REVIEW ARTICLE

Turmeric (*Curcuma longa* L.): A promising spice for phytochemical and pharmacological activities

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Turmeric (*Curcuma longa*) is a small rhizomatous perennial herb belonging to Zingiberaceae family originating from South-Eastern Asia, most probably from India. The plant produces fleshy rhizomes of bright yellow to orange colour in its root system, which are the source of the commercially available spice turmeric. In the form of root powder, turmeric is used for its flavouring properties as a spice, food preservative and food-colouring agent. Turmeric has a long history of use in Ayurvedic medicine as it is credited with a variety of important beneficial properties. Turmeric constituents include the three curcuminoids: Curcumin (diferuloylmethane; the primary constituent and the one responsible for its vibrant yellow colour), demethoxycurcumin and bisdemethoxycurcumin, as well as volatile oils (tumerone, atlantone and zingiberone), sugars, proteins and resins. Several studies using the modern techniques have authenticated turmeric used as anti-inflammatory, antimicrobial, anti-fertility, anticancer, anti-diabetic, antioxidant, hypolipidemic, anti-venom, anti hepato-toxic, nephroprotective, anticoagulant, etc., Most importantly, the plant has shown to possess anti HIV activity which could be of great value to combat AIDS particularly in third world countries. In this present work, we make an overview of the phytochemistry and pharmacological activities of turmeric, showing its importance.

Key words: *Curcuma longa*, phytochemistry, turmeric

INTRODUCTION

Curcuma longa L., belongs to the Zingiberaceae family, is a perennial herb that measures up to 1 m high with a short stem, distributed throughout tropical and subtropical regions of the world, being widely cultivated in Asiatic countries, mainly in India and China. Turmeric is one of the most essential spices all over the world with a long and distinguished human use particularly in the Eastern civilization.[1] Apart from its culinary uses, turmeric has been used widely in the traditional medicine in India, Pakistan and Bangladesh because of its several beneficial properties.[2] In India it is popularly known as 'Haldi'. Its rhizomes are oblong, ovate, pyriform and often short-branched and are used as a household remedy in Nepal.[3] As a powder, called turmeric, it has been in continuous use for its flavouring, as a spice in both vegetarian and non-vegetarian food preparations and it also has digestive properties.[4] Current traditional Indian medicine claims the use of its powder against biliary disorders, anorexia, coryza, cough, diabetic wounds, hepatic disorder, rheumatism and sinusitis.[5] The colouring principle of turmeric was isolated in the 19th century and was named curcumin, which was extracted from the rhizomes of *C. longa* L. with yellow colour and is the essential component of this plant, being responsible for the anti-inflammatory effects. In old Hindu medicine, is extensively used for the treatment of sprains and swellings caused by injury.[5] Several studies using the modern techniques have authenticated turmeric used as anti-inflammatory, antimicrobial, anti-fertility, anticancer, anti-diabetic, antioxidant, hypolipidemic, anti-venom, anti hepato-toxic, nephroprotective, anticoagulant, etc.as shown in Figure 1. Most importantly, the plant has shown to possess anti HIV activity which could be of great value to combat AIDS particularly in third world countries.

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PHYTOCHEMISTRY

Turmeric contains protein (6.3%), fat (5.1%), minerals (3.5%), carbohydrates (69.4%) and moisture (13.1%). Phenolic diketone, curcumin (diferuloylmethane) (3-4%) is responsible for the yellow colour, and comprises curcumin I (94%), curcumin II (6%) and curcumin III (0.3%). Other phenolic diketones demethoxycurcumin and bis-demethoxycurcumin have also been isolated from the rhizomes of *C. longa*.[2] Presence of tumerones (a and b), curdione, curzerenone, mono- and di-demethoxycurcumin have been reported

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in the rhizomes. The essential oil (5.8%) obtained by steam distillation of rhizomes has α-phellandrene (1%), sabinene (0.6%), cineol (1%), borneol (0.5%), zingiberene (25%) and sesquiterpines (53%).[6] The essential oils of leaves of *C. longa* have been analyzed by Gas Liquid Chromatography (Perkin–Elmer auto-system fitted with capillary column carbowa ×20 m of 50 m length flux ionization detector) and reported to contain α-pinene, β-pinene, sabinene, myrcene, α-phellandrene, 1,8-cineole, *p*-cymene, C8-aldehyde, linalool, caryophyllene, geraniol and methyl heptanone.[7]

One novel sesquiterpene with new skeleton, (6S)-2-methyl-6-(4- hydroxyphenyl-3-methyl)-2-hepten-4-one, two new bisabolane sesquiterpenes, (6S)-2-methyl-6-(4-hydroxyphenyl)-2-hepten-4-one, (6S)-2- methyl-6-(4-formylphenyl)-2-hepten-4-one, and two calebin derivatives, 4″-(4‴-hydroxyphenyl-3‴-methoxy)-2″-oxo-3″-butenyl-3-(4′-hydroxyphenyl)-propenoate and 4″-(4‴-hydroxyphenyl)-2″-oxo-3″-butenyl-3-(4′-hydroxyphenyl-3′-methoxy)-propenoate were isolated along with five known bisabolane sesquiterpenes from *C. longa.* The structures have been elucidated by spectral methods.[8] Composition and phytoconstituents of turmeric are shown in Tables 1 and 2, respectively.

PHARMACOLOGY

Inflammation and Oedema

Several animal studies have investigated the anti-inflammatory effects of curcumin. Early work by Srimal *et al*. demonstrated curcumin anti-inflammatory action in a mouse and rat model of carrageenan induced paw oedema. In mice, curcumin inhibited oedema at doses between 50 and 200 mg/kg. A 50% reduction in oedema was achieved with a dose of 48 mg/kg body weight, with curcumin nearly as effective as cortisone and phenylbutazone at similar doses. In rats, a lower dose of 20-80 mg/kg decreased paw oedema and inflammation. Curcumin also inhibited formaldehyde induced arthritis in rats at a dose of 40 mg/kg, had a lower ulcerogenic index (0.60) than phenylbutazone (1.70) (an anti-inflammatory drug often used to treat arthritis and gout), and demonstrated no acute toxicity at doses up to 2 g/kg body weight.[9]

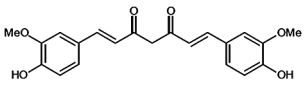
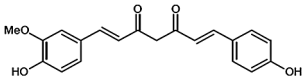
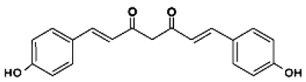
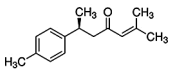
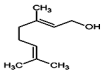
Ulcerative Colitis

Curcumin has also been shown to reduce mucosal injury

Table 1: Chemical composition of turmeric[2]

Constituents	Quantity (%)
Curcumin	2-6
Volatile oil	3-7
Fibre	2-7
Mineral matter	3-7
Protein	6-8
Fat	5-10
Moisture	6-13
Carbohydrate	60-70

Table 2: Structure of chemical constituents present in turmeric

Phytoconstituents	Structure
Curcumin I	
Curcumin II (demethoxycurcumin)	
Curcumin III (bis-demthoxycurcumin)	
Ar-tumerone	
α-Phellandrene	
Sabinene	
Geraniol	

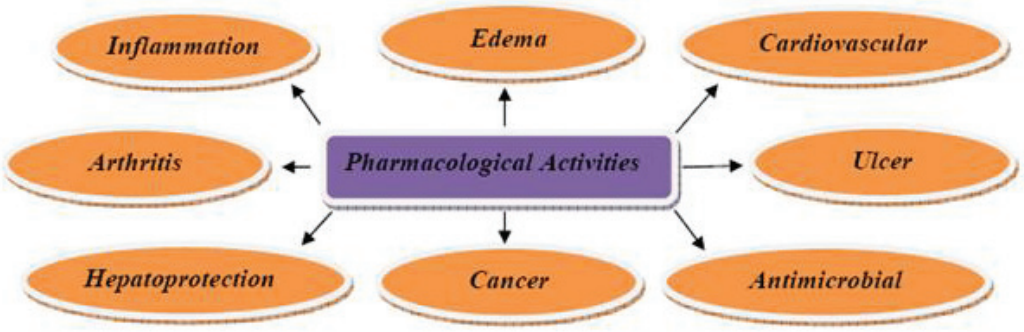


Figure 1: Various pharmacological activity of turmeric

in mice with experimentally-induced colitis. A dose of 50 mg/kg curcumin for 10 days prior to induction of colitis with 1,4,6-trinitrobenzene sulphonic acid resulted in a significant amelioration of diarrhoea, improved colonic architecture, and significantly reduced neutrophil infiltration and lipid peroxidation in colonic tissue. Reduced levels of nitric oxide and O_2 radicals and suppressed NF-κB activation in colonic mucosa, all indicators of reduced inflammation and symptom improvement, were also reported.[10]

Rheumatoid Arthritis

In an animal model of streptococcal cell wall-induced rheumatoid arthritis, a turmeric extract devoid of essential oils was given to Wistar female rats. Intraperitoneal injection of an extract containing 4 mg total curcuminoids/kg/day for four days prior to arthritis induction significantly inhibited joint inflammation in both the acute (75%) and chronic (68%) phases. To test the efficacy of an oral preparation, a 30-fold higher dose (to allow for possible low gastrointestinal absorption) of the curcuminoid preparation, given to rats four days prior to arthritis induction, significantly reduced joint inflammation by 48% on the 3rd day of administration.[11]

Pancreatitis

In two rat models of experimentally - induced pancreatitis, curcumin decreased inflammation by markedly decreasing activation of Nuclear factor-kappa B and Activating Protein-1 as well as inhibiting mRNA induction of interleukin-6, tumour necrosis factor-α, and inducible Nitric Oxide Synthetase in the pancreas. Both cerulean induced and ethanol induced pancreatitis, curcumin showed inhibitory effect on the inflammatory mediators resulted in improvement in disease severity as measured by histology, serum amylase, pancreatic trypsin, and neutrophil infiltration.[12]

Cancer

Numerous animal studies have explored curcumin anti-inflammatory mechanisms and their influence on the carcinogenesis. Table 3 lists animal studies in which oral or dietary curcumin inhibited carcinogenesis through anti-inflammatory mechanisms.

Antioxidant Effects

Water and fat-soluble extracts of turmeric and its curcumin component exhibit strong antioxidant activity, comparable to vitamins C and E.[5] A study of ischemia in the feline heart demonstrated that curcumin pre-treatment decreased ischemia-induced changes in the heart.[6] An *in vitro* study measuring the effect of curcumin on endothelial heme oxygenase-1 an inducible stress protein, was conducted utilizing bovine aortic endothelial cells. Incubation (18 h) with curcumin resulted in enhanced cellular resistance to oxidative damage.[7]

Hepatoprotective Effects

Turmeric has been found to have a hepatoprotective characteristic similar to silymarin. Animal studies have demonstrated turmeric's hepatoprotective effects from a variety of hepatotoxic insults, including, carbon tetrachloride (CCl_4),[8] galactosamine,[2] acetaminophen (paracetamol)[3] and Aspergillus aflatoxin.[4] Turmeric hepatoprotective effect is mainly a result of its antioxidant properties, as well as its ability to decrease the formation of pro-inflammatory cytokines. In rats with CCl_4-induced acute and subacute liver injury, curcumin administration significantly decreased liver injury in test animals compared to controls. Turmeric extract inhibited fungal aflatoxin production by the 90% when given to ducklings infected with *Aspergillus parasiticus*. Turmeric and curcumin also reversed biliary hyperplasia, fatty changes, and necrosis induced by aflatoxin production.[4] Sodium curcuminate, a salt of curcumin, also exerts choleretic effects by increasing biliary excretion of bile salts, cholesterol, and bilirubin, as well as increasing bile solubility, therefore, possibly preventing and treating cholelithiasis.[5]

Antimicrobial Effects

Turmeric extract and the essential oil of *C. longa* inhibit the growth of a variety of bacteria, parasites, and pathogenic fungi. A study of chicks infected with the caecal parasite *Eimera maxima* demonstrated that diets supplemented with 1% turmeric resulted in a reduction in small intestinal lesion scores and improved weight gain.[12] Another animal

Table 3: Animal studies in which oral or dietary curcumin inhibited carcinogenesis

Animal model	Route of administration	Dose	References
Murine (liver) iNOS production	Oral by gavage, intravenous	0.5 mL of 10 μM solution, 0.5 μg/g body weight	7
Rat colonic aberrant crypt foci	Oral (diet), subcutaneous	50-2000 ppm, 15 mg/kg body weight	8
Rat colon cancer	Oral (diet)	2000 ppm	13
Murine familial adenomatous polyposis	Oral (diet), intraperitoneal	0.1%, 0.2%, 0.5% diet 100 mg/kg body weight	14
Rat colonic aberrant crypt foci	Oral (diet)	0.6% diet	15
Rat colonic apoptosis	Oral	0.6% diet	16
Murine xenograft tumour	Intraperitoneal	200 μL of 0.2-1.0 μg/mL curcumin suspension	17
Murine lymphomas/leukaemias	Oral (diet)	2% diet	18
Murine T-cell leukaemia	Oral (gavage)	300 mg/kg body weight	19

Inducible nitric oxide synthetase

study, in which guinea pigs were infected with either dermatophytes, pathogenic moulds or yeasts found that topically applied turmeric oil inhibited dermatophytes and pathogenic fungi, but neither curcumin nor turmeric oil affected the yeast isolates. Improvements in the lesions were observed in the dermatophytes and fungi-infected guinea pigs and at 7 days post-turmeric application the lesions disappeared.[20] Curcumin has also been found to have moderate activity against *Plasmodium falciparum* and *Leishmania major* organisms.[21]

Cardiovascular Effects

Turmeric protective effects on the cardiovascular system include lowering cholesterol and triglyceride levels, decreasing susceptibility of low density lipoprotein (LDL) to lipid peroxidation[22] and inhibiting platelet aggregation.[23] These effects have been noted even with low doses of turmeric. A study of 18 atherosclerotic rabbits given low-dose (1.6-3.2 mg/kg body weight daily) turmeric extract demonstrated decreased susceptibility of LDL to lipid peroxidation, in addition to lower plasma cholesterol and triglyceride levels. The higher dose did not decrease lipid peroxidation of LDL, but cholesterol and triglyceride level decreases were noted, although to a lesser degree than with the lower dose.[22] Turmeric extract effect on the cholesterol levels may be due to decreased cholesterol uptake in the intestines and increased conversion of cholesterol to bile acids in the liver.[5] Inhibition of platelet aggregation by *C. longa* constituents is thought to be via potentiation of prostacyclin synthesis and inhibition of thromboxane synthesis.[23]

CONCLUSION

Medicinal plants have provided copious leads to combat diseases, from the dawn of civilization. The extensive survey of the literature revealed that *C. longa* is highly regarded as a universal panacea in the herbal medicine with diverse pharmacological activity spectrum. This versatile medicinal plant is the unique source of various types of chemical compounds, which are responsible of the various activities of the plant. Hence, extensive investigation is needed to exploit their therapeutic utility to combat diseases. A drug development programme should be undertaken to develop modern drugs with the compounds isolated from henna. Although crude extracts from leaves of the plant have medicinal applications from time immemorial, modern drugs can be developed after extensive investigation of its bioactivity, mechanism of action, pharmacotherapeutics and toxicity after proper standardization and clinical trials. As the global scenario is now changing towards the use of non-toxic plant products having traditional medicinal use, development of modern drugs from *C. longa* should be emphasized for the control of various diseases. Henna imbibing a tremendous potential deserves a special attention of the scientific fraternity to emerge as a milestone for medical science of this millennium due to its various medicinal uses. Further evaluation needs to be carried out on *C. longa* in order to explore the concealed areas and their practical clinical applications, which can be used for the welfare of mankind.

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