



# *Calendula Officinalis* L.: Phytochemistry, Pharmacological Activities, And Emerging Therapeutic Perspectives

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## Abstract

*Calendula officinalis* L., commonly known as pot marigold, is one of the most extensively used medicinal plants in traditional and complementary medicine systems worldwide. Belonging to the Asteraceae family, this herb has been employed for centuries in the management of wounds, inflammatory disorders, gastrointestinal disturbances, and skin ailments. Contemporary scientific investigations have revealed that its therapeutic potential is closely associated with a diverse spectrum of bioactive compounds, including flavonoids, triterpenoids, carotenoids, phenolic acids, coumarins, quinones, and essential oils.

Experimental studies, supported by growing clinical evidence, demonstrate antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, antidiabetic, cytotoxic, and wound-healing activities. In addition to validating traditional claims, modern research has begun to clarify the molecular pathways responsible for these biological effects. This review provides a comprehensive and updated synthesis of phytochemical composition, pharmacological mechanisms, therapeutic applications, extraction technologies, and future research directions. The aim is to offer an integrated scientific perspective that supports the rational and evidence-based utilization of *C. officinalis* in modern healthcare.

**Keywords:** *Calendula officinalis*, pot marigold, Asteraceae, phytochemistry, flavonoids, triterpenoids, carotenoids, phenolic compounds, anti-inflammatory activity, antioxidant activity, wound healing, antimicrobial activity, hepatoprotective effect, antidiabetic activity, cytotoxic activity, medicinal plants, herbal medicine, phytopharmaceuticals, bioactive compounds, complementary medicine.

## 1. Introduction

The use of medicinal plants has accompanied human civilization since antiquity. Ancient healing traditions—from Mediterranean herbal practices to Asian and Middle Eastern systems—relied heavily on botanical remedies for disease prevention and treatment. Over time, empirical observations were gradually supported by chemical and pharmacological investigations, transforming traditional herbs into subjects of modern scientific research<sup>[1]</sup>.

Among these medicinal plants, *Calendula officinalis* L. occupies a distinctive position due to its versatility and long-standing therapeutic use<sup>[3]</sup>. The plant derives its name from the Latin word “calendae,” referring to the first day of the month, as it was believed to bloom throughout the year. Commonly known as pot marigold,

it has historically been applied to treat wounds, burns, rashes, and inflammatory conditions. Folk medicine traditions also recommended it for digestive complaints, menstrual irregularities, and infections<sup>[2]</sup>.

Botanically, *C. officinalis* is an annual herb characterized by bright yellow to deep orange composite flowers. It thrives in temperate climates and is widely cultivated in Europe, Asia, and parts of the Americas. While multiple species exist within the *Calendula* genus, *C. officinalis* remains the most studied due to its rich phytochemical profile and pharmacological relevance<sup>[9]</sup>.

In recent decades, renewed interest in plant-based therapeutics has stimulated extensive research into its chemical constituents and biological mechanisms. The integration of traditional knowledge with experimental validation has strengthened its credibility within evidence-based complementary medicine<sup>[10]</sup>.

## 2. Phytochemical Profile

The therapeutic value of *Calendula officinalis* is largely attributed to its diverse secondary metabolites. These compounds are distributed across different plant parts—flowers, leaves, stems, and roots—with flowers containing the highest concentration of active constituents<sup>[4]</sup>.

### 2.1 Flavonoids

Flavonoids are among the most abundant bioactive compounds in *C. officinalis*. Major representatives include quercetin, isorhamnetin, rutin, and various glycosylated derivatives. Structurally characterized by phenolic rings, these compounds exhibit strong antioxidant activity through hydrogen donation and metal chelation mechanisms<sup>[1]</sup>.

Beyond antioxidant activity, flavonoids contribute to anti-inflammatory and wound-healing effects<sup>[3]</sup>. They modulate inflammatory mediators, reduce oxidative tissue damage, and promote fibroblast proliferation. Some flavonoids also display neuroprotective and mild antidepressant effects through enzyme inhibition pathways<sup>[6]</sup>.

### 2.2 Triterpenoids and Triterpene Esters

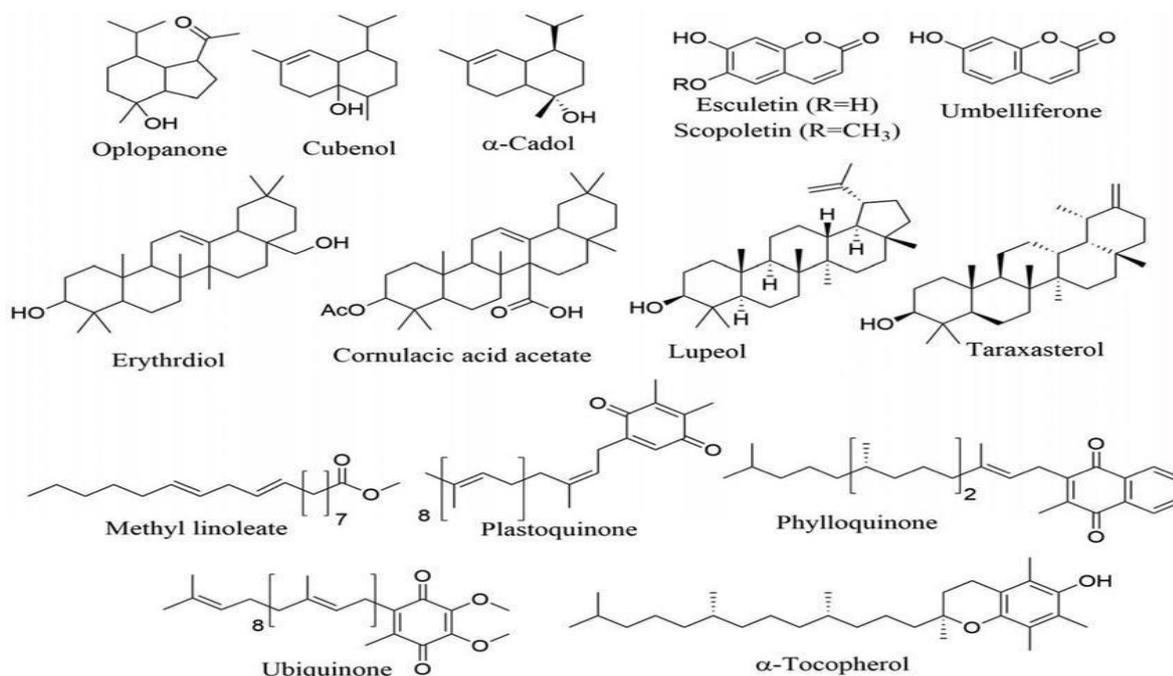
Triterpenoids represent another pharmacologically significant class of compounds in *C. officinalis*. These include faradiol and its fatty acid esters, which are strongly associated with anti-inflammatory activity<sup>[8]</sup>. Experimental studies suggest that these compounds inhibit cyclooxygenase enzymes and suppress pro-inflammatory cytokines, thereby reducing tissue inflammation and edema<sup>[5]</sup>.

Triterpenoids also contribute to gastroprotective and hepatoprotective effects, highlighting their systemic therapeutic relevance beyond topical use<sup>[10]</sup>.

### 2.3 Carotenoids

The characteristic orange color of the flowers reflects their high carotenoid content. Compounds such as lutein, beta-carotene, zeaxanthin, and lycopene serve as powerful antioxidants. By neutralizing reactive oxygen species, carotenoids protect cellular membranes and prevent lipid peroxidation<sup>[12]</sup>.

Lutein and zeaxanthin, in particular, are associated with ocular health and protection against age-related macular degeneration. Their presence enhances the nutraceutical value of *C. officinalis*<sup>[6]</sup>.

**Figure 1**

Chemical structures of some of the important chemical constituents present in CO

## 2.4 Phenolic Acids and Coumarins

Phenolic acids—including caffeic acid and chlorogenic acid—exhibit radical-scavenging properties that support the plant's antioxidant capacity. Coumarins such as umbelliferone and scopoletin contribute mild spasmolytic and vasoprotective effects. Together, these compounds enhance cellular defense mechanisms against oxidative stress<sup>[14]</sup>.

## 2.5 Quinones, Fatty Acids, and Minor Constituents

Leaf extracts contain quinones such as phylloquinone and ubiquinone, which have been associated with anticancer potential through DNA interaction and enzyme modulation.

Additionally, calendic acid and other fatty acids may contribute cytotoxic effects against abnormal cells<sup>[5]</sup>.

Amino acids, sterols, tocopherols, and essential oils further enrich the plant's chemical complexity and may act synergistically with primary active components<sup>[3]</sup>.

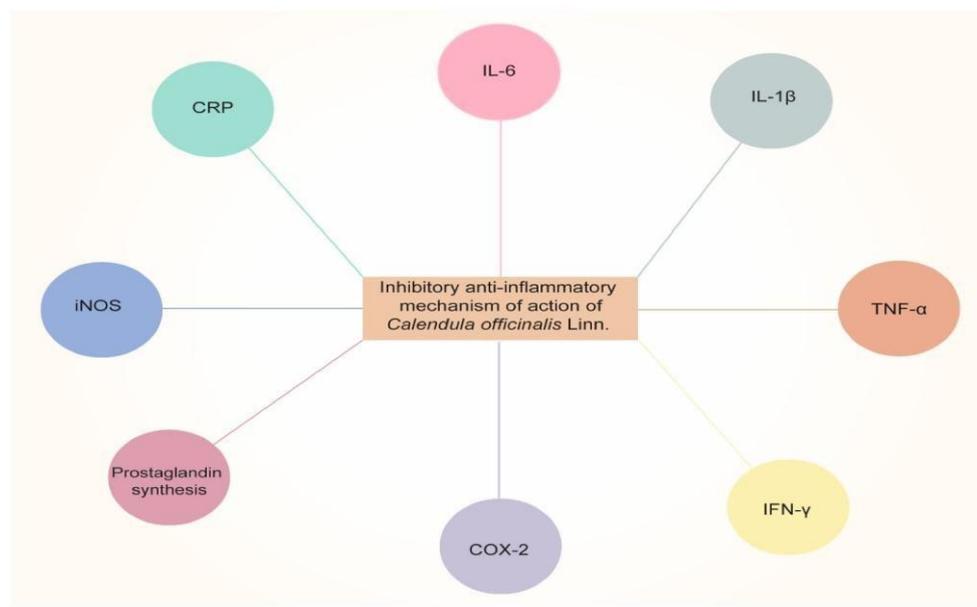
## 3. Extraction Techniques

The efficiency of phytochemical recovery significantly depends on the extraction method employed. Traditional approaches include maceration, solvent extraction, hydrodistillation, and Soxhlet extraction. These methods are reliable but often time-consuming and solvent-intensive<sup>[9]</sup>.

Modern technologies such as ultrasound-assisted extraction, microwave-assisted extraction, and supercritical fluid extraction have improved yield, reduced processing time, and enhanced environmental sustainability. Solvent polarity plays a crucial role in extracting phenolic and flavonoid compounds, with hydroalcoholic solutions often providing optimal results<sup>[2]</sup>.

## 4. Pharmacological Activities

### Figure 2



Anti-inflammatory effects of *Calendula officinalis* Linn by inhibiting pro-inflammatory cytokines (IL-6, IL-1 $\beta$ , TNF- $\alpha$ , and IFN- $\gamma$ , etc.), COX-2, prostaglandin synthesis, iNOS (inducible nitric oxide synthase), and CRP (C-Reactive Protein).

#### 4.1 Anti-Inflammatory Effects

Anti-inflammatory activity is one of the most thoroughly investigated properties of *C. officinalis*. Laboratory studies demonstrate inhibition of pro-inflammatory cytokines such as TNF- $\alpha$ , IL-1 $\beta$ , and IL-6. Suppression of cyclooxygenase-2 (COX-2) and nitric oxide production further contributes to reduced inflammatory responses. Clinically, topical preparations have been used to alleviate dermatitis, gingivitis, diaper rash, and radiation-induced skin irritation. These findings align with its long-standing traditional applications<sup>[1]</sup>.

#### 4.2 Antioxidant Potential

Oxidative stress underlies many chronic diseases, including cardiovascular disorders, diabetes, neurodegeneration, and cancer. The synergistic interaction between flavonoids, carotenoids, and phenolic acids provides *C. officinalis* with substantial antioxidant capacity<sup>[3]</sup>.

Experimental assays confirm its ability to scavenge free radicals, inhibit lipid peroxidation, and restore antioxidant enzyme balance. This property supports its protective role in systemic health<sup>[15]</sup>.

#### 4.3 Wound-Healing Activity

Perhaps the most recognized therapeutic use of *C. officinalis* is in wound management. Extracts promote angiogenesis, collagen synthesis, and re-epithelialization. By enhancing oxygen and nutrient supply to injured tissues, the plant accelerates tissue regeneration<sup>[11]</sup>.

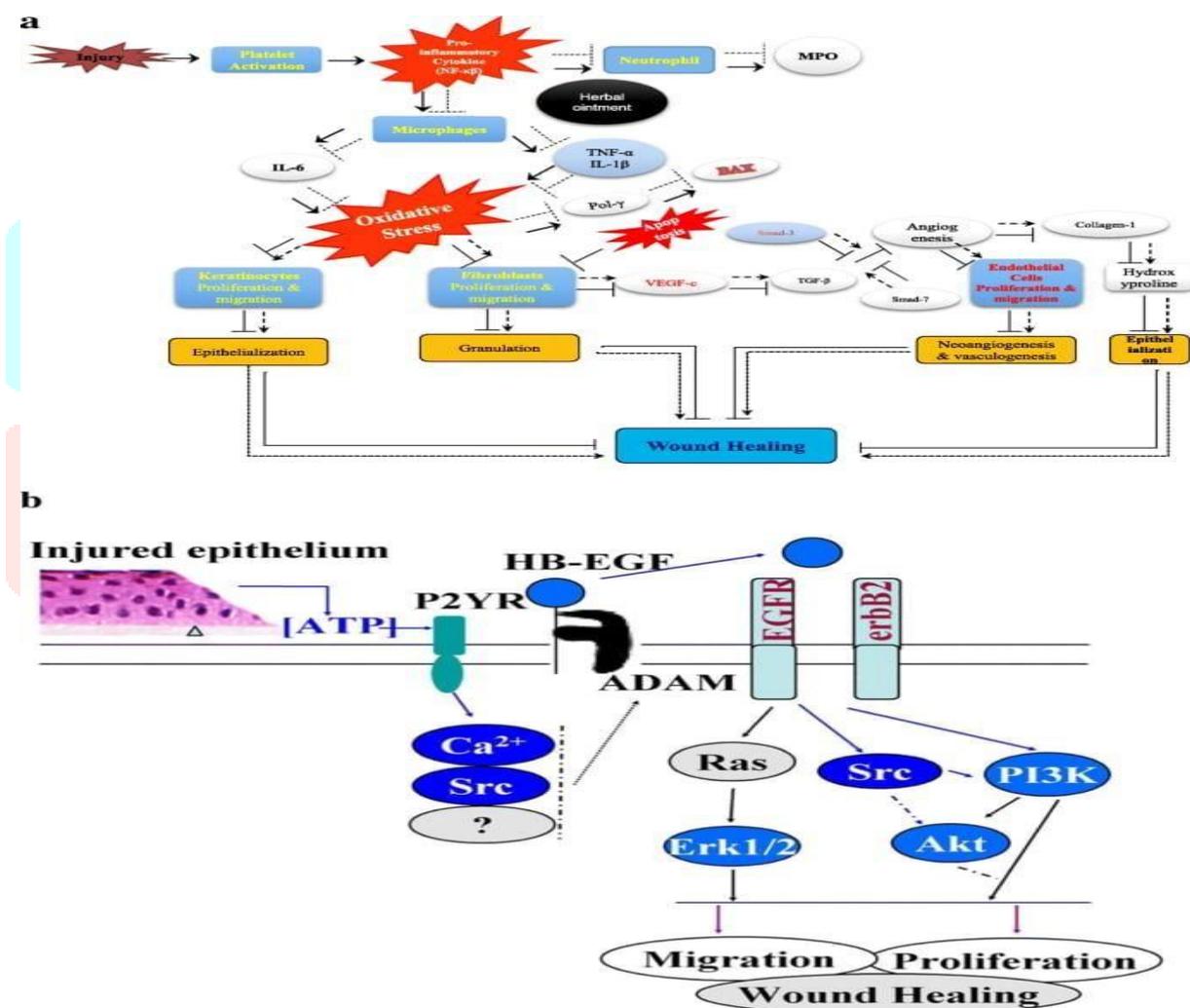
Clinical observations indicate effectiveness in minor burns, surgical wounds, venous ulcers, and post-episiotomy care. Its soothing and moisturizing properties further support skin repair<sup>[7]</sup>.

The wound-healing potential of *Calendula officinalis* is one of its most extensively recognized therapeutic properties. Traditionally, preparations derived from its flowers have been applied to cuts, burns, abrasions, and ulcerative lesions to accelerate tissue repair. Contemporary experimental research supports these traditional uses and provides insight into the biological mechanisms involved<sup>[4]</sup>.

The healing process involves a coordinated sequence of inflammation, proliferation, and tissue remodeling. Extracts of *C. officinalis* appear to positively influence multiple stages of this cascade. During the early inflammatory phase, the plant's bioactive compounds— particularly triterpenoids and flavonoids—help regulate excessive inflammation by modulating cytokine production and reducing oxidative stress. This controlled inflammatory response creates a favorable environment for tissue regeneration<sup>[2]</sup>.

Overall, the wound-healing efficacy of *Calendula officinalis* can be attributed to its combined anti-inflammatory, antioxidant, antimicrobial, and tissue-regenerative effects. These multifaceted actions make it a promising natural agent for topical wound management and supportive dermatological care<sup>[6]</sup>.

Figure 3



A. Mechanism of action OF CO on interleukin 6(IL-6) B. Mechanism of action of epidermal

#### 4.4 Antimicrobial and Antifungal Activity

Extracts exhibit inhibitory effects against several Gram-positive and Gram-negative bacteria. Terpenoids and flavonoids are believed to disrupt microbial membranes and interfere with metabolic pathways<sup>[8]</sup>.

Antifungal activity against species such as *Candida albicans* has also been observed, though typically milder compared to synthetic antifungal agents. These findings suggest potential use as an adjunct or preventive agent<sup>[9]</sup>.

#### 4.5 Anticancer and Cytotoxic Properties

Preclinical investigations have demonstrated cytotoxic activity against certain cancer cell lines. Proposed mechanisms include apoptosis induction, caspase activation, cell cycle arrest, and modulation of transcription factors involved in tumour progression<sup>[3]</sup>.

While promising, these findings require further validation through well-designed clinical trials to determine safety and efficacy in humans<sup>[13]</sup>.

#### 4.6 Hepatoprotective and Antidiabetic Effects

Animal studies suggest protective effects against chemically induced liver injury. Restoration of antioxidant enzymes and reduction of inflammatory markers indicate hepatoprotective potential. Similarly, antidiabetic activity has been associated with improved glucose regulation and reduced oxidative stress, though clinical confirmation remains limited<sup>[5]</sup>.

#### 5. Safety and Toxicological Considerations

Available toxicological data indicate that *C. officinalis* is generally safe when used within recommended dosages. Adverse reactions are rare but may include mild allergic responses, particularly in individuals sensitive to Asteraceae family plants<sup>[13]</sup>.

Standardization of extracts and careful dosage determination remain essential for ensuring safety and therapeutic consistency<sup>[15]</sup>.

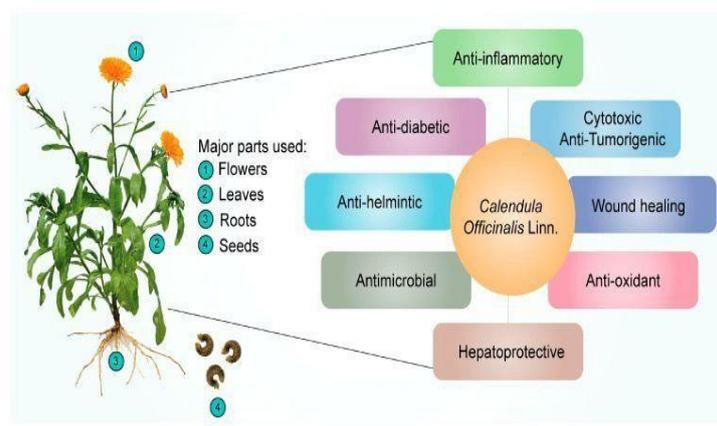
#### 6. Emerging Applications and Future Directions

With advancements in pharmaceutical technology, research has expanded toward nanoformulations, liposomal delivery systems, and bioactive encapsulation to improve stability and bioavailability. Integration with computational drug design, molecular docking, and systems biology may further clarify target interactions and optimize therapeutic potential<sup>[2]</sup>.

Future studies should focus on:

- Standardized clinical trials
- Dose-response relationships
- Bioavailability and pharmacokinetics
- Comparative studies among different *Calendula* species<sup>[9]</sup>

**Figure 4**



Pharmacological effects of *Calendula officinalis* Linn.

## Conclusion

*Calendula officinalis* L. represents a scientifically promising medicinal plant with multifaceted therapeutic potential. Its rich phytochemical composition underlies diverse pharmacological activities, including anti-inflammatory, antioxidant, antimicrobial, hepatoprotective, woundhealing, and anticancer effects. Although many traditional uses are increasingly supported by experimental data, further rigorous clinical research is necessary to establish standardized therapeutic guidelines. The integration of traditional knowledge with modern pharmacological research positions *C. officinalis* as a valuable candidate for future phytopharmaceutical development.

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