



The advantages of chamomile (*Matricaria recutita*) extract for health: a review

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Abstract

Chamomile (*Matricaria recutita*) is an edible flowering herb widely valued for its medicinal, aromatic, and technological attributes, making it an important raw material in contemporary food applications. This review evaluates the chemical profile, bioactivity, and functional health potential of chamomile extract based on current scientific evidence. The extract contains diverse bioactive constituents, particularly flavonoids, terpenoids, and phenolic compounds, which are responsible for its strong antioxidant, antimicrobial, and anti-inflammatory properties. Owing to these characteristics and its pleasant sensory profile, chamomile extract has been incorporated into various functional foods, especially fermented and probiotic products such as herbal beverages and chamomile-enriched yogurt. Experimental findings from *in vitro* and *in vivo* studies indicate that chamomile may suppress cancer cell growth, reduce anxiety symptoms, promote gastrointestinal health, support cardiovascular function, and modulate immune responses. Beyond its therapeutic relevance, chamomile extract also serves as a natural substitute for synthetic preservatives and additives, aligning with increasing consumer demand for clean-label and plant-based ingredients. Its multifunctional properties contribute to improved food stability, safety, and shelf life while enhancing nutritional value. In addition, chamomile imparts a characteristic floral aroma, mild taste, and appealing color, which further support consumer acceptance. Collectively, chamomile extract demonstrates substantial promise as a natural functional ingredient, nutraceutical component, and bio-preservative for the development of health-oriented and technologically advanced food products, highlighting its expanding role in human nutrition and future food innovation.

Keywords

chamomile, extraction, food industry, natural bioactive ingredient, nutrition



Introduction

Humans have been focusing on the quality of food. The food quality products acquired through the sustainable food industry and agricultural products are chemical-free to prevent negative effects on health. Consuming good food quality also has superior sensorial and preservation characteristics [1]. Antioxidant potential refers to the intrinsic ability of chamomile extract to scavenge free radicals and inhibit oxidative processes, thereby contributing to its functional role as a natural antioxidant in food and health-related applications. These properties could be developed into functional products [2]. For instance, aromatic plants that can be processed into an extract containing bioactive compounds are chamomile flowers.

Chamomile flower (Figure 1) is a part of the Asteraceae family, mostly used for traditional medical herbs. This plant is one of the oldest plants in the world. Chamomile is extensively grown in Germany, Hungary, France, Yugoslavia, Brazil, and India, and is distributed around the world. The most well-known chamomile species is *Matricaria recutita*, known as German chamomile. German chamomile is frequently regarded as the original chamomile species. The Greek terms “Chamos” and “Melos”, which translate to “on the ground” and “apple”, respectively, are the basis of the English term “chamomile”. It is called for the nation because, historically, Germany was a significant producer, exporter, and grower of this particular, highly valued medicinal plant. It became a major supplier to the international market and was widely utilized in German traditional medicine. Chamomile has been used as a medicine for thousands of years in ancient Greek, Roman, and Egyptian cultures. The German Commission approved that the chamomile extract could treat cough, bronchitis, fever, cold, inflammation, infection, wounds, burns, etc. [3].



Figure 1. Image of chamomile flowers. Created using Canva AI.

The chamomile flower (*M. recutita*) is native to temperate regions of Europe and Asia and can thrive in cooler climates with well-drained soils; it produces straight, thin, spindle-shaped roots and erect stems approximately 10–80 cm long, with pinnate leaves and flower heads 10–30 mm in diameter. The small white ray petals and yellow tubular disc florets characteristic of *M. recutita* (Asteraceae) contribute to its botanical identification, and more than 120 secondary metabolites, including 28 terpenoids and 36 flavonoids, have been identified in its flowers, which largely account for its therapeutic potential [4]. The flower heads are the principal medicinal part used for anti-inflammatory and sedative applications, and the whole flower has been traditionally used to alleviate postoperative symptoms and support recovery in hospitalized patients. Functional foods are foods or dietary components that provide health advantages beyond basic nutritional functions, such as increasing physiological functioning and lowering illness risk [1]. Unlike pharmaceutical products, which do not act as primary remedies but rather help to maintain and avoid health problems. Chamomile extract has gained popularity as a functional food component due to its bioactive chemicals, which include antioxidant and antibacterial qualities that may aid in food preservation and human health without behaving like prescription medications [5].

As a medicinal plant, chamomile exhibits analgesic, anti-allergic, antispasmodic, antibacterial, anti-inflammatory, and sedative properties, and its flowers are increasingly processed as raw material for the extraction of functional ingredients. The extracts are rich in phenolic compounds, primarily flavonoids like apigenin and hydroxycinnamic acids that dominate antioxidant activity and belong to the phenylpropanoid group of secondary metabolites. Chamomile flowers also yield essential oils with major sesquiterpene constituents such as α -bisabolol and its oxides, and azulene derivatives including chamazulene, which are best preserved in alcoholic tinctures [5].

The biological activity of chamomile extract is determined by the extraction method, particularly the solvent used, which determines the recovery of bioactive components such as flavonoids, phenolic acids, and terpenoids. Polar solvents, such as water and ethanol, are often employed because of their efficacy and compatibility for food and beverage applications, allowing chamomile extract to be integrated into functional food systems. Compared to aqueous fractions, methanolic chamomile extracts demonstrate stronger physiological responses in inhibiting cell proliferation and inducing apoptosis in various human cancer cell lines, with apigenin glycosides playing a significant role through cellular deconjugation to the active aglycone form, apigenin [6]. The extract from chamomile can be processed into functional food products and nutraceutical beverages that contribute not only to health promotion but also to technological quality, such as product stability, shelf life, and consumer acceptance. Its incorporation into fermented and probiotic drinks represents an important approach for delivering bioactive compounds through daily diet in the food industry, including probiotic beverages and fermented foods; their biological activities are influenced by extraction methods and storage conditions [7].

The future issue with food products needs food innovation processing to include functional and medicinal beverages in the human diet. Utilizing chamomile extracts with bioactive metabolites and developing innovative processing technologies might be crucial tools. To describe and assess the pharmacological, phytochemical, and technical characteristics of chamomile with traditional and classical ethnobotanical uses [7]. Medicinal ingredients of dry chamomile are extracted normally by using water, ethanol, or methanol as solvents, and extracts that are obtained are aqueous and ethanolic or methanolic extracts. The alcohol of chamomile extracts contains approximate 50% of alcohol [8].

Chamomile extract has gained popularity in recent years as both a therapeutic herb and a functional ingredient in food creation. Its use in beverages, dairy products, and fermented meals allows for the development of value-added products with superior nutritional and technological features. Chamomile extract contains antioxidants and antimicrobials, which can improve product stability and safety, while its natural aroma and flavour increase consumer appeal. Applications include chamomile-fortified yogurt, herbal tea infusions, and probiotic drinks, demonstrating its potential as a clean-label food additive. As a result, chamomile extract can operate as a nutritional enhancer, natural preservative, and sensory modifier all at once, facilitating the development of functional foods that meet current market demand for health-oriented products [6–8].

Recently, the popular use of chamomile extract in probiotic beverages has been in chamomile tea and as a preservative in yoghurt. Chamomile tea is an herbal tea and the most consumed million cups per day worldwide as an herbal tea and functional beverage due to its bioactive compounds, especially flavonoids and terpenoids. These substances provide antioxidant, antibacterial, and relaxing effects that may aid in relaxation, digestive comfort, and general health maintenance. Chamomile tea bags contain either chamomile blossom powder or a combination with other therapeutic herbal remedies. Four parts water to a part of chamomile flowers with 12% of alcohol in chamomile tea bags to make chamomile tincture, which is used to treat diarrhea, insomnia, calm anxiety, etc. Chamomile blossoms are often used for external inflammation conditions, such as facial inflammation connected to underlying infection or inflammation, and used as a poultice (hot foment) for inflammatory pain or congestive neuralgia. The tea infusion of chamomile is used to wash or gargle the inflamed mucous membrane of the mouth, while the chamomile essential oil is used to relieve anxiety and depression. Unlike pharmaceutical medications, chamomile tea is used as a dietary supplement to improve health and wellness, rather than as a main medical therapy [8]. Another food product is chamomile yoghurt. Chamomile has been evaluated as a natural additive for yogurt

fortification, providing high antioxidant functionality without adversely affecting pH, nutritional quality, or sensory acceptance, which supports its application as a clean-label ingredient in dairy product development with natural additives. Thus, chamomile extract is a potential functional food component with prospective uses in food and nutrition. Chamomile was tested as a natural synthetic additive for yoghurt fortification, which contains antioxidants and does not cause significant changes to pH and the nutritional benefits of yoghurt. Fortified chamomile yoghurt has high antioxidant activity with natural additives [9].

The purpose of this study is to evaluate the bioactive content, health benefits, antioxidant and antibacterial properties, and possible uses of chamomile extract in functional food and human nutrition using scientific literature from peer-reviewed global databases.

Methodology

This review collected and analyzed scientific literature on chamomile (*M. recutita*) extract, concentrating on its bioactive content, antioxidant and antibacterial activities, and functional food uses. Relevant publications were retrieved from peer-reviewed scientific databases such as PubMed, ScienceDirect, MDPI, and Google Scholar. The literature search was conducted from 2014 to 2026, including keywords such as “*Matricaria recutita*”, “chamomile extract”, “bioactive compounds”, “antioxidant activity”, “antimicrobial activity”, and “functional food”. Priority was given to studies that investigated bioactive content, biological activity, and food applications. The collected literature was evaluated and summarized to assess the functional potential and uses of chamomile extract in food and health. The inclusion criteria were peer-reviewed scientific publications published in English that focused on the chemical composition, biological activity, and food uses of chamomile extract. Duplicate papers, non-peer-reviewed sources, articles with little scientific merit, and research unrelated to the bioactivity of chamomile extract or food applications were also excluded. The collected literature was extensively evaluated and summarized to assess the functional potential and usability of chamomile extract in the food and health sectors.

Chemical and bioactive composition of chamomile extract

Chamomile extract contains diverse bioactive compounds, including terpenoids such as α -bisabolol, its oxides, and chamazulene, as well as flavonoids (e.g., luteolin, rutin, and apigenin), coumarins, tannins, mucilage, and other phenolics. German chamomile essential oil is rich in sesquiterpene alcohols like α -bisabolol and its oxides and the azulene derivative chamazulene, which contribute to its pharmacological properties, including anti-inflammatory and antioxidant effects [10]. These bioactive constituents exhibit topical therapeutic actions, particularly in skin health, demonstrating anti-allergic, antioxidant, analgesic, and anti-inflammatory functions [11]. α -Bisabolol is a key compound associated with spasmolytic effects on smooth muscle, while chamazulene, formed from matricin during processing, has potent antioxidant and anti-inflammatory properties. Flavonoids such as luteolin and apigenin and their glycosides also contribute to chamomile’s anti-inflammatory, carminative, and antispasmodic activities [12]. Apigenin, particularly in its glycosylated form (apigenin-7-O-glucoside), is reported in chamomile extracts at significant levels and is associated with anxiolytic, antioxidant, and anti-inflammatory properties [13]. Spiroethers like cis- and trans-en-yn-dicycloethers present in chamomile essential oil have documented antifungal, anti-inflammatory, and spasmolytic effects. Coumarins such as herniarin and umbelliferone also display antifungal, antibacterial, and antispasmodic activities [14]. Phenolic compounds, classified as secondary plant metabolites, are abundant in chamomile and are primarily responsible for its high antioxidant activity, which protects against oxidative stress and related diseases [12].

Chamomile extracts have been quantified to contain substantial amounts that chamomile flowers contain considerable levels of bioactive terpenoids. The total phenolic contents in chamomile dry flower extract are 67.4 mg/GAE per gram, including phenolic acids (e.g., chlorogenic and caffeic acids) and flavonoids, supporting their role in scavenging free radicals. Apigenin-7-glucoside content in chamomile extract has been reported at ~0.25% of dry flower weight and is implicated in spasmolytic and anti-inflammatory effects. Flavonoids also exert chemopreventive effects, including modulation of inflammatory pathways and potential anti-cancer activity. Chamomile extract contains 0.25% of apigenin 7-glucoside,

which has been reported as one of the dominant flavonoids. The presence of apigenin, apigenin-7-O-glucoside, and its acetylated derivatives is primarily responsible for the spasmolytic and antiphlogistic effects. Flavonoids are also known for their calming impact and anti-inflammatory activity, chemopreventive against ultraviolet (UV) radiation, and anti-cancer against a variety of tumours. The α -bisabolol and its oxides are significant sesquiterpenes with antibacterial and spasmolytic effects. These quantitative ranges demonstrate that chamomile extract is not only rich in various metabolites but also contains adequate quantities to support functional and technological uses in food products [13]. There are 26 organic acid components in chamomile, and 4 among the organic acids are primary metabolites, and 22 remaining organic acids are secondary metabolites. Additionally, essential compounds show immense potential in cancer treatment, immune system disorders, and cardiovascular problems. Organic acid compounds found in chamomile flowers are isobutyric acid, tiglic acid, 4-hydroxybenzoic acid, galacturonic acid, chlorogenic acid, etc., while the compounds in essential oil chamomile extracts contain organic compounds such as benzaldehyde, isobutyl phenylacetate, benzyl acetate, etc [15]. These organic compounds become more polar when extracted at low temperatures, vice versa if the organic compound becomes less polar when extracted at high temperatures. This extraction uses subcritical water to extract selectively different classes of compounds. This extraction method is to separate the physiologically active substances from biological compounds, which requires taking into an isolation of strong water reactivity at high temperatures [16]. Chemical and bioactive composition of chamomile extract, and their biological could be seen in Table 1.

Table 1. Chemical and bioactive composition of chamomile extract.

Compound category	Representative compounds/constituents	Major source/plant part	Biological relevance	Food/pharma application relevance	Ref.
Flavonoids	Apigenin, apigenin-7-glucoside, quercetin, kaempferol glycosides	Flowers (inflorescences)	Antioxidant, anti-inflammatory, anticarcinogenic	Functional beverages, nutraceuticals, anti-aging formulations	[17]
Phenolic acids and derivatives	Gallic acid, chlorogenic acid, caffeic acid, esculetin	Flowers and aerial parts	Free radical scavenging contributes to antioxidant activity	Natural antioxidant additives, functional foods	[17]
Essential oil components	Germacrene, α -curcumene, capric acid (in essential oil)	Flower essential oil	Antimicrobial, insecticidal, aromatic components	Natural preservatives, aromatherapy, and flavoring agents	[18]
Coumarin glycosides	Four coumarin glycosides (in roots)	Roots	Antioxidant, possible antibacterial activity	Pharmaceutical ingredients, herbal extracts	[19]
Polyphenols (Total)	High total phenolic and flavonoid contents quantified	Whole plant (mainly flowers)	Major contributors to antioxidant activity	Functional tea, dietary supplements, fortified foods	[20]
Other bioactives	Glyceroglycolipids, phenolic acid esters (roots)	Roots	Bioactive, antioxidant potential	Pharmaceutical and nutraceutical ingredient development	[19]

The concentration and biological activity of chamomile bioactive components are heavily determined by the extraction process and solvent choice. According to studies, methanolic extracts have better antiproliferative efficacy than aqueous extracts because phenolic chemicals are extracted more efficiently [6]. Furthermore, different formulation techniques, such as ethanolic extract and Pickering emulsion, exhibit varied antibacterial activity, with Pickering emulsions having much lower minimum inhibitory concentration (MIC) values against microbial strains. These data suggest that extraction conditions influence the concentration, stability, and biological activity of chamomile bioactive components. Thus, optimizing extraction procedures is critical to maximizing the functional and therapeutic potential of chamomile bioactive chemicals [8].

Despite growing interest in chamomile extract as a functional ingredient, its use in the food industry confronts several hurdles. The stability of bioactive chemicals during processing, extraction efficiency, dosage optimization, sensory acceptance, and interaction with food matrices are all essential challenges for large-scale application. Variations in solvent systems, temperature, and storage conditions can also have a

substantial impact on chamomile metabolite concentration and activity [6]. Most previous research has mostly focused on pharmacological qualities, with few publications methodically discussing chamomile extract from a food technology and product development standpoint. As a result, this review emphasizes the application of chamomile extract in functional foods, beverages, and fermented products, assesses its chemical, biological, and technological relevance, and identifies current limitations and future opportunities for incorporating chamomile extract into nutritionally valuable and clean-label food products [7, 9].

Although chamomile extract has massive medicinal and functional benefits due to its high bioactive content, some limitations remain. The concentration and stability of active chemicals such as flavonoids and terpenoids might vary based on extraction procedures, solvent type, plant origin, and storage conditions, thereby affecting biological efficacy and repeatability in food applications [6]. Furthermore, variability in preparation methods, particularly in consumer-prepared infusions like chamomile tea, makes it challenging to achieve a uniform bioactive dose and predictable health results. As a result, a careful assessment of chamomile extract composition, biological activity, and suitability as a functional food component is required [9].

Health benefits of chamomile extract

Traditionally, chamomile has been used as a medicinal herb with anti-inflammatory, antioxidant, and astringent properties, and has been applied for conditions such as wounds, ulcers, eczema, burns, and various skin irritations. Traditional uses, including anti-inflammatory and wound care, are well-documented in historical and therapeutic studies of chamomile's medicinal role. Chamomile has been widely used against bacterial skin infections, inflammation of the oral cavity and gums, and respiratory tract ailments. Evidence supports chamomile's antimicrobial and anti-inflammatory activities on mucous membranes and skin surfaces [8].

Antioxidants in chamomile extract have a chemical compound including apigenin and flavonoids. The majority of research evaluating chamomile's ability to prevent tumor development uses apigenin. Research on preclinical models of ovarian, breast, prostate, lung cancer, oral carcinogenesis, colon cancer, and skin cancer caused by UV-B has revealed encouraging growth inhibitory effects [16]. Chamomile extracts significantly decreased the viability of several human cancer cell lines while having no growth-inhibiting effects on normal cells. Primarily, flavonoids, such as apigenin, cause apoptosis via activating mitochondrial pathways and modulating oxidative stress [11]. These data imply that chamomile extract may help with illness prevention and functional food [21]. At comparable dosages, chamomile exposure caused apoptosis in cancer cells instead of in normal cells. Recent studies have examined the effectiveness of the new agent TBS-101, which is a blend of seven standardized botanical extracts, including chamomile. The findings demonstrate that it has a strong anticancer effect on androgen-refractory human prostate cancer cells and an excellent safety profile. Usage of flavonoids was inversely correlated with myocardial infarction incidence and substantially negatively correlated with coronary heart disease mortality. Hemodynamic measures taken before and 30 minutes after oral chamomile tea consumption showed a little but substantial rise in average brachial artery pressure in 12 individuals with heart disease who had heart catheterization. Following chamomile ingestion, no more noteworthy hemodynamic alterations were noted. Shortly after consuming the beverage, ten out of the 12 patients experienced profound slumber. To evaluate chamomile's potential benefits for enhancing heart health, a sizable, carefully planned randomized controlled study is required [8].

It has been discovered that chamomile contains components that are crucial in the treatment of central nervous system disorders, including epilepsy and Alzheimer's. The injection of kainic acid caused convulsions in research conducted by Hashemi and colleagues. Seizures were considerably less frequent and less severe after therapy. Apigenin increased the amount of live neurons in the hippocampus, reducing neurodegeneration, according to immunohistochemical tests. The study also showed that apigenin helps those with epilepsy who have memory problems. The activation of neurodegeneration is caused by chronic oxidative stress. Since chamomile is a natural antioxidant and may scavenge free radicals, it may be useful

in treating neurological conditions such as cerebral ischemia, Parkinson’s disease, and Alzheimer’s disease [16].

The chamomile extract also plays roles for astringent properties such as mild sedative activities, for skin health, oral health, digestive health, eye health, wound healing, etc. In many mouthwash formulations, chamomile serves as the primary active component. This extract can be used orally to treat stomach discomfort and pain from functional digestive problems. Chamomile also reduces muscle atrophy by upregulating the genes for mitochondrial transcription factor A (TFAM), MyoD, and myogenin-1 while inhibiting muscle ring finger-1 (MuRF1). It helps those with osteoarthritis in their knees by reducing stiffness and discomfort. It also reduces anxiety in general, and its effectiveness is on par with that of traditional anti-anxiety medications [22]. Health benefits of chamomile can be seen in Table 2.

Table 2. Health benefits of chamomile extract.

Health benefit	Effect/Mechanism	Active compounds	Potential application	Ref.
Antioxidant activity	Neutralizes free radicals and reduces oxidative stress via phenolic and flavonoid compounds	Apigenin, quercetin, luteolin, phenolic acids	Functional beverages, nutraceuticals, and anti-aging products	[23]
Anti-inflammatory effects	Suppresses pro-inflammatory signaling pathways and reduces inflammation in tissues	Chamazulene, apigenin, bisabolol	Herbal supplements, topical formulations	[24]
Cancer-preventive potential	Exhibits anti-inflammatory and multiple anticancer activities through inhibition of cytokines and modulation of cellular pathways	Apigenin, flavonoids, terpenoids	Adjunct nutraceuticals for cancer prevention research	[25]
Oral mucositis management	Topical application reduces the severity of mucosal inflammation and supports healing in clinical settings	Bisabolol, chamazulene, flavonoids	Mouthwash, oral gel formulations	[26]
Glycemic control and metabolic improvement	Improves glycemic control, reduces oxidative stress, and improves lipid profile in diabetic conditions	Polyphenols, flavonoids	Functional tea, dietary supplements for metabolic health	[27]
Digestive support	Traditionally used to alleviate gastrointestinal discomfort and soothe the digestive tract conditions	Essential oils, flavonoids	Herbal tea, digestive formulations	[16]
Antimicrobial properties	Exhibits activity against various microbial pathogens, contributing to infection control	Essential oils, α -bisabolol, flavonoids	Natural preservative, oral care, topical products	[23]
Anxiolytic and neuroprotective effects	May modulate neural responses and support mood regulation, stress, and anxiety	Apigenin, flavonoids	Functional drinks, sleep and stress supplements	[16]

***In vivo* antioxidant activity in chamomile extract**

Compared to normal cells, cancer cells produce more reactive oxygen species (ROS) and have a different redox environment. Furthermore, carcinogenesis and the response to cancer therapy are significantly influenced by redox regulation and signaling. By encouraging DNA mutations, genomic instability, and aberrant pro-tumorigenic signaling, ROS are linked to the development and spread of cancers. On the other hand, elevated ROS levels may also cause cancer cells to die via cytotoxicity. The use of natural antioxidants is largely responsible for preventing diseases linked to oxidative stress, since synthetic antioxidants are frequently linked to high toxicity and carcinogenic or mutagenic effects [28]. Antioxidative enzymes are the most prevalent natural antioxidants, whereas other antioxidants are found in various plants and spices. The terpenoids α -bisabolol make up the majority of the essential oil derived from chamomile, which has been shown to cause cancer cells to undergo apoptosis [20].

Polyphenolic compounds in plants are largely responsible for their antioxidant properties, as these secondary metabolites can donate electrons or hydrogen atoms to neutralize ROS, thereby interrupting the chain reactions of free radical formation and reducing oxidative damage. Flavonoids and phenolic acids, in particular, are effective at stabilizing free radicals due to the presence of multiple hydroxyl groups on their aromatic structures, which facilitate electron donation and radical quenching. This intrinsic chemical activity underlies the restorative potential of many plant extracts as antioxidant agents [29].

In the phytochemical profiling of chamomile (*M. recutita*) extracts, analyses using gas chromatography–mass spectrometry (GC-MS) have identified a range of volatile and semi-volatile constituents, including sesquiterpene derivatives such as β -farnesene and other structurally related compounds [30]. Additionally, advanced liquid chromatographic techniques coupled with diode-array detection and mass spectrometry (HPLC-DAD-MSⁿ) have revealed the presence of multiple bioactive secondary metabolites, including coumarin glycosides (e.g., aesculin, scopolin, and fraxin), caffeoylquinic acids, and various glyceroglycolipids [19]. These classes of compounds contribute to the overall bioactivity profile of chamomile extracts, including anti-inflammatory, antioxidant, and enzyme-modulating effects.

In vivo studies have shown that chamomile extract can be used as a functional element in food systems due to its antioxidant properties by enhancing the activity of antioxidant enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase while decreasing lipid peroxidation levels. Its ability to scavenge free radicals and minimize oxidative stress suggests that it could be used to improve the oxidative stability of food products, particularly those containing lipids like dairy and drinks. Incorporating chamomile extract into functional foods may help to promote health while also extending shelf life and maintaining quality. For instance, extracts comprising these natural components were mixed into cottage cheese together with chamomile powder. The nutritional composition, colour, and antioxidant activity of all samples were assessed throughout storage duration. Chamomile decoctions (natural bioactive ingredient) did not significantly affect the nutritional and fatty acid profiles of cottage cheese, but they did increase its antioxidant potential, regardless of storage period. Furthermore, it extended the shelf life because only the control samples exhibited evidence of disintegration after 14 days in storage. This unique functional dairy product highlights chamomile's bioactive and preservation capabilities [11]. These findings indicate the possible use of chamomile extract in functional foods to promote long-term health and disease prevention.

***In vitro* antimicrobial activity of chamomile extract**

The antibacterial activity of CPe was contrasted with that of ethanolic solution (CEt) and emulsion buffered with Tween 80 (CT80). The minimum inhibitory level (MIC₉₀) and minimum effective concentration (MEC₁₀) of the antimicrobials were used to evaluate their effects. In addition to growth inhibition (CFU/mL), the production of oxygen-free radical species and the metabolic activity and survival of Gram-positive and Gram-negative microbes, as well as *Candida* species, were investigated. Utilizing unilamellar liposomes as a cellular model, the lethal activity of EO–Pickering the nanoemulsion (CPe) was monitored, and the effectiveness of the EO administration for the formulations under investigation. Compared to CT80 and CEt, CPe exhibited much stronger antibacterial and antifungal properties. The primary mechanism of action of chamomile essential oils may be the generation of superoxide anion and peroxide-related oxidative stress [31]. Using the broth microdilution technique, the MIC of chamomile extract on microorganisms in the planktonic phase was found to be 83 and 100 mg/mL. The MIC was utilized during the planktonic phase and increased doses until the extract's maximum concentration (300 mg/mL) was reached in order to confirm the extract's activity on the biofilm [32].

Surface-modified silica nanoparticles were used as a stabilizing agent in Pickering nanoemulsion. In each instance, the concentration of the particles was 1 mg/mL. The concentration of chamomile essential oil was 100 μ g/mL. An emulsion containing the stabilizing agent Tween 80 was also made in order to compare the characteristics of chamomile CPe with those of traditional, surfactant-stabilized nanoemulsions. The surfactant concentration of 1 mg/mL was identical to that of the nanoparticles [31]. Through the phospholipid lecithin, chamomile extracts prevent *H. pylori* from producing urea and stop the microbe's adhesions. According to the study, chamomile has antiviral properties against poliovirus and herpes virus. Additionally, chamomile sites and esters showed substantial anti-mycobacterial activities, namely against *Mycobacterium avium*. Furthermore, the study found that a 25 mg/mL dose of chamomile extract had noteworthy bactericidal effects against *Streptococcus mutans*, *Bacillus subtilis*, and *Staphylococcus aureus*, along with a few fungicidal activities against *Candida albicans* [33].

When compared to unrestrained essential oil in CEt, CPe exhibited antibacterial action against the chosen microorganisms at an average concentration that was fourteen times lower. At the same time, CPe demonstrated an antifungal impact on *Candida tropicalis* that was comparable to that of caspofungin (Cas) [31]. With a rise in the chamomile extract content, the amount of *C. albicans* biofilms CFU/mL decreased. The extract's highest decrease of 300 mg/mL was comparable to the 0.12% reduction brought on by chlorhexidine [34]. It has been demonstrated that permeabilizing agents are used in conjunction with chamomile extracts; the MBC standards of chamomile extracts with liberal *Pseudomonas aeruginosa* varieties are similar for sensitive strains. Antibacterial effects may be due to its ability to inhibit cell membrane enzymes and interrupt the cell wall permeability barrier. Chamomile extract's sesquiterpenoid compounds, such as bisabolol, have the ability to interrupt the G+ bacterial cell membrane, which can be explained by the existence of its outer membrane in gram-negative bacteria. This antibacterial impact is also mostly caused by phenolic chemicals and terpenoids, which prevent microbial development. The MIC values indicate effective antibacterial activity, especially in the methanolic and ethyl acetate fractions, which contain larger levels of bioactive chemicals [33].

The antibacterial activity shown *in vitro* supports the use of chamomile extract as a natural preservative in food products. The suppression of foodborne pathogens and biofilm formation suggests that chamomile extract may improve microbiological safety in beverages and fermented foods. These findings indicate the potential for using chamomile extract in food recipes as a clean-label alternative to synthetic preservatives that maintain functional and sensory quality [11].

Functional foods and pharmaceutical preparation applications

Many pharmaceutical treatments and beneficial food items have used chamomile extract. The most widely used method of delivering chamomile's beneficial ingredients is still herbal tea, which is how it is traditionally ingested. In contemporary gastronomy uses, chamomile extract has been added to yogurt, fermented drinks, nutritional supplements, tinctures, and functional drinks with the goal of enhancing immune system function, relaxation, and digestive comfort. According to a number of studies, chamomile extract improves antioxidant activity and aids in microbial stability when added to dairy and beverage matrices without appreciably changing sensory acceptability. The stability and bioavailability of chamomile phenolics and terpenoids in food systems have also been investigated using encapsulation and emulsion-based systems, such as Pickering emulsions and ethanolic extracts. As a functional ingredient for food innovation, these advancements show that chamomile extract is not only pharmacologically active but also technically practical. There are several proven advantages for chamomile, making it one of the most often used herbal remedies for rashes, cramps, stomach issues, and mild infections [4]. One such example of a traditional oil is chamomile oil. Traditional Persian medicine incorporates extensive use of oils as one of the pharmacological dosing forms. It offers nutritional, medicinal, and cosmetic benefits and is utilized globally in a variety of products, including tea, raw materials, decoctions, and commercial goods [35].

M. recutita galenic formulations are used to treat inflammation, spasms, and minor skin conditions. They have also been shown to have sedative and anxiolytic properties. In ethnomedicine, chamomile's therapeutic applications are widely recognized. However, it isn't optimized. The tincture's primary drawback is its low chemical stability, which alters the pharmacodynamics of its active ingredients when used medicinally. Furthermore, several patient groups are excluded from using chamomile tinctures since ethanol is employed as an extracting solvent in their manufacture. For the aforementioned patients, chamomile decoctions and teas are indicated. However, because they are not standardized preparations, decoctions and teas also have limits when it comes to their medical applications. Additionally, it takes a long time to prepare decoctions and teas, and the chemical makeup of these liquid preparations might alter over time with limited storage duration. In order to promote the medical use of chamomile, there is a genuine need for new standardized galenic formulations based on tinctures and decoctions. This technique makes it feasible to broaden the variety of medications, use natural resources wisely, boost pharmaceutical company profitability, and lessen the negative impact of pharmaceutical production on the environment [5].

Clinical investigations have showed that chamomile is effective in lowering inflammation and discomfort in oral mucosal lesions, such as those produced by chemotherapy-induced mucositis or mild aphthous stomatitis. The bitterness of chamomile extract is a significant obstacle to its therapeutic application, as taste sensitivity in youngsters frequently results in treatment rejection. Traditional formulations like as mouthwashes and gels typically fail to disguise this bitterness and may not offer long-term distribution of active components, which is crucial for successful ulcer treatment. Pastilles, which include chamomile extract into a gelatin-based matrix with non-cariogenic sweeteners such as xylitol, aspartame and flavoring ingredients, can conceal bitterness while maintaining stability and extended therapeutic effect [36].

Conclusion

Chamomile extract includes a variety of bioactive components, including flavonoids and terpenoids. The overall phenolic content is roughly 67.4 mg GAE/g, with apigenin-7-glucoside levels at around 0.25%. These chemicals have considerable biological activity. *In vivo* studies show that chamomile extract boosts antioxidant defenses, reduces oxidative stress, and promotes cellular protection, while *in vitro* studies show antimicrobial activity against microorganisms like *Streptococcus mutans*, *Bacillus subtilis*, *Staphylococcus aureus*, and *C. albicans* at concentrations as low as 25 mg/mL. Beyond its medicinal effects, chamomile extract has tremendous promise in functional food applications. Into food systems such as yogurt, herbal drinks, and fermented goods increases antioxidant stability, microbiological safety, shelf life, and sensory acceptability due to its natural scent, mild taste, and color qualities. Chamomile extract can work as a natural preservative, functional ingredient, and nutraceutical component, hence promoting the production of clean-label and health-conscious goods. However, the concentration and biological efficiency of chamomile bioactive components are defined by extraction procedures, solvent type, and processing conditions, all of which have an impact on stability and repeatability. Future study should concentrate on optimizing extraction processes, enhancing formulation stability, and standardizing chamomile extract usage in food systems. Overall, chamomile extract is a promising natural component for functional food innovation and nutraceutical development, with great potential to improve food quality, safety, and human health.

Abbreviations

Cet: ethanolic solution

CT80: tween 80

MIC: the minimum inhibitory concentration

ROS: reactive oxygen species

Declarations

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During the preparation of this work, the authors used the Quillbolt and perplexity AI to improve the language and readability of the paper, used Canva AI to generate Figure 1, and took full responsibility for the content of the publication.

Author contributions

SS: Resources, Writing—original draft. CR: Conceptualization, Writing—review & editing. WW: Supervision, Investigation. ZW: Visualization. All authors read and approved the submitted manuscript.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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