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Evaluation of the Quality of Yard-Long Bean (*Vigna unguiculata* sub sp. *sesquipedalis* L.) Cultivars to Meet the Nutritional Security of Increasing Population

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Abstract: It is well-known that eating highly nutritious foods has health benefits which may include the prevention of diabetes, heart disease, cancers and other diseases. We examined five yard-long bean cultivars commonly grown in Bangladesh to determine their quality and nutritional composition in terms of carbohydrates, protein, moisture content, fat, ash, sugar crude fiber, as well as their average concentrations of the important nutrients vitamins A (folate) B1 (thiamine), B2 (riboflavin), B3 (niacin), B6 (pyridoxamine), and C (ascorbic acid), the electrolytes sodium and potassium, and the minerals iron, calcium, magnesium and zinc. The experiment was conducted at the Horticulture Research Centre (latitude 23.9920° N and longitude 90.4125° E, having an elevation of 8.2 m asl) of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Bangladesh during 2019–2020 to find out the best yard-long bean cultivar to meet the nutritional security of the increasing population of Bangladesh. We observed average energy concentrations of the five yard-long bean cultivars between 37.62 to 45.94 Kcal/100 g. Similarly, average carbohydrate concentrations ranged between 6.28 to 8.41 g/100 g, average protein between 2.80 and 3.30 g/100 g, average fat between 0.10 and 0.19 g/100 g, average sugar between 1.47 to 2.34 g/100 g, and average crude fiber between 1.23 to 1.85 g/100 g. All five yard-long bean cultivars had high average concentrations of folate and key vitamins critical for human health: vitamin A (846.23–869.36 IU), vitamin B1 (0.096–0.115 mg), vitamin B2 (0.109–0.118 mg), vitamin B3 (0.40–0.42 mg), vitamin B6 (0.020–0.025 mg), and vitamin C (18.20–20.22 mg). Average sodium concentrations in the yard-long bean pods ranged from 3.97 to 4.18 mg, while average potassium concentrations varied between 230.03 and 246.57 mg. We observed high average concentrations of the minerals iron (0.85–1.28 mg), calcium (42.11–58.83 mg), magnesium (40.44–46.50 mg), and zinc (0.36–0.40 mg). Following this thorough investigation, we recommend the five yard-long bean cultivars be promoted for production and consumption within Bangladesh to improve human health and nutrition and to contribute to the prevention of key health complications including diabetes, obesity and some cancers.

Keywords: nutritional content; proximate composition; vitamins; minerals; yard long bean

1. Introduction

Edible beans are a nutrient-rich food high in protein, starch, minerals and vitamins (including folate, iron, potassium and magnesium) and other nutrients including folate. Beans are also low in total fat, trans fat, salt, and cholesterol [1–3]. A diet high in beans can improve health by reducing the likelihood of developing heart disease, obesity, and several types of cancer, due to the high concentration of health-promoting elements. Foods that are high in dietary fiber, including beans, protect the colon mucosa by reducing the time during digestion in which the mucosa is exposed to ingested toxins, and by binding to compounds that can cause cancer within the colon and facilitating the ejection of these from the body. High-fiber foods have also been reported to lower LDL cholesterol levels by reducing the reabsorption within the colon of the bile acids which bind cholesterol.

During the growth and development of a bean pod, the seed tissues accumulate nutrients, particularly protein and carbohydrates: dry beans are approximately 55–65% carbohydrate and 15–25 % protein [4–8], with significant iron and zinc content. Additionally, beans provide 90–95% of daily folic acid requirements. Colon cancer risk is inversely correlated with folic acid consumption [9]. As well, dry beans contain the B vitamins thiamine, riboflavin, niacin, and B12. When beans are cooked, roughly 70–75% of the water-soluble vitamins within the pod are retained [10].

The yard-long bean is one of the most significant leguminous vegetables in Asia: it is also known as the asparagus bean, string bean, snake bean, or snake pea. This bean was first cultivated in West Africa, and it is now widely grown across Southeast Asia, including Malaysia, the Philippines, Indonesia, and Thailand, where it can be grown year-round [11–13]. The ideal growing temperature for yard-long beans ranges between 27 to 30 °C, and it is better able to withstand heat and dryness than other common beans such as lima bean. Usually, the yard-long bean is harvested while still young and consumed as a green vegetable [14]. The average length of the bean pods varies between 30 to 80 cm [15]. The yard-long bean is an annual plant with rapid growth that thrives when supported by a trellis. There are both tall and short climbing types. It bears blue-to-violet blooms approximately 6 to 10 weeks from seedling emergence, depending on the cultivar type. Approximately two to four weeks after flowering, a large number of pencil-thin, tender, light-green, pliable-textured pods begin to form.

The yard-long bean is frequently known as "poor man's meat" as the pods are high not only in protein (23–32% of seed weight) but also in lysine, tryptophan and a significant number of critical vitamins and minerals including folic acid and vitamin B [14,16–18]. Fresh yard-long beans are very high in folates which are necessary for pregnant women to prevent neural tube defects in babies. To optimize the health benefits associated with yard-long beans, consumption of about 1.5 cups of beans weekly is recommended [19].

In Bangladesh, increasing incomes and urbanization have recently led to some dietary diversification but the rate has been slow, with cereals still accounting for 65–70% of the dietary energy intake. Diets have remained largely unbalanced with diets of more than 50% of the population being deficient in Vitamin A, calcium, zinc and iron. There is also the need to avoid the "multiple burdens of malnutrition" that can result in high incidences of obesity and non-communicable diseases. These are important factors, if not addressed properly, can even threaten the progress made so far in reducing food and nutrition insecurity in Bangladesh. Moreover, beans have an effective role in fulfilling the gap in food and nutrition insecurity. Since yard-long beans contain various kinds of nutritional facts, there is an opportunity to minimize nutritional deficiency by consuming the yard-long bean.

Various yard-long bean cultivars including short and long types, and deep green, light green, and violet varieties are grown in farmers' fields in Bangladesh. These cultivars display diverse physiological traits and nutritional properties. Quantification of the nutritional status of commonly grown yard-long bean cultivars is important. In this study, five yard-long bean varieties commonly grown in Bangladesh were assessed in terms of their nutritional value and composition for the food and nutritional security of the increasing population.

2. Materials and Methods

2.1. Experimental Site

The experiment was conducted at the Horticulture Research Centre (latitude 23.9920° N and longitude 90.4125° E, having an elevation of 8.2 m asl) of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh in 2019–2020. The research station is situated in agroecological zone 28 [20]. Soils in the valleys are dark grey heavy clays. They are strongly acidic in reaction with the low status of organic matter, low moisture holding capacity and low fertility level. This is a sub-tropical zone characterized by light rainfall, particularly during the period when beans were grown. Average minimum and maximum temperatures were 18.37 °C and 29.37 °C during crop growth (Figure 1).

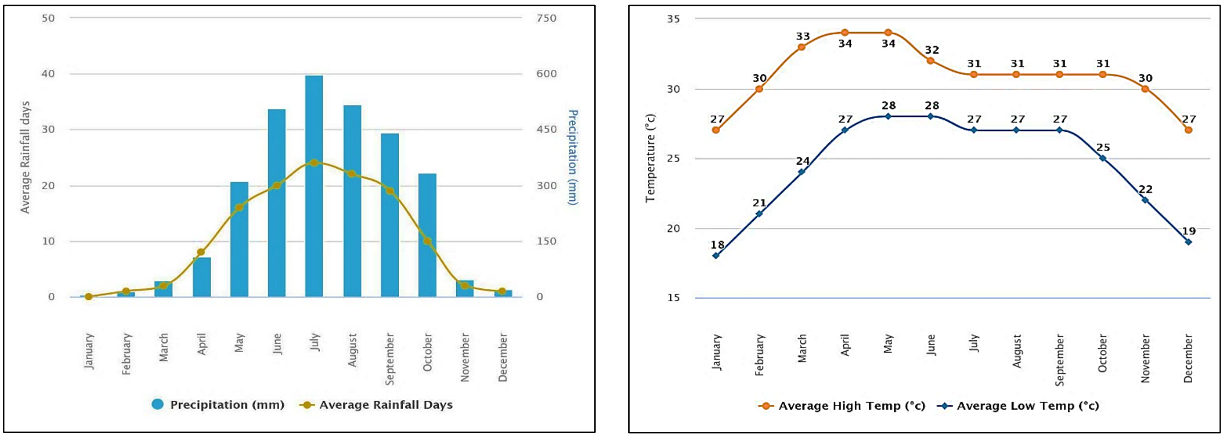

Figure 1. Average rainfall, maximum and minimum temperature during crop growth stage.

2.2. Experimental Materials Used in the Study

Five yard-long bean cultivars viz., VS-21, VS-32, VS-49, BARI Barboti-1 and BARI Barboti-2 were used in this study (Figure 2). These are all varieties of yard-long beans which are commonly grown in Bangladesh.

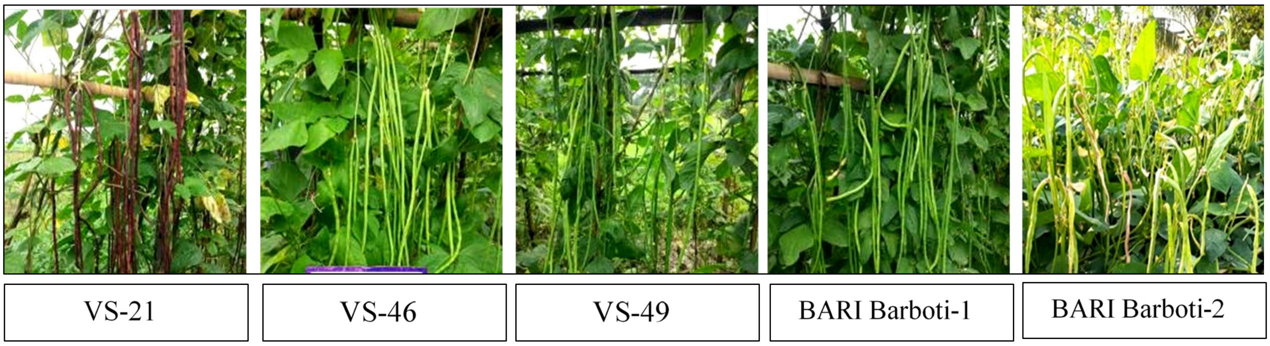

Figure 2. Morphological views of five yard-long bean cultivars commonly grown in Bangladesh.

2.3. Sample Preparation

Yard-long bean pods were collected when mature and washed in flowing water. Bean pods were sorted by color and size and divided into two sampling groups. The first sampling group of fresh pods was used for proximate and mineral analysis. The second sampling group was used for the estimation of ascorbic acid; for this analysis all pods were freeze-dried and stored at 80 °C until analysis. Please note that Analyses of yard-long bean pod quality and nutritional composition were conducted at the laboratory of the Bangladesh Council of Scientific and Industrial Research, Dhaka, Bangladesh.

2.4. Estimation of Proximate Contents in the Pods of Yard-Long Bean Cultivars

Characteristics of yard-long bean pods including moisture, protein (N × 6.25), crude fiber, ash, carbohydrates (by difference) and fat content were estimated using the methods described by AOAC [21].

2.5. Estimation of Macro and Microelements in the Pods of Yard-Long Bean Cultivars

The macro-and micronutrient concentrations of the yard-long bean pods were determined using the mass spectrometry method. The concentrations of sodium, potassium, calcium, magnesium, iron and zinc in the pods of all yard-long bean cultivars were measured using ICP-OES [21].

2.6. Vitamins Concentrations in the Pods of Yard-Long Bean Cultivars

The concentrations of vitamins A, B1, B2, B3, B6 and C Vitamins in bean pods of the five cultivars were determined. Vitamin A content was measured by determined using a reverse-phase analytical HPLC UV detector following direct extraction and placing the extract into the proper dissolvent [22]. B complex vitamins (i.e., vitamins B1, B2, B3 and B6) were measured using an HPLC HL detector following an enzymatic incubation [23]. Vitamin C (L-dehydroascorbic acid) concentrations were determined using an HPLC UV detector following the sample extraction with metaphosphoric acid [24].

2.7. *Data Arrangement and Their Statistical Analysis Procedures*

All quality and nutritional parameters were analyzed using a one-way ANOVA (Analysis of Variance); mean separation used the least significant difference test (LSD) at a significance level of 5% level [25].

3. Results

3.1. Energy and Carbohydrate Content in Five Yard-Long Bean Cultivars

The average energy content across all five yard-long bean cultivars ranged between 37.62 to 45.94 Kcal/100 g. The BARI Barboti-1 variety had the highest energy content (45.94 Kcal/100 g), followed by the VS-49 (41.04 Kcal/100 g) and VS-32 (40.33 Kcal/100 g), while the VS-21 had the lowest energy content (37.62 Kcal/100 g) (Figure 3a).

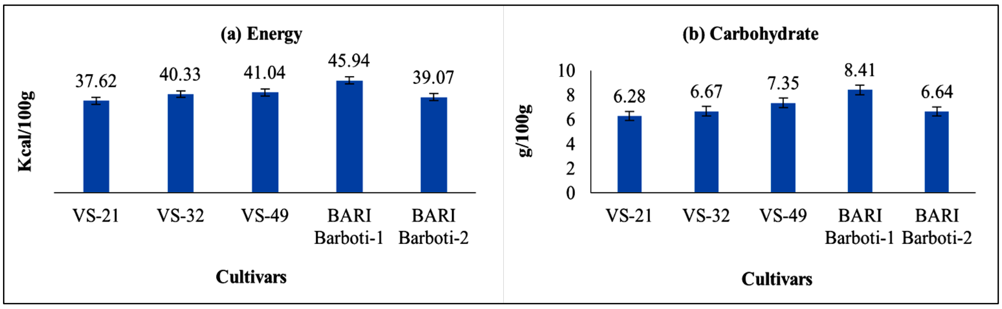

Figure 3. (**a**): energy and (**b**): carbohydrate content of five yard-long bean cultivars commonly grown in Bangladesh. Note: The parameters were estimated from 100 g of dry matter.

Average carbohydrate content ranged between 6.28 to 8.41 g/100 g across all five yard-long bean cultivars. The BARI Barboti-1 had the highest carbohydrate content (8.41 g/100 g), followed by the VS-49 (7.35 g/100 g) and VS-32 (6.67 g/100 g) cultivars. The VS-21 (6.28 g/100 g) was the lowest in carbohydrate content (Figure 3b).

3.2. Protein, Moisture, Fat, Ash, Sugar and Crude Fiber Content of Five Yard-Long Bean Cultivars

The average protein content of fresh (not dried) yard-long beans was highest in VS-32 (3.30 g/100 g), followed by the BARI Barboti-2 (3.08 g/100 g) and VS-21 (2.89 g/100 g), while the protein in the fresh pod was lowest in VS-49 (2.80 g/100 g) (Figure 4a). In widely consumed pulses grown in Bangladesh, protein content in dried beans ranges between 20.47 to 25.0 g/100 g.

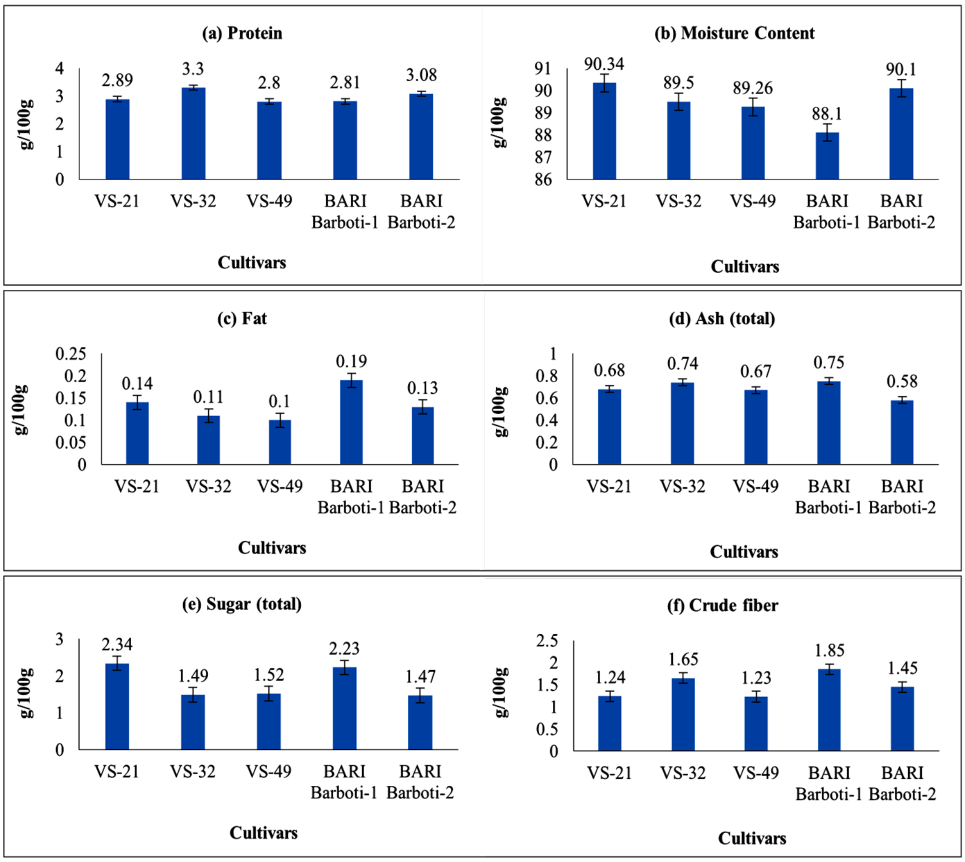

Figure 4. (**a**) protein, (**b**) moisture, (**c**) fat, (**d**) ash, (**e**) sugar and (**f**) crude fiber content of five yard-long bean cultivars commonly grown in Bangladesh [The parameters were estimated from 100 g dry matter].

All five yard-long bean cultivars had an average moisture content of less than 91.00%; ranging between 88.10 to 90.34%. The highest moisture content was in the VS-21 (90.34%), followed by the BARI Barboti-2 (90.10%) and VS-32 (89.50%), while the lowest moisture content was observed in the BARI Barboti-1 variety (88.10%) (Figure 4b).

We observed the average fat content in the five yard-long bean cultivars between 0.10 and 0.19 g/100 g. Fat content was highest in the BARI Barboti-1 (0.19 g/100 g), followed by VS-21 (0.14 g/100 g) and BARI Barboti-2 (0.13 g/100 g). The VS-32 (0.11 g/100 g) and VS-49 (0.10 g/100 g) had the lowest fat contents (Figure 4c).

The average ash content was between 0.58 and 0.75 g/100 g. Ash content was highest in the BARI Barboti-1 (0.75 g/100 g), with more moderate ash contents observed in the VS-32 (0.74 g/100 g), VS-21 (0.68 g/100g), and VS-49 (0.67 g/100 g). The lowest ash content was in the BARI Barboti-2 (0.58 g/100 g) (Figure 4d).

All five yard-long bean cultivars had an average sugar content of less than 3.00%; these ranged between 1.47 to 2.34 g/100 g, with the VS-21 (2.34 g/100 g) having the highest sugar content followed by the BARI Barboti-1 variety (2.23 g/100 g). The VS-32 (1.49 g/100 g) and BARI Barboti-2 (1.47 g/100 g) had the lowest sugar contents (Figure 4e).

Yard-long bean pods are rich in both soluble and insoluble fibers which are present in the entire edible green pod. The average crude fiber measured across the five cultivars ranged between 1.23 to 1.85 g/100 g, with the BARI Barboti-1 having the highest crude fiber (1.85 g/100 g). The moderate crude fiber was observed in the VS-32 (1.65 g/100 g) and BARI Barboti-2 (1.45 g/100 g) varieties, while the lowest crude fiber was in the VS-49 (1.23 g/100 g) (Figure 4f).

3.3. Folate and Vitamin Content of Five Yard-Long Bean Cultivars

Folate is the water-soluble, naturally occurring form of vitamin B9 and is found in a variety of foods. Folate and vitamin B12 are critical for DNA synthesis and cell division, particularly during pregnancy. We observed folate contents in the five yard-long bean cultivars of between 58.75 and 67.31 μg, with the BARI Barboti-1 variety having the highest folate (67.31 μg) level. The VS-21 cultivar had a moderate folate content of 65.03 μg, while lower folate levels were observed in VS-49 (58.75 μg), BARI Barboti-2 (60.50 μg) and VS-32 (60.76 μg) (Figure 5a).

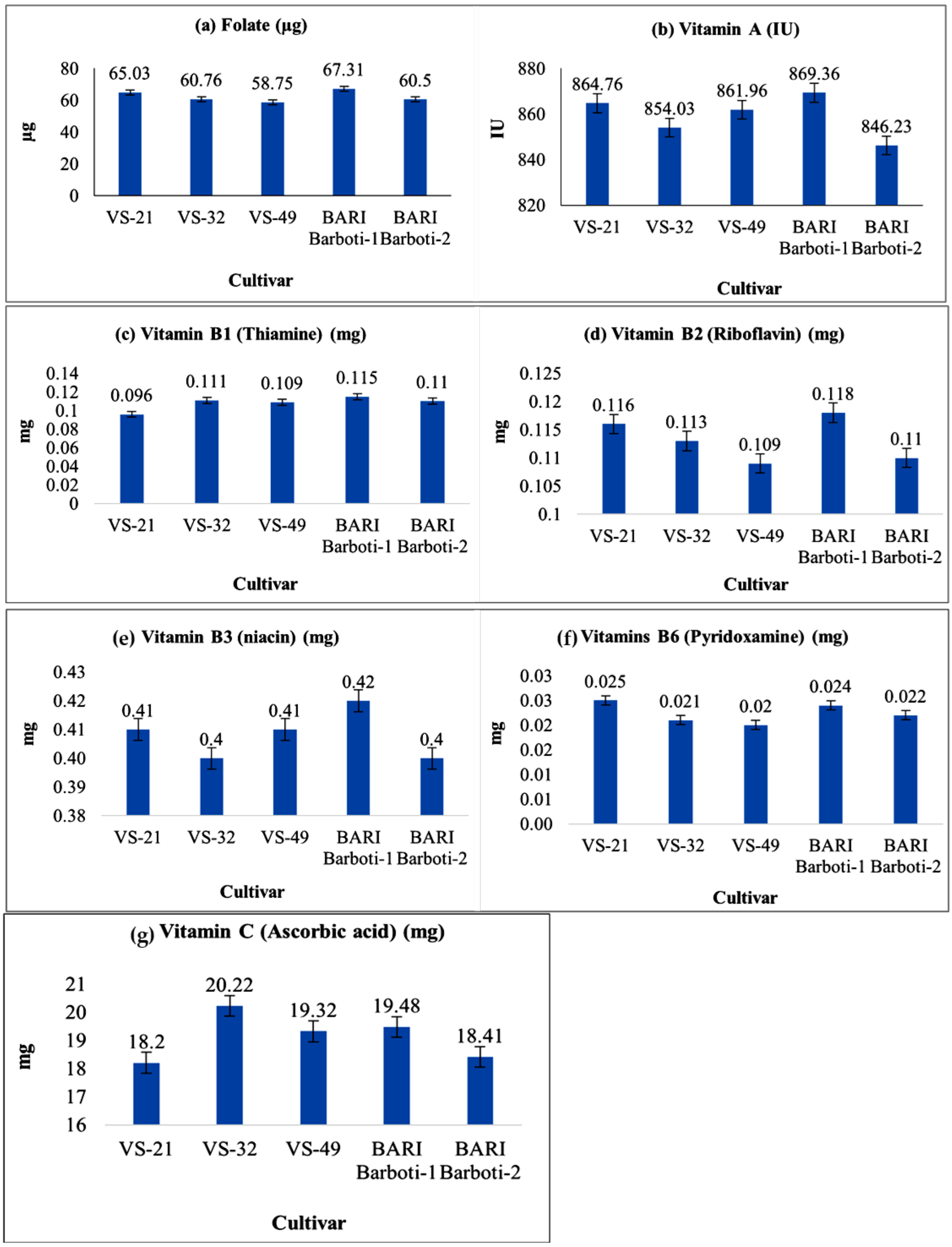

Figure 5. (**a**) folate, (**b**) vitamin A, (**c**) vitamin B1, (**d**) vitamin B2, (**e**) vitamin B3, (**f**) vitamin B6 and (**g**) vitamin C content of five-yard-long bean cultivars are commonly grown in Bangladesh [The parameters were estimated from 100 g dry matter].

Vitamin A contributes to the health of the gut mucosa, improves the skin, and promotes night vision. The five yard-long bean cultivars had average vitamin A values ranging between 846.23 IU and 869.36 IU. The highest vitamin A was observed in the BARI Barboti-1 variety (869.36 IU) and the lowest in the BARI Barboti-2 variety (846.23 IU). The three remaining cultivars had moderate vitamin A content ranging between 854.03 IU to 864.76 IU (Figure 5b).

The average vitamin B1 (thiamine) content in the yard-long bean cultivars ranged between 0.096 and 0.115 mg in VS-21 and BARI Barboti-1, respectively. The VS-32 cultivar was also high in vitamin B1 (0.111 mg), while the remaining two cultivars had moderate amounts of vitamin B1: 0.109 mg (VS-49) and 0.110 mg (BARI Barboti-2) (Figure 5c).

All yard-long bean cultivars had average vitamin B2 (riboflavin) content lower than 0.120 mg. The highest content was in the BARI Barboti-1 variety (0.118 mg), with moderate amounts in the VS-21 (0.116 mg) and VS-32 (0.113 mg). The lowest vitamin B2 content was in the VS-49 (0.109 mg) (Figure 5d).

Average vitamin B3 (niacin) content ranged from 0.40 mg to 0.42 mg, with the highest vitamin B3 content in the BARI Barboti-1 variety (0.42 mg). A moderate vitamin B3 content was observed in the VS-49 (0.41 mg) cultivar while the BARI Barboti-2 and VS-32 (both 0.40 mg) had the lowest vitamin B3 content (Figure 5e).

Average vitamin B6 (pyridoxamine) content was above 0.020 mg in all five-yard-long bean cultivars. The highest vitamin B6 content was observed in the VS-21 (0.025 mg) cultivar, with more moderate levels in the BARI Barboti-1 and BARI Barboti-2 varieties (0.024 and 0.022 mg, respectively), and the lowest vitamin B6 in the VS-49 (0.020 mg) (Figure 5f).

Fresh yard-long beans are high in vitamin C, which is a potent water-soluble antioxidant that strengthens the body's defenses against infections, helps keep blood vessels supple, and may provide some protection against cancer when eaten in sufficient quantities. All five yard-long bean cultivars had an average vitamin C (ascorbic acid) content above 18.0 mg, with a range between 18.20 and 20.22 mg. The highest vitamin C content was observed in the VS-32 (20.22 mg). Moderate vitamin C content was measured in the BARI Barboti-1 (19.48 mg) and VS-49 (19.32 mg), and the lowest vitamin C amount was in the VS-21 (18.20 mg) (Figure 5g).

3.4. Sodium, Potassium, Iron, Calcium, Magnesium and Zinc Contents of Five Yard-Long Bean Cultivars

We observed an average sodium content of between 3.97–4.18 mg across the five cultivars. The highest sodium content was observed in the VS-21 (4.18 mg) cultivar, with more moderate content in the VS-32 (4.17 mg) and BARI Barboti-1 (4.06 mg) varieties. The BARI Barboti-2 (3.97 mg) had the lowest sodium content (Figure 6a).

All five yard-long bean cultivars had an average potassium content above 230 mg, with values observed between 230.03 and 246.57 mg. The highest potassium content was observed in the BARI Barboti-1 (246.57 mg) variety, with moderate content in the VS-32 (242.33 mg), VS-21 (238.17 mg) and BARI Barboti-2 (236.50 mg). The lowest potassium content was in the VS-49 (230.03 mg) (Figure 6b).

We observed average iron contents between 0.85 and 1.28 mg which is higher than the average range of iron content in yard-long beans of 0.50 to 1.0 mg. The cultivar with the highest iron content was VS-32 (1.28 mg), followed in order by the BARI Barboti-2 (1.17 mg), VS-49 (0.92 mg), VS-21 (0.86 mg) and BARI Barboti-1 (0.85 mg), cultivars (Figure 6c).

All five yard-long bean cultivars had an average calcium content in the range of 42.11 to 58.83 mg. The highest calcium content was observed in the VS-21 (58.83 mg) (Figure 4d). The BARI Barboti-2 (53.03 mg) and BARI Barboti-1 (50.18 mg) varieties had moderate calcium concentrations, while the lowest content was observed in the VS-49 (42.11 mg) (Figure 6d).

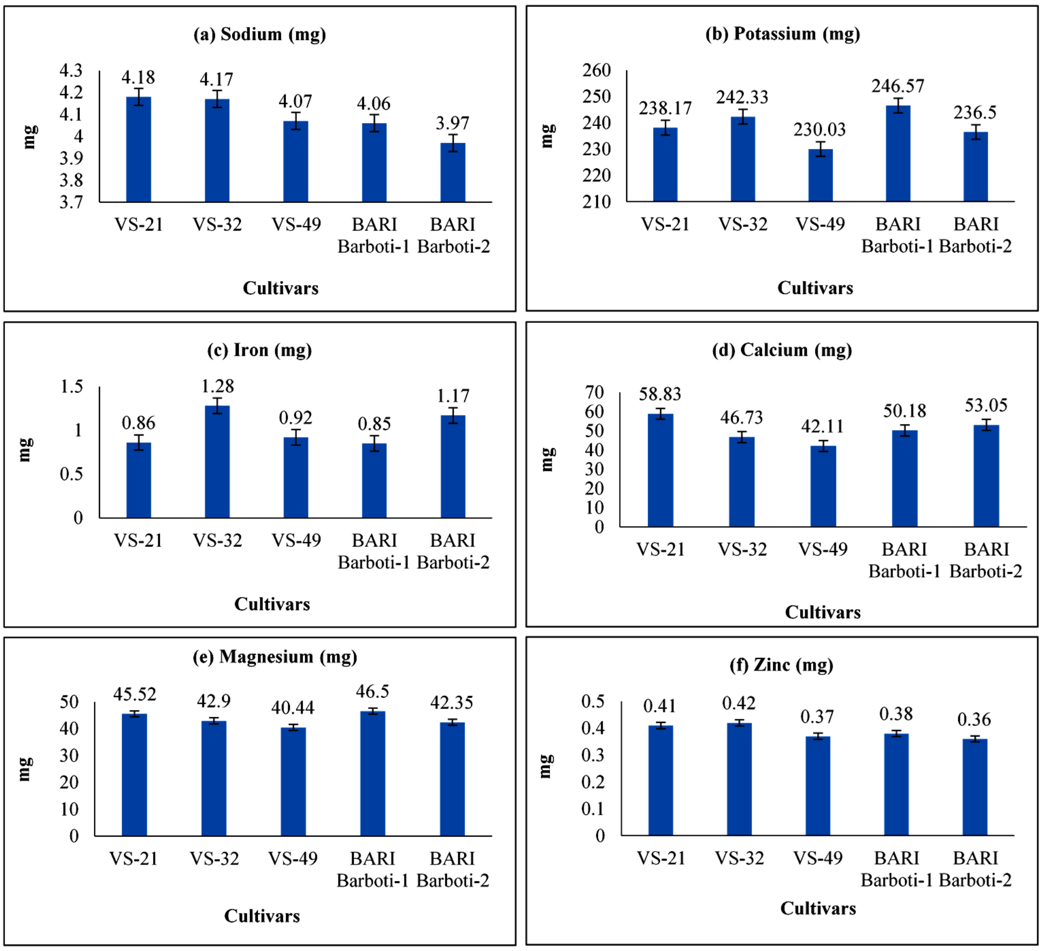

Figure 6. (**a**) sodium, (**b**) potassium, (**c**) iron, (**d**) calcium, (**e**) magnesium and (**f**) zinc content of five yard-long bean cultivars commonly grown in Bangladesh [The parameters were estimated from 100 g dry matter].

The average magnesium content in the five yard-long bean cultivars varied between 40.44 and 46.50 mg. Magnesium content was highest in the BARI Barboti-1 variety (46.5 mg) and lowest in VS-49 (40.44 mg). In all five yard-long bean cultivars, magnesium levels were above 40.0 mg, which is relatively high. Magnesium levels were moderate in the VS-21 (45.52 mg), VS-32 (42.90 mg), and BARI Barboti-2 (42.35 mg) varieties (Figure 6e).

Across all five yard-long bean cultivars, the average zinc content varied between 0.36 and 0.40 mg, with the highest content in the VS-32 (0.42 mg) variety, followed by the VS-21 (0.41 mg), BARI Barboti-1 (0.38 mg) and VS-49 (0.37 mg). The BARI Barboti-2 (0.36 mg) had the lowest zinc content (Figure 6f).

4. Discussion

The Yard-long bean is a good source of nutrients critical to human health including iron, calcium, magnesium and zinc: the bean contains similar levels of these nutrients to those found in tomatoes, carrots, potatoes, pumpkin, cauliflower, or eggplant. The content of some key nutrients in the five cultivars examined here was abundant, while others were observed at lower levels than had been reported in previous research [25–28]. These differences in nutrient content may be a result of the cultivars themselves, or of the influence of specific ecological or growing conditions. Environmental factors play a significant role in the quality and nutrient composition of beans and vary by region and harvest season [20]. The most significant environmental factors that affect bean quality during growth and maturation are rainfall and temperature [26–28].

The cultivar-specific nutrient compositions varied depending on the cultivar genetics and growing conditions (Figures 1–6). The observations we report here are similar to those previously documented which reported variations in bean pod protein, ash, energy, lipids, minerals and moisture content in response to different environmental conditions, growing seasons, light intensity, day length, temperature, nutrient management and irrigation practice [29–35].

The energy and carbohydrate contents of the fresh pods in the five yard-long beans varieties ranged between 37.62 to 45.94 Kcal/100 g and 6.28 to 8.41 g/100 g, respectively: these values are similar to those observed by [31], who reported that an energy range of 317 to 378 Kcal/100 g and a carbohydrate range of 41.9 g to 63.35 g/100 g in commonly consumed dried pulses and brown beans. The average carbohydrate content of a variety of beans is 38.41 g/100 g [36]. These differences in nutrient content may be a result of the cultivars themselves, or of the influence of specific ecological or growing conditions.

Folate is a naturally occurring water-soluble form of vitamin B9, widely found in beans and pulses [37]. We observed folate contents in the five yard-long bean cultivars of between 58.75 and 67.31 μg, with VS-49 and BARI Barboti-1 having the lowest and highest content, respectively. Similarly [36], observed similar variations of folate content in bean genotypes (*Phaseolus vulgaris* L.). Additionally, [36] reported average thiamine content (0.50 mg) and riboflavin content (0.16 mg) in bean genotypes (*Phaseolus vulgaris* L.), which are similar to those we report here across all five yard-long bean cultivars. [36] also reported an average niacin content of 3.82 mg 100 g^{-1} in bean genotypes, which is similar to that observed here, where we observed vitamin B3 (niacin) values between 0.40 mg to 0.42 mg in all yard-long bean cultivars (Figure 5e). We reported average vitamin B6 levels between 0.020 and 0.025 mg (Figure 5f), while [36] and [38] observed an average pyridoxine content of 0.33 mg in bean genotypes, and Nordin [39] reported an average pyridoxine range of 0.28 to 0.35 mg/100 g in brown beans. These differences in nutrient content may be a result of the cultivars themselves.

Average zinc content varied across the five yard-long bean cultivars between 0.36 and 0.40 mg and was a result of genotypic variation, which was also observed by [40–44], who reported that zinc content in the Yenice and Pınarli bean genotypes was 29.56 and 30.55 mg, respectively. They also observed the average content of magnesium, calcium and iron to be 1261.0 and 1275.0 mg, 1468.0 and 1482.0 mg, and 56.40 and 53.53 mg in Yenice and Pınarli bean genotypes, respectively, which is similar to the results reported here for magnesium, calcium and iron content in the five yard-long bean concentrations. These differences in nutrient content may be a result of the influence of specific ecological or growing conditions.

5. Conclusions

Yard-long beans are highly nutritious for humans and beneficial to health. They are considerable in protein, dietary fiber, and minerals and are widely grown in Bangladesh. We have demonstrated that five cultivars of yard-long beans commonly grown in Bangladesh are high in average values of critical nutrients. In particular, all cultivars were high in folate (58.75–67.31 μg), vitamin A (846.23–869.36 IU), vitamin B1 (0.096–0.115 mg), vitamin B2 (0.109–0.118 mg), vitamin B3 (0.40–0.42 mg), vitamin B6 (0.020–0.025 mg), and vitamin C (18.20–20.22 mg). Moreover, the five yard-long beans had considerable content of sodium (3.97 to 4.18 mg) and potassium (230.03 and 246.57 mg). There was some variability in the average content of key minerals between the five bean cultivars examined, for example, iron (0.85–1.28 mg), calcium (42.11–58.83 mg), magnesium (40.44–46.50 mg), and zinc (0.36–0.40 mg). We recommend that these five cultivars of yard-long bean may be produced and consumed to improve human health and nutrition outcomes in Bangladesh. Our research shows that a daily intake of yard-long beans will provide useful quantities of critical nutrients and thus we suggest the five yard-long bean cultivars examined here to be used as foods to promote health and wellness in Bangladesh.

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