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Chemical and biological study of Curcumin longa L. plant

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

{وَمِنَ ٱلنَّاسِ وَٱلدَّوَآبِّ وَٱلۡأَنۡعَٰمِ مُخۡتَلِفٌ أَلۡوَٰنُهُۥ كَذَٰلِكَۗ إِنَّمَا يَخۡشَى ٱللَّهَ مِنۡ عِبَادِهِ ٱلۡعُلَمَٰٓؤُاْۗ إِنَّ ٱللَّهَ عَزِيزٌ غَفُورٌ} : سورة فاطر - آية٢٨

{قُلۡ هَلۡ يَسۡتَوِي ٱلَّذِينَ يَعۡلَمُونَ وَٱلَّذِينَ لَا يَعۡلَمُونَۗ إِنَّمَا يَتَذَكَّرُ أُوْلُواْ ٱلۡأَلۡبَٰبِ}: سورة الزمر- آية ٩

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Content

Abstract

Curcuma longa (Turmeric) is a popular and widely used Indian rhizomatous medicinal plant from the family Zingiberaceae. Curcumin, Demethoxycurcumin (DMC), and Bisdemethoxycurcumin (BDMC) are the constituents of turmeric and are collectively known as curcuminoids. Curcumin (1,7-bis(4- hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5- dione) or Diferuloylmethane is well-known for its different biological activities such as Anti-inflammatory, Anti-viral, Anti-oxidant, Anti-cancer, Anti-bacterial, Anti-asthmatic, Antiarthritis, Anti-diabetic, Anti-venom, Anti-obesity, Wound-healing, in depression and anxiety and other activities. Various clinical trials and their observations regarding these activities have been discussed here. Curcumin is a tautomeric compound existing in an enolic form in organic solvents and as a keto form in water. (Rathore.et.al.2020)

Keywords: Curcuma longa, Curcuminoids, Curcumin, Anti-inflammatory

1. Introduction

Traditional medicine derived from plants is a manifestation of the active participation of the community in solving health problems and the role has been recognized by various nations in improving the degree of public health. World Health Organization (WHO) recommends the use of traditional medicines including herbal medicines in the maintenance of public health, prevention and treatment of diseases, especially for diseases that have not yet found a cure such as chronic diseases, degenerative diseases, and cancer. (Permatananda.et al.2021)

Plants are widely investigated throughout the world owing to their nutritional, antioxidant, antimicrobial, and pharmaceutical potential. Curcuma longa L. (Turmeric) is also a medicinal plant of the Zingiberaceae family. It is a well-known herb that is used in medicine in the Ayurvedic and Unani systems of medicine. Turmeric is a perennial plant having medium height and an underground stem. Rhizomes are short-branched, ovate, oblong, and pyriform. The plant has unique pharmaceutical characteristics and is widely grown in tropical areas including Pakistan, India, China, and Peru. In South Asia, India, and China, It needs temperatures between 20 °C and 30 °C to grow. this plant is frequently used as a preservative, coloring, and flavoring agent. It is also considered a food additive throughout the world. It is commonly known as Haridraor Haldi (in the subcontinent), and Manjal (in the Tamil language). Turmeric is also considered as the Indian saffron because it is generally used as a substitute for costly saffron spices. Turmeric species have been used in traditional medicines for the treatment of diabetes, ulcers, cough, enlarged spleen and liver, hepatic disorder, chest pain, skin diseases blood purifiers, boils, and rheumatism. Curcuma longa consists of a variety of compounds that are important for spice, and cosmetics and are medicinally important. It is rich in bioactive compounds including flavonoids, polyphenols, and antioxidants, and can be used as a substitute for antibiotics in food items. Turmeric contains nonvolatile constituents (e.g., curcuminoids) and volatile components (e.g., curlone, ar-turmerone, zingiberene, and turmerone). Curcuminoids are predominant phenolic compounds and are responsible for the distinguishing color of turmeric. They are majorly comprised of curcumin, desmethoxycurcumin, and bisdemethoxycurcumin other essential macromolecules are sugars, protein, and resins. The main and

useful active ingredient is curcumin which consists of 0.3-5.4% of raw turmeric. Curcumin is a crystalline and orange-yellow colored component that is water-insoluble and is considered to be the main ingredient responsible for the biological functions of turmeric due to its highly powerful bioactivity. Curcumin is a potent bioactive antioxidant of turmeric acting as an antioxidant, anti-inflammatory, anti-platelet, cholesterol-decreasing, antibacterial, and antifungal properties. It also prevents the growth of Helicobacter pylori, which causes gastric ulcers and may act as an anti-inflammatory in conditions like arthritis, bursitis, and back pain. Curcumin can attach to heavy metals like cadmium and lead, hence lowering the toxicity of these heavy metals. Its most commonly used commercial products include oleoresins, extracts, and turmeric powder. Various parts of turmeric plants are used widely in many Asian countries either in cooked (as vegetables) or in raw form. Turmeric is also reported to be a nutritional valued species because the plants contain different minerals, vitamins, fats, proteins, carbohydrates, and starch. (Javed.et al.2020)

Fig.1. Curcuma plant

1.1 Names and distribution in the world

The name Curcuma is derived from the Arabic word kurkum, meaning “yellow,” which refers to the color of the rhizome. (Lal, J.2012)

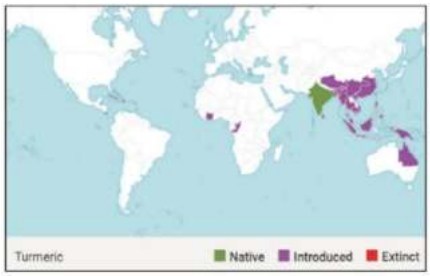
In Kurdish (زەردەچۆ)

Figure.2. Rhizome of Curcuma

Entry	Language	Name	Entry	Language	Name
1	Arabic	Kurkum	21	Kannada	Arishina
2	Armenian	Toormerik, Turmerig	22	Korean	Kolkuma, Tomerik
3	Assamese	Halodhi	23	Malayalam	Manjal
4	Bengali	Halud	24	Marathi	Halad
5	Bulgarian	Kurkuma	25	Nepali	Haldi, Hardi
6	Burmese	Hsanwen, Sanwin	26	Norwegian	Gurkemeie
7	Chinese	Wat gam	27	Portuguese	Acafrao da India
8	Dutch	Kurkuma, Tarmeriek	28	Punjabi	Haldi
9	English	Indian saffron	29	Russian	Kurkumy
10	Farsi	Zardchubeh	30	Sanskrit	Ameshta, haridra
11	French	Safran des Indes	31	Spanish	Curcuma
12	German	Indischer safran	32	Swedish	Gurkmeja
13	Greek	Kourkoumi	33	Tamil	Manjal
14	Gujrati	Halad	34	Telugu	Haridra, Pasupu
15	Hindi	Haldi	35	Thai	Kha min chan
16	Hungarian	Kurkuma	36	Tibetan	Gaser, Sga ser
17	Icelandic	Turmerik	37	Turkish	Hint safrani
18	Indonesian	Kunyit	38	Ukrainian	Kurkuma
19	Italian	Curcuma	39	Urdu	Haldi, Zard chub
20	Japanese	Ukon	40	Vietnamese	Botnghe, Uatkim

Curcuma species are mainly distributed in the tropics and subtropics of South and Southeast Asia and are extensively largely cultivated in Bengal, China, Taiwan, Sri Lanka, Indonesia, Peru, Australia, and the West Indies.(Esatbeyoglu.et.al.2012)

Figure 3. Global distribution of Curcuma longa plant



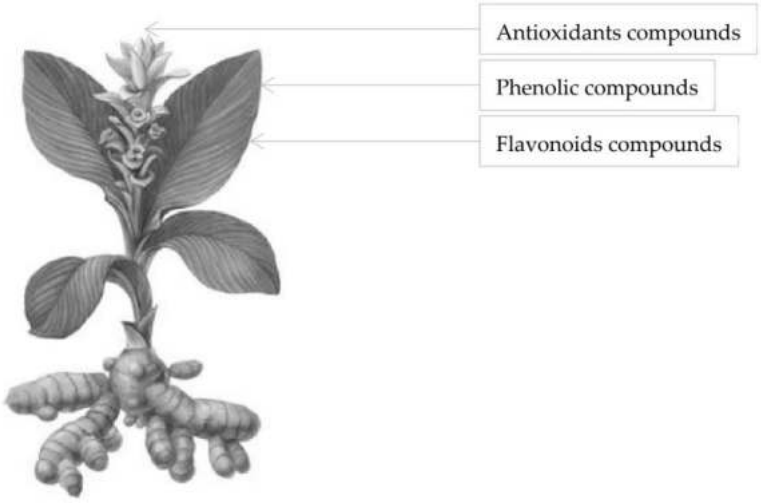
1.2 History of curcumin

Marco polo (1280 AD) refers to turmeric as Indian saffron used for dying cloths. As far as documented evidence, it has been used daily in India for at least 6000 years as medicine, beauty aids, cooking spice, and a dye. Ostensibly it was used to worship the Sun during the solar period of India, a time when Lord Ram Chandra walked the Earth. It was mentioned in the Artharveda of India. Buddhist monks have used turmeric as a dye for their robes for at least 2000 years. It was listed in an Assyrian herbal circa 600 BC and was mentioned by Discorides in the herbal that was the western herbal rediscovered 700 years ago via Marco Polo and it is used in the traditional lethal poison of pit vipers. In China, it was mentioned in the Pent-Sao of the 7th century. For at least 1000 years Chinese have used turmeric as medicine, especially for the spleen, stomach, and liver medicines. They use it to stimulate and purify and as an anti-biotic, anti-viral, and analgesic. As such it is used to stimulate and strengthen the blood and decrease blood pressure, to clean abdominal pain and stagnation in men, women, and children. They consider it one of the better herbals for women because it stimulates the uterus and clears menstrual stagnation. In the 1870s, chemists discovered turmeric orange-yellow root powder turned reddish brown when exposed to alkaline chemicals. This discovery led to the development of turmeric paper to test for alkalinity. European and American herbalists up until the rate 20th century had little interest in turmeric. In one Western herbal from the early 20th century, Maude Greve's book A Modern Herbal, she gives a botanical description and the constituents of the herb as if the herb was of some importance, but then under medicinal actions and uses she says; "Turmeric is a wild aromatic stimulant seldom used in medicine except as a coloring. It was once a cure for jaundice. Its chief use is in the manufacture except as a coloring. It was once a cure for jaundice. Its chief use is in the manufacture of curry powder. It is used as an adulteration of mustard and a substitute for it and forms one of the ingredients of cattle condiments. Turmeric paper is used as a test for alkaloids and boronic acid". Daniel B. Mowrey tells the story. "Serious research on turmeric began in Germany, in the early 1920's. Sesqueterpenes in the essential oil of turmeric were isolated in 1926 and to them was ascribed the therapeutic activity. (Lal.2012)

1.3 Morphology of Curcuma longa

Turmeric is an herbaceous perennial plant that grows up to 1 m tall. The rhizomes are branching, bright to orange, cylindrical, and scented. The leaves are placed in two rows and alternate. Leaf-sheath, petiole, and leaf blade are the three parts of the leaf. A fake stem is created from the leaf sheaths. The petiole can range in length from 50 to 115 cm. Simple leaf blades range in length from 76 to 115 cm, with some reaching up to 230 cm. They are 38 to 45 cm wide and oblong to elliptical, narrowing at the tip. Stem bracts, which are white to green in color and sometimes tinged reddish-purple, are located at the top of the inflorescence and have tapered upper ends. The flowers of hermaphrodites are threefold and zygomorphic. The three sepals are white, united, and contain fluffy hairs; the three calyx teeth are uneven. The three vivid yellow petals are united into a 3-centimetre-long corolla tube. The three corolla lobes are triangular with soft-spiny top tips and measure 1.0 to 1.5 cm in length. Only the median stamen of the inner circle is fertile, even though the average corolla lobe is larger than the two lateral ones. Figure 2 represents the morphology of curcumin. The base of the dust bag is spurred. The remaining stamens are transformed into staminodes. The staminodes on the outside are shorter than those on the inside. The labellum is yellowish, with a yellow ribbon in the center, and is obovate, measuring 1.2 to 2.0 cm in length. Three carpels are held in place by a trilobed, sparsely hairy ovary. Three sections open up when the fruit capsule is opened. The blossoming season in East Asia is normally in August. An inflorescence stalk, 12 to 20 cm long and with many flowers, grows at the end of the false stem. The bracts are light green and elliptical to oblong shape with a blunt upper end, measuring 3 to 5 cm in length.(Srivastava.et.al.2022)

Figure 4. morphological description of turmeric



1.4 Botanical Classification of C. longa

The taxonomic classification of turmeric botanically known as Curcuma longa is presented in Table 2

Table 2. Taxonomical classification of turmeric

Taxa	Name
Domain	Eukaryota
Kingdom	Plantae
Phylum	Spermatophyta
Subphylum	Angiospermae
Class	Monocotyledonae
Order	Zingiberales
Family	Zingiberaceae
Genus	Curcuma
Species	*Curcuma longa*

1.5 Molecular constituents in turmeric

Turmeric has hundreds of molecular constituents, each with a variety of biological activities. For instance, there are at least 20 antibiotic molecules,14 are known cancer preventives, 12 are anti-tumor, 12 are anti-inflammatory

and there are at least 10 different anti-oxidants. Infect,326 biological activities of turmeric are known. This is also testimony to the use of whole herbs and not just isolated molecules. Speaking of molecules by far the most researchers in turmeric are the three gold-colored alkaloids curcuminoids viz. Curcumin, Demethoxycuccumin, and Bisdemethoxycurcumin (Figure 5). Most of the research done is with 95% curcuminoid extract of turmeric, though in its raw state turmeric is only 3-5% curcuminoids. The yield of essential oil in various parts is 1.3% in the leaf, 0.3% in the flower, 4.3% in the root, and 3.8% in the rhizome. The composition of essential oils obtained from the root, rhizome, leaf, and flower and the nutritional composition of Curcuma longa are given in table-3 and 4 respectively. (Lal.2012)

Figure 5: Natural metabolites of turmeric and curcumin

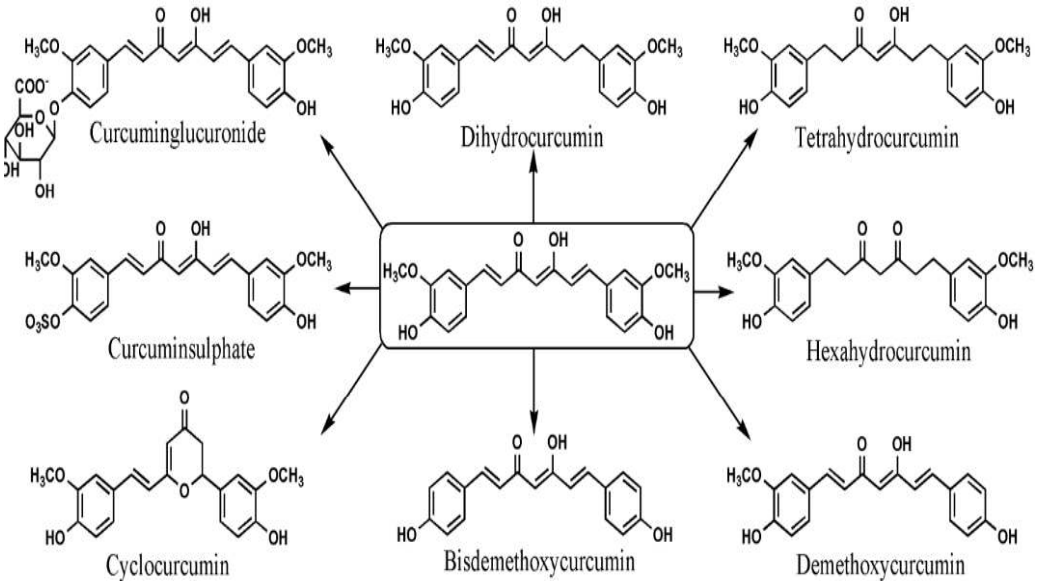


Table 3: Composition of essential oils of Curcuma longa

Entry	Component	Concentration (%)			
		Root	Rhizome	Leaf	Flower
1.	β-Bisabolene	2.3	1.3	-	0.9
2.	1,8-Cineole	0.7	2.4	6.5	4.1
3.	p-Cymene	3.3	3.0	5.9	1.6
4.	p-Cymen-8-ol	1.5	0.3	0.8	26.0
5.	Tr-Curcumin	7.0	6.3	0.2	1.9
6.	Curlone	0.6	10.6	0.2	0.3
7.	Dehydrocurcumin	4.3	2.2	Tr	-
8.	Myrcene	Tr	0.1	2.3	0.2
9.	α-Phellandrene	0.1	0.1	32.6	-
10.	β-Phellandrene	-	Tr	3.2	Tr
11.	α-Pinene	0.1	0.1	2.1	0.4
12.	β-Pinene	0.1	Tr	2.8	0.1
13.	Terpinolene	0.1	0.3	26.0	7.4
14.	Tr-Turmerone	46.8	31.1	0.1	1.2
15.	Turmerone	-	10.0	0.9	1.0
16.	Others	33.1	32.2	16.4	54.9

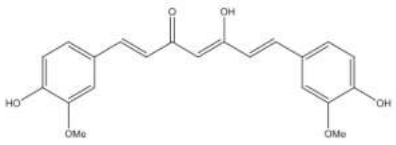
Tr-Trace

Table 4: Nutritional composition of turmeric

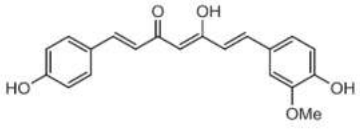
Entry	Constituents	Quantity per 100g
1.	Ascorbic acid (mg)	50.0
2.	Ash (g)	6.8
3.	Calcium (g)	0.2
4.	Carbohydrate (g)	69.9
5.	Fat (g)	8.9
6.	Food energy (K Cal)	390.0
7.	Iron (g)	47.5
8.	Niacin (mg)	4.8
9.	Potassium (mg)	200.0
10.	Phosphorus (mg)	260.0
11.	Protein (g)	8.5
12.	Riboflavin (mg)	0.19
13.	Sodium (mg)	30.0
14.	Thiamine (mg)	0.09
15.	Water (g)	6.0

1.7 Structural and chemical properties

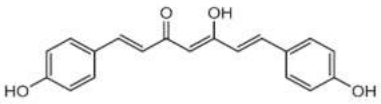
Curcumin is a diarylheptanoid composed of two aromatic rings linked by a chain of seven carbons. Curcumin's chemical name is 1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6- heptadiene-3,5-dione. It has several functionally active groups: two o-methoxy phenolic groups, two enone moieties, and a keto-enol moiety.
(Its molecular formula is C21H20O6, and it has a molecular weight of 368.38 Daltons. It is a lipophilic polyphenol that is insoluble in water but soluble in organic solvents such as ethanol and acetone. It is also insoluble at acidic and neutral pH but highly soluble at alkali or extremely acidic medium Curcumin is a bis-α, β-unsaturated β-diketone where its structure shows a keto-enol tautomerism and a cis-trans isomerism that depends on the solution's acidic state. At acidic and neutral pH as well as in the cells, the dominant form is the keto-form. At such pHs, curcumin potentially donates H-atom because its keto-form contains a highly active Carbon atom in its heptadienone linkage between the two methoxyphenol rings. This carbon has very weak C–H bonds since the unpaired electrons on the adjacent oxygens are delocalized. On the other hand, at alkali pH, the enol form predominates where curcumin donates electrons in a mechanism that reflects its antioxidant scavenging activities. The resonance-assisted hydrogen bonding in the enol-form of curcumin stabilizes its structure. In fact, the anti-inflammatory and antioxidant properties of curcumin are attributed to the presence of an enolic center and two phenolic groups separated by a hydrophobic bridge. These hydrophobic and hydrophilic features facilitate the penetration of curcumin into the blood-brain barrier which have been proven by density functional and Møller-Plesset perturbation (MP2) computations. More importantly, the enolic form was shown to be the most favored form with the ideal antioxidant properties including its binding ability to human proteins such as amyloid β that is involved in Alzheimer's disease.(Slika.et al.2020)



Curcumin (77%)



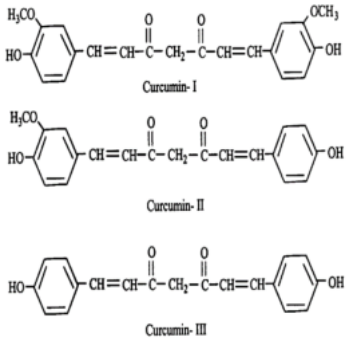
Demethoxycurcumin (17%)



1.8 Chemical composition of turmeric

Turmeric contains protein (6.3%), fat (5.1%), minerals (3.5%), carbohydrates (69.4%) and moisture (13.1%). The essential oil (5.8%) obtained by steam distillation of rhizomes has a-phellandrene (1%), sabinene (0.6%), cineol (1%), borneol (0.5%), zingiberene (25%) and Sesquiterpenes (53%)5. Curcumin (diferuloylmethane) (3–4%) is responsible for the yellow color, and comprises curcumin I (94%), curcumin II (6%) and curcumin III (0.3%)6. Demethoxy and bisdemethoxy derivatives of curcumin have also been isolated7 (Figure 7). Curcumin was first isolated in 1815 and its chemical structure was determined by Roughley and Whiting9 in 1973. It has a melting point of 176–177°C; forms a reddish-brown salt with alkali and is soluble in ethanol, alkali, ketone, acetic acid, and chloroform. (Kumar.et.al.2011)

Figure 7. Demethoxy and bisdemethoxy derivatives of curcumin



2. Pharmacology of curcumin

I. Anti-inflammatory activity

Curcumin is a potent anti-inflammatory with specific lipoxygenase- and COX-2-inhibiting properties. Animal, in vitro, and in vivo studies demonstrate turmeric's effectiveness at decreasing both acute and chronic inflammation. A double-blind, crossover, placebo-controlled

human study of 42 patients with osteoarthritis used a combination product containing turmeric, Boswellia serrata, Withania somnifera, and zinc. After three months on the combination or placebo, patients noted a significant reduction in pain ($p<0.05$)

II. Antioxidant activity

The antioxidant activity of curcumin was reported77 as early as 1975. It acts as a scavenger of oxygen-free radicals. It can protect hemoglobin from oxidation. In vitro, curcumin can significantly inhibit the generation of reactive oxygen species (ROS) like superoxide anions, H2O2, and nitrite radical generation by activated macrophages, which play an important role in inflammation. Curcumin also lowers the production of ROS in vivo. Its derivatives, demethoxycurcumin and bis-demethoxycurcumin also have antioxidant effects. Curcumin exerts a powerful inhibitory effect against H2O2-induced damage in human keratinocytes and fibroblasts31 and in NG 108-15 cells80.

III. Antifertility activity

Petroleum ether and aqueous extracts of turmeric rhizomes Show a 100% antifertility effect in rats when fed orally. Implantation is completely inhibited by these extracts. Curcumin inhibits 5a-reductase, which converts testosterone to 5a-dihydrotestosterone, thereby inhibiting the growth of flank organs in the hamster. Curcumin also inhibits human sperm motility and has the potential for the development of a novel intravaginally contraceptive

IV. Wound healing activity

The topical administration of curcumin extracts on skin wounds on the skin of diabetic rats demonstrated an improvement in the wound healing process. The reparation action mechanism involved an increase in the levels of beta-transforming growth factor plus an increase in the activity of the enzyme nitric oxide synthase. The wound-healing activity of turmeric has been widely studied and it has been seen that

its local application is effective. In Chinese medicine, it has been used for this purpose since ancient times

V. Anticoagulant activity

Curcumin shows anticoagulant activity by inhibiting collagen and adrenaline-induced platelet aggregation in vitro as well as in vivo in rat thoracic aorta.

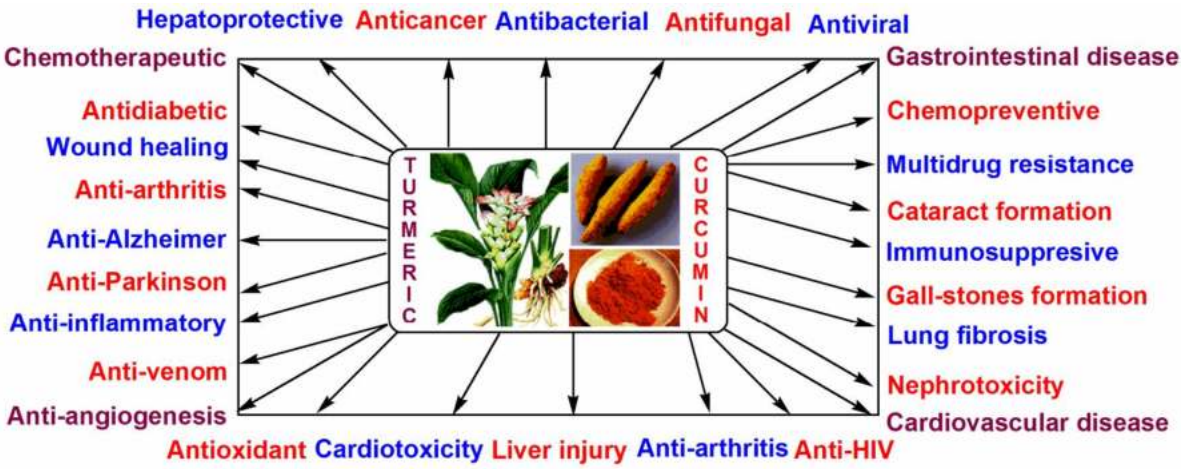
VI. Antidiabetic effect

Curcumin prevents galactose-induced cataract formation at very low doses. Both turmeric and curcumin decrease blood sugar level in alloxan-induced diabetes in rat. Curcumin also decreases advanced glycation end products induced Complications in diabetes mellitus.

VII. Anticarcinogenic effects

Animal studies involving rats and mice, as well as in vitro studies utilizing human cell lines, have demonstrated curcumin's ability to inhibit carcinogenesis at three stages: tumor promotion, angiogenesis, and tumor growth. In two studies of colon and prostate cancer, curcumin inhibited cell proliferation and tumor growth.

Figure 8: Medicinal properties of turmeric and curcumin



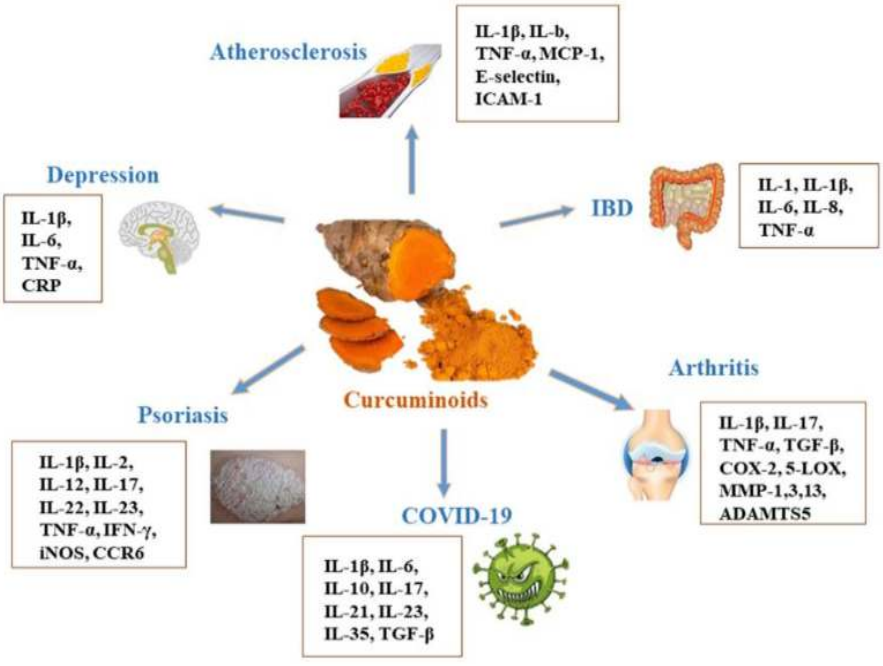
2.1 Pharmacokinetics

Pharmacokinetic studies in animals have demonstrated that 40-85 percent of an oral dose of curcumin passes through the gastrointestinal tract unchanged, with most of the absorbed flavonoid being metabolized in the intestinal mucosa and liver. Due to its low rate of absorption, curcumin is often formulated with bromelain for increased absorption and enhanced anti-inflammatory effect.(Akram.et.al.2010)

2.2 Anti-Inflammatory Effects of Curcumin in Several Inflammatory Diseases

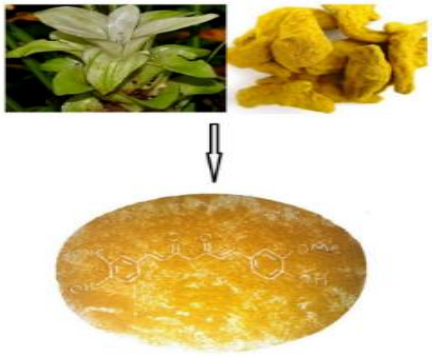
Curcumin has significant anti-inflammatory effects, and a large number of preclinical or clinical researchers have studied its effect on inflammatory diseases, among them, inflammatory bowel disease, arthritis, psoriasis, depression, atherosclerosis, and COVID-19 are the focus of research hotspots. Current evidence suggest that curcumin is effective in reducing levels of inflammatory mediators and that curcumin's anti-inflammatory properties may have a beneficial effect on these diseases (Figure 9). In this review, the inflammatory mechanism of the above diseases,(Peng, et al.2021). The therapeutic effect and the current application of curcumin are described as follows.

Figure 9 The effect of curcumin on IBD, arthritis, psoriasis, depression, and atherosclerosis.



3. Source and Bioavailability

C. longa, the main source of curcumin, is a short-stemmed rhizomatous perennial plant of the Zingiberaceae family). The plant is widely cultivated in different countries of Asia such as India and China. In traditional medicine, C. longa has been used for mitigation of rheumatism and inflammatory and ulcerative diseases. The bright orange-colored rhizome of C. longa is commonly used as a spice in Asian and many other countries. The main coloring constituent of the C. longa rhizome, "curcumin," has been isolated and its chemical structure determined in 1910 The poor bioavailability of curcumin limits the translation into clinically relevant.strategies.Low absorption, rapid metabolism, and quick elimination .are known as the main complications that limit .its bioavailability and have prompted the researchers to investigate not only the bio functional and therapeutic properties in clinical studies, but also to develop new delivery systems. Curcumin is poorly dissolved in water. Furthermore, UV light can degrade curcumin solution and therefore photochemical degradation is another limitation of its uses). There are several methods for increasing its bioavailability, such as using adjuvants such as piperine, nanoparticles, liposomal curcumin, complexes of curcumin with phospholipids, and structural analog of curcumin.(Nabavi.et.al.2014)



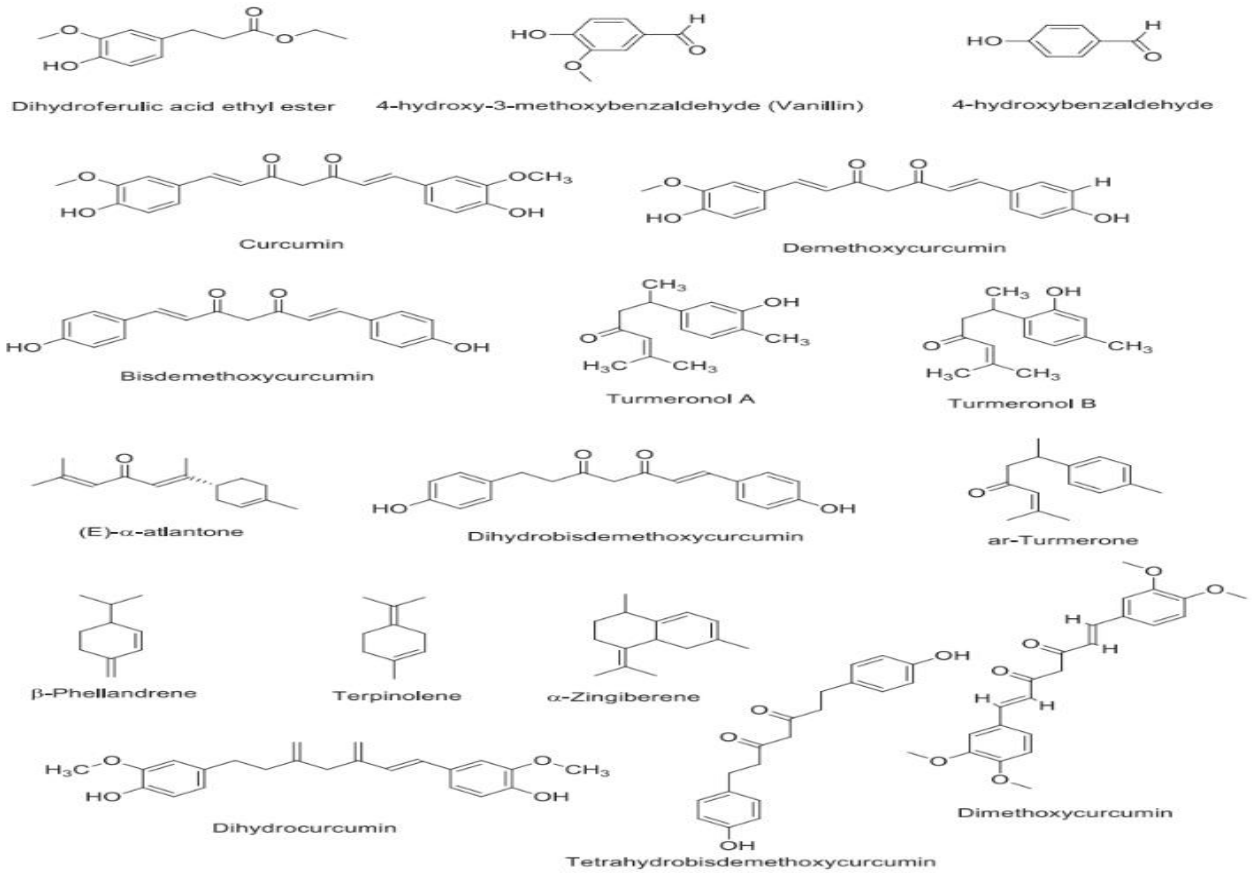
Phytochemistry of curcumin

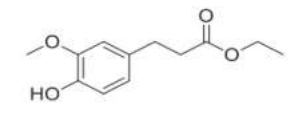
4.1. Phenolic compounds

Phytochemical analysis of different parts of C. longa revealed many bioactive phenolic compounds across a wide range of studies wherein different

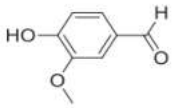
identification methods were utilized. identified phenolic compounds such as dimethoxycurcumin, dihydrocurcumin, and tetrahydro bisdemethoxycurcumin using a mass spectrometer coupled with liquid chromatography (LC-ESI-Q-TOF-MS) to analyze methanol and diethyl ether extracts of C. longa rhizome. Cyclocurcumin was identified through spectroscopic analyses (H NMR, C NMR, HSQC, HMBC, and NOESY) of ethanol extract of C. longa rhizomes also, through the GC-MS and HPLC analysis of methanol extract of C. longa rhizomes, as well as IR, H, and C NMR analysis, compounds such as 2-methoxy-4-vinylphenol and isolongifolol were identified. Characterized phenolic compounds, including coumaric, caffeic acid, sinapic acid, quercetin-3-D-galactoside, casuarinin, and isohammetin through the HPLC analysis of ethanol extract of C. longa rhizome. Alternatively, gallic acid, protocatechuic acid, hydroxybenzoic acid, vanillic acid, syringic acid, vanillin, p-coumaric

Figure 10. Bioactive compounds isolated from C. longa.

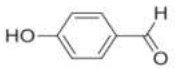




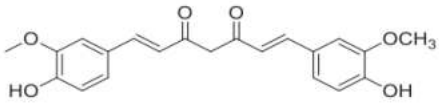
Dihydroferulic acid ethyl ester



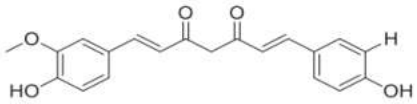
4-hydroxy-3-methoxybenzaldehyde (Vanillin)



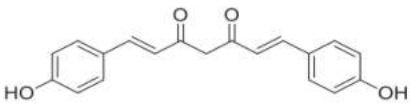
4-hydroxybenzaldehyde



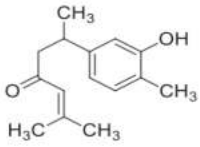
Curcumin



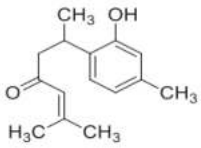
Demethoxycurcumin



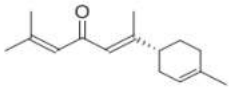
Bisdemethoxycurcumin



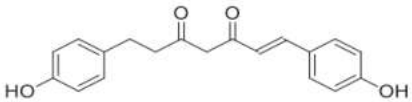
Turmeronol A



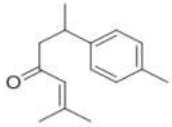
Turmeronol B



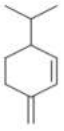
(E)-α-atlantone



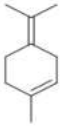
Dihydrobisdemethoxycurcumin



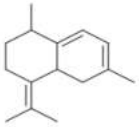
ar-Turmerone



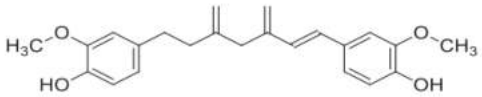
β-Phellandrene



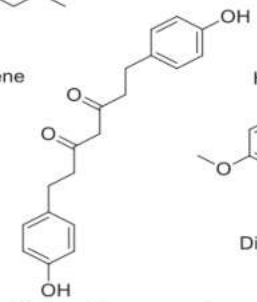
Terpinolene



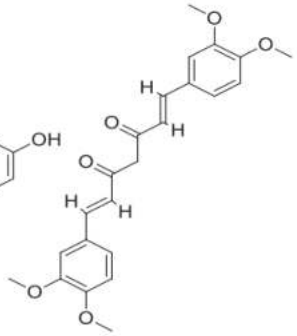
α-Zingiberene



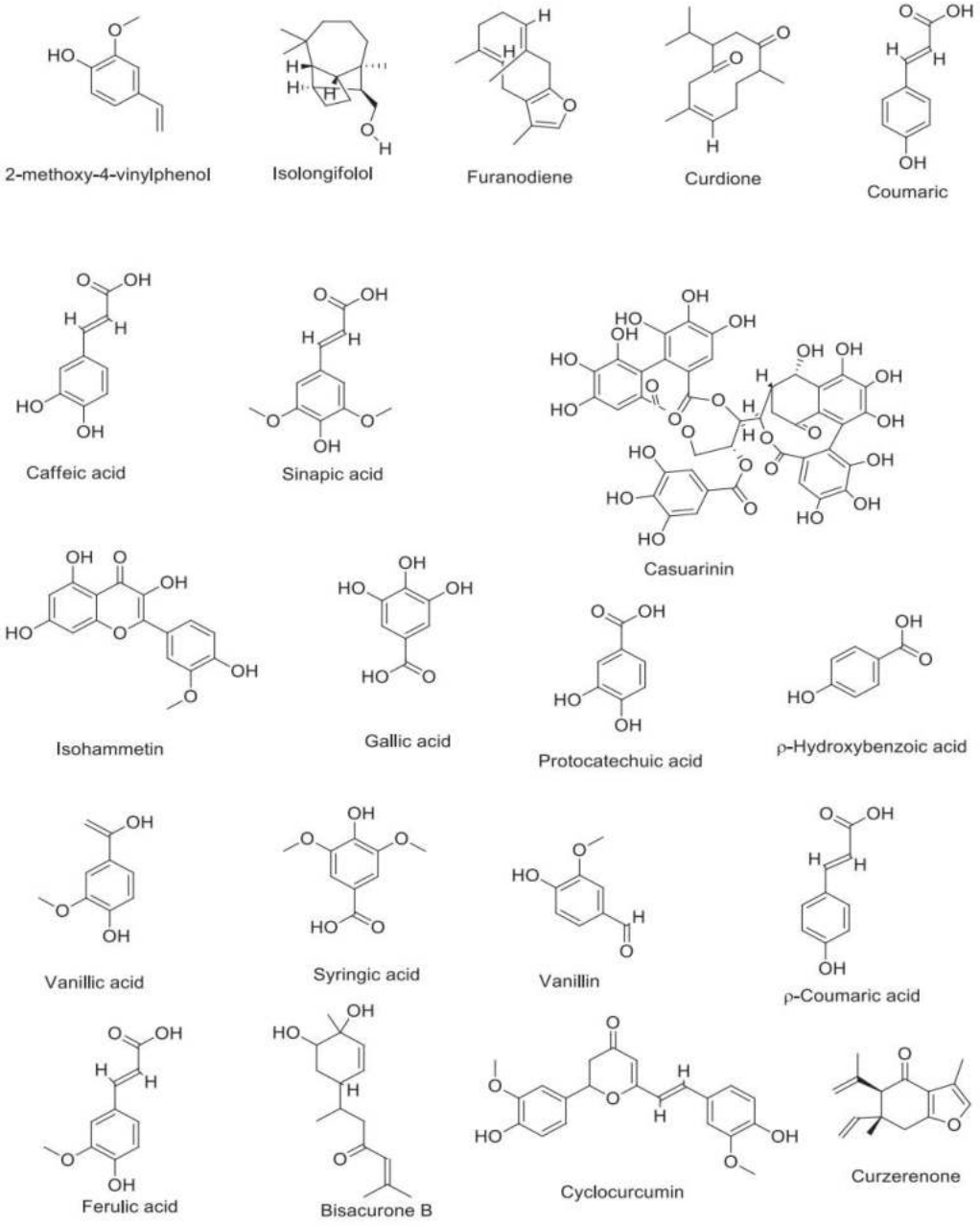
Dihydrocurcumin



Tetrahydrobisdemethoxycurcumin



Dimethoxycurcumin


2-methoxy-4-vinylphenol
Isolongifolol
Furanodiene
Curdione
Coumaric
Caffeic acid
Sinapic acid
Casuarinin
Isohammetin
Gallic acid
Protocatechuic acid
ρ-Hydroxybenzoic acid
Vanillic acid
Syringic acid
Vanillin
ρ-Coumaric acid
Ferulic acid
Bisacurone B
Cyclocurcumin
Curzerenone

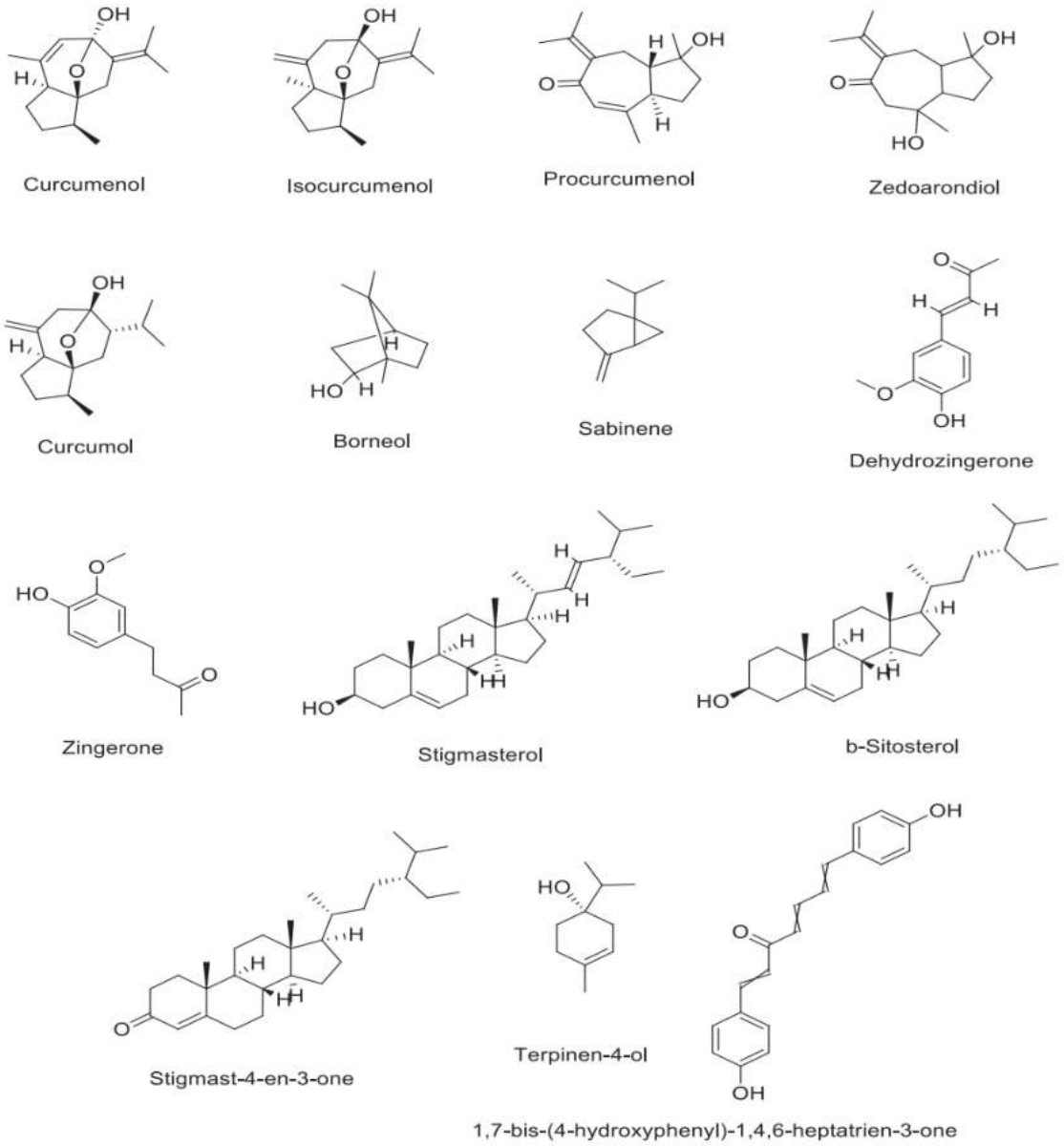


Figure 10. Bioactivate compounds isolated from *C. longa.*

acid, and ferulic acid were identified through HPLC analysis of methanol extract of C. longa rhizome. Wang et al. elucidated the chemical structure of dehydroxingeron and zingerone through spectroscopic analysis. Li et al. characterized 1,7-bis-(4-hydroxyphenyl)-1,4,6- heptatrien-3-one using column chromatography and preparative HPLC of methanol extracts of C. longa rhizomes, as well as spectroscopic analyses, including 1D and 2D NMR.

4.2. Terpenes

Different researchers identified several terpenes, including monoterpenes and sesquiterpenes, in the plant. Spectral analyses (H NMR and C NMR) and liquid chromatography-tandem mass spectrometry (LC-MS-MS) of ethyl acetate fraction of C. longa powder by Akter et al. identified sesquiterpenes such as turmeronol B, turmeronol A, (E)-α-atlantone, dihydrobisdemethoxycurcumin also more identified sesquiterpenes, including ar-Turmerone and α-Zingiberene, using the DVB/CAR/PDMS fiber in solid phase microextraction (SPME) of C. longa. Similarly, the researchers also identified monoterpenes, which include β-Phellandrene and terpinolene, through the same method. Also identified furanodiene and curdione using GC-MS and HPLC analysis of methanol extract of C. longa rhizomes and IR, H, and C NMR analysis to elucidate their chemical structures. identified the sesquiterpene, and bisacurone B, through spectroscopic analyses (H NMR, C NMR, HSQC, HMBC, and NOESY) of ethanol extract of C. longa rhizomes. Alternatively, further elucidated the structure of bisacurone C through spectroscopic analysis. Silica gel column chromatography and HPLC of ethyl acetate-soluble fraction of the methanol extract of C. longa rhizomes and NMR analysis methods were employed to identify sesquiterpenes including curzerenone, curcumenol, isocurcumenol, procurcumenol, zedoarondiol. identified the sesquiterpene curcumol through gas chromatography combined with surface acoustic wave sensor (GC-SAW) analysis of the C. longa plant. Also, through Silica gel column chromatography and preparative HPLC analysis of hexane portion obtained from methanolic extract of C. longa dried rhizomes, as well as advanced spectroscopic analyses (H-, C-NMR, UV, and 1R) of the plant, Lee identified borneol and sabinene, which are typical monoterpenes.

4.3. Phytosterols

Phytochemical studies also revealed the presence of bioactive phytosterols. identified three phytosterols, including stigmasterol, b-sitosterol, and stigmast-4-en-3-one, and one monoterpene, terpinene-4-ol, through GC-MS analysis of ethanol oleoresin constituents of fresh and dry C. longa rhizome.(Iweala.et.al.2023)

4.4 Qualitative Analysis of Phytochemicals in curcumin

Phytochemical analysis was used to determine the presence of saponins (foam test), terpenoids (Salkowski test) , glycosides (Borntrager's test), tannins (ferric chloride test) and alkaloids (Dragendorff's test) in methanolic extract of Curcuma longa L. rhizomes. These results were used to determine the presence and absence of phytochemicals

1.Determination of Total Phenolic Content (TPC)

Curcuma longa L. extract with Folin-Ciocalteu reagent was used to determine total phenolic content. This reagent was used by Singleton and Rossi in 1965 for the first time. Firstly 2 mL sample of turmeric extract was inserted into different test tubes and mixed with a 5ml Folin-Ciocalteu reagent. After this, 4 mL of 5% sodium carbonate Na2 CO3 solution was added and remained for half an hour. Gallic acid was involved as the standard. The absorbance was measured at 765 nm by using a UV-Visible spectrophotometer

In the quantitative phytochemical analysis, total phenolic content was determined. It was performed by using a UV-Visible spectrophotometer at 765 nm. Methanolic extract of fresh rhizomes from Curcuma longa L. were obtained. Different concentrations of gallic acid were made and then their absorbance was determined (Table 5). Gallic acid was used as a standard. Total phenolic content was determined by using the calibration curve against concentrations and absorbance obtained from a UV-Visible spectrophotomet

Table 5. Nutritional analysis of Curcuma longa L.

Constituents	Amounts
Moisture	71.43%
Ash	1.95%
Protein	2.76%
Fat	4.40%
Fiber	6.85%
Carbohydrate	12.62%
Energy	101.12 Kcal/100g

2. Determination of Antioxidant Activity by DPPH Method

2, 2-diphenyl-1-picrylhydrazyl (DPPH) solution with methanol is monitored on a UV-Visible spectrophotometer is a much effective, simple, and accurate method. The absorbance of DPPH occurred at 517 nm at the maximum level. The color change occurred from purple to yellow due to absorption from an oxidant Antioxidant potential of methanolic extract of fresh rhizome of Curcuma longa L. was determined by DPPH radical scavenging activity with UVVisible spectrophotometer .The DPPH solution was made with methanol as solvent and DPPH as a solute. The sample was used to prepare different concentrations of 50, 40, 30, 20, and 10 µm respectively with methanol. Then various concentrations of the sample were added to 3ml methanolic solution of DPPH solution in different test tubes. After this, the absorbance of the blank and resultant solution was determined at 517 nm by a UV-Visible Spectrophotometer at normal temperature under light protected area.(Javed.et al.2020)

Then percentage inhibition was determined by using the following equation.

$$Inhibition = \frac{\text{Abs. of Control} - \text{Abs. of Sample}}{\text{Abs. of control}}$$

Curcuma longa acts as a natural antioxidant for the treatment of oxidative species in our body that decreases the production of oxidative species. DPPH was used as a stable free radical for the determination of antioxidant. Natural and artificial antioxidants convert DPPH free radicals into diphenyl picryl hydrazine which was yellow. Different studies have investigated that turmeric species are important sources of natural antioxidants that provide significant protection against free radical damage. The antioxidant activity was determined for the methanolic extract of fresh rhizomes of Curcuma longa L. by the DPPH method. The obtained data are summarized in Table 8. The investigated extract has shown the strongest antioxidant potential (87.92%) at 50 µg/mL. When the concentration was increased up to 50 µg/mL then % inhibition was also increased. Thus, Curcuma longa L. fresh rhizomes can be

used in the treatment of different diseases due to their strong antioxidant activity.

Table 6. Antioxidant activity of Methanolic extract of fresh rhizomes of Curcuma longa L.

S. No.	Conc. µg/mL	Absorbance	% Inhibition
1	10	0.5450	49.19
2	20	0.3635	66.11
3	30	0.1820	83
4	40	0.1557	85.48
5	50	0.1295	87.92

3.Antibacterial and Antifungal Activities of Curcuma longa L. rhizomes

Antibacterial activity was performed against Gram-positive bacteria Salmonella typhi, Bacillus subtilis, and Staphylococcus aureus and Gram-negative bacteria such as Escherichia coli. The tested strains (ATCC) of fungus and bacteria were obtained from Applied Chemistry Research Centre (ACRC), PCSIR Labs Complex, the antifungal studies were performed against fungal strains such as Aspergillus flavus, Fusarium oxysporum, Aspergillus niger, and Alternaria alternate were used. Streptomycin (0.1 %) was used as a standard against bacterial strains in petri plates with turmeric methanolic extract samples. Sodium azide was used against fungal strains in petri plates with turmeric extract samples. These bacterial and fungal strains were collected from a laboratory in Lahore. Curcuma longa L. fresh rhizome extract was tested by disc diffusion method against four bacterial strains such as Gram-positive bacteria (S. typhi, S. aureus, and B. subtilis) and Gram-negative bacteria (E. coli). The antifungal activity was performed against four fungal strains (A. niger, A. alternate, F. oxysporum, and A. flavus). Bacteria were at a temperature of 37 °C and 25 °C, respectively. The zones of inhibition were measured in millimeters (mm) by a zone reader and are given in Table (9).The methanolic extract of Curcuma longa L. has shown insignificant antibacterial and antifungal potential. The zone of inhibition of methanolic extract of turmeric was comparatively small (3mm) against Escherichia coli

as compared to that (5 mm) displayed against Bacillus subtilis, Salmonella typhi, and Staphylococcus aureus (Table 4). The lower activity of the methanolic extract was rendered to the solvent effect. The OH group in the phenolic content of Curcuma longa L reacts with the OH group of methanol and this caused the decreased behavior of antibacterial activity which dissolves in sugars present in bacterial disc plate. The maximum zone of antifungal inhibition (22 mm) was displayed against Aspergillus flavus while the minimum zone of inhibition (15 mm) was shown against Fusarium oxysporum (Table 7).

Table 7. Antimicrobial data of extract of Curcuma longa L.

Antibacterial Activity Data				Antifungal Activity Data		
Pathogen Bacteria	**Gram +/-**	**Zone of inhibition (mm)**	**Standard (Streptomycin 0.01%)**	**Pathogen Fungi**	**Zone of Inhibition (mm)**	**Standard (Sodium Azide) mm**
E. coli	-	3	20	*F. oxysporum*	5	15
B. subtilis	+	5	12	*A. niger*	5	20
S. aureus	+	5	21	*A. flavus*	10	22
S. typhi	+	5	15	*A. alternata*	10	21

5. Applications of curcumin

Curcumin's full potential is hampered by poor oral bioavailability and insufficient solubility in aqueous solvents, which result in poor absorption, rapid metabolism and rapid systemic elimination. Curcumin microcapsules with improved solubility are suitable for use as a preservative and colourant in the food industry, with MIC values ranging from 15.7 to 250 g/mL against food-borne pathogens such as Penicillium notatum, Saccharomyces cerevisiae, Yersinia enterocolitica, B. cereus, E. coli, Staph. aureus and B. subtilis. With the need to maintain the performance and health of birds, there is increased interest in creating natural alternatives to antibiotic growth promoters. Over the last decade, turmeric has been widely employed in chicken

diets. For decades curcumin has been utilized to mitigate various medical conditions and recently to mitigate COVID-19. According to the literature, curcumin is a promising preventative and therapeutic candidate for COVID-19. Curcumin's antiviral effect against various enveloped viruses, including SARS-CoV-2, is aided by many mechanisms: direct contact with viral membrane proteins; breakdown of the viral envelope; inhibition of viral proteases and induction of host antiviral responses. Curcumin has been publicised to be safe and well-tolerated in healthy and ill humans and protects against deadly pneumonia and acute respiratory distress syndrome (ARDS) by inhibiting the pathways NF-B, inflammasome, IL-6 trans signal, and HMGB1, indicating its future use as a preventive treatment in clinical and public health settings.

- **Traditional Uses and Ethnopharmacology of Curcumin**

  Curcuma longa is an important nutritional plant with antioxidant, antibacterial, anti-inflammatory, anticancer and anti-clotting properties. Alternative therapeutic options such as medicinal plants have a long history of treating many diseases, and it is widely known that herbs are a good source of possible therapeutic chemicals. Turmeric (Curcuma longa) has been used as a spice in daily cooking and traditional medicine for over 6000 years. C. longa is a South and Southeast Asian plant rhizome found in Pakistan, China, Indonesia, India, Nepal, Jamaica, Bangladesh, Malaysia, El Salvador, Taiwan and Haiti. Curcuma is a genus of medicinal plants with therapeutic properties that include about 70 identified species. They have long been employed as food preservatives, coloring pigments and spices and have great therapeutic potential. Curcuma longa plant belongs to Zingiberaceae (ginger) family widely grown in Southeast Asia, primarily in China and India.

- **Application of Curcumin-Based Nano-Formulations**

  Curcumin-based nano-formulations have a promising future in preventing, diagnosing, and treating medical disorders such as cancer, but further research is needed to determine the safety and delivery strategy. Efficient curcumin delivery via nanotechnology

helps overcome issues with solubility, rapid drug metabolism, degradation, and drug stability. It should also diffuse or target indent tissues while minimizing unintended toxicity to surrounding normal cells/tissues. For example search for more effective cancer treatment with fewer side effects is ongoing; curcumin has demonstrated potential anticancer activities through numerous pathways, including inhibiting and/or inducing the generation of multiple cytokines, interfering with multiple cellular mechanisms, enzymes, or growth factors including IκB kinase β (IκKβ), tumour necrosis factor-alpha (TNF-α), signal transducer, and activator of transcription 3 (STAT3), cyclooxygenase II (COX-2), protein kinase D1 (PKD1), nuclear factor-kappa B (NF-κB), epidermal growth factor, and mitogen-activated protein kinase (MAPK), indicating that curcumin nano formulations may have potential applications. Ahmed and colleagues synthesized and characterized the curcumin-loaded AgNPs based on the size, polydispersity index, potential, morphology, size distribution, drug loading effectiveness and interactions with excipients. The anti-cancer potentials of the nanoparticles were evaluated against MM-138, FM-55 and MCF-7 cell lines. The nanoparticles effectively transported a greater amount of curcumin, indicating that it is a superb nanocarrier. In addition, the curcumin-loaded nanoparticles effectively fought against three different cancerous cell lines: MM-138, FM-55 and MCF-7. The potential of curcumin-based drugs, including nano formulations, is yet to be utilized to manage communicable and non-communicable diseases. Haghnegahdar and colleagues fabricated CM-functionalized nanocomposite with a large surface area, extended stability, strong adaptation, anti-interference capability and considerable reproducibility. The fabricated nanocomposite exhibits a strong electrocatalytic activity toward the oxidation of analytes, especially for dopamine (DA) (vs. Ag/AgCl), according to the electrochemical data. While the DA, uric acid (UA) and guanine (GU) results are consistent, there was no equivalent electrochemical peak for ascorbic acid (AA). It was further reported for DA, GU and UA, respectively, that their calibration curves were linear in the ranges of 12.0–200.0, 16.0–400.0, and 18–650.0 mol/L and the detection limits for DA, GU, and UA values were 0.14

mol/L, 0.19 mol/L and 0.38 mol/L, respectively. The produced electrode was effectively used for the simultaneous analysis of analytes in samples of blood, serum, urine and dopadic ampoules. The electrode had a lower detection limit, indicating its potential application for the detection of disease biomarkers as may be present at lower concentrations. This may be helpful in the early detection of diseases and hence their early mitigation. Results of a study by Proença-Assunção and colleagues revealed that without metabolic activation, Cur-AgNPs are not mutagenic, but when exposed to S9, Cur-AgNPs become mutagenic to the TA98 and TA100 strains, demonstrating the importance of metabolizer enzymes to activate Cur-AgNPs on these bacteria, which regained their capacity to synthesize histidine (His+). The curcumin-based nanoparticles may be a potential drug for managing medical disorders. The possibility of engineering nano-formulations to multifunctionality, merging therapeutic, targeting and diagnostic features, has shown potential advancement in managing diseases globally. These potentials caused the nanoparticles to rise as therapeutic agents with increased efficacy and diminished systemic drug side effects helpful for managing chronic diseases.

- **Electrostatic Nature and Size of Curcumin-Based Nano-Formulations**

  Electrostatic forces are among the most versatile interactions for mediating nanostructured material assembly. These forces can be long or short-ranged, attractive or repulsive, and the shapes of the charged nano-objects can control their directionality, depending on the experimental conditions. Electrostatic interactions operate in nano-formulations such as electroactive and or switchable nanoparticles, charged nanoparticle mixtures, nanoparticle chains, sheets, coatings, crystals, crystals-within-crystals, and other structures used in chemical sensing and amplification. On the other hand, the nano-formulations charge can be used to arrange nanoparticles to higher-order structures, but it is necessary to utilize oppositely charged nanoparticles. The electrostatic repulsion is the potential for the increased surface activity of nanoparticles, drug delivery, and formation of static and dynamic structures, which are necessary to diagnose and mitigate medical conditions. Nano

particles range from 1 to 100 nm and close to 100 nm and are efficient drug delivery systems. Curcumin nanoparticles are reported to range from 2 to 40 nm, but usually their size depends on the methodology used for their preparation. The size of a particle influences the overall charge density of a particle. Smaller size creates larger charge density for molecules with the same charge but differing size. A study by Vatanparast and colleagues investigated the role of electrostatic interactions in improving surface properties of anionic surfactants in silica nanoparticles. Results indicated that the observed SDS interfacial behavior in the presence of nanoparticles was due to the electrostatic repulsive interaction, leading to the increased surfactant surface activity and the adsorption of the dodecanal on the surfaces of particles, affecting the adsorption dynamic and resulting in faster interfacial relaxation, indicating the potential of the electrostatic interactions in the functioning of nano-formulations.

- **Curcumin Therapy for Mitigation of COVID-19**

  Coronavirus disease (COVID-19) is a virus-borne infection caused by the SARSCoV-2 virus. Most people infected with the virus will have mild to moderate respiratory illness and recover without special treatment. Some, however, will become critically ill and require medical attention. People over 65 and those with underlying medical conditions such as cardiovascular disease, diabetes, chronic respiratory disease or cancer are at a higher risk of developing a serious illness. Any age can become seriously ill or die due to COVID-19. Curcumin is an effective molecule for treating viral infections due to its ability to modulate various molecular targets involved in the infection process. These processes include inactivation and attack on virus structures, inhibition of virus attachment and entry into cells, protease inhibition, and transcription and replication regulation. These factors led to the wide application of curcumin during the era of COVID-19 pandemic in the clinical setting. Curcumin therapy decreased symptoms, hospitalization duration and death. In a recent study, Kow and colleagues reported significantly reduced odds of mortality with the use of curcumin relative to the non-use of

curcumin in patients with COVID-19, indicating the potential use of cumin for mitigation of the pandemic. Bormann and colleagues reported that turmeric root extract, dissolved turmeric capsule and pure curcumin effectively neutralized SARS-CoV-2 in Vero E6 and human Calu- 3 cells at subtoxic levels concentrations. It was further observed that curcumin significantly reduced SARS-CoV-2 RNA levels in cell culture, indicating it is a promising complementary COVID-19 treatment. In this case, curcumin, turmeric root or capsules may be used to manage COVID-19. Therefore, studies are needed to potentially investigate further curcumin-based drugs for managing COVID-19 and future pandemic.

- **User Preference for Curcumin**

  Turmeric has been widely used for various applications globally since the prehistoric period. However, literature is silent about user preference for this precious herb. All aspects of turmeric are widely reviewed, such as medical use due to potential pharmacological activities, inclusion in daily diet, and its use as a preservative. Future research should cover information on user preference apart from its acceptability due to its potential.

- **Safety Aspects of Curcumin**

  Curcumin is the chief bioactive compound in turmeric, one of the most effective nutritional supplements and traditional medicine. Studies demonstrated that curcumin has anti-inflammatory, anti-oxidant and anti-neoplastic properties. Previous literature has described the potential roles of this phytochemical in treating and preventing specific diseases such as metabolic syndrome, arthritis, anxiety, hyperlipidaemia and cancers. The US FDA recognized turmeric as safe and granted an acceptable daily intake (ADI) level of 3 mg/kg-BW by the joint FAO and WHO Expert Committee on Food Additives in 1996. Despite enthusiasm for the potential value of curcumin on human health that has led to more than 120 clinical trials of curcuminoids, efforts in curcumin-based drug development have been hampered by certain obstacles, including its poor bioavailability, which is primarily due to poor absorption and metabolic instability, and enigmatic diverse effects (or promiscuous

bioassay profile) that leads to speculation of curcumin being a pan-assay interference compound (PAINS). The poor bioavailability issue has led to numerous efforts to improve bioavailability, such as modulation of route and medium of curcumin administration, blocking of metabolic pathways by concomitant administration with other agents, conjugation and structural modifications of curcumin. Alafiatayo and colleagues embryotoxicity and teratogenic effects of Curcuma longa extract on zebrafish (Danio rerio). Results indicated that the toxicity effects were reliant on a dose, while, at 125.0 μg/mL, mortality of embryos was observed, and physical body deformities of larvae were recorded among the hatched embryos at higher concentrations. The teratogenic effects of the extract were severe at higher doses leading to physical body deformities such as bend trunk, enlarged yolk sac oedema and kink tail. Lastly, the therapeutic index (TI) values were roughly identical for different doses investigated. The results revealed that plants with therapeutic potential could also threaten when consumed at higher doses, especially in the embryos. Thus, detailed toxicity analysis should be conducted on medicinal plants to ascertain their safety on the embryos and their development. A phase 1 human trial consisting of 25 clients administered up to 8000 mg of curcumin per day for 3 months revealed no toxicity from curcumin. Similarly, five other trials using 1125–2500 mg of curcumin daily have also found it safe for consumption. These human trials have found some evidence of the anti-inflammatory activity of curcumin. The laboratory studies have identified several different molecules involved in inflammation that is inhibited by curcumin, including phospholipase, lipoxygenase, cyclooxygenase 2, leukotrienes, thromboxane, prostaglandins, nitric oxide, collagenase, elastase, hyaluronidase, monocyte chemoattractant protein-1 (MCP-1), interferon-inducible protein, tumour necrosis factor (TNF) and interleukin-12 (IL-12). It may exert anti-inflammatory activity by inhibiting several different molecules that play a role in inflammation, indicating potential medical applicability.

- **Availability of Finished Products**

  Root and rhizome of the turmeric plant (Curcuma longa L.) are of high therapeutic and economic potential globally, mainly used as a food and supplement. Reports of finished products made of turmeric are available. It was reported that quality differences were observed, which may interfere with its use in clinical settings. Therefore, establishing and managing integrated systems for dietary supplements quality monitoring throughout the supply chain from seed to finished product is essential. Booker and colleagues evaluated turmeric finished products, which were formulated in tablets (2), powder (1), extracts (2), soft gels (2) and capsules (43) which contained either plant extract or crude ground material of the plant or a combination of plant extract and crude ground material. This indicates the availability of finished products in the various formulations. Table 8 details the application of Curcuma longa. (Srivastava.et .al.2022)

Table 8. Application of Turmeric (Curcuma longa).

Purpose of Usage	Remarks
Curcumin is used in the mitigation of inflammatory disorders	This is due to its ability to inhibit different molecules involved in inflammation, such as lipooxygenase, COX-2, interferon-inducible protein, and tumour necrosis factor
Used in the management of diabetes mellitus:	Turmeric rhizome powder is very useful with amla juice and honey in Madhumeha (diabetes mellitus)
Used in the mitigation of cardiovascular disorders	This is contributed by the ability of the antioxidants in turmeric to prevent damage to cholesterol, hence its protection against atherosclerosis.
Used in the mitigation of allergic activity	This is due to the ability of curcumin to inhibit nonspecific and specific mast cell-dependent allergic reactions.
Used in the mitigation of dermatophytic activity:	Rhizomes of Haridra fresh juice have the antiparasitic ability in numerous skin affections.
Used in mitigation of drug resistance:	This is due to the ability of curcumin as a potent drug resistance preventer.
Used as additives in other drugs	This is due to the synergism of Curcumin and other drugs.
Used in the management of jaundice (Hepatoprotective)	Due to the synergistic interaction of the rhizome with amla juice and other substances.
Used in mitigation of ischemic brain injury	This is attributed to Curcuma oil's neuroprotective action, which reduces the negative effects of ischemia by reducing nitrosative and oxidative stress.

Used for mitigation of respiratory disorders	The rhizome is used for gargling, and the piece of the rhizome is slightly burnt and given for chewing.
Gastrointestinal disorders:	This is due to the anthelmintic activity of the fresh juice of Haridra.
Used as an additive in poultry diet	Used as a natural growth promoter and disease control.
Used for management of Alzheimer's disease	This is due to the ability of curcumin to reduce oxidative damage and reverse the amyloid pathology.
Used for chemoprotection In tumour cells or tissue	Curcumin is nutraceutical. Chemopreventive ability.
Used in mitigation of cancer	Curcumin possesses anticancer activities via its effect on diverse biological pathways involved in mutagenesis, oncogene expression, cell cycle regulation, apoptosis, tumorigenesis and metastasis.

6. Conclusion

Turmeric has a vital role in Asian culture, and its wide variety in traditional medical systems such as Ayurveda, Siddha, and Unani have long been utilized. Turmeric, a golden spice of the long-plant Rhizome of the Curcuma longa plant, has been used in food preparations from ancient times to give color, taste, and flavor. Due to its high phenolic and flavonoid content, which provides excellent antioxidant activity, it is also used as a medicine to treat a variety of diseases. Gynecological problems, gastric problems, hepatic disorders, cough, sore throat, respiratory ailments, infectious diseases, and blood disorders have all been treated with this spice as folk medicine in the past. Polyphenols, alkaloids, diterpenes, sesquiterpenes, triterpenoids, and sterols have been isolated from this spice's chemical constituents. Curcumin, which makes up 2–5% of turmeric, is probably the most researched component. Turmeric has been shown to have antimicrobial, antimutagenic, anti-cancer, insecticidal, larvicidal, and radioprotector properties in cell studies. Several animal studies have proven the anti-inflammatory, neurodegenerative, cancer, diabetic, depressive, obese, and atherosclerotic effects of this spice.

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حکومەتی هەرێمی کوردستان-عێراق

وەزارەتی خوێندنی باڵاو توێژینەوەی زانستی

زانکۆی سەلاحەدین -هەولێر کۆلێژی زانست -بەشی کیمیا

لێکۆڵینەوەی کیمیایی و بایۆلۆجی لەڕووەکی زەردەچۆ

پڕۆژەی دەرچونە پێشکەش بە بەشی کیمیا کراوە وەك بەشێك لە پێداویستیەکانی)
(بەدەستهێنانی بڕوانامەی بەکالۆریۆس لە زانستی کیمیا

ئامادەکردنی:-

هێلین ئادەم عومەر

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