

## Research Article

# Antioxidant Properties of Popular Turmeric (*Curcuma longa*) Varieties from Bangladesh

E. M. Tanvir,<sup>1,2</sup> Md. Sakib Hossen,<sup>1</sup> Md. Fuad Hossain,<sup>3</sup> Rizwana Afroz,<sup>1,4</sup> Siew Hua Gan,<sup>5</sup> Md. Ibrahim Khalil,<sup>1,5</sup> and Nurul Karim<sup>1</sup>

<sup>1</sup>Laboratory of Preventive and Integrative Biomedicine, Department of Biochemistry and Molecular Biology, Jahangirnagar University, Savar, Dhaka 1342, Bangladesh

<sup>2</sup>Veterinary Drug Residue Analysis Division, Institute of Food & Radiation Biology, Atomic Energy Research Establishment, Savar, Dhaka 1349, Bangladesh

<sup>3</sup>Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Mapalana, Matara, Sri Lanka

<sup>4</sup>School of Pharmacy, Pharmacy Australia Centre of Excellence, The University of Queensland, Woolloongabba, QLD 4102, Australia

<sup>5</sup>Human Genome Centre, School of Medical Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia

Correspondence should be addressed to Md. Ibrahim Khalil; [drmikhailil@gmail.com](mailto:drmikhailil@gmail.com) and Nurul Karim; [nkripon@yahoo.com](mailto:nkripon@yahoo.com)

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We investigated the aqueous and ethanolic extracts of different forms (local names: *mura* and *chora*) of turmeric (*Curcuma longa*) from the Khulna and Chittagong divisions of Bangladesh for their antioxidant properties and polyphenol, flavonoid, tannin, and ascorbic acid contents. The antioxidant activity was determined using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical-scavenging activity and ferric reducing antioxidant power (FRAP) values. The ethanolic extract of Chittagong's *mura* contained the highest concentrations of polyphenols (16.07%), flavonoids (9.66%), and ascorbic acid (0.09 mg/100 g) and *chora* resulted in high yields (17.39%). The ethanolic extract of Khulna's *mura* showed a higher DPPH radical-scavenging activity with the lowest 50% inhibitory concentration (IC<sub>50</sub>) (1.08 µg/mL), while Khulna's *chora* had the highest FRAP value (4204.46 ± 74.48 µM Fe [II] per 100 g). Overall, the ethanolic extract had higher antioxidant properties than those in the aqueous extract. However, the tannin concentration was lower in the ethanolic extract. We conclude that the turmeric varieties investigated in this study are useful sources of natural antioxidants, which confer significant protection against free radical damage.

## 1. Introduction

The complex biochemical reactions of the body and increased exposure to environmental toxicants and dietary xenobiotics result in the generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS), leading to oxidative stress under different pathophysiological conditions [1]. Antioxidants prevent oxidative damage through one-electron reactions with free radicals [superoxide radicals (O<sub>2</sub><sup>•-</sup>), hydroxyl radicals (OH<sup>•</sup>), singlet oxygen (O<sup>•</sup>), and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>)] that adversely alter cellular lipids, protein, DNA, and polysaccharides [1, 2]. Therefore, a balance between free radical and antioxidant concentrations is necessary to maintain proper physiological functions [2].

Many people consume antioxidants as a defense against oxidative stress. Antioxidants in the form of commercial food additives have been manufactured synthetically and may contain high amounts of preservatives [3]. Some synthetic antioxidants, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and tertiary butyl hydroquinone (TBHQ), have been reported to produce toxins or act as carcinogens [2, 4]. Therefore, identifying potential natural antioxidant sources can be a useful alternative to ensure sound health [5]. Food is the source of essential nutrients for growth and maintenance, but other bioactive compounds of plant origin promote health by slowing the aging process and preventing disease [6]. As a result, antioxidant constituents in plant material have piqued the interest of scientists, food

manufacturers, cultivators, and consumers for their roles in the maintenance of human health [3].

Turmeric is a golden spice derived from the rhizome of the *Curcuma longa* plant, which belongs to the Zingiberaceae family [7]. Since ancient times, turmeric has been used as the principal ingredient of dishes originating from Bangladesh and India for its color, flavor, and taste. It is also used in social and religious ceremonies in Ayurvedic and folk medicines against various ailments, including gastric, hepatic, gynecological, and infectious diseases [7, 8].

Dry turmeric contains 69.43% carbohydrates, 6.3% proteins, 5.1% oils, 3.5% minerals, and other elements [9]. The bioactive chemical constituents in turmeric have been extensively investigated. To date, approximately 235 compounds, primarily phenolics and terpenoids, have been identified from various species of turmeric, including twenty-two diarylheptanoids and diarylpentanoids, eight phenylpropenes as well as other phenolics, sixty-eight monoterpenes, 109 sesquiterpenes, five diterpenes, three triterpenoids, four sterols, two alkaloids, and fourteen other compounds [10]. Curcuminoids (mostly curcumin) and essential oils (primarily monoterpenes) are the major bioactive constituents showing different bioactivities. Calebin-A, vanillic acid, vanillin, quercetin, and other phenolic compounds have also previously been identified from turmeric [7, 11].

The herbaceous perennial is extensively cultivated in the tropical areas of South Asia, including Bangladesh, India, and China, while India is the primary exporter of turmeric [7]. To meet increased demands in both national and international markets, Bangladesh has developed many promising and sustainable spice companies including Square, BD foods, Archu, Pran, ACI, and Dekko, maximizing its conducive geographical location for turmeric cultivation, especially in hilly areas of the greater Chittagong division. The turmeric yield was 5.16 metric tons per hectare in the 2007-2008 production period and increased daily due to the development and dissemination of improved varieties [8]. Popular turmeric rhizome shapes include oblong with short branches, which is locally named “chora,” as well as ovate, which is locally named “mura” (Figure 1). However, in the Khulna district, these local turmeric varieties are popularly known as “kopil moni chora” and “kopil moni mura.”

The medicinal values and antioxidant properties of some turmeric varieties have already been reported [6, 12]. However, there are little knowledge and scientific data on the antioxidant compositions and activities of turmeric produced in Bangladesh. Thus, the present study aimed to investigate the antioxidant properties of turmeric varieties from Khagrachari and Khulna districts, Bangladesh, using different solvent extraction methods.

## 2. Materials and Methods

**2.1. Chemicals and Reagents.** Gallic acid, catechin, 1,1-diphenyl-2-picrylhydrazyl radical (DPPH), and 2,4,6-tris(2-pyridyl)-1,3,5-triazine (TPTZ) were purchased from Sigma-Aldrich (St. Louis, MO, USA). L-ascorbic acid, tannic acid, Folin-Ciocalteu's phenol reagent, and ferrous sulfate heptahydrate ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ) were purchased from Merck Co.

(Darmstadt, Germany). All of the chemicals and reagents used in this study were of analytical grade.

**2.2. Turmeric Collection.** Two different turmeric varieties (“mura” and “chora”) were collected from the Khulna district of Khulna division and the Khagrachari district of Chittagong division in Bangladesh in July 2013. Following collection, the turmeric samples were packed into sterile polybags before transportation to the Laboratory of Preventive and Integrative Biomedicine in the Biochemistry and Molecular Biology Department, Jahangirnagar University, Savar, Dhaka, Bangladesh.

**2.3. Extract Preparation and Yield Determination.** Turmeric samples were cleaned and air-dried in the shade for two days before being ground to a fine powder in a blender (CM/L7360065, Jaipan, Mumbai, India). The fine powder was used to prepare both ethanolic and aqueous extracts based on Kang's method [13] with slight modification. Briefly, 20% ethanolic extract was prepared by adding turmeric powder (20 g) in 70% ethanol solution to make a 100 mL solution. Similarly, for 20% aqueous extract preparation, 20 g of turmeric powder was dissolved in water to make a 100 mL solution. Both ethanol and aqueous extract solutions were placed in the dark to avoid reactions that may occur in the presence of light and were shaken in a shaker for 72 h at room temperature. Then, the solutions were filtered through Whatman No. 1 filter paper and concentrated in a rotary evaporator (Buchi, Tokyo, Japan) under reduced pressure (100 psi) at 40°C (for ethanol) and 55°C (for water). The dried extracts were collected and preserved at -20°C for subsequent analysis. The percentage of yield of the extracts was determined according to the following formula: % yield = [weight of sample extract/initial weight of sample] × 100. Eight different turmeric extracts were prepared for antioxidant analysis (Table 1).

### 2.4. Phytochemical Analysis

**2.4.1. Estimation of Total Polyphenol Content.** The total polyphenol content (TPC) of the turmeric extracts was estimated spectrometrically according to the Folin-Ciocalteu method [14] and adopted by Afroz et al. [15]. Briefly, 0.4 mL of the extract (0.25 mg/mL) was mixed with 1.6 mL of 7.5% sodium carbonate solution. Then, 2 mL of 10-fold diluted Folin-Ciocalteu reagent was added, and the final reaction mixture was incubated for 1 h in the dark. The intensity of the blue-colored complex was measured at 765 nm using a PD-303S spectrophotometer (APEL, Japan). The total polyphenol content present was determined as gallic acid equivalent (GAE) (6.25, 12.50, 25.00, 50.00, 100.00, and 200.00  $\mu\text{g/mL}$ ,  $r^2 = 0.9970$ ) and was expressed as g of GAE/100 g of turmeric.

**2.4.2. Estimation of the Total Flavonoid Content.** The total flavonoid content (TFC) was estimated using an aluminum chloride colorimetric assay [16]. First, 1 mL of the extract (1 mg/mL) was mixed with 0.3 mL of 5% sodium nitrite and added to the reaction mixture. After approximately 5 min, 0.3 mL of 10% aluminum chloride was added. Subsequently,

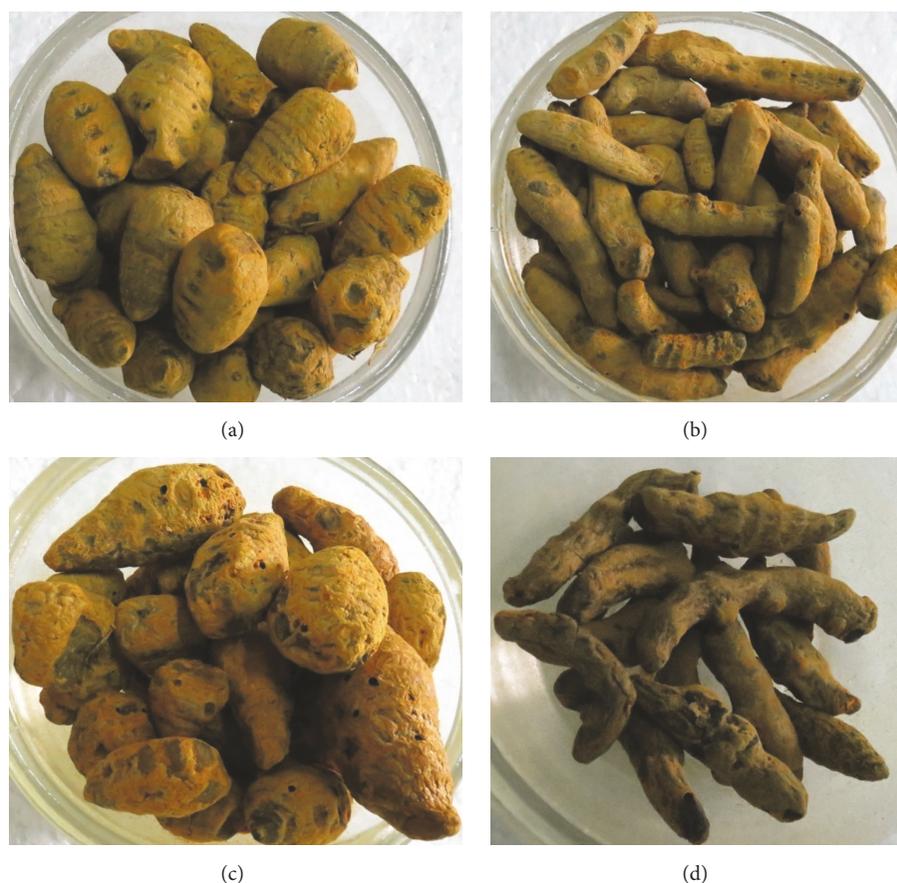


FIGURE 1: Turmeric varieties: (a) Kopil moni mura, (b) Kopil moni chora, (c) Chittagong mura, and (d) Chittagong chora.

TABLE 1: Details of the eight turmeric extracts collected from Khulna and Chittagong districts.

Variety name	Extraction solvent	Collection division	Code name	Scientific name
<i>Mura</i>	Water	Khulna	KMW	<i>Curcuma longa</i>
<i>Mura</i>	Ethanol	Khulna	KME	<i>Curcuma longa</i>
<i>Chora</i>	Water	Khulna	KCW	<i>Curcuma longa</i>
<i>Chora</i>	Ethanol	Khulna	KCE	<i>Curcuma longa</i>
<i>Mura</i>	Water	Chittagong	CMW	<i>Curcuma longa</i>
<i>Mura</i>	Ethanol	Chittagong	CME	<i>Curcuma longa</i>
<i>Chora</i>	Water	Chittagong	CCW	<i>Curcuma longa</i>
<i>Chora</i>	Ethanol	Chittagong	CCE	<i>Curcuma longa</i>

after 6 min, another 2 mL of 1 M sodium hydroxide (NaOH) was added, followed by the immediate addition of 2.4 mL of distilled water to produce a total volume of 10 mL. The color intensity of the flavonoid-aluminum complex was measured at 510 nm. The total flavonoid content was determined as catechin equivalent (CE) (6.25–200.00  $\mu\text{g}/\text{mL}$ ) and was expressed as g of CE/100 g of turmeric.

**2.4.3. Estimation of the Total Tannin Content.** The total tannin content (TTC) in the turmeric extracts was estimated using the Folin-Ciocalteu method [15, 17] with tannic acid as a standard. Briefly, 0.1 mL of the solution containing 1 mg of the extract was mixed with 7.5 mL of distilled water, and 0.5 mL

of Folin-Ciocalteu reagent was added. To the above mixture, 1 mL of 35% sodium carbonate and 0.9 mL of distilled water were added. The solution was mixed and then incubated for 30 min. The intensity of the developed blue-colored complex was measured at 725 nm. The results were expressed as g of tannic acid equivalent (TE) per 100 g of turmeric.

**2.4.4. Determination of the Ascorbic Acid Content.** The ascorbic acid content (AAC) in the turmeric samples was estimated as described by Omaye et al. [18] with slight modifications. Briefly, 1 mL of extract (500 mg/mL) was mixed with 1 mL of a 5% trichloroacetic acid (TCA) solution, followed by centrifugation for 15 min at 3500 rpm. Then, 0.5 mL

of the supernatant was mixed with 0.1 mL of DTC (2,4-dinitrophenylhydrazine/thiourea/copper) solution and incubated for 3 h at 37°C. To the mixture, 0.75 mL of ice-cold 65% sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) was added. The solution was allowed to stand for an additional 30 min at room temperature. The developed colored complex was monitored at 520 nm. The ascorbic acid concentration was determined as ascorbate equivalent (AE) and expressed as mg of AE per 100 g of turmeric.

**2.5. Antioxidant Activity.** The antioxidant activity of the turmeric samples was determined using the DPPH radical-scavenging activity and FRAP values.

**2.5.1. DPPH Free Radical-Scavenging Activity.** The antioxidant activities of all turmeric extracts were evaluated according to the DPPH radical-scavenging activity as described by Braca et al. [19]. Briefly, 1 mL of the extract was mixed with 1.2 mL of 0.003% DPPH in methanol at varying concentrations (2.5–80.0 µg/mL). The percentage of DPPH inhibition was calculated using the following equation:

$$\% \text{ of DPPH inhibition} = \left[ \left( \frac{A_{\text{DPPH}} - A_{\text{S}}}{A_{\text{DPPH}}} \right) \right] \times 100, \quad (1)$$

where  $A_{\text{DPPH}}$  is the absorbance of DPPH in the absence of a sample and  $A_{\text{S}}$  is the absorbance of DPPH in the presence of either a sample or the standard.

DPPH scavenging activity is expressed as the concentration of a sample required to decrease DPPH absorbance by 50% (IC<sub>50</sub>). This value can be graphically determined by plotting the absorbance (the percentage of inhibition of DPPH radicals) against the log concentration of DPPH and determining the slope of the nonlinear regression.

**2.5.2. Ferric Reducing Antioxidant Power (FRAP) Assay.** The FRAP assay was performed as described by Benzie and Strain [20]. The reduction of a ferric tripyridyltriazine complex into its ferrous form produces an intense blue color at low pH that can be monitored by measuring the absorbance at 593 nm. Briefly, 200 µL of the extract solution at different concentrations (62.5–1000.0 µg/mL) was mixed with 1.5 mL of the FRAP reagent, and the reaction mixture was incubated at 37°C for 4 min. The FRAP reagent was prepared by mixing 10 volumes of 300 mM acetate buffer (pH 3.6) with 1 volume of 10 mM TPTZ solution in 40 mM hydrochloric acid and 1 volume of 20 mM ferric chloride (FeCl<sub>3</sub>·6H<sub>2</sub>O). The FRAP reagent was prewarmed to 37°C and was always freshly prepared. A standard curve was plotted using an aqueous solution of ferrous sulfate (FeSO<sub>4</sub>·7H<sub>2</sub>O) (100–1000 µmol), with FRAP values expressed as micromoles of ferrous equivalent (µM Fe [II] per 100 g of sample).

**2.6. Statistical Analysis.** All analyses were performed in triplicate, and the data are reported as the mean ± standard deviation (SD). Data were analyzed using SPSS (Statistical Packages for Social Science, version 16.0, IBM Corporation, NY, USA) and Microsoft Excel 2007 (Redmond, WA, USA). Statistical analyses of the biochemical data were conducted using Tukey's test.  $P < 0.05$  was considered statistically significant.

### 3. Results and Discussion

This study is the first to report the antioxidant properties of some popular turmeric varieties from Bangladesh. The antioxidant properties and extraction yield depend on both the extraction method and the type of solvent used during the extraction. The various antioxidant compounds with different chemical characteristics and polarities of plant materials are soluble in different solvents. Ethanol is an organic polar solvent suitable for the extraction of phenolic compounds and is safe for human consumption [21]. On the other hand, polar inorganic solvent water is usually used for the extraction of various bioactive phytochemicals [12, 21]. Our experiments indicate that the highest yield of antioxidant compounds can be obtained from the ethanolic extract of turmeric varieties (both mura and chora) collected from Chittagong division, while the aqueous extract of chora from Khulna division gave the lowest yield (7.43%) (Table 2).

**3.1. Polyphenol Content.** Plant phenolics are important constituents that contribute to functional quality, color, and flavor and have significant roles both as singlet oxygen quenchers and free radical scavengers, helping to minimize molecular damage [3]. The health benefits of phenolics are primarily derived from their antioxidant potentials because the radicals produced after hydrogen or electron donation are resonance stabilized and thus relatively stable [6]. To counter the potential hazards of oxidative damage, the dietary consumption of antioxidant phenolics including phenolic acids and flavonoids may be regarded as the first line of defense against highly reactive toxicants [6]. Table 3 shows that turmeric varieties contain a significant amount of polyphenols. The concentration of phenolics determined in ethanolic extracts was significantly higher than the corresponding aqueous extracts ( $P < 0.05$ ). This agrees with the report of Qader et al. [12], who indicated that a higher TPC in ethanolic extracts is present compared to that in aqueous extracts. The TPC in turmeric ranged from 4.52% to 7.68% in aqueous extracts and from 6.15% to 16.07% in ethanolic extracts, respectively. Among the four ethanolic extracts of the turmeric varieties (mura and chora) of Khulna and Chittagong divisions, the highest TPC was measured in Chittagong's mura (16.07%) and the lowest in Khulna's mura (6.15%). Similarly, the aqueous extract of Khulna's mura had the lowest TPC, while the highest concentration (7.68%) was found in Chittagong's chora. Similarly, Qader et al. [12] reported that the TPC in the ethanolic and aqueous extracts of *Curcuma xanthorrhiza* was 2.43% and 8.80%, respectively. On the other hand, turmeric extract from West Bengal of India was reported to contain a TPC of only 1.3% [6]. In addition, Moure et al. [22] demonstrated that higher polarity of solvent tend to yield greater amounts of polyphenolics. Therefore, the significant differences in TPC observed in this study may be attributed to the solvents of the extracts.

**3.2. Flavonoid Content.** Flavonoids are the plant pigments responsible for plant colors and exert their health-promoting activities through their high pharmacological potentials as radical scavengers [23]. The TFC of turmeric varieties ranged

TABLE 2: The yield of different extracts.

Parameters	KMW	KME	KCW	KCE	CMW	CME	CCW	CCE
Initial weight (g)	121.19	121.19	108.2	108.2	68.035	68.035	122.4	122.4
Yield (g)	10.09	15.02	8.05	14.77	7.23	11.83	9.19	21.95
Yield (%)	8.36	12.39	7.43	13.65	10.63	17.39	7.51	17.93

Data are expressed as the mean.

TABLE 3: Concentrations of total polyphenols, flavonoids, tannins, and ascorbic acid of the turmeric varieties (mura and chora) collected from Khulna and Chittagong divisions.

Turmeric extracts	Phytochemicals			
	Polyphenols (g GAE/100 g of sample)	Flavonoids (g CE/100 g of sample)	Tannin (g TE/100 g of sample)	Ascorbic acid (mg AE/100 g of sample)
KMW	4.52 ± 0.250 <sup>a</sup>	0.43 ± 0.015 <sup>a</sup>	0.87 ± 0.092 <sup>a</sup>	0.04 ± 0.001 <sup>a,b</sup>
KME	6.15 ± 0.255 <sup>b</sup>	4.28 ± 0.340 <sup>b</sup>	7.74 ± 0.125 <sup>b</sup>	0.06 ± 0.004 <sup>b,c</sup>
KCW	5.53 ± 0.016 <sup>c</sup>	0.67 ± 0.055 <sup>a</sup>	20.31 ± 0.057 <sup>c</sup>	0.06 ± 0.001 <sup>a,b,c</sup>
KCE	13.16 ± 0.324 <sup>d</sup>	4.79 ± 0.196 <sup>c</sup>	8.93 ± 0.338 <sup>d</sup>	0.11 ± 0.00 <sup>d,e</sup>
CMW	5.42 ± 0.054 <sup>c</sup>	0.48 ± 0.003 <sup>a</sup>	16.38 ± 0.075 <sup>e</sup>	0.04 ± 0.001 <sup>a,b,c</sup>
CME	16.07 ± 0.301 <sup>e</sup>	9.66 ± 0.042 <sup>d</sup>	11.78 ± 0.211 <sup>f</sup>	0.09 ± 0.026 <sup>c,d</sup>
CCW	7.68 ± 0.071 <sup>f</sup>	0.29 ± 0.007 <sup>a</sup>	28.33 ± 0.255 <sup>g</sup>	0.03 ± 0.002 <sup>a</sup>
CCE	8.97 ± 0.146 <sup>g</sup>	5.46 ± 0.291 <sup>e</sup>	7.15 ± 0.113 <sup>h</sup>	0.06 ± 0.002 <sup>c</sup>

Data are expressed as the mean ± SD. Different letters (a, b, c, d, e, f, g, and h) in each column indicate a significant difference ( $P < 0.05$ ).

between 0.29% and 0.67% in aqueous extract but was higher (between 4.28% and 9.66%) in ethanolic extracts (Table 3). The highest TFC was measured in the ethanolic extract from Chittagong's mura (approximately 9.66%), corresponding to its high TPC, while the lowest TFC was found in the aqueous extract from Chittagong's chora (nearly 0.29%).

Turmeric from Malaysia (*Curcuma longa*) has been reported to contain 0.094 mg/g of TFC of dry sample [24], while Sumazian et al. [25] reported the presence of 4.05 mg/g of TFC of dry sample of *Curcuma domestica*. Similarly, Tilak et al. [26] reported a TFC of turmeric from India ranging from 3.58 to 7.86 mg/g of turmeric. Polyphenols including flavonoids are extensively investigated in turmeric for their wide range of pharmacological activities [27]. Flavonoids are the antioxidants that can prevent or delay the oxidation of substrates even when it is present in low concentrations, so as to prevent oxidation by the prooxidants (ROS and RNS). These nonenzymatic antioxidants (phenolics and flavonoids) react with the prooxidants leading to inactivation. In the redox reaction, the antioxidants act as reductants and serve as the first-line defense to suppress the formation of free radicals [26]. According to previous reports, turmeric is a good source of natural flavonoids, which have been shown to have antioxidant activity, free radical-scavenging capacity, coronary heart disease preventive activities, and anticancer activities [28].

**3.3. Tannin Content.** Tannins are other important water-soluble plant secondary metabolites that have been reported to have astringent, antioxidant, and antimicrobial activities [3, 29]. An analysis of TTC indicated that the studied turmeric varieties are very good sources of tannins (Table 3). Generally, the chora variety of both Khulna and Chittagong

divisions contained a higher TTC than that of the mura variety. Among the four ethanolic extracts, Khulna's chora had a significantly higher TTC than did the mura variety, whereas Chittagong's chora had a lower TTC compared to that of the mura variety. The TTC in the studied turmeric varieties differed significantly, reflecting the effects of geographical variation between Chittagong and Khulna divisions.

**3.4. Ascorbic Acid Content.** Ascorbic acid is a strong antioxidant that directly interacts with a broad spectrum of harmful ROS, terminates the chain reaction initiated by free radicals via electron transfer, and is involved in the regeneration of other antioxidants, such as tocopherol, to their functional state [30]. The content of this powerful antioxidant in turmeric ranged from 0.03 to 0.11 mg/100 g of turmeric. Khulna's chora contained the highest amount of ascorbic acid, and the aqueous extract from Chittagong's chora contained the lowest amount (Table 3). Free radicals have been implicated in the aetiology of several human ailments. Antioxidant activities of several therapeutic compounds like ascorbic acids possess significant properties which could ameliorate the effects seen [31]. Turmeric and its constituents have been credited to have many therapeutic benefits where antioxidants are believed to play the major therapeutic role related to the beneficial effects [26].

### 3.5. Antioxidant Activity

**3.5.1. DPPH Free Radical-Scavenging Activity.** DPPH free radical-scavenging activity of the aqueous and ethanolic extracts of the turmeric varieties was investigated to determine their antioxidant properties. The findings are expressed

TABLE 4: FRAP and IC<sub>50</sub> of DPPH values of turmeric varieties (mura and chora) collected from the Khulna and Chittagong divisions.

Parameters	KMW	KME	KCW	KCE	CMW	CME	CCW	CCE
DPPH radical-scavenging activity, IC <sub>50</sub> (μg/mL)	5.31	1.08	12.51	3.03	13.42	1.97	16.55	1.19
FRAP (μM Fe [II] per 100 g of sample)	646.67 ± 2.48 <sup>a</sup>	3475.36 ± 173.10 <sup>b</sup>	1015.52 ± 3.11 <sup>a</sup>	4204.46 ± 74.48 <sup>c</sup>	681.18 ± 24.20 <sup>a</sup>	3231.89 ± 337.10 <sup>b</sup>	976.61 ± 2.48 <sup>a</sup>	1972.66 ± 104.78 <sup>d</sup>

FRAP data are expressed as the mean ± SD. IC<sub>50</sub>: inhibitory concentration 50%. Different letters (a, b, c, and d) in each row indicate a significant difference ( $P < 0.05$ ).

as percentage of inhibition against concentration in Figure 1, and IC<sub>50</sub> values are presented in Table 4. According to the derived IC<sub>50</sub> values, the ethanolic extracts exhibited higher scavenging activities than did the corresponding aqueous extracts, indicating the influence of solvent on the measurement of antioxidant properties. Our findings agree with the previous reports of Qader and coworkers [12]. Based on the DPPH radical-scavenging activity, the mura variety has greater activity than the chora variety of Khulna division, whereas the chora variety from Chittagong had slightly lower IC<sub>50</sub> values (1.19 μg/mL) than did the mura variety (1.97 μg/mL) from the same division.

The antioxidant activities of aqueous extracts of turmeric support the activity shown by the corresponding ethanolic extracts. The obtained results indicate that the free radical-scavenging activity may be attributed to the high contents of phenolics and flavonoids with a higher reducing capacity. Denre [6] reported similar IC<sub>50</sub> values of turmeric from West Bengal, India (5.99 mg/mL), while turmeric from Indonesia had higher IC<sub>50</sub> values (8.33 μg/mL) compared with those of curcumin (7.85 mg/mL) in the same study [32].

**3.5.2. FRAP.** FRAP assay treats the antioxidants in the sample as reductants in a redox reaction and measures the reducing potential of the test sample [33]. The antioxidants exert their activities by donating electron or hydrogen atoms to the ferric complex which converts to ferrous complex (Fe<sup>3+</sup> to Fe<sup>2+</sup>-TPTZ complex), thus breaking the radical chain reaction [20, 33]. The FRAP values of aqueous and ethanolic extracts of turmeric ranged from 646.67 to 1015.52 μM Fe [II]/100 g of sample and from 1972.66 to 4204.46 μM Fe [II]/100 g of sample, respectively (Table 4). A higher FRAP value indicates more robust antioxidant properties of the turmeric samples from Bangladesh. Considering both the FRAP value and the IC<sub>50</sub> value from DPPH radical-scavenging assays, our analysis indicated that the mura variety is superior to the chora variety. Overall, Khulna's chora had the highest FRAP value with a slightly lower percent of DPPH inhibition (Figure 2).

Lipid peroxidation is believed to be the primary mechanism involved in many major diseases such as liver problem, myocardial infarction, diabetes, and cancer, causing major cell damage [26]. Curcuminoids and other polyphenols in turmeric can ameliorate lipoprotein oxidation, prevent lipid peroxidation, and stabilize the cell membrane, suggesting its

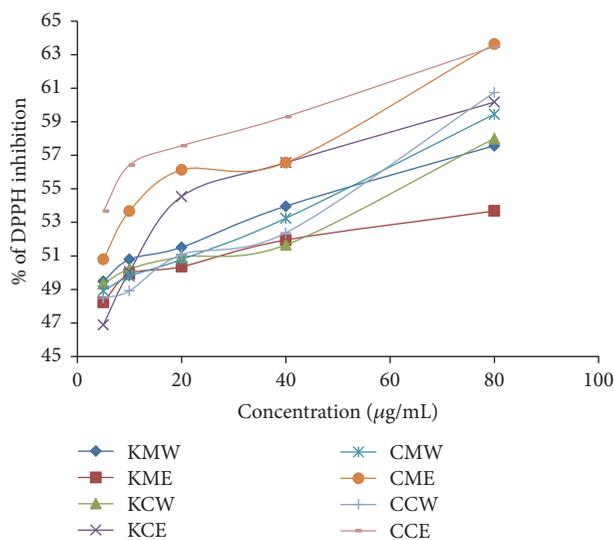


FIGURE 2: Percentage of DPPH inhibition for different turmeric extracts at different concentrations.

important role in prevention of atherosclerosis [34]. Furthermore, the inhibitory action of turmeric polyphenols (curcuminoids) on lipid accumulation, oxidation, nitric oxide as well as the formation of inflammatory molecules, nuclear factor-kappa B- (NF-κB-) dependent gene expression, and its activation can influence the therapeutic effects of turmeric in the pathogenesis of hepatic, pancreatic, intestinal diseases, and cancer as well as in tobacco smoke-induced injury [34].

The ethanolic extract of turmeric can produce remarkable symptomatic relief on external cancerous lesions in human [35]. In addition, turmeric (curcumin) has potential in the prevention and treatment of neurodegenerative diseases as a free radical scavenger, including Alzheimer's disease [34, 36]. Moreover, short-term supplementation of turmeric has been reported to decrease proteinuria, hematuria, and systolic blood pressure in patients with relapsed or refractory lupus nephritis and can be used as a safe adjuvant therapy for the patients [37]. Overall, our study indicates that the high antioxidant properties of turmeric from Bangladesh may inhibit cellular lipid peroxidation and ameliorate other oxidative damage caused by free radicals [32].

We hope that the findings from this research will encourage the design of appropriate studies to identify potent

flavonoids in dietary food supplements. Further study is warranted to identify the individual bioactive compounds in turmeric underlying this high antioxidant activity.

#### 4. Conclusion

Our findings strongly suggest that the turmeric varieties from Bangladesh are promising sources of natural antioxidants, as indicated by their high contents of polyphenols, flavonoids, tannins, and ascorbic acid and by their considerable DPPH free radical-scavenging activities and FRAP values. The extraction yields investigated in both aqueous and ethanol extracts of the turmeric varieties suggest that higher antioxidant compounds could be obtained with ethanol. Chittagong's mura contains the highest TPC, TFC, and ascorbic acid content with considerable DPPH free radical-scavenging activity and a high FRAP value.

#### Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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