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PHYTOCHEMISTRY OF TURMERIC: AN OVERVIEW

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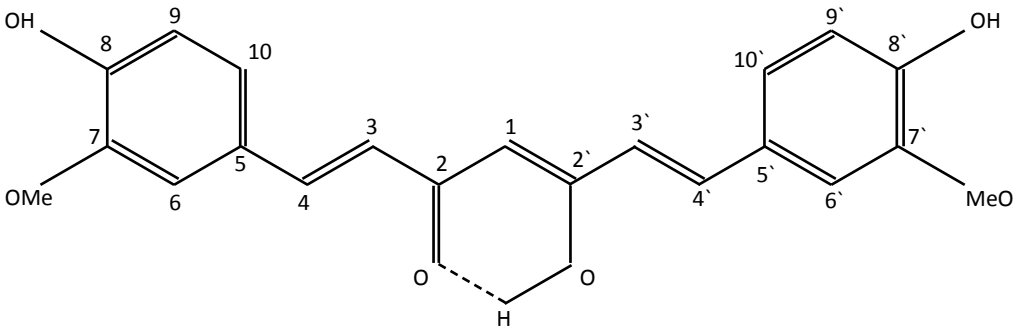
Abstract. The review intended to describe the phytochemistry of turmeric (curcumin longa). Turmeric contains a wide variety of phytochemicals, including curcumin demethoxycurcumin, bisdemethoxycurcumin, zingiberene, curcumenol, curcumol, eugenol, tetrahydrocurcumin, triethylcurcumin, turmerin, turmerones, and turmeronols. Among these, the most active component of turmeric is curcumin which gives a yellow color to turmeric and responsible for most of the therapeutic effects. The physico-chemical properties of curcumin are dependent on the pH of the medium. This review helps of chemists to understand the phytochemistry of curcumin and its medicinal values in a better way.

Keywords: curcumin, phytochemistry, turmeric, curcuminoids

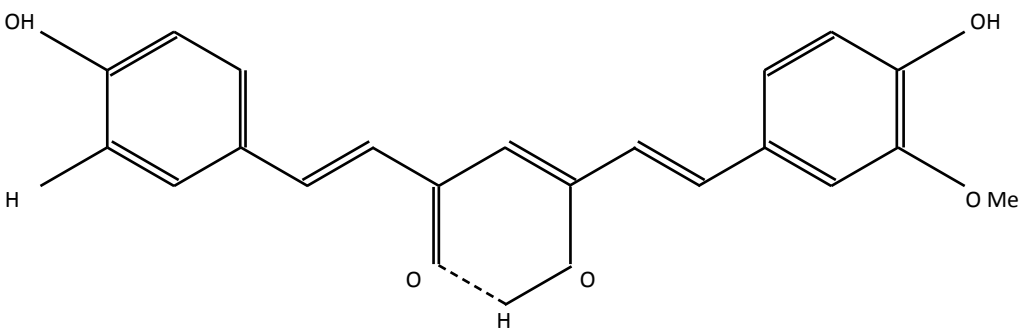
Turmeric

Turmeric (Fig. 1) is valued mainly for its principal coloring pigment, curcumin, which imparts the yellow color to turmeric, besides other nutritive constituents like potassium (Peter, 1999). The main coloring constituent of turmeric and other yellow *Curcuma* species is curcumin. Curcumin is the product obtained by solvent extraction of turmeric, i.e. the ground rhizomes of *Curcuma longa L*. (*Curcuma domestica Valeton*) and purification of the extract by crystallization. Coloring principles are present to the extent of 3-5 % in turmeric. In fact, besides curcumin there are a few other related pigments which impart the yellow color, all together called

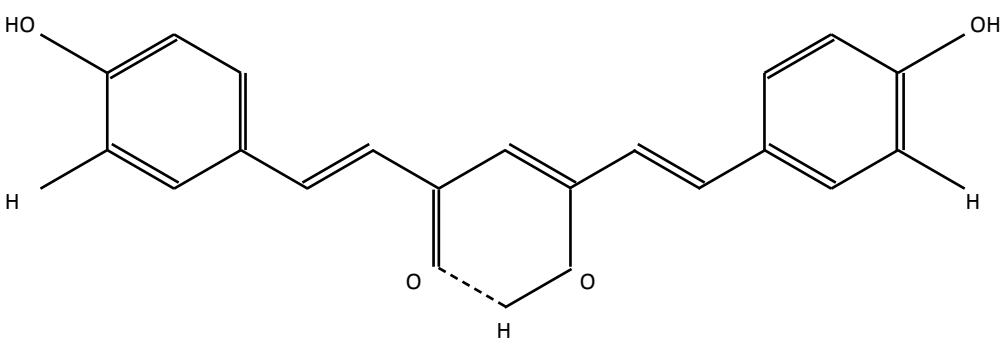
Fig.1. Indian turmeric (from Wikipedia)



Curcumin ([1,7-bis (4-hydroxy-3-methoxy-phenyl)-1,6-heptadiene-3, 5-dione]



Demethoxycurcmin [4-hydroxy-cinnamoyl (4-hydroxy-3-methoxycinnamoyl) methane



bis-demethoxycurcmin [bis-(4-hydroxy cinnamoylmethane]

Fig. 2. Structure of curcumiminoids from C. *longa*

curcuminoids (Verghese, 1999). Curcumin [1,7-*bis* (4-hydroxy-3-methoxy-phenyl)-1, 6- heptadiene-3, 5-dione]; demethoxycurcumin [4-hydroxy-cinnamoyl (4-hydroxy-3-methoxycinnamoyl) methane and *bis*-demethoxy curcumin [bis-(4-hydroxy cinnamoyl-methane] together make the coloring pigment in the turmeric rhizomes (Fig. 2).

Phytochemistry of turmeric

Turmeric contains a wide variety of phytochemicals, including curcumin demethoxy-curcumin, bisdemethoxycurcumin, zingiberene, curcumenol, curcumol, eugenol, tetrahydrocurcumin, triethylcurcumin, turmerin, turmerones, and turmeronols (Chattopadhyay, et al., 2004). The most active component of turmeric is curcumin which makes up 2 to 5% of the spice. Curcumin is the phytochemical that gives a yellow color to turmeric and is now recognized as being responsible for most of the therapeutic effects (Fig. 3). Curcumin is hydrophobic in nature and freely soluble in dimethylsulfoxide, acetone, ethanol, chloroform, oils and insoluble in water. Curcumin oxidation yields vanillin. It has an absorption maximum around 420 nm (Abas et al., 2005).

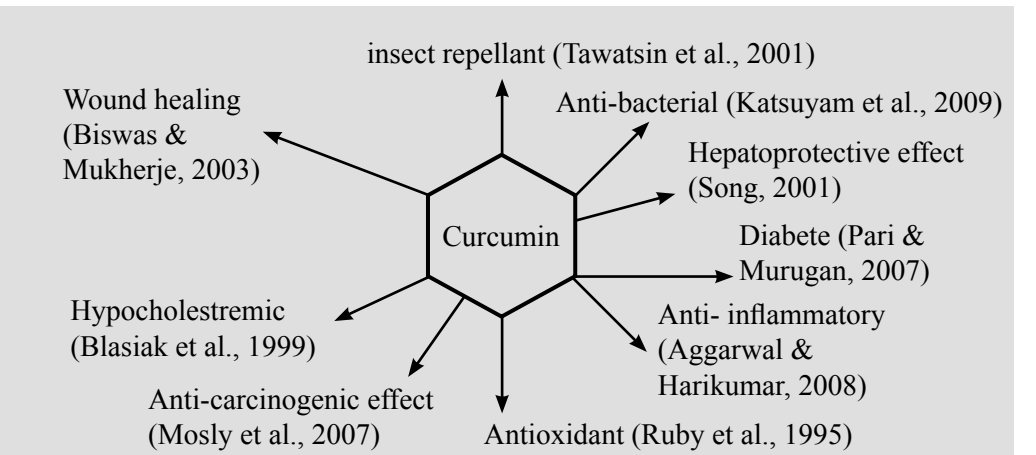


Fig. 3. Medicinal properties of curcumin

Extraction of curcumin

Curcumin is extracted from the dried root of the rhizome *Curcuma longa*. The process of extraction requires the raw material to be ground into powder, and washed with a suitable solvent that selectively extracts coloring matter. This process after distillation of the solvent yields an oleoresin with coloring matter content in the region of 25-35 % along with volatile oils and other resinous extractives. The oleoresin so obtained is subjected

to further washes using selective solvents that can extract the curcumin pigment from the oleoresin. This process yields a powdered, purified food color, known as curcumin powder, with over 90 % coloring matter content and very little volatile oil and other dry matter of natural origin. The selection of solvents is done with care to meet extractability and regulatory criteria. The following solvents are considered suitable (Table 1).

Physico-chemical properties

Curcumin is an oil-soluble pigment, practically insoluble in water at acidic and neutral pH, and soluble in alkali. Preparations of water-soluble curcumin by incorporation into various surfactant micellar systems (e.g., sodium dodecyl sulfate, cetylpyridinium bromide, gelatine, polysaccharides, polyethylenglycol, cyclodextrins) have been reported (Tonnesen, 2002). In solutions the principal coloring components of curcumin exhibit keto-enol tautomerism and, depending on the solvent, up to 95 % are in the enol form. The kinetics of hydrolytic degradative reactions of curcumin over the pH range 1- 11 was studied using HPLC technique (Tonnesen & Karlsen, 1985). At pH <1, aqueous solutions of curcumin have a red color which indicates the protonated form (H_4A^+). In the pH range 1-7, the majority of curcumin species are in the neutral form (H_3A). Water solubility is very low in this pH range and solutions are yellow. At pH>7.5, the color changes to red and the pKa values for the dissociation of the three acidic protons in curcumin (forms H_2A^-, HA^{2-} and A^3) have been determined to be 7.8, 8.5 and 9.0, respectively (Fig.4).

Table 1. Solvents used for extraction of curcumin from turmeric

Solvent	Description
Isopropanol	In the curcumin manufacturing process isopropyl alcohol is used as a processing aid for purifying curcumin
Ethyl acetate	With a restriction placed on the use of chlorinated solvents, such as dichloroethane, it is found that ethyl acetate, owing to its polarity, is a reasonable replacement providing acceptable quality of product and commercially viable yields
Acetone	This is used as a solvent in the curcumin manufacturing process
Ethanol	This solvent is used sparingly because curcumin is completely soluble in ethanol

The principal coloring components of curcumin are relatively stable at acidic pH, but they rapidly decompose at pH above neutral. In a study of alkaline degradation of

curcumin (Tonnesen & Karlsen, 1985), products of decomposition at pH 7-10 were determined by HPLC. The initial degradation products are formed after 5 minutes and the chromatographic pattern obtained after 28 h at pH 8.5 is representative. In addition to this, curcumin are not particularly stable to light, especially in solutions. After the photo-irradiation of curcumin, a cyclisation product was detected, as well as decomposition products, such as vanillic acid, vanillin, and ferulic acid (Sasaki et al, 1998).

Chemistry of curcuminoids

The coloring principle of turmeric was isolated in the 19th century and was named curcumin. Curcuminoids refers to a group of phenolic compounds present in turmeric, which are chemically related to its principal ingredient curcumin. Three curcuminoids were isolated from turmeric *viz.,* curcumin, demethoxycurcumin and bis-demethoxycurcumin (Fig. 2). All three impart the hallmark yellow pigmentation to the *Curcuma longa* plant and particularly to its rhizomes. Although the chemical structure of curcumin was determined in the 1970's and 1980's, recently the potential uses of curcuminoids in medicine have been studied extensively. The structure of curcumin as diferuloylmethane was confirmed by the degradative work (Majeed et al., 1995). On boiling with alkali, curcumin gave vanillic acid and ferulic acids whose structures were established. Fusion with alkali yielded protocatechuic acid and oxidation with potassium permanganate yielded vanillin. On hydrogenation a mixture of hexahydro and tetrahydro derivative were obtained. Based on these the structure of curcumin was established as diferuloylmethane.

Analysis of curcuminoids

A variety of methods for quantification of the curcuminoids were reported (Tonnesen & Karlsen, 1986). Most of these are spectrophotometric methods, expressing the total color content of the sample. Commercially obtained *Curcuma* products contain mixtures of curcumin, demethoxycurcumin and bisdemethoxycurcumin. For an exact determination of the curcumin content a pre- separation of the three curcuminoids is essential. The curcuminoids isolated from C. *longa* exhibit strong absorption between 420 - 430 nm in organic solvents. The official methods for assaying curcumin or *curcuma* products as food color additives are based upon direct spectrophotometric absorption measurements. The evaluation of the total amount of curcuminoids in a sample by use of direct absorption measurements is only valid if the calculations are based on reference values obtained from pure standards. It should however, be noted that the presence of other compounds absorbing in the region of 420-430 nm influence the results strongly. A direct fluorimetric method for the assay of curcumin in food products was reported (Karasz et al., 1973). The difficulties in obtaining reproducible results could be ascribed to the difference in fluorescence intensity of curcumin and the two demethoxy compounds

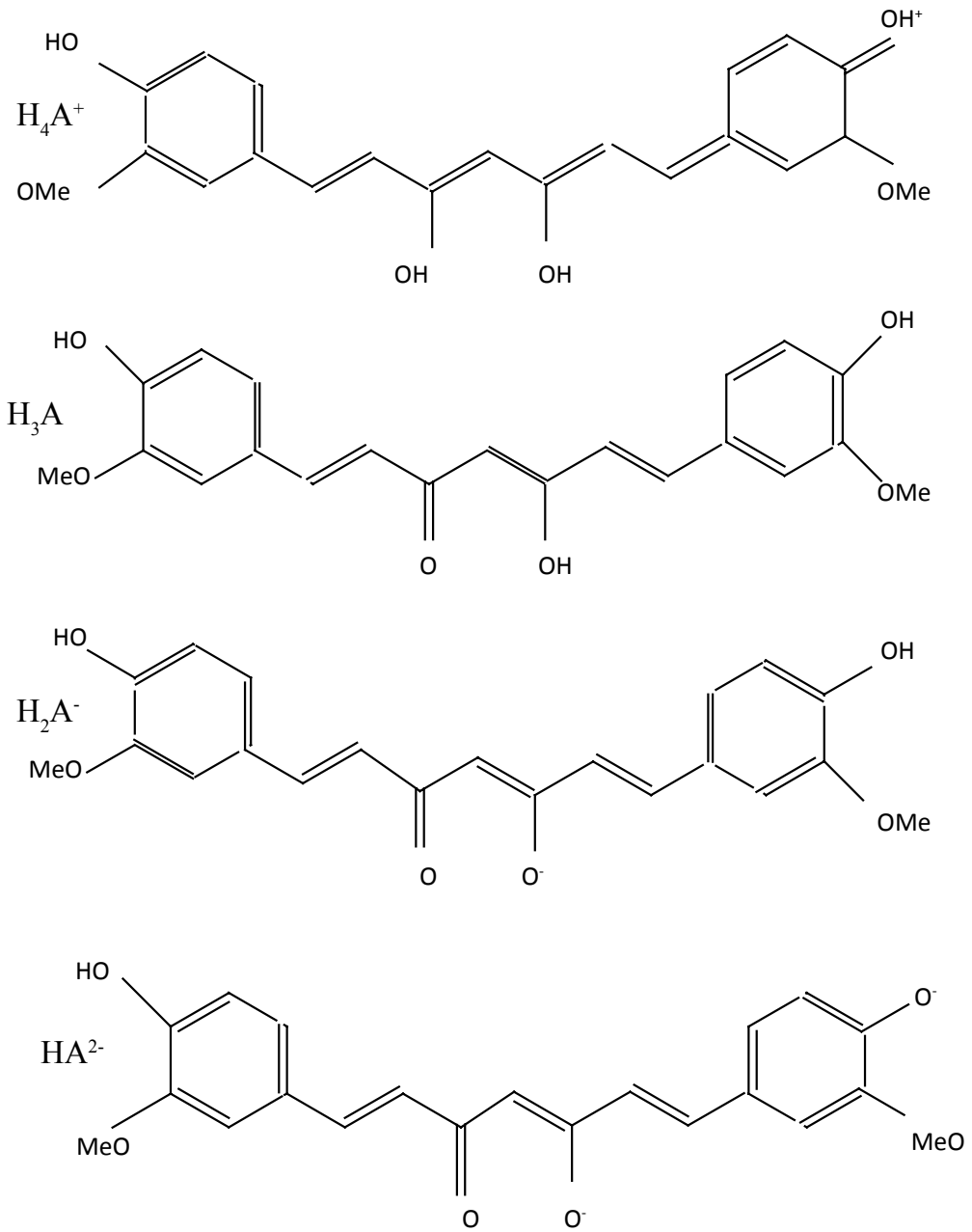


Fig. 4. Structure of curcumin at different pH values

in organic solvents. At fixed excitation and emission wavelengths (420 - 470 nm), the relative fluorescence intensities of curcumin, demethoxycurcumin and bisdemethoxycurcumin in ethanol are 1:2, 2:10.4 at equimolar concentrations (Tonnessen & Karlsen, 1983). Unless these differences are taken into account small changes in sample composition may lead to large variations in the curcumin content calculated. To increase the molar absorptivity of curcumin, intensely colored complexes were developed by reaction with alkalis, strong mineral acids or boric acid (Karasz et al., 1973; Krishnamurthy et al., 1976; Janssen & Gole, 1984). However, the colors formed were found to be very unstable and severe fading was reported after 5-10 minutes with the exception of the boric acid complexes (Dyrssen et al., 1972; Janssen & Gole, 1984).

A pre-separation of the curcuminoids can be accomplished by thin-layer chromatography (TLC) or high-pressure liquid chromatography (HPLC) (Tonnesen & Karlsen, 1983). Separation of the curcuminoids is strongly dependant on the chromatographic conditions. Curcumin and the related 1, 3-diketones are shown to adsorb strongly onto the silicic acid used as the solid support in TLC and HPLC. By removing one of the keto groups from a diketone the adsorption to silica gel can be prevented (Tonnesen & Karlsen, 1986). The adsorption is therefore ascribed to intermolecular hydrogen bonding between the keto-enol unit of the 1, 3-diketones and the silicic acid. Quantitative analysis of curcumin and related compounds by TLC or HPLC is difficult to carry out unless the chromatographic support is properly deactivated, e.g. the number of free silanol groups is kept at a minimum. HPLC systems based on C_{18} stationary phases did not completely resolve the three curcuminoids (Asakawa et al., 1981; Smith & Witowska, 1984). A reproducible separation of the colored compounds was achieved by the use of an amino bonded stationary phase, provided that the water content of the system is kept below 10%. HPLC system based on an amino-bonded stationary phase, however, seems to have a catalytic effect upon curcumin degradation. To obtain reproducible results the experimental conditions must be carefully controlled. HPLC in combination with fluorescence detection is the most sensitive method for the determination of curcumin, the detection limit lying in the picogram range (Tonnesen & Karlsen, 1983). GC methods provide no alternative to HPLC due to the low volatility and thermally labile nature of the curcuminoids. Spectroscopic methods (IR, NMR, and MS) are widely used for identification and characterization of the curcuminoids (Tonnesen & Karlsen, 1986; Unterhalt, 1980; Roughley & Whiting, 1973; Govindarajan, 1980). NMR has also been tried for quantitative determinations (Unterhalt, 1980). Mass spectrometry (MS) is often the method of choice when trace amounts of organic compounds are to be detected. The detection limit for curcumin in biological samples by MS needs to be determined, and then the possibility of using quantitative MS in curcumin analysis could be evaluated. It was reported that the strong interactions observed between curcumin and silanol groups

also occur in a glass container. Unless precautions are taken, curcumin in solution will adsorb strongly to the container wall, leading to inaccurate results (Unterhalt, 1980).

Conclusion

The major constituent, curcumin (diferuloylmethane), is the most important fraction of *C. longa*. Curcumin is the photochemical that gives a yellow color to turmeric and is now recognized as being responsible for most of the therapeutic effects. It is hydrophobic in nature and freely soluble in dimethylsulfoxide, acetone, ethanol, chloroform, oils and insoluble in water. In addition to this, it is relatively stable at acidic pH, but they rapidly decompose at pH above neutral. That means in the basic media, curcumin undergo degradation reaction into another compounds. This review describes the detailed characteristics of curcumin and its medicinal values.

REFERENCES

Abas, F., Lajis, N.H.., Shaari, K., Israf, D.A., Stanslas, J., Yusuf, U.K. &. Raof, S.M. (2005). A labdane diterpene glucoside from the rhizomes of *Curcuma mangga*. *J. Nat. Products, 68*, 1090–1093.

Aggarwal, B.B. & Harikumar, K.B. (2009). Potential therapeutic effect of curcumin, the anti-inflammatory agent, against neurodegenerative, cardiovascular, pulmonary, metabolic, autoimmune and neoplastic diseases. *Intern. J. Biochem. Cell Biol*., *41*, 40-59.

Asakawa, N., Tsuno, M., Hattori, T., Ueyama, M., Shinoda, A., Miyake, Y. & Kagei, K. (1981). Determination of curcumin content of turmeric by high performance liquid chromatography. *Yakugaki Zasshi*, *101*, 374-377 [In Japanese].

Biswas, T.K. & Mukherjee, B. (2003). Plant medicines of Indian origin for wound healing activity: a review. *Intern. J. Lower Extremity Wounds, 2*(1), 25–39.

Blasiak, J., Trzeciak, A., Malecka-Panas, E., Drzewoski, J., Iwamienko, T., Szumiel, I. & Wojewodzka, M. (1999). DNA damage and repair in human lymphocytes and gastric mucosa cells exposed to chromium and curcumin. *Teratogonesis, Cancerogenesis & Mutagenesis, 19*(1), 19-31.

Chattopadhyay, I., Biswas, K., Bandyopadhyay, U. & Banerjee, R.K. (2004). Turmeric and curcumin: biological actions and medicinal applications. *Current Sci., 87*, 44–53.

Dyrssen, D.W., Novikov, Y.P. & Uppstöm, L.R. (1972). Studies on the chemistry of the determination of boron with curcumin. *Anal. Chim. Acta, 60*, 139-151.

Govindarajan, V.S. (1980). Turmeric - chemistry, technology, and quality. *Crit. Rev. Food Sci. & Nutrition, 12*, 199-301.

Janssen, A. & Gole, T. (1984). Thin-layer chromatographic determination of curcumine (turmeric) in spices. *Chromatographia, 18*, 546-549.

Katsuyama, Y., Kita, T., Funa, N. & Horinouchi, S. (2009). Curcuminoid biosynthesis by two type III polyketide synthases in the *Curcuma longa*. *J. Biolog. Chem*., *284*, 11160-11170.

Karasz, A.B., DeCocca, F. & Bokus, L. (1973). Detection of turmeric in foods by rapid fluorimetric method and by improved spot test. *J. Assoc. Offic. Anal. Chem., 56*, 626-628.

Krishnamurthy, N., Mathew, A.G., Nambudiri, E.S., Shivashankar, S., Lewis, Y.S. & Natarajan, C.P. (1976). Oil and oleoresin of turmeric. *Trop. Sci., 18*, 37-45.

Majeed, M., Badmaev, V., Shivakumar, U. & Rajendran, R. (1995). *Curcuminoids - antioxidant phytonutrients*. Piscataway: NutriScience Publishers.

Mosley, C.A., Liotta, D. C. & Snyder, J.P. (2007). Highly active anticancer curcumin analogues. *Adv. Exp. Medicine & Biology*, *595*, 77-103.

Pari, L. & Murugan, P. (2007). Antihyperlipidemic effect of curcumin and tetrahydrocurcumin in experimental type 2 diabetic rats. *Renal Failure, 29*, 881-889.

Peter, K.V. (1999). Informatics on turmeric and ginger. *Indian Spices, 36*(2-3), 12–14.

Roughley, P.J. & Whiting, D.A. (1973). Experiments in the biosynthesis of curcumin. *J. Chem. Soc. Perkin I*, 2379-2388.

Ruby, A. J., Kuttan, G., Dinesh, B.K., Rajasekharan, K.N. & Kuttan, R. (1995). Antitumour and antioxidant activity of natural curcuminoids. *Cancer Lett., 94*, 79-83.

Sasaki, S.S., Sato, K., Abe, M., Sugimoto, N. & Maitani, T. (1998). Components of turmeric oleoresin preparations and photo-stability of curcumin. *Japanese J. Food Chem., 5*(1), 64-68.

Smith, R.M. & Witowska, B.A. (1984). Comparison of detectors for the determination of curcumin in turmeric by high-performance liquid chromatography. *Analyst*, *109,* 259 - 261.

Song, E.K., Cho, H., Kim, J.S., Kim, N.Y., Lee, S.H. & Kim, Y.C. (2001). Diarylheptanoids with free radical scavenging and hepatoprotective activity in vitro from *Curcuma longa*. *Planta Med., 67*, 876-877.

Tawatsin, A., Wratten, S.D., Scott, R.R., Thavara, U. & Techadamrongsi, Y. (2001). Repellency of volatile oils from plants against three mosquito vectors. *J. Vector Ecology,* 26, 76–82.

Tonnesen, H.H. (2002). Solubility, chemical and photochemical stability of curcumin in surfactant solutions. Studies of curcumin and curcuminoids, XXVIII. *Pharmazie, 57,* 820-824.

Tonnesen, H.H. & Karlsen, J. (1983). High-performance liquid chromatography of curcumin and related compounds. *J. Chromatography, 259,* 367-371.

Tonnesen, H.H. & Karlsen, J. (1985). Studies of curcumin and curcuminoids VI. Kinetics of curcumin degradation in aqueous solutions. *Z. Lebensm. Unters. Forsch.,* 180, 402-404.

Tonnesen, H.H.& Karlsen, J. (1986). Studies on curcumin and curcuminoids. VII Chromatographic separation and quantitative analysis of curcumin and related compounds. *Z. Lebensm. Unters. Forsch*., *182*, 215-218.

Unterhalt, B. (1980). Curcuma und seine Verwendung im Speisesenf. Z. *Lebensm. Unters. Forsch., 170*, 425-428.

Verghese, J. (1999). Curcuminoids, the magic dye of *C. longa* L. rhizome. *Indian Spices*, *36*(4), 19–26.

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