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Curcuma longa L: Elemental and Nutritional Profiling of Fifty Accessions from Uttarakhand Region in India

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In present study, the elemental and nutritional values of *Curcuma longa* L. cultivated from 50 different regions of Uttarakhand in India were analyzed. The result showed wide variations in different elemental and nutritional content. Turmeric rhizomes collected from different regions were nutritious and falls within the safe limit which was required for normal body functioning, reproduction, development and maintenance.

Keywords: *Curcuma longa* L., Uttarakhand, Elemental, Nutritional profiling.

INTRODUCTION

The Himalayas have a great wealth of medicinal plants and traditional medicinal knowledge. Among the diversified flora of medicinal plants the Zingiberaceous herbs were characterized by their tuberous or non-tuberous rhizomes, which have strong aromatic and medicinal properties. The plants belonging to this family were found to be a rich source of substances of phytochemical interest[1]. Number of plants from this family was used in traditional system of medicine. One of these was the rhizomes of *Curcuma longa* which play an important role in traditional as well as in modern system of medicinal sciences.

Curcuma longa L. commonly known as Turmeric in English and Haldi in Hindi occupies an important position in the life of Indian people as it forms an integral part by the rituals, ceremonies and cuisine[2]. The old Hindu texts described it as an aromatic stimulant and carminative[3]. Due to the strong antiseptic properties, turmeric has been used as a remedy for all kinds of poisonous affections, ulcers and wounds[4]. It gives good complexion to the skin and so it is applied to face as a depilatory and facial tonic. The drug cures diseases due to morbid vata, pitta and kapha, diabetes, eye diseases, ulcers, oedema, anaemia, anorexia, leprosy and scrofula[5]. It purifies blood by destroying the pathogenic organism.

Curcuma longa L. is a potent scavenger of a variety of ROS, including superoxide anion[6], hydroxyl radical, singlet oxygen[7], nitric oxide and peroxynitrite. It has the ability to protect lipids, haemoglobin and DNA against oxidative degradation. Turmeric has also been reported to possess anti-inflammatory hepatoprotective, antitumor anti-diabetes and anticancer, antibacterial activity and is used in gastrointestinal and respiratory disorders[8].

Uttarakhand is a big repository of aromatic and medicinal plants. Geographically, it is distributed to sub-tropical to temperate and alpine regions. Plant species growing in these regions possessed different phytochemicals make up and biological activities because of different climatic and edaphic conditions. Less studies have been carried out to investigate the nutritional values of *Curcuma longa* L. cultivated in Uttarakhand (India). Hence keeping the above fact in view the present research has been planned to determine the elemental and nutritional values of *Curcuma longa* L. cultivated in 50 different regions of Uttarakhand in India.

EXPERIMENTAL

The rhizomes of plant turmeric were collected from 50 different altitudes *viz.* hills and Tarai regions of Uttarakhand (Garhwal and Kumaun region) in India in the month of October-November (Table-1). All the samples were washed thoroughly under tap water, sliced, air dried, grounded to fine powder and finally stored in deep freezer for further analysis. The solvents and chemicals used were of laboratory and analytical grade and were obtained from E. Merck, Molychem and Himedia. The glassware's used for the study were either of corning or borosil.

Elemental profiling: 0.5 g of dried plant material was transferred in a 150 mL conical flask. 10 mL of diacid or triacid

mixture was added. A funnel was placed on the flask and allowed to stand for overnight. Heated gently at first and then heated more vigorously until a clear, colourless solution was obtained. Discontinued heating when the volume was reduced to approximately 3 to 5 mL. Cooled and transferred quantitatively to a 100 mL volumetric flask, marked it to volume, mixed, allowed to stand overnight and filtered through Whatman No. 1 filter paper. This solution was retained and used for analysis of P, K, Ca, Mg, Fe, Zn, Cu and Mn.

Estimation of phosphorus: Phosphorus was estimated spectrophotometrically as described by Jackson[9] in brief: 10 mL aliquot (of the plant material digested) was added in a 50 mL volumetric flask; 10 mL vanadate-molybadate solution was added and diluted to 50 mL with distilled water. Colour intensity was taken at 470 nm on spectrophotometer. Percent P_2O_5 in the plant sample was determined from the standard curve.

Estimation of potassium: Potassium was estimated by flame photometer as described by Jackson[9]. The procedure followed in brief: Flame photometer was set up to 0 scale reading by atomizing distilled water adds to 100 by atomizing 100 mg K/I solution alternatively. Atomized the unknown solution through the flame and recorded flame photometer reading, the amount of potassium in the given acid extract was determined by a standard curve of known potassium concentrations.

Estimation of Fe, Mn, Mg, Zn and Cu: Fe, Mn, Zn and Cu were estimated spectrophotometrically as described by Elwell and Gidley[10]. The standard belonging to the element was feeded along with double distilled water (0 ppm) to AAS to standardize the instrument to read concentration in the samples having the given element within the standard range. Then the plant acid extracts was added and the concentration of the element was recorded. Repeated the above steps for each element.

Estimation of total nitrogen: The content analysis of total nitrogen in the dried sample was done by Kjeldahl method[11] as described below:

Digestion: 0.5 g powdered plant sample wrapped in piece of filter paper was transferred to 100 mL Kjeldahl flask, 50 mL of the sulphuric + salicyclic acid mixture were added in the flask and was shaked to get intimate contact of the sample with the reagent. Now 5 g sodium thiosulphate was added and heated gently for about 5 min, taking care to avoid frothing. Now the mixture was cooled and 10 g catalyst mixture was added and then digested in Kjeldahl flask at full heat till the solution become clear. Solution was cooled and 100 mL of distilled water was added into the solution. Finally distillation was carried out as follows:

Distillation: 25 mL of 4 % boric acid solution containing mix indicator was taken in a conical flask and flask was placed in such a way that condenser outlet of distillation apparatus was dipped into this boric acid solution. The content of Kjeldahl flask was transferred to distillation flask. Washed 2 to 3 times with distilled water to ensure that whole content of Kjeldahl flask transferred into distillation flask, 100 mL of 40 % sodium hydroxide was added along the sides of the flask. Connected to distillation head and distilled off 150 mL into 25 of 4 % boric acid solution. Titrated it to the first faint pink colour with standard (0.1 N) sulphuric acid solution. Blank was run and the titration carried to the same end point in exactly the same manner. Finally the % of N was calculated by the equation:

$$\text{N in plant (\%)} = \frac{(S - B) \times N \text{ of } H_2SO_4 \times 0.014}{0.5} \times 100$$

Estimation of ascorbic acid: Ascorbate is converted into dehydroascorbate on treatment with activated charcoal,which reacts with 2,4-dinitrophenyl hydrazine to form osazones. These osazones produced an orange coloured solution when dissoloved in sulphuric acid, whose absorbance can be measured spectrophotometrically at 540 nm.

Ascorbate was extracted by homogenizing 1 g of the sample with 10 mL of 4 % trichloroacetic acid. The supernatant obtained after centrifugation at 2000 rpm for 10 min was treated with a pinch of activated charcoal, shaken vigorously using a cyclomixer and kept for 5 min. The charcoal particles were removed by centrifugation and aliquots were used for the estimation.

1 mL of aliquots was taken and made up to 2 mL with 4 % trichloroacetic acid. 0.5 mL of dinitrophenyl hydrazine reagent was added to all the test tube. After few minutes, 2 drops of 10 % thiourea solution was added and incubated at 37 °C for 3 h resulting in the formation of osazone crystals. The crystals were dissolved in 2.5 mL of 85 % sulphric acid, in cold. To the blank alone, dinitrophenyl hydrazine reagent and thiourea were added after the addition of sulphuric acid. The test tubes were cooled in ice and the absorbance was read at 540 nm. The ascorbic acid content (µg/g fresh wt.) was calculated by using a standard curve (10-100 µg) prepared by using ascorbic acid as standard[12].

Estimation of carbohydrate: 100 mg of each powdered rhizome samples were grinded separately in 80 % ethanol and centrifuge. The supernatant was evaporated up to dryness. 1 mL of saturated basic lead acetate and distilled water was added to make the final volume of 100 mL. After some time the solution was precipitated. It was filtered and a pinch of sodium oxalate was added and filtered again. This clear solution was used for the estimation of total sugar, reducing sugar and non reducing sugar.

Total sugar content: The basic principle of this method is that, when carbohydrates dehydrated by reaction with concentrated sulfuric acid, produced furfural derivatives. Further reaction between furfural derivatives and phenol develops detectible colour. 200 µL of aliquot of a carbohydrate solution was madeup to 1 mL by distilled water and mixed with 1 mL of 5 % aqueous solution of phenol in a test tube. Subsequently, 5 mL of concentrated sulphuric acid was added rapidly to the mixture. After allowing the test tubes to stand for 10 min, they were vortexed for 30 s and placed for 20 min in a water bath at room temperature and finally the absorbance was read at 490 nm. A calibration curve was prepared with D-glucose (10-100 µg) and results are expressed as mg equivalents per g sample[13].

Total reducing sugar and non-reducing sugar: 500 µL of aliquot of a carbohydrate solution was madeup to 1 mL by distilled water and mixed with 2 mL of 3,5-dinitrosalicylic acid (DNS) reagent. The content was mixed and heated in a boiling water bath for 5 min. After the colour had developed

1 mL of 40 % Rochelle salt and 10 mL of water were added. The intensity of colour was read at 540 nm and the amount of reducing sugar present in the sample was calculated using the calibration curve. A calibration curve was prepared with maltose (10-100 µg) and results were expressed as mg equivalents per g sample[14]. Non-reducing sugar was estimated by the difference of total sugar and reducing sugar.

Estimation of total protein content: 1 g fresh rhizome of turmeric was grinded with 5 mL of phosphate buffer (pH 7). The content was centrifuge at 8000 rpm for 15 min at 4 °C. 1 mL of supernatant was taken and 1 mL of 20 % trichloroacetic acid was mixed in it. The mixture was incubated for 1 h at room temperature. On centrifuging the tube at 8000 rpm for 15 min, a pallet was formed. Discarding the supernatant the pallet was washed by chilled acetone twice. The pallet was dissolved in 5 mL of 0.1 N NaOH. The total protein was estimated by Bradford method. Bovine serum albumin (BSA) was used as standard and result was expressed in mg equivalent per g sample[15].

RESULTS AND DISCUSSION

The elemental results obtained quantitatively from AAS of 50 different accessions for their elemental profiling has been recorded in Table-1.

Iron content: The result showed that Fe concentration was ranging from 3462.58 to 20.89 mg/kg in different collection. The lowest concentration (20.89 mg/kg) was observed in sample collected from Kathgodam (Nainital) and the highest (3462.58 mg/kg) was observed in Dholiya pata (Bageshwar) collection. Iron is an essential element in production of red blood cells. Low intake of Fe may cause anemia, tiredness and pallid physique, while hight intake may result into hepatic megaly, cardiac infraction and nephric malfunction. The acceptable limit for human consumption of iron is 8 to 11 mg/day[16]. Among all the metals under investigation, Fe shows the maximum concentration which can be due to the iron rich soil in which the plants are grown. It has been found that vitamin C enhances the potential of iron for mucosal uptake[17]. It was also found that turmeric is also rich in vitamin C (Table-2). Therefore consumption of turmeric can be a good remedy for iron deficiency control as it will promote better bioavailability.

Copper content: Copper is required for the development of foetal brain and maintenance of brain throughout the life. It is also involved in the formation of the cells of the immune system and it also maintains proper structure and function of circulating blood vessels[18]. When Cu exceeds its safe level concentration, it causes hypertension, sporadic fever, uremias, coma, *etc*. The acceptable limit for human consumption of copper is 2 mg/day[16]. Present investigation reveals that Cu varies from 1.11 to 198.03 mg/kg. The highest concentration (198.03 mg/kg) was observed in Nanakmatta (Udham Singh Nagar) collection and lowest (1.11 mg/kg) in Harsil (Uttarkashi) collection. Kumar *et al*., has been also reported the similar range of Cu in vegetables[19].

Zinc content: Zinc is a cofactor of over 270 enzymes involved in metabolic pathways but its high levels in human body can be toxic due to its interference with copper metabolism[20]. Therefore, dietary zinc intake should be appropriate. Zinc is an essential element in the human diet as it is required to maintain the proper functions of the immune system. It is also important for normal brain activity and is fundamental in the growth and development of the foetus. The average daily intake of zinc is 7-16.3 mg/day; the recommended dietary allowance for it is 15 mg/day for men and 12 mg Zn/day for women[16]. The high concentration of Zinc may cause vomiting, renal damage, cramps *etc*. The acceptable limit for human consumption of Zn is 150 ppm. Present study, revealed presence of Zn in the range from 3.56 to 211.75 mg/kg, which falls within the safe limit. The highest concentration of Zn was found in Pantnagar (Udham Singh Nagar) collection (211.75 mg/kg), while lowest concentration was detected in Bhimtal (Nainital) collection (3.56 mg/kg). Bhowmik *et al*., has also been reported Zn (38.68 ppm) in curcumin[21].

Manganese content: The experimental results showed that the Mn concentration in different samples was ranged from 5.56 to 110.88 mg/kg. The lowest concentration (5.56 mg/kg) was observed in sample collected from Dharchula (Pithoraghar) and highest concentration (110.88 mg/kg) was observed in collection from Kanda. It has been reported that Mn act as co-factor in more than 300 metabolic reactions. Deficiency of manganese causes myocardial infarction. 62 % of diabetic patients are at risk with higher manganese content. The recommended daily requirement of manganese is 1.6 to 2.3 mg/day in humans[16].

Phosphorus content: Persual of results as recorded in Table-1 revealed the range of phosphorus between 0.04 to 0.99 %. Maximum content was detected in Devprayag (Chamoli) collection and minimum was found in Barswar (Pauri Garhwal) collection. The balance of phosphorus and calcium is regulated by parathyroid hormone, which increases urinary excretion of phosphate under conditions of high phosphate and low calcium intake[22]. The United States Institute of Medicine recommended dietary dose of phosphorus is 460-1250 mg per day for different age groups[23].

Calcium content: Calcium content in *C. longa* was found in the range between 0.19 to 1.42 %. The highest concentration (1.42 %) was found in Khatima (Udham Singh Nagar) collection while lowest (0.19 %) was found in Pithoragarh collection. The recommended daily allowance of Ca for children is between 500 mg to 1000 mg and for adults 800 mg[24]. There are several factors involved in determining the calcium content. The absorption of calcium by roots is a genetically determined factor that decides the rate of root growth as well as the apoplastic and symplastic calcium absorption by the roots and subsequent transfer to the other plant parts. High level of root growth can increase the rate of calcium absorption by the plants[25].

Magnesium content: Magnesium content in *C. longa* was found in the range between 0.09 to 0.85 %. Maximum content was detected in Chamoli collection and minimum was recorded in Ramnagar (Udham Singh Nagar) collection. The recommended daily requirement of magnesium is 1.6 to 2.3 mg/day and 3,000 to 5000 mg/day respectively for humans.[16] Magnesium is an important for energy production and transport is involved in glycolysis, oxidative phosphorylation. It is also required for maintaining normal heart rhythm.[18] Magnesium is also involved in muscular activity and also required by more than 300 enzymes in the body to catalyze various important functions such as protein synthesis, muscle and nerve function.

TABLE-1
COLLECTION SITE, ALTITUDE AND ELEMENTAL PROFILING IN DIFFERENT COLLECTIONS OF *Curcuma longa* L.

S. No.	Collection site	District	Altitude (m)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	P (%)	K (%)	Mg (%)	Ca (%)	N (%)
1	Haridwar	Haridwar	295	33.24	12.94	25.59	1353.24	0.48	1.19	0.71	0.59	21.56
2	Kotdwar	Pauri Garhwal	454	93.80	12.60	112.60	159.60	0.32	0.92	0.32	0.32	11.48
3	Pantnagar	Udham Singh Nagar	241	211.75	8.50	6.25	23.50	0.35	1.08	0.70	0.60	22.96
4	Barswar	Pauri Garhwal	806	6.15	1.90	165.41	469.49	0.04	0.69	0.10	0.31	16.24
5	Dharchula	Pithoragarh	909	60.00	5.33	5.56	876.44	0.75	1.12	0.37	0.44	13.16
6	Jhankayia	Udham Singh Nagar	212	24.17	2.06	71.53	78.33	0.27	1.44	0.55	0.33	11.76
7	Pithoragarh	Pithoragarh	1650	32.79	2.15	26.21	316.51	0.41	1.58	0.45	0.19	17.08
8	Didihat	Pithoragarh	1725	33.91	2.01	32.61	489.78	0.33	1.01	0.21	0.35	14.56
9	Nainital	Nainital	1938	36.45	3.18	8.40	151.29	0.31	1.75	0.39	0.52	12.88
10	Chamoli	Chamoli	1755	61.29	3.46	49.55	30.32	0.48	2.99	0.85	0.39	19.04
11	Harsil	Uttarkashi	2620	14.44	1.11	21.19	221.67	0.26	1.46	0.20	0.67	17.08
12	Kapkot	Bageshwar	1104	30.51	1.98	9.59	337.18	0.32	1.94	0.25	0.62	14.28
13	Dwarahat	Almora	1466	20.28	1.26	61.32	78.33	0.35	1.73	0.48	0.89	9.52
14	Jeolikot	Nainital	1219	14.00	1.66	96.46	169.00	0.44	1.12	0.24	0.40	18.2
15	Kathgodam	Nainital	554	36.00	3.04	50.30	20.89	0.51	2.33	0.59	0.27	25.2
16	Ukhimath	Rudraprayag	1317	33.60	2.69	27.60	244.20	0.41	1.77	0.61	0.56	24.64
17	Moani	Pithoraghar	844	42.20	2.80	55.00	216.00	0.34	2.15	0.53	0.32	11.48
18	Champawat	Champawat	1615	111.60	15.62	110.88	206.60	0.27	1.17	0.34	0.32	23.52
19	Patwadanger	Nainital	1155	142.40	19.03	70.00	159.60	0.41	0.63	0.34	0.32	15.96
20	Maram	Almora	1650	78.00	9.23	140.20	84.40	0.36	0.79	0.34	0.32	10.92
21	Ramgarh	Nainital	1518	73.60	2.80	90.00	93.80	0.60	1.78	0.43	0.32	17.64
22	Patanpatni	Champawat	258	36.80	6.08	110.20	816.80	0.44	1.93	0.53	0.32	14.84
23	Dhari	Nainital	520	57.60	6.75	72.60	497.60	0.46	1.15	0.38	0.24	14.56
24	Mukteswar	Nainital	2170	23.80	8.03	126.18	591.60	0.45	1.97	0.19	0.48	14.00
25	Roorkee	Haridwar	268	29.47	7.92	81.14	350.49	0.56	1.86	0.33	0.47	35.28
26	Deharadun	Deharadun	640	31.30	1.13	12.20	702.36	0.51	2.32	0.14	0.39	22.12
27	Karnaprayag	Chamoli	788	29.53	5.19	199.61	388.19	0.20	0.88	0.14	0.39	10.92
28	Kausani	Almora	1890	80.79	19.70	180.99	65.15	0.35	1.25	0.10	0.55	22.68
29	Chaukhutia	Almora	1039	17.17	1.81	77.51	515.37	0.35	0.97	0.48	0.32	17.64
30	Haldwani	Nainital	425	61.63	8.75	9.94	130.62	0.28	1.06	0.19	0.56	19.04
31	Munsiyari	Pithoragarh	2298	111.07	22.33	96.44	185.57	0.41	1.57	0.24	0.40	21.56
32	Binsar	Almora	2412	72.44	18.31	100.98	157.09	0.53	1.04	0.38	0.39	24.92
33	Ramnagar	Udham Singh Nagar	344	9.63	12.38	151.51	73.87	0.32	1.32	0.09	0.39	15.68
34	Takula	Almora	1400	37.99	6.69	87.36	74.02	0.28	1.27	0.19	0.31	22.68
35	Lohaghat	Champawat	1745	78.98	12.38	341.85	184.48	0.43	1.42	0.24	0.39	20.44
36	Kota	Champawat	1020	131.29	16.44	282.57	148.71	0.36	1.16	0.29	0.40	22.4
37	Gopeshwar	Chamoli	1300	10.89	16.04	397.41	297.43	0.49	2.35	0.24	0.40	21.28
38	Kanda	Bageshwar	345	154.89	12.57	457.09	431.14	0.33	0.57	0.34	0.48	20.72
39	Tehri	Tehri Garhwal	1550	36.15	24.17	56.61	36.94	0.34	1.28	0.19	0.31	13.72
40	Khantoli	Bageshwar	520	17.76	18.56	182.44	215.57	0.15	0.98	0.51	0.80	13.44
41	Devprayag	Chamoli	475	12.06	18.38	106.31	519.57	0.99	1.31	0.44	1.19	15.12
42	Ganai gangoli	Pithoraghar	520	27.65	16.27	17.06	552.35	0.64	1.13	0.33	0.39	14.84
43	Dholiya pata	Bageshwar	522	37.64	39.82	49.23	3462.58	0.58	1.62	0.29	0.35	14.00
44	Narendranagar	Tehri Garhwal	1322	51.20	8.05	62.92	145.20	0.65	1.41	0.21	0.40	14.56
45	Bhimtal	Nainital	1375	3.56	24.36	12.59	743.76	0.58	1.22	0.36	0.32	10.64
46	Chakrata	Deharadun	2270	8.57	26.49	7.37	514.34	0.44	1.98	0.26	0.88	12.32
47	Joshimath	Chamoli	2100	9.54	34.39	96.43	679.86	0.35	1.94	0.65	0.27	17.36
48	Shrinagar	Pauri Garhwal	560	60.00	33.06	183.88	478.98	0.49	2.00	0.14	0.65	21.00
49	Nanakmatta	Udham Singh Nagar	298	61.14	198.03	399.80	342.60	0.50	0.91	0.24	0.87	12.88
50	Khatima	Udham Singh Nagar	198	5.68	58.71	274.85	681.61	0.45	2.87	0.31	1.42	14.03

Potassium content: The experimental result showed that the potassium concentration in different samples was ranging from 0.57 to 2.99 %. The lowest concentration (0.57 %) was observed in sample collected from Kanda (Bageshwar) and highest concentration (2.99 %) was observed in collection from Chamoli. The recommended daily requirement of potassium was 3,000 to 5000 mg/day for humans[16]. Potassium is an electrolyte that is essential to cardiac and tissue health, skeletal contraction and gastrointestinal function. Optimum potassium levels can also decrease the risk of stroke, cardiovascular disease, osteoporosis, kidney stones and high blood pressure. Low potassium levels, or hypokalemia, can lead to weakness, lack of energy, high blood pressure, muscle cramping, gastrointestinal distress, arrhythmia and abnormal electrocardiograms. Abnormally high levels of potassium can lead to potassium toxicity, or hyperkalemia. Hyperkalemia can cause muscular weakness, tingling in the extremities, temporary paralysis and, ultimately, death by cardiac arrest due to cardiac arrhythmia.

TABLE-2
NUTRITIONAL PROFILING IN DIFFERENT COLLECTIONS OF *Curcuma longa* L.

S. No.	Sample name	Ascorbic acid (mg/g)	Total sugar (mg/g)	Reducing sugar (mg/g)	Non-reducing sugar (mg/g)	Total protein (mg/g)
1	Haridwar	0.734118 ± 0.02 ^{q}	22.08333 ± 1.50 ^{g,h,i}	5.6 ± 0.188^{s,t,u,v}	16.48 ± 1.676^{d,e}	17.0 ± 0.277^{s}
2	Kotdwar	0.974118 ± 0.01 ^{t}	41.66667 ± 1.50 ^{u,v,w}	4.4 ± 0.288^{o,p,q}	37.26 ± 1.681^{k,l}	13.3 ± 0.277^{m,n}
3	Pantnagar	0.211765 ± 0.01 ^{d}	14.58333 ± 1.44 ^{a}	6 ± 0.288^{v,w,z}	8.58 ± 1.241^{a}	17.4 ± 0.086^{s}
4	Barswar	1.286275 ± 0.02 ^{v}	45 ± 0.72 ^{y}	5.2 ± 0.108^{r,s,t,u}	39.8 ± 0.839^{l,m,n,o}	18.0 ± 0.086^{t}
5	Dharchula	0.275294 ± 0.01 ^{g}	33.75 ± 1.10 ^{n,o}	11.2 ± 0.392^{z}	22.55 ± 0.625^{f}	12.6 ± 0.063^{l}
6	Jhankayia	0.449569 ± 0.01 ^{j}	25.83333 ± 0.42 ^{j,k}	4 ± 0.288^{n,o}	21.83 ± 0.758^{f}	16.0 ± 0.063^{r}
7	Pithoragarh	1.110588 ± 0.02 ^{v}	37.5 ± 1.10 ^{q,r,s}	6.13 ± 0.108^{v,w,x}	31.36 ± 1.229^{h,i}	08.3 ± 0.063^{e}
8	Didihat	0.224314 ± 0.07 ^{e}	40.41667 ± 0.83 ^{t,u,v}	3.6 ± 0.288^{l,m,n}	36.81 ± 0.841^{k}	17.3 ± 0.110^{d}
9	Nainital	0.242353 ± 0.01 ^{e,f}	37.08333 ± 0.42 ^{p,q,r}	7.2 ± 0.188^{y}	29.88 ± 0.245^{h}	14.4 ± 0.063^{o,p}
10	Chamoli	0.842353 ± 0.08 ^{r}	32.08333 ± 0.72 ^{m,n}	5.68 ± 0.273^{t,u,v}	26.39 ± 0.434^{g}	16.3 ± 0.041^{r}
11	Harsil	0.676078 ± 0.07 ^{p}	44.58333 ± 1.82 ^{x,y}	3.06 ± 0.108^{I,j,k,l}	41.51 ± 1.694^{o}	13.2 ± 0.063^{m,n}
12	Kapkot	0.310588 ± 0.04 ^{h}	24.16667 ± 0.72 ^{i,j}	6.4 ± 0.188^{w,x}	17.76 ± 0.638^{e}	10.2 ± 0.133^{i}
13	Dwarahat	0.16 ± 0.08 ^{b}	42.5 ± 1.10 ^{v,w,x,y}	4.13 ± 0.288^{n,o,p}	38.36 ± 0.785^{k,l,m}	08.8 ± 0.063^{f}
14	Jeolikot	0.916078 ± 0.01 ^{s}	35 ± 1.50 ^{o,p}	5.2 ± 0.108^{r,s,t,u}	29.8 ± 1.470^{h}	19.0 ± 0.110^{u}
15	Kathgodam	0.574118 ± 0.08 ^{m,n}	21.25 ± 0.42 ^{f,g,h}	4.8 ± 0.188^{p,q,r}	16.45 ± 0.627^{d,e}	15.6 ± 0.063^{b}
16	Ukhimath	1.369412 ± 0.02 ^{w}	42.22222 ± 0.86 ^{v,w,x}	5.28 ± 0.166^{r,s,t,u}	36.93 ± 0.970^{k}	13.1 ± 0.133^{m}
17	Moani	0.545882 ± 0.08 ^{l}	33.75 ± 0.42 ^{n,o}	2 ± 0.217^{b,c,d,e,f}	31.75 ± 0.596^{h,i}	08.1 ± 0.168^{e}
18	Champawat	0.837647 ± 0.08 ^{r}	34.58333 ± 1.10 ^{o}	4.93 ± 0.188^{q,r,s}	29.65 ± 1.198^{h}	12.3 ± 0.127^{l}
19	Patwadanger	1.083922 ± 0.05 ^{u}	42.91667 ± 1.50 ^{u,w,x,y}	3.06 ± 0.288^{I,j,k,l}	39.85 ± 1.729^{l,m,n,o}	09.0 ± 0.104^{f}
20	Maram	0.230588 ± 0.01 ^{d,e,f}	40.41667 ± 0.72 ^{t,u,v}	2.53 ± 0.474^{f,g,h,I,j}	37.88 ± 0.158^{k,l,m}	13.1 ± 0.041^{m}
21	Ramgarh	0.600784 ± 0.07 ^{o}	43.33333 ± 1.10 ^{w,x,y}	5.86 ± 0.288^{u,v,w}	37.46 ± 0.975^{k,l}	09.0 ± 0.110^{f,g}
22	Patanpatni	0.122353 ± 0.08 ^{a}	37.08333 ± 0.42 ^{p,q,r}	2.8 ± 0.188^{g,h,I,j,k}	34.28 ± 0.245^{j}	06.4 ± 0.072^{c}
23	Dhari	0.233725 ± 0.07^{e,f}	27.91667 ± 1.44 ^{k,l}	2.4 ± 0.108^{e,f,g,h,i}	25.51 ± 1.560^{g}	06.1 ± 0.096^{c}
24	Mukteswar	1.598431 ± 0.07 ^{x}	42.08333 ± 0.72 ^{v,w,x}	2.13 ± 0.288^{b,c,d,e,f,g}	39.95 ± 0.691^{m,n,o}	13.5 ± 0.063^{n}
25	Roorkee	2.619608 ± 0.07 ^{y}	38.75 ± 1.50 ^{r,s,t}	1.46 ± 0.188^{a,b}	37.28 ± 1.676^{k,l}	24.0 ± 0.110^{w}
26	Deharadun	1.171765 ± 0.08 ^{v}	18.75 ± 1.50 ^{c,d,e}	1.2 ± 0.108^{a}	17.55 ± 1.544^{e}	19.0 ± 0.133^{u}
27	Karnaprayag	1.044706 ± 0.02 ^{u}	33.75 ± 1.10 ^{n,o}	1.6 ± 0.188^{a,b,c,d}	32.15 ± 1.198^{h,i,j}	09.0 ± 0.063^{f,g}
28	Kausani	0.367059 ± 0.08 ^{i}	31.25 ± 1.10 ^{m}	5.06 ± 0.288^{q,r,s,t}	26.18 ± 1.204^{g}	13.0 ± 0.041^{m,n}
29	Chaukhutia	0.585098 ± 0.09 ^{n,o}	22.91667 ± 0.72 ^{h,i}	2.22 ± 0.273^{c,d,e,f,g,h}	20.69 ± 0.830^{f}	11.9 ± 0.166^{k}
30	Haldwani	0.381176 ± 0.04 ^{i}	42.5 ± 0.72 ^{v,w,x,y}	2.66 ± 0.288^{f,g,h,I,j}	39.83 ± 0.901^{l,m,n,o}	08.0 ± 0.168^{e}
31	Munsiyari	0.602353 ± 0.08 ^{o}	56.25 ± 0.72 ^{z}	6.57 ± 0.226^{x,y}	49.67 ± 0.842^{p}	12.3 ± 0.041^{l}
32	Binsar	0.545882 ± 0.08 ^{l}	18.75 ± 0.41 ^{c,d,e}	3.11 ± 0.226^{i,j,k,l}	15.63 ± 0.687^{c,d,e}	21.1 ± 0.127^{v}
33	Ramnagar	0.44549 ± 0.02 ^{j}	14.58333 ± 1.10 ^{a}	1.6 ± 0.288^{a,b,c,d}	12.98 ± 0.785^{b}	14.7 ± 0.104^{p,q}
34	Takula	0.583529 ± 0.08 ^{n,o}	17.08333 ± 0.72 ^{b,c}	3.06 ± 0.288^{i,j,k,l}	14.01 ± 0.901^{b,c,d}	14.2 ± 0.063^{o}
35	Lohaghat	0.572549 ± 0.07 ^{m,n}	42.91667 ± 0.42 ^{v,w,x,y}	3.2 ± 0.288^{j,k,l,m}	39.71 ± 0.275^{l,m,n,o}	17.3 ± 0.063^{s}
36	Kota	0.316863 ± 0.05 ^{h}	34.58333 ± 1.10 ^{o}	3.24 ± 0.166^{j,k,l,m}	31.33 ± 1.282^{h,i}	05.6 ± 0.133^{b}
37	Gopeshwar	0.56 ± 0.08 ^{l,m}	15.41667 ± 1.44 ^{a,b}	1.51 ± 0.273^{a,b,c}	13.90 ± 1.190^{b,c}	14.7 ± 0.209^{p,q}
38	Kanda	0.851765 ± 0.01 ^{r}	42.5 ± 0.41 ^{v,w,x,y}	3.2 ± 0.288^{j,k,l,m}	39.3 ± 0.758^{k,l,m,n,o}	13.1 ± 0.104^{m}
39	Tehri	0.363922 ± 0.05 ^{i}	19.58333 ± 0.72 ^{d,e,f}	3.06 ± 0.217^{i,j,k,l}	16.51 ± 0.961^{d,e}	10.2 ± 1.192^{i}
40	Khantoli	0.307451 ± 0.09 ^{h}	35.83333 ± 0.72 ^{o,p,q}	2.93 ± 0.288^{h,i,j,k,l}	32.9 ± 1.070^{I,j}	08.2 ± 0.072^{e}
41	Devprayag	0.312157 ± 0.07 ^{h}	43.75 ± 0.42 ^{w,x,y}	3.06 ± 0.217^{i,j,k,l}	40.68 ± 0.365^{n,o}	09.7 ± 0.086^{h}
42	Ganai gangoli	0.498824 ± 0.04 ^{k}	17.5 ± 1.10 ^{b,c,d}	3.06 ± 0.377^{I,j,k,l}	14.43 ± 0.654^{b,c,d}	04.9 ± 0.041^{a}
43	Dholiya pata	0.294902 ± 0.01 ^{g,h}	20.41667 ± 1.10 ^{e,f,g}	2.66 ± 0.288^{f,g,h,i,j}	17.75 ± 1.314^{e}	16.4 ± 0.173^{r}
44	Narendranagar	0.25098 ± 0.07 ^{f}	23.75 ± 0.72 ^{I,j}	3.2 ± 0.217^{j,k,l,m}	20.55 ± 0.769^{f}	14.8 ± 0.063^{q}
45	Bhimtal	0.188235 ± 0.02 ^{c}	42.5 ± 0.72 ^{v,w,x}	3.86 ± 0.108^{m,n,o}	38.63 ± 0.609^{k,l,m,n}	07.3 ± 0.104^{d}
46	Chakrata	0.597647 ± 0.08 ^{o}	18.75 ± 1.50 ^{c,d,e}	3.28 ± 0.125^{j,k,l,m}	15.46 ± 1.650^{b,c,d,e}	04.8 ± 0.086^{a}
47	Joshimath	0.489412 ± 0.08 ^{k}	39.58333 ± 1.50 ^{s,t,u}	1.73 ± 0.217^{a,b,c,d,e}	37.85 ± 1.698^{k,l}	11.1 ± 0.063^{j}
48	Shrinagar	0.142745 ± 0.07 ^{b}	28.75 ± 0.41 ^{l}	2.26 ± 0.188^{d,e,f,g,h}	26.48 ± 0.476^{g}	18.9 ± 0.086^{u}
49	Nanakmatta	0.574118 ± 0.01 ^{m,n}	13.75 ± 0.72 ^{a}	3.46 ± 0.288^{k,l,m,n}	10.28 ± 0.381^{a}	07.3 ± 0.086^{d}
50	Khatima	0.919216 ± 0.05 ^{s}	19.58333 ± 1.10 ^{d,e,f}	2.17 ± 0.062^{b,c,d,e,f,g}	17.40 ± 1.1780^{e}	09.2 ± 0.086^{g}

Each value is the mean (± standard deviation) of three replicate experiments.
Different letters (a-z) within columns indicates significant different ($P < 0.01$)

Nitrogen content: According to the International Dairy Foundation, a healthy adult male needs about 105 mg of nitrogen per kg and about 0.83 g of protein per kg per day is considered sufficient to cover nitrogen requirements[26]. The breakdown of protein results in ammonia, a nitrogen-containing byproduct that our body eliminates. The total nitrogen content in different samples varied from 9.52 to 35.28 % with highest content in Roorkee (Haridwar) collection and lowest in Dwarahat (Almora) collection.

Ascorbic acid content: Ascorbic acid content of *C. longa* L. rhizomes in different collection varied from 0.122 ± 0.008 to 2.62 ± 0.0071 mg/g. Ascorbate was used as a standard compound and the total ascorbic acid content was expressed as mg/g ascorbate equivalent. Maximum ascorbic acid content (2.62 ± 0.07 mg/g) was found in sample collected from Roorkee (Haridwar) whereas sample collected from Patanpatni (Champawat) showed minimum (0.122 ± 0.008 mg/g) amount of ascorbic acid content (Table-2). A significant variation was

observed in ascorbic acid content in *C. longa* L. rhizome. Based on the Duncan Post hoc analysis by SPSS, the samples can be grouped into 25 groups. No significant difference ($p \leq 0.01$) was observed between samples falling in a single group, depicted with same superscript. The turmeric samples in different groups differed significantly ($P \leq 0.01$) from each other with respect to their ascorbic acid content. Almost similar values have been reported earlier by Sharma *et al.*[27], in different samples of *C. longa* collected from different sites of Uttar Pradesh.

Total sugar content: Among the colorimetric methods for carbohydrate analysis, the phenol-sulfuric acid (PSA) method of DuBois *et al.*[13], is so far the most reliable method and has been extensively used in a wide range of fields. The PSA method has mostly been used for quantitative determination of total sugar and expressed in glucose equivalents. In this method, sugars are dehydrated in the presence of concentrated H_2SO_4 at high temperature, forming furfurals (from pentoses) or hydroxymethylfurfurals (from hexoses). Condensation of the latter compounds with a phenol group produces orange-yellow substances was absorbed at 480-490 nm. The colour produced at a constant phenol concentration is proportional to the amount of sugar originally present.

In this study, the total sugar content present in the rhizomes of *Curcuma longa* of different origin varied from 56.25 to 13.75 mg/g. D-Glucose was used as a standard compound and the total sugar content was expressed as mg/g glucose. The maximum sugar content was found in sample collected from Munsiyari (Pithoraghar) whereas minimum amount of sugar content was found in the sample collected from Nanakmatta (Udham Singh Nagar) (Table-2). Based on the Duncan Post hoc analysis by SPSS, the samples can be grouped into 26 groups. No significant difference ($p \leq 0.01$) was observed between samples falling in a single group, depicted with same superscript. The turmeric samples in different groups differed significantly ($P \leq 0.01$) from each other with respect to their total sugar content.

Total reducing and non-reducing sugar: The most abundant free sugars in plants are the disaccharides, sucrose and maltose and the monosaccharide, glucose and fructose. Glucose and maltose have a free aldehyde group when in the chain form, while fructose has a free keto group. The presence of these carbonyl groups means that glucose and fructose can act as reducing agents and hence are known as reducing sugars. The amount of reducing sugar content varied from 11.2 to 1.2 mg/g. D-Maltose was used as a standard compound and the total reducing sugar content was expressed as mg/g maltose equivalent. The maximum amount of total reducing sugar was found in the sample of Dharchula (Pithoraghar) collection whereas minimum was found in Dehradun collection respectively (Table-2). Based on the Duncan Post hoc analysis by SPSS, the samples can be grouped into 26 groups. No significant difference ($p \leq 0.01$) was observed between samples falling in a single group, depicted with same superscript. The turmeric samples in different groups differed significantly ($P \leq 0.01$) from each other with respect to their total reducing sugar content.

Sugars that do not contain free aldehydic or ketonic group with adjacent hydroxyl (OH) group are non reducing sugar. The amount of non reducing sugar content in rhizomes of *Curcuma longa* varied from 49.67 ± 0.84 to 8.58 ± 1.24 mg/g. The comparison among the concentrations of non-reducing sugar content in the samples collected from different regions has been shown in the Table-2 respectively**.** Maximum amount of total non-reducing sugar (49.67 ± 0.84) was found in sample collected from Munsiyari (Pithoraghar) whereas minimum (8.58 ± 1.24 mg/g) was observed in Pantnagar (Udham Singh Nagar). Based on the Duncan Post hoc analysis by SPSS, the samples can be grouped into 16 groups. No significant difference ($p \leq 0.01$) was observed between samples falling in a single group, depicted with same superscript. The turmeric samples in different groups differed significantly ($P \leq 0.01$) from each other with respect to their total non-reducing sugar content. According to Panneerselvam & Jaleel, there was a slight increase in reducing and non-reducing sugars in the rhizomes of *C. longa* up to 7 weeks and sharp increase from 7 to 10 week respectively[28]. There was an increase of 12.72 % of non-reducing sugars in the rhizomes of *C. longa* from the beginning of the storage period to sprouting. However in present study fresh rhizomes were included for study.

Total protein content: The total protein content in different turmeric samples varied from 4.85 ± 0.08 to 24.03 ± 0.11 mg/g. Bovine serum albumin (BSA) was used as a standard compound and the total protein content was expressed as mg/g BSA equivalent. The maximum protein content was recorded in sample collected from Roorkee (Haridwar) while, minimum protein content is recorded in sample collected from Chakrata (Dehradun) (Table-2). Based on the Duncan Post hoc analysis by SPSS, the samples can be grouped into 23 groups. No significant difference ($p \leq 0.01$) was observed between samples falling in a single group, depicted with same superscript. The turmeric samples in different groups differed significantly ($P \leq 0.01$) from each other with respect to their total protein content.

Plant protein represents the primary source of food protein for human and animals. Protein quality is affected by essential amino acid composition, amino acid imbalance, digestibility and biological availability of the amino acids and by the antinutritional activity of some components of the plant[29]. A wide range of proteinaceous inhibitors are present in plants to protect themselves from hydrolytic enzymes. In *C. longa* "Turmerin" an antioxidant protein is present which exhibits antihyperglycaemic effects. The inhibitory potential showed by turmerin against enzymes linked to type 2 diabetes, as well as its moderate antioxidant capacity, could rationalize the traditional usage of turmeric rhizome preparations against diabetes[30]. Present studies reveal that *C. longa* is a good source of protein also.

From our results it was correlated that in reference of the different contents, found that Zn was positively correlated with N and negatively correlated with K at the significance level of 0.05. Cu was negatively correlated with Total Sugar and non-reducing sugar at the level of 0.05 and positively with Ca at the level of 0.01. Fe was positively correlated with P and total ascorbic acid with total protein at the level of 0.05. N was positively correlated with total ascorbic acid and total protein as well as total sugar also showed positive correlation with non-reducing sugar at the level of 0.01 (Table-3).

TABLE-3
CORRELATION SIGNIFICANCE

	Zn	Cu	Mn	Fe	P	K	Mg	Ca	N	T.A	T. S.	T. RS	T. NRS	T. P
Zn	1	.031	.264	-.205	-.071	-.351*	.114	-.167	.292*	-.085	.114	.237	.074	.043
Cu		1	.243	.149	.145	-.064	-.132	.383**	-.133	-.070	-.297*	-.133	-.279*	-.215
Mn			1	-.124	-.077	-.129	-.208	.022	.149	.032	-.037	-.131	-.041	.011
Fe				1	.285*	.065	.009	.022	-.134	-.050	-.150	-.075	-.140	.056
P					1	.229	.140	.206	.080	-.070	-.122	.095	-.141	.000
K						1	.254	.218	.134	.125	-.181	-.076	-.171	.082
Mg							1	-.013	.071	-.068	.019	.263	-.027	-.047
Ca								1	-.137	-.061	-.093	-.051	-.086	-.183
N									1	.459**	-.060	-.016	-.059	.544**
T. A										1	.192	-.143	.222	.351*
T. S											1	.197	.985**	-.084
T. RS												1	.023	.042
T. NRS													1	-.093
T. P														1

*Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level; T.A= total ascorbic acid content; T.S= total sugar content; T.RS= total reducing sugar; T.NRS= total non-reducing sugar content; T.P= total protein content.

Conclusion

Environmental factors *viz*. temperature, humidity, light intensity, the supply of water, minerals and CO_2 influence the growth of a plants and secondary metabolite production. Metal ions (lanthanum, europium, silver, copper, cobalt and cadmium) and oxalate also influence secondary metabolite production. In order to introduce turmeric cultivation into non-traditional areas, cultivars that are adapted to specific agroclimates and give high yields need to be identified. Our study showed that turmeric cultivated in different regions were nutritious and falls within the safe limit, required for normal body function, reproduction, development and maintenance. Sample collected from Roorkee showed maximum amount of total protein, total ascorbic acid and nitrogen content and from Munsiyari showed maximum amount of total sugar and non-reducing sugar whereas Dharchula showed total reducing sugar. Sample collected from Chamoli showed maximum amount of magnesium and potassium content whereas sample collected from Dholiya pata, Nanakmatta, Pantnagar, Kanda, Devprayag and Khatima showed maximum amount of iron, copper, zinc, manganese, phosphorus and calcium content respectively.

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