum was 31.79%, 38.67%, 65.03%, 76.81%, and 79.83% (Figure 1). Whereas, the IC_{50} values of the eggplant fruit accessions were 147.14, 131.44, 17.78, 266.07, 216.46, 254.35, 167.42, 288.34, 142.52, 199.61, and 128.21 mg/ml, respectively, and ascorbic acid was 5.79 mg/mL. As a result, the genotypes China, Akshita, Sri Lanka, CHT-1, CHT-2, HVSP-1, HVSP-2, HVSP-3, HVSP-4, HVSP-5, and HVSP-6 had higher IC_{50} values than ascorbic acid, indicating that they were less powerful antioxidants (Figure 2).

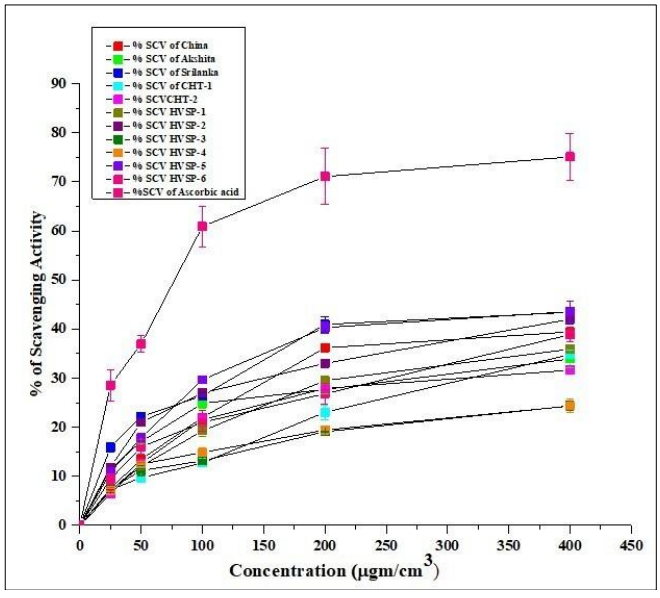

Fig 1: Scavenging activity of different eggplant fruits of methanolic extract. Values are mean ± Standard error (n = 3).

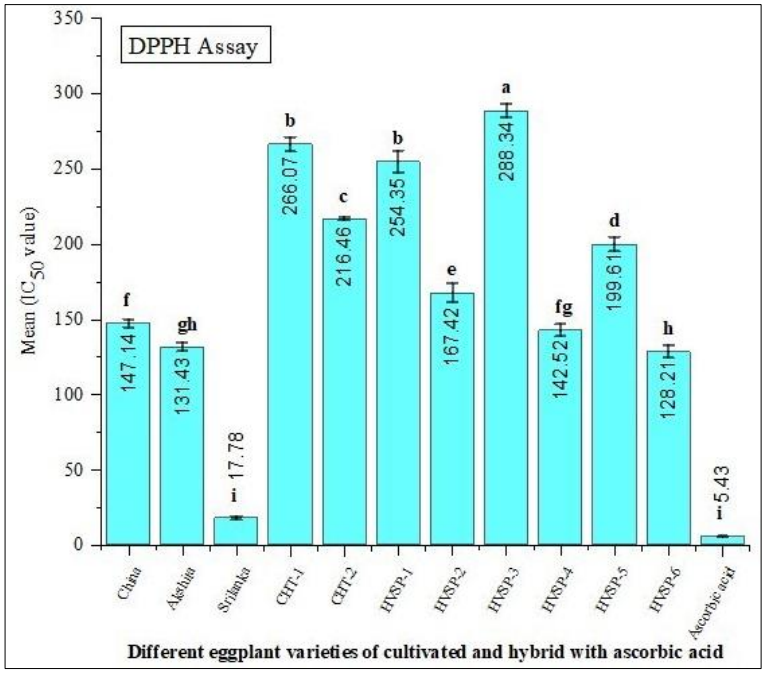

Fig 2: IC_{50} values of fruits of different eggplant genotypes. Each value is the mean of three replicate determination ± standard error (p<0.05).

Table 3 represents different genotype and their corresponding TPC, TFC, and TTC values. China, Akshita, Srilanka, CHT-1, CHT-2, HVSP-1 to HVSP-6 are eleven of the genotypes listed, with varying levels of TPC, TFC, and TTC. The table provides information on the antioxidant activity of different genotypes based on their TPC, TFC, and TTC values. The values vary greatly between genotypes with some having significantly higher values than others.

The TPC content ranges from 55.94 µg/ml for China to 197.82 µg/ml for HVSP-5. The highest TPC was observed in HVSP-5 (197.82 µg/ml) and it was followed by CHT-1 (167.91 µg/ml), HVSP-2 (138.85 µg/ml), HVSP-3 (98.68 µg/ml). The lowest TPC was obtained in China (55.64 µg/ml) and it was similar to Akshita (63.64 µg/ml) and HVSP-1 (58.51 µg/ml) according to DMRT at a 5% level of significance (Table 3). The TFC content ranges from (16.75 µg/ml) for CHT-1 to 22.92 µg/ml for CHT-2. The highest TFC was obtained in CHT-2 (22.92 µg/ml) which was followed by Srilanka (22.58), HVSP-1 (21.58 µg/ml), HVSP-5 (20.75 µg/ml), HVSP-6 (20.42 µg/ml), HVSP-3 (21.08 µg/ml), Akshita (21.08 µg/ml). The lowest was observed by CHT-1 (16.75 µg/ml). Here, Srilanka, CHT-2 and HVSP-1; HVSP-3, HVSP-5 and HVSP-6; China and Akshita have no significant difference according to DMRT at 5% level of significance (Table 3).

The TTC content ranges from 0.75 µg/ml for Srilanka to 3.95 µg/ml for CHT-2. The highest TTC was observed in CHT-2 (3.95 µg/ml) which was followed by HVSP-3 (3.62 µg/ml), CHT-1 (2.69 µg/ml), Akshita (2.42 µg/ml), HVSP-2 (2.10 µg/ml). Interestingly, among the genotype, there is no significant difference according to DMRT at a 5% level of significance for the TTC observation (Table 3).

Table 3: Total phenolic, total flavonoid, and total tannin (µg/ml)) content of different eggplant fruits.

Genotypes name	TPC (µg/ml)	TFC (µg/ml)	TTC (µg/ml)
China	55.94±2.96^{f}	19.58±0.33^{def}	1.58±0.04^{a}
Akshita	63.64±1.48^{ef}	21.08±0.33^{bcd}	2.42±1.51^{a}
Srilanka	73.04±4.52^{e}	22.58±0.72^{ab}	0.75±0.44^{a}
CHT-1	167.91±4.76^{b}	16.75±0.57^{g}	2.69±1.91^{a}
CHT-2	75.60±2.26^{e}	22.92±0.44^{a}	3.95±2.40^{a}
HVSP-1	58.51±5.91^{f}	21.58±0.44^{abc}	1.83±1.16^{a}
HVSP-2	138.85±3.72^{c}	18.42±0.44^{fg}	2.10±0.99^{a}
HVSP-3	98.68±5.19^{d}	20.08±0.92^{cde}	3.62±2.13^{a}
HVSP-4	100.39±8.67^{d}	18.92±0.44^{ef}	1.13±0.44^{a}
HVSP-5	197.82±3.72^{a}	20.75±0.28^{cd}	1.11±0.39^{a}
HVSP-6	90.99±3.08^{d}	20.42±0.44^{cde}	1.21±0.41^{a}
Significance	*	*	*
CV%	7.83	4.46	10.56

CV, coefficient of variation; in a column, different letters in mean values ± SE are significantly differed by Duncan Multiple Range Test (*, p<0.05); n = 3.

Mineral concentration

Calcium (Ca) content (mg/kg)

The utmost quantity of Ca was found in Akshita (139.35 mg/kg), whereas the bottom quantity was found in Srilanka (8.29 mg/kg). The highest Ca Akshita (139.35 mg/kg) was followed by CHT-1 (134.94 mg/kg), China (131.26 mg/kg), CHT-2 (92.53 mg/kg) and HVSP-3 (45.53 mg/kg). The lowest was observed in Srilanka (8.29 mg/kg). Here, Akshita and CHT-1; China and CHT-1; HVSP-1, HVSP-5 and HVSP-6 have no significant difference according to DMRT at a 5% level of significance (Table 4).

Zinc (Zn) content (mg/kg)

The mineral Zinc (Zn) content ranges from 0.17 for HVSP-5 to 7.14 for HVSP-2. The highest was 7.14 followed by 3.33 (mg/kg) for CHT-1, 3.18 (mg/kg) for HVSP-3, 2.56 (mg/kg) for HVSP-4, 2.49 (mg/kg) for Akshita, 2.47 (mg/kg) for Srilanka. The lowest was observed in HVSP-5 (0.17 (mg/kg). Here, CHT-1 and HVSP-3; Akshita, Srilanka, HVSP-1 and HVSP-4; China and HVSP-5 have no significant difference according to DMRT at 5% level of significance (Table 4).

Iron (Fe) content (mg/kg)

The iron content ranges from 8.94 (mg/kg) for HVSP-2 to 22.42 (mg/kg) for China. The highest 8.94 (mg/kg) iron was followed by Akshita (21.03 mg/kg), Srilanka (20.73 mg/kg), CHT-2 (20.25 mg/kg), CHT-1 (15.68 mg/kg), HVSP-3 (15.51 mg/kg), HVSP-5 (15.34 mg/kg), HVSP-6 (15.18 mg/kg), HVSP-4 (11.38). The lowest iron content was observed in HVSP-2 (8.94 mg/kg). Here, Akshita, Srilanka and CHT-2; CHT-1, HVSP-3, HVSP-5 and HVSP-6; HVSP-1, HVSP-1 and HVSP-4 have no significant difference according to DMRT at 5% level of significant (Table 4).

Manganese (Mn) content (mg/kg)

The mineral manganese content ranges from 17.06 mg/kg for CHT-2 to 11.2 mg/kg for HVSP-1. The highest 17.06 mg/kg was followed by HVSP-4 (16.15 mg/kg), HVSP-5 (15.05 mg/kg), CHT-1 (15.7 mg/kg), China (15.12 mg/kg). The lowest was observed in HVSP-2 (9.88 mg/kg). Here, CHT-2, HVSP-4; China, Akshita, HVSP-3, HVSP-5; Srilanka, HVSP-1 have no significant difference according to DMRT at 5% level of significance (Table 4).

Lead (Pb) content (mg/kg)

The lead content of different fruits of eggplant genotype ranged from CHT-2 (0.23 mg/kg) to Akshita (6.01 mg/kg). The values was followed by HVSP-4 (3.12 mg/kg), HVSP-2 (2.42 mg/kg), HVSP-3 (2.25 mg/kg), HVSP-5 (1.86 mg/kg), Srilanka (1.56 mg/kg). The lowest was observed in CHT-2 (0.23 mg/kg). Here, HVSP-2 and HVSP-3; China, CHT-1, and HVSP-1 have no significant difference according to DMRT at 5% level of significance (Table 4).

Table 4: The four important minerals calcium, zinc, iron, manganese (µg/ml) and a toxic mineral lead content of different fruits of eggplant parents and segregating population of their hybrids.

Genotypes name	Ca (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Pb (mg/kg)
China	131.26±2.81^{b}	0.83±0.08^{ef}	22.42±0.27^{a}	15.12±0.17^{cd}	0.88±0.05^{f}
Akshita	139.35±1.82^{a}	2.49±0.27^{c}	21.03±0.23^{b}	14.94±0.49^{cd}	6.01±0.06^{a}
Srilanka	8.29±0.74^{h}	2.47±0.12^{c}	20.73±0.62^{b}	11.08±0.39^{e}	1.56±0.10^{e}
CHT-1	134.94±0.63^{ab}	3.33±0.22^{b}	15.68±0.36^{c}	15.7±0.53b^{c}	0.87±0.00^{f}
CHT-2	92.53±1.52^{c}	1.46±0.16^{d}	20.25±0.19^{b}	17.06±0.14^{a}	0.23±0.17^{g}
HVSP-1	21.67±0.65^{g}	2.44±0.00^{c}	11.33±0.28^{d}	11.29±0.25^{e}	0.85±0.03^{f}
HVSP-2	75.8±0.53^{d}	7.14±0.49^{a}	8.94±0.14^{e}	9.88±0.13^{f}	2.42±0.12^{c}
HVSP-3	45.53±0.68^{f}	3.18±0.02^{b}	15.51±0.37^{c}	14.86±0.44^{cd}	2.25±0.18^{c}
HVSP-4	55.73±0.43^{e}	2.56±0.15^{c}	11.38±0.29^{d}	16.15±0.14^{ab}	3.12±0.17^{b}
HVSP-5	24.64±0.62^{g}	0.17±0.02^{f}	15.34±0.34^{c}	15.05±0.06^{cd}	1.86±0.11^{d}
HVSP-6	23.34±0.29^{g}	1.3±0.13^{de}	15.18±0.26^{c}	14.34±0.28^{d}	0.82±0.02^{f}
Significance	*	*	*	*	*
CV%	6.56	14.41	3.55	3.98	10.41

CV, coefficient of variation; in a column, different letters in mean values ± SE are significantly differed by Duncan Multiple Range Test (*, $p < 0.01$); n = 3.

Discussion

The present investigation was a layout for the estimation of proximate analysis such as moisture%, crude carbohydrate%, fat%, crude protein%, and ash%; antioxidant activity such as DPPH radical scavenging; total phenolic content (TPC); total flavonoid content (TFC); and total tannin content (TTC); some important mineral content such as calcium (Ca), zinc (Zn), iron (Fe), manganese (Mn); and a heavy metal of lead (Pb) were also estimated.

The present finding of moisture% was a little bit lower than some of the cultivated varieties that were reported by Quamruzzaman *et al.* [14]; Flick *et al.* [15]; Munoz *et al.* [16] and Nino-Medina *et al.* [17]. Quamruzzaman *et al.* [14]; Flick *et al.* [15] and Munoz *et al.* [16] found an average of 91.39–94.87 per cent moisture in some cultivated varieties, whereas Nino-Medina *et al.* [17] observed 90.10–92.70 per cent, which is a little bit similar to the present study. In this regard, it is worth noting that the hybrid population has a similar moisture percentage.

The current study found a higher percentage of crude protein than previous studies by Quamruzzaman *et al.* [14]; Flick *et al.* [15]; Munoz *et al.* [16] and Nino-Medina *et al.* [17]. The higher crude protein percentage could be due to methodological errors, soil nutrition, environmental effects, or any other genetic effects that have yet to be identified for the investigated varieties.

The fat level in this study was estimated to be between 0.02% and 0.12%, which was about the same as what other researchers found. For example, Nino-Medina *et al.* [17] looked at the fat levels in different types of eggplant and found values between 0.03 and 0.04%, and Quamruzzaman *et al.* [14] also found values between 0.02% and 0.4%. Thus, the observations made earlier and the observations made now were very similar.

The amount of ash found was higher than what had been found in earlier research studies of Quamruzzaman *et al.* [14]; Flick *et al.* [15]; Munoz *et al.* [16]. Those studies only found 0.37–0.62 per cent ash in hybrid and cultivated varieties.

The coefficient of variation (CV%) varies between the different proximate ranging from a low of 1.77% for the observation of moisture% to a high of 4.45% for the observation of crude fat%. Meanwhile, the coefficient of variability of all the investigated characters was below 10 revealing the accuracy of the data. Overall, the table provides information on the composition and variability among different types of parents/hybrids in terms of their nutritional content which could be useful in various fields such as agriculture and food science research and development.

DPPH radical is commonly employed as a substrate to assess the antioxidant activity of antioxidants by measuring the free radical-scavenging capacity of different samples [18]. The IC_{50} value indicates the quantity of antioxidative components needed to eliminate 50% of free radicals in the test system. Antioxidant activity increases as the IC_{50} value decreases. The results indicated a significant difference ($P<0.05$) in DPPH radical scavenging activity between the samples. The IC_{50} values of the extracts varied between 17.78 and 288.34 mg/ml (Figure 2). Sri Lanka exhibited the highest antioxidant activity, followed by HVSP-6, Akshita, HVSP-4, China, and HVSP-2. CHT-1, CHT-2, HVSP-1, and HVSP-3 exhibited the lowest antioxidant activity. Ascorbic acid demonstrated a low IC_{50} value of 5.79 mg/ml, indicating notably higher antioxidant activity than the various brinjal varieties examined in the study. Variations in scavenging activities may result from the presence of distinct phenolic compounds and variations in the total phenolic content.

Polyphenolic compounds are a diverse group of secondary metabolites that possess strong antioxidant properties due to their structure. They are primarily accountable for the majority of the health advantages linked to fruits [19]. All eggplant fruit varieties examined in this research contained measurable amounts of phenolic compounds. The total phenolic compounds in eggplant fruits from China, Akshita, Srilanka, CHT-1, CHT-2, and hybrid varieties HVSP-1 to HVSP-6 ranged from 55.94 to 197.82 µg gallic acid equivalent (GAE)/g of extract. Plant phenolics are being studied for their potential as natural antioxidants due to their ability to effectively scavenge radicals and chelate metals. Hence, it is important to ascertain the overall quantity of phenolic content in the selected plant for the research.

The relative comparisons are made more difficult by the fact that TFC is expressed in different genotypes in comparable studies published in the literature. As an example, a study [20] determined that the total flavonoid content (TFC) of eggplant was around 23.6 mg quercetin/100 g dry weight (DW). Those findings are consistent with what Chioti *et al*. [21] found, with TFC values of around 4.9, 6.0, 13.7, and 9.3 mg quercetin equivalent/g dw for the C1, C2, C3, and Hyb2 genotypes, respectively. The current study's corresponding amounts of TFC were significantly lower than those found in twenty-six Indian eggplants, as shown more recently [22] (5.3 to 28.7 mg/100 g fw).

Tannins irreversibly bind to proteins to form insoluble complexes and also efficiently bind to Fe, as well as to a lesser extent to Cu, Mn, Al, Zn, and Co [23]. The eggplant varieties examined yielded values ranging from 0.75 µg/ml to 3.95 µg/ml. The recommended daily intake of tannic acid for a man is 560 mg per 100 g. Therefore, the tannin levels in eggplant varieties are below the critical toxicity threshold. Thus, the tannin's toxicity effects may be insignificant.

CHT-1 has the highest TPC value at 167.91±4.76 µg/ml while HVSP-5 has the highest TTC value at 3.95±0.39 µg/ml for CHT-2 and the highest TFC value at 22.92 µg/ml CHT-2. The CV% values for TPC, TFC, and TTC are 7.83%, 4.46%, and 10.56%, respectively. Most of the coefficients of variability (CV%) were above 10 revealing the authentication of the data handling. It is important to note that the CV% values for each parameter are relatively low indicating that the results are consistent across multiple measurements.

The data presented in the table can be used to compare the antioxidant activity of different genotypes and determine which ones have higher levels of TPC, TFC, and TTC. This information can be useful in selecting accessions for further study or use in food or pharmaceutical industries.

Mineral content is additionally necessary for the organic process of fruits of eggplant.

The genotype provides an affordable quantity of minerals compared with vegetables [24]. Determination of the key minerals and trace components in fruits of eggplant genotype are dole out and reportable that genotype, soil kind and chemical content of the soil will cause variation within the minerals content of fruits of eggplant. Most of the parents population has lower concentrations of some mineral components in their fruit than their segregating populations of hybrids once grownup in some atmosphere-however this is often not universally discovered.

Zinc (Zn) is a necessary metal and an element of a large form of completely different enzymes within which it's concerned with chemical change, and structural and regulative roles. The lower concentration of Zn is present within the studied samples. The permissible limit of Zn is 60 mg/kg in foods [25].

Iron (Fe) was additionally present in fairly low amounts however could be a contribution to dietary intake. It's a necessary metal concerned in biochemical processes. Among all the different micronutrients, iron is needed by plants in the largest quantity. The Fe content of the tested eggplant fruits ranged nearly the safe limit of 15 mg/kg set by the World Health Organization [26].

Manganese (Mn) is a necessary metal required for biological systems like metalloproteinase [28]. The toxic threshold for Mn is 400-1000 mg/kg according to the World Health Organization [27]. The study demonstrated that the level of manganese (Mn) ranged from 11.2 mg/kg to 17.06 mg/kg, a concentration considered safe for human consumption.

The CV% values for Calcium (Ca), Zinc (Zn), Iron (Fe), manganese (Mn) and Lead (Pb) are 6.56%, 14.41%, 3.55% 3.98 and 10.41 respectively. Most of the coefficient of variability (CV%) were near above 10 revealing the authentication of the data handling. The findings showed that eggplant is a rich source of vital macro and micro-metals. It is also devoid of the toxic metal Pb. However, it does not exceed the permissible level set by WHO/FAO for lead (Pb). Hybrid eggplants have phytochemicals similar to their parent plants and are resistant to BFSB.

Conclusions

The study examined the nutritional composition of different eggplant types, emphasizing moisture, crude protein, fat, ash content, antioxidant activity, and mineral content. Results demonstrated reduced moisture content relative to certain cultivated varieties, although higher crude protein levels, maybe attributable to environmental or methodological factors. Fat content was consistent with other investigations, however ash content exceeds past findings. The antioxidant activity exhibited considerable variation, with samples from Sri Lanka demonstrating the highest values. Phenolic molecules were identified, adding to antioxidant capacity, however the total flavonoid content was lower to that observed in other investigations. Mineral examination indicated acceptable amounts of manganese and lead, but lowered concentrations of zinc and iron. The study emphasized the nutritional availability of eggplants, indicating that hybrid cultivars preserve advantageous phytochemicals and insect resistance, which may be valuable for agricultural practices and food science research.

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Disclosure statement
The authors report there are no competing interests to declare.

Conflict of interest
None to declare.

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