EVALUATION OF ANTIOXIDANT ACTIVITY IN ETHANOLIC EXTRACTS OF FIVE CURCUMA SPECIES
Gayatri Nahak and Rajani Kanta Sahu*
B.J.B Autonomous College, Bhubaneswar, Odisha, India

INTRODUCTION
Zingiberaeae family constitutes a vital group of rhizomatous medicinal and aromatic plants characterized by the presence of volatile oils and oleoresins of export value. Generally, the rhizomes and fruits are aromatic, tonic and stimulant; occasionally they are nutritive. Some are used as food as they contain starch in large quantities while others yield an astringent and diaphoretic juice. The important genera coming under Zingiberaeae is Curcuma. Turmeric is a medicinal plant extensively used in Ayurveda, Unani and Siddha medicine as home remedy for various diseases. C. longa L., botanically related to ginger (Zingiberaeae family), is a perennial plant having a short stem with large oblong leaves and bears ovate, pyri form or oblong rhizomes, which are often branched and brownish yellow in colour. It also is used as a food additive (spice), preservative and colouring agent in Asian countries, including China and South East Asia. It is also considered as auspicious and is a part of religious rituals. In old Hindu medicine, it is extensively used for the treatment of sprains and swelling caused by injury. In recent times, traditional Indian medicine uses turmeric powder for the treatment of biliary disorders, anorexia, coryza, cough, diabetic wounds, hepatic disorders, rheumatism and sinusitis. In India, ladies anoint their bodies with turmeric paste, which is considered to be an antiseptic. Purseglove and Haines describe the various uses of Curcuma. Purseglove also gives a limited account of its uses. The medicinal properties of turmeric are innumerable and very ancient. Kirtikar and Basu state that the rhizome is very pungent, bitter, healing, laxative, anthelmintic, vulnerary, tonic, astringent and emollient. It is used as a medicine in various kapha and vata diseases of blood. In Commbodia it is used as a tonic and antipyretic. In China it is used as a stimulant, aspirant, carminative, cordeal, emmenagogue, astringent, detergent, diuretic and matrinent. It is used in Unani systems in treating, jaundice, scabies and bruises. On the whole it is used in the treatment of bronchitis, dropsy, vertigo, skin diseases, liver infections, burns, boils, leucorrhoea, sprains, hysteric effects, fevers, swellings, chronic gonorrhoea, bruises, small pox, chicken pox, scorpion snake and leech bites, congestions, scabies, dyspepsia, ring worm, etc.

Curcuma longa Linn. syn. Curcuma domestica Valeton. is a perennial herb, 60-90cm in height, with a short stem and tufts of erect leaves. Rhizome is cylindric, ovoid, orange coloured and branched. Leaves are simple, very large, petiole as long as the blade, oblong-lanceolate, tapering to the base up to 45cm long. Flowers are pale yellow, arranged in spikes concealed by the sheathing petioles and flowering bracts are pale green. The botanical description is also done by Gamble, Kirtikar and Basu, Sivarajan and Balachandran and Thakur. C. longa contains curcumin, alkaloid and an essential oil. Dry rhizomes of C. longa yield 5.8% essential oil. A ketone and an alcohol are obtained from the volatile distillate. Fresh rhizomes yield 0.24% oil containing Zingibereae. The colouring principle of turmeric is the main component of this plant and is responsible for the antiinflammatory property. Curcumin (diferuloylmethane), the main yellow bioactive component of turmeric has been shown to have a wide spectrum of biological actions. These include its anti-inflammatory, antioxidant, anticarcinogenic, antimutagenic, anticoagulant, antifertility, antidiabetic, antibacterial, antifungal, antiprotozoal, antiviral, antifibrotic, antivenom, antiallergic, hypotensive and hypocholesteremic activities. Its antiinflammatory, anticancer and antioxidant roles may be clinically exploited to control rheumatism, carcinogenesis and oxidative stress-related pathogenesis. The successive extraction of C. longa with petroleum ether, alcohol and distilled water yielded extracts when administered on 1-7 days of pregnancy at dose levels of 100 and 200mg/kg have been found to exhibit significant anti-fertility activity.

Curcuma aromatica Salisb. is a perennial tuberous herb with annulate, aromatic yellow rhizome which is internally orange-red in colour. Leaves are elliptic or lanceolate-oblong, cuate-acuminated, 30-60cm long, petioles as long or even longer, bracts ovate, recurved, more or less tinged with red or pink. Flowers are pink, lip yellow, obovate, deflexed, sub-entire or obscurely three lobed. Fruits are dehiscents, globose, 3-valved capsules. The plant is also described by Gamble and Kirtikar and Basu. Rhizomes yield...
6.1% essential oil\(^{11}\). Essential oil contains a-and b-curcumene, d-camphene and p-methoxy cinnamic acid. The colouring matter is curcumin. Rhizomes are used in combination with astringents and aromatics for bruises, sprains, hiccough, bronchitis, cough, leucoderma and skin eruptions\(^{51}\). The rhizomes have an agreeable fragrant smell and yield a yellow colouring matter like turmeric, and the fresh root has a camphoraceous odour. The dried rhizome is used as a carminative and aromatic adjunctant to other medicines\(^{32}\). Oil is used for treatment of early stage of cervix cancer\(^{3}\). Verghese\(^{29}\) established the use of mango-ginger as an exotic flavourant.

**Curcuma zedoaria** (Berg.) Rosc. syn. C.zerumbet Roxb; *Anomum zedoaria* Christm. has 4 -6 leaves with 20-60cm long lamina. The leaf lamina is oblong-lanceolate, finely acuminate and glabrous on both surfaces. The flower stalk is 20-25cm long, emerging before the leaves. Flowers are yellow, while the flowering bract is green tinged with red. Calyx is 8mm long, corolla tube is twice as long as the calyx. Capsule is ovoid, trigonous, thin smooth and bursting irregularly. Tubers are palmately branched and camphoraceous\(^{46}\). The botanical description of the plant is also given by Sivarajan and Balachandram\(^{26}\). The medicinal uses of *C.zedoaria* were summarized from various sources by Duke\(^{23}\) as antipyretic, aromatic, carminative, demulcent, expectorant, stomachic, stimulant, and tonic. A decoction of rhizomes along with long pepper, cinnamon, and honey is said to be beneficial for colds, fevers, bronchitis, and coughs. Rhizomes are used in medicines given to women after childbirth\(^{46}\). It is an odoriferous substance of the cosmetics used for the chronic skin diseases caused by impure or deranged blood\(^{36}\).

**Curcuma angustifolia** (Zingiberaceae) is an attractive ginger with stout underground rhizomes which is also recognized as East Indian arrowroot. In early spring the flowers are produced before the leaves. Very colorful bracts make this a showy species. The inflorences lasts in full bloom on the plants for about three weeks and more. Leaves grow to about 2ft tall and die down in autumn. This species is found in the Eastern Himalayas and inhabits bright open hillsides woods\(^{16}\). Rhizomes are dried and powdered, and the starch obtained forms the chief source of Indian arrowroot. It is nutritive and is used as an agreeable, non-irritating diet in certain chronic diseases, during convalescence from fevers, in irritations of the alimentary canal, pulmonary organs, or of the urinary apparatus and also used in consumption, excessive thirst, jaundice, kidney disorder, and fattening the body\(^{27}\). The rhizomes are used in inflammation, bone fracture, intestinal diseases, etc. by the tribes of Madhya Pradesh and Chattisgarh states of India\(^{52}\). **Curcuma amada** Roxb. is a rhizomatous aromatic herb with a leafy tuft and 60-90cm in height. Leaves are long, petiolate, oblong-lanceolate, tapering at both ends, glabrous and green on both sides. Flowers are white or pale yellow, arranged in spikes in the centre of tuft of the leaves. Lip is semi-elliptic, yellow, 3-lobbed with the middle lobe emarginate\(^{51}\). The plant is also described by Gamble\(^{3}\) and Kirtikar and Basu\(^{15}\). The rhizomes of this plant are useful in vitiated conditions of pitta, anorexia, dyspepsia, flatulence, colic, bruises, wounds, chronic ulcers, skin diseases, pruritus, fever, constipations, strangury, hiccough, cough, bronchitis, sprains, gout, halitosis, otalgia and inflammations\(^{23}\). The fresh root possesses the smell of green mango and hence the name mango ginger. The rhizomes are used externally in the form of paste as an application for bruises and skin diseases generally combined with other medicines. Tubers rubbed with the leaf-juice of *Caesalpinia bonduc* is given for worms\(^{32}\). Rhizome is also used in applications over contusions and sprains\(^{15}\).

Free radicals were a major interest for early physiicists and radiologists and much later, the free radicals were found to be a product of normal metabolisations. Today, it is well known that radicals cause molecular transformations and gene mutations that curcumin and other antioxidant products from the dried rhizome of turmeric may be useful in the prevention or treatment of some age-related degenerative processes\(^{41}\). This study was undertaken to verify the variation of total curcumin contents and antioxidant activity in turmeric rhizomes collected from different villages of Koraput district of Odisha.

**MATERIALS AND METHODS**

**Plant Materials**

The rhizomes of five curcuma species i.e. *Curcuma longa*, *Curcuma zedoaria*, *Curcuma angustifolia*, *Curcuma aromatica* and *Curcuma amada* of family Zingiberaceae were collected from the local tribal people of Jeyapore, Baipariguda, Sashahandi, Koraput, Orissa. Fresh rhizomes were rinsed several with clean tap water to make it dust and debris free. Then they were dried in the shady condition for 3t04 days until they become moisture free. Dried rhizomes were ground in electric chopper to get fine powder form for further use.

**Preparation of plant extracts**

The dried and powdered form of rhizomes of curcuma species (each 50g) were extracted successively with ethanol (each 400ml.) for 10-12 hrs, using a Soxhlet apparatus. Then collected solutions were filtered through Whatman No-1 filter paper. The extracts were evaporated to dryness under reduced pressure at 90°C by Rotary vacuum evaporator to obtain the respective extracts and stored in a freeze condition at −18°C until used for further analysis.

**Phenolic Estimation**

The total phenol content of plant extracts were determined by using Folin-Ciocalteu Spectrophotometric method according to the method described\(^{29}\). Reading samples on a UV-vis spectrophotometer at 650 nm. Results were expressed as Catechol equivalents (mg/mg).

**Estimation of Curcumin Contents**

Curcumin contents were determined from rhizomes of five Curcuma species i.e. *Curcuma longa*, *Curcuma zedoaria*, *Curcuma angustifolia*, *Curcuma aromatica* and *Curcuma amada* by solvent extraction and spectrophotometer method\(^{39}\).

**Antioxidative activity**

The evaluation of radical scavenging activity (antioxidant activity) was conducted by the method of (Brand-Williams *et al.*\(^{5}\) with modifications. The following concentrations of extracts were prepared 40μg/mL, 80μg/mL, 120μg/mL, 160μg/mL and 200μg/mL. A stock solution of the sample (100mg/ml) was diluted for 5 concentrations. Each concentration was tested in triplicate. The portion of sample solution (0.5ml) was mixed with 3.0ml of 0.1M 1,1-Diphenyl-2-picrylhydrazyl (DPPH, in 95% distilled ethanol) and allowed to stand at room temperature for 30 minute under light protection. The absorbance was measured at 517nm. The scavenging activity of the samples at corresponded intensity of quenching DPPH. Lower the absorbance of the reaction mixture indicates higher free radical scavenging activity. The different in absorbance between the test and the control (DPPH in ethanol) was calculated expressed as (\% scavenging of DPPH radical). The capability to scavenge the DPPH radical was calculated by using the following equation.

Scavenging effect (\%) = (1 -Abs/.Ac) \times 100

As is the absorbance of the sample at t =0 min.

Ac is the absorbance of the control at t=30 min.

In the DPPH test, antioxidants were typically characterized by their IC\(_{50}\) value (Inhibition Concentration of Sample required to scavenge 50% of DPPH radicals). The results were obtained by linear regression analysis of the dose response curve plotted using % inhibition and concentration.

**RESULTS AND DISCUSSION**

Initially crude extracts were obtained through the extraction process using ethanol as solvent and the amount of extracts yields *C.longa*...
The unique properties of the spice are attributable to the essential oil of Curcuma as reported by Hirasa and C.longa close to ascorbic acid, the lowest antioxidant principle of turmeric. The results were reported as Catechol equivalents (mg/g). The highest concentration of total phenol was 285mg/g present in the ethanolic extract of C.longa rhizome followed by C.zedoaria (205mg/ml), C.aromatica(195mg/ml), C.angustifolia (110mg/ml) and C.amada(50mg/ml) respectively. The total phenolic content varied significantly between the five species of Curcuma.

The total phenolic content varied from one species to another. Several studies have shown that soil factors, including nutrients and level acidity as well as the genus diversity, may affect the content of curcumin in plants. Similar results are obtained by Chavalitumrong and Jirawattanapon (1992) who studied variation in the active constituents of C.domestica rhizomes collected from Nakhon Pathom, Central Thailand, where they found the highest curcumin content was 10.12% w/w. In addition, they reported that a sample from the South contained the highest total curcumin (8.99-0.83%)w/w, while the lowest was found in the North (4.80-1.83%)w/w where the climate is cooler and the dry period is longer and more pronounced. The significance of turmeric in medicine has increased considerably with the discovery of the antioxidant properties of naturally occurring phenolic compounds present therein. Curcumin exhibits strong antioxidant activity6,17,41,42,48. In DPPH assay, DPPH is a stable free radical with purple color. The antioxidants scavenge DPPH radical by donating hydrogen atoms leading to a non radical scavenging activity in (%) inhibition in table-2. The lower the IC50 is the higher the antioxidant activity of the compound. The result showed that the ethanolic fraction of C.longa rhizome exhibited the highest radical scavenging activity with 74.61±0.02% followed C.zedoaria (63.27±0.06%), C.angustifolia (58.35±0.06%), C.aromatica (55.38±0.06%) and C.amada (52.61±0.02%) respectively. Antioxidant activity using DPPH radical scavenging assay reported with IC50 value is shown in the (Table-2). The lower the IC50 is the higher the antioxidant activity of the compound. The result showed the lowest IC50 value in ethanolic extract of C.longa which is very close to ascorbic acid i.e. 24µg/ml followed by C. zedoaria (40µg/ml), C. angustifolia (100µg/ml), C.aromatica (120µg/ml) and C.amada (121µg/ml) respectively. Similar results are observed in C.longa by Unghaihoon et al.29 and showed strong activity. The antioxidant principle of turmeric as reported by Hirasa and Takemasa19 includes curcumin, 4-hydroxy cinnmyl (feruloyl) methane, and Bis (4-hydroxy cinnamoyl) methane which shows 50% inhibitory concentrations and IC50 values of these compounds were lower than that of α-tocopherol meaning that they are more effective antioxidants. Noguchi et al.33 reported that curcumin reacted with stable radicals such as galvinoxyl and N,N-diphenyl-1-picryl hydrazyl, suggesting that it can serve as a hydrogen donor and is a strong antioxidant as compared to eugenol. Song et al.43 reported free radical scavenging and heptato-protective activity of turmeric rhizomes in in vitro system, and the activity was much better than that of ascorbic acid. The mechanism of antioxidant activity of curcumin has been reported by Masuda et al.30 He found that curcumin formed dimers as radical termination products especially at 2-position of curcumin molecule and oxidative coupling reaction at 3-position29. Watanabe and Fuku19,53 have reported that curcumin suppresses the oxidative stress by scavenging various free radicals and antioxidant activity seems to be derived from its suppressive effects. Asai and Miyazawa27 showed that phenolic yellowish pigments of turmeric display antioxidant activity in rats while Okada et al.34 in his study on induced oxidative renal damage in male mice showed that curcumin is an effective protectant against oxidative stress. Curcumin, having antioxidant property, may act as an anticancer agent, but also inhibits the regulatory enzymes and shows anticarcinogenic action. A peculiar thing is noticeable in case of C.angustifolia crude extract which contain a very negligible amount of curcumin content but having good antioxidant potential in comparison to C.aromatica and C.amada. It may be due to presence of more than 30% components from the fresh and dried rhizome oils of C.angustifolia of Vietnamese origin in which camphor (12.6 and 12.1%) and curzerenone (>57 and 38%) are the major constituents55. It is interesting to note that a significant amount of methyl eugenol (10.5%), α-murolene (1.9%), pentadecanoic acid (1.8%), (E,E)-(E)-farnesyl acetone (1.3%) and n-heptyl salicylate (1.1%) are present in the oil of C.angustifolia. Apart from the above, Nguyen et al.56 also reported furanodienone and isofuranodienone from the dried rhizome of C.angustifolia Roxb.

We observed a correlation between the DPPH radical scavenging activity of the plant extracts and their phenol contents with the sample correlation coefficient R= 0.861. A significant correlation is also seen between curcumin content and antioxidant activity of these Curcuma species with correlation coefficient R= 0.735(Fig-3). The results showed that the antioxidant activity in turmeric was due to the presence of total phenol content. Consequently the antioxidant activity of plant extracts are often explained with respect to their total curcumin content16,25. In a study by Majeed28, the free-radical scavenging ability of various curcuminoids were evaluated using the DPPH (1.1 diphenyl-2-pircrylhydrazyl) radical scavenging method. The results indicated that curcuminoids neutralize free radicals in a dose-dependent manner. Tetrahydrocurcumin (THC) was the most effective, followed by curcumin and bisdemiethoxycurcumin. It is suggested that the antioxidant mechanism of curcuminoids may include one or more of the following interactions: (1) scavenging or neutralizing of free radicals, (2) interacting with oxidative cascade and preventing its outcome, (3) oxygen quenching and making it less available for oxidative reactions, (4) inhibition of oxidative enzymes like cytochrome P-450, and (5) chelating or disarming oxidative properties of metal ions like iron (Fe). Masuda et al.27 investigated the antioxidant mechanism of curcumin against peroxide radicals in the presence of ethyl linoleate as one of the polysaturated lipids. They found that during the antioxidation process, curcumin reacted with four types of linoleate peroxyl radicals to yield six reaction products. On the basis of the formation pathway for their chemical structures, an antioxidant mechanism of curcumin in polysaturated lipids was proposed, which involved an oxidative coupling reaction at the 3′-position of the curcumin with the lipid.
and a subsequent intramolecular Diels–Alder reaction. The significance of turmeric in medicine has increased considerably with the discovery of the antioxidant properties of naturally occurring phenolic compounds present therein. Curcumin exhibits strong antioxidant activity.5,17,24,42,48

CONCLUSION

Over all observation indicates the presence of free radical scavenging activity in all species (>50%), however Curcuma longa and C.zedoaria are superior to the other three species. The activity could be attributed to superior reducing power of both phenol and curcumin content. Moderate antioxidant activity is possible due to 95% oil contents having major constituents camphor, curzerenone, methyl eugenol, α-murolene, pentadecanoic acid, (E,E)-farnesyl acetone and 3- heptyl salicylate. The results indicate the higher medicinal use of C.longa and C.zedoaria due to its rich phytochemical contents.

ACKNOWLEDGMENT

The authors are thankful to University Grants Commission New Delhi, for Financial Assistance in form of major research project to one of the author (R.K.S) we are also thankful to Head of the Department of Botany and principal B.J.B. (A) College for providing necessary facilities for carrying out the experimental work. Finally we are thankful to Sabitri Nahak for helping in computer work.

REFERENCES

Table 1: Preliminary Phytochemical screening of Five Curcuma Species

<table>
<thead>
<tr>
<th>Phytoconstituents</th>
<th>C. longa</th>
<th>C. aromatica</th>
<th>C. zedoaria</th>
<th>C. angustifolia</th>
<th>C. amada</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaloids</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Glycosides</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Terpinoid</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Protein &amp; Amino acids</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Fixed oils &amp; fats</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Tannins</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Saponins</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Steroids (Phytosterols)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Flavonoids</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Phenols</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Curcumin</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Reducing sugar</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Anthraquinones</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

+ = Denotes Present and -- = Denotes Absent

Table 2: Crude extracts, Phenol content, IC₅₀ Values, Curcumin content and Colour of Rhizomes of Curcuma Species

<table>
<thead>
<tr>
<th></th>
<th>C. longa</th>
<th>C. aromatica</th>
<th>C. zedoaria</th>
<th>C. angustifolia</th>
<th>C. amada</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude extracts(gm)</td>
<td>3.35</td>
<td>2.56</td>
<td>2.67</td>
<td>2.62</td>
<td>2.20</td>
</tr>
<tr>
<td>Phenol content(mg/ml)</td>
<td>285</td>
<td>205</td>
<td>195</td>
<td>110</td>
<td>50</td>
</tr>
<tr>
<td>IC₅₀ Value(µg/ml)</td>
<td>24</td>
<td>120</td>
<td>40</td>
<td>100</td>
<td>121</td>
</tr>
<tr>
<td>Curcumin content</td>
<td>8.22</td>
<td>7.35</td>
<td>6.07</td>
<td>-----</td>
<td>1.54</td>
</tr>
<tr>
<td>mg/100mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colour of Rhizomes</td>
<td>Yellow</td>
<td>Creamy yellow</td>
<td>Creamy yellow</td>
<td>White</td>
<td>Creamy yellow</td>
</tr>
</tbody>
</table>

Table 3: DPPH scavenging activity of Five Curcuma Species

<table>
<thead>
<tr>
<th>Conc. of extract(µg/ml)</th>
<th>40</th>
<th>80</th>
<th>120</th>
<th>160</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. longa</td>
<td>67.69±0.04</td>
<td>69.23±0.05</td>
<td>70.76±0.04</td>
<td>72.30±0.03</td>
<td>74.61±0.02</td>
</tr>
<tr>
<td>C. zedoaria</td>
<td>52.11±0.07</td>
<td>54.45±0.04</td>
<td>58.00±0.06</td>
<td>61.07±0.01</td>
<td>63.27±0.05</td>
</tr>
<tr>
<td>C. angustifolia</td>
<td>45.52±0.03</td>
<td>48.61±0.02</td>
<td>52.00±0.08</td>
<td>56.07±0.07</td>
<td>58.35±0.04</td>
</tr>
<tr>
<td>C. aromatica</td>
<td>44.61±0.06</td>
<td>47.61±0.03</td>
<td>50.00±0.07</td>
<td>53.07±0.02</td>
<td>55.38±0.06</td>
</tr>
<tr>
<td>C. amada</td>
<td>47.69±0.04</td>
<td>49.23±0.05</td>
<td>50.76±0.04</td>
<td>52.61±0.02</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Photograph showing morphology of different Curcuma Species
Figure-2: DPPH scavenging activity of Five Curcuma Species in comparison to standard Ascorbic acid

![Graph showing DPPH scavenging activity of different Curcuma species compared to Ascorbic acid.](image)

Figure-3: Correlation between Phenol content, Curcumin content and Antioxidant activity of Five Curcuma Species

![Graph showing correlation between Phenol content and Curcumin content with Antioxidant activity.](image)

Source of support: Nil, Conflict of interest: None Declared