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Study Of Chemical Constituents of *Curcuma Longa* (Turmeric), Its Medicinal and Agricultural Importance – A Review

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Abstract

Curcuma longa linn (turmeric) is a rhizomatous herb of zingiberaceae family. Extensive research over the last fifty years has revealed several essential functions of chemical constituents of Curcuma longa. Turmeric has a long history of traditional therapeutic uses. It is attributed to various beneficial properties like antioxidant, anti-bacterial, anti-inflammatory, anti-fungal, anti-malarial, and digestive properties. Its anti-cancer effect induced mainly mediated through induction of apoptosis and many more medicinal values. Turmeric has been used as a spice, food flavouring, colouring agent and in medicinal preparation for various diseases more over it is also used as body paint during traditional Indian celebration. However, except from the above, it also uses as a medicinal plant. The fresh juice, the aqueous extracts, and the essential oil of the plant are credited with interesting pesticidal properties against certain pests of agricultural importance and a noticeable repellent activity against noxious mosquito species. Various research data obtained from the international literature have shown the promising potential of turmeric as a natural pesticide for possible use in protecting crops from different pests. This review article mainly discusses the different chemical constituents of turmeric, their medicinal and agricultural benefits, and their H-1, C-13 NMR and mass spectra. Different components of *Curcuma longa* have shown various activities and favourable results in various research.

Keywords

Indian saffron, Zingiberaceae, Curcumin, Demethoxycurcumin, Diacetylcurcumin, Ar- turmerone, Rhizome powder, Plant Extract, Essential Oil.

1. Introduction

Curcuma longa Linn [vernacular names: Arabic - Urooq ul Asfar, Chinese – Chiang Huang, Yu Chin, English – Turmeric, (Indian saffron), Sanskrit- Haridra, Persian – Zard chob, Darzardi, Urdu- Haldi, Halda] belongs to the family Zingiberacea , which is extensively cultivated for its rhizome. It is perennial herb , belived to be originated from Southern Asia and is mainly cultivated in tropical region. It is widely cultivated tropical part of India, grown from sea level to 1200 meters above MSL (Mean Sea Level). The chief turmeric growing regions in the world are India, China, Sri-Lanka, Indonesia and West Indies. India is the largest turmeric producing and exporting country in the world [(1)]. There are roughly 93-100 accepted Curcuma species, but the exact number of species is still controversial[(2)].

It is an herbaceous plant with large leaves (see Figure 1)[a] that are oblong. The lamina is green above and pale green below. Inflorescence (see Figure 2)[b] is a central spike of 10-15 cm in length. Flowers of the turmeric appear on a spike-like stalk. Its flowers are pale yellow in colour. They are sterile and do not produce viable seeds. It has a short underground stem called rhizome. The rhizome is thick, short, rounded and hairy and bears fibrous adventitious roots. Its rhizomes are harvested, washed and boiled in mild alkaline water to soften and dried in sun or in electric driers. It is used as a coloring agent in pharmacy, confectionery, and food industry for dyeing wool, silk, cotton, and other natural dyes to get different shades (3). Rhizomes of turmeric are used as cosmeceutical, expectorant anthelminthic, antiseptic, blood purifier in leprosy, spleen disorders, rheumatism, bronchitis, cough and cold, insecticide, spasmolytic, hypotensive, cholera and syphilis (4). It is also used as an anti-fungal, anti-inflammatory, anti-bacterial and to fight decaying metabolism to prevent cancer (5)(6). Turmeric is used widely as a spice in South Asian and Middle Eastern cooking. The turmeric milk drink known as Haldi Doodh (Haldi means turmeric in Hindi) is a South Asian recipe. Turmeric paper (see Figure 3)[c,] also called curcuma paper, is used in chemical analysis to indicate acidity or alkalinity (7). The paper is yellow in acidic and neutral solution and turns brown to reddish-brown in alkaline solution with transition between pH 7.4 and 9.2 (7).

Turmeric has been used extensively used in traditional medicine since ancient times as a household remedy against different types of disease including Diabetes, Cough, sinusitis, skin disease etc. Turmeric is a source of polyphenolic active compound curcuminand another different constituent which has very promising result as medicine. The objective of this paper is studying the different chemical constituents of Turmeric to know the benefit of these, their medicinal values, and how we can use them. Because Thousands of people will benefit by knowing the medicinal importance of turmeric, it is readily available and economical.

Figure 1 : Turmeric Leaves

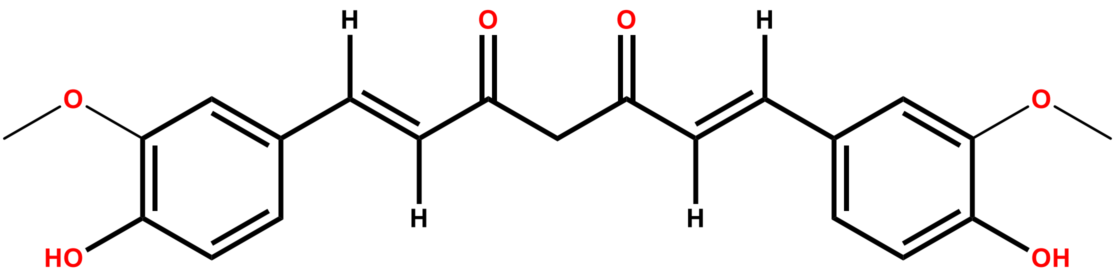
Figure 2 : Turmeric Inflorescence

Figure 3 : Turmeric paper

2. Chemical constituents and its medicinal importance

In this section we discuss the various chemical constituent of Turmeric (Indian Saffron), its structure, history and medicinal importance.

1. Curcumin



Chemical Formula: $C_{21}H_{20}O_6$
Exact Mass: 368.13
Molecular Weight: 368.39
m/z: 368.13 (100.0%), 369.13 (23.2%), 370.13 (3.7%)
Elemental Analysis: C, 68.47; H, 5.47; O, 26.06

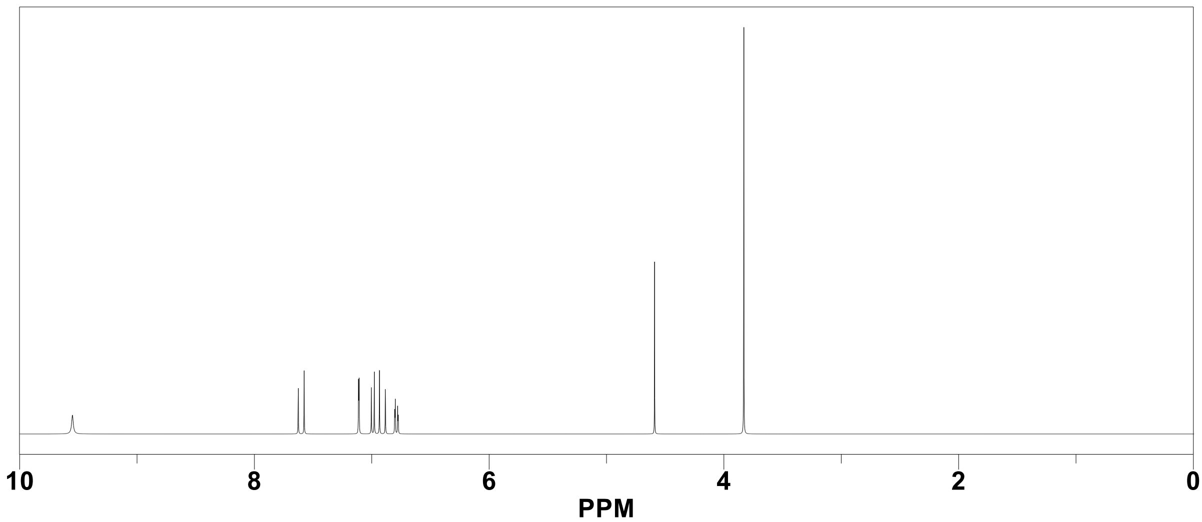


Figure 4: ^{1}H NMR of Curcumin

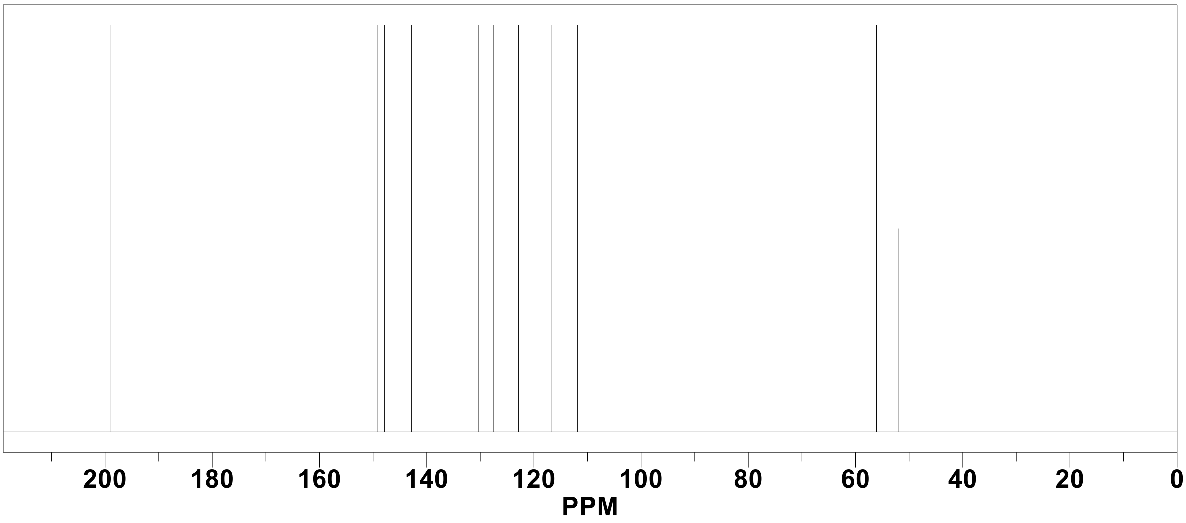


Figure 5: [13]NMR of Curcumin

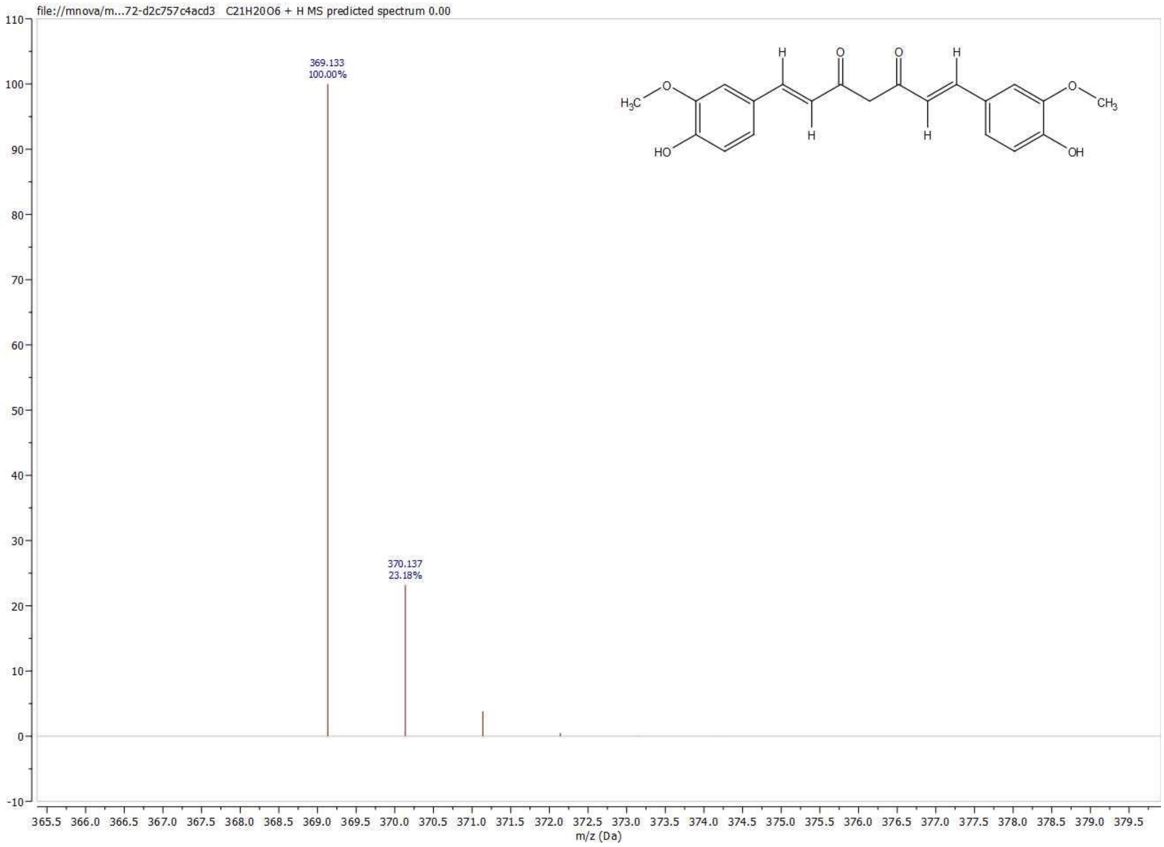
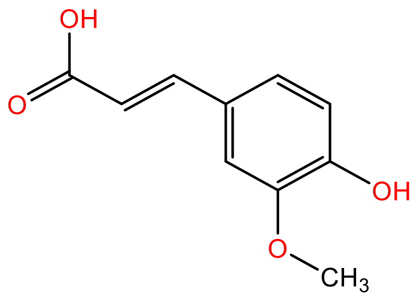


Figure 6 : Mass Spectrum of curcumin

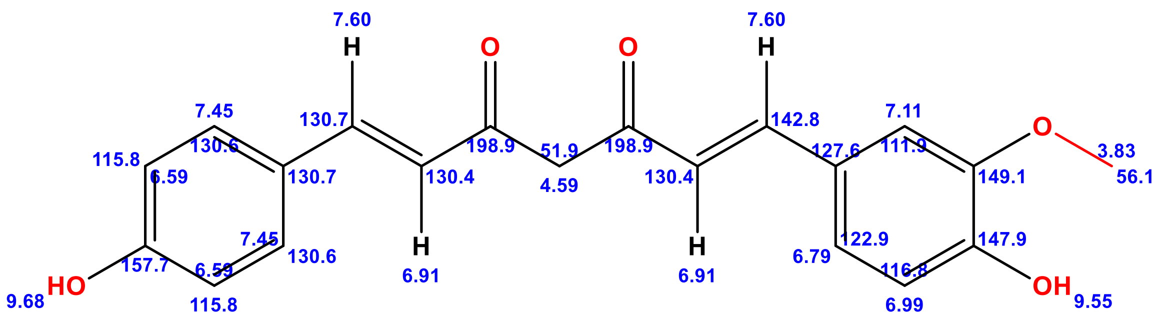
In 1910 firstly Milobedzka and Lampe identified the chemical structure of curcumin as diferuloylmethane, or 1,6-heptadiene-3,5-dione-1,7-bis (4-hydroxy-3-methoxyphenyl) -(1E, 6E) [8]. Additionally, work by the same group in 1913 resulted in the synthesis of the compound [9]. Afterward, Srinivasan separated and quantified the components of curcumin by chromatography [10]. Curcumin is a beta-diketone that is methane in which two of the hydrogens are substituted by feruloyl groups (Structure 1) It is s natural dyestuff found in the root of Curcuma longa.

Curcumin act as an anti- inflammatory ([11][12], antioxidant [13][14], anti- tumor and anti-cancer [15][16], anti-HIV [17], antimutagenic [18], Antidiabetic [19], antifungal [20], antifibrinogenic [21], Wound healing [22], Lipid lowering [23], Radioprotective [24], Immunomodulating [25].



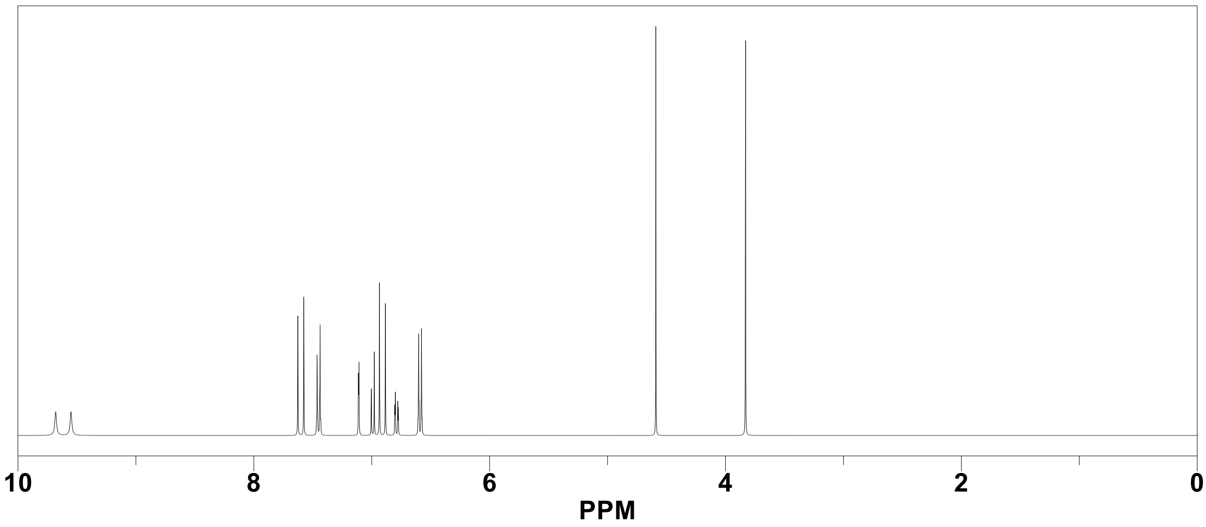
Structure 1: Ferulate

2. Demethoxycurcumin



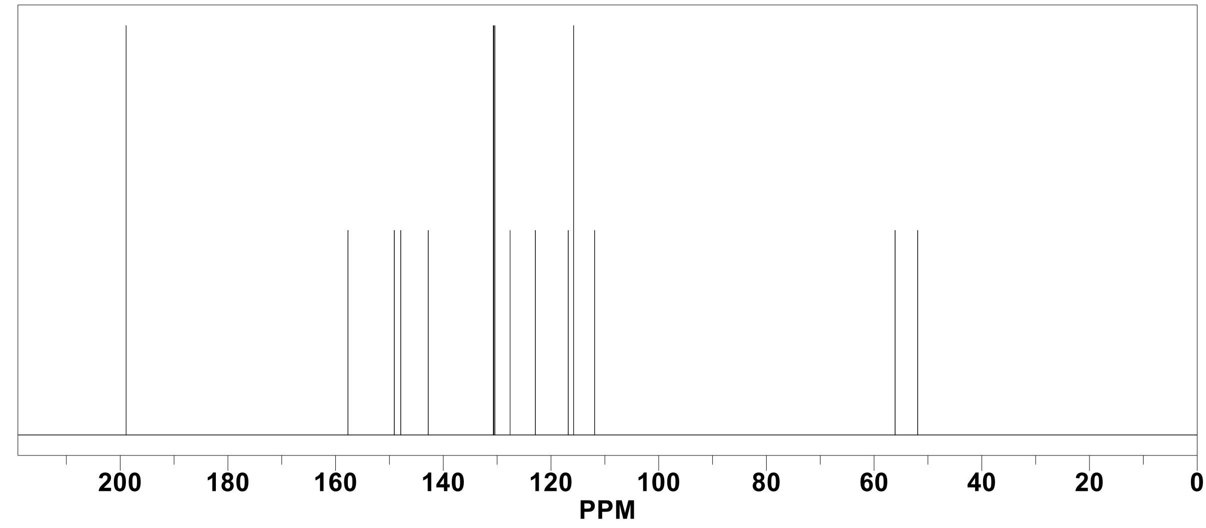
Chemical Formula: $C_{20}H_{18}O_5$
Exact Mass: 338.12
Molecular Weight: 338.36
m/z: 338.12 (100.0%), 339.12 (22.0%), 340.12 (3.3%)
Elemental Analysis: C, 71.00; H, 5.36; O, 23.64

Estimation quality is indicated by color: good, medium, rough

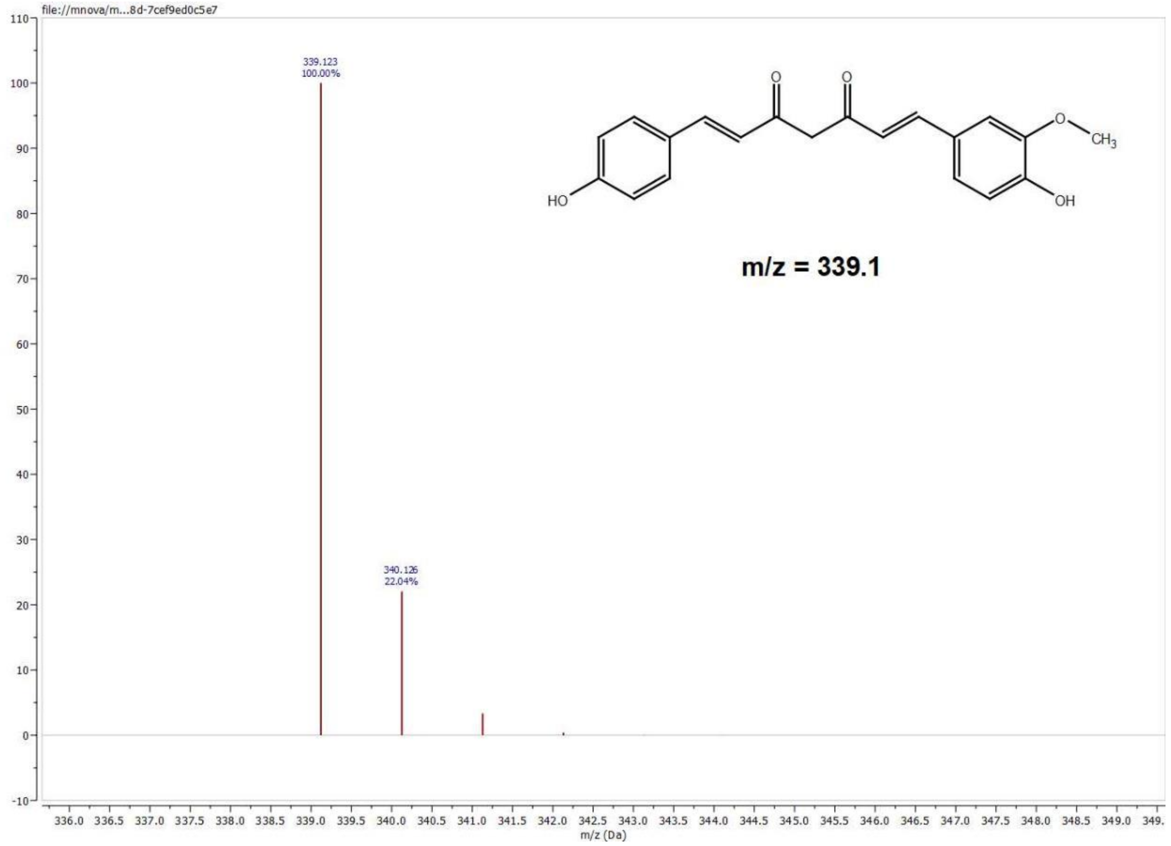


H-1 NMR of Demethoxycurcumin, solvent- DMSO, 300Mhz

Estimation quality is indicated by color: good, medium, rough



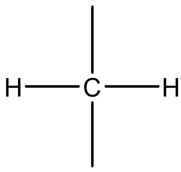
C -13 NMR of Demethoxycurcumin



Mass spectra of Demethoxycurcumin

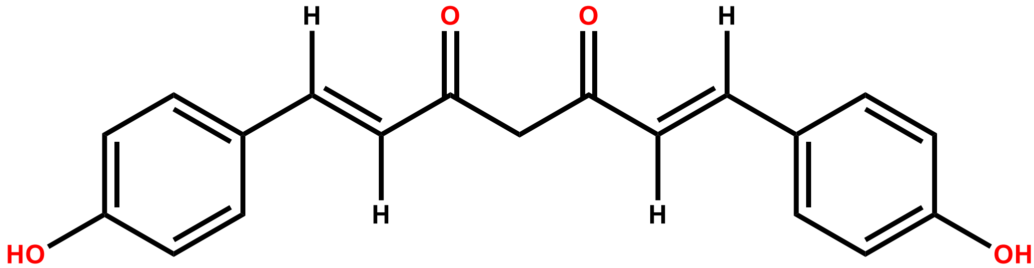
Demethoxycurcumin is also known as curcuminii or BHCFM which belongs to the class of organic compounds known as curcuminoids. These are aromatic compounds containing a curcumin moiety, which is composed of two aryl buten-2-one (feruloyl) chromophores joined by a methylene group (Structure 2). 1

Demethoxycurcumin or BHCHM acts as an antioxidant [26].



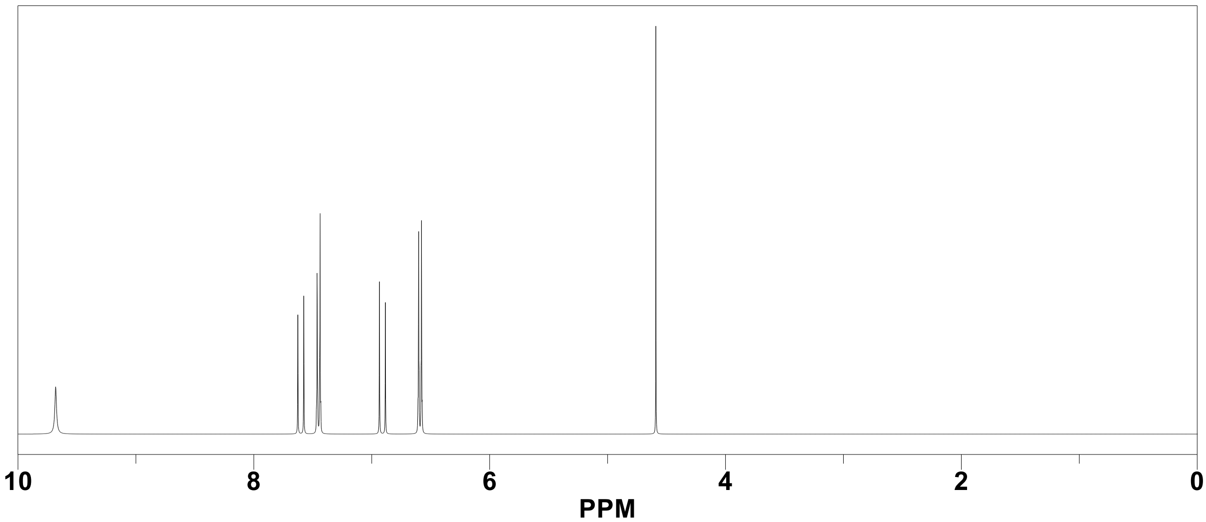
Structure 2 : Methylene group

3. Bisdemethoxycurcumin



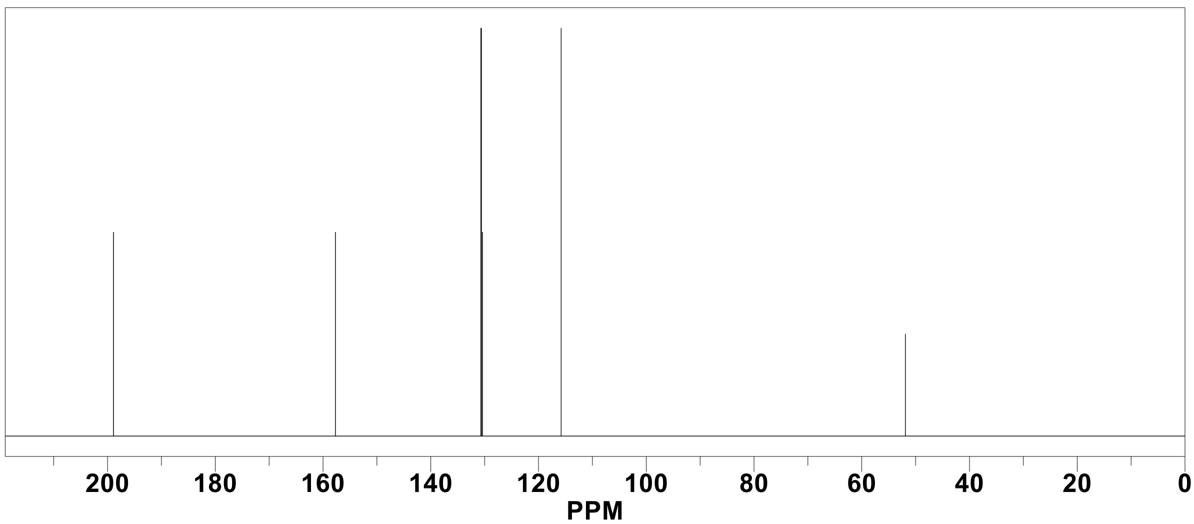
Chemical Formula: C19H16O4
Exact Mass: 308.10
Molecular Weight: 308.33
m/z: 308.10 (100.0%), 309.11 (20.9%), 310.11 (2.9%)
Elemental Analysis: C, 74.01; H, 5.23; O, 20.76

Estimation quality is indicated by color: good, medium, rough



H-1 NMR of Bisdemethoxycurcumin, Solvent- DMSO, 300 MHz

Estimation quality is indicated by color: good, medium, rough



C-13 NMR of Bisdemethoxycurcumin

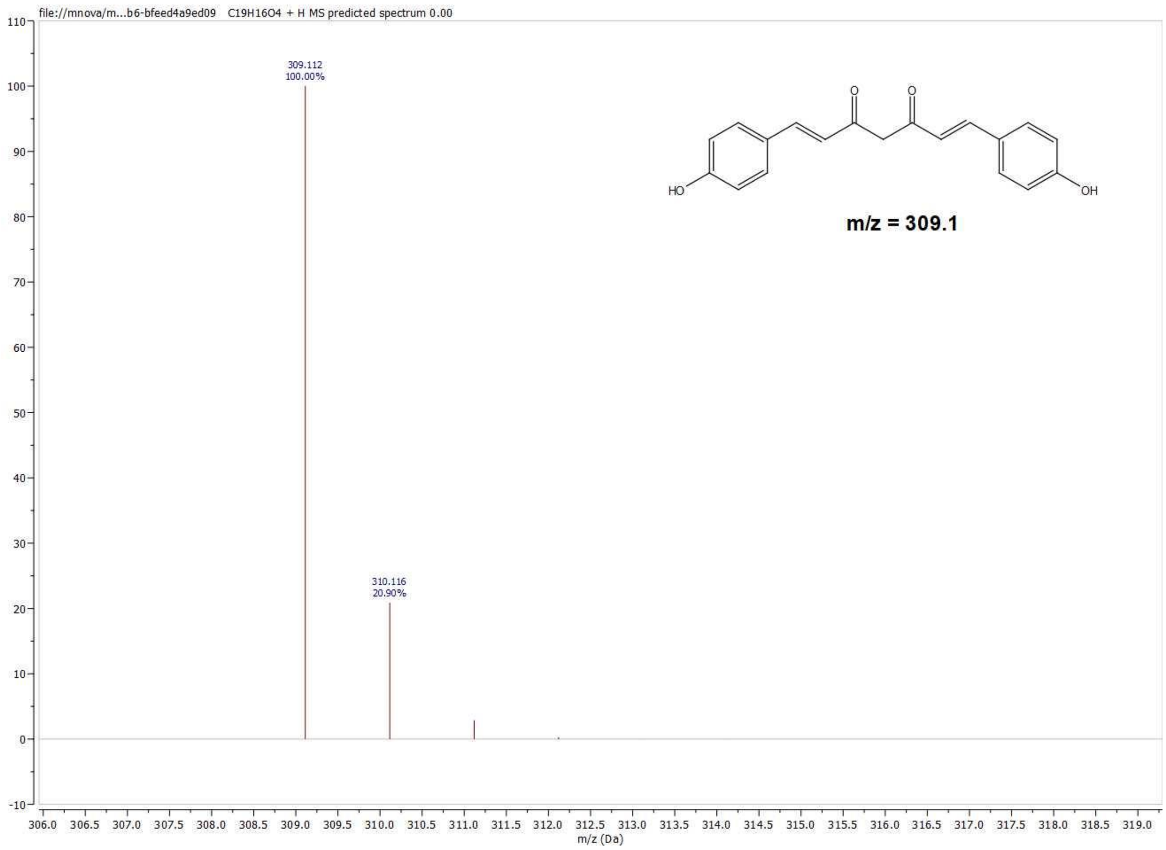
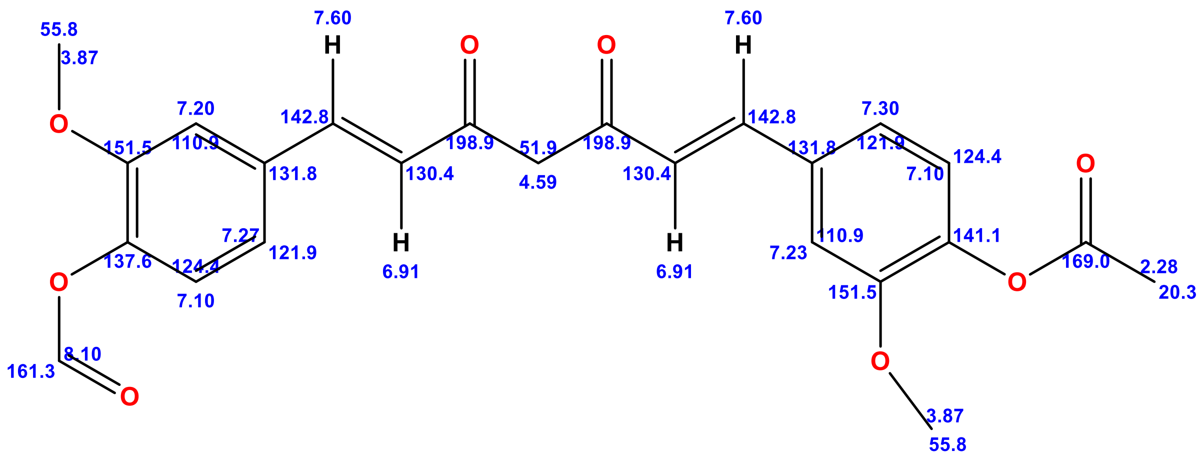


Figure 7 mass spectrum of Bisdemethoxycurcumin

Bisdemethoxycurcumin is a curcuminoid found turmeric (Curcuma longa) but it is absent in Javanese Turmeric (*Curcuma xanthorrhiza*) (27).

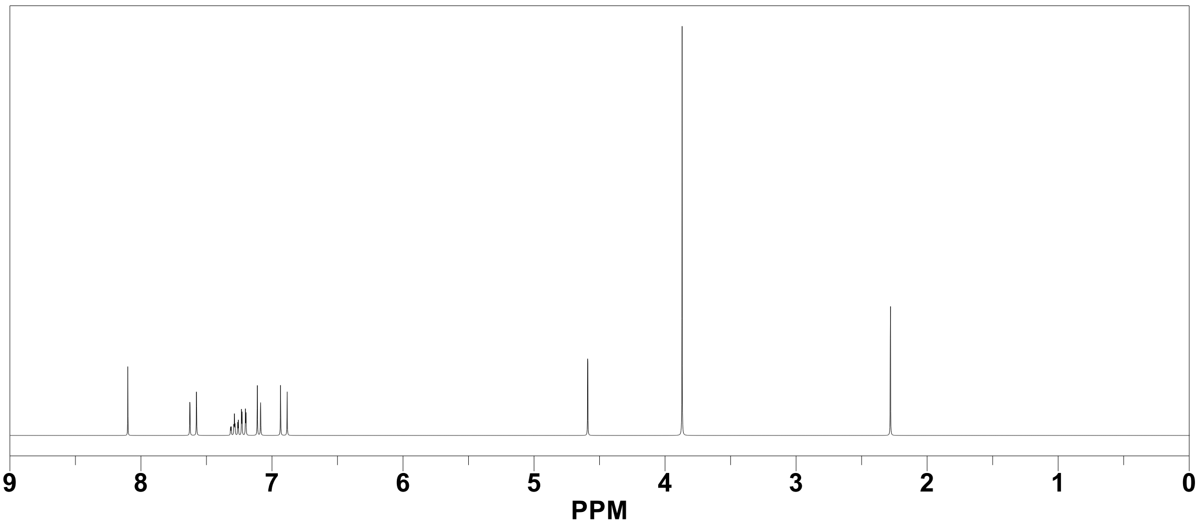
It acts as an antioxidant (26), it is also used as a pigment and nutraceutical with antimutagenic properties (28)(29)

4. Diacetylecurcumin (DAC)



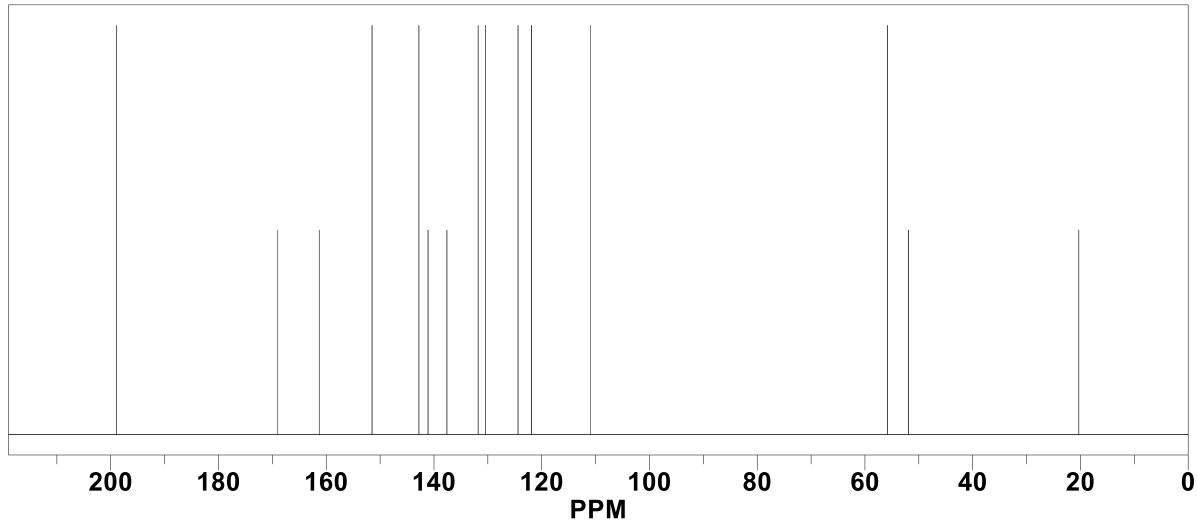
Chemical Formula: C24H22O8
Exact Mass: 438.13
Molecular Weight: 438.43
m/z: 438.13 (100.0%), 439.13 (26.0%), 440.14 (5.0%)
Elemental Analysis: C, 65.75; H, 5.06; O, 29.19

Estimation quality is indicated by color: good, medium, rough



H-1 NMR of Diacetylecurcumin, Solvent- DMSO, 300 MHz

Estimation quality is indicated by color: good, medium, rough



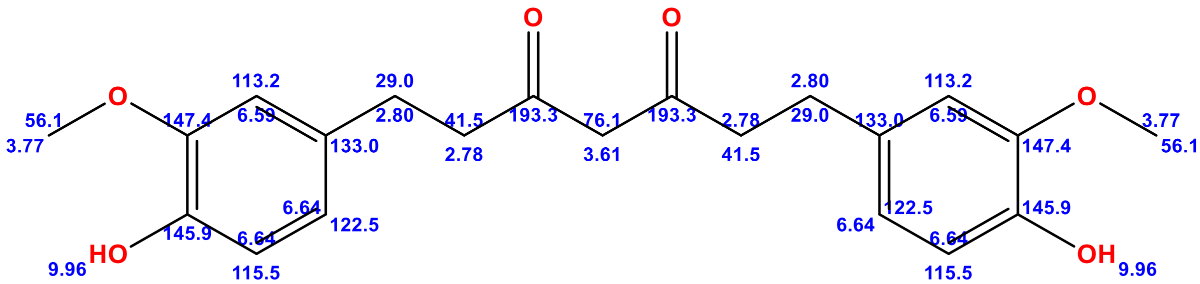
C-13 NMR of Diacetylecurcumin

Figure 8: Mass spectrum of Diacetylecurcumin

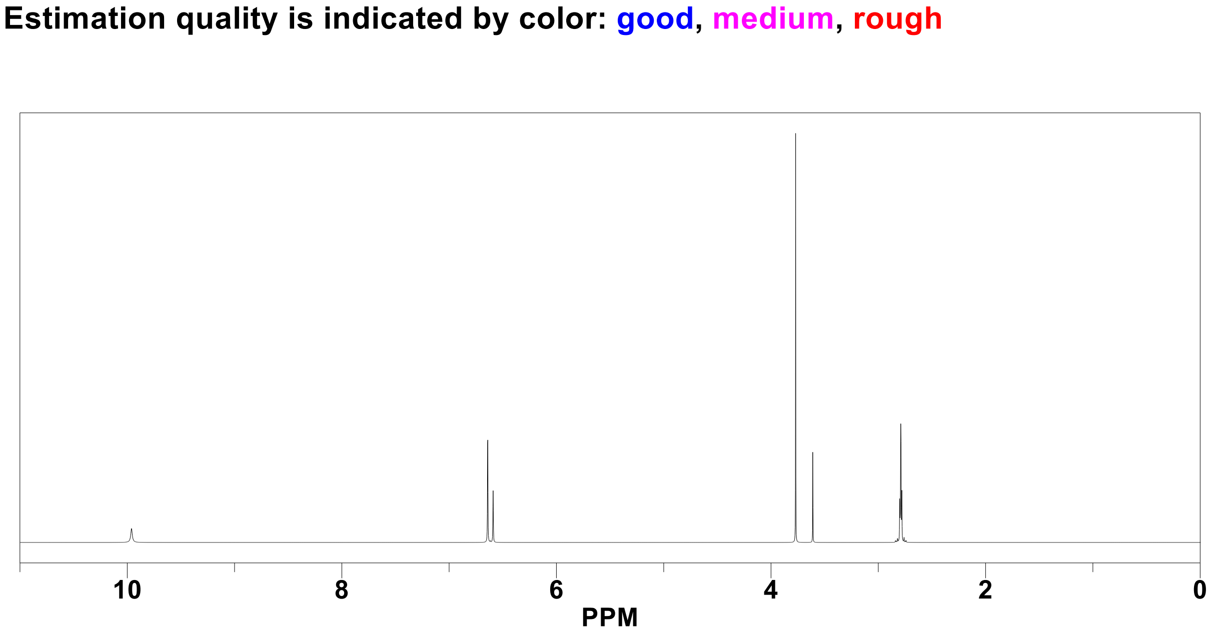
Diacetylcurcumin (DAC) is a synthetic derivative of curcumin where phenolic OH groups are protected with acetyl groups. This increases lipophilicity, possibly leading to a higher bio-membrane penetration rate.

Diacetylecurcumin (DAC) has significant biological properties such as high antibacterial activity, anti-biofilm activity against methicillin-resistant *Staphylococcus aureus* strains (30) and antimalarial activity in vitro against chloroquine-resistant *Plasmodium falciparum* (31). It has potential as an antiproliferative agent in anticancer therapies (32). It also acts as an anti-inflammatory (11).

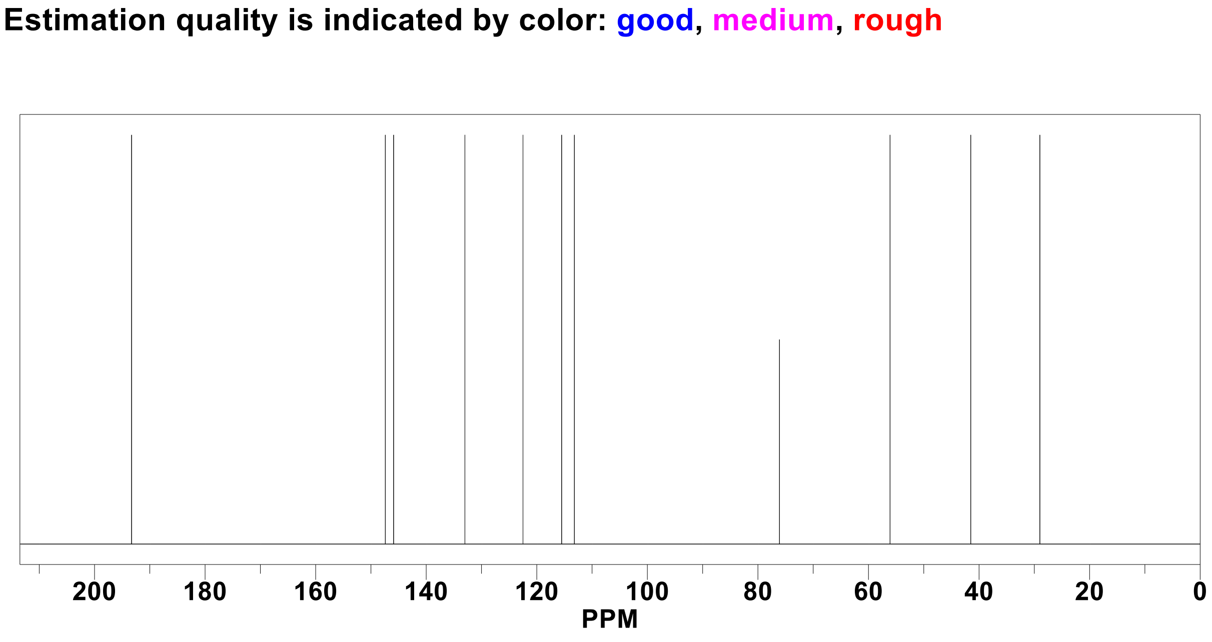
5. Tetrahydrocurcumin (THC)



Chemical Formula: C21H24O6
Exact Mass: 372.16
Molecular Weight: 372.42
m/z: 372.16 (100.0%), 373.16 (23.2%), 374.16 (3.7%)
Elemental Analysis: C, 67.73; H, 6.50; O, 25.78



H-1 NMR of Tetrahydrocurcumin, Solvent-DMSO, 300 MHz



C-13 NMR of Tetrahydrocurcumin

Tetrahydrocurcumin is a beta-diketone that is curcumin in which both double bonds have been reduced to single bonds. It is a beta-diketone, a polyphenol, and a diarylheptanoid. Tetrahydrocurcumin oids (THC) is the main product of curcumin metabolism in the human body and is obtained by hydrogenation of curcumin. It is an odorless powder that is white in colour, and it is more hydrophilic than curcumin [(33)].

It acts as an anti-inflammatory [(34)], antidiabetic [(35)]. It also has been used as a raw material for various skincare products in the research and development of cosmetics and has broad development prospects [(33)].

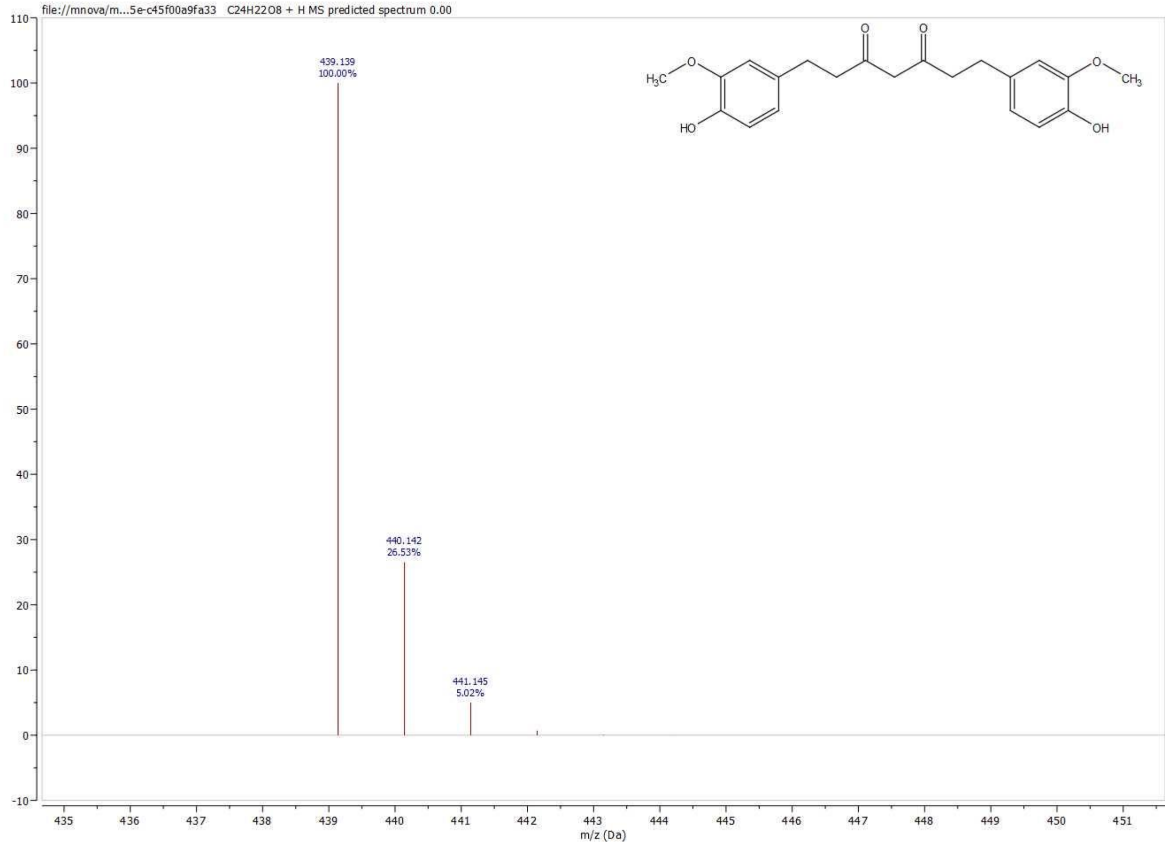
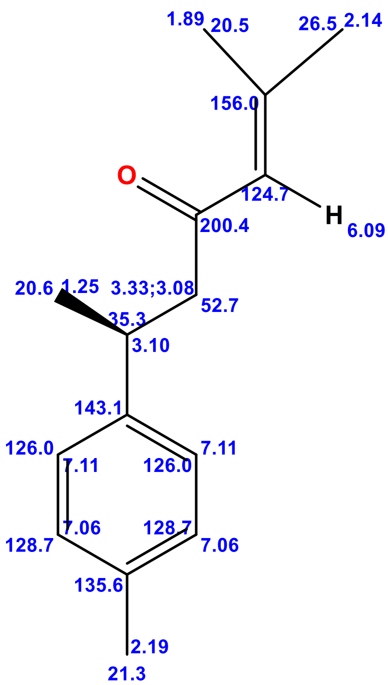


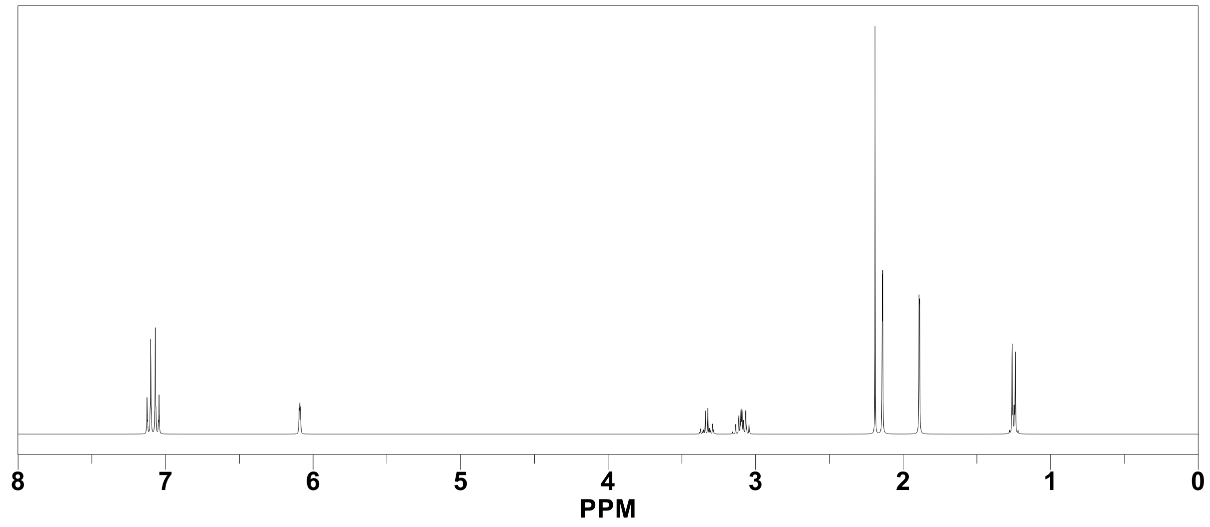
Figure 9: Mass spectrum of Tetrahydrocurcumin

6. Ar-turmerone



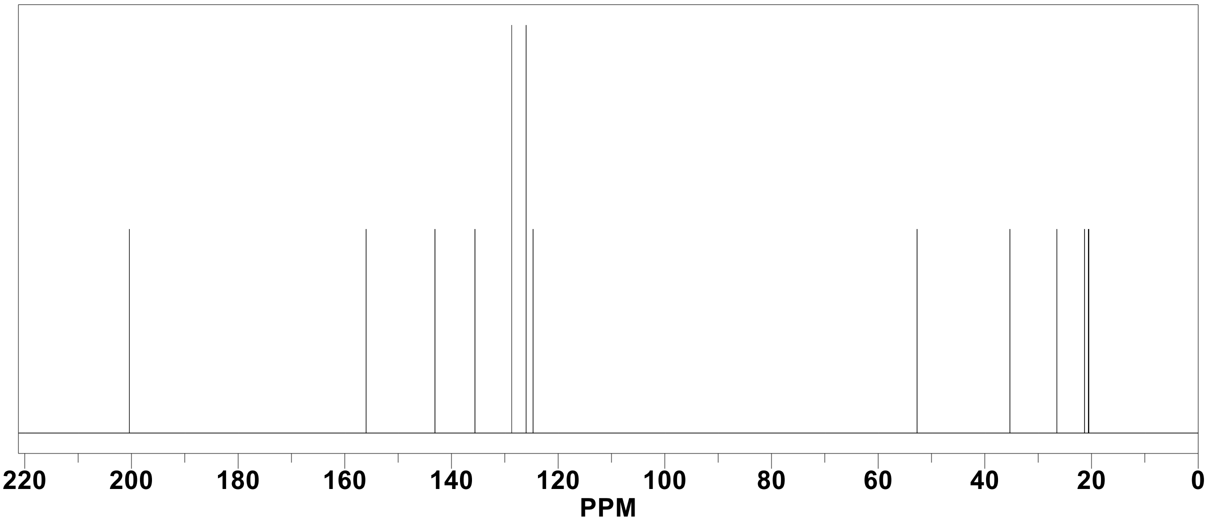
Chemical Formula: C15H20O
Exact Mass: 216.15
Molecular Weight: 216.32
m/z: 216.15 (100.0%), 217.15 (16.2%), 218.16 (1.5%)
Elemental Analysis: C, 83.28; H, 9.32; O, 7.40

Estimation quality is indicated by color: good, medium, rough



H-1 NMR of Aromatic turmerone, Solvent- DMSO, 300MHz

Estimation quality is indicated by color: good, medium, rough



C-13 NMR of Ar-turmerone

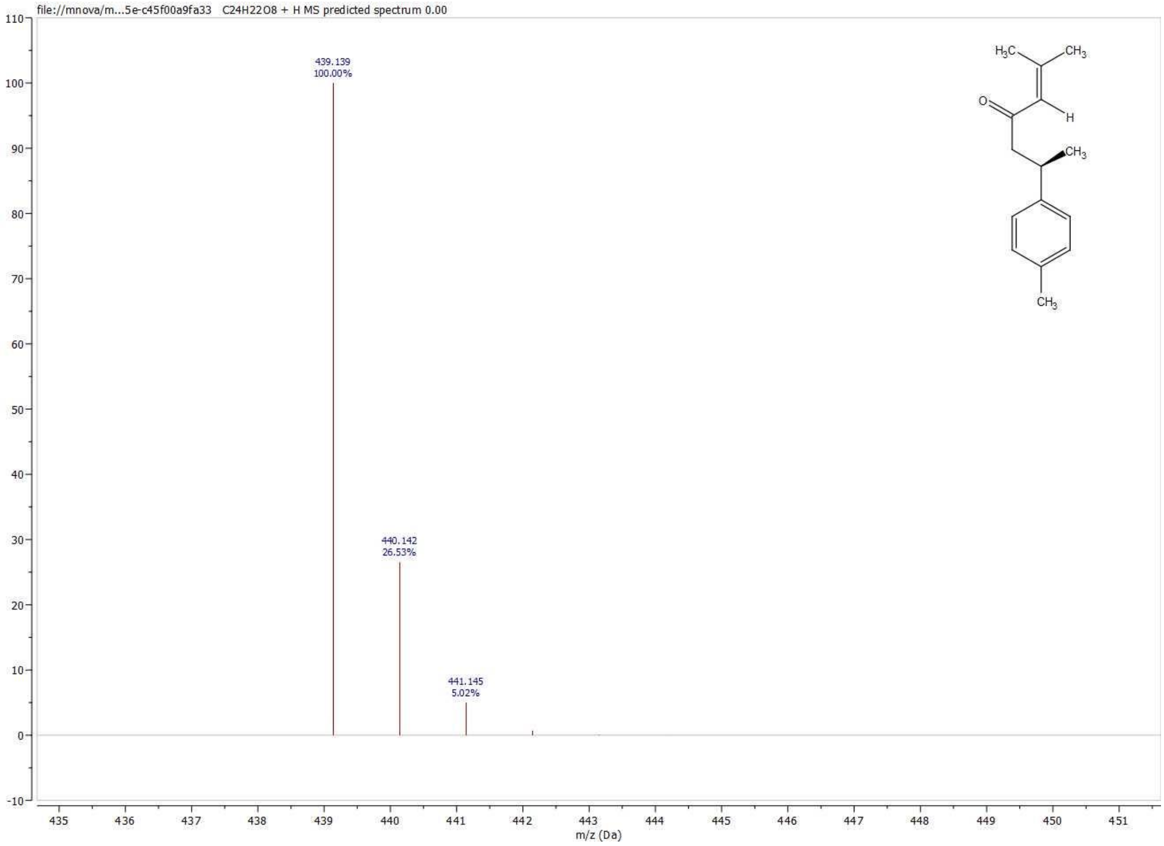


Figure 10 Mass spectrum of Ar-turmerone

Aromatic (ar-) turmerone is a major bioactive compound of the herb Curcuma longa (turmeric). It is also found in two different species of genus Curcuma, such as *Curcuma zedoaria* and *Curcuma xanthorhizza.*

It acts as an anti- dermatophyte [36]. It is also helpful in treating neurodegenerative diseases [37].

Chemical Constituent	Function
1. Curcumin	Anti-inflammatory, Antioxidant, Anti-tumour and Anti-cancer, Anti- HIV, Anti-Mutagenic, Anti-fungal, Anti-diabetic, Anti-fibrinogenic, Wound healing, Lipid lowering, Radioprotective, immunomodulating.
2. Demethoxycurcumin	Antioxidant
3. Bisdemethoxycurcumin	Antioxidant, antimutagenic
4. Diacetylecurcumin	Anti-inflammatory, Antibacterial, Antimalarial, Anti-proliferative.
5. Tetrahydrocurcumin	Anti-inflammatory, Anti-diabetic
6. Ar-turmerone	Anti-dermatophyte, Anti-neurogenerative

Table.1-Medicinal importance of the different constituents of **Curcuma longa**

3. Benefits of Curcuma longa (Turmeric) in agricultural practices

a. Plant extracts as pesticides

A wide range of chemical pesticides is commercially available to combat the threat of pests and pathogens (38). However, injudicious use and overreliance of farmers on these chemical tools emerging as a catastrophe to human and environmental health. Hence it is the need of the hour to shift on some alternative management practices which not only assure an efficient reduction of losses caused pest/ pathogen but at the same time stands eco-friendly as well (39). Hence the plant extracts from wild weed, minor vegetables and spices are being actively exploited for their active compounds which are hazardous to the pest and pathogen population and hold no threat to environment or humans. Their plant extracts and essential oils may have a broad spectrum of activity against insect pests, plant pathogenic or other fungi, weeds, and nematodes.

Many plant-based materials are effective against a number of insects, pathogens, and nematodes; among all the listed plant extracts, turmeric holds a significant stake in managing various pest problems (40).

b. Insecticidal Activity of Turmeric

The presence of bioactive constituents in the turmeric has been found effective in controlling certain animal and agricultural pests. These bioactive substances interfere with insect behaviour and growth. Different turmeric products have been found active as insecticidal agents and repellents (41).

Many experiments were conducted on the plant extracts of *C. Longa* and found positive results against different insects on various hosts. Some of the important host pathogens are listed below.

Insect	**Scientific name**	**Reference**
Cabbage looper	*Trichoplusia ni*	[42]
Red floor beetle	*Tribolium castaneum*	[43]
Rice plant hopper	*Nelaparvata lugens*	[44]
Diamondback moth	*Plutella xylostella*	[44]
Floor beetle	*Tribolium castaneum*	[45]
Australian sheep blowfly	*Lucilia cuprina*	[46]
Lesser grain borer	*Rhizopertha dominica f.*	[47]
Rice beetle	*Sitophilus oryzae l.*	[47]

Rhizomes of *C. Longa* were assessed for their repellency against adults of three insects of stored products, *Tribolium castaneum*, *Sitophilus granarius*, and *Rhyzopertha dominica* and the powder was effective against *S. granarius* and *R. dominica* (48).

An insecticide based on turmeric powder or some of its derivatives chiefly the sesquiterpene ar-turmerone could potentially control the looper larvae of cabbage (49).

When mixed with mustard oil, turmeric powder has been reported to protect milled rice 1against *sitophilus oryzae* (50).

Solvent extracted from turmeric rhizomes was effective against *T. castaneum* (51).

Jilani and su(52)reported that petroleum ether extracts from rhizomes of *C. Longa* were more effective than acetone and ethanol extracts when tested against *tribolium castaneum*. Acetone extracts of turmeric were evaluated by chander et al (53) in the laboratory as repellents on the jute fabric against *tribolium castaneum*. These extracts were highly effective even at lowest concentrations of 2.5 and 3.12 mg/cm^2 of jute fabric. Turmeric extracts also showed some repellency on *Tribolium castaneum*, *Oryzaephilus surinamensis*, *Cryptolestes ferrugineus*, *Sitophilus oryzae*, and *Corcyra cephalonica* (54).

Fewer adults of red flour beetle (*Tribolium castaneum*) settled in rice grain in a food preference chamber, when treated with 100, 500, 1000 ppm of turmeric oil and when treated with more concentrations of the turmeric oil lesser the number of beetles settled due to increasing repellency (55). Repellency of turmeric oil was also monitored against the lesser grain borer (*Rhyzopertha dominica*) for 8 weeks and during this week study it was found that turmeric oil was significantly more repellent during the first 2 weeks, but repellency decreased after that (56).

Two compounds Ar-Turmerone and turmerone that were isolated from turmeric powder showed strong repellency against *Tribolium castaneum* (57). Ar-Turmerone caused 100 and 82 % mortality at 1000 and 500 ppm, respectively, in a test against female adults of brown planthopper *(Nilaparvata lugens*) (58). Volatile oils obtained from turmeric rhizomes by fractionation also afforded ar-turmerone, which displayed insecticidal activity against mosquitoes with an LD_{100} of 50 mg/ml^{-1}on ades aegyptii larvae (59). Curcuminoids which comprise three closely related curcumins (I, II, III) of turmeric rhizome powder, were tested for their inhibitory activity on insect growth (60).

The insect control activity of most turmeric products was comparable or better in pest control activity than that of a commercial neem formulation (61).

c. Turmeric against pathogenic fungus

Many of the spices plants extracts and biocontrol agents have the potential to inhibit the plant pathogens in different ways. K.t Apet el al in vitro evaluation revealed that all the test fungicides, botanicals and bioagents significantly inhibited mycelial growth of *A. alternata*, over untreated control. Of the systemic fungicides tested, the highest average mycelial growth inhibition was recorded with Hexaconazole (94.44%), followed by Carbendazim (84.93%); aqueous extracts of all the botanicals tested (@ 10 and 20%) were antifungal to the test pathogen. However, the significantly highest average mycelial growth inhibition was recorded with *A. sativum* (74.45%), followed by *C. longa* (63.99%), *D. metal* (53.06%), *C. gigantica* (48.99%) and *P. hysterophorus* (48.90%).

Jakathinath et al. investigate carried out to test the efficacy of fungicides, botanicals, and bio-agents in vitro. Among botanicals tested in vitro revealed that *Curcuma longa* extracts inhibit the mycelial growth of *Phomopsis vexans* efficiently.

disease	**pathogen**	**Reference**
Fusarium wilt	*Fusarium oxysporium f.sp. lycopersici*	[62]
Sclerotinia rot	*Sclerotinia sclerotiorum*	[62]
Leaf blight	*Colletrotricu capsici*	[63]
Rice blast	*Pyricularia oryzae*	[64]
Aspergillus ear and Kernel rot.	*Aspergillus flavus*	[65]
Gray mold disease	*Botrytis cineria*	[66]
Bakane disease	*Gibbrella fujikuroi*	[66]
Anthracnose	*Colletrotricum gloeosporioides*	[67]
Purple blotch disease	*Alternaria porri*	[68]

d. Nematicidial effects of *curcuma longa*

Plant-parasitic nematodes significantly caused huge losses to economies in the top vegetables producing countries worldwide. Rather than controlling the main pathogenic nematode species as usual; one of the innovative strategies to control plant-parasitic nematodes would be to manage diversity in communities to lead them to be less pathogenic. The plants and their materials are one of the potential remedies for nematodes management. Turmeric (*Curcuma longa*) and its various biological applications have the potential to act as a biopesticide against major plant-parasitic nematodes, particularly root-knot nematode Meloidogyne species. Bioassay-guided isolation of various fractions of turmeric was subjected to nematicidal activity compared with Azadirachta indica against *Meloidogyne incognita* larvae at the concentration of 0.25, 0.5, and 1% for 48 hours. Larvae and nematodes eggs were inoculated around the tomato seedlings in experiments with turmeric in a growth chamber. The control contains water instead of turmeric. Root gall severity and final nematode population were suppressed significantly. It was observed that the use of turmeric is very important for selected phyto-parasitic nematodes management (69).

Nematode	**Scientific name**	**Reference**
Root-knot nematode	*Meloidogyne incognita*	[70],[71],[72]
Stunt nematode	*Tylenchorhynchus annulatus*	[73]
Lance nematode	*Hoplolaimus pararobustus*	
Dagger nematode	*Xiphinema spp.*	
Root-knot nematode	*Meloidogyne javanica*	[74]

4. Conclusion

This article summarises the important chemical constituents of turmeric. Its medicinal importance also touches on the importance of some elements present in the turmeric in agricultural science. Turmeric contains curcumin and other critical chemical substances with potent anti-inflammatory, antioxidant, and anti-diabetic properties. Curcumin has been studied as a beneficial herb in cancer treatment and affects growth and development. With a lot of information available about the use of turmeric as a spice, dye, food flavouring. Turmeric has numerous medicinal uses and benefits and is credited with intriguing pesticide properties against certain agricultural pests such as phytopathogenic fungi, bacteria, and nematodes and promising repellent properties against harmful mosquito species. Growing demand for natural pesticides has developed researchers' interest in developing new products based on turmeric plants for pest control.

In recent times, great interest has been given to studies of herbal drugs as traditional remedies are indicated worldwide. There has been an upsurge in the scientific investigation in the research area. So, we proposed that if we do more study on turmeric, its more medicinal and agricultural properties will be discovered, which is excellent for humankind.

Reference

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