

Review

Calendula officinalis L. as a Source of Bioactive Compounds for Functional Foods: A Review

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Abstract

Calendula officinalis L. (pot marigold) is a medicinal and edible plant used as a source of bioactive compounds with potential applications in functional foods. This review brings together current data on the phytochemical profile, biological activity, agronomic factors, and food applications of *C. officinalis*, based on 76 publications. More than 500 secondary metabolites have been reported in this species, including flavonoids, carotenoids, terpenoids, polysaccharides, coumarins, and essential-oil components. Reported levels depend strongly on cultivar, growing conditions, plant part, and analytical method. Total flavonoid content in dried flowers ranges from 0.21 to 0.68% across 20 European cultivars, with up to 1.7% in selected Estonian-grown cultivars such as ‘Radio’. Reported total carotenoid values cover almost two orders of magnitude (about 48 to 3510 mg/100 g of dried material), reflecting differences in plant part, colour variant, and method (spectrophotometric sum vs. HPLC). Dried flowers contain up to 62.33 g/100 g of total dietary fibre (mostly insoluble). The associated activities are antioxidant, anti-inflammatory, antimicrobial, regenerative, cytotoxic, and neuroprotective. Recent food-application studies show useful effects in yogurt (0.25 g lyophilized extract/100 g), wheat bread (10–15% of formulation water replaced with aqueous extract), and fresh pasta (5% flower powder substitution), with notable increases in antioxidant capacity and acceptable sensory scores. The number of full food-product trials is still small, and this review identifies the processing variables and the research gaps that determine whether *C. officinalis* can be used as a standard functional-food ingredient.

Keywords: *Calendula officinalis*; functional food; bioactive compounds; edible flowers; antioxidant activity; natural preservatives



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1. Introduction

C. officinalis L. belongs to the Asteraceae family. The species originates from the south-western Mediterranean region and includes about 15 botanical varieties. It is also known under the botanical synonym *Caltha officinalis* (L.) Moench, and its common names include pot marigold, common marigold, English marigold, Scotch marigold, and ruddles. Traditional uses include support of wound healing, burn care, cardiovascular and digestive conditions, and skin and eye inflammation. In food, the dried petals have been used as a colourant for bread, butter, cheese, soups, and rice—a use that earned the plant the name ‘poor man’s saffron’ [1].

More than 500 compounds have been reported in *C. officinalis*, mainly from flowers. Related species used in regional studies include *C. arvensis*, *C. suffruticosa*, *C. stellata*, and *C.*

tripterocarpa. The flowers range in colour from yellow to deep orange and contain triterpene saponins, carotenoids, flavonoids, and essential oils. Two morphological types are distinguished: outer ligulate flowers, with higher levels of flavonoids and carotenoids, and inner tubular flowers, which contain more caffeoylquinic acids, coumarins, and anthocyanins (Figure 1) [2,3].



Figure 1. Flower of *Calendula officinalis*.

The ligulate-to-tubular ratio depends on cultivar and on climatic and agronomic conditions; in the ‘Orange’ cultivar, the ratio of ligulate to tubular flowers varied from 13% to 62% across environments [3].

Cultivars used for pharmaceutical purposes are selected for high inflorescence number and strong flower colour (orange to red), and for a high proportion of ligulate flowers [4].

Although the chemistry of *C. officinalis* is well documented, evidence-based research on its use as a functional-food ingredient is still limited. Most studies address chemical composition or biological activity in isolation, and the available reviews focus mainly on pharmaceutical and cosmetic uses; few cover the chemical profile, the biological activity, the agronomic factors that affect raw-material quality, and the food applications together. This review therefore aims to summarize current data on the phytochemical composition of marigold flowers, to review the biological activity of their main bioactive compounds, to assess the nutritional value of the flowers and their use in functional foods, and to discuss the agronomic and processing factors that affect raw-material quality—and, on that basis, to assess whether *C. officinalis* can be used as a practical ingredient in functional food products.

2. Materials and Methods

A literature search was carried out in Scopus and Web of Science between January 2025 and February 2026, covering publications from 2003 to 2026. Search terms for the species were “*Calendula*”, “*Calendula officinalis*”, “pot marigold”, and “marigold”, each combined with “bioactive compounds”, “antioxidant activity”, “antimicrobial activity”, and “functional food” using Boolean operators (AND, OR). Additional screening terms were chemical composition, biological activity, antioxidant, antimicrobial, pharmaceutical application, food application, and cultivation.

Selection followed PRISMA guidelines. After duplicate removal, 86 records were screened by title and abstract. Full-text articles were then assessed against the inclusion criteria: original research articles and reviews in English; studies on chemical composition, biological activity, pharmaceutical or food applications, or agronomic aspects of *C. officinalis*; and full-text access. Exclusion criteria were conference abstracts, patents,

preliminary reports, and studies not directly related to the topic. After full-text assessment, 76 publications met the criteria.

3. Bioactive Compounds

Medicinal plants with a high content of bioactive compounds are increasingly studied as sources of functional-food ingredients. *C. officinalis* has been used in folk medicine for centuries; the first studies of its metabolites date from the late 18th century [5]. It remains a popular herbal and cosmetic raw material, and recent work increasingly looks at its potential for the prevention of diet-related chronic diseases [6]. The compound groups relevant to food use—flavonoids, carotenoids, essential oil, other terpenoids, carbohydrates and dietary fibre, and coumarins—are described in Sections 3.1–3.7, with the plant part, the reported content, and the food-relevant property given for each group. Flowers and petals are the focus throughout, because these are the plant parts used in the food applications reviewed in Section 5.

3.1. Flavonoids

Flavonoids are one of the main groups of bioactive compounds in *C. officinalis* flowers and petals. Together with phenolic acids, they form the two main classes of polyphenols in this species; the property most relevant to functional-food use is their antioxidant activity, which is discussed in Section 4.1. Their content depends on cultivar, environmental conditions, plant part, flower developmental stage, and analytical method.

Total flavonoid content in dried flowers varies widely. Raal & Kirsipuu (2011) analyzed 20 commercial cultivars from 8 European countries grown in Estonia and reported 0.21–0.68% (spectrophotometric, λ = 370 nm), with ‘Kablouna’ (Finland) giving the highest value (0.68%) and ‘Touch of Red’ (Latvia, 0.55%), ‘Golden Emperor’ (Finland, 0.50%) and ‘Pomyk’ (Poland, 0.50%) also above 0.5% [7]. A later study on Estonian-grown cultivars found up to 1.7% in ‘Radio’ [8]. Palma-Tenango et al. (2025) showed that the flavonoid content also depends on the flowering stage: the highest values are reached around day 11, at full flower-head development, while earlier and later stages give 22–27% lower values [9].

Reported values expressed per gram of dry weight also vary widely (Table 1).

Table 1. Total flavonoid content of dried *Calendula officinalis* flowers reported in selected recent studies.

Flavonoid Content	Solvent	Raw Material	Unit	Ref.
0.21–0.68% DM	Methanol (spectro., 370 nm)	Dried flowers, 20 cultivars	% per dry raw material	[7]
up to 1.7% DM	Methanol (spectro.)	Dried flowers, ‘Radio’	% per dry raw material	[8]
12.12 ± 0.02 mg QE/g	Ethanol 80%	Dried flowers	mg QE per g of dry extract	[10]
13.61 ± 0.54 mg QE/g	Ethanol 80%	Dried flowers	mg QE per g of dry extract	[11]
15.2 ± 0.3 mg/g (flowers); 12 ± 0.02 mg/g (leaves)	Methanol	Dried flowers and leaves	mg per g of dry plant material	[12]
147.82 mg QE/100 g (≈1.48 mg QE/g)	Ethanol 50%	Dried flowers	mg QE per 100 g of dry extract	[13]

QE—quercetin equivalents; DM—dry matter. Values are not directly comparable because of differences in solvent, plant part, and expression basis.

The differences are not random: they follow from the extraction solvent, the cultivar, the flower developmental stage, and the basis on which the value is expressed—per unit of dry raw material or per unit of dry extract. Among the recent studies, Ibragić et al. (2025) reported 12.12 ± 0.02 mg QE/g of extract in dried flowers (80% ethanol) [10], Ivanišová et al. (2023) 13.61 ± 0.54 mg QE/g of extract (80% ethanol, Slovak material) [11], and Mubashar

Sabir et al. (2015) 15.2 ± 0.3 mg/g of dry plant material in flowers and 12 ± 0.02 mg/g in leaves [12]. Escher et al. (2019) reported 147.82 mg QE/100 g of extract (about 1.48 mg QE/g of extract) in dried flowers extracted with 50% ethanol [13].

This last value is expressed on the same basis as the Bosnian and Slovak data, yet it is about one order of magnitude lower. The difference therefore cannot be explained by the expression basis. It is more likely to reflect the lower ethanol concentration used for extraction (50% vs. 80%), which recovers less of the flavonoid aglycone fraction, together with differences in cultivar, flower developmental stage, and the calibration standard. This illustrates the wider point that flavonoid values for *C. officinalis* are interpretable only when the solvent, the plant part, and the expression basis are all reported—which is why these are given as separate columns in Table 1.

Two main groups of flavonoids are reported in *C. officinalis*: aglycones (quercetin, isorhamnetin, kaempferol, quercetagetin) and glycosides. Water-soluble glycosides include calendoflaside; calendulaglycosides A, B, C; calendulosides E, F, G, H; isorhamnetin-3-O-glucoside; isorhamnetin-3-neohesperidoside; narcissin (isorhamnetin-3-rutinoside); quercetin-3-O-rutinoside (rutin); and quercetin-3-O-glucoside (isoquercitrin) [14,15]. Quercetin and isorhamnetin derivatives are the most frequently reported, while kaempferol glycosides are absent from samples of French, Egyptian, and Russian origin and present in Tunisian samples—a pattern attributed to environmental and genotypic factors [15].

3.2. Carotenoids

Carotenoids are responsible for the yellow-to-orange flower colour and are one of the most useful groups of compounds for food applications, both as natural colourants and as antioxidants. Their content depends strongly on cultivar, colour variant, plant part, fresh or dried state, growing conditions, drying, storage, and the analytical method (spectrophotometric sum vs. HPLC of individuals).

Reported values cover almost two orders of magnitude (Table 2). Higher figures (700–2700 mg/100 g in dried flowers [8]; 200–3510 mg/100 g [16]) come from spectrophotometric measurements that sum all carotenoids in the visible range. Lower figures (48.2–276 mg/100 g) come from HPLC analyses that report the sum of individually quantified compounds [17]. The differences are not random—they reflect method, plant part (ligulate petals vs. whole head), and the dry/fresh basis. Pintea et al. (2003) showed that orange cultivars contain several times more carotenoids than yellow cultivars; the ‘Double Esterel Orange’ cultivar contained 276 mg/100 g in fresh flowers, with 103.8 mg/100 g in ligulate flowers and only 8 mg/100 g in tubular flowers [2].

Table 2. Total carotenoid content of *Calendula officinalis* flowers in selected studies, grouped by method and plant material.

Value (mg/100 g)	Method	Raw Material	Varieties	Source
200–3510	Spectrophotometric	Dried flowers	Mixed varieties	[16]
700–2700	Spectrophotometric	Dried flowers	‘Dracon’ (highest)	[8]
48.2–276	HPLC (sum)	Dried petals	Yellow to orange	[17]
160	HPLC (sum)	Dried flowers	Not specified	[18]
276	HPLC (sum)	Fresh flowers	‘Double Esterel Orange’	[2]
103.8 vs. 8	HPLC (sum)	Fresh ligulate vs. tubular	‘Double Esterel Orange’	[2]

Spectrophotometric sums and HPLC sums are not directly comparable; the former tend to be higher because they include all light-absorbing carotenoid species, including degradation products.

Around 100 different carotenoids have been detected in *C. officinalis* petals. Four main hydrocarbons (β -carotene, ζ -carotene, γ -carotene, lycopene) and six xanthophylls (rubixanthin, flavochrome, mutachrome, flavoxanthin, lutein, chrysanthemaxanthin) are most

commonly reported [19,20]. Kishimoto et al. (2005) identified 19 carotenoids in petals of three orange-flowered and three yellow-flowered cultivars; flavoxanthin was the main carotenoid in 'Alice Orange' (28.5% of total), followed by (8'R)-luteoxanthin (11.0%) and (all-E)-lycopene (8.7%) [20]. A later HPLC-DAD-MS study revised this assignment, identifying chrysanthemaxanthin with the 8S configuration, rather than flavoxanthin, as the main 5,8-epoxy-carotenoid [21]. Ten carotenoids were unique to orange cultivars, and four cis-isomers of lycopene and γ -carotene were identified as new natural products. β -Carotene typically represents about 15% of total carotenoids and was reported at 97–673 $\mu\text{g}/100\text{ g}$ in dried flowers [13].

Growing conditions influence carotenoid content: flowers grown in the shade retain more carotenoids (1.154 mg/g in dried petals) than those exposed to direct sunlight (0.872 mg/g) [21]. Drying also affects the carotenoid profile; Bako et al. (2002) showed that in herbal tea (*Calendula flos*) the carotenoid content is lower than in fresh material and only antheraxanthin and 9Z-antheraxanthin remain in significant amounts, with an increase in the ratio of Z-isomers of lutein and carotene [19].

3.3. Essential Oil

C. officinalis flowers contain a small amount of essential oil (about 0.1–0.97% depending on developmental stage [22]). The highest value is reached at full flowering and the lowest at pre-flowering. The oil is dominated by sesquiterpene hydrocarbons and sesquiterpenols (in some studies up to 68% and 27% of total, respectively [1]). The main components reported across multiple GC-MS studies are α -cadinol (up to ~32% in flowers, up to ~52% in whole-plant oil), δ -cadinene, γ -cadinene, T-murolol, epi-cubenol, nerolidol, and aromadendrene. Monoterpene constituents include α -pinene, β -pinene, sabinene, limonene, p-cymene, α -thujene, and 1,8-cineole, but at lower levels than the sesquiterpenes. The composition depends on cultivar, growth stage, soil, and extraction method; supercritical CO_2 extraction gives a different profile from hydrodistillation, with more globulol and viridiflorol and less α -cadinol, which matters for food use because the extraction method therefore determines which terpenes reach the final product [23].

3.4. Other Terpenoids

Triterpenoids are the second-largest group of bioactive compounds in *C. officinalis*. Faradiol monoesters (faradiol-3-O-myristate, faradiol-3-O-palmitate, faradiol-3-O-laurate) and arnidiol monoesters, together with calenduladiol and its esters, are characteristic of the species [24]. α -Amyrin, β -amyrin, lupeol, erythriodiol, and ψ -taraxasterol are also present, alongside oleanane-type triterpene glycosides (calendulaglycosides A, B, C and their 6'-O-methyl and 6'-O-*n*-butyl esters; calendulosides E, F, G, H) [14].

Across the genus, more than 300 terpenoids have been identified, including approximately 44 monoterpenes, 129 sesquiterpenes, 34 sesquiterpene glycosides, 12 diterpenes, and 133 triterpenes [1]. The triterpene fraction is responsible for much of the anti-inflammatory activity of the species and is the main reason why methanol or ethanol extracts of marigold flowers are used in topical preparations for skin care.

3.5. Carbohydrates and Dietary Fibre

Polysaccharides isolated from *C. officinalis* flowers include three pectic fractions, PS-I, PS-II, and PS-III, with a (1→3)- β -D-galactan backbone and side chains of arabinan and rhamnan [25,26]. These polysaccharides have shown immunostimulant activity in granulocyte phagocytosis tests and are also of interest as potential prebiotic ingredients in functional foods [25].

Dried marigold flowers are a useful source of dietary fibre. Jakubczyk et al. (2022) reported $62.33 \pm 9.17\text{ g}/100\text{ g}$ of total fibre in dried flowers, of which $57.54 \pm 8.32\text{ g}/100\text{ g}$

was insoluble and 4.79 ± 0.86 g/100 g was soluble [27]. The dominance of the insoluble fraction is technologically important: in baking and pasta applications, insoluble fibre interacts with proteins, weakens the gluten network, and reduces CO₂ retention in dough [28]. This explains why most published food applications either use water extracts (which retain phenolics but exclude insoluble fibre) or limit the powdered flower addition to $\leq 5\%$ of the flour.

3.6. Coumarins

Coumarins are a small group of secondary metabolites in *C. officinalis*. Ten compounds are reported in flowers: scopoletin, scopolin, umbelliferone, esculin, cichoriin, aesculetin, neoisobaisseoside, haploperoside A, haploperoside D, and isobaisseoside [5,29]. Their content is low, and comparable quantitative data across studies are not available. Despite their low content, coumarins are often listed among the main active substances because of their anti-inflammatory, anticoagulant, antispasmodic, antioxidant, and mild sedative activities.

3.7. Other Constituents

Other compounds detected include quinones and related compounds (α - and γ -tocopherol, plastoquinone, phyloquinone, ubiquinone, ubiquinone-9, 7- and 8-methyltolcol, 5-phytyltoluquinone, 6- and γ -phytyltoluquinone, tocopherolquinone), 15 free amino acids (alanine, arginine, aspartic acid, asparagine, valine, histidine, glutamic acid, leucine, lysine, proline, serine, tyrosine, threonine, methionine, phenylalanine) and the bitter compound loliolide (calendin) [1]. *C. officinalis* seed oil is dominated by calendic acid (a conjugated 18:3 fatty acid, 51.47–57.63%), linoleic acid (28.5–31.9%), oleic acid (4.44–6.25%), and palmitic acid (3.86–4.55%) [30]. Calendic acid is used in cosmetic formulations and is of interest for food applications because of its reported cytotoxic and anti-inflammatory activity, although the seed oil is so far little used in food products.

4. Biological Activities

4.1. Antioxidant Activity

The antioxidant activity of *C. officinalis* extracts is mainly due to flavonoids, phenolic acids, saponins, and carotenoids. Of these, the flavonoids and phenolic acids described in Section 3.1 are the main contributors in aqueous and hydroethanol extracts, while carotenoids contribute mostly to lipid matrices, where they act as both colourant and oxidation inhibitor (Section 5.5). Preethi et al. (2006) tested an alcoholic flower extract in a panel of in vitro assays and obtained the values shown in Table 3, with ginger extract as a reference [31].

Table 3. IC₅₀ values of *Calendula officinalis* alcoholic flower extract in standard antioxidant assays, as reported by Preethi et al. (2006) [31].

Assay	<i>C. officinalis</i> Alcoholic Flowers (IC ₅₀ µg/mL)	Reference Compound (IC ₅₀ µg/mL)
Superoxide radical scavenging	500 µg/mL	22 µg/mL
Hydroxyl radical scavenging	480 µg/mL	150 µg/mL
Inhibition of lipid peroxidation	2000 µg/mL	30 µg/mL
DPPH scavenging	100 µg/mL	7 µg/mL
ABTS scavenging	6.5 µg/mL	2.75 µg/mL
Nitric oxide scavenging	575 µg/mL	Not determined

All values are taken from the single study cited [31]; the table reproduces the values reported there and is not a comparison assembled by the present authors. The “reference compound” column gives the positive control used in that study (ginger extract).

The values show that *C. officinalis* extract is a useful but not exceptional radical scavenger compared with ginger, except in the ABTS assay where the IC₅₀ values are within the same order of magnitude. Relative to the concentrations reachable in a food matrix, IC₅₀ values of this size are high, so a direct radical-scavenging contribution from marigold extract in a finished product is likely to be modest. The more notable effect is in vivo: oral administration of the extract to mice for one month increased catalase activity, increased blood and liver glutathione levels, and increased glutathione reductase activity, while inhibiting superoxide generation in macrophages by 12.6% (100 mg/kg) and 38.7% (250 mg/kg) [31]. This suggests that part of the antioxidant effect is due to in vivo upregulation of the endogenous antioxidant system rather than direct scavenging.

Other studies confirm the antioxidant activity in DPPH, ABTS, FRAP, and NO assays [5]. In the food matrices reviewed in Section 5, the effect tracks total phenolic content: bread enriched with 10% and 15% replacement of formulation water with marigold aqueous extract gave a 77% and 95% increase in total phenolic content, respectively, and significant increases in DPPH and ABTS scavenging [32].

4.2. Anti-Inflammatory Activity

Anti-inflammatory activity is the best-documented biological effect of *C. officinalis* and is the basis of its use in dermatology and wound care. The active compounds include flavonoids, sterols, carotenoids, glycosides, triterpene alcohols, mucilage, and polysaccharides [33,34].

Among the triterpenoids, the esters of faradiol (faradiol-3-*O*-myristate, faradiol-3-*O*-palmitate) and ψ -taraxasterol were shown to be the most active in croton oil-induced mouse ear edema, with edema inhibition near 50% at 240 μ g/cm²; doubling the dose increased inhibition to 65–66% with no synergism between the two faradiol esters [35]. Ukiya et al. (2006) isolated ten oleanane-type triterpene glycosides from the flowers and tested nine of them in TPA-induced mouse ear edema; all except calendulaglycoside A showed marked anti-inflammatory activity, with ID₅₀ values of 0.05–0.20 mg/ear, in the same range as the positive control indomethacin (ID₅₀ = 0.3 mg/ear) [14]. Golubova et al. (2025) showed that C-16-hydroxylated triterpenoids in *C. officinalis* regulate interleukin-6 release, providing a molecular basis for the inhibition of pro-inflammatory cytokines [36].

In skin tissues, even low concentrations of marigold preparations reduce swelling and pain caused by tissue damage [37]. A 10% and 30% cream reduced pain after a single application and reduced TNF- α concentration after repeated use [34]. Topical and subcutaneous application of *C. officinalis* extract has been reported to reduce TNF- α and accelerate wound healing in rats [38]. Marigold oil reduced nitrite production in inflamed tissues in a dose-dependent way; cytotoxicity of the oil was observed at ≥ 147 μ L/mL [1,34].

4.3. Wound Healing and Tissue Regeneration

Rutin, hesperidin, and chlorogenic acid in *C. officinalis* increase collagen expression [18]. Hexane and ethanol extracts of the flowers increased fibroblast proliferation in vitro by 50.76–64.35% and 60.80–70.53%, respectively, 12 h after application. Aqueous extracts increased α -smooth muscle actin expression in connective tissue [29].

In a rat thermal burn model, oral administration of three doses of flower extract (20, 50, and 200 mg/kg body weight) for 11 days accelerated wound healing, increased collagen, hydroxyproline, and hexosamine content in tissues, reduced lipid peroxidation, and reduced acute-phase proteins such as orosomucoid [39]. In a rat Achilles tendon healing model, *C. officinalis* cream increased total collagen (hydroxyproline) and non-collagen protein and accelerated the first phase of healing [40].

4.4. Cytotoxic and Antiproliferative Activity

Ukiya et al. (2006) isolated fifteen compounds from *C. officinalis* flowers—ten oleanane-type triterpene glycosides (compounds 1–10) and five flavonol glycosides (compounds 11–15)—and evaluated all fifteen for inhibition of Epstein–Barr virus early antigen (EBV-EA) activation induced by TPA [14]. The ten triterpene glycosides showed moderate inhibitory effects (IC₅₀ 471–487 mol ratio/32 pmol TPA)—close to that of β -carotene (IC₅₀ 397 mol ratio/32 pmol TPA), a reference compound in chemoprevention models—while the flavonol glycosides were only weakly active (IC₅₀ 570–592 mol ratio/32 pmol TPA). Inhibition of EBV-EA activation is an in vitro screening model for potential chemopreventive (anti-tumour-promoting) activity; it indicates interference with tumour promotion in a viral-antigen assay and is not in itself evidence of an anticancer effect in vivo.

Two of these glycosides—calenduloside F 6'-O-*n*-butyl ester (compound 9) and calenduloside G 6'-O-methyl ester (compound 10)—were further tested for cytotoxicity against the NCI-60 panel of human cancer cell lines [14]. Compound 9 gave GI₅₀ values below 10 μ M against most lines, with the most potent effects against leukemia, colon, and melanoma cells (GI₅₀ 0.77–0.99 μ M); compound 10 gave GI₅₀ values below 20 μ M across the panel. The activity was broad across the panel rather than selective for a single cancer type, with the strongest effects in colon, leukemia, and melanoma lines. Both compounds occur in the flowers, which are the plant part used in the food applications reviewed here.

Cruceriu et al. (2020) tested ethanol and aqueous extracts of marigold flowers against several breast cancer cell lines and found that both were more cytotoxic to the cancer cells than to non-cancerous endothelial cells [41]. The extracts activated two pro-apoptotic genes, one anti-apoptotic gene, and one cell-cycle regulatory gene. Jiménez-Medina et al. (2006) tested an aqueous extract against tumour cell lines derived from leukemia, melanoma, fibrosarcoma and cancers of the breast, prostate, cervix, lung, pancreas and colon, and reported inhibition of proliferation through cell-cycle arrest in G0/G1 and caspase-3-mediated apoptosis; in nude mice bearing human Ando-2 melanoma cells, administration of the extract inhibited tumour growth and prolonged survival [42].

Taken together, the available in vitro and animal data support cytotoxic and antiproliferative activity of *C. officinalis* extracts and of isolated triterpene glycosides against selected cancer cell lines. The evidence base is small—a few in vitro studies and single animal models—and no clinical data are available, so these findings should be read as preliminary rather than as evidence of anticancer activity in humans. In the context of this review, they are relevant as part of the general bioactivity profile of the species; they do not support a health claim at the intake levels reached in the food applications discussed in Section 5.

4.5. Antibacterial Activity

In vitro studies have shown activity of *C. officinalis* extracts against a broad range of Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Bacillus subtilis*, *Bacillus cereus*, *Enterococcus faecalis*, *Salmonella typhi*, and *Vibrio cholerae* [34,37,43]. Aqueous and ethanol extracts often give the strongest activity, with *S. aureus* among the most sensitive species [44].

For food use, the relevant findings concern foodborne pathogens. Hydroethanol extracts of marigold had the strongest activity against *Campylobacter jejuni* of 21 plant extracts tested, with an IC₅₀ of 0.62 mg/mL [45]. Activity against *Listeria monocytogenes*, *Clostridium perfringens*, *Bacillus cereus*, and *E. coli* supports the use of marigold as a natural food preservative or as an active ingredient in food packaging [37,44]. Activity against oral pathogens (*Streptococcus mutans*, *Actinomyces odontolyticus*, *Porphyromonas gingivalis*, *Fusobacterium nucleatum*) has also been reported and supports the use of marigold in dentistry, which is outside the scope of this review [43].

The antibacterial activity is mainly attributed to terpenes (notably α -cadinol and related sesquiterpenes), flavonoids, saponins, and phenolic compounds, which damage bacterial cell membranes, disrupt enzymes, and inhibit nucleic acid synthesis [34,46].

Reported antibacterial activity values are difficult to compare across studies because of differences in extract concentration, solvent, assay type (disc diffusion, agar well diffusion, broth microdilution MIC), and microbial strain. A summary of selected studies is given in Table 4.

Table 4. Antimicrobial activity of *Calendula officinalis* extracts against selected pathogens—selected examples.

Microorganisms	Type of Extracts Used	Marking Method	Ability to Inhibit Bacterial Growth	Refs.
<i>Staphylococcus aureus</i>	Ethanol 40 mg/mL	DIZ	High (>12 mm)	[47]
<i>Staphylococcus aureus</i>	Ethanol	Agar well	Low (3 mm)	[48]
<i>Escherichia coli</i>	Ethanol/Methanol	DIZ	Low–High	[47,49]
<i>Campylobacter jejuni</i>	Hydroethanol	MIC	IC ₅₀ 0.62 mg/mL	[45]
<i>Pseudomonas aeruginosa</i>	Ethanol/Methanol/Water	MIC	Low (>25 mg/mL)	[50]
<i>Klebsiella pneumoniae</i>	Ethanol/Methanol/Water	DIZ	Moderate–High	[49]
<i>Bacillus cereus</i>	Ethanol/Methanol	DIZ	Moderate–High	[49,50]
<i>Candida albicans</i>	Methanol/Ethanol	DIZ	Moderate (7–10 mm)	[49]

DIZ—disc inhibition zone; MIC—minimum inhibitory concentration. Activity descriptors are study-specific and not directly comparable.

4.6. Antifungal Activity

Efstratiou et al. (2012) tested methanol and ethanol marigold extracts against *Candida albicans*, *C. krusei*, *C. glabrata*, *C. parapsilosis*, *Aspergillus flavus*, *A. fumigatus*, *A. niger*, and *Exophiala dermatitidis*, with inhibition zones of 7–14 mm—comparable in some cases to fluconazole [49].

The food-relevant point is a negative result: ethanol extract from marigold flowers did not inhibit *Saccharomyces cerevisiae* [13]. This is useful from a food-technology perspective, because it means that marigold extract can be added to bread and other yeast-fermented products without affecting the leavening yeast—a property confirmed in the bread application discussed in Section 5.3, where the extract suppressed *Aspergillus niger* without impairing the bake.

4.7. Other Reported Activities

By inhibiting lipid peroxidation, *C. officinalis* extracts have been studied as potential support in Parkinson’s disease [51]. In zebrafish models, extracts reduced degradation of blood vessels and dopaminergic neurons and reversed disturbed expression of disease-related genes [5].

Antidepressant activity—eight compounds from *C. officinalis* leaves were shown to inhibit catechol-O-methyltransferase [52]. Ethanol flower extract reduced reaction time in forced swim and tail suspension tests in rats, in a way comparable to standard antidepressants [53]. Quercetin and rutin in the flowers can block monoamine oxidase and reduce GABA concentration, while quercetin derivatives can inhibit acetylcholinesterase.

Digestive system protection, in Wistar rats with DSS-induced colitis, marigold flower infusions reduced oxidative stress and inflammatory markers [54]. In acetic acid-induced ulcerative colitis in rats, *C. officinalis* extract gave protective effects comparable to mesalamine [55,56]. Marigold has also been shown to be effective against *Helicobacter pylori* [45].

5. Applications in the Food Industry

Four properties of *C. officinalis* justify its use in food. Its carotenoids give a yellow-to-orange colour that works as a natural, clean-label pigment (Section 3.2); its flavonoids and phenolic acids provide antioxidant capacity that can both raise the functional value of a product and slow lipid oxidation in it (Sections 3.1 and 4.1); its dried flowers are a concentrated source of dietary fibre (Section 3.5); and its aroma is close to saffron, which supports use as a low-cost substitute in delicately flavoured products (Section 5.8). These are the properties that the applications below draw on.

C. officinalis flowers are a traditional food ingredient in the European Union rather than a novel food, and marigold is GRAS-listed in the United States, so no novel-food authorization is required for the applications reviewed here (Section 7). The toxicological data support use at food-relevant levels, but Asteraceae cross-allergy is a real, if not uncommon, risk and is relevant to allergen labelling (Section 8).

The technological constraints are the most restrictive in practice. The high insoluble-fibre content of the dried flowers weakens the gluten network, which caps the direct addition of flower powder in gluten-based products at about 5% of the flour and pushes bakery and beverage applications toward extracts. Above the optimal dose, the extract itself increases astringency and reduces sensory acceptance, and the strong pigment limits the matrices in which the colour shift is acceptable. Each of the applications below therefore represents a compromise between the functional gain and one or more of these limits, and none of the studies reviewed has yet defined the full technological window.

5.1. Overview

Edible flowers, including *C. officinalis*, are increasingly used as ingredients in functional foods. They provide flavonoids, carotenoids, anthocyanins, and phenolic acids with antioxidant and other activities, as well as natural pigments and aroma compounds that can improve the sensory profile of the final product. Reported applications of *C. officinalis* cover dairy products (yogurt), bakery (bread, biscuits), pasta, juices, oils, and encapsulated additives. A summary is given in Table 5.

Table 5. Reported food applications of *Calendula officinalis*—matrix, form and amount of addition, technological and functional effects.

Food Application	Form of Addition	Amount of Addition	Technological Effect	Functional Effects	Ref.
Organic yogurt	Lyophilized hydroethanol extract	0.25 g/100 g	Yellow-orange shift; LAB viability maintained	+TPC, +flavonoids, +FRAP, +Cu/Fe chelation	[13]
Wheat bread	Aqueous flower extract (5 mg/mL)	10–15% of recipe water	Slightly higher loaf volume, lower yeast/mould count, no off-flavour	+TPC by 77–95%, +DPPH, +ABTS	[32]
Fresh pasta	Dried, ground flowers (powder)	5% <i>w/w</i> of flour	+Ash 2.15 g, +Fat 2.36 g, +Protein 3.19 g, −CHO 6.19 g per 100 g	+Fibre, +phenolics, +carotenoids; activity retained after cooking	[57]
Biscuits	Edible flower powders (incl. marigold)	Partial flour replacement	Natural colour, no negative impact on texture	+Antioxidant activity, +bioactives	[58]

Table 5. Cont.

Food Application	Form of Addition	Amount of Addition	Technological Effect	Functional Effects	Ref.
Mustard oil	Carotenoid extract	10, 25, 50 ppm	Lower peroxide and TBA in light-stored samples	Oxidative stability	[59]
Cold-pressed flaxseed/chia oil	Edible flower extracts	Not specified	Slowed lipid oxidation	Natural antioxidant	[60]
Grape juice	Hydroalcoholic extract	Not specified	Slight sugar reduction due to dilution	+Antioxidant activity, +phenolics	[61]
Encapsulated extract	Calcium alginate microparticles (~789 µm)	87% encapsulation efficiency	Stable in gastric fluid; ~70% release in intestinal fluid	Controlled release antioxidant	[62]

5.2. Dairy Products

Yogurt is the food matrix for which the most detailed single study is available. Escher et al. (2019) added a lyophilized water-ethanol flower extract to organic yogurt [13]. The extract was rich in total phenolic and flavonoid content, and added quercetin-3-rutinoside, procyanidin A2, ferulic, caffeic, p-coumaric, and ellagic acids to the product. These are the phenolic acids most consistently reported for *C. officinalis* flower extracts. Antioxidant capacity (FRAP, TRC, Cu²⁺/Fe²⁺ chelation) increased significantly. Lactic-acid bacteria viability was not affected. The extract gave the product a yellow-orange colour and subtle floral notes; at 0.25 g/100 g, taste, texture, and overall flavour received the highest scores in the sensory panel. Higher doses increased astringency and reduced acceptance, so the level should be controlled.

5.3. Bakery Products

Podgórska-Kryszczuk & Pankiewicz (2023) added an aqueous *C. officinalis* extract to wheat bread by replacing 10% or 15% of the formulation water [32]. The extract significantly reduced mycelial growth and biomass of *Aspergillus niger* (although it did not inhibit *Penicillium* spp.). Bread enriched at 15% gave a 95% increase in total phenolic content and significantly higher DPPH and ABTS scavenging. Loaf volume and baking losses were not negatively affected, crumb moisture and acidity increased slightly, and sensory properties remained acceptable.

The choice of water extracts rather than powdered flowers in this study is technologically important. As Jakubczyk et al. (2022) showed, dried marigold flowers contain about 62 g/100 g of fibre, of which only ~5 g is soluble [27]. Adding powdered flowers at high levels would weaken the gluten network and reduce CO₂ retention in dough. Using an aqueous extract avoids this problem while retaining phenolic and flavonoid content useful for antioxidant activity and natural preservation. The absence of any effect on *S. cerevisiae* (Section 4.6) is what makes this combination workable: the extract suppresses spoilage moulds without impairing the leavening yeast.

By analogy, Alotaibi et al. (2021) used freeze-dried African marigold (*Tagetes erecta*) petal powder to produce lutein-enriched wheat bread (0.424 ppm lutein in white-flour bread vs. 0.260 ppm in control) [63]. The same approach could be applied to *C. officinalis*, which contains comparable carotenoid levels.

5.4. Pasta

Vinha et al. (2025) replaced 5% of wheat flour in fresh pasta with dried, ground *C. officinalis* flowers [57]. The change increased ash by 2.15 g, fat by 2.36 g, and protein by 3.19 g per 100 g, while total carbohydrate decreased by 6.19 g per 100 g. Dietary fibre, phenolic compounds, and carotenoid content increased. The pasta took on a subtle yellow-orange colour. Antioxidant capacity was retained after cooking, which indicates that thermal processing did not fully degrade the bioactives. The 5% substitution level is a reasonable upper limit for direct incorporation of powdered flowers into a gluten-based product. Above this level, the high insoluble-fibre fraction is expected to disrupt gluten development and to increase cooking loss. The original study reports acceptable texture and sensory scores at 5% but does not provide a full range of substitution levels, so the technological window remains to be defined precisely [57].

5.5. Beverages, Oils, and Encapsulation

Mankovecký et al. (2021) added marigold extract to grape juice from two varieties (Welschriesling, Cabernet Sauvignon) [61]. The enriched juices showed increased antioxidant activity and higher phenolic content, with only a slight reduction in sugar content from dilution. Yerenova et al. (2016) added marigold to melon-based juice blends with the aim of improving nutritional and biological value [64].

Islam & Kumar (2014) used a marigold carotenoid extract at 10, 25, and 50 ppm to slow the oxidation of mustard oil in light [59]. The 50 ppm dose gave the strongest effect: peroxide value and TBA reactive substances were significantly lower than in the control over 7 days of storage. Mikołajczak et al. (2020) demonstrated similar protective effects of edible-flower extracts (including marigold) on cold-pressed flaxseed and chia oils [60].

Savic Gajic et al. (2022) developed an encapsulated marigold additive: an aqueous flower extract (5.59 g GAE per 100 g DW, IC₅₀ 0.096 mg/mL) was loaded into calcium alginate microparticles of mean diameter ~789 µm, with an encapsulation efficiency of ~87% [62]. The microparticles were stable in simulated gastric fluid and released about 70% of the antioxidants in simulated intestinal fluid. This approach is useful for adding marigold antioxidants to food products where direct addition would cause off-flavour or colour changes.

5.6. Use as a Natural Preservative

The antioxidant and antimicrobial activity of *C. officinalis* extracts support its use as a natural preservative or as an active component in food packaging. Martins de Deus et al. (2023) screened phenolic extracts of eight European species, including *C. officinalis*, as candidate natural preservatives; all extracts showed antioxidant potential and activity against some of the microorganisms tested, although *C. officinalis* was among the weaker performers [65].

Mishra et al. (2019) tested a methanolic petal extract against the aflatoxigenic fungus *Aspergillus flavus*—mycelial growth fell by about 25% and aflatoxin B₁ accumulation by up to 59.5%, and direct treatment of the toxin with the extract (5 h, 80 °C) degraded about 78% of it [66]. Together with the suppression of *A. niger* in wheat bread [32], these results support the use of marigold extract to extend shelf life in stored foods.

The activity is not general, however: the same bread study found no inhibition of *Penicillium* sp. [32], so the antifungal spectrum of *C. officinalis* is narrower than that of the strongest plant preservatives, and any mycotoxin-control application would have to be established organism by organism rather than assumed.

5.7. Nutritional Value of Dried Flowers

Dried *C. officinalis* flowers have a high fibre content and a moderate protein and lipid content (Table 6). Two recent studies give consistent values for fibre [27] and complementary data on protein, fat, ash, and carbohydrates [57].

Table 6. Macronutrient composition of dried *Calendula officinalis* flowers per 100 g.

Macronutrients	Content	Source
Total fibre	62.33 ± 9.17	25
Insoluble fibre	57.54 ± 8.32	25
Soluble fibre	4.79 ± 0.86	25
Protein	8.70 ± 0.30/4.64 ± 0.08	25/55
Fat	6.09 ± 0.21	55
Ash	5.66 ± 0.14	55
Total carbohydrates	81.02 ± 0.17	55

The differences between the two studies (e.g., protein 8.70 vs. 4.64 g/100 g) are most likely due to differences in cultivar, growing conditions, drying, and analytical method. For practical use in functional food formulation, the high insoluble fibre content is the most useful nutritional feature, while the moderate protein content adds nutritional value without dominating the formulation. Adding two tablespoons of edible flowers to a meal has been reported to support intestinal transit and to increase satiety, due to this fibre content [27].

5.8. Sensory Value

Marigold flowers have an aroma and colour close to saffron, which makes them useful as a low-cost saffron substitute and as a natural colour for delicately flavoured products [67]. Reported uses include salads, cheese, soups, rice, butter, and baked goods. Yogurt enriched with marigold extract reached 80.4% acceptance in a sensory panel [68]. The main sensory limit is dose: above the optimum, the extract increases astringency and reduces acceptance (Section 5.2), and the strong pigment restricts use to matrices in which a yellow-orange shift is acceptable. Systematic sensory descriptor mapping for *C. officinalis* is not yet available.

6. Agronomic Factors

C. officinalis is grown in Europe, North Africa, and the south-western Mediterranean region. Pharmaceutical and cosmetic demand has driven research into cultivation methods that increase yield and the content of active compounds, and into varieties with more ligulate petals, more intense orange colour, or higher essential-oil content [29]. In Estonian trials, the highest-yielding cultivars were ‘Radio’ (highest total carotenoids 2.5% and flavonoids 1.7%) and ‘Double Ball’ (highest oil yield 0.43%) [8].

The ratio of ligulate to tubular flowers depends on cultivar and environment. In the ‘Orange’ cultivar, this ratio varied from 13% to 62% across environments [3]. Essential-oil content is not correlated with total flavonoid content, so each compound class must be optimized separately. The most valuable part of the flower head is the ligulate petals, which contain the highest concentration of active compounds. A study of flower lifespan (8 days) showed that ligulate flowers mature and age in parallel across the head; ageing is associated with loss of active compounds [69]. For high-quality raw material, flowers should be harvested every few days, when fully open.

Boztaş & Bayram (2025) tested five seeding rates (5, 10, 15, 25, 35 kg/ha) over two seasons under Mediterranean conditions [70]. The optimum for flower and seed yield was

10 kg/ha; higher rates reduced plant branching, plant height, and dried flower yield. Rainfall during the flowering period was a key factor.

Greenhouse and protected cultivation reduce the impact of weather and pests and avoid the use of plant protection products. Hydroponic systems are an option, and Plant Factories with Artificial Lighting (PFALs) are increasingly proposed for edible-flower production [71]. PFALs allow year-round production, full control of light, temperature, and nutrient solution, and avoid pesticides. For marigold, the optimum nutrient-solution electrical conductivity is around 1.5 dS/m for maximum flower number; combined with a 0.5 µM brassinosteroid foliar spray, this gave the highest yield. Higher EC (4.5 dS/m) increases flavonoid content but reduces yield—a trade-off that matters when the raw material is grown for its bioactive content rather than for flower mass. Phosphorus above 5 mg/L favours green mass over flowers. Photoperiod for bud development should be 12–16 h.

Light quality also affects active-compound content. Milenković et al. (2025) compared open-field cultivation with cultivation under pearl, blue, and red nets across three cultivars [72]. Blue nets reduced the antioxidant activity of water-ethanol extracts, possibly due to free-radical release; pearl nets had a less restrictive but still negative effect on yield and quality. Red nets gave the highest yield, the largest number of flowers, larger flower diameter, and higher green mass than open-field cultivation. Together with the shade effect on carotenoids described in Section 3.2, this shows that light management is the growing variable with the clearest effect on the bioactive content of the raw material.

Drying is a key processing step that determines the quality of the raw material. Hernández Fernández et al. (2024) showed that drying at 40 °C and $55 \pm 5\%$ relative humidity gave optimal results when the final moisture content was below 12% ($\geq 15\%$ moisture in petals indicated free water and a risk of contamination) [73]. The drying kinetics followed a two-term model, with one term describing the loss of free water and the second describing the loss of bound water.

7. Legal Status

C. officinalis flowers are classified as a traditional food ingredient in the European Union, not as a novel food, because there is documented evidence of their consumption in the EU before 15 May 1997 (Regulation (EU) 2015/2283 [74]). No special hazard statements, hazard classes, or hazard categories are defined for *C. officinalis* flowers used as a food ingredient [74].

Marigold is recognized as Generally Recognized As Safe (GRAS) by the US Food and Drug Administration. It is listed by the Flavor and Extract Manufacturers Association under FEMA number 2658 as an approved flavouring substance [75]. The European Medicines Agency Assessment Report on *Calendula officinalis* L., flos, provides recommended concentrations and safe levels for extracts and infusions [76]. Allergic reactions are rare but possible, particularly in people sensitive to other *Asteraceae* plants; about 2% of patients tested gave a positive skin reaction in patch tests [29]. This is relevant to allergen labelling in functional food products.

8. Safety and Toxicity

In OECD-423 acute oral toxicity tests in rats, doses of 2 g/kg and 5 g/kg of alcoholic marigold extract gave no significant changes in behaviour, physiological parameters, food intake, or body weight over 14 days. No pathological changes were observed in liver and kidney histology, and serum biochemistry showed no signs of toxicity [77]. Methanol extracts of marigold flowers also gave no clinical or histopathological signs at up to 5 g/kg.

Subchronic studies (50, 250, 1000 mg/kg for 90 days) showed only slight changes in blood biochemistry, suggesting possible mild stress on the liver and kidneys at high doses [77]. Silva et al. (2007) reported increased ALT and BUN with no morphological changes; localized inflammatory foci were observed in lung and liver tissue and may indicate a mild hepatotoxic effect at high long-term doses [78]. Hydroalcoholic extracts have shown no acute toxicity at doses up to 5 g/kg and low subacute toxicity at doses up to 1 g/kg [29].

A comet assay on human lymphocytes showed no clear genotoxic effect of marigold extract up to 400 µg/mL; a small statistically significant increase in DNA damage was observed at the highest concentrations, possibly due to pro-oxidant activity of some polyphenols in vitro. In vivo genotoxicity has not been confirmed [1,12].

For food applications, the relevant dose is far below the levels tested in toxicology studies. For example, a 5% flower-powder substitution in a 75 g portion of pasta provides ~3.75 g of dried flower per serving, well below the no-observed-adverse-effect levels reported for animal studies. The available data therefore support the use of *C. officinalis* as a functional food ingredient at moderate doses. The main remaining concerns are possible cross-reactivity in people sensitive to other *Asteraceae*, which is relevant to allergen labelling, and liver and kidney load with prolonged high-dose use, which is relevant to dietary supplements rather than food.

9. Conclusions

The evidence reviewed here is asymmetric: the phytochemistry and pharmacology of *C. officinalis* are well documented, while the food-application literature consists of a small number of single studies. That asymmetry, rather than any shortage of bioactive compounds, is what currently prevents the species from being treated as a standard functional-food ingredient.

Three findings are firm enough to act on. First, the dried flowers are, above all, a fibre source—about 62 g/100 g, roughly 92% of it insoluble—and this single property drives most of the technology: it caps direct powder addition in gluten-based products at about 5% of the flour and pushes bakery and beverage work toward extracts. Second, the reported contents of flavonoids and carotenoids vary up to two orders of magnitude, and this variation is largely methodological—solvent, plant part, and expression basis—rather than biological, so values from different studies cannot be compared unless all three are stated. Third, the antioxidant benefit in real matrices is measurable and reproducible: 77–95% increases in total phenolic content in bread, retained activity after pasta cooking, and increased chelating capacity in yogurt.

The choices supported by current evidence follow from these findings. For raw material, cultivars with a predominance of ligulate flowers give the richest material, with ‘Radio’ for high flavonoid and carotenoid content, ‘Kablouna’ for high total flavonoids, and ‘Double Esterel Orange’ for high ligulate-flower carotenoids; light management at the growing stage and drying below 12% moisture do more for the bioactive content than any other agronomic variable. For formulation, the evidence supports aqueous or hydroalcoholic extracts in bakery and beverages, where insoluble fibre would interfere with structure: powdered ligulate flowers in fresh pasta at up to 5% substitution; lyophilized hydroethanol extracts in dairy at 0.25 g/100 g; alginate-encapsulated extracts where direct addition would cause off-flavour; and carotenoid extracts at 10–50 ppm to slow lipid oxidation in vegetable oils.

The limitations are equally clear. Only two food matrices—yogurt and pasta—have been characterized in full, and each rests on a single study, so no substitution curve or technological window exists for any product. No clinical study has tested marigold-

containing food at realistic intake levels, and nothing is known about the bioavailability of the main compounds from a food matrix, which means that the cytotoxic and anti-inflammatory activities described in Section 4 cannot presently support any health claim. There is no standardized extraction or drying protocol, which is the direct cause of the incomparability noted above. Sensory descriptor mapping is absent, and the regulatory position, while permissive, still requires *Asteraceae* allergen labelling.

The most useful next steps are therefore not the discovery of further compounds but the standardization of what is already known: agreed extraction and reporting conventions, dose–response studies across a range of substitution levels in a few well-chosen matrices, and bioavailability data from real foods. *C. officinalis* has the composition and the regulatory position of a mainstream functional-food ingredient; what it lacks is the applied evidence base, and that gap can be closed with existing methods.

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