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Curcuma species: phytochemical composition, Nutritional value and Pharmacological activities: A review

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Abstract

The traditional medicine all over the world is nowadays revalued by an extensive activity of research on different plant species and their therapeutic principles. *Curcuma* plants has an importance place during centuries as one of the significant ingredients in food and traditional medicines. The volatile components of various *Curcuma* species as well as non-volatile curcuminoids offer the wide use as nutritionally rich food products. Analytical Chemistry permits the discovery of novel bioactive compounds possessing wide bioactivities such as antioxidant, antiviral, antimicrobial, and anti-inflammation activities. Curcuminoids (curcumin, demethoxycurcumin, and bisdemethoxycurcumin) are non-toxic polyphenolic derivatives of curcumin that exert a wide range of biological activities. Survey literature containing thousands of documents on *Curcuma* is sign of researcher concerns on the nutritional values and various medicinal uses.

Keywords: Curcuma; Chemical composition; Nutritional composition; Medicinal uses; Phenolic, Flavonoid; antioxidant

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1. Introduction

The genus *Curcuma L.* (Zingiberaceae) belongs to the group of perennial rhizomatous herbs native to tropical and subtropical regions. *Curcuma* is extensively cultivated in tropical and subtropical regions of Asia, Australia, and South America [1-5]. There are approximately 93–100 accepted Curcuma species, however the exact number of species is still controversial [6-10]. Among the Curcuma species, C. longa, C. aromatica and C. xanthorrhiza are the most popular [11]. *Curcuma* herb measures up to 1

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m high with a short stem, having oblong, pointed leaves and funnel-shaped yellow flowers [12].

A source of a yellow dye, *Curcuma* is well-known and has been historically used as spices, food preservatives, flavoring agent, and household remedy for treatment of many diseases [13-17]. As black pepper : the king of spices, *Curcuma* also known as the gold spice (Figure 1), find wide in traditional medicinal uses like treatment of enlarged liver, spleen, stomach ulcer, diabetes, cough, hepatic disorders, chest pain, skin diseases, boils, blood purifier, and rheumatism [18–21].

Figure 1 : Turmeric / Curcuma Longa

Various parts of these plant species (Curcuma …) are reportedly eaten either raw or cooked as vegetables in most kitchen [22-26]. They are also considered as nutritionally rich food products since the plants are a rich source of starch, carbohydrates, proteins, fats, vitamins, and minerals [27–34]. Numerous works focused on the phytoconstituents, essential oils, and pharmacological actions have been published [35–40]. The progress in Science characterization try to explain and reinforce the mystery of this plant containing bioactive molecules that possess pharmacological properties like anti-inflammatory, antimicrobial, antidiabetic, antirheumatic, antiviral, antifibrotic, antivenomous, antihepatotoxic, antinociceptive, anticancerous, hypocholestraemic, and gastroprotective properties… [41–45]. The use of turmeric dates back nearly 4000 years to the Vedic culture in India, where it was used as a culinary spice and had some religious significance. It probably reached China by 700 ad, East Africa by 800 ad, West Africa by 1200 ad, and Jamaica in the eighteenth century [46].

2. Chemical composition

Turmeric powder contains approximately 11.4% water, 7.8% protein, 9.9% fat and 64.9% carbohydrate in addition to minerals (Ca, Mg, Fe ...) and vitamins (vit. E, C…) and about 2 to 7% essential oil [47].

2.1. Discovery of curcumin

The discovery of curcumin goes back nearly two centuries when Vogel and Peletier reported isolating a "yellow coloring substance" from the roots of Curcuma longa (turmeric) and named it curcumin (Figure 2) [48]. Later, this substance was found to be a mixture of resin and turmeric oil. In 1842, Vogel Jr. obtained a pure preparation of curcumin but did not report its formula [49]. In the decades

that followed, several chemists reported possible structures of curcumin [50-52]. However, it was not until 1910 that Milobedzka and Lampe identified the chemical structure of curcumin as diferuloylmethane, or 1,6-heptadiene-3,5-dione-1,7-bis (4-hydroxy-3-methoxyphenyl)-(1E, 6E) [53]. Further work by the same group in 1913 resulted in the synthesis of the compound [54]. Subsequently, Srinivasan separated and quantified the components of curcumin by chromatography [55]

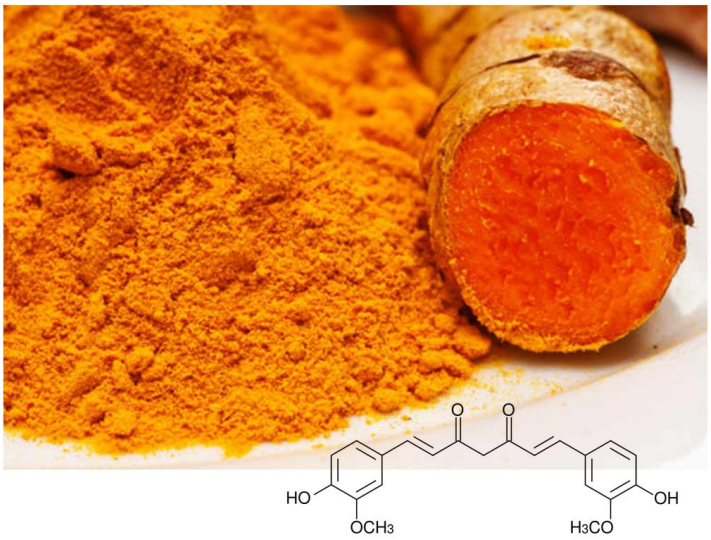

Figure 2: Curcumin molecule

Curcuma longa contains approximately 5% curcumin and two other compounds, demethoxy-curcumin (DMC), and bis-demethoxy-curcumin (BDMC) [56] (Figure 3), curcumin present (75–90%) of these curcuminoids [57]. In general, the fresh rhizomes of turmeric are richer in curcuminoids compared to the dry and hardened rhizomes [58]. Curcumin is a very strong but safe anti-inflammatory agent [59], it exhibits some inhibitions of HIV proteases [60], where hydroxy groups on phenyl rings are apparently essential for inhibitory activity [61]. It exhibits anti-cancer activity [62], and it acts as a chemopreventive agent for cancer of the colon, duodenum, anterior stomach, mammary and skin cancers [63], it acts as an inhibitor of cyclo-enzymes. oxygenase [64], but the main action of curcumin is due to its ability to inhibit the formation of reactive oxygen species such as hydroxyl radicals and superoxide anions [65]. The results obtained by F. Shakeri et al. [66], suggest a preventive therapeutic potential for Curcuma longa and its active factor, curcumin, on inflammatory cells and oxidative stress in asthma. Other curcuminoids such as tetra-hydro-curcuminoid (THCs) are useful in non-colored food and cosmetic applications, which currently employ synthetic antioxidants [67], several independent studies, have reported that THCs have a considerable antioxidant effect [68]. The good activity of curcumin and THCs may be due to the phenolic hydroxyl group or the methylene group of half beta-diketone. However, the phenolic group appears to play the major role in the activity of the curcuminoid antioxidant [69,70].

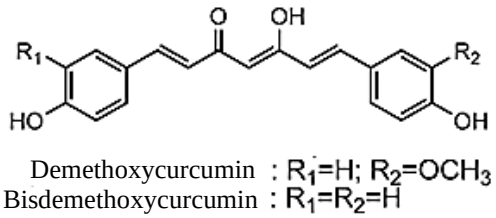

Figure 3: Chemical structure of curcuminoids.

Curcumin has two tautomeric forms, ketone and enol (Figure 4). Curcumin is practically insoluble in neutral and acidic aqueous solutions, but soluble in organic solvents. Curcumin is in the ketone form in neutral and acidic media, in contrast, the enol form is predominant in basic media, and however, the enol tautomer is exclusively present under alkaline conditions [71]. The solubility of curcumin increases in alkaline solution, but it can degrade quickly.

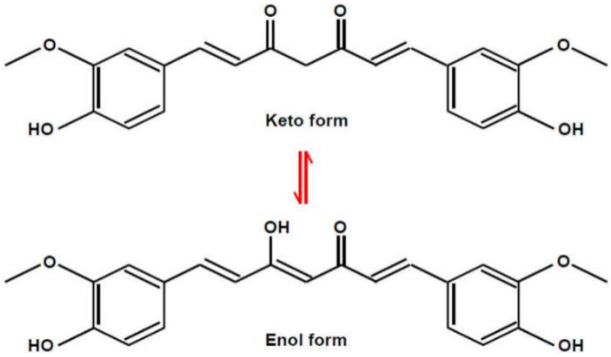

Figure 4: Both forms of curcumin

Curcumin mainly has three reactive sites (Figure 5), a hydrogen atom donor, a Michael acceptor and a metal chelator [71,72]. The metal chelating ability of curcumin has shown great promise as a therapeutic agent against diseases such as Alzheimer's disease, cancer, depression and arthritis [71, 73].

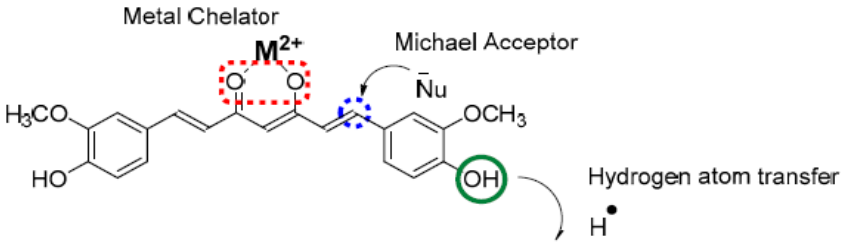

Figure 5: Chemical reactivity sites in curcumin [74].

However, despite extensive research and development, the poor solubility of curcumin in aqueous solution remains a major obstacle to its bioavailability and clinical efficacy. Its low bioavailability is due to its rapid metabolism in the liver and the intestinal wall. Several studies have been carried out to increase its solubility and by extension its bioavailability.

❖ **Piperine as a cofactor:**

The effect of the combination of piperine was evaluated on the bioavailability of curcumin in rats and healthy human volunteers. Administration of piperine at a known dose to rats increased the serum concentration of curcumin and the bioavailability was increased by 154%. Concomitant administration of 20 mg / Kg piperine produces much higher serum curcumin concentrations and the bioavailability increases to 2000% [75]. The mechanism is not known with certainty, but this effect is probably due to the increased absorption of curcumin and a reduction in its metabolism through the inhibition of liver and intestinal enzymes by piperine [76].

❖ **Encapsulation by nanoparticles:**

Another technique for improving the oral bioavailability of molecules such as estradiol [77, 78] and cyclosporine [79] (Fig. 6) is to encapsulate them in biodegradable nanoparticles. In addition, the improved safety and efficacy of atorvastatin in the treatment of hyperlipidemia has also been demonstrated by encapsulating it in nanoparticles [80]. Several studies have investigated the encapsulation of curcumin using nanoparticles in order to improve its oral bioavailability [81, 82].

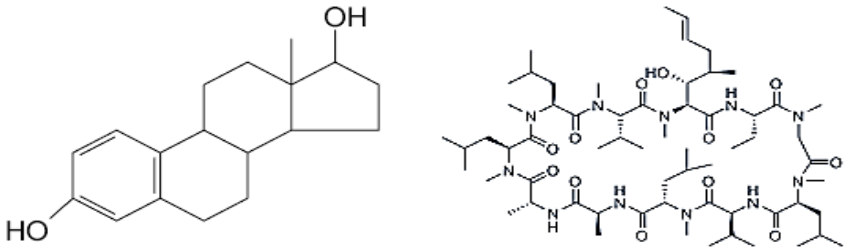

Figure 6: Structures of estradiol (left) and cyclosporine (right).

❖ **Encapsulation by liposomes:**

Li et al. [83] encapsulated curcumin in a liposomal system and showed that liposomal curcumin inhibits tumor growth in vivo, more potently than curcumin alone. Other preclinical studies have also shown an increase in the bioavailability of liposomal curcumin when taken with curcumin.

❖ **Complexation with micelles:**

Complexation of curcumin by micelles (a spherical aggregate of molecules with a solvent-directed hydrophilic polar head and an inward-directed hydrophobic chain) may improve bioavailability by increasing digestive absorption [84].

2.2. Essential oil of Curcuma

Turmeric essential oil is a liquid with a fresh, spicy and woody scent, pale yellow to dark yellow in colour. It has 2 to 7% of the mass of the turmeric rhizome. The table below gives a comparison between the chemical composition of the essential oil of fresh and dry rhizomes from Curcuma longa [85].

Table 1. Chemical composition of the essential oil of fresh and dry rhizomes from C. longa.

Compound	Fresh rhizomes	Dry rhizomes
Terpinolene	2.7	Tr
p-Cymen-8-ol	0.9	Tr
β- Caryophyllene	3.1	0.5
α- Santalene	0.4	7.2
Trans- α- Bergamotene	0.1	1.6
Epi- β- Santalene	Tr	1.0
Sesquisabinene	0.2	1.6
Ar-Curcumene	1.6	6.6
α- Zingibrene	2.5	0.8
β- Bisabolene	0.8	4.1
β- Sesquiphellandrene	2.9	4.2
Santalenone	1.1	5.6
ar- turmerone	**24.4**	**21.4**
α- turmerone	**20.5**	0.6
β- Bisabolol	-	3.0
Germacrone	1.0	2.6
β- turmerone	11.1	4.3
6R,7R- Bisabolone	1.7	0.8
Trans- α- Atlantone	0.9	2.6

Table 2 represents the chemical composition of essential oils of turmeric rhizomes collected in different regions. The planting area (with the climate, the altitude ...) plays an important role in the chemical composition of turmeric essential oil. Table 3 [89] represents a comparison between the chemical compositions of the essential oils obtained by two methods, conventional hydro-distillation and microwave assisted hydro-distillation. Microwave assisted hydro-distillation (especially at low power) promotes the extraction of oxygenated compounds in the essential oil which has a positive influence on the quality of the essential oil. The figure 7 shows some structures of the major compounds that make up turmeric essential oil.

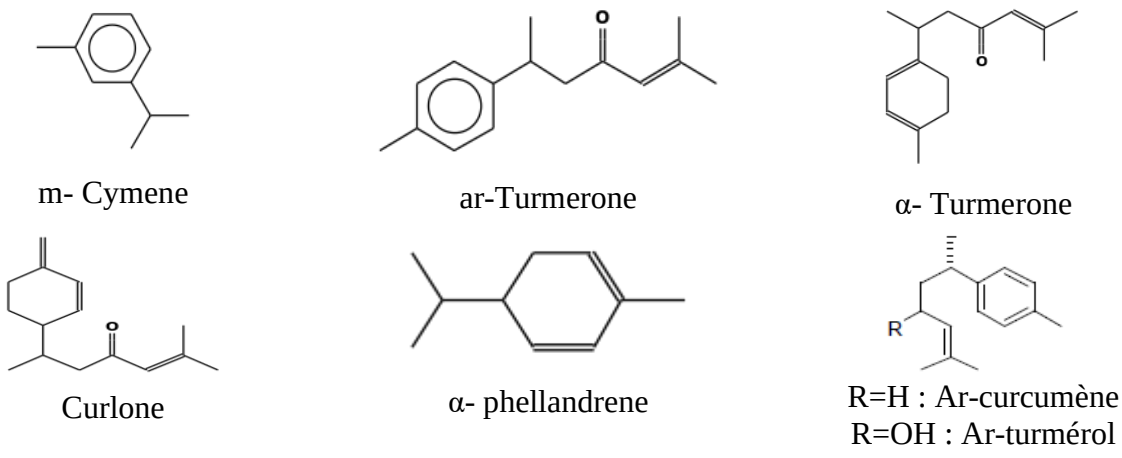

Figure 7: Structures of the major compounds of the *curcuma longa L.* essential oil

Table 2. Chemical composition of rhizome essentials oil of curcuma longa L. growing in different regions.

Compound	Abundance (%)		
	[86]	[87]	[88]
α- thujene	6.7	Tr	-
α- pinene	2.8	Tr	Tr
β- pinene	2.4	Tr	-
Myrcene	7.6	Tr	Tr
Car-2-ene	4.0	-	-
α- phellandrene	-	-	6.5
β- phellandrene	3.1	8.0	0.6
Limonene	5.3	-	-
p-Cymene	-	4.3	0.9
1,8- cineole	6.9	11.2	3.2
Terpinolene	-	-	1.4
Cis-ocimene	2.6	Tr	-
Trans-ocimene	9.8	Tr	-
Iso- artimisa ketone	1.1	-	-
γ- terpinene	2.6	Tr	Tr
borneol	3.3	-	-
Terpineol	2.1	Tr	
α- terpineol	2.0	Tr	Tr
Thymol	6.4	Tr	-
β-Caryophyllene	-	9.8	Tr
ar- Curcumene	-	4.4	1.0
Zingibrene	5.2	5.6	1.9
β- Bisabolene	13.9	2.8	Tr
β- Curcumene	-	4.2	
Sesquiphellandrene	5.2	7.1	1.4
Caryophyllene oxide	-	3.4	-
ar-Turmerone	-	7.3	12.9
α- Turmerone	3.5	11.1	42.6
β- Turmerone	-	5.0	16.0
β- Caryophyllene	-	9.8	Tr

4. Medical uses

4.1. Antioxidant active chemicals

Oxidation is part of a redox reaction that transfers electrons from a substance to an oxidizing agent. Although oxidation reactions are necessary for life, they can also be destructive because these reactions can produce free radicals, which lead to destructive chain reactions. Plants and animals use and produce many antioxidants for their protection. Antioxidants are very diverse compounds, which include

proteins with enzymatic activity (superoxide dimutase, glutathione peroxidase and catalase) and non-enzymatic (sequestering metals) and small fat-soluble molecules (vitamin E, β-carotene) or water-soluble (vitamin C, uric acid).

Table 3. Comparison between the chemical compositions of the essential oils obtained by two methods, conventional hydro-distillation and microwave assisted hydro-distillation.

Compound	**Abundance (%)**	
	CHD *	**MHD (300W) ****
α-Phellandrene	1.42	-
p-Cymene	1.21	-
Caryophyllene	4.63	1.63
Cuparene	16,06	18.38
α-Curcumene	-	9.50
α-Farnesene	-	1.20
α-Himachalene	2.63	2.95
Alloaromadendrene	11.44	4.57
Caryophyllene oxide	2.15	1.01
Tumerone	2.21	2.94
Menthol	3.88	4.52
Cubenol	1.41	1.60
Nuciferol	3.91	3.46
cis-Thujopsene	1.92	2.10
α-Cedrane	1.05	2.51
Aromadendrènépoxide -(I)	-	1.34
1-Phenyl-3-hydroxymethyl-2(aH)-pyridinethione	7.74	17.57
α-trans-Bergamotenol	10.06	18.86
Ylangene	1.11	-
Rate of oxygenated compounds (%)	**31.36**	**51.30**

* Conventional hydro-distillation.
** Microwave assisted hydro-distillation (at a power of 300 W).

According to Halliwel [90], an antioxidant is any substance, which, present at low concentration compared to that of the oxidizable substrate, significantly delays or prevents the oxidation of the substrate. In general, an antioxidant is a substance capable of neutralizing the active forms of oxygen and helps maintain non-cytotoxic levels of free radicals in the cell and the body. The study of the antioxidant activity of essential oils of turmeric was carried out by Dhanalakshmi K. G. et al. [91]. The results obtained revealed a weak antioxidant activity. Another study was carried out by RMILI R. **[**89], revealed a better activity but which remains weak compared to the antioxidant activity of ascorbic acid. The analysis of the results of the antioxidant activity of the extracts of ethyl acetate and of ethanol, obtained by RMILI R., [89] reveals the presence of a good antioxidant efficiency with IC50s of approximately 11.86 and 13.41 µg / mL, respectively (compared to an IC50 of approximately 7.75 µg / mL for ascorbic acid). Which is expected, as these extracts are rich in phenolic compounds such as curcuminoids.

4.2. Antibacterial activity

The results obtained by RMILI R. [89], clearly show that the ethanolic extract of turmeric has a very strong antibacterial activity against eight types of bacteria. This activity is clearly stronger than those of the two reference antibiotics (ampicillin and streptomycin). Ram Kumar et al. [91], confirmed these results and reported that aqueous and ethanolic extracts of turmeric longa L. exhibited activity against food-associated bacteria, such as ethanolic extract which is highly active against isolates of E. Coli whereas the aqueous extracts are strongly active against S. aureus isolates. On the other hand, Chandrana et al. [92], who studied the antimicrobial activity of curcuma longa L., indicated that it was effective against E. coli, B. subtilis and S. aureus and suggested that the activity is due to the presence of curcuminoids. Gur et al. [93], reported that ethanolic turmeric extract was effective in extracting active antimicrobial substances compared to aqueous extract and hexane.

4.3. Anticancer

A study of anti-cancer activity was performed by Jasim H. N. et al. [94], revealed that the vast majority of curcumin and ethanolic extract are strongly cytotoxic against all human hepatocellular carcinoma cell lines with an IC50 less than 1 µg / ml, (The compounds were classified according to their activity as highly active if IC50 <1 µg / ml), compared to doxorubicin, which confirms their anticancer activities. Another study [95] confirmed that the components of turmeric without curcumin possess anticancer activities. Certain components have been shown to work synergistically with curcumin by increasing absorption by cells through modulation of P-glycoprotein.

Conclusion

In this review, we exposed a brief on *Curcuma Longa* during its use. The solvent extracts of *Curcuma Longa* were found to be effective antioxidants by in vitro assays, and can therefore be proposed as new potential sources of natural additives for the food and/or pharmaceutical industries. There is a relationship between the total phenol content and antioxidant activity. Indeed, it is extremely important to point out that there is a positive correlation between the antioxidant activity potential and the amount of phenolic compounds.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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