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Nutritional Profiling of Sugarcane Juice: Mineral and Water-Soluble Vitamin Composition Across Selected Bangladeshi Varieties

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Abstract

The present study provides a detailed nutritional profiling of sugarcane juice from eight different varieties grown in Kushtia District, Bangladesh. Among minerals, sodium (Na), potassium (K), calcium (Ca), iron (Fe), and zinc (Zn) were measured by flame photometry and atomic absorption spectroscopy (AAS), while thiamine (vitamin B_1) and riboflavin (vitamin B_2) were estimated by high-performance liquid chromatography (HPLC). In the validation study, all calibration curves exhibited an excellent linear relationship ($R^2 \geq 0.99$). Significant variation among the varieties was detected, and ISD 24 and ISD 18 contained higher amounts of minerals and vitamins. These two varieties of Sugarcane juice are considered as potential dietary sources for electrolytes and water-soluble vitamins and may contribute positively to the development of functional beverage and to public health nutrition in Bangladesh.

Key words: Sugarcane juice, mineral content, thiamine, riboflavin, flame photometry, AAS, HPLC, nutritional analysis, Bangladesh agriculture.

Introduction

Sugarcane (*Saccharum officinarum L.)* is a perennial tropical grass and one of the most economically important industrial crops worldwide. In Bangladesh, it is a major source of sugar and jaggery; however, domestic production only meets a small part of the national demand. (Rahaman *et al*., 2016) Contributing factors include the decline in cultivation area, agronomic practices, low extraction efficiency and delayed payments from sugar mills, all of which have discouraged farmers.

Despite these challenges, sugarcane remains nutritionally valuable beyond its industrial use. Sugarcane juice is widely consumed as a natural beverage, particularly during the summer months. Beyond its sweetness, it provides essential minerals and vitamins that contribute to metabolic health. Thiamine (vitamin B_1) and riboflavin (vitamin B_2) are crucial for energy metabolism and nervous system function (Akter *et al*., 2025, Ali *et al.*, 2024), while minerals such as sodium (Na), potassium (K), calcium (Ca), iron (Fe) and zinc (Zn) play critical roles in maintaining electrolyte balance, bone integrity, enzymatic activity, and immune support (Islam *et all*.,2021).

The nutrient composition of sugarcane juice varies across cultivars, influenced by factors such as soil composition, irrigation practices, maturity at harvest and environmental conditions. Characterizing varietal differences is therefore essential for identifying nutrient-rich cultivars and optimizing their use as functional food sources. The study aims to assess the nutritional composition of sugarcane juice from eight prominent varieties cultivated in Kushtia, Bangladesh, through validated analytical techniques such as flame photometry for Na, K, Ca,

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and AAS for Fe and Zn, and HPLC for thiamine and riboflavin. The outcomes provide insights into varietal differences and support strategies for nutritional enhancement and sustainable sugarcane utilization.

Materials and Methods

Sample collection: Eight sugarcane varieties (White Gendari, Red Gendari, ISD 24, ISD 20, ISD 29, ISD 33, ISD 18 and Red Sugarcane) were collected from the Daulatpur region of Kushtia, Bangladesh, a major sugarcane-producing area (Figure 1). After ten to twelve months of planting during the growth season (2024-2025), mature canes were harvested at full physiological maturity. Three samples of each variety were randomly collected from different fields to minimize environmental bias. The samples were cleaned with deionized water and peeled to remove the outer rind. After that, samples were immediately transported to the laboratory for analysis.

Sample preparation: Juice was extracted using a mechanical crusher, filtered through Whatman No. 1 filter paper, and analyzed within 24 hours of extraction to prevent degradation of vitamins and enzymatic oxidation. Subsamples were diluted (1:10, v/v) with deionized water before mineral analysis and stored at 4°C in amber bottles to avoid photo degradation of light-sensitive vitamins. All glassware was acid-washed and rinsed thoroughly to prevent trace metal contamination.

Determination of sodium (Na), potassium (K) and calcium (Ca): Sodium (Na), potassium (K) and calcium (Ca) concentrations were determined using a digital flame photometer (Model: Systronics 128). Calibration curves were constructed using analytical-grade standards (Merck, Germany) prepared from 1000 ppm stock solutions (Sultana *et al.*, 2019). Emission intensities were recorded at characteristic wavelengths of 589 nm (Na), 766 nm (K), and 422.7 nm (Ca). Sample concentrations were obtained by interpolation from calibration curves, ensuring linearity within the analytical range where $R^2 \geq 0.99$ (Table 1). Triplicate analyses were conducted for each sample, and results were expressed as mean ± standard deviation (ppm).

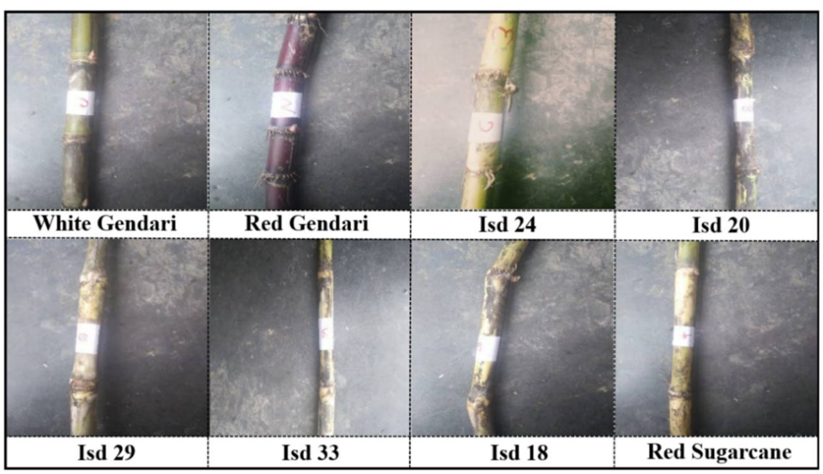

Figure 1. Sugarcane varieties including white gendari, red gendari, ISD 24, ISD 20, ISD 29, ISD 33, ISD 18 and red sugarcane.

Determination of iron and zinc: Iron (Fe) and zinc (Zn) were quantified using Atomic Absorption Spectroscopy (AAS, Shimadzu AA-7000) (Sultana *et al.*, 2019). Samples (10 mL) were digested with 5 ml concentrated HNO_3 and 2 mL H_2O_2 on a hot plate until clear. The digests were cooled, filtered, and diluted to 25 ml with deionized water. Hollow cathode lamps were used for Fe (248.3 nm) and Zn

(213.9 nm) detection. Calibration was performed using 0.5–5.0 ppm standard solutions, and blank corrections were applied. Detection limits were 0.01 ppm for Zn and 0.05 ppm for Fe (Table 2).

*Vitamin analysis (Thiamine & Riboflavin)****:*** Thiamine (vitamin B_1) and riboflavin (vitamin B_2) were determined by High-Performance Liquid Chromatography (HPLC) (Shimadzu LC-20AT) (Islam *et al.*, 2025) equipped with a fluorescence detector. Approximately 5 ml of juice was mixed with 0.1 M HCl and incubated at 100°C for 30 min to hydrolyze bound forms of vitamins. The extract was cooled, treated with Takadiastase enzyme (0.1%, w/v) at 37°C for 1 h to ensure enzymatic release of coenzyme forms, and filtered through a 0.45 µm syringe filter before injection. Chromatographic separation was achieved using a C18 reversed-phase column (250 × 4.6 mm, 5 µm particle size) with a mobile phase of methanol: water (35:65 v/v, acidified with 0.01 M H_2SO_4), at a flow rate of 1 ml/min (Mia *et al*.,2024) Detection was performed at excitation/emission wavelengths of 365/435 nm for thiamine and 450/530 nm for riboflavin. Standard calibration curves were established using certified reference standards (Sigma-Aldrich), yielding R^2 values > 0.995 (Table 3). All analytical methods are validated for precision, linearity, accuracy, and limits of detection according to the IUPAC guidelines. Instrument calibration was verified with mid-level reference standards after every 10 samples. Blanks and reagent controls were analyzed to ensure that no contamination was occurring. Each result is the mean of three independent determinations. Linearity for all analytes showed an $R^2 \geq 0.99$. Precision (%RSD) for replicate runs was < 5% (Akter *et al.*, 2025).

Table 1. Calibration parameters for Na, K and Ca (flame photometry).

Element	Calibration equation	Regression coefficient (R^2)
Sodium (Na)	y = 0.3129x + 0.2619	0.9976
Potassium (K)	y = 0.5971x + 2.2381	0.9937
Calcium (Ca)	y = 0.2314x + 0.7143	0.9966

Table 2. Calibration parameters for Fe and Zn (AAS).

Element	Calibration equation	Regression coefficient (R^2)
Iron (Fe)	y = 0.0545x - 0.0144	0.9983
Zinc (Zn)	y = 0.3912x - 0.0008	1.0

Table 3. HPLC method validation parameters for thiamine and riboflavin.

Vitamin	Calibration equation	Regression coefficient (R^2)	LOD (ppm)	LOQ (ppm)
Thiamine (B_1)	y = 12399x - 2E+06	0.9967	0.018	0.056
Riboflavin (B_2)	y = 2629.3x - 19405	0.9953	0.003	0.009

Statistical analysis: Data were statistically analyzed using one-way analysis of variance (ANOVA) in SPSS (v.25). Differences among mean values were considered significant at $p < 0.05$, and the Least Significant Difference (LSD) test was applied for pairwise comparisons. Correlation analysis was also performed to explore relationships among minerals and vitamins.

Results and Discussion

*Analytical validation****:*** All calibration curves for the target analytes showed excellent linearity ($R^2 \geq 0.99$). Precision (%RSD) for replicate measurements was less than 5 %. Spike-recovery tests for each analyte showed recoveries within a range of 96-104%, confirming analytical accuracy. Calibration curves for the quantification of Na, K, Ca, Fe, Zn, thiamine, and riboflavin showed strong linearity, reflected by their regression coefficients (R^2), which were greater than 0.99, reflecting a high reliability of the analytical methods. The precision (%RSD) for all analytes was less than 5%, and the recovery values confirmed the acceptability of accuracy. High linearity ($R^2 > 0.99$) was observed in the calibration equations for all elements and vitamins, confirming method reliability (Tables 1, 2, and 3)

Macro-mineral composition (Na, K, Ca): There is significant variation in Na, K, and Ca content among the tested eight varieties of sugarcane (Figure 2). Significant varietal variations ($p < 0.05$) were observed. Potassium content was highest in ISD 24 (733.5 ppm), followed by White Gendari (649.5 ppm), confirming that sugarcane juice is a potassium-rich beverage, with health benefits related to maintaining electrolyte balance and muscle function. Calcium levels were remarkably high in ISD 24 (1275.7 ppm) and ISD 18 (1275.0 ppm), underlining their potential contribution to bone and dental health. Sodium levels were moderate, with ISD 33 exhibiting the highest concentration of 680 ppm (Figure 2) High Content of Ca and K supports the previous reports that sugarcane is an efficient accumulator of divalent cations due to its highly developed root system and high rate of transpiration (Smith *et al.*,2005*)*. Varietal differences could be attributed to genetic variability and differential efficiency of nutrient uptake.

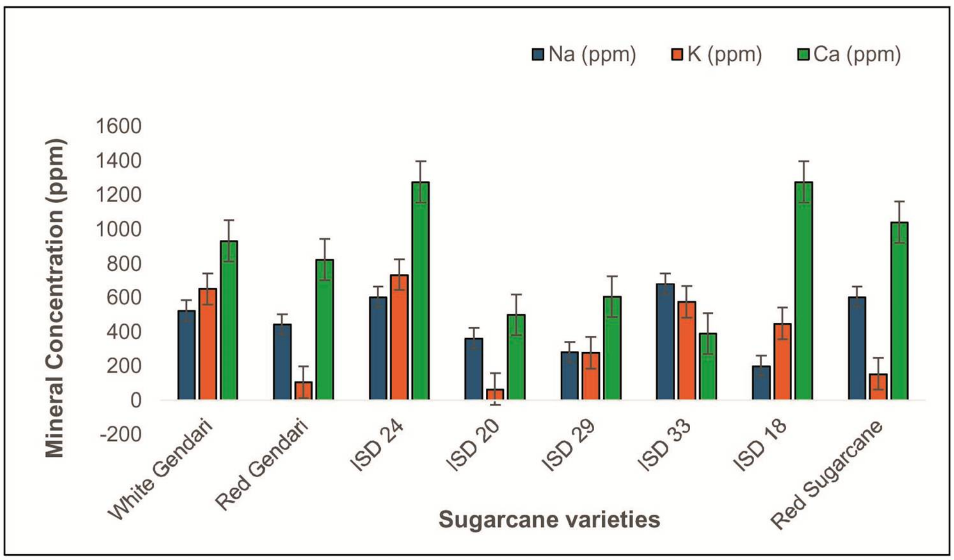

Figure 2. Comparison of Na, K, and Ca content among sugarcane varieties (ppm).

Micro-mineral composition (Fe, Zn): Concentration of iron and zinc also differed between varieties (Figure 3). White Gendari showed the highest Fe rate (7.49 ppm), while Red Sugarcane and Red Gendari had higher Zn concentrations, with 2.46 and 2.23 ppm, respectively. Iron and zinc are essential cofactors in metabolism and immune responses. Thus, these varieties can be said to offer better nutrition. Although the zinc content was relatively low in all samples, Red Sugarcane and Red Gendari demonstrated higher values with 2.46 ppm and 2.23 ppm, respectively. Variation in Zn concentration might depend on the availability of Zn in the soil as well as the cultivar-specific uptake mechanism (Figure 3) The Zn:Fe ratio affects bioavailability; therefore, moderate co-presentation in these varieties may provide a balanced intake of micronutrients (Smith *et all.*, 2005*)*

Water-soluble vitamin content (Thiamine, B_1 and Riboflavin, B_2): Vitamin analysis (Figure 4) revealed substantial differences across cultivars. ISD 18 exhibited the highest concentrations of thiamine (2.65 ppm) and riboflavin (0.258 ppm), followed closely by ISD 24 and ISD 33. These water-soluble vitamins are critical for carbohydrate metabolism and oxidative energy production. The observed variations are likely due to varietal genetics and enzymatic activity influencing vitamin biosynthesis and stability during juice extraction. The vitamin B_1 content observed in this study surpasses several reported tropical cane varieties, reinforcing the nutritional potential of Bangladeshi cultivars. The co-occurrence of vitamins and essential minerals also enhances the functional beverage potential of sugarcane juice.

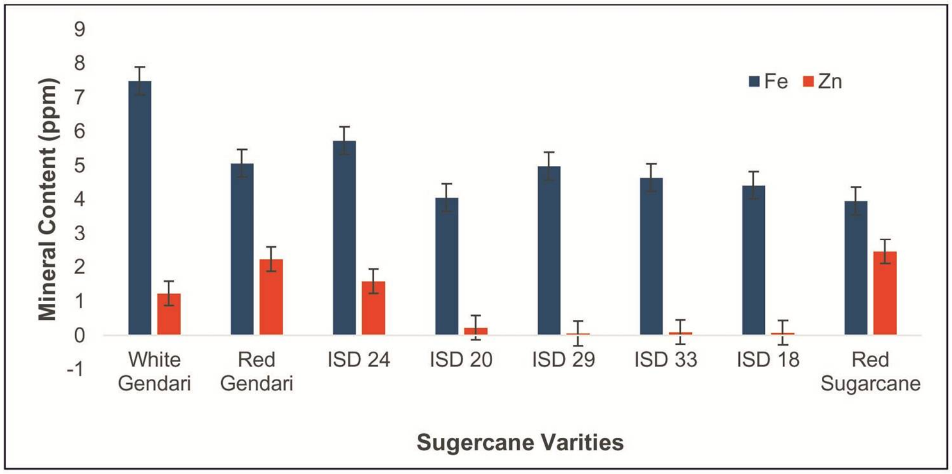

Figure 3. Comparison of Fe and Zn content among sugarcane varieties (ppm).

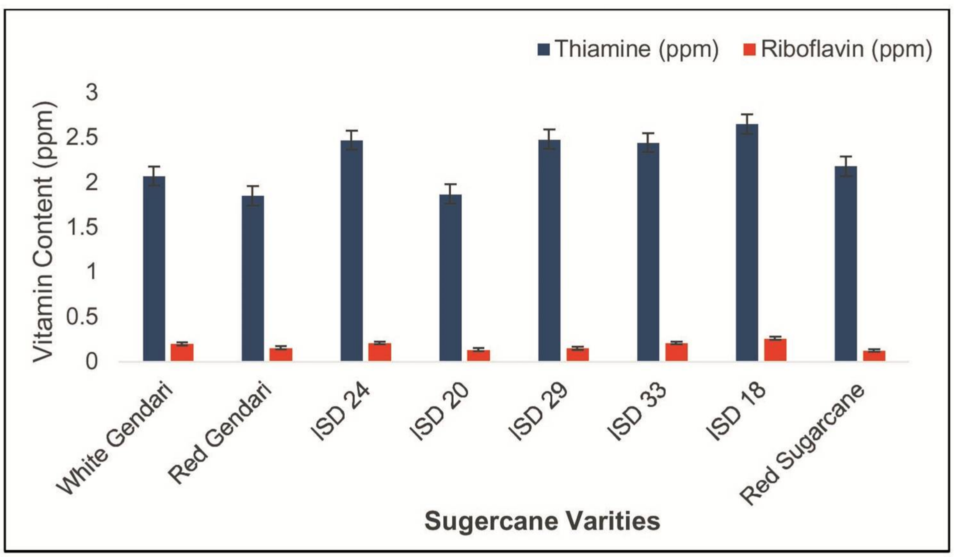

Figure 4. Comparison of thiamine and riboflavin (ppm) among sugarcane varieties.

Correlations and nutritional implications: Pearson correlation showed a strong positive relationship between Ca and thiamine ($r = 0.82$, $p < 0.01$) and between K and riboflavin ($r = 0.76$, $p < 0.05$) (Shah *et al*., 2023). These correlations suggest possible common accumulation or translocation mechanisms within the plant and could therefore be used to advantage in breeding programs targeting multi-nutrient enhancement. From the nutritional and public health point of view, the varieties ISD 24 and ISD 18 have the added advantage of being simultaneously rich in critical macro-minerals, K and Ca, as well as water-soluble vitamins, B_1 and B_2. In rural Bangladeshi communities, where access to a sufficiently large number of micronutrient-rich foods is limited, sugarcane juice prepared from such cultivars would provide a source of essential nutrients apart from simple sugars.

The nutrient profile suggests that specific varieties, particularly ISD 18 and ISD 24, are richer in minerals and vitamins and, therefore, may be suitable for the production of functional beverages and biofortified sugarcane improvement programs. High K and Ca contents place sugarcane juice as a natural source of electrolytes, while its Fe and Vitamin B content may help address mild micronutrient deficiencies among the local populations (khan *et al*., 2022., Akter *et al*.,2024). This nutrient rich sugarcane juice can be used as a functional beverage. Functional beverage development is the process of developing drinks that are not only used for hydrating the body or for meeting nutritional needs but also for their additional health benefits using bioactive compounds. Functional beverages are engineered for enhanced physiological functioning, maintenance of good health, and prevention of diseases by adding compounds such as vitamins, minerals, antioxidants, electrolytes, or probiotics. These high-nutrient sugarcane varieties should be included in agronomic breeding programs, where their genes can be incorporated into other varieties to develop nutritionally improved varieties of sugarcane.

Conclusion

The nutrient profile suggests that specific varieties, particularly ISD 18 and ISD 24, are richer in minerals and vitamins and therefore, may be suitable for the production of functional beverages and biofortified sugarcane improvement programs. High K and Ca contents place sugarcane juice as a natural source of electrolytes, while its Fe and Vitamin B content may help address mild micronutrient deficiencies among the local populations. This is the first such study in Bangladesh, focusing on mineral and vitamin profiling of sugarcane juice from various cultivars, using validated spectrophotometry, AAS and HPLC methods. Identifying nutrient-dense sugarcane varieties provides a practical strategy for functional beverage development and supports agronomic–breeding programs for nutritional biofortification

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