Heliyon 9 (2023) e21495

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Nutritional characteristics and antiradical activity of turmeric (*Curcuma longa* L.), beetroot (*Beta vulgaris* L.), and carrot (*Daucus carota* L.) grown in Bangladesh

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ARTICLE INFO

Keywords:
Antiradicals
Turmeric
Beetroot
Carrot
Amino acids
Phenols
Flavonoids

ABSTRACT

Curcuma longa L. (turmeric), *Beta vulgaris* L. (beetroot), and *Daucus carota* L. (carrot) grown in Bangladesh were analyzed for nutritional and phytochemical contents to reveal their comparative nutritional compositions and antiradical properties. Ash, protein, and carbohydrate content were significantly preeminent in beetroot as compared to others. Whereas fat content was found to be high in turmeric, carrots contained a great percentage of crude fiber. Beetroot was shown to have much greater potassium, calcium, and iron levels than others. Regarding amino acids, glutamic acid was found to be greater in beetroot and carrot whereas turmeric had significantly high aspartic acid content. Leucine had the highest concentration among essential amino acids in these three samples. Total antioxidant activity, total flavonoids, and phenolic contents in the methanolic extract of turmeric were found to be substantially higher than in beetroot and carrot. Furthermore, the extract of turmeric (IC_{50} value: 13.46 μg/mL) scavenged 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) free radicals considerably to a greater extent than beetroot (IC_{50} value: 380.61 μg/mL) and carrot (IC_{50} value: 1252.85 μg/mL). A positive correlation was found between the phytochemical contents and antiradical activity. The information from this study will help to find the potential ingredients from these plants for functional food.

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https://doi.org/10.1016/j.heliyon.2023.e21495
Received 25 March 2023; Received in revised form 17 October 2023; Accepted 23 October 2023
Available online 31 October 2023

1. Introduction

Understanding the therapeutic or nutraceutical purposes of plants, herbs, fruits, and vegetables is currently the most promising scientific field. Plants that are reservoirs of compounds such as nutrients required for daily intake as well as carotenoids, steroids, tocopherols, flavonoids, and other phenolic compounds have shown effective pharmacological properties [1]. Different parts of plant materials like fruits, vegetables, cereal crops, oilseeds, barks, leaves, roots, spices and herbs, and crude plant drugs have been studied for exploring potential nutrient constituents and antioxidant sources [2]. Many diseases, including cardiovascular disease, neurological disease, autoimmune disease, and cancer can be prevented by eating a diet rich in vegetables and fruits, which provide natural antioxidants and other essential nutrients [3,4]. Nowadays, food industries are focused on finding reliable natural pigments as an alternative to synthetic color additives due to their health concerns [5]. Tetrapyrroles, tetraterpenoids, and flavonoids are the major group of natural food colorants that are abundantly found in plants [6]. These food colorants can be used to formulate varieties of foods that could be more attractive and suitable for consumption. So, it is necessary to search for effective nutrients and antioxidants from edible natural sources containing colorants. Regarding this concern, the present study selected three colorful plant parts: the rhizome of *Curcuma longa* L. (turmeric), as well as the roots of *Beta vulgaris* L. (beetroot) and *Daucus carota* L. (carrot). These three are the most colorful plants widely available and consumed in Bangladesh. It was evident previously that they have abundant resources of compounds responsible for health-promoting benefits.

Curcuma longa L. or turmeric, a member of the Zingiberaceae family, is widely grown throughout tropical Asia [7]. Turmeric, also known as "Halud," is a curry spice, flavoring enhancer, and food preservative, and used in traditional medicine for jaundice, hematuria, bleeding, menstruation problems, and colic [7,8].

Beetroot (*Beta vulgaris* L.) from the Chenopodiaceae family, a most common dietary element is known as a 'Superfood' due to its rich in nutrients and has adapted well in Bangladesh [9,10]. Beetroot contains betalains, phenols, vitamin B (B1, B2, B6, B12), carotenoids, folate, and minerals that impart antioxidant activity including inhibition of lipid peroxidation [9].

Carrot (*Daucus carota* L.), an Apiaceae family member, is a nutritious root vegetable grown worldwide [11]. Orange carrots are most common nationwide and utilized in salads, desserts, and curries [12]. Orange carrots contain carotenes, vitamins, carbohydrates, minerals, and nutritional fibers [12].

Previous studies have been reported on natural dyes extraction from beetroot and turmeric in Mauritius; and the antioxidant activities of carrot and beetroot available in India [10,13,14]. Several studies reported about some functional foods such as noodles from wheat-beetroot, energy drinks from beetroot, beverages from carrot promace, and rice muffin enriched with carrot promace [15–17]. But there is no such type of functional food in Bangladesh made of any of these targeted plants due to the lack of information about their nutritional value. The lack of antioxidants, proteins or amino acids, minerals, and fiber in modern food is a big concern nowadays. The growing children are very much fond of modern food rather than available vegetables or spices which are healthy and low in cost. So, it is necessary to make such kind of fusion food with those low-cost available vegetables and spices and make them popular for a healthy population in the future. Although many scientific studies have been carried out with the passage of time, no comparative and comprehensive analysis has been done so far on the nutritional compositions especially the amino acids and antiradical activities of available color containing plants like turmeric, beetroot, and carrot cultivated in Bangladesh. This study set out to compare turmeric, beetroot, and carrot in terms of their nutritional value and antiradical characteristics to highlight their significance and encourage their widespread production, consumption, and the possibility of an optimal combination of these three as a functional food.

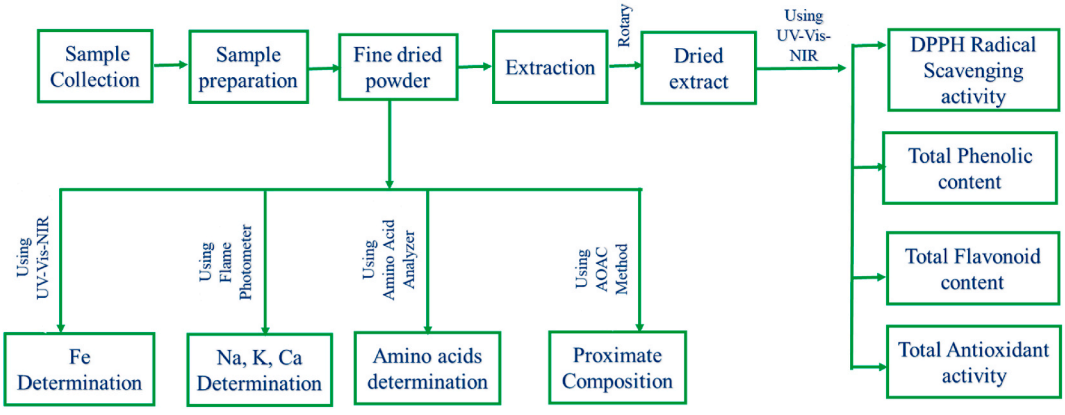

Fig. 1. Experimental procedure.

2. Materials and methods

2.1. Sample collection and preparation

Around 5.0 kg of each plant material of turmeric (50–60 pieces), beetroot (20–25 pieces), and carrot (30–35 pieces) were randomly collected from six wholesalers of the local market (24°21'57.54" N latitude and 88°38'34.18" E longitude) of Rajshahi in Bangladesh. The sample's undesired components (such as soil, dust, peel of the targeted part of plants, etc.) were taken out. Then the sample was kept in a tray by cutting it into small pieces. The sample was then dried for two to three days by placing it on the tray covered partially with glass in a well-ventilated room by flowing constant air with a ceiling fan. This work was carried out in the cold and dry season (November–December) which was helpful to dry up quickly and without any fungal infestation. This dried sample was processed into a fine dried powder in a blender. The dried powder (DP) was weighed and subjected to carry out extraction in an Ultrasonic water bath (Philippine, Digital Ultrasonic Bath, UBT-1080) at 40 °C for 1hr in methanol. A rotary evaporator (Germany, Heidolph Instruments Gmb H&Co.KG, Basis Hei-VAP ML, 562-00000-00-0) was used to remove the solvent followed by a desiccator. These dried extracts and dried powder (DP) were stored at 4 °C in the refrigerator for further experiments according to Fig. 1. All these investigations were performed with three replicates to ensure the quality of the experiment.

2.2. Experimental design

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2.3. Chemicals and reagents

All the chemicals purchased for this study were reagent grade. The standards (Quercetin Dihydrate, Gallic acid, DPPH, Butylated hydroxytoluene (BHT) and L-ascorbic acid) also used in this analysis were purchased from Sigma Aldrich (St, Louis, MO, USA) and Merck CO. (Darmstadt, Germany).

2.4. Proximate analysis

The proximate analysis of dry powder of turmeric, beetroot, and carrot was accomplished using standard Association of Official Analytical Chemists (AOAC) method [18]. A definite amount of ground samples was taken and the moisture was determined (AOAC 930.15) at 105 °C [18]. For the determination of ash content (AOAC 942.05), a specific amount of sample was placed in a crucible and heated to 600 °C in a muffle furnace (Germany, Naffletherm, L(T)15/12) [18]. The sample's crude fat content (AOAC 2003.05) was determined using the Soxhlet Extraction technique where n-hexane was used as a solvent [18]. In order to determine the amount of crude fiber present, the sample was boiled in acid, then in base, dried, and finally burned at 550 °C (AOAC 925.10) [18]. According to the Kjeldahl method the protein (crude) of these selected samples was determined (AOAC 978.04) [18]. The value of carbohydrates was calculated from the difference between 100 and the total of all components (moisture, crude protein, fat, ash, and fiber). All the results were expressed in percentages (g/100g).

2.5. Estimation of mineral (Na, K, Ca) contents

Minerals (Na, K, Ca) content in turmeric, beetroot, and carrot were measured according to the method with slight modification [19]. A definite amount of sample was taken for dry ash. The hydrochloric solution of ashes was used for the determination of mineral content by flame photometry (UK, LABDEX, LX406FP). The mineral contents were represented as mg of each mineral per 100 g of sample DP.

2.5.1. Estimation of iron content

The iron content of turmeric, beetroot, and carrot was determined by 1, 10 Phenanthroline method [20]. Standard iron solutions having various concentrations were prepared for the calibration curve. 2.0 mL sample/standard solution was mixed with 1.0 mL hydroxylamine hydrochloride (10 %), 2.0 mL 1,10-phenanthroline (0.1 %), and 5.0 mL ammonium acetate (buffer). In order to measure the absorbance at 510 nm using a Shimadzu UV-3600i plus Spectrophotometer (Tokyo, Japan), the solutions were diluted to a volume of 25.0 mL [20]. Iron concentrations were reported in mg per 100 g of DP.

2.6. Amino acid composition

The amino acid composition of turmeric, beetroot, and carrot were profiled through an amino acid analyzer (Germany, Sykam Co. Ltd, S433D). The samples were treated with 6.0 N HCl in a glass tube (sealed) and placed in an oven at 110 °C for 24 h [21]. Finally, the samples were filtered and brought to 100 mL with distilled water. The diluted samples were filtered with a 0.21 μm membrane for determining amino acid through the amino acid analyzer. The Sykam Standard Type H (a mixture of 17-amino acids) was employed for this study [20]. The amino acid data were estimated as mg per g of DP.

2.7. DPPH radical scavenging capacity

Extracts of turmeric, beets, and carrots were tested for their ability to neutralize 1,1-diphenyl-2-picrylhydrazyl (DPPH) radicals using a version of the method with some modifications [22]. BHT (standard) was taken and made various concentrations for this test. Different concentrations of the extracts (turmeric, beetroot, and carrot) were prepared for sample test solutions. Then these were mixed with 2.5 mL of 0.004 % DPPH dissolved in methanol. Absorbance of the mixtures (Japan, Tokyo, Shimadzu UV-3600i plus Spectrophotometer) was recorded at 517 nm after 30 min [20], and then percentage of DPPH inhibition was calculated from the following equation:

$$\%\ \text{of DPPH Inhibition} = \left(\frac{Ac - As}{Ac}\right) \times 100$$

in which Ac represents the absorbance of control and As represents the absorbance of the standard. The ability to scavenge DPPH is measured by its IC_{50}, or the concentration of a sample needed to inhibit DPPH activity by 50 %. The IC_{50} value was calculated by constructing a line of best fit from the data (concentration in μg/mL vs percentage of inhibition in %).

2.8. Estimation of total antioxidant activity

The total antioxidant activity (TAA) of these extracts was measured using phosphomolybdenum method according to Barbosa et al. with some modifications [23]. The method is gleaned from the formation of a green phosphate/molybdate (V) complex under acidic conditions after the reduction of M_O (VI) -M_O (V) by the extract. The standard named ascorbic acid was used for this analysis. In this test, 350 μg/mL of standard solution was prepared as a stock solution and from there different concentrations of working standard were made. 1000 μg/mL of stock solutions of the extracts (turmeric, beetroot, and carrot) was prepared for sample test solutions. A mixture of reagent solution containing 0.6 M sulfuric acid, 28.0 mM sodium phosphate and 1 % ammonium molybdate was added to 0.5 mL of sample/standard solutions. The solution-containing tubes were then incubated at 95 °C for 90 min. After cooling to room temperature, the absorbance of the mixture was measured at 695 nm using a spectrophotometer (Japan, Tokyo, Shimadzu UV-3600i plus Spectrophotometer) against blank [20]. The total antioxidant activities were expressed as mg of ascorbic acid equivalents (AAE) per g of extract (mg AAE/g sample) and also as mg AAE/g of DP.

2.9. Estimation of total phenolic content

The total phenolic content (TPC) of these extracts was determined spectrophotometrically using the Folin-Ciocalteu method [24] where Gallic acid was used as a standard. 500 μg/mL stock solution of Gallic acid was prepared. From this, various standard concentrations were formulated for an appropriate calibration curve. 1000 μg/mL of stock solutions of the extracts (turmeric, beetroot, and carrot) was prepared for sample test solutions. 0.5 mL of each sample/standard solution was combined with a mixture of Folin-Ciocalteu reagent (10-fold diluted) and sodium carbonate (7.5 %). These reaction mixtures were then incubated in the dark for 30 min. After that, the absorbance of the solutions was taken at a wavelength of 760 nm using a spectrophotometer (Japan, Tokyo, Shimadzu UV-3600i plus Spectrophotometer) [20]. The total phenolic content was expressed as mg of gallic acid equivalents (GAE) per g of extract (mg GAE/g extract) and also as mg GAE/g of DP.

2.10. Estimation of total flavonoid content

The total flavonoid content (TFC) of these extracts was estimated according to the aluminum chloride colorimetric assay [25]. 500 μg/mL of quercetin solution was used for the preparation of different concentrations of working standards. 1000 μg/mL of stock solutions of the extracts (turmeric, beetroot, and carrot) was prepared for sample test solutions. Briefly, 0.5 mL of each sample/standard solution was mixed with 2.5 mL of distilled water and 0.15 mL of 5 % sodium nitrate. After 5 min of break, 0.3 mL of 10 % aluminum chloride was added to these mixtures and left these for 5 min. Then, 1 mL of 1 mM sodium hydroxide and subsequently 0.55 mL of distilled water were added. After centrifuging at 4000 rpm for 10 min, the supernatant was transferred and the absorbance was measured at 415 nm against blank using a spectrophotometer (Japan, Tokyo, Shimadzu UV-3600i plus Spectrophotometer) and the data were expressed as mg of quercetin equivalents (QE) per g of extract (mg QE/g extract) and also as mg QE/g of DP [20].

2.11. Estimation of total carotene content

The determination of total carotene content (TCC) of turmeric, beetroot, and carrot was performed according to S. Panpraneecharoen et al. with some modifications [26]. About 0.2 g of dry powder of samples were taken and subjected to extract using n-hexane as solvent. After extraction, these were filtered (Whatman #1444 150, Maidstone, England) and the absorbance of the solutions was taken at 446 nm through a spectrophotometer (Japan, Tokyo, Shimadzu UV-3600i plus Spectrophotometer) against blank and the results of total carotene content (mg/kg of dry powder) were calculated by using the following formula 25×383 (As – Ab)/100W, where A_s is the absorbance of the sample, A_b is the absorbance of blank, 25 is the volume of n-hexane (mL), 383 is the diffusion coefficient, and W is the weight of DP in g [20].

2.12. Statistical analysis

Results of the analyses were expressed as mean ± standard deviation (SD) using three replicates for proximate and six replicates of data for phytochemical analysis. The variation among the samples in the reported parameters were determined with a one-way analysis of variance (ANOVA) where significant differences were measured at the level of 5 % ($p < 0.05$). Correlations between TAA, TPC, TFC, DPPH, and TCC were determined using Pearson Correlation Analysis. The obtained data were statistically analyzed using Statistical Package for Social Science (SPSS) (Version 25).

3. Results and discussion

3.1. Proximate composition

The proximate composition of turmeric, beetroot, and carrot based on their dry powder is summarized in Table 1. As shown in Table 1, beetroot had the highest ash content (7.14 %) and carrot had significantly lowest ash content (5.11 %). Britto et al. reported the ash content of turmeric in a range of 1.98 %–7.03 % [27] and comparable with the present result (5.72 %). A previous study revealed the ash content of carrot (7.60 %) and beetroot (6.82 %) which has a good agreement with this study [13]. The protein content in beetroot (13.59 %) was significantly greater as compared to others, though the protein content in turmeric (7.23 %) and carrot (9.82 %) was not shown to be significantly different. The results of the protein content of turmeric, beetroot, and carrot were similar to the previous studies [13,27,28]. The fat (7.27 %) and moisture (8.68 %) content of turmeric was found to be significantly higher than others [28]. On the other hand, beetroot (2.28 %) had the lowest fat content among these three samples. Carrot (13.03 %) had the highest fiber content among these three dried samples and the lowest crude fiber was found in turmeric powder (4.80 %). High carbohydrate content was observed in beetroot (68.40 %) but it was not found significantly different from turmeric (66.55 %). Carrots contained significantly lower carbohydrate content (66.32 %) in comparison with others.

The results of fat, fiber, and carbohydrate content of three samples are comparable with the previous studies [13,27–29]. The protein and carbohydrate, which makes up the bulk of plant-based meals, is an important proximate parameter because it reduces the body's reliance on unhealthy fats and cholesterol [30]. Overall, results of proximate composition revealed that the beetroot had the highest content of protein and carbohydrate in comparison with turmeric and carrot. Several studies reported that beetroot is one of the potential sources of vitamins, dietary fiber, protein, carbohydrates, and minerals [31,32]. Vegetables are excellent sources of fiber, which plays a key role in reducing the chance of developing many different health problems and carrots could be promising in this particular scenario [33]. So, these three targeted samples contained a significant amount of nutrients that are required in daily intake helping to maintain a proper health beneficiary effect. The results of proximate composition and minerals differ due to varietal differences, geographical locations, agricultural practices, use of fertilizer, maturity of rhizome and roots, and processing [27].

3.2. Mineral contents

The results of mineral contents in turmeric, beetroot, and carrot based on their dry powder are presented in Table 1. The high levels of potassium (704.14 mg/100g), calcium (36.77 mg/100g), and iron (0.36 mg/100g) were observed in beetroot ($p < 0.05$). However, carrots had a significantly high content of sodium (299.04 mg/100g). The result of minerals found in beetroot and carrot is higher than those reported in some studies [31,32,34]. The mineral contents in turmeric of this study are comparable with the previous studies [27,28,35]. To get adequate amounts of all the different minerals, it is important to eat a variety of vegetables. So, these plants are a good source of necessary minerals which might be able to meet the daily recommended intake [36].

Table 1
Proximate composition (g/100g) and mineral contents (mg/100g) of turmeric, beetroot, and carrot.

Parameter	Turmeric	Beetroot	Carrot
Moisture	8.68 ± 0.44^{aB}	2.37 ± 0.37^{cE}	7.40 ± 0.40^{bD}
Ash	5.72 ± 0.07^{bC}	7.14 ± 0.03^{aC}	5.11 ± 0.08^{cE}
Protein	7.23 ± 1.57^{bBC}	13.59 ± 0.46^{aB}	9.82 ± 0.03^{bC}
Fat	7.27 ± 0.13^{aBC}	2.28 ± 0.12^{cE}	3.29 ± 0.14^{bF}
Fiber	4.80 ± 0.09^{cC}	6.19 ± 0.27^{bD}	13.03 ± 0.14^{aB}
Carbohydrate	66.55 ± 1.7^{aA}	68.40 ± 0.42^{aA}	61.32 ± 0.49^{bA}
Sodium	24.38 ± 0.97^{cB}	130.82 ± 5.56^{bB}	299.04 ± 8.16^{aB}
Potassium	466.20 ± 9.33^{bA}	704.14 ± 7.74^{aA}	407.56 ± 8.20^{cA}
Calcium	19.92 ± 0.30^{bB}	36.77 ± 1.17^{aC}	19.33 ± 0.29^{bC}
Iron	0.27 ± 0.01^{cC}	0.36 ± 0.004^{aD}	0.19 ± 0.02^{bD}

*Values are presented as mean ± SD (n = 3) which are statistically analyzed by ANOVA (significantly different at the level of 5 %) for proximate composition and mineral contents separately. Different uppercase letters in the same row (small letters) and in the same column (capital letters) indicate that mean values differ significantly.

3.3. Amino acid composition

The amino acid profile of turmeric, beetroot, and carrots were summarized in Table 2. About sixteen out of twenty amino acids were spotted in these samples. Overall, glutamic acid was found to be higher in these three samples and beetroot had a significantly higher content of glutamic acid (36.51 mg/g) as compared to others. The content of essential amino acids including lysine, arginine, phenylalanine, histidine, leucine, isoleucine, methionine, valine, and threonine was statistically different among these three samples. Leucine had the highest concentration among essential amino acids in the turmeric (4.45 mg/g) and carrot (2.67 mg/g) whereas beetroot (2.82 mg/g) had the highest concentration of histidine among essential amino acids. Among nonessential amino acids, aspartic acid was found to be high besides glutamic acid in these samples and that was highest in the turmeric sample (9.69 mg/g). The results of amino acid composition in turmeric, beetroot, and carrot are in good concordance with prior research [35,37,38]. Approximately 65 % of the world protein supply per person originates from plant-based foods, and combinations of plant proteins can provide a complete and balanced source of amino acids to meet physiological needs in humans [39,40]. Since these plants contain both essential and non-essential amino acids, they may play an important role in achieving nutritional balance.

3.4. Antiradical properties

3.4.1. Total phenolic content (TPC)

TPC analysis was carried out in methanolic extract. As shown in Table 3, significant variations were observed in TPC among beetroot, turmeric, and carrot. The turmeric sample contained the highest total phenolic compounds (200.99 mg GAE/g) whereas carrot and beetroot contained 20.95 mg GAE/g and 12.96 mg GAE/g of extract respectively. J. Akter et al. reported that TPC in the methanol extract of turmeric was about 157.4 mg GAE/g of extract [41]. A previous study has reported higher amounts of TPC in dry methanolic extract of beetroot and carrot as compared to the present study [42]. The degradation of phenolic compounds during the sample processing step could affect the deviation of TPC value in different studies.

3.4.2. Total flavonoid content (TFC)

The TFC in turmeric was found significantly higher ($p < 0.05$) than others and that was 70.53 mg QE/g of dry extract. However, there was no discernible difference in TFC between beetroot (7.31 mg QE/g) and carrot (7.95 mg QE/g). A previous study reported higher amounts of TFC in the methanolic extract of turmeric [43]. El-Beltagi et al. also have concluded that the flavonoid content in beetroot was 1.54 mg QE per g of dry powder [44]. A study reported by Mohammed et al. found 11.86 mg CE/g and 39.08 mg CE/g of TFC in beetroot and carrot dry methanolic extract [42].

3.4.3. Total antioxidant activity (TAA)

The total antioxidant activity of turmeric, beetroot, and carrot was estimated through phosphomolybdenum method. Table 3 illustrates statistically significant differences in the total antioxidant capacity of dry extracts and powders of carrot, beetroot, and turmeric. The increasing order of total antioxidant activity is as follows carrot (51.45 mg AAE/g) < beetroot (57.78 mg AAE/g) < turmeric (105.85 mg AAE/g). A previous study concluded that the TAA of turmeric was about 37.66 mg AAE/g of dry samples, though the sample was extracted in ethanol [23]. Venkatachalam et al. have reported that TAA in beetroot and carrot were about 61.11 mg AAE/100g and 47.65 mg AAE/100g of fresh weight where samples were extracted in ethanol [14].

Table 2
Amino acid compositions (mg/g of dried powder) in turmeric, beetroot, and carrot.

Amino acid	Turmeric	Beetroot	Carrot
Aspartic Acid	9.69 ± 0.22^{aA}	$4.85 \pm .08^{bB}$	4.27 ± 0.04^{cB}
Threonine	2.61 ± 0.06^{aE}	1.93 ± 0.02^{bB}	1.61 ± 0.05^{cE}
Serine	$2.65 \pm .08^{aE}$	2.61 ± 0.14^{aB}	1.47 ± 0.05^{bEF}
Glutamic acid	7.53 ± 0.09^{bB}	36.51 ± 2.18^{aA}	6.68 ± 0.31^{bA}
Glycine	2.20 ± 0.12^{aF}	1.62 ± 0.05^{bB}	1.44 ± 0.08^{bEF}
Alanine	1.95 ± 0.05^{cG}	4.21 ± 0.09^{aB}	2.84 ± 0.07^{bC}
Valine	2.37 ± 0.04^{aF}	2.23 ± 0.10^{ab}	2.04 ± 0.13^{bD}
Methionine	Absent	Absent	0.41 ± 0.01^{I}
Isoleucine	2.19 ± 0.12^{aF}	1.80 ± 0.07^{bB}	1.58 ± 0.09^{bE}
Leucine	4.45 ± 0.09^{aC}	2.64 ± 0.12^{bB}	2.67 ± 0.10^{bC}
Tyrosine	2.24 ± 0.07^{aF}	1.55 ± 0.04^{bB}	1.13 ± 0.06^{cFG}
Phenylalanine	2.94 ± 0.07^{aD}	1.34 ± 0.03^{cBC}	1.6 ± 0.15^{bE}
Histidine	0.77 ± 0.01^{bI}	2.82 ± 0.15^{aB}	0.84 ± 0.05^{bH}
Lysine	1.48 ± 0.04^{bH}	2.47 ± 0.07^{aB}	1.42 ± 0.04^{bEF}
Arginine	3.03 ± 0.17^{aD}	1.62 ± 0.04^{bB}	1.66 ± 0.07^{bE}
Proline	1.45 ± 0.04^{aH}	1.22 ± 0.03^{bBC}	1.24 ± 0.07^{bG}

*Values are presented as mean ± SD (n = 3) which are statistically analyzed by ANOVA (significantly different at the level of 5 %). Different uppercase letters in the same row (small letters) and in the same column (capital letters) indicate that mean values differ significantly.

Table 3
The total phenolic content, total flavonoid content, total antioxidant activity, and total carotene content of turmeric, beetroot, and carrot.

Sample	TPC		TFC		TAA		TCC
	mg GAE/g extract	mg GAE/g dry powder	mg QE/g extract	mg QE/g dry powder	mg AAE/g extract	mg AAE/g dry powder	mg/kg dry powder
Turmeric	200.99 ± 2.45[a]	26.37 ± 1.03[a]	70.53 ± 3.21[a]	9.24 ± 0.24[a]	105.85 ± 1.09[a]	13.88 ± 0.42[a]	30.276 ± 4.83[a]
Beetroot	12.96 ± 0.34[c]	1.97 ± 0.07[c]	7.31 ± 0.33[b]	1.11 ± 0.03[b]	57.78 ± 2.35[b]	8.80 ± 0.54[b]	5.94 ± 0.89[c]
Carrot	20.95 ± 1.22[b]	3.19 ± 0.21[b]	7.95 ± 0.73[b]	1.21 ± 0.13[b]	51.45 ± 0.96[c]	7.83 ± 0.18[c]	23.84 ± 1.56[b]

*Values are presented as mean ± SD (n = 6) which are statistically analyzed by ANOVA (significantly different at the level of 5 %). Different uppercase letters in the same column (small letters) indicate that mean values differ significantly.

3.4.4. DPPH scavenging capacity

Fig. 2 demonstrates the radical scavenging (DPPH) capacity of the studies, implying that the rate of radical scavenging increases with increasing concentrations of the three extracts. In Fig. 3, it represents the IC_{50} value of BHT, turmeric, beetroot, and carrot as 3.70 μg/mL, 13.46 μg/mL, 380.61 μg/mL, and 1252.85 μg/mL respectively. Moreover, the IC_{50} value of turmeric was below 30 μg/mL and it shows similarity with a previous study [41]. It was also stated that turmeric has potentially high antioxidant-rich constituents [41]. On the other hand, IC_{50} values of beetroot and carrot were more than 200 μg/mL which represents a weak antioxidant activity similarly reported by previous study [45,46]. The higher value of IC_{50} values or lower DPPH scavenging activity of beetroot may be due to the lower content of phenolic compounds in beetroot in comparison with turmeric and carrot. This result also showed that the free radical scavenging properties of these plant extracts were lower than the positive control BHT.

3.4.5. Total carotene content (TCC)

The TCC of these samples is shown in Table 3. It was found that the TCC value of the plants we chose varied considerably from one another. The highest carotene content was found in turmeric (30.28 mg/kg of dry powder) and beetroot had the lowest value for carotene content (5.94 mg/kg of dry powder). When carotene and betanin are combined, the red color of major pigment in beetroot could predominate, making the presence and detection of carotene difficult and hence possess a lowest value of carotene in beetroot [9]. The total carotenoid value in turmeric powder was estimated to be 1.581 mg BCE/g by Da-Young Oh and Han-Soo Kim [47]. A previous study reported that carrot and beetroot contained 18.3 mg/100 g and 1.9 mg/100 g of total carotenoid content, respectively [48]. Another study observed a higher value of carotenoid content in orange carrot (76.8 mg/kg) [34]. Difference in carotene content might happen due to the degree of maturation, drying method, and method of extraction [49].

3.4.6. Correlation among TPC, TAA, DPPH, and TFC

Correlations among TPC, TAA, DPPH, TCC, and TFC are presented in Table 4. There was a strong positive correlation between TAA and TPC, TPC and DPPH, TFC and DPPH, TAA and DPPH, TFC and TAA, and TFC and TPC with significant values (p-value*). There was a moderate positive correlation between TAA and TCC with a significant value (p-value*) of 0.008. TPC is impacted by the concentration of flavonoids in these extracts, and phenolic, flavonoid, and carotene concentrations all have a substantial effect on the antioxidant activity of the extracts, as indicated by the R^2 value. Barbosa et al. have also reported high positive correlation between TPC and TAA of turmeric [23]. So, the positive correlation between the respective phyto-constituents and antioxidant activity implies that the phenolic, flavonoids, and carotene of these selected plants can be responsible for antioxidant activity.

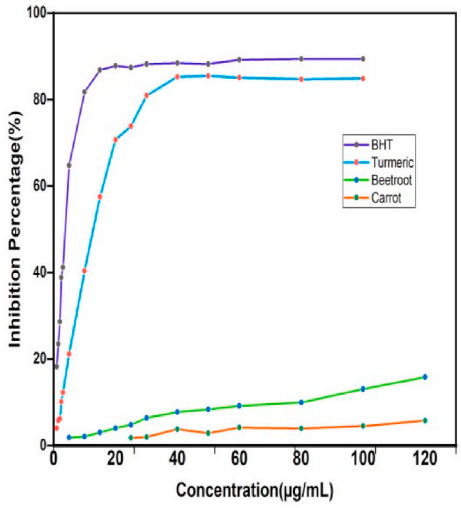

Fig. 2. Radical scavenging (DPPH) activity of BHT, turmeric, beetroot, and carrot.

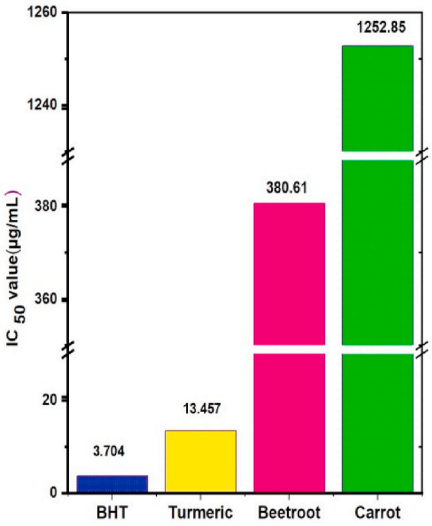

Fig. 3. IC_{50} of BHT, turmeric, beetroot, and carrot.

Table 4
Pearson correlation coefficient (r) between TPC, TFC, TCC, DPPH, and TAA.

	Correlation Coefficient (r)	*p*-value[a]
TAA vs TPC	0.988	0.000
TAA vs TFC	0.990	0.000
TFC vs TPC	0.997	0.000
TAA vs TCC	0.606	0.008
TPC vs DPPH	0.993	0.000
TFC vs DPPH	0.995	0.000
TAA vs DPPH	0.998	0.000

[a] Correlation is significant at the (*p*-value*) 0.01 level.

Overall, turmeric, beetroot, and carrot extracts showed potential antioxidant activity according to this finding. Also, it was revealed that the content of phenolic, flavonoids, and carotene was greater in turmeric than other two plants. Although beetroot and carrot extracts were proven to scavenge the free radicals to a considerable extent. However, turmeric extract showed more scavenging properties over other two investigated plants. It was well established that turmeric is enriched with curcuminoids (polyphenols) and non-curcumoids compounds responsible for its antioxidant activities [50]. Similarly, beetroot contains betalain, betaine, and betaxanthin as well as ascorbic acid, rutin, epicatechin, folate and many other phenolic and flavonoids that may impart the radical scavenging property [51]. Whereas, carrots are one of the prominent sources of carotenes, polyphenols (hydroxycinnamic acids and its derivatives), anthocyanins, lycopene, and lutein which together provide potent antioxidant properties [52]. Several studies have reported the presence of phenolic and flavonoids compounds in these selected plants [23,42–44]. Variations in geographic location, climatic conditions, use of fertilizers, harvest and storage, the extraction procedures, solvents, and analytical methods may have an impact on both the extraction yield and their antioxidant properties [14,53]. Because of their naturally vivid color and the noteworthy results about the nutraceuticals and antioxidant activity of the portions of turmeric, beetroot, and carrots chosen in this study show the potential to be used in food colorants, functional foods, or industrial applications.

4. Conclusion

The findings of the study provided a comparative analysis of nutritional profiles and antioxidant capacities of three natural sources that contain edible and health-beneficial colorants. The selected colored parts of turmeric, beetroot, and carrot contained a significant amount of nutritive material as well as showed considerable antioxidant properties. Beetroot (higher K, Ca, and Fe) and carrot (higher Na) had comparatively higher mineral contents whereas turmeric showed higher antioxidant activity (flavonoids, phenols, radical scavenging activity). A considerable amount of carotenoid, proximate, and amino acid content was also present in these three components. Therefore, these resources in various dishes can be employed to enhance their nutritional value in addition to their aesthetic appeal. Still there are some limitations of this study regarding sample processing procedure which might cause loss of some polyphenol or other bioactive compounds and additionally much more investigation is necessary to identify the existence of anti-nutrients so that the right combination of these resources can be used to create functional foods that increase immunity. But the results nevertheless encourage many individuals to cultivate, consume, and use these resources for their health.

Funding

The whole investigation was performed as a part of an R & D project that was supported by Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka -1205, Bangladesh.

Data availability statement

Data will be available on request.

CRediT authorship contribution statement

Shyama Prosad Moulick: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Farhana Jahan:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Md Badrul Islam:** Visualization, Resources, Methodology, Investigation. **Mahci Al Bashera:** Writing – original draft, Validation, Formal analysis. **Md Sabbir Hasan:** Validation, Formal analysis, Methodology. **Md Jahidul Islam:** Visualization, Formal analysis. **Sabbir Ahmed:** Visualization, Formal analysis, Resources. **Debabrata Karmakar:** Resources, Formal analysis. **Firoz Ahmed:** Visualization, Formal analysis. **Trissa Saha:** Visualization, Formal analysis. **Subarna Sandhani Dey:** Validation, Formal analysis. **Farhana Boby:** Methodology, Formal analysis. **Mandira Saha:** Visualization, Formal analysis. **Barun Kanti Saha:** Resources, Investigation, Funding acquisition. **Md Nurul Huda Bhuiyan:** Supervision, Investigation, Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships which can influence the results of this study and also do not have any conflict with any other research work.

Acknowledgements

We would like to acknowledge the authority of Bangladesh council of Scientific and Industrial Research (BCSIR), Dhaka-1205, Bangladesh for their financial logistic support. We are also grateful to BCSIR Rajshahi laboratories for accumulation of all research facilities.

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