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Assessment of nutritional, anti-nutritional and functional properties of marketed biofortified sweet potato cultivars

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Abstract

Sweet potatoes, a nutrient-dense crop are recognized as a potential functional food to mitigate an array of nutritional disorders. In India, sweet potato is considered a secondary staple crop due to its unique nutritional properties. Owing to its high consumption, food interventions like biofortification have been made to enrich the essential bioactive compounds (carotenoids and anthocyanins). The current study highlighted the nutritional, anti-nutritional and mineral analysis of farmer-grown biofortified sweet potatoes i.e., Bhu-sona and Bhu-Krishna varieties and compares them with officially available data. High antioxidant activity was observed in Bhu-Krishna with 40 mg followed by Bhu-Sona and white flesh (unfortified variety) (19.3 and 18.7 mg/100 g dry basis). The total carotenoid content ranged from 0.9 to 12.6 mg/100 g dry weight, with the highest content in Bhu-Sona. The anti-nutritional content like phytates and tannins in sweet potato cultivars ranged between 57.35 and 60.82%. However, the antinutrient content was comparatively high in selected biofortified varieties, establishing research prospects concerning human health. These results provide insights into the suitability of biofortified varieties for inclusion in diets that are nutritionally adequate and have sufficient nutritional information for policymakers to promote these varieties to the vulnerable.

1. Introduction

Sweet potato is one of the nutritious tuber staple roots, extensively produced in tropical and subtropical regions (Grace *et al.,* 2014). Cultivation of sweet potato has increased by over 130 million tons globally. Among the other staple storage roots, sweet potato possesses unique characteristics such as a short growth period [3-4 months] with exceptional nutriment properties, making them one of the functional foods (Malhotra *et al.,* 2022). Sweet potatoes are an excellent source of carbohydrates, proteins, polyphenols, carotenoids and others. Among these, the predominant bioactive components are carotenoids (e.g. β carotene), phenolic acids (e.g., caffeic acid), flavonoids (e.g., quercetin, myricetin), and anthocyanins (cyanidin-, peonidin-derivatives) which are essential in combating many serious illness (Truong *et al.,* 2007). Further, sweet potatoes possess a low glycemic index making them a suitable food for diabetics (Zhao *et al.,* 2020). However, the presence of antinutrients such as phytic acid, cyanide, tannins, oxalates and anthraquinones in sweet potatoes could impede the bioavailability and bioaccessibility of bioactive compounds upon human consumption (Alam, 2021).

Vitamin A is one of the fat-soluble vitamins, essential for maintaining tissue integrity and immune functions. Major sources of vitamin A are orange/yellow colored (carrots and sweet potatoes) and green leafy vegetables. Malnutrition of vitamin A is majorly due to malabsorption, prolonged deprivation and inability to process vitamin A. In order to curb vitamin A deficiency, the Government of India launched biofortified staple foods (such as maize, sweet potatoes and others) enriched with provitamin A or β-carotene (Yadava *et al.,* 2018). Among many biofortified varieties, Bhu-sona is a widely marketed sweet potato variety due to its higher β-carotene content (~14 mg/100 g dry basis), ease of cultivation, and drought-resistant, making it broadly accepted among farmers and consumers (Behera *et al.,* 2022; Anil *et al.,* 2023). Apart from the beta-carotene rich variety, Bhu Krishna, an anthocyanin-enriched sweet potato was also introduced to replace the synthetic food colorants (Figure 1). Further, anthocyanins were well-established with many functional properties including antioxidant, anticancer, cardiovascular protection, anti-inflammatory, glucose regulating and

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neuroprotective activities etc. Overall, these biofortified sweet potato varieties exhibited higher β-carotene and anthocyanin contents in lab-grown conditions which does not mimic the external environmental conditions.

Figure 1. Indian-based unfortified (white flesh) and biofortified sweet potato cultivars.

In order to assess the variation due to external environmental conditions, the nutritional, anti-nutritional and mineral analysis of farmer-grown biofortified sweet potatoes i.e., Bhu-sona and Bhu-Krishna varieties were evaluated and compared with official data of Indian Food Composition Table 2017 and Central Tuber Crops Research Institute, India (Longvah *et al*., 2017).

2. Materials and methods

2.1 Collection of sweet potato varieties and sample preparation

Fresh sweet potato tubers of two biofortified varieties i.e., orange flesh and purple flesh and unfortified variety (white flesh) were procured from the commercial markets of Bhubneswar, Odisha, India. Approximately 2.2 kg of individual sweet potato varieties were washed, freeze-dried pulverized and sieved (60 mesh) to obtain a fine powder. The fine powder obtained was packed in airtight laminates and stored at 2-8°C until further analysis. All the standards, chemicals and reagents used in this work are of analytical grade procured from Sigma-Aldrich, India. Deionized and millipore water was used in the entire study.

2.2. Nutritional content and mineral analysis

The powdered samples were used for determining the nutritional composition using standard methods. The moisture, ash, fibre, fat and carbohydrate content were determined using AOAC methods (AOAC, 2005; Annoh *et al.,* 2022).

2.2.1 Determination of moisture content

The moisture content was done using air circulated oven procedure in AOAC Official Method 934.01. Briefly, 1 g of each sample was transferred to a previously dried dish (W_1) in the oven at 130-133°C for 2 hrs. The time was recorded from the moment the oven attained 130°C after the dishes had been placed. The dishes were removed after 2 hrs, cooled in the desiccators and weighed (W_2). The process of drying, cooling, and weighing was repeated until the weight remained constant. The calculation of moisture content was as follows:

$$\text{Moisture (\%)} = [(W_1 - W_2)/(W_1 - W)] \times 100.$$

Where W = Weight in g of the empty dish.

2.2.2. Determination of total ash content

Dry ashing was carried out by placing the crucibles containing the samples in the furnace at 550°C for 24 hrs, calculating the difference between initial and final weights using AOAC Official Method 942.05. Approximately, 1 g of each sample was weighed into a tarred crucible which was pre-dried. The crucibles were placed in the furnace at 550°C for 24 hrs. Later, the furnace was turned off and opened when the temperature dropped to at least 250°C preferably lower. The door was carefully opened to avoid losing ash that may be fluffy. Safety tongs were used to transfer crucibles to a desiccator and were allowed to cool prior to weighing. The calculation was as follows:

$$\%\,\text{Ash} = \frac{(\text{weight of crucible} + \text{ash}) - \text{weight of empty crucible}}{(\text{weight of crucible} + \text{sample}) - \text{weight of empty crucible}} \times 100$$

2.2.3 Determination of crude fat

The crude fat content was determined using the Soxhlet extraction method using AOAC Official Mehod 925.10 (AOAC, 2000). Briefly, 1 g of each sweet potato sample were weighed and added in a labeled thimble. About 150 mL of petroleum ether was then added to it and boiled up to 40–60°C in 250 mL boiling flask. The thimble was tightly plugged with cotton wool and soxhlet apparatus was assembled and allowed it to reflux for 24 hrs. After extraction, the thimble was removed and recovered solvent by distillation. The flask and fat/ oil were heated in an oven at about 103°C to evaporate the solvent, cooled and determined the weight of fat/oil collected. The calculation was as follows:

$$\%\,Crude\ Fat = \frac{(weight\ of\ flask + oil) - weight\ of\ flask}{weight\ of\ sample} \times 100$$

2.2.4 Determination of crude fibre

Crude fiber analysis was conducted on the digestible fraction of the fat-free extract, undergoing successive hydrolysis through mild acid and alkali treatments (AOAC, 2005). Briefly, 1g of each sample was weighed and into three different conical flasks (W_1). Then 100

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mL of 1.25% H_2SO_4 was added to each flask connected to a condenser set on a hot plate and subjected to boiling for 30 mins. The filtrate collected from the flask was returned to another flask containing 100 mL of 1.25% NaOH and the procedure continued. Finally, the residue obtained was washed with water and 15mL of 96% alcohol was added. The contents were dried and weighed to determine the fiber content (%) (W_2). The calculation was as follows:

$$\text{Crude fiber \% by wt.} = [(W_1 - W_2)/W] \times 100.$$

Where W is the weight of the empty flask.

2.2.5 Determination of protein content

The protein content estimation was determined using the Bradford protein assay (Kruger, 2009). Briefly, 1 g of each sample was weighed and homogenized with 30 mL of 0.1 M sodium hydroxide (NaOH) in 3.5% sodium chloride (NaCl). The homogenate was further incubated at 60°C for 90 mins and subjected to centrifugation at 4000×*g* for 30 mins at 4°C. Further, 3 mL of supernatant was collected and mixed with 1 mL of Bradford reagent, incubated the mixture at room temperature for ten mins to allow dye-protein binding and subjected to analysis. A series of 0.2, 0.4, 0.6, 0.8, and 1.0 mg/mL BSA standards by diluting in distilled water were prepared and absorbance was recorded at 595 nm in the microplate reader.

2.2.6 Determination of carbohydrate content

The carbohydrate content (%) of a sample was calculated based on the content of protein, fat, fiber, ash and moisture (Kowmudi *et al.,* 2023).

2.2.7 Elemental analysis using inductively coupled plasma mass spectrometry

Orange (Bhu-sona), purple (Bhu krishna) and white flesh (unfortified) sweet potato samples were subjected to mineral estimation (such as Na, Ca, Mg, K, Mn, Se, Fe, Cr, Co, Ni, Cu, Zn, Ar, Cd, Hg and Pb) by employing inductively coupled plasma - mass spectrometry (NexION 5000, Perkin Elmer, Inc., USA) in conjunction with a microwave sample digestor (TITAN MPS, Perkin Elmer, Inc., USA). The entire experiment was maintained with the following instrumental conditions: plasma (Ar) gas flow of 15 L/ min; carrier (Ar) gas flow of 1 L/min; nebulizer (He) gas flow of 0.98 L/min; spray chamber temperature of 2°C; sampler and skimmer cones with nickel tips; plasma power of 1600 W; sample uptake rate of 300 µL/min. 0.2 g of each sample was subjected to microwave digestion with 5 mL of nitric acid and 2 mL of hydrogen peroxide (following the digestion program mentioned in Table 1) for about 30 mins heating and 15 min cooling; diluting the final solution with 50 mL deionized water (Kowmudi *et al.,* 2023). Further, multi-elemental internal standards had been used.

Table 1. Microwave digestion program for estimation of minerals.

Step	Power (W)	Ramp (min)	Hold (min)
1	500	1	4
2	1000	5	5
3	1400	5	10
4	0	-	15

2.3 Determination of anti-nutrients in orange (Bhu-sona), purple (Bhu krishna) and white flesh (unfortified) sweet potatoes

Phytates and tannins are the major antinutrients present in sweet potato cultivars. The analysis of phytate content was carried out following a previously reported study (Duguma *et al.,* 2021). Approximately 0.1 g of the sample was weighed and extracted with 10 mL of HCl (2.4%) and kept in a mechanical shaker for 1 hr. Then,, the mixture was subjected to centrifugation at 3,000 rpm for 30 mins (Remi R-12C Plus, Remi Lab World, Maharashtra, India). Then, 3 mL of clear supernatant was mixed with 2 mL of wade reagent (containing 0.03% solution of $FeCl_3.6H_2O$ and 0.3% of sulfosalicylic acid in water) and was homogenized, centrifuged at 3,000 rpm for 10 min. An aliquot volume of 3 mL supernatant was collected for further analysis. A series of phytic acid standard solutions ranging from 1-10 µg/mL were prepared using the above procedure and the absorbance of both was measured at 500 nm using a UV-Vis spectrophotometer (Shimadzu UV-1700, Tokyo, Japan). The phytic acid content (mg/100 g dry weight basis) was determined by the obtained standard calibration curve.

The tannin content present in the sweet potato was determined by following the previously described method in literature (Maxson and Rooney 1972). Approximately, 2 g of the sample was extracted using 10 mL of acidified methanol (1% HCl) for 24 hrs at room temperature with continuous mechanical shaking. The prepared solutions were centrifuged at 1,000 rpm for 5 min and the supernatant was collected. Then, 1 mL of supernatant was mixed with 5 mL of vanillin-HCl reagent for further analysis. D-catechin was used as a standard to express all results as D-catechin equivalent tannin content.

For this, a calibration curve was built with standard using different concentrations in the range of 0.2 to 1 mg/mL, following the same procedure of sample. The absorbance of the sample solutions and the standard solutions (0.2-1 mg/mL) was measured at 500 nm using a UV-Vis spectrophotometer (Shimadzu UV-1700,

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Tokyo, Japan). Standard curves were prepared from absorbance vs. concentration and the slopes and intercepts were used for calculation. The obtained results were expressed as D-catechin equivalent of tannin (mg/100 g dry basis).

2.4 Functional attributes quantification in sweet potato cultivars

2.4.1 Determination of total carotenoid content

The carotenoid content of sweet potato samples was determined using organic solvents (acetone-petroleum ether) for the extraction followed by the spectrophotometric method of analysis, as described in the literature (Koala *et al.,* 2013). Briefly, 2 g of pulverized samples were weighed and acetone was added to the sample in a ratio of 5:1 (v/w). The mixture was transferred to a separating funnel and repeatedly extracted with petroleum ether and acetone (1:1) until a clear solution was obtained. The petroleum eluent was collected and subjected to centrifugation at 3000 rpm for 5 mins. 3 mL of supernatant was collected and the concentration of β-carotene was measured using a UV-Vis spectrometer at 454 nm with acetone control and β-carotene standard solutions (0.2-10 µg/mL). The complete experiment was carried out in the dark to avoid carotenoid degradation in the samples. The obtained results were expressed as β-carotene equivalent to mg/100 g dry basis.

2.4.2 Determination of total phenolic content

To determine organic phenols, the folin-Ciocalteu method was used as described in the literature (Kupina *et al.,* 2018). Briefly, the samples were first extracted in 0.1 mL of 70% aqueous acetone, reacted with 0.2 mL of the Folin-Ciocalteu reagent (a complex mixture of heteropolyphosphotungstate-molybdate) in the presence of 1.25 mL 20% aqueous sodium carbonate solution. A calibration curve consisting of gallic acid standards was prepared, ranging from 0.02-0.10 mg/mL. The phenolic content was calculated by measuring the sample's absorbance at 765 nm and was calculated as gallic acid equivalent (GAE). The obtained results were expressed as mg GAE/100 g dry weight by interpolating with the calibration curve range.

2.4.3 Determination of total anthocyanin content

The total anthocyanin content (TAC) was quantified using a spectrophotometric method as illustrated in the literature (Lee *et al.,* 2005). Briefly, 1 g of powdered sample was extracted for 24 hrs in the dark at 4℃ with 25 mL acidified methanol (1% v/v HCl). The samples were then centrifuged at 5,000 rpm for 15 mins at 4℃. Finally, 5 mL of supernatant was collected for further analysis. Similarly, anthocyanin standards are prepared in a range of (10-100 µg/mL) and the absorbance was measured at 530 and 657 nm. The total anthocyanins were determined as cyanidin-3-glucoside equivalents (mg/100 g dry basis).

2.4.4 Determination of total antioxidant activity by DPPH assay

The DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) assay was performed for sweet potato samples using the method described in the literature (Brand-Williams *et al.,* 1995). In brief, 1 mL of aquas methanolic (50%) sweet potato extract samples and antioxidant standards such as ascorbic acid were mixed with 5 mL of DPPH methanolic solution (0.1 mM). DPPH solution and an equal amount of methanol were used as blank. All samples were prepared in triplicates, vortexed for 1 min and incubated in the dark for 30 mins at 37℃. The samples were analyzed at 517 nm using a multimode plate reader (Infinite M200 pro, TECAN, Switzerland). DPPH activity = [1-(absorbance of sample - absorbance of blank)/absorbance of control]×100%) was expressed as mg of ascorbic acid equivalent (AAE/100 g) of sweet potato.

2.4.5 Statistical analysis

The significance of data was measured in triplicates and was analyzed statistically by Statistical Package for Social Science (SPSS) version 27.0.1 (IBM Corp., USA). The data was expressed as mean ± standard deviation (SD). The analysis of variance (one-way ANOVA) followed by the Duncan multiple range test was employed for significant mean difference comparing the groups with a 95% confidence level ($p \leq 0.05$).

3. Results

3.1 Differentiation of proximate compositions in sweet potato cultivars

The nutritional composition analysis provided better insights into the selected biofortified and unfortified sweet potatoes. The data concerning protein content (%), moisture content (%), ash content (%), carbohydrate content (%), fat content (%) and fibre content (%) of non-fortified and biofortified sweet potatoes are illustrated in Figure 2. The white flesh sweet potato showed the highest moisture content of 71.3% followed by orange flesh and purple flesh (68.3 and 53.6%). The ash and total carbohydrate contents were significantly higher in purple flesh (4% and 32.7% respectively) than in other selected sweet potatoes. The total protein content was significantly high in both orange and purple flesh (2.79% and 2.93% respectively) when compared with white flesh sweet potato (1.53%). The fibre content ranged from 2.7 to 3.9% implying the richness of dietary fibre of sweet

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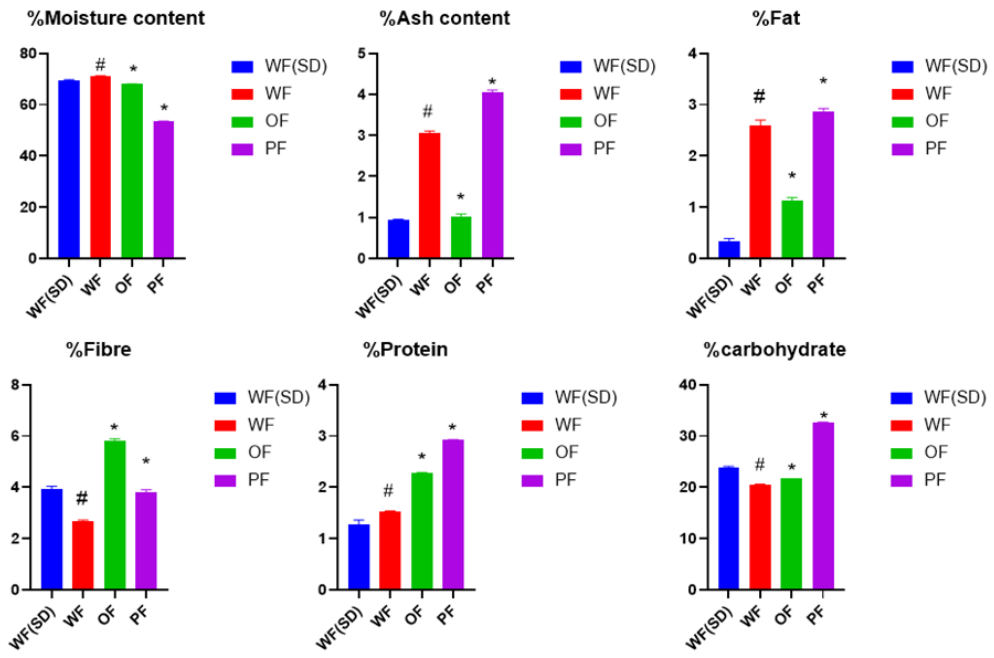

Figure 2. Proximate analysis of white flesh (unfortified variety), Bhu-sona (biofortified OF) and Bhu-Krishna (biofortified PF). Data are presented as mean±SD (n = 3). WF(SD): standard values of the Indian Food Composition Table 2017 (Longvah *et al.*, 2017), WF: White flesh, OF: Orange flesh, PF: Purple flesh.
#p<0.05 statistically significantly different vs SD (WF)
*p<0.05 statistically significantly different vs white flesh (unfortified).

potato. Interestingly, the fibre content of orange flesh was higher (5.7%) than the other two varieties (3.9% for purple and 2.7% for white flesh). The results obtained in the current study were further compared with standard available data in the Indian Food Composition Table.

3.2 Determination of mineral content

The mineral composition of different sweet potato cultivars is represented in Table 2. The results revealed that the heavy metals tested were within the recommended dietary allowances, confirming the absence of contaminants in the sweet potato cultivars (FSSAI, 2011). The orange flesh sweet potato showed the highest value of calcium (12250.6 µg/100 g) and potassium (7753.6 µg/100 g). The manganese content was also significantly high in orange flesh (3001.6 µg/100 g) when compared to the other two varieties (750 µg/100 g). Whereas the purple flesh showed the highest value for sodium (3750.6 µg/100 g).

3.3 Determination of functional properties in selected sweet potato cultivars

3.3.1 Total phenolic content and antioxidant properties

The total phenolic content in the sweet potatoes ranged from 5 to 11.9 mg/100 g gallic acid equivalent. The highest phenolic content was observed in purple flesh sweet potato with 11.8 mg/100 g followed by orange flesh and white flesh (8.8 and 5.06 mg/100 g). The antioxidant assay of selected sweet potato cultivars ranged from 18.6 to 40.1 mg/100 g. The antioxidant activity was observed high in purple flesh sweet potato with 40.1 mg/100 g followed by orange and white flesh (19.3 and 18.6 mg/100 g). The results are represented in Table 3.

3.3.2 Total carotenoid and anthocyanin content analysis

The total carotenoid content ranged from 0.93 to 12.5 mg/100 g. The highest carotenoid content was observed in orange flesh (12.5 mg/100 g), followed by purple flesh (5.36 mg/100 g) while the least was observed in white flesh (0.93 mg/100 g). The anthocyanin content analyzed in the cultivars ranged from 1.76-50.16 mg/100 g. As known, the purple flesh was identified with high levels of anthocyanins (50.16 mg/100 g). The results are represented in Table 3.

3.4 Determination of anti-nutrient content in selected sweet potato cultivars

The phytate content in sweet potato cultivars ranged from 57.35 to 76.44 mg/100 g. The tannin content ranged from 20.56-50.23 mg/100 g. The obtained results (Table 4) are similar to the previously reported results (Oloniyo *et al.,* 2021).

4. Discussion

Dietary nutrients are important in everyday meals to enrich human health. As many developing and under-

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Table 2. Mineral quantification for three sweet potato varieties (µg/100g dry basis).

Minerals	White Flesh (UF)	Orange Flesh (BF)	Purple Flesh (BF)
Sodium (Na)	2500.33±0.5	3000.33±0.5*	3750.6±0.3*
Calcium (Ca)	500.3±0.5	12250.6±0.5*	3250.3±0.5*
Magnesium (Mg)	2250.3±0.5	5750.6±0.5*	1750.6±0.5*
Potassium (K)	3000.6±0.5	7753.6±0.5*	2250.3±0.5*
Manganese (Mn)	750.3±0.5	3001.6±0.5*	750.33±0.5
Selenium (Se)	250.3±0.5	ND	ND
Iron (Fe)	250.6±0.5	250.6±0.5	ND
Chromium (Cr)	ND	ND	ND
Cobalt (Co)	ND	ND	ND
Nickel (Ni)	ND	ND	ND
Copper (Cu)	ND	ND	ND
Zinc (Zn)	ND	ND	ND
Arsenic (Ar)	ND	ND	ND
Cadmium (Cd)	ND	ND	ND
Mercury (Hg)	ND	ND	ND
Lead[a] (Pb)	ND	ND	ND

Values are presented as mean±SD, n = 3. BF: Biofortified varieties, UF: Unfortified Variety, ND: Not detected.
*p<0.05 statistically significantly different vs white flesh (unfortified).

Table 3. Functional properties of three sweet potato varieties (mg/100 g).

Functional properties	White Flesh (UF)	Orange Flesh (BF)	Purple Flesh (BF)
Total phenol	5.06±0.5	8.8±0.1*	11.8±0.1*
Total carotenoid	0.933±0.5	12.5±0.1*	5.36±0.05*
Total Anthocyanins	1.76±0.05	10.53±0.11*	50.16±0.05*
Total Antioxidant Levels	18.6±0.05	19.3±0.05*	40.1±0.1*

Values are presented as mean±SD, n = 3. BF: Biofortified varieties, UF: Unfortified Variety.
*p<0.05 statistically significantly different vs white flesh (unfortified).

Table 4. Anti-nutrients for three sweet potato varieties (mg/100 g).

Anti-nutrients	Standard data SD (WF)	White Flesh (UF)	Orange Flesh (BF)	Purple Flesh (BF)
Phytate	63.69±1.65	57.33±0.03[#]	76.44±0.04*	60.83±0.04
Tannin	NA	24.65±0.01	20.56±0.02*	50.23±0.15*

Values are presented as mean±SD, n = 3. SD (WF): standard values of the Indian Food Composition Table 2017, UF: Unfortified Variety, OF: Orange Flesh, PF: Purple flesh.
[#]p<0.05 statistically significantly different vs SD (WF)
*p<0.05 statistically significantly different vs white flesh (unfortified).

developing countries are still tackling malnutrition, enhancing the nutrient content either with fortification or biofortification has been a key approach. Among them, biofortification has been widely employed due to its ability to enhance the nutrient/nutrients and production. Among many biofortified food cultivars, sweet potatoes are considered a "poor man's diet" with cost-effectiveness and easy accessibility.

Very limited evidence has been reported on the nutritional and anti-nutritional profiling of marketed, farmer-grown Indian biofortified sweet potato cultivars. The proximate results obtained may be attributed to previous studies due to cultivar responses to different environmental conditions, crop adaptations and genetic modifications (Rosero *et al.,* 2022).

In the present study, all the obtained values were compared with the official data testified by the Indian food composition table (IFCT) and they were statically significant ($p \leq 0.05$) in terms of nutritional, antinutritional and elemental analysis (Longvah *et.al*.,2017). The current study identified the protein content in the range of 1.53-2.93%. Compared with the previous studies, the decrease in protein content can be correlated with the enhancement of other nutritional factors (Oloniyo *et al.,* 2021). Similarly, carbohydrate content in the selected sweet potatoes was found to be in the range of 20-32.7%, which was significantly higher than the previous reports (12-14%) (Shekhar *et al.,* 2015).

The presence of polyphenols is generally influenced

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by environmental factors (soil conditions, light exposure, rainfall, level of ripeness and cultivation method) which could be also modified by genetic variations (Siracusa and Ruberto, 2014). No significant changes in polyphenols were observed when compared with the previous reports. (i.e., range of 1.4-28.04%) (Shekhar *et al.,* 2015). Notably, purple flesh sweet potatoes have been reported to possess high polyphenol content. Contrastingly, some studies revealed that high phenolic content was observed (16-80%) in processed sweet potato flours. For instance, Rebecca *et al.* (2021), quantified the total phenolic content (TPC) of sweet potato flours (orange flesh and cream flesh) ranging from 16.20 to 40.70 mg/g GAE dry basis. The mineral compositions in the orange flesh were significantly high when compared to other selected varieties (Oloniyo *et al.,* 2021). It is noteworthy that, the current study exhibited less mineral content in context to the previous reports. This difference in the mineral content could mainly be linked to selected varieties along with, soil and storage conditions. Therefore, the difference in mineral composition in the storage roots reflects the metal composition of the soil and the environment in which the sweet potatoes were grown (Luis *et al.,* 2014). Further, the presence of anti-nutritional factors in sweet potatoes can also affect mineral bioavailability. For instance, phytic acid can bind to minerals like iron, calcium and zinc thus rendering them inaccessible to the body (Lopez *et al.,* 2002). The richness of the calcium content in orange flesh sweet potato could be a vital food for bone health and infant development. The sodium-potassium levels in sweet potatoes also contribute to lowering blood pressure and associated cardiovascular diseases (Loughrill *et al.,* 2017).

The antioxidant assay (i.e., DPPH) has revealed that purple flesh possesses the highest antioxidant levels at 40.1 mg/100 g followed by orange flesh (19.3 mg/100 g). These high antioxidant levels in purple flesh could be due to the presence of higher concentrations of phenolic compounds. These findings are consistent with the existing literature (Žilić *et al.,* 2012). Additionally, orange flesh also showed better antioxidant activity (19.3 mg/100 g). This could be due to an elevated amount of carotenoids in orange flesh (~12 mg/100 g). Moreover, few evidences suggest that the presence of carotenoids especially β-carotene content enhances the antioxidant levels due to its conjugated double bonds (Fu *et al.,* 2011).

The highest carotenoid content was exhibited in orange flesh sweet potato with 12.5 mg/100 g than the other varieties. The white flesh sweet potato has a very negligible content of carotenoid content (0.933 mg/100 g) when compared to the purple flesh cultivar (5.36 mg/100 g). Provitamin A, also known as beta-carotene, is recommended with respect to age, gender and other factors. However, the World Health Organization (WHO) and Food and Nutrition Board recommend 400-600 micrograms of vitamin A equivalents per day for adults (Trumbo *et al.,* 2001). The results obtained encourage promoting the consumption of orange-fleshed sweet potatoes to the vulnerable population, therefore, could be an effective strategy to combat vitamin A malnutrition and improve overall health. Similarly, the highest anthocyanin content was observed in purple flesh sweet potato with 50.1 mg/100 g dry basis. Presently, there is no established daily intake recommendation for anthocyanins specifically, but previous reports suggest that consuming a diet rich in anthocyanins may provide various health benefits, such as reducing the risk of chronic diseases like heart disease and diabetes (Oki *et al.,* 2016). To increase consumer awareness, the government and private entities should initiate some innovative efforts to promote the nutritional benefits of these biofortified varieties. A few of such initiatives may include nutritional education, collaboration with farmers, providing them incentives for the cultivation of these varieties and incorporation in school midday meal programs.

In general, plant-based foods contain anti-nutrients such as phytates, tannins, lectins, oxalates and others, which would hinder the absorption of essential nutrients. Sweet potatoes contain high levels of phytates and tannins which could be interfering factors for absorption of nutrients, digestion and others. In the current study, the orange flesh sweet potato was identified with a high amount of phytic acid (76.4 mg/100 g dry basis) followed by purple and white flesh (6083 and 57.33 mg/100 g dry basis respectively). The purple flesh sweet potato showed significantly high tannin content (50.23 mg/100 g dry basis). For instance, Dako *et al*. (2016) quantified tannin content in different sweet potato cultivars and identified that yellow flesh sweet potato was high in tannin content with 34 mg/100 g dry basis and negligible in other cultivars. Contrastingly, Rebecca and co-workers reported less tannin content with a range of 3-5 mg/100 g dry basis in orange flesh and cream flesh sweet potato (Oloniyo *et al.,* 2021). Nevertheless, limited research suggests that anti-nutrient effects could be mitigated through various cooking methods such as soaking, sprouting and fermenting. These methods may aid in masking anti-nutrient content, allowing the essential nutrients in sweet potatoes to be absorbed (Samtiya *et al.,* 2020).

4. Conclusion

In the present study, the nutritional, anti-nutritional

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and mineral composition of farmer-grown biofortified sweet potatoes were successfully evaluated. Overall, the study highlighted the variation in the lab-grown and farmer-grown varieties which provides an emphasis on the regional diversity and composition of these biofortified sweet potato varieties. To increase the potentiality of biofortified sweet potatoes as functional food, additional research should be carried out in the context of nutritional kinetics such as bioavailability, bioaccessibility, impact of anti-nutrients on absorption of bioactive constituents, environmental conditions and stability studies.

Conflict of interest

The authors declare no conflict of interest.

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