CHAPTER 18

BIOLOGICALLY ACTIVE COMPOUNDS OF *CURCUMA LONGA L.* AND ASPECTS OF THEIR APPLICATION

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INTRODUCTION

Curcuma longa L., known worldwide as a source of valuable golden spice, is a perennial herbaceous plant that has been the basis of traditional Asian medicine for centuries and is now the focus of modern science. Its unique morphological structure with a characteristic orange-yellow rhizome acts as a natural laboratory in which highly active polyphenolic compounds are synthesized. The key component of this plant is diferuloylmethane, which, thanks to its universal therapeutic properties, is becoming the basis for modern treatment strategies for many diseases. Modern pharmacology pays special attention to the ability of this polyphenol to modulate complex inflammatory pathways. Preclinical studies confirm its high efficacy in reducing airway obstruction, which is crucial in the treatment of asthma and allergies. This mechanism is based on the precise inhibition of enzymes such as sPLA2 and cyclooxygenase-2 (COX-2), as well as the blocking of key signalling kinases (ERK, p38 MAPK, JNK) responsible for the progression of pathological changes. In addition, polyphenol plays an important role in preventing irreversible remodelling of lung tissue by reducing the activity of MMP-9 metalloproteinase and decreasing the expression of proteins associated with fibrosis. Beyond its medicinal aspects, turmeric has enormous potential in the fields of healthcare, agriculture and economic innovation. The cultivation of this plant, of which India remains the leading producer, is key to the economic revival of many regions. Treating *Curcuma longa* as a high value-added commodity stimulates the local economy, creates jobs and strengthens export potential. Its rich history and status as a "golden spice" also attract tourists interested in cultural heritage and natural healing methods.

1. Characteristics of *Curcuma Longa. L.*

Curcuma Longa. L. is perennial herbaceous plant distinguished be its unique morphological structure. The basis of the plant is a strong cylindrical rhizome? Which has a characteristic orange-yellow hue in its core. From this underground system grows an egg-shaped, sessile stem, which serves as the central axis for the formation of leaves. The leaves are basal and grow in dense clusters, often reaching a total height of up to 1.5 meters, including the petiole and blade. These leaves have a membranous base that transitions into a simple, oblong-lanceolate lade that tapers to its starting point. The flowering part of the plant manifests itself in a basal inflorescence in the form of a cluster. This structure is supported by a peduncle that can reach 15 cm or more. The flower inflorescence, approximately 10–15 cm × 6 cm in size, is crowned with bright pink terminal bracts, while the lower flower bracts are pale green in colour. The flowers themselves are full and fragrant, regular, zygomorphic. The are protected be two different types of bracts: sterile ones, which form a bright pink cone (5–8 cm long) at the top, and fertile ones, which are pale green in colour, 4–6 cm in size, noticeably curved and rounded at the ends. At their base, the bracts and bracteoles merge to form small sacs in which the flowers develop. The calyx consists of three sepals connected be three small, uneven lobes. The corolla consists of three fused petals forming a tube about 3 cm long, its upper half is funnel-shaped with pale pink blades. The rear blade is egg-shaped, concave a curved above the fertile stamens. The androecium has five stamens (2+3). In the inner ring, two parts merges to form a lip-like staminode, leaving only one stamen, which is fertile. This stamen is characterized by a short filament and an anther that has grown at the base. The gynoecium has three carpels with a lower, syncarpous, three-nested ovary. The pistil is thread-like, and the stigma is bilobed. The plant forms a spherical capsule containing elongated or egg-shaped seeds[1].

Origin and distribution. *Curcuma Longa*, which originates from the tropical landscapes of Southeast Asia, has established itself as a staple of Asian heritage. It is widely used in Chine, Bangladesh and Southeast Asia, serving a triple function: as a delicious food additive, a natural preservative and a powerful colouring agent. Today, it is grown worldwide in regions such as Taiwan, Sri Lanka, Myanmar, Nigeria, Australis, Peru, Jamaica, and various countries in the West Indies, the Caribbean, and Latin America. However, India retains its undisputed dominance in the global market, accounting for

[1] Pratima Dolase, Vivek Chaudhari. Review on Cultivation Practices of Haridra (Curcuma Longa Linn.). *International Journal of Ayurveda and Pharma Research*. 2024. P. 56–61. DOI: https://doi.org/10.47070/ijapr.v12i9.3394 (date of access: 25.10.2025).

approximately 78 % of world production, making it the leading producer, consumer and exporter of this spice. In India, the agricultural base of this industry is in states such as Odisha, Andhra Pradesh, Maharashtra, Tamil Nadu, Kerala, Assam, Bihar and Bengal. Erode, in Tamil Nadu, historically known as the ’Yellow City’ or ’City of Turmeric’, is recognized as the world’s leading centre for production and trade. Sangli, a city in Maharashtra, ranks second among the largest trading centres and plays an important role in the distribution of spices. In particular, the variety grown in the state of Kerala, known commercially as Alleppey Finger Turmeric (AFT), is recognized as the highest quality on the market[2].

Cultivation. Curcuma grows in warm and humid climates and requires fertile, well-drained soil rich in humus for optimal growth. Turmeric is sensitive to excess water and does not tolerate waterlogged areas. Although it prefers alkaline soils, it demonstrates the ability to adapt to a wide pH range, from 5.0 to 7.5. the key factor determining its development is temperature. The planting phase is best carried out at a temperature of 30–35 °C, and rhizome formation can take place at 30–35 °C, 20–25 °C and 18–20 °C.

The soil preparation process is labour-intensive and involves four to six cycles of digging and ploughing to properly loosen the soil. The necessary fertilisers are applied during the last ploughing. The method of field formation depends on the soil structure. On porous soil, wide beds are formed, separated be water channels. On non-porous soils, ridges and furrows are formed, and the rhizomes are placed in shallow pits on the ridges or on the sides.

Curcuma Longa is usually propagated vegetatively using rhizomes, as growing from seed is economically unprofitable. The best seed material is considered to be the mother rhizomes. They can be planted whole or divided into smaller pieces, provided that each piece has at least one bud. However, using whole mother rhizomes guarantees stronger and better plant growth.

The planting period is usually from mid-April to August, depending on local weather conditions and the specific variety. The traditional method of propagation has certain limitations, as the two-month dormant period allows only one plant to be obtained from each rhizome, forcing growers to reserve a significant portion of the harvest for future sowing. This plant has a high demand for nutrients, so farmers use manure as the main fertilizer, supplemented by two applications of peanut meal.

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[2] Gopinath H., Karthikeyan K. Turmeric: A condiment, cosmetic and cure. *Indian Journal of Dermatology, Venereology, and Leprology*. 2018. Vol. 84, no. 1. P. 16. DOI: https://doi.org/10.4103/ijdvl.ijdvl_1143_16 (date of access: 25.10.2025).

Proper irrigation is critical in three phases: germination, formation of rhizomes and their swelling. In regions with abundant rainfall, cultivation is carried out during the rainy season, while in others, artificial irrigation is necessary. Even a few days without access to water can drastically reduce yields.

The plant is considered mature when the above-ground part, including the base of the stem, is completely dry. Depending on the variety, harvesting takes place several months after planting. After ripening, dry leaves are cut off at ground level. To facilitate the digging up of the rhizomes, it is recommended to water the soil. The next step is to clean the rhizomes and divide them into smaller round pieces and parts. Often, a small part of the field is left untouched in order to collect seed material the following month[3].

Storage, processing and preparation. Cleaned rhizomes intended for sowing required special care. They are stored in shaded areas, protected from the sun by the leaves of the plant itself or stacked in piles and covered with soil mixed with cow manure. In some regions, these piles are additionally sprinkled with ash and periodically moistened with water to maintain optimal humidity.

The rest of the harvest, after preliminary hardening, is stored in large quantities directly at the collection sites. Before the onset in sealed underground pits, which are lined and covered with insulating materials such as reed grass (*Saccharum spontaneum*) or date palm leaves. These storage facilities are only opened after the heavy rains have ended.

The first stage of processing is to boil the rhizomes in water until they soften. This process is key to destroying pests and must be carried out with extreme care. Boiling time varies depending on the region and ranges from 30 minutes to as long as 6 hours. An interesting traditional element is the addition of a small amount of cow manure to the water, as it is believed that ats alkalinity gives the final product a better, deeper colour. An effective technique is to use perforated troughs immersed in cauldrons, which allows up to 700 kg of raw materials to be processed in about 30 minutes, significantly saving time and fuel. After boiling, the rhizomes are gradually cooled and then dried. Traditionally, they are laid out in the sun for 10–15 days, turning them regularly to ensure even drying. An alternative is electric dryers that maintain a constant temperature between 50 °C and 60 °C. Once dried, the

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[3] Choudhary A. K., Rahi S. Organic cultivation of high yielding turmeric (Curcuma longa L.) cultivars: a viable alternative to enhance rhizome productivity, profitability, quality and resource-use efficiency in monkey–menace areas of north-western Himalayas. *Industrial Crops and Products*. 2018. Vol. 124. P. 495–504. DOI: https://doi.org/10.1016/j.indcrop.2018.07.069 (date of access: 25.10.2025).

hard rhizomes are rubbed against rough surfaces or trampled to remove the outer layer of pores and skin. The next step is polishing, which gives the product an aesthetic appearance. This is done using special machines consisting of a large horizontal polishing drum, which is driven manually or mechanically. The drum is protected by a fine wire mesh that prevents small fragments from falling out. This process takes about 30 minutes for a batch weighing 32 kg. Complete polishing results in a weight loss of 5–8 %, while partial polishing limits this loss to 2–3 %. The final stage is to give the rhizomes an intense colour, for which two main methods are used. The first is a dry method, which involves mixing the rhizomes with chemicals, mainly chromium. However, it is not recommended due to the harmful effects of chemical dyes on health. Therefore, the wet method is usually preferred. In this case, a solution of golden dye is mixed with water and sprayed onto the semi-polished rhizomes, and then rubbed in. Another, more complex process involves coating the dried rhizomes with a special emulsion containing castor paste, alum, sodium bisulphate, sulphuric acid and turmeric powder. After applying this mixture, the product is dried again in the sun for about 7 days. The finished, fully processed *Curcuma longa* is characterized by its brittle structure and intense bright yellow colour[4].

Content of biologically active substances. Turmeric rhizomes, known in India under the traditional names 'Haridra' or 'Haldi', are an extremely complex mixture of nutrients and active compounds. They contain carbohydrates (69.4 %), proteins (6.3 %), fats (5.1 %), minerals (3.5 %), moisture (23.1 %), as well as volatile and non-volatile oils. The most important components of the rhizome can be divided into two groups:

– Curcuminoids: curcumin (curcumin I), demethoxycurcumin (curcumin II), bis-demethoxycurcumin (curcumin III) and cyclocurcumin (curcumin IV).

– Essential oils (5–8 %): a mixture of sesquiterpene ketones and alcohols, including d-sabinene (0.6 %), α-phellandrene (1 %), cineol (1 %), and borneol.

It is the curcuminoids that are responsible for the plant's characteristic intense yellow colour. In turn, essential oils give the plant its characteristic aromatic smell and taste. Due to their antioxidant, anti-inflammatory and analgesic properties, these oils are widely used not only in medicine, but also in aromatherapy and the perfume industry. Curcumin is the main component, accounting for aput 70 % of all curcuminoids. It is considered the primary

[4] Pratima Dolase, Vivek Chaudhari. Review on Cultivation Practices of Haridra (Curcuma Longa Linn.). *International Journal of Ayurveda and Pharma Research*. 2024. P. 56–61. DOI: https://doi.org/10.47070/ijapr.v12i9.3394 (date of access: 25.10.2025).

source of the golden pigment and most of the therapeutic properties. It is estimated to constitute between 2 % and 5 % of the total mass of turmeric[5].

Pharmacological action and aspects of use. *Curcuma longa*, often referred to as the 'golden spice', has an extremely rich history of use dating back to ancient times. For centuries, the inhabitants of the Indian subcontinent have used it not only as an integral part of their diet, but also, above all, as a traditional medicine for treating a wide range of diseases. Importantly, centuries of practice have not revealed any negative side effects associated with its prolonged use. Historical documents show that turmeric has been present in India for at least 6,000 years, used as medicine, cosmetic, culinary spice and natural dye. The first mentions of it in the Western world appeared in Marco Polo's 1280 writings describing his travels to China and India. Although it reached Europe in the 13th century thanks to Arab merchants, its true 'discoverer' for the West is considered to be the Portuguese navigator Vasco da Gama, who reached India in the 15th century. Due to its unique colour and aroma, turmeric was given the name 'Indian saffron' in Europe[6].

Chinese medicine has been using the rhizomes of this plant for over a millennium to purify the blood, lower blood pressure, relieve stomach pain, and as a natural antibiotic and antiviral agent. In both Indian and Chinese traditions, turmeric has been used as an anti-inflammatory agent to treat toothache and chest pain, menstrual disorders, stomach and liver diseases, wound healing and scar lightening. Historically in India, it has also been used for skin diseases, upper respiratory tract infections, and joint and digestive tract problems. Although its preservative properties were widely recognized due to its antioxidant action, its health benefits, including promoting digestion, suppressing excessive appetite and treating jaundice, were no less important elements of traditional therapy.

Turmeric is currently advertised as an effective dietary supplement that helps treat many diseases, such as arthritis, digestive disorders (dyspepsia), respiratory tract infections, allergies (e. g., hay fever) and even depression. Scientific studies confirm that oral administration of turmeric alleviates hay fever symptoms such as sneezing, itching and nasal congestion. For digestive disorders, the main active ingredient is curcumin, which has an effect similar to Omeprazol, a popular drug for high acidity. The therapeutic effects of the plant are due to the presence of biologically active molecules, primarily curcuminoids. They interact with flavonoids, phenolic compounds, vitamin C and carotenoids, enhancing antioxidant activity, promoting collagen

[5] Gopinath H., Karthikeyan K. Turmeric: A condiment, cosmetic and cure. *Indian Journal of Dermatology, Venereology, and Leprology*. 2018. Vol. 84, no. 1. P. 16. DOI: https://doi.org/10.4103/ijdvl.ijdvl_1143_16 (date of access: 25.10.2025).

[6] Ibid.

synthesis and strengthening antibacterial barriers. In addition to their antiseptic and appetite-stimulating effects, extracts and oils from *Curcuma longa* are used in cosmetology they have photoprotective properties for matte and dark skin, so they are used in creams and suspensions to provide natural sun protection at a level of approximately SPF-20[7, 8, 9, 10].

2. Characteristics of curcumin

Curcumin. Curcumin, also known by its chemical name difurloilmethane, is a hydrophobic polyphenol obtained from the rhizomes of perennial herbs of the genus Curcuma, belonging to the ginger family (Zingiberaceae). Although it is found in many species, such as Curcuma amada, Curcuma zedoaria, Curcuma aromatica, and Curcuma raktakanta, Curcuma longa is its most popular source. Typically, rhizomes contain 3 % to 5 % curcuminoid derivatives, which include curcumin, demethoxycurcumin, and bis-demethoxycurcumin, whose formulas can be seen in Figure 1.

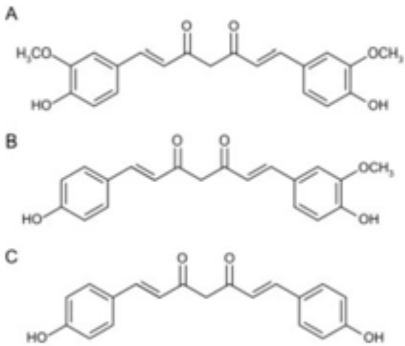

Fig. 1. Curcumin (A), demethoxycurcumin (B), bis-demethoxycurcumin (C)

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[7] Anti-Inflammatory, Wound Healing, and Anti-Diabetic Effects of Pure Active Compounds Present in the Ryudai Gold Variety of Curcuma longa / M. Z. Islam et al. *Molecules*. 2024. Vol. 29, no. 12. P. 2795. DOI: https://doi.org/10.3390/molecules29122795 (date of access: 28.10.2025).

[8] Daily J. W., Yang M., Park S. Efficacy of Turmeric Extracts and Curcumin for Alleviating the Symptoms of Joint Arthritis: A Systematic Review and Meta-Analysis of Randomized Clinical Trials. *Journal of Medicinal Food*. 2016. Vol. 19, no. 8. P. 717–729. DOI: https://doi.org/10.1089/jmf.2016.3705 (date of access: 28.10.2025).

[9] Effect of Phenolic Compounds Extracted from Turmeric (Curcuma longa L.) and Ginger (Zingiber officinale) on Cutaneous Wound Healing in Wistar Rats / C. Bouchama et al. *Cosmetics*. 2023. Vol. 10, no. 5. P. 137. DOI: https://doi.org/10.3390/cosmetics10050137 (date of access: 25.10.2025).

[10] Research Progress on Sesquiterpenoids of Curcumae Rhizoma and Their Pharmacological Effects / T. Cui et al. *Biomolecules*. 2024. Vol. 14, no. 4. P. 387. DOI: https://doi.org/10.3390/biom14040387 (date of access: 28.10.2025).

In its pure form, difurylomethan is a crystalline compound with an intense orange-yellow colour. The World Health Organisation (WHO) has set the acceptable daily intake (ADI) of this substance as a food additive at 0–3 mg/kg of body weight.

The chemical structure of curcumin is defined as [1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadieno-3,5-dione], molecular formula is $C_{21}H_{20}O_6$, molecular weight is 368.38 daltons, and melting point is 183 °C. Curcumin is practically insoluble in water at acidic and neutral pH. It dissolves in polar and non-polar organic solvents, alkaline solutions (bases) and in extremely acidic environments, such as glacial acetic acid.

An extremely important chemical phenomenon in the case of curcumin is keto-enolic tautomerism (Figure 2), which depends on the acidity of the environment. In acidic and neutral environments, the stable ketone form predominates, while in alkaline environments, the compound converts to the enolic form.

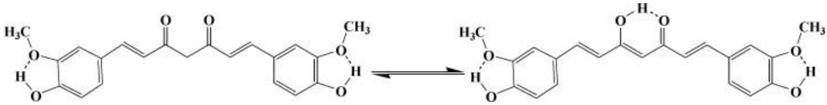

Fig. 2. Keto-enolic tautomerism of curcumin

The enolic form is further stabilised by intramolecular hydrogen bonding, enhanced by resonance, which affects the reactivity and antioxidant properties of this polyphenol.

In aqueous environments, the key factor determining the stability of diferuloylmethane is pH, which manifests itself in the form of a noticeable change in the colour of solutions. When the pH falls below 1, the solution turns red, which is explained by the presence of the protonated form of the compound. In a wide pH range from 1 to 7, molecules in neutral form predominate, giving the solution a characteristic yellow colour. In turn, exceeding a pH value of 7.5 leads to a transition to an orange-red hue[11].

Studies of curcumin degradation kinetics conducted in various buffer systems (pH 1–11) at a temperature of 31.5 °C showed that this process occurs according to second-order kinetics. In the pH range of 7.0–7.8, changes in phosphate buffer concentration had no significant effect on the rate of decay.

[11] Physical and Chemical Stability of Curcumin in Aqueous Solutions and Emulsions: Impact of pH, Temperature, and Molecular Environment / M. Kharat et al. *Journal of Agricultural and Food Chemistry*. 2017. Vol. 65, no. 8. P. 1525–1532. DOI: https://doi.org/10.1021/acs.jafc.6b04815 (date of access: 24.01.2026).

Other analyses conducted at 37 °C in 0.1 M citrate, phosphate, and carbonate buffers (pH 3–10) at constant ionic strength indicated first-order kinetics. Three decomposition products were identified during these processes: vanillin, ferulic acid (FK), and feruloylmethane. Detailed chemical structures of all decomposition products are provided in the technical documentation (Figure 3).

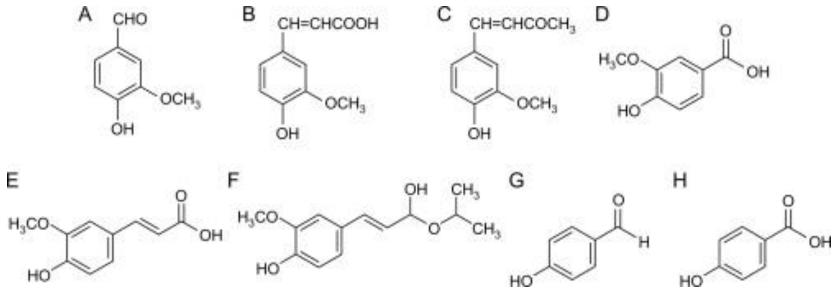

Fig. 3. Curcumin degradation products: (A) vanillin, (B) ferulic acid, (C) feruloyl methane, (D) vanillic acid, (E) ferulic aldehyde, (F) 4-vinylguaiacol, (G) p-hydroxybenzaldehyde, (H) p-hydroxybenzoic acid

Vanillin is usually the main degradation product, but at pH values between 7 and 10 and a temperature of 31.5 °C, ferulic acid and feruloylmethane dominate as key degradation products[12].

TLC. The identification and quantification of the active components of turmeric rhizome is based on precise chromatographic techniques that allow three main compounds to be distinguished: curcumin, demethoxycurcumin and bis-demethoxycurcumin.

According to the official recommendations of the European Pharmacopoeia, the main tool for verifying the identity of raw materials is thin-layer chromatography (TLC). This procedure requires the preparation of solutions (test and reference, containing fluorescein and thymol) in methanol. An ice acetic acid system with toluene in a volume ratio of 80:20 is used as the mobile phase. After development and drying, the plate is sprayed with a solution of dichloroquinone chloride in isopropanol and then exposed to ammonia vapour. The presence of difurylmethane and demethoxycurcumin

[12] Stability of curcumin in buffer solutions and characterization of its degradation products / Y.-J. Wang et al. *Journal of Pharmaceutical and Biomedical Analysis*. 1997. Vol. 15, no. 12. P. 1867–1876. DOI: https://doi.org/10.1016/s0731-7085 (96)02024-9 (date of access: 24.01.2026).

is confirmed by the appearance of two characteristic yellow-brown or brown bands. They are located between the blue-violet zone of thymol and the yellow zone of fluorescein (visible at the bottom of the plate)[13].

HPLC. High-performance liquid chromatography (HPLC) is a technique for determining the components of turmeric rhizome and is used to analyse: diferuloylmethane, demethoxycurcumin and bis-demethoxycurcumin.

Scientists have conducted many studies on the use of HPLC for curcuminoids to find the best technique, so here are a few methods for performing HPLC.

Using the HPLC method on a C18 column, four different varieties of turmeric were analysed with detection at 425 nm using three solvents (methanol, 2 % AcOH and acetonitrile) to determine the percentage composition of the fractions: Differuloylmethane – 1.06 ± 0.061 to 5.65 ± 0.040, Demethoxycurcumin – 0.83 ± 0.047 to 3.36 ± 0.040 and Bis-demethoxycurcumin – 0.42 ± 0.036 to 2.16 ± 0.06. The total content of curcuminoids in the samples studied ranged from 2.34 ± 0.171 to 9.18 ± 0.232 %[14].

In order to obtain high resolution and repeatability of results, a validated isocratic method was developed, which is characterised by the following steps. Sample preparation – dissolution of the extract in acetonitrile and dilution with a solution of this solvent. The mobile phase is a mixture of acetonitrile and acetic acid (40:60). An Alltima C18 column was used, with a flow rate of 2.0 ml/min, a temperature of 33 °C, and UV detection at 425 nm. This method allows for accurate concentration determination with a very high recovery rate and low detection limits, which is necessary in pharmaceutical research[15].

Due to the low bioavailability of curcumin, innovative forms of administration are being developed, such as micellar powders based on casein (CMP) and poloxamer (PMP). The analysis of diferuloylmethane trapped in these polymer matrices required the creation of a C18 column (250 × 4 mm, 5 mm) with a diode array detector. A mixture of acetonitrile

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[13] Lestari M. L. A. D., Indrayanto G. Curcumin. *Profiles of Drug Substances, Excipients and Related Methodology*. 2014. P. 113–204. DOI: https://doi.org/10.1016/b978-0-12-800173-8.00003-9 (date of access: 24.01.2026).

[14] Jayaprakasha G. K., Jagan Mohan Rao L., Sakariah K. K. Improved HPLC Method for the Determination of Curcumin, Demethoxycurcumin, and Bisdemethoxycurcumin. *Journal of Agricultural and Food Chemistry.* 2002. Vol. 50, no. 13. P. 3668–3672. DOI: https://doi.org/10.1021/jf025506a (date of access: 24.01.2026).

[15] A simple isocratic HPLC method for the simultaneous determination of curcuminoids in commercial turmeric extracts / W. Wichitnithad et al. *Phytochemical Analysis*. 2009. Vol. 20, no. 4. P. 314–319. DOI: https://doi.org/10.1002/pca.1129 (date of access: 24.01.2026).

and water with added acetic acid was used as the mobile phase for isocratic elution at a flow rate of 1.0 mL/min and detection at 421 nm. The method demonstrated excellent linearity in the ranges of 2–20 and 10-50 mg/ml, confirming its effectiveness in the accurate dosing of polyphenol in modern medical preparations[16].

Fluorimetric identification method. Given the growing importance of diferuloylmethane, a key task for scientists has been to develop quality control methods that are faster and more sensitive than routinely used liquid chromatography (HPLC).

An innovative, rapid spectrofluorimetric method was developed on 96-well microplates, which allows for mass analysis of samples in a short time. The limit of detection (LOD) for the fluorimetric method was only 7 and 15 ng/ml, and the linear range is 15 to 3900 ng/ml. This method has been successfully used to study diferuloylmethane encapsulated in solid lipid nanoparticles (SLNs) and chitosan nanoparticles (Chi-NPs)[17].

Another breakthrough is the use of copper nanoclusters stabilised with polyvinylpyrrolidone (PVP-Cu NCs) as fluorescent probes. This technique is based on the phenomenon of FRET (Fluorescence Resonance Energy Transfer), where the excitation/emission spectra of nanoclusters coincide with the absorption spectrum of curcumin, leading to the quenching of the probe's fluorescence. The reduction in fluorescence lifetime after the addition of the analyte allows for the accurate determination of diferuloylmethane in the range of 0.1–10 mg/ml^{-1} with a detection limit of 21 mg/ml^{-1}. This method is characterised by exceptional selectivity in the analysis of real samples[18].

A simple and sensitive fluorimetric method using acetonitrile as a solvent was developed for the early stages of drug development. The excitation wavelength is set at 397 nm and the emission wavelength at 508 nm. The method has demonstrated excellent linearity and accuracy, allowing effective

[16] Analytical method for the determination of curcumin entrapped in polymeric micellar powder using HPLC / H. Yusuf et al. *Journal of Basic and Clinical Physiology and Pharmacology*. 2021. Vol. 32, no. 4. P. 867–873. DOI: https://doi.org/10.1515/jbcpp-2020-0491 (date of access: 24.01.2026).

[17] A Sensitive Spectrofluorimetric Method for Curcumin Analysis / A. B. Sravani et al. *Journal of Fluorescence*. 2022. DOI: https://doi.org/10.1007/s10895-022-02947-w (date of access: 24.01.2026).

[18] FRET-based fluorometry assay for curcumin detecting using PVP-templated Cu NCs / Z. Yao et al. *Talanta*. 2021. Vol. 223. P. 121741. DOI: https://doi.org/10.1016/j.talanta.2020.121741 (date of access: 24.01.2026).

control of the content of diferuloylmethane in suspensions of lipid and polymer nanocapsules[19].

Anti-inflammatory and antioxidant effects. These processes are inextricably linked. Inflammatory cells release reactive oxygen and nitrogen species (ROS and RNS) at the site of infection or injure, which directly induces oxidative stress. On the other hand, these reactive molecules activate intracellular signalling cascades the enhance the expression of pro-inflammatory genes. This mechanism underlies many chronic diseases, such as Alxheimer's, Parkinson's, multiple sclerosis, cancer, diabetes, and cardiovascular and respiratory diseases[20, 21].

A key mediator in this process is tumour necrosis factor α (TNF-α), whose action is strictly regulated by the transcription factor NF-κB. NF-κB is activated by a wide range of stimuli: from inflammatory cytokines and viruses, through environmental pollution (tobacco smoke, UV radiation), to psychological and dietary stress (high glucose levels, fatty acids). Curcumin has the unique ability to block NF-κB activation induced be these factors, making it a powerful therapeutic agent[22].

From chemical point of view, diferuloylmethane is a classic phenolic antioxidant that interrupts radical chain reactions. Its unique structure, containing double carbon-carbon bonds, an β-diketone group and phenyl rings with hydroxyl substituents, allows it to effectively donate hydrogen atoms from phenolic groups to neutralize free radicals[23].

As a lipophilic compound, curcumin is incorporated into cell membranes, protecting them from lipid peroxidation, mainly due to its ability to bind iron. In addition, it significantly increases the activity of the body's protective

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[19] Development and validation of a fluorimetric method to determine curcumin in lipid and polymeric nanocapsule suspensions / L. Mazzarino et al. *Brazilian Journal of Pharmaceutical Sciences*. 2010. Vol. 46, no. 2. P. 219–226. DOI: https://doi.org/10.1590/s1984-82502010000200008 (date of access: 24.01.2026).

[20] Kocaadam B., Şanlier N. Curcumin, an active component of turmeric (Curcuma longa), and its effects on health. *Critical Reviews in Food Science and Nutrition*. 2015. Vol. 57, no. 13. P. 2889–2895. DOI: https://doi.org/10.1080/10408398.2015.1077195 (date of access: 24.01.2026).

[21] Ak T., Gülçin İ. Antioxidant and radical scavenging properties of curcumin. *Chemico-Biological Interactions*. 2008. Vol. 174, no. 1. P. 27–37. DOI: https://doi.org/10.1016/j.cbi.2008.05.003 (date of access: 24.01.2026).

[22] Boroumand N., Samarghandian S., Hashemy S. I. Immunomodulatory, anti-inflammatory, and antioxidant effects of curcumin. *Journal of Herbmed Pharmacology*. 2018. Vol. 7, no. 4. P. 211–219. DOI: https://doi.org/10.15171/jhp.2018.33 (date of access: 24.01.2026).

[23] On the Antioxidant Mechanism of Curcumin: Classical Methods Are Needed To Determine Antioxidant Mechanism and Activity / L. R. C. Barclay et al. *Organic Letters*. 2000. Vol. 2, no. 18. P. 2841–2843. DOI: https://doi.org/10.1021/ol000173t (date of access: 24.01.2026).

enzymes, such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx).

Curcumin is particularly important for protecting the reproductive system, where it restores the redox balance necessary for normal sperm function, protecting their DNA and mitochondria. In vital organs such as the drain, liver and kidneys, curcumin mitigates the effects of chronic stress[24].

Antibacterial effect. Modern research confirms that curcumin has a broad spectrum of action against Gram-positive and Gram-negative bacteria, including drug-resistant strains such as methicillin-resistant *Staphylococcus aureus* (MRSA)[25].

Curcumin can act in several ways, for example, due to its lipophilic structure, it has the ability to directly embed itself into the lipid bilayers of bacteria. Curcumin molecules penetrate deep into the membranes, leading to their permeability and loss of structural integrity. Damage to the membrane barrier facilitates the penetration of other drugs into the bacterial cell, which explains the strong synergistic effect of curcumin when used in combination therapies.

The key bacteriostatic mechanism of curcumin is the inhibition of cell division. Curcumin directly binds to the FtsZ protein, which is necessary for the formation of the Z-ring during cytokinesis. By increasing the activity of the GTPase of the FtsZ protein, curcumin interrupts the process of its polymerisation, preventing the reproduction of bacteria.

The next method involves curcumin's ability to induce processes in bacteria that resemble programmed cell death (apoptosis). Treatment of cells with curcumin at MIC (minimum inhibitory concentration) leads to a sharp accumulation of reactive oxygen species (ROS), membrane depolarisation and calcium ion influx, and the expression of the RecA protein, a mediator of the apoptotic response, increases under the influence of curcumin. Strains lacking this protein (RecA) show significantly greater resistance to the action of polyphenol. Curcumin also weakens bacterial DNA repair mechanisms by suppressing LexA protein expression.

Curcumin effectively counteracts the formation of biofilms that protect bacteria from antibiotics and the immune system. This compound disrupts intercellular communication between bacteria, limiting their ability to adapt

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[24] Boroumand N., Samarghandian S., Hashemy S. I. Immunomodulatory, anti-inflammatory, and antioxidant effects of curcumin. *Journal of Herbmed Pharmacology*. 2018. Vol. 7, no. 4. P. 211–219. DOI: https://doi.org/10.15171/jhp.2018.33 (date of access: 24.01.2026).

[25] Yun D. G., Lee D. G. Antibacterial activity of curcumin via apoptosis-like response in Escherichia coli. *Applied Microbiology and Biotechnology*. 2016. Vol. 100, no. 12. P. 5505–5514. DOI: https://doi.org/10.1007/s00253-016-7415-x (date of access: 24.01.2026).

and settle on host receptors. It inhibits the adhesion of bacteria to surfaces, which is key in the prevention of chronic infections.

An innovative application of this polyphenol is its use as a photosensitiser in photodynamic therapy. When exposed to light with a wavelength of 455-460 nm, curcumin generates additional portions of ROS, destroying the proteins, lipids and DNA of pathogens. Treatment of bacteria with curcumin affects the level of nitric oxide and the kynurenine pathway, depriving them of nutrients necessary for growth, such as L-tryptophan[26].

Arthritis. Osteoarthritis (OA) is a chronic disease characterized by progressive destruction of joint cartilage, in which inflammation and oxidative stress play a key role. Due to the lack of effective causal drugs, diferuloylmethane is attracting increasing attention as a promising therapeutic alternative.

Mechanistic studies conducted on human and animal chondrocytes have shown that this polyphenol has a multi-vector protective effect. Although it does not directle stimulate cell proliferation at physiological doses, it effectively counteractsthe destructive effects of interleukin-1β (IL-1β). At the cellular level, curcumin prevents chondrocyte death by increasing the expression of anti-apoptotic proteins (Bcl-2, Bcl-XL) and inhibiting the caspase-3 cascade, prevents inflammation-induced inhibition of chondrocyte differentiation, by increasing the level of type II collagen and β1-integrin. Treatment with curcumin also restores the normal appearance of cell organelles, preventing swelling of the mitochondria and endoplasmic reticulum.

The mechanism of action in osteochondrosis is based in the anti-inflammatory effect of the compound, mainly through its effect on the NF-κB system. Curcumin prevents movement of the p65 subunits of this factor to the cell nucleus, blocking the activation of genes responsible for inflammation. This leads to a significant reduction in the levels of matrix metalloproteinases, which destroy cartilage, cyclooxygenase-2 (COX-2) and prostaglandin E2 (PGE-2) enzymes, and pro-inflammatory cytokines such as IL-6 and IL-1β. Studies involving patients confirm the high clinical efficacy of curcuminoid supplementation. In double-blind studies at doses of 1000-1500 mg per day (often with the addition of piperine for better absorption), the following was observed: reduction in pain and stiffness, efficacy compared to ibuprofen, and a better safety profile, as patients who used curcumin reported significantly fewer gastrointestinal disturbances.

[26] The Natural Product Curcumin as an Antibacterial Agent: Current Achievements and Problems / C. Dai et al. *Antioxidants*. 2022. Vol. 11, no. 3. P. 459. DOI: https://doi.org/10.3390/antiox11030459 (date of access: 24.01.2026).

Wound healing. The optimal wound healing agent should perform several key functions: protect tissues from bacterial infections, reduce inflammation, and stimulate cell proliferation to repair damaged structures. Diferuloylmethane has all these properties, combining anti-inflammatory, anti-infective and antioxidant effects. Free radicals are considered the main cause of inflammation during healing, so the antioxidant potential of this compound is key to protecting newly formed tissues.

Studies have shown that curcumin significantly accelerates the repair processes in several ways: it actively participates in the formation of new granulation scar tissue and collagen deposition, supports the restoration of the epithelial layer and increases the density of blood vessels at the site of injury, and stimulates the cells responsible for the elasticity and mechanical strength of the skin.

Inflammation is a necessary phase of healing, but its uncontrolled course leads to tissue destruction. Curcumin optimises this process mainly by suppressing the production of key cytokines: tumour necrosis factor alpha (TNF-α) and interleukin-1 (IL-1). The key mechanism here is the blocking of the transcription factor NF-κB, where curcumin inhibits kinases, i.e. affects the AKT, PI3K and IKK pathways, which normally activate NF-κB.

Studies using COP polymer dressings impregnated with curcumin have shown a reduction in the expression of pAKT and P13K kinases in rats, which directly reduced inflammation[27].

Antiallergic and antiasthmatic agent. Since turmeric has traditionally been used in Asian medicine to treat itching and skin diseases, its active compounds are now the subject of intensive research in the context of treating allergies and bronchial asthma.

A key aspect of curcumin's anti-allergic action is its ability to inhibit the release of histamine from mast cells. For example, it has been found to regulate Th2 responses, where it reduces the production of IgE antibodies and inflammatory cytokines, leading to the suppression of excessive immune system reactions. This polyphenol also has the ability to inhibit the activity of Th17 cells while promoting the development of regulatory Treg cells, which restores immune balance in the airways.

Regarding the treatment of asthma, in studies on animal models induced with ovalbumin (OVA), curcumin at doses of 20 to 100 mg/kg demonstrated efficacy comparable to corticosteroids. A significant reduction in inflammatory cell infiltration, cup cell (mucus-producing) hypertrophy, and alveolar

[27] Curcumin as a wound healing agent / D. Akbik et al. *Life Sciences*. 2014. Vol. 116, no. 1. P. 1–7. URL: https://doi.org/10.1016/j.lfs.2014.08.016 (date of access: 24.01.2026).

oedema was observed. Diferuloylmethane inhibited the expression of NF-κB, HSP70 protein, and kinases such as ERK and JNK, which directly leads to less airway obstruction. Curcumin also increased the levels of aquaporins (AQP-1 and AQP-5), which in turn helps to reduce pulmonary oedema by improving water transport in tissues.

However, due to the low solubility of curcumin in water, there are some problems with its delivery to the body, so researchers are currently improving these methods. For example, nasal application is highly effective in suppressing bronchial spasms and can be used in the form of drops, quickly improving breathing comfort after an asthma attack. There are also lipid nanoparticles (SLNs) and dry emulsions that significantly increase the absorption of the compound from the gastrointestinal tract, more effectively suppressing airway hyperresponsiveness.

Curcumin also has a protective effect in cases of viral infections (RSV), as it suppresses virus replication and enhances the barrier function of the nasal epithelium without exhibiting cytotoxicity. In acute lung injury (ALI/ARDS), it protects lung tissue from damage caused by oxidative stress and toxins (e.g., paraquat)[28, 29, 30, 31].

Anticancer effect. Diferuloylmethane is also considered a chemopreventive and therapeutic agent due to its pleiotropic action, i.e. its ability to simultaneously affect multiple molecular targets and signalling pathways. Its efficacy has been confirmed in studies of breast, lung, prostate, head and neck, and brain cancers.

Curcumin has the ability to stop the uncontrolled proliferation of cancer cells by reducing the levels of cyclins and cyclin-dependent kinases (CDK4, cyclin D1), which leads to the arrest of the cell cycle. It further inhibits the expression of the epidermal growth factor receptor (EGFR), which is often overactive in adenocarcinomas, and reduces the levels of endothelial nitric oxide synthase and nitric oxide (NO) itself, which promote tumour growth.

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[28] Shahid M. T., Khair-ul-Bariyah S. Anti-Asthmatic and Cardioprotective Efficacy of Curcumin-A Review. *International Journal of Scientific Research in Knowledge*. 2014. Vol. 2, no. 5. P. 215–223. DOI: https://doi.org/10.12983/ijsrk-2014-p0215-0223 (date of access: 24.01.2026).

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[30] Immunomodulatory and Anti-Inflammatory Potential of Curcumin for the Treatment of Allergic Asthma: Effects on Expression Levels of Pro-inflammatory Cytokines and Aquaporins / H. Shahid et al. *Inflammation*. 2019. Vol. 42, no. 6. P. 2037–2047. DOI: https://doi.org/10.1007/s10753-019-01066-2 (date of access: 24.01.2026).

[31] Kurup V. P., Barrios C. S. Immunomodulatory effects of curcumin in allergy. *Molecular Nutrition & Food Research*. 2008. Vol. 52, no. 9. P. 1031–1039. DOI: https://doi.org/10.1002/mnfr.200700293 (date of access: 24.01.2026).

This polyphenol also restores balance in cell death processes, which is key in the fight against treatment-resistant tumours. It increases the levels of pro-apoptotic proteins (e.g., Bax) while simultaneously suppressing anti-apoptotic proteins (Bcl-2) and activates enzymatic cascades that lead to the destruction of cancer cells. In cells resistant to classical apoptosis, curcumin induces severe endoplasmic reticulum stress and leads to so-called mitotic catastrophe, in particular by reducing survivin levels.

For growth, a tumour needs new blood vessels and the ability to penetrate tissues. Curcumin blocks these processes by Inhibiting vascular growth factors (reducing levels of VEGF, VEGFR2 and basic fibroblast growth factor (b-FGF)) or degrading the extracellular matrix, where it inhibits the activity of matrix metalloproteinases (MMP-2 and MMP-9), preventing the migration and metastasis of cancer cells.

Chronic inflammation is also the basis of many tumours, and curcumin effectively interrupts this process by switching off the NF-κB pathway, which is constitutively active in tumours, reducing the levels of inflammatory cytokines (IL-1β, IL-6, IL-8, TNF-α) and inhibiting the activity of COX-2 and 5-LOX, limiting the formation of pro-inflammatory eicosanoids.

Despite its enormous potential, the use of diferuloylmethane faces obstacles such as low bioavailability due to poor water solubility and rapid metabolism, and hydrophobicity, as the molecule often binds to the membrane without reaching the interior of the cytoplasm. To overcome these difficulties, science is developing delivery systems such as nanomicelles, liposomes, and structural modifications that increase selective toxicity to cancer cells while protecting healthy tissues (chemoprotective effect)[32, 33, 34].

CONCLUSIONS

Curcuma longa L. is a perennial plant belonging to the *Zingiberaceae* family, characterised by a specific morphology, the key element of which is a cylindrical underground stem with intense pigmentation, which is the main repository of bioactive polyphenols. Diferuloylmethane plays a central

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[32] Curcumin and its promise as an anticancer drug: An analysis of its anticancer and antifungal effects in cancer and associated complications from invasive fungal infections / J. Chen et al. *European Journal of Pharmacology*. 2016. Vol. 772. P. 33–42. DOI: https://doi.org/10.1016/j.ejphar.2015.12.038 (date of access: 24.01.2026).

[33] Biological and therapeutic activities, and anticancer properties of curcumin / D. Perrone et al. *Experimental and Therapeutic Medicine*. 2015. Vol. 10, no. 5. P. 1615–1623. DOI: https://doi.org/10.3892/etm.2015.2749 (date of access: 24.01.2026).

[34] Tomeh M., Hadianamrei R., Zhao X. A Review of Curcumin and Its Derivatives as Anticancer Agents. *International Journal of Molecular Sciences*. 2019. Vol. 20, no. 5. P. 1033. DOI: https://doi.org/10.3390/ijms20051033 (date of access: 24.01.2026).

role in the chemical profile of the raw material, which, due to its molecular structure, exhibits a wide range of pharmacological activities, including strong antioxidant, anti-inflammatory and immunomodulatory properties. Preclinical studies show that this compound effectively inhibits the processes of pulmonary fibrosis and airway obstruction by precisely modifying signaling pathways and reducing the expression of metalloproteinases and structural proteins. Despite its high therapeutic potential, the clinical efficacy of *Curcuma longa* extracts is determined by their physicochemical instability. Diferuloylmethane undergoes rapid degradation in an alkaline environment and under the influence of UV radiation and high temperatures, which necessitates the application of strict technological standards in the extraction and storage process. *Curcuma longa* is a valuable raw material for modern pharmacy and cosmetology, but optimising its use requires further research into the crystalline polymorphism of active substances in order to improve their stability and bioavailability in biological systems.

SUMMARY

This paper presents an in-depth analysis of the botanical, biochemical and pharmacological characteristics of *Curcuma longa L.* The main focus is on a detailed description of the morphological structure of the plant, the peculiarities of its cultivation and a critical analysis of the properties of its main bioactive component, diferuloylmethane.

The aim of the work is to systematise scientific data on the morphology of *Curcuma longa L.* and to study in detail the therapeutic effect of diferuloylmethane on pathophysiological processes in the body. It also aims to identify the molecular mechanisms of action of the plant and determine the factors that influence the stability of its active substances in order to optimise their use in medicine.

The novelty of the study lies in its focus on the molecular aspect of the interaction of diferuloylmethane with key signalling pathways and enzymatic systems. The work substantiates the relevance of using turmeric as a means of preventing airway obstruction and pulmonary fibrosis. Particular attention is paid to the problem of low physicochemical stability of the active substance under the influence of light, alkaline environment and heat treatment, which is critical for pharmaceutical development.

Curcuma longa L. is a strategically important plant for modern phytotherapy. It has been proven that diferloylmethane has a pronounced ability to inhibit inflammatory mediators and regulate the expression of structural proteins, which makes it indispensable in the treatment of chronic inflammatory diseases. The work also highlights the economic importance of

the plant, considering it a highly valuable product for the agro-industrial sector and export potential, contributing to the development of local economies.

The results of the study confirm that *Curcuma longa L.* is a unique source of bioactive polyphenols with a powerful therapeutic profile. It has been established that the effectiveness of preparations based on it directly depends on compliance with technological processing standards, since active compounds undergo significant degradation at high temperatures. Further research should be aimed at increasing the bioavailability of diferuloylmethane, which will allow the full potential of the 'golden spice' to be realised in modern pharmacology and industry.

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