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Bioactive components and beneficial nutritive properties of sweet sorghum juice from Indian cultivars

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Abstract

Sweet sorghum juice is beneficial in terms of nutritive properties like bioactive components, including various phytochemicals, with some acting as potential antioxidants, inorganic and organic components like minerals, sugars, and proteins. The current study examines seven Indian cultivars of sweet sorghum for their bioactive components, which are essential nutritive supplements imparting health benefits, to commercialize sweet sorghum juice as an energy drink. The juice was sweet due to the presence of carbohydrates, in the range of 1.4-5.8 g/100 ml reducing monosaccharides, 6.3-11.3 g/100 ml sucrose and 20.6-65.3 mg/100 ml starch. The bioactive components in sweet sorghum juice among the seven varieties were phenols (39.8-68 mg/100 ml gallic acid equivalents), flavonoids (29.3-65.4 mg/100 ml quercetin equivalents), tannins (0.135-0.423 g/100 ml catechin equivalents) and antioxidants (11.2-17.2 mg ascorbic acid equivalent antioxidant capacity/100 ml). The protein constitution of juice was in the range of 37.1 -53.1 mg/100 ml. CSV 19 SS showed higher phytochemical and carbohydrate content among the seven varieties. Sweet sorghum juice was found to be rich in potassium, sodium, phosphorous and iron with moderate zinc and manganese. Sweet sorghum juice has four times more bioactive components than sugarcane juice, showing its competent antioxidative power. This study suggests the potential of sweet sorghum juice as a natural energy drink with additional benefits of phytochemicals and minerals to use in treatment of various ailments.

1. Introduction

Juice production is an increasing market nowadays as consumers are becoming health-oriented and are more inclined to have healthier and more nutritive foods. The ever-increasing demand for fruit and vegetable juices is observing a compound annual growth rate (CAGR) of approximately 1-10% and is estimated to reach approximately 26.2 billion dollars by 2027. The juice market is mainly driven by urbanized lifestyle, health consciousness and easy availability of products. Consumers prefer fruit or vegetable-based beverages over carbonated drinks, which have low levels of externally added sugars, artificial flavors, preservatives and caffeine. The crucial challenges faced by the juice market such as the cost of production, post-harvest techniques, processing, stability of juices, consistent supply of raw materials and seasonal changes, limit their availability (Gaurav and Brijesh, 2018). Therefore, there is an unequivocal demand to meet these challenges with an alternative without compromising the quality of nutritive value. In this scenario, sweet sorghum juice can be the best alternative as an energy drink and for several food-based applications.

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Sweet sorghum (Sorghum bicolor (L.) Moench) is a versatile crop with varieties like grain sorghum, sweet sorghum and biomass sorghum, depending on their extensive usage. Grain sorghum, available in various colors such as red, yellow, tan, black and white is used as flour in the food industry. Sweet sorghum and biomass sorghum are grown for non-grain biomass through stalks, used for syrup and biofuel production (Vinutha *et al.*, 2014).

Sweet sorghum is a better alternative to sugarcane, given its agronomic properties as it can be cultivated in all seasons with less water requirement ($1/5^{th}$ of sugarcane), low fertilizer (1/2 of sugarcane), short duration ($1/3^{rd}$ of sugarcane) requirements and can withstand biotic and abiotic stresses (Vinutha *et al.*, 2014). The biochemical constituents and phytochemicals like polyphenols, flavonoids and polycosanols are known to have analgesic, antihepatotoxic, antihyperglycemic, diuretic, anti-inflammatory, antihypercholesterolemic, antithrombotic and antiradical activities (Singh *et al.*, 2015; Shreeja *et al.*, 2021).

A recent analysis of commercial-grade sweet sorghum syrups have shown a predominance of phenolic acids like synapic acid, protocatechuic acid, vanillic acid, ellagic acid, catechin and apigenin (Eggleston *et al.*, 2021). Studies on the use of syrup prepared by clarification and concentration of juice in replacement to Indian traditional sweeteners like sugar in cakes, sesame chikki, glazed tamarind candy (Kulkarni *et al.*, 2018b) and natural sweetener in drinks, jellies, pharmaceutical formulations showed favorable results with increased shelf life and nutritional qualities. Thus, sweet sorghum can supplement as an alternative source to sugarcane in many ways.

The composition of sugars, minerals, antioxidants and other phytochemicals are dependent on the cultivar type (Yuvraj *et al.*, 2013). So, it is essential to screen the cultivars for basic juice components and extensively evaluate all the phytochemicals before their commercial exploitation, including juice processing, formulations and stability to produce healthy drinks.

Evaluating the composition of sweet sorghum juice from seven different cultivars concerning the presence of phytochemicals, sugars, proteins, macro and microelements compared to sugarcane juice forms the context of this paper. The study aims to establish sweet sorghum juice for direct consumption and other food-based formulations at par with sugarcane juice.

2. Materials and Methods

2.1 Collection of plant material

Juice samples of seven Sweet Sorghum cultivars; CSV 19 SS (Coordinated Sorghum Variety 19 Sweet Sorghum), CSV 24 SS, Phule Vasundhara, RVICSH 28 (Rajamate Vijayaraje Scindia ICRISAT Sweet Sorghum Hybrid 28), SPV 1871 (Sorghum Project Variety 1871), SSV 74 (Sweet Sorghum Variety) and SSV 84 were obtained from the Indian Council of Agricultural Research-Indian Institute of Millets Research, Hyderabad (ICAR-IIMR), the nodal agency for the sorghum research in India. These included released cultivars for commercial cultivation in India and also pre-release cultivars. The crop was raised at the ICAR-IIMR farm, Hyderabad, Telangana, India (latitude 17_190N, longitude78_230E). The cultivars were harvested at physiological maturity in May 2019, and juice (Figure 1) was extracted using a mechanized three-roller crusher after removing the leaves and stored at –20°C until further use. The stored juice was filtered and analyzed for minerals, sugars, antioxidants, polyphenols, flavonoids, proteins and starch content. The commercially available sugarcane from the local market was used to extract sugarcane juice for comparison.

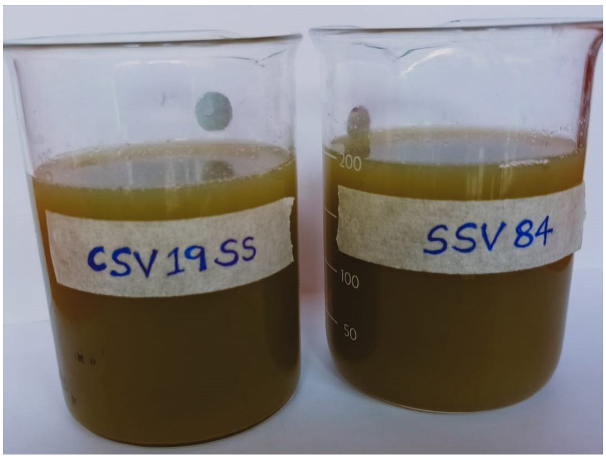

Figure 1: Sweet sorghum juice.

Chemicals like DPPH (2,2-diphenyl-1-picrylhydrazyl), ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid)), TPTZ (2,4,6-Tri(2-pyridyl)-s-triazine), Folin-Ciocalteu reagent used were from Sigma Aldrich. Ascorbic acid, quercetin, catechin, gallic acid, glucose, sucrose, fructose and starch of analytical grade were used as standards. Acetonitrile, methanol and ethanol solvents were of HPLC grade.

2.2 Phytochemical and protein content

The total phenolics content of juice samples was estimated using Folin-Ciocalteu (FC) reagent (Singleton *et al.*, 1999), total flavonoid content by $AlCl_3$ and tannins with Vanillin-HCl method (Burns 1971). Protein content was estimated by the Bradford method. The results were expressed as mg standard equivalents per ml of juice.

2.3 Antioxidant activity

The radical quenching property of sorghum extracts was determined by DPPH, ABTS and FRAP (ferric reducing antioxidant power). A modified version of Sanchez *et al.* (1999) was used to estimate the antiradical property of sorghum juice samples by DPPH reagent. ABTS radical cation decolorization assay was performed with a slightly modified Re *et al.* (1999) version. Results were expressed as mg AEAC/ml (ascorbic acid equivalent antioxidant capacity). The protocol for FRAP as specified by Benzie and Strain (1996) was followed. Results were expressed as mg Fe^{+2} equivalents/ml of sample.

2.4 Sugars and starch

The quantification of sugars was done by HPLC (Waters, Austria) with a RID-10A refractive index detector (Waters, Ireland) using carbohydrate high performance 4 µm column (Waters) and a mobile phase of 70% aqueous acetonitrile in an isocratic elution at room temperature with a 1.0 ml/min flow rate. The sample injection volume was 20 µl. Before injection, the juice samples were diluted and filtered using 0.22 µm PVDF syringe filters. Starch was estimated by iodine reagent (Vahasalo and Holmbom, 2004). The results were expressed as mg starch per ml of juice.

2.5 Mineral analysis

The mineral content of the collected sweet sorghum juice samples was estimated for major elements, *i.e.*, Na, K, P, Mg and Ca; trace elements, *i.e.*, Ag, Al, B, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn. Na^+ and K^+ were estimated by flame photometry, P in the form of phosphates was quantified spectrophotometrically using the $SnCl_2$ method. A complexometric titration method with EDTA was used to measure Ca^{+2} and Mg^{+2}. Trace elements were evaluated by an Inductively Coupled Plasma-Optical Emission Spectrometer (Shimadzu, ICPS-7510) (Saranga *et al.*, 2020; Jayachithra *et al.*, 2019).

2.6 Statistical analysis

All the experiments were carried out in six replicates (n=6) and the results were expressed as mean ± standard deviation. The results were further analyzed for significant difference between means using one-way analysis of variance and Tukey's method for post hoc analysis ($p \leq 0.05$) (Microsoft Excel version 2019).

3. Results

3.1 Total phenolics content

Consumption of dietary polyphenols is implicated in preventing lifestyle diseases such as cancer, cardio and cerebrovascular diseases, ageing and viral diseases (Rashmi and Dumka, 2019; Yuva *et al.*, 2020; Sevgi *et al.*, 2020). The total amount of phenols present in seven different cultivars of sorghum juice is depicted (Table1). SSV 84 variety has phenolics content of 0.680 ± 0.043 mg (gallic acid equivalents) GAE/ml, followed by CSV 19 SS, RVICSH 28, SSV 74, Phule Vasundhara, CSV 24 SS and SPV 1871. Studies on the total phenolic content of CSV 22 SS and RSSV 9 have shown 0.178 mg GAE/ml and 0.14 mg GAE/ml, respectively (Yuvraj *et al.*, 2013). The TPC content of sugarcane juice was found to be 0.143 ± 0.052 mg GAE/ml, consistent with that of 0.16 mg GAE/ml (Mauricio *et al.*, 2006), which accounts for 1/4th of sweet sorghum juice, implying sweet sorghum juice can be a better source of antioxidative phenols than sugarcane juice. Consumption of 250 ml (one glass) of sorghum juice would provide 140 to 170 mg of phenolics, accounting for 15 to 20% of the daily intake, which explains the potential antioxidative power (Figure 2) of sweet sorghum juice.

3.2 Total flavonoid content

Flavonoids such as apigenin and luteolin were detected in sugarcane juice and grain sorghum (Maurício *et al.*, 2006; Shen *et al.*, 2013). Flavonoids account for two-thirds of the dietary polyphenols taken per day (Grosso *et al.*, 2014). Studies show varied results in flavonoid intake ranging from 170 - 890 mg per day, again dependent on the population and their regular diet (Scalbert and Williamson, 2000). On an average, 0.424 ± 0.114 mg QE/ml (quercetin equivalents) of flavonoids are present in sorghum juice which can increase depending on sweet sorghum variety. Of the seven cultivars CSV 19 SS, RVICSH 28 and SSV 84 showed comparatively higher content of flavonoids. Similar to phenolics content, sorghum juice had higher amounts of flavonoids than sugarcane juice (Table 1).

3.3 Tannins

Tannins are a group of polyphenols with high molecular weight (1,000-20,000 Da), formed from polymerized flavanols and flavandiols that are said to be antinutrients in that they react with enzymes, protein and starch forming complexes and reducing their bioavailability (Soares *et al.*, 2020). On the other hand, tannins also act as anticarcinogens, antimutagens, antimicrobial and antiviral agents (Chung *et al.*, 1998). Tannins were extensively studied in grain sorghum, classified as tannin-free and tannin-rich varieties (Awika *et al.*, 2004). The tannin content in sweet sorghum varieties was found to be in the range of 1-4 mg CE/ml (catechin equivalents) (Table 1) compared to that of sugarcane 0.0721 ± 0.003 mg CE/ml. The difference in the range may depend on the cultivar type, similar to that of high tannin grain sorghum cultivars (Awika *et al.*, 2004). Although, sorghum tannins have been implicated in cholesterol, blood-thinning effects, obesity lowering and cancer (Awika *et al.*, 2004), further studies are required for deriving appropriate conclusions. Among the studied variants, CSV 19 SS and CSV 24 SS had tannin content above 4 mg CE/ml, while half was found in SSV 74 and SSV 84 varieties.

3.4 Antioxidant activity

Studies on sorghum seed extracts containing 3-deoxyanthocyanins, polyphenols and polycosanols showing antiproliferative effect on breast cancer cell line, antiradical activity, antidiabetic, antimicrobial activity and cholesterol-lowering ability suggest their importance in regular diet (Awika *et al.*, 2004). The antiradical activity of the juice of seven cultivars of sweet sorghum was estimated using DPPH, ABTS and FRAP assay based on electron transferability (Moharram and Youssef, 2014). The results showed consistency among the DPPH and ABTS tests (Figure 2). Among the seven varieties, the antioxidant activity ranged from 0.122 ± 0.017 to 0.16 ± 0.014 mg (ascorbic acid equivalent antioxidant capacity) AEAC/ml for DPPH and 0.112 ± 0.01 to 0.165 ± 0.007 mg AEAC/ml for ABTS, which are twice compared to sugarcane juice. Radical quenching activity was high among the studied variants in CSV 24 SS and RVICSH 28 (0.16 mg AEAC/ml) for DPPH and ABTS assays, respectively. 50% inhibition was obtained at a range of 6-9 µl for ABTS and 22-40 µl for DPPH for sorghum juice, whereas in sugarcane, it was at 55 µl.

Table 1: Polyphenolic and protein content of different varieties of Sweet Sorghum juice

Samples	Phenols (mg GAE/ml)	Flavanoids (mg QE/ml)	Tannins (mg/ml CE)	FRAP (mg/ml Fe^{+2} eq)	Protein (mg/ml)
CSV 19 SS	0.641 ± 0.15^{a}	**0.654 ± 0.058^{a}**	4.099 ± 1.45^{a}	0.159 ± 0.004^{a}	0.489 ± 0.094^{a}
CSV 24 SS	0.437 ± 0.024^{b}	0.347 ± 0.016^{b}	**4.234 ± 1.79^{a}**	**0.166 ± 0.004^{a}**	0.486 ± 0.159^{ab}
Phule Vasundhara	0.463 ± 0.017^{b}	0.434 ± 0.054^{bd}	1.351 ± 1.20^{b}	0.144 ± 0.01^{a}	0.371 ± 0.172^{ab}
RVICSH 28	0.615 ± 0.069^{ad}	0.530 ± 0.097^{bd}	1.756 ± 1.23^{abc}	0.148 ± 0.009^{a}	0.531 ± 0.074^{ab}
SPV 1871	0.398 ± 0.037^{b}	0.293 ± 0.012^{be}	1.801 ± 2.09^{ab}	0.157 ± 0.008^{a}	0.509 ± 0.144^{ab}
SSV 74	0.493 ± 0.11^{bd}	0.388 ± 0.01^{bdef}	2.072 ± 1.36^{ab}	0.164 ± 0.01^{a}	0.509 ± 0.103^{ab}
SSV 84	**0.680 ± 0.043^{ad}**	0.55 ± 0.032^{bef}	2.387 ± 0.92^{ab}	0.152 ± 0.01^{a}	0.448 ± 0.055^{ab}
Sugarcane juice	0.143 ± 0.052^{c}	0.105 ± 0.024^{c}	0.0721 ± 0.003^{bc}	0.095 ± 0.01^{b}	0.425 ± 0.098^{b}

* Results expressed as Mean ± standard deviation.
**Means followed by different superscript letter(s) in a column differ significantly at $p \leq 0.05$.

As per the ferric reducing ability of sorghum juice varieties as given (Table 1), all the varieties showed a consistent result with 0.144 ± 0.01 to 0.166 ± 0.004 mg Fe^{+2} equivalents/ml of juice. Compared to ABTS and DPPH, FRAP showed slightly increased values even within the varieties as reducing power in FRAP is related to polyphenols by the degree of hydroxylation and extent of conjugation (Prior *et al.*, 2005). The ferric reducing ability of sorghum juice was 50% greater than sugarcane juice (Table1).

3.5 Protein content

Sorghum is the primary source of beta and gamma kafirins and is gluten-free. On average, the daily recommended intake of protein in individuals of all age groups ranges from 50 to 75 g/kg per day, increasing or decreasing depending on health. A glass of sorghum juice can provide up to 0.24% of this protein requirement. RVICSH 28 has a protein content of 0.531 ± 0.074 mg/ml, but it varies widely among all the studied sweet sorghum cultivars. The protein content in sugarcane juice and sweet sorghum juice was equal in the range of 0.4 to 0.5 mg/ml.

3.6 Sugars and starch

The monosaccharide content (Table 2) of sorghum juice was lower than that of sugarcane juice except for CSV 19 SS, which showed 58.18 ± 1.2 mg/ml. Similarly, sucrose content with exception of SSV 74 (111.75 ± 0.53 mg/ml) and CSV 19 SS (113.57 ± 0.32 mg/ml) were in the range of 63.23 ± 0.62 mg/ml to 98.86 ± 0.56 mg/ml. However, the sucrose content of sugarcane juice (194.5 ± 0.68 mg/ml) was found to be 42% higher compared to sweet sorghum juice. Starch is an important constituent of sorghum, both in seeds and juice. The amount of starch in sweet sorghum cultivars ranged from 0.191 ± 0.074 mg/ml in CSV 24 SS to 0.653 ± 0.022 mg/ml in CSV 19 SS; compared to 0.423 ± 0.015 mg/ml in sugarcane juice (Table 2).

A healthy individual requires more than 2000 kcal of energy per day, of which carbohydrates meet 60%, *i.e.*, 275-300 g, is recommended. With 100-170 mg/ml of glucose and sucrose content, a glass of sorghum juice can meet more than 1/6[th] of this requirement instantly, excluding the additional starch content.

Table 2: Carbohydrate content of Sweet Sorghum and Sugarcane juices

Samples	Starch (mg/ml)	Glucose and fructose (mg/ml)	Sucrose (mg/ml)
CSV 19 SS	**0.653 ± 0.022^{a}**	**58.18 ± 1.2^{a}**	**113.57 ± 0.32^{a}**
CSV 24 SS	0.191 ± 0.074^{b}	33.1 ± 0.55^{bc}	63.23 ± 0.62^{b}
Phule Vasundhara	0.389 ± 0.059^{c}	14.76 ± 0.27^{d}	78 ± 0.29^{bd}
RVICSH 28	0.552 ± 0.093^{d}	25.54 ± 0.94^{bd}	94.4 ± 0.34^{ad}
SPV 1871	0.206 ± 0.024^{be}	20.38 ± 0.81^{bd}	78.2 ± 0.65^{bd}
SSV 74	0.359 ± 0.047^{cf}	25.81 ± 0.59^{bd}	**111.75 ± 0.53^{a}**
SSV 84	0.319 ± 0.016^{cf}	25.58 ± 0.54^{bd}	98.86 ± 0.56^{ad}
Sugarcane juice	0.423 ± 0.015^{cf}	42.36 ± 0.29^{c}	**194.5 ± 0.68^{c}**

* Results expressed as Mean ± standard deviation.

**Means followed by different superscript letter(s) in a column differ significantly at $p \leq 0.05$.

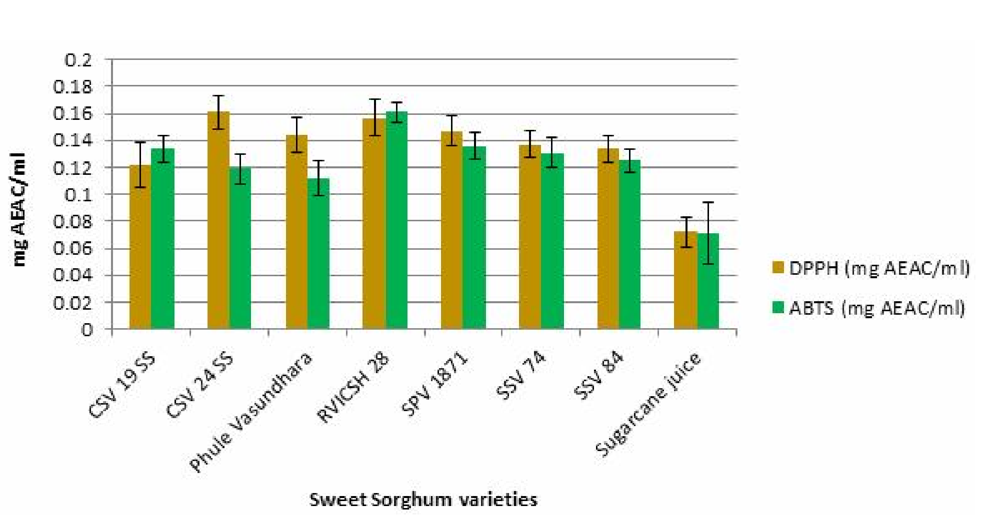

Figure 2: Antioxidant activity of Sweet Sorghum juice variants and Sugarcane juice.

3.7 Mineral content

Major elements, *viz.*, Na, K, Mg, Ca and P content of sorghum juice were estimated in the present study. Sweet sorghum juice is a rich source of Na, K and P (Table 3). Essential trace elements like Fe, Mn, Zn are present in considerable amounts in sorghum juice, whereas negligible Pb, Cu, B, Ag, Cd, Co (Table 3). The results show the absence of Cr, Ni and Al. The sugarcane juice has less mineral content than juice from sweet sorghum cultivars (Table 3), consistent with a similar study on syrups from sugarcane and sweet sorghum (Asikin *et al.*, 2018).

Zinc is an essential element in many catabolic and anabolic pathways involving various enzymatic reactions and also acts as a stabilizer of the membrane and molecular structure in cells. Consumption of sweet sorghum juice can provide a moderate amount of Zn compared to the recommended dietary allowance, *i.e.*, RDA (8 to 11 mg/day). Sweet sorghum juice from the tested varieties has shown a minimum of 1.896 ± 0.069 mg/l (SSV 74) to a maximum of 6.103 ± 0.203 mg/l (SPV 1871). Zn content and that of sugarcane juice was found to be 1.34 ± 0.03 mg/l.

Iron is an essential prosthetic group of many proteins, including hemoglobin and cytochromes. Almost all the tested sweet sorghum varieties are a potential source of iron as the content ranges from 17.262 ± 1.058 to 56.013 ± 0.231 mg/l suggesting, a glass of sweet sorghum juice can provide 1/2 - 1/4th of the daily requirement (8 to 18 mg/day) of iron. Varieties like CSV 24 SS and SPV 1871 have iron content that can quickly meet the daily requirement. Comparatively, sugarcane juice has shown less iron content of 12.656 ± 0.023 mg/l.

Manganese is an essential nutrient in carbohydrate, amino acid, cholesterol metabolism and is required for bone formation. It is also an essential component of superoxide dismutase, an antioxidative enzyme. An intake of 2.8-1.8 mg/day (for adult men and women, respectively) is considered adequate. Sweet sorghum cultivars studied have Mn content in the range of 1.233 ± 0.022 to 8.396 ± 0.243 mg/l, implying that they can be an apt source for manganese. The highest Mn content was found in SPV 1871 (8.396 ± 0.243 mg/l). The Mn content of sugarcane juice (3.351 ± 0.034 mg/l) is comparable to few sweet sorghum varieties (RVICSH 28 and SSV 74).

Phosphorous, a vital constituent of the membrane and nucleic acids, is also required for maintaining the pH and activation of many catalytic proteins by phosphorylation. Phosphorous (in the form of PO_4^{-3}) content in present seven varieties of sweet sorghum varied greatly in the range of 380.15 ± 37.78 mg/l to 1225.094 ± 61.568 mg/l. 250 ml of juice can provide 175 mg - 250 mg of phosphorous corresponding to 25%-36% of RDA (700 mg/day). Sugarcane juice has less phosphorous content (228.46 ± 19.543 mg/l) than the studied seven sweet sorghum varieties.

All age groups require calcium and magnesium, with the former having skeletal importance and the latter required by over 300 enzymes as a cofactor. Sweet sorghum juices have calcium (Ca^{+2}) content between 27.555 ± 2.505 to 50.1 ± 5.01 mg/l, which is twice that of sugarcane juice (18.19 ± 5.01 mg/l) and magnesium (Mg^{+2}) content of 24.31 ± 0.001 to 45.581 ± 3.039 mg/l compared to the daily requirement of 1 g/day and 420 mg/day, respectively, which are negligible. The magnesium content of sugarcane juice (25.31 ± 1.519 mg/l) is equivalent to SSV 74 and CSV 19 SS.

Sodium and potassium are essential as the blood electrolytes required for maintaining physiological homeostasis and blood pressure. Their role has been studied exclusively in many chronic disease risks, especially in cardiovascular due to their effect on blood pressure (Aaron and Sanders, 2013). Further, potassium is involved in many biochemical reactions like carbohydrate metabolism, energy metabolism. Sweet sorghum juice can be a rich source of potassium (K^+) and sodium (Na^+), with more potassium content and less sodium, as required by the human body. Compared to others, the Na^+ and K^+ content was high in Phule Vasundhara (3760 ± 60 mg/l and 15246.67 ± 11.547 mg/l, respectively). Consuming a glass of sweet sorghum juice can immediately replenish the body's sodium and potassium levels as they make up to 1/4th - ½ of recommended dietary allowance, which is 1.5 g/day and 3.4 g/day, respectively. Sugarcane juice has ½ and 1/5th content of sodium and potassium compared to that of sweet sorghum juice.

Table 3: Elemental analysis of Sweet Sorghum juices

Elements (mg/L)	Sweet Sorghum Juice varieties							
	CSV 19 SS	CSV 24 SS	*Phule Vas-undhara*	RVICSH 28	SPV 1871	SSV 74	SSV 84	Sugarcane juice
Trace Elements								
Fe	17.262 ± 1.058	46.947 ± 0.611	17.612 ± 0.36	28.478 ± 0.058	**56.013 ± 0.231**	27.962 ± 0.257	19.677 ± 0.008	12.656 ± 0.023
Pb	0.4508 ± 0.032	0.428 ± 0.016	0.415 ± 0.029	0.316 ± 0.001	0.372 ± 0.003	0.189 ± 0.003	0.284 ± 0.001	0.01 ± 0.001
Cd	0.0184 ± 0.001	0.039 ± 0.003	0.047 ± 0.004	0.044 ± 0.002	0.056 ± 0.008	0.031 ± 0.004	0.053 ± 0.009	0.01 ± 0.001
Cr	0.0625 ± 0.002	BDL	BDL	BDL	BDL	BDL	BDL	0.02 ± 0.001
Ni	0.0228 ± 0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	3.617 ± 0.46	3.325 ± 0.062	2.179 ± 0.099	2.452 ± 0.023	**6.103 ± 0.203**	1.896 ± 0.069	2.842 ± 0.02	1.34 ± 0.03
Mn	2.576 ± 0.0865	5.13 ± 0.179	1.233 ± 0.022	3.674 ± 0.021	**8.396 ± 0.243**	3.635 ± 0.020	1.31 ± 0.065	3.351 ± 0.034
Cu	0.48 ± 0.0614	0.104 ± 0.002	0.298 ± 0.006	0.367 ± 0.007	**1.03 ± 0.006**	0.495 ± 0.015	0.432 ± 0.023	0.312 ± 0.032
B	2.701 ± 0.462	0.549 ± 0.114	0.082 ± 0.001	0.560 ± 0.0002	0.211 ± 0.002	0.266 ± 0.006	0.615 ± 0.013	0.031 ± 0.002
Al	BDL	BDL	BDL	BDL	BDL	BDL	0.995 ± 0.022	0.142 ± 0.012
Ag	BDL	0.148 ± 0.022	0.196 ± 0.013	BDL	0.555 ± 0.021	0.124 ± 0.006	0.054 ± 0.004	BDL
Co	0.019 ± 0.001	0.012 ± 0.002	BDL	0.002 ± 0.001	0.0166 ± 0.0005	BDL	0.007 ± 0.001	0.014 ± 0.006
Macrominerals								
Na	1130 ± 25	1910 ± 85.44	**3760 ± 60**	2903.33 ± 15.275	2876.66 ± 25.166	2186.667 ± 15.275	2050 ± 10	1140 ± 15.275
K	6158.33 ± 7.638	9770 ± 20	**15246.67 ± 11.547**	9763.33 ± 30.551	9573.33 ± 15.275	11263.33 ± 11.547	6366.67 ± 15.275	2108 ± 15.275
Mg^{+2}	28.868 ± 1.519	31.907 ± 1.519	36.465 ± 6.078	**45.581 ± 3.039**	41.023 ± 1.519	24.31 ± 0.001	37.984 ± 1.519	25.31 ± 1.519
Ca^{+2}	45.09 ± 0.001	27.555 ± 2.505	**50.1 ± 5.01**	45.09 ± 5.01	30.06 ± 0.13	45.09 ± 3.02	35.07 ± 5.01	18.19 ± 5.01
P	380.15 ± 37.78	1067.79 ± 56.553	**1225.094 ± 61.568**	960.674 ± 55.604	681.648 ± 13.545	408.239 ± 19.013	731.46 ± 27.268	228.46 ± 19.543

*BDL is below detection level.

* Results are expressed as Mean ± standard deviation (n=3).

4. Discussion

Sweet sorghum, a multipurpose crop, has multivariate uses both as an edible and commercial source. Sweet sorghum is gaining much importance in recent years which is attributable to its use, in the form of grain as staple food and juice for food, jaggery and syrup (Datta *et al*., 2012). The present study describes the innovative use of sweet sorghum juice as an instant energy drink similar to sugarcane juice. The potential of sweet sorghum juice as an energy drink can be well known by understanding the composition of the sorghum juice for the presence of phytochemicals like phenols, flavonoids and tannins, antioxidative power, sugars (glucose, fructose, sucrose), proteins, starch, major minerals and trace elements.

Although, the bioavailability of polyphenols is not entirely understood, polyphenol-rich foods and beverages are shown to increase plasma antioxidant capacity within 1-2 h after ingestion (Scalbert and Williamson, 2000). Recent studies on dietary intake of polyphenols in various populations showed a daily intake of approximately 1 g, through various foods like fruits, vegetables, beverages like tea, coffee and alcohol (Karam *et al.,* 2018). Nevertheless, these studies are limited and mainly dependent on the diet and lifestyles of the populations. Among the various polyphenols ingested, flavonoids and phenolic acids were reported to be in higher amounts (Grosso *et al.*, 2014). Bioactive components like ferulic acid, p-coumaric acid, cinnamic acid, catechin, gallic acid, apigenin, apigeninidin, luteolin and lutein were found in sweet sorghum grains of Durra variety (Shen *et al.,* 2013).

Similar to grain sorghum, sweet sorghumjuice also has phytochemicals like polyphenols, flavonoids and tannins in considerable amounts (Table 2) with 140-170 mg GAE/250 ml. The phenolic and flavonoid content of sorghum juices relevantly accounts for the antiradical activity as shown in Figure 2. The differences in the polyphenolic and antiradical activity of the RVICSH 28 and SSV 84 can be attributed to the phytochemical compositions of the two varieties.

Proteins are an essential source for nitrogen-containing amino acids required for synthesizing *in vivo* proteins and other N_2 containing compounds like hormones, neurotransmitters and creatine. According to the work of Belton and Taylor (2004), the protein content of sorghum is comparable to that of cereals. Although, sweet sorghum juice cannot contribute majorly for daily requirement of protein, being gluten free gives it an additional benefit for consumption. The role of carbohydrates like glucose, fructose and sucrose as energy fuels is indomitable. Presence of these mono and di-sachharides in sweet sorghum juice substantiates its utilization as an instant energy source. Studies on the stability of sorghum juice (Wu *et al.*, 2010) show that 50% of the sugar content was lost in 2 weeks when juice was maintained at room temperature of 25°C, but under refrigerated conditions, the loss decreased to 1 to 3% in 2 weeks. Very few studies have been done on the effect of storage conditions on the phytochemical content of sorghum juice.

The essential minerals, calcium, phosphorus, potassium, sodium, chlorine, and magnesium (macrominerals) and trace elements chromium, copper, iodine, magnesium, manganese, molybdenum, phosphorus and zinc, have diverse and well characterized physiological functions in human metabolism. Their deficiency usually leads to specific mineral associated pathophysiology and affects related organs. The mineral analysis of sweet sorghum juice reveals that it can be a good source of all major and trace minerals.

Among the seven sweet sorghum cultivars evaluated, CSV 19 SS had higher carbohydrate content along with polyphenols, flavonoids and tannins. Proteins, phenols and antioxidant content were high in RVICSH 28. Although, the phytochemical content of SPV 1871 was found to be less, its mineral content was notably superior to other varieties. Sweet sorghum juice can be used as an alternative to sugarcane juice in view of its nutritive components.

5. Conclusion

Most of the literature available on sorghum antioxidants is based on grains. However, there is ample information on juice-based antioxidants in sorghum. The results conclude that sorghum juice can also be a potential source of antioxidants, nutrients like iron, manganese and other components like reducing sugars and proteins similar to that of sugarcane juice. Due to presence of sucrose, glucose, and fructose, sorghum juice can be a source of instant energy, thus it can be recommended for daily consumption. Sweet sorghum juice has a much-added benefit with higher polyphenolic content compared to sugarcane juice. Further, research might enhance knowledge on the health-improving aspects of sweet sorghum juice.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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