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Pros and Cons of Curcumin as Bioactive Phyto-Compound for Effective Management of Insect Pests

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Abstract

Phyto-compounds as insecticides have expanded impetus in recent insect pest management programme owing to health hazards and perpetual toxicity of conservatively applied deleterious insecticides of diverse commercial brands. Turmeric plant produces fleshy rhizomes of bright yellow to orange color in its root system, which are the source of commercially available spice turmeric. Curcumin, a Phytochemical gives yellow colour to turmeric and is used for time immemorial for most of the remedial practices. Curcumin is also used as a spice in foods, as a dye for fleeces and as an ingredient in dietetic supplements. As root powder, turmeric is used for its flavoring properties as a spice, food preservative and food-coloring agent. Turmeric has a long history of soothing uses as it is accredited with a diversity of imperative valuable properties such as its antioxidant, antibacterial, anti-inflammatory, analgesic and digestive properties respectively. The fresh juice, the aqueous extracts and the essential oil of the plant are endorsed with fascinating pesticidal properties against certain pests of agricultural importance as well as a perceptible repugnant activity against noxious mosquito species.

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Results have exposed a pleasurable impending potentiality of turmeric as a natural pesticide for achievable use in current crop protection and thus an exceedingly promising future towards this route, that is, the possibility of effective control of certain pests of agricultural importance with the use of turmeric products as an economical and more effective eco-friendly alternative to chemical pesticides which is by now put into practice.

Keywords**:** *Curcuma longa*; Curcumin; Toxic chemical insecticides; Insect pests.

1. Introduction

The growing demand for environmentally sound strategies in the control of agricultural insect pests, the development of alternative insecticides with minimal ecological hazards has now become an imperative need [1]. This demand is also supported by the increasing concerns over the level of insecticide residues in food and over the level of resistance of pests to several pesticides, which both result from the overuse of chemical pesticides [2]. Thus, increasing reports about the negative effects of synthetic pesticides often resulting from indiscriminate application have renewed the interest in natural pesticides as an eco-chemical approach in insect pest control [3]. Natural pesticides are active substances derived from plants and are often used for pest management [2]. Many plant extracts show a broad spectrum of activity against several pests and pose little threat to human health and the environment. Therefore, they have long been touted as attractive alternatives to synthetic pesticides for pest control. Moreover, plant essential oils or their constituents have a broad spectrum of activity against insect pests, plant pathogenic or other fungi, weeds, and nematodes [4, 5]. Natural products showing activity against pests have been and are still being explored for possible production of commercially available natural products that can be effective on certain pests, selective in crops, non-toxic for the user, easily biodegradable, and that can be locally and easily produced, especially by farmers who usually cannot afford expensive synthetic pesticides.

Curcumin is the chemical constituent of turmeric. Turmeric is one of most essential spices all over the world with a long and distinguished human use particularly in the Eastern civilization [6] and can be considered in this regard. This is basically a spice with the subtle flavor which is obtained from the dried and grounded rhizomes of the plant. The rhizomes are yellowish to orange tuberous juicy stems that are formed below the ground at the base of the plant consisting of the mother rhizomes with the primary, secondary, and even tertiary fingers. Turmeric has been found effective in controlling certain agricultural and animal pests due to the presence of a variety of bioactive constituents that interfere with insect behavior and growth.

The name comes from Arabic kurkum meaning “turmeric”.Turmeric (*Curcuma longa*) is a rhizomatous herbaceous perennial plant of the ginger family, Zingiberaceae [7]. It is thought to have arisen by selection and vegetative propagation of a hybrid between the wild turmeric (*Curcuma aromatica*), native to India, Sri Lanka and the eastern Himalayas and some other closely related species. Turmeric is a sterile plant, and does not produce seed. Curcuma (Cúr-cu-ma) is a genus of about 80 accepted species.

Turmeric it is known to be one of the oldest spices that have been used in India since ages. That is why it is also known as, ‘Indian Saffron’. It is used as condiment, dye, drug and cosmetic in addition to its use in religious ceremonies. It include antioxidant [8], antirheumatic [9], antimutagenic [10], antitumor [11], antivenom [12], antibacterial [13], antifungal [14], antiviral [8], nematocidal [15] and hemagglutinating [16, 17] activities. Turmeric rhizome is used as a food additive (spice), preservative and colouring agent [18] in Asian countries, including China and India and also as natural dye [19]. Just few drops of turmeric juice from the rhizomes can create permanent stain on clothes.

Turmeric cultivation is basically confined to South East Asian countries such as India, Sri Lanka, China, Indonesia, Australia, Africa, Peru and the West Indies. India is one of the largest producers of turmeric in the world (93.7% of the total world production) and is cultivated in 150,000 hectares in India [20, 21]. In this country about 6% of the total area under species is occupied by turmeric. India is a leading producer and exporter of turmeric in the world. Andhra Pradesh, Tamil Nadu, Orissa, Karnataka, West Bengal, Gujarat, Meghalaya, Maharashtra, Assam are some of the important states cultivates turmeric, of which, Andhra Pradesh alone occupies 35.0% of area and 47.0% of production. About 92% of the produce is consumed in the domestic market, and 8% exported annually. The plant is cultivated in all parts of India [22].Turmeric requires a hot and moist climate. It is cultivated on loamy or alluvial, loose, friable and fertile soils with a pH range of 4.5-7.5 with good organic status. India produces most of the world supply [21, but turmeric is cultivated also in southern China, Taiwan, Japan, Burma, and Indonesia [23] as well as throughout the African continent [24]. The commercially available material (i.e. turmeric powder) in Europe is obtained mainly from India and somewhat from other south eastern Asian countries [25].

2. Origin, History, Diversification and Distribution

The origin of the plant is not certain, but it is thought to be originated from south eastern Asia, most probably from India. The plant is cultivated in all parts of India [22]. The exact origin of turmeric is not known but it originates from South or Southeast Asia, most probably from western India and southern India [26]. Turmeric has been grown in India since ancient times more than 5000 years ago. Although, turmeric originated in India, but it had reached China by 700 AD, East Africa by 800 AD and West Africa by 1200 A.D. It is also known that Arab traders had carried with them turmeric to Europe in the 13^{th} century. It was introduced to Jamaica in the 18th Century. Today, turmeric is widely cultivated throughout the tropics.

On turmeric, Marco Polo (1280 AD) said that, "I have found a plant that has all the qualities of Saffron, but it is a root." This is an ancient talisman tradition used to ward off evil and grant to the wearer healing and protection. Buddhist monk shave used Turmeric as a dye for their robes for at least 2000 years. Europe rediscovered it 700 years ago via Marco Polo and it is used in traditional Brazilian medicine as potent anti-venom to neutralize the bleeding and lethal poison of Pit Vipers. For at least 1000 years Chinese Medicine has used Turmeric especially for the treatment of Spleen, Stomach, and Livers. In Unani Turmeric is considered to be the safest herb of choice for all blood disorders since it purifies, stimulates, and builds blood. When the ancient Polynesians made their fantastic voyages in canoes across the Pacific Ocean to Hawaii they took with them the roots, cuttings, and seeds of about 25 of their most valuable plants. The Indian practice of applying the root paste to the face to cure any blemishes is popular in this tradition as well.

3. Species diversity of *Curcuma* sp.

The genus *Curcuma* is economically and medicinally important with many species of it [20]. *Curcuma* species exhibit inter- and intra specific variation along with morphological variation like the vegetative and floral characters and rhizome features also. Thus, the overall appearance of many species is often similar as they only differ in small morphological details. This genus shows high diversity in India and Thailand, with at least 40 species in each, estimates vary from about 50 to 80 or even 100 species. But, a detailed botanical exploration of India and Southeast Asia may well bring their number to 120 [20]. *C. Longa* (the common turmeric) is the most known and madiconomically valuable member of the genus *Curcuma*.

Taxonomic classification of it was given by Linnaeus followingly:

Class Liliopsida
Subclass Commelinids
Order Zingiberales
Family Zingiberaceae
Genus Curcuma
Species *Curcuma longa*

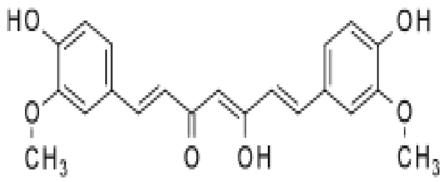
C. aromatica and *C. longa*. is the wild and domestic species of turmeric respectively. Other economically important species of the genus is *C. petiolata, C. australasica, C. zedoaria* etc. which are used in medicine and toiletry articles as well as several other species used as folk medicine in the southeast Asian nations, especially in culinary preparations, pickles, and salads or certain species with mainly floricultural importance [20].

4. Curcumin-Chemical nature

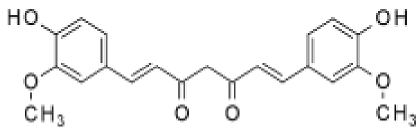
The characteristic yellow color of turmeric is due to the curcuminoids, first isolated by Vogel in 1842. Curcumin is an orange–yellow crystalline powder practically insoluble in water. The structure of curcumin ($C_{21}H_{20}O_6$) was first described in 1910 by Lampe and Milobedeska. Curcumin, commonly called diferuloyl methane, is a hydrophobic polyphenol derived from the rhizome (turmeric) of the herb *C. longa*. Curcumin has been identified as the active principle of turmeric; chemically, it is a bis-a, b-unsaturated b-diketone that exhibits keto-enol tautomerism [27, 28, 29, 30, 31].

5. Bioactive compounds of Turmeric-As natural pesticides

Turmeric is a low growing shrubby species. Its various plant parts contain different types of bioactive materials which have insecticidal, pesticidal or insect repellent activity. Turmeric contains protein (6.3%), fat (5.1%), minerals (3.5%), carbohydrates (69.4%) and moisture (13.1%). The major components (~60%) of the turmeric extracted oil were identified as turmerone and ar-turmerone [32,33].The compounds present in rhizomes are 1,8-Cineole, alpha-Terpineol, Ar-Termerone, Ascorbic acid, Azulene, Beta-Carotene, Beta-sesquiphellandrene, Barneol, Caffeic acid, Caprylic acid, Cinnamic acid, Curcumin, Guaiacol, Isoborneol, p-Coumaric acid, p-Cymene and p-methoxy cinnamic acid [34](Duke and James, 1999). The bioactive compounds with insecticidal or pesticidal activity are present in the form of essential oil, those are alpha-Penene, beta-Pinene, Caryophyllene, Eugenol and Limonene [34]. O-Coumaric acid and protocatechuic acid are extracted from leaf of *C. longa* [34]. Curcumin (diferuloylmethane) (34% is responsible for the yellow colour, and comprises curcumin I (94%), curcumin II (6%) and curcumin III (0.3%) and it is the most active chemical which acts as natural pesticides [13].



[Curcumin: enol form]



[Curcumin: keto form]

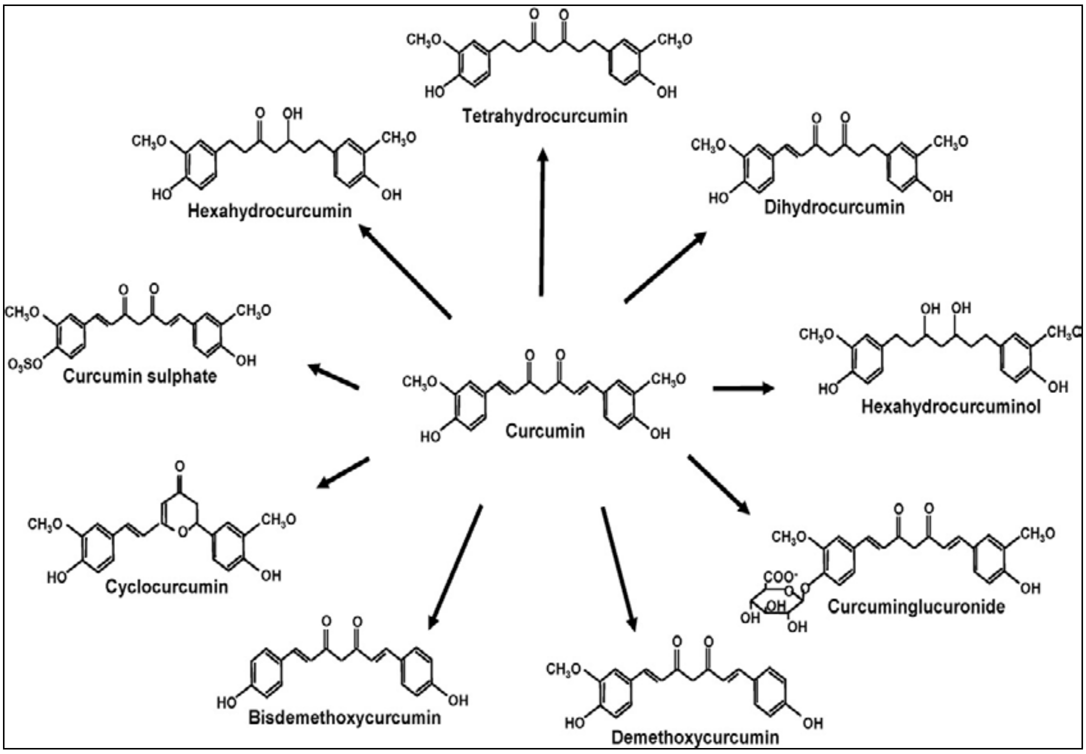


Figure 1: Natural analogues from turmeric and curcumin metabolites.

Turmeric contains three important analogues, curcumin, demethoxycurcumin (DMC), and bisdemethoxycurcumin (BDMC). Collectively called curcuminoids, the three compounds differ in methoxy substitution on the aromatic ring. While curcumin has two symmetric o-methoxy phenols linked through the a,b-unsaturated b-diketone moiety, BDMC, also symmetric, is deficient in two o-methoxy substitutions, and DMC has an asymmetric structure with one of the phenyl rings having o-methoxy substitution. Of the three curcuminoids, curcumin is the most abundant in turmeric, followed by DMC and BDMC. Commercially available curcumin mixture contain 77% curcumin, 17% DMC, and 3% BDMC. A lesser known curcuminoid from turmeric is cyclocurcumin [15]. The common natural analogues are Tetrahydrocurcumin, Dihydrocurcumin, Hexahydrocurcuminol, Curcuminglucuronide, Curcumin sulphate, Hexahydrocurcumin.

6. Method of extraction of Curcumin from Turmeric Plant

The rhizomes from fresh plant of *C. longa* were collected and washed under running tap water followed by distilled water. Rhizomes were sliced and peeled. 250 gm of sliced and peeled rhizome were mixed with 400 ml of distilled water into the 1000 ml round bottom flask. Extraction was carried out by hydro distillation following the method of Guenther (1948) out at room temperature [35]. The homogenate mixture in the RBF was heated for 6-8 hours. The oil, present at the upper layer in the ependroff tube, was separated from the water using separating funnel and examined for the presence of curcumin.

The rhizomes of turmeric were ground to a fine powder in an electric grinder. A weighed amount of turmeric powder was extracted separately with acetone, petroleum ether and ethanol on Soxhlet's extraction apparatus each for eight hours. The extracts were concentrated on rotary evaporator and finally made solvent free in vacuum desiccators.

In another method of extraction 500 g of dried turmeric is first grinded in a mixer grinder and then subjected to separation through a vibrating sieving machine. Four different particle sizes as 250µ size, 44 mesh sizes, and 30 mesh sizes and above 30 mesh size are separated. 2 g of sample from each particle size is taken and mixed with 30 ml of ethanol and 30 ml of water respectively, separately and then filtered. The concentration of each of the filtrate is kept same and then the absorbance is measured using spectrophotometer at 425nm.

Curcumin content g/100 g is measured using the following formula:

$$= \frac{\mathbf{0.0025 \times Absorbance\ at\ 425\ nm \times volume\ made\ up \times Dilution\ factor \times 100}}{\mathbf{0.42 \times weight\ of\ sample \times 1000}}$$

Since 0.42 absorbance at 425 nm =0.0025 g of curcumin.

After, further purification it is used as pesticides [12].

Ether and chloroform extracts and oil of *C. longa* have antifungal effects. Crude ethanol extract also possesses antifungal activity [12].

7. Application in insect pest management

Turmeric has been found effective in controlling certain agricultural and animal pests due to the presence of a variety of bioactive constituents that interfere with insect behavior and growth. Turmeric contains pungent, odoriferous oils and oleoresins; the rhizomes have been reported to possess many kinds of biological activities [13]. Insecticidal properties of turmeric have been well documented in the literatures [36]. The insect repellent components in turmeric are turmerones and Ar-turmerone [37]. According to Jilani and Saxena [38] then extract of *C. longa* had insecticidal, repellent and antifeeding activities against some stored product insects [39]. Insect control properties of turmeric pertains to the powder, the plant extracts, the essential oil, and certain bioactive constituents of the plant. Its products have been found active as insect repellents and insecticidal agents. Jilani, *et al.* [40] observed the repellent and growth-inhibiting effects of the essential oil of Turmeric on rust red flour beetle. Investigations confirm that some plant essential oils not only repel insects but possess contact and fumigant toxicity against stored product insects as well as exhibited feeding inhibition [41, 42].

7.1 For stored grain pest

7.1. a. As life cycle and growth modulator

Essential oil extracted from various plant leaves of turmeric, *C. longa* showed contact and speices shown toxic and growth inhibitory activity fumigant toxicity, antifeedent and affects the progeny against stored grain insects. It reduced oviposition and eggs hatching in cinnamaldehyde and cinnamyl acetate have shown stored grain insects [8]. Moreover, turmeric powder in combinations with mustard oil has been reported to protect milled rice against *S. oryzae* [43]. A combination of 4 ml/kg of mustard oil and turmeric powder at 20 g/kg provided the best protection of milled rice by completely suppressing progeny emergence of *S. oryzae*. Dust from rhizomes was shown to be effective against store-grain pests such as lesser grain borer (*Rhyzopertha dominica*) [44]. In particular, turmeric powder (or grit) provided 63.2% suppression of progeny of the test insect at 0.5% level [44]. The rhizome and aerial part extract offered dose mortality action against *T. castaneum* adults which was found promising [45]. In an experiment on apterous adults of cardamom aphid (*Pentalonia nigronervosa*), it is found that higher number of these aphid are on control shoots than the shoots treated with 0.5 and 1% concentration of turmeric oil [46]. In comparision of a commercial neem formulation, the insecticidal activity of most turmeric products was much better.

7.1. b. As repellent

In 1983, Jilani and Su evaluated rhizomes of *C. longa* for their repellent activity against adults of three insects of stored products, *Tribolium castaneum*, *Sitophilus granarius*, and *Rhyzopertha dominica* and this turmeric powder was found effective against *S. granarius* and *R. dominica.* Likewise, in another experiment Chander et al., [44] found that there was complete mortality of adult insects on milled rice treated with 6 ml oil plus 1-4 g of turmeric powder, whereas mustard oil in various combinations with turmeric powder suppressed the progeny by more than 92%. Solvent extracts from rhizomes were effective against *T. castaneum* [47]. Also, the petroleum ether extracts from rhizomes were more effective than the acetone and ethanol extracts [47]. The acetone extracts of turmeric, in the laboratory, as repellents on the jute fabric against *T. castaneum* [48]. Chander et al. [48] observed that acetone extract of turmeric rhizomes acted as repellent against *T. castaneum* . Turmeric extracts showed some repellency on *T. castaneum*, *Oryzaephilus surinamensis*, *Cryptolestes ferrugineus*, *S. oryzae*, and *Corcyra cephalonica* [49, 50]. Likewise, Petroleum ether and diethyl ether extracts of turmeric showed noticeable reduction (36.0 and 33.6 %, respectively) in F1 progeny of *S. oryzae* repellency of turmeric oils was monitored against the lesser grain borer (*R. dominica*) for 8 weeks [38]. The essential oil extracted from the leaves of turmeric for contact and fumigant toxicity and its effect on progeny production in three stored-product beetles, namely *R. dominica*, *S. oryzae*, and *T. castaneum* [38]. In another experiment, three plant-based essential oil formulations provided complete protection from mosquito landing and biting for up to 9 hour [51].

Turmeric contains pungent, odoriferous oils and oleoresins; the rhizomes have been reported to possess many kinds of biological activities [13]. Patro and Pati [36] investigated the insecticidal properties of *C. longa*. Rhizome extract with petroleum ether show repellency against *T. castaneum* [45]. Hexane extract of rhizome of *C. longa* reduced progeny production in *T. castaneum* at 200 ppm concentration [51]. Aqueous extract of *C. longa* rhizome acted as repellent against *Callosobruchus chinensis* [52, 36]. The insecticidal activity of these plant extracts against *S. zeamais* could be attributed to the presence of monoterpenoids, sesquiterpenoids, and curcuminoids [53]. The result agrees with the findings of Bhardwaj et al. (13) who reported that *C. longa* rhizomes possess many kinds of biological activities against insects. Turmeric rhizome extract has been reported to show insecticidal activity against *Nilaparvala Iugens* females and *Plutella xylostella* larvae [54]. The result obtained from these studies suggest good potential for the use of petroleum ether essential oil extract of C. *longa* for the control of *S. zeamais* in stored maize grains.

7.2 For field crop

In a test with female adults of brown planthopper (*N. lugens*), ar-turmerone caused 100 and 64% mortality at 1,000 and 500 ppm, respectively [55]. In an experiment on another cotton pest which is more commonly known as red cotton stainer *Dysdercus koenigii* found that turmeric is very effective. A simple method has been devised for their efficient extraction and separation of curcuminoids. Their structures have been confirmed by ^{1}H NMR spectroscopy and unique mass fragmentation pattern. The major constituent Curcumin-I, has been converted to five alkyl ether derivatives, which have been tested along with the parent compounds and other extractives for insect growth inhibitory activity against *D. koenigii* and *S. gregaria* nymphs. At 50 μg per nymph, benzene extract and dibutyl curcumin-I were the moderately active (45% inhibition) against *D. koenigii* whereas at 20 μg per nymph these substances were highly active (60% inhibition) against *S. gregaria* nymphs. At these concentrations, turmeric oil caused 50–60% nymphal mortality in both test insects. The insect control activity of most of the turmeric products was most effective [56]. Likewise, Experiments were conducted to manage the *Alternaria* leaf spot and blight disease and aphids (*Aphis gossypii*) of blond psyllium through seed and foliar treatments. The other effective treatments against aphid infestation is the foliar treatment of mixture of margosa oil (*Azadirachta indica)* (10 ml/l), leaf extract of mesquite (*Prosopis juliflora*) and thorn apple (*Datura. stramonium*)and turmeric tuber extracts(*C. longa*) (10%). This method is found effective in this disease management [57].

8. Limitation and future directions

Botanical pesticides have the advantage of providing novel modes of action against insects that can reduce the risk of cross-resistance as well as offering new leads for design of target specific molecules [58]. Surface treatment of wheat seeds with turmeric extracts were not effective in causing mortalities among adults of *S.*

oryzae, except from petroleum ether extract which gave low mortality percentage (20.4%) at 4.0% concentration. The same concentration of extracts gave the highest effect (90.8%) against the adults of *R. dominica* [59]. Experimental data from the international literature, as reviewed herein, indicated a highly promising potential of turmeric products as natural pesticides. Although there is plenty of information about the use of turmeric as a spice and apart from its multiple medicinal uses, turmeric is credited with interesting pesticidal properties against certain agricultural pests and with promising repellent properties against noxious mosquito species. Rhizomes of turmeric have been used widely particularly in Asia, not only as a spice, but also as a common household medicine without showing toxicity to humans.

9. Conclusion

Prospective pesticides based on turmeric products could find commercial application not only in the protection of stored commodities, but also in protected crops (e.g. greenhouse crops), high-value row crops, and within organic food production systems, where only few alternative pesticides are available. Such natural pesticides would be a practical alternative for effective and sustainable crop protection that could substantially minimize potential for environmental contamination and human health risks. Whether new products based on turmeric plant will be eventually developed in the future for pest control remains to be proved in practice. The field application reports of most of the methods are scarce.

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