***Review Article***

**Recent Advances in Functional Dairy Products Enriched with Herbal Extracts: A Comprehensive Review**

**Abstract**

The worldwide functional food industry has grown at an unprecedented rate, with functional dairy products emerging as a prominent category due to its intrinsic nutritional value and consumer appeal. The incorporation of herbal extracts into dairy matrices is a ground-breaking strategy to developing health-promoting foods that combine traditional dairy nutrition with the medicinal qualities of bioactive plant chemicals. This comprehensive analysis looks at current breakthroughs in herbal-fortified dairy products, including their development, technological implications, nutritional benefits, and market possibilities. The investigation includes numerous herbal extracts, including turmeric, tulsi, ashwagandha, fenugreek, and moringa, as well as their inclusion into different dairy product categories, such as milk, yogurt, cheese, and frozen sweets. The review discusses the problems and prospects in this quickly changing industry, including as technological advancements in microencapsulation, consumer perception research, and regulatory considerations. The research reveals that herbal-enriched dairy products have significant promise for illness prevention, immune system strengthening, and overall health promotion, putting them at the forefront of the functional food future.

**Keywords:** Functional dairy products, herbal extracts, bioactive compounds, probiotic enhancement, microencapsulation, consumer acceptance, health benefits

**1. Introduction**

Functional foods, according to the International Food Information Council, are foods that give health advantages in addition to basic nutrition because they contain physiologically active components (Granato *et al.,* 2020). These products are intended to provide bioactive chemicals that improve physiological functioning, immunological responses, metabolic processes, and overall health (Kussmann *et al.,* 2023).

The functional food business has grown dramatically as consumers become more aware of the link between nutrition and health outcomes (Siro *et al.,* 2008). The global market was valued at USD 317.22 billion and is predicted to increase at a compound annual growth rate (CAGR) of 9.6% between 2024 and 2030 (Chhabra *et al.,* 2025). This expansion reflects the growing acknowledgment of food as medicine, as well as the increasing demand for items that promote health maintenance and disease prevention (Childs., 1997).

Functional dairy products are an important and quickly growing part of the functional food market, utilizing the intrinsic nutritional qualities of milk and dairy derivatives as transporters for bioactive chemicals (Halder *et al.,* 2021). Dairy products are inherently high in protein, essential amino acids, calcium, phosphorus, riboflavin, vitamin B12, and other minerals, making them excellent vehicles for functional component delivery (Warsewicz *et al.,* 2021).

**2. Rising Consumer Demand for Health-Promoting Foods**

The COVID-19 pandemic has advanced this tendency, increasing consumer interest on immune system support and preventive healthcare. Recently, there has been an increase in global interest in exploiting the functional and medicinal health attributes of herbs and spices to preserve and promote health, nutrition, and immunity, particularly during the Covid-19 pandemic (Djaoudene *et al.,* 2023).

Aging populations in wealthy countries are increasingly interested in items that promote healthy aging, cognitive function, and illness prevention (Tucker and Buranapin, 2001). The global functional food industry reflects this demand, with the Functional Dairy Products industry predicted to reach $64.1 billion by 2033, growing at a 4.5% CAGR between 2023 and 2033 (Jimenez-Ortega *et al.,* 2025).

Consumer preferences have shifted toward items made with natural ingredients, little processing, and sustainable manufacturing methods. The incorporation of herbal extracts into dairy products precisely matches these tastes, giving natural alternatives to synthetic chemicals while also delivering additional health benefits (Ghosh *et al.,* 2024).

**3 Significance of Herbal Extracts in Dairy Fortification**

The addition of herbal extracts to dairy products symbolizes a fusion of traditional herbal medicine and modern food technology, resulting in unique products that combine ancient wisdom with current scientific validation (Balkrishna *et al.,* 2024). This strategy has numerous benefits for both product development and consumer health, establishing herbal-fortified dairy products as a key advancement in functional food technology (Jaffar *et al.,* 2024).

Herbal extracts contain a variety of bioactive components such as polyphenols, flavonoids, essential oils, alkaloids, saponins, and other phytochemicals with various biological activity. These molecules can increase the nutritional value of dairy products while also providing natural preservation benefits, thereby lowering the need for synthetic preservatives and additives (Altemimi *et al.,* 2017). Herbal extracts' antioxidant qualities can prevent lipid oxidation and protein degradation while preserving product quality during storage, prolonging shelf life and minimizing food waste (Blasi and Cossignani, 2020).

Traditional Indian herbs such as turmeric, tulsi (holy basil), ashwagandha, fenugreek, and moringa have been widely explored for their therapeutic effects, and they hold great promise for dairy fortification. These herbs have numerous recognized health advantages, including anti-inflammatory, immunomodulatory, adaptogenic, and antioxidant qualities. Their combination with dairy products yields functional foods that can help with illness prevention, immune system support, and overall health maintenance (Ashok *et al.,* 2024).

**3.1 Functional Dairy Products: An Overview**

Functional dairy products are a sophisticated type of food that has been modified beyond its basic nutritional profile to give specific health benefits. These products are divided into numerous groups based on their functional components and intended health advantages (Granato *et al.,* 2010). Probiotic dairy products, fortified dairy products, and bioactive dairy products are the three main classes, each providing a different nutritional and therapeutic function.

Probiotic dairy products contain live beneficial bacteria that, when taken in sufficient quantities, provide health advantages to the host. These products often include Lactobacillus, Bifidobacterium, and other beneficial bacteria that promote digestive health, immunological function, and overall well-being (Jena and Choudhury, 2023). Numerous research have been conducted to determine a link between gut health and immunological function, as well as to explain how probiotics, prebiotics, and nutraceuticals alter the gut microbiota and immune function. Probiotic dairy products have been extensively studied for their medicinal potential, including benefits such as improved lactose tolerance, increased immunological response, and a lower risk of gastrointestinal infections (Kopp-Hoolihan, 2001).

Fortified dairy products contain specific nutrients, vitamins, minerals, or bioactive compounds that help to alleviate nutritional deficiencies or provide additional health advantages. Vitamin D and B12, calcium, iron, omega-3 fatty acids, and antioxidants are all common fortification additives (Shahidi and Ambigaipalan, 2016).

Bioactive dairy products contain bioactive chemicals that occur naturally or are added and give particular physiological benefits in addition to basic nutrition. Peptides, lipids, carbohydrates, and other substances can influence biological processes such blood pressure regulation, cholesterol metabolism, and immunological function (Ma *et al.,* 2023). The bioactive components in these products frequently synergize with the natural nutrients in dairy to increase their medicinal potential.

**3.2 Common Functional Dairy Examples**

The functional dairy product market includes a wide variety of products, each meant to treat a unique health condition or nutritional requirement. Probiotic yogurt is one of the most successful functional dairy products, combining the nutritional value of yogurt with the medicinal qualities of helpful bacteria (Sarkar, 2019). These products have been demonstrated to improve digestive health, boost immunological function, and promote general well-being by influencing gut microbiota composition and activity (Wan *et al.,* 2019).

Pearl millet (Pennisetum glaucum) is a versatile and nutritious grain that has great potential for increasing food security and human nutrition. Pearl millet is high in energy, dietary fiber, and vital elements like iron, magnesium, and phosphorus. It contains complex carbs with a low glycemic index, making it ideal for diabetics or anyone looking to control blood sugar levels. Furthermore, pearl millet is gluten-free, making it a feasible option for persons with celiac disease or gluten intolerance (Meena *et al.,* 2024).

DCBPRP is a spray-dried probiotic beverage powder made from maize flour, skimmed milk powder, and probiotic culture. The conventional approach was used to characterize the physicochemical (water activity, density, hygroscopicity, porosity, wettability, flowability, rehydration, degree of caking, and solubility) and morphological properties (XRD, TGA, and FTIR) (Meena *et al.,* 2025).

Lactiplantibacillus plantarum KMUDR7 isolated from "Makka ki Raab" has outstanding probiotic properties and could be used for product manufacture. Other strains, such as Lactobacillus delbrueckii subsp. bulgaricus KMUDR1 and Lacticaseibacillus rhamnosus KMUDR9, demonstrated good probiotic qualities, as have KMUDR14, -17, and -20(Meena *et al.,* 2022).

Omega-3 fortified milk has grown in popularity as a functional dairy product that addresses the common lack of essential fatty acids in modern diets. These products often contain EPA and DHA omega-3 fatty acids, which help with cardiovascular health, cognitive function, and inflammation regulation (Shahidi and Ambigaipalan, 2016). Milk fortification with omega-3 fatty acids offers consumers a straightforward and appealing option to enhance their consumption of these critical nutrients (Ganesan *et al.,* 2014).

Protein-enhanced dairy products have grown in favor among health-conscious consumers looking to boost protein intake for muscle building, weight loss, or sports performance (Padgaonkar, 2009). These products frequently include whey protein, casein, or plant-based proteins, which improve their nutritional profile while retaining the sensory properties of typical dairy products. These advantages include improved digestive health, increased immunological function, and maybe lower risk of some chronic diseases (Galarraga *et al.,* 2025).

**4 Herbal Extracts: A Source of Bioactive Compounds**

**4.1 Types of Herbal Extracts Commonly Used**

Herbal extracts are chosen for dairy fortification based on a variety of criteria, including their bioactive chemical profile, compatibility with dairy matrices, sensory qualities, and documented health advantages. Turmeric, tulsi (holy basil), ashwagandha, fenugreek, moringa, mint, and other traditional medicinal plants confirmed by scientific study are among the most often utilized herbal extracts in functional dairy products (Basu *et al.,* 2023).

Turmeric (Curcuma longa) is one of the most extensively researched and commonly utilized herbal extracts in functional food applications. Turmeric's principal bioactive ingredient, curcumin, has powerful anti-inflammatory, antioxidant, and antibacterial properties. Curcumin has been shown in studies to reduce inflammation, support immunological function, and perhaps lower the risk of chronic diseases like cardiovascular disease and some types of cancer (Razavi *et al.,* 2021).

Tulsi, often known as holy basil (Ocimum sanctum), is another highly appreciated botanical extract that has substantial traditional and scientific support. Sanctum-infused functional meals shown cognition boosting, adaptogenic, anti-obesity, gastroprotective, anti-inflammatory, hypoglycemic, and immune-modulatory characteristics (Thakur and Thapa, 2023). Ashwagandha (Withania somnifera) is a well-known adaptogen that has found popularity in functional food applications. The root extract contains withanolides, alkaloids, and other bioactive chemicals that help the body adapt to stress and promote general health. Ashwagandha (Singirala *et al.,* 2025).

Moringa (Moringa oleifera) has emerged as a superfood component due to its superior nutritional profile and bioactive chemical concentration. The leaves are high in vitamins, minerals, antioxidants, and phytochemicals, which promote immune function, give anti-inflammatory benefits, and help to maintain general health. Moringa extract can considerably increase the nutritious value of dairy products while also adding a natural green hue (Kaur *et al.,* 2023).

**4.2 Key Bioactive Compounds**

Herbal extracts in functional dairy products have medicinal potential due to their diverse bioactive component composition. Polyphenols, flavonoids, alkaloids, saponins, essential oils, and a variety of other phytochemicals all contribute distinct qualities to the finished product (Ali *et al.,* 2022).

Polyphenols are one of the most important types of bioactive chemicals found in plant extracts. These chemicals include phenolic acids, flavonoids, stilbenes, and lignans, which have strong antioxidant, anti-inflammatory, and antibacterial properties. Polyphenols can protect against oxidative stress, improve cardiovascular health, and possibly lower the risk of chronic diseases. Their addition into dairy products can greatly increase antioxidant capacity while also providing natural preservation benefits (Khan *et al.,* 2019).

Flavonoids are a wide class of polyphenols that includes chemicals like quercetin, kaempferol, catechins, and anthocyanins. These chemicals are responsible for many of the health advantages associated with herbal extracts, such as their anti-inflammatory, antibacterial, and cardioprotective effects. Flavonoids can interact with dairy proteins and lipids, thereby increasing their bioavailability and therapeutic efficacy (Karak, 2019).

**4.3 Health Benefits**

Herbal extracts in functional dairy products provide numerous health benefits, including antioxidant, anti-inflammatory, antibacterial, and immunomodulatory properties (Paswan *et al.,* 2021). These advantages are mostly due to the wide range of bioactive chemicals found in herbal extracts, which work together to give overall health support. The combination of herbal bioactive substances and the inherent nutritional benefits of dairy results in products with greater therapeutic potential than either component alone (Kanekanian, 2014).

Antioxidant properties are one of the most important health benefits of herbal extracts in dairy products. The anti-inflammatory capabilities of herbal extracts are especially important for treating chronic inflammatory diseases that underpin many current health problems (Yatoo *et al.,* 2018). Curcumin, rosmarinic acid, and other flavonoids can help modify inflammatory pathways, lower inflammatory indicators, and boost the body's natural anti-inflammatory responses.

The antimicrobial properties of herbal extracts offer both health benefits and technological advantages in dairy product applications (Aziz *et al.,* 2023). Herbal extracts' immunomodulatory actions can aid in the maintenance of healthy immune function via a variety of methods. These substances can improve immune cell activity, promote the development of helpful antibodies, and modify immunological responses in order to maintain optimal balance. Alkaloids are nitrogen-containing chemicals that frequently exhibit strong pharmacological activity (Bribi, 2018).

Table 1. Functional foods components with physiologic effects

|  |  |
| --- | --- |
| **Compound** | **Food sources** |
| Allyl sulfur | Garlic, onions, leeks, chives |
| Carotenoids | Fruits, vegetables |
| Flavonoids | Fruits, vegetables, grains, nuts |
| Indoles | Cruciferous vegetables |
| Isothiocyanates | Cruciferous vegetables |
| Inulin/Oligofructose | Bananas, wheat, chicory, garlic |

**5. Incorporation of Herbal Extracts into Dairy Products**

**5.1 Types of Dairy Products Fortified with Herbs**

Successful incorporation of herbal extracts into dairy products necessitates careful consideration of product qualities, processing conditions, and consumer preferences. Different dairy product categories present distinct potential and problems for herbal fortification, each necessitating distinctive approaches to enhance the integration of bioactive ingredients while maintaining product quality and sensory appeal.

**5.1.1 Milk and Milk Beverages**

Milk and milk-based beverages are suitable vehicles for herbal enrichment because to their liquid consistency, ease of absorption, and consumer familiarity. Fortified milk products including turmeric (golden milk), tulsi, ginger, and ashwagandha milk have grown in favor due to their therapeutic effects, which include immune boost and stress alleviation (Ashok *et al.,* 2024).

Powders, liquid extracts, and encapsulated forms are some examples of herbal integration methods. To maintain milk quality and bioactive stability, processing factors such as temperature, pH, and homogenization pressure must be considered. Furthermore, these functional beverages can be tailored to certain demographics or health objectives, such as stress reduction or immunological support (Gupta *et al.,* 2023).

**5.1.2 Yogurt**

Yogurt provides a great fermented matrix for herbal fortification. The acidic environment promotes the stability and bioavailability of herbal components (Mehra *et al.,* 2022). The combination of herbal bioactives and probiotics can enhance therapeutic effects such as digestive health and inflammation reduction (Curro *et al.,* 2017). Herbal yogurts can be designed to address a variety of health concerns, such as turmeric and ginger for anti-inflammatory properties and ashwagandha for stress treatment. However, flavor and texture must be improved, as some plant ingredients might add bitterness or astringency. Natural sweeteners and fruit tastes are frequently utilized to increase sensory appeal (Dwivedi, 2022).

Maize is one of the very important cereals which contains major nutrients, carbohydrates, proteins, vitamins, minerals, and various other constituents like β-glucan, oligosaccharides, and resistant starch. Maize contains various bioactive components like phenolic acids, flavonoids, carotenoids, and phytosterols. These effectively prevent and cure diseases such as night blindness, agerelated disorders, cardiovascular and neural disorders, and colon cancer (Meena *et al.,* 2022)

Meena, K. K., Taneja, N. K., Jain, D., Ojha, A., Saravanan, C., & Mudgil, D. (2022). Bioactive components and health benefits of maize-based fermented foods: A review. *Biointerface Research in Applied Chemistry*, *13*(4), 338.

Probiotic strained yogurt dish made with toasted pearl millet flour and Hibiscus rosa-sinensis extract. The components (pearl millet: 2.5-8%, hibiscus: 2.5-8%, and sugar: 25-45%) were optimized for probiotic viability, lactic acidity, sensory qualities, and acceptance using Design Expert software. The optimal formulation (pearl millet: 4.86%, Hibiscus: 4.4%, and sugar: 29.47%) demonstrated a probiotic viability of 7.53 ± 0.33 log10 CFU g−1, above the necessary threshold (Joshi *et al.,* 2025).

**5.1.3 Cheese and Paneer**

Cheese and paneer contain a rich fat and protein matrix that helps to stabilize and protect herbal components. Paneer's mild flavor and little processing allow it to accommodate herbs without affecting texture or palatability, and it successfully preserves heat-sensitive components (Singh et al. 1982).

Herbs can be mixed into cheeses during the curdling process, added to the milk beforehand, or applied to the surface. Herbal cheeses not only benefit from the health benefits of plant ingredients, but they also have better flavor and antibacterial characteristics. The effect of herbs on microbial activity during cheese ripening must be carefully controlled to avoid unwanted fermentation alterations (Ritota and Manzi, 2020).

**5.1.4 Ice Creams**

Herbal-fortified ice cream combines enjoyment and wellbeing. The chilly environment protects heat-sensitive molecules, while the fat-rich matrix improves the delivery of lipophilic bioactives like curcumin. Ice cream infused with turmeric, moringa, or adaptogenic herbs appeals to health-conscious consumers looking for functional treats (Poonia, 2020).

However, formulation must take into account the effects of herbs on freezing behavior and texture. Stabilizers and emulsifiers are frequently needed. Furthermore, disguising herbal harshness with sweeteners and complimentary flavors increases consumer pleasure in the luxury ice cream market (McDonald, 2017).

**5.1.5 Butter and Ghee**

Butter and ghee, with their high fat content, become good transporters for fat-soluble plant components. Their usage in Ayurvedic medicine provides the foundation for modern applications. Herbs can be infused while heating, incorporated into oils, or added in powdered form. Ghee enhanced with turmeric has anti-inflammatory properties, whilst tulsi-infused butter boosts immunity (Mehram *et al.,* 2016).

**5.2 Methods of Incorporation**

The successful inclusion of herbal extracts into dairy products necessitates careful consideration of acceptable methods that optimize bioactive ingredient delivery while maintaining product quality, stability, and customer appeal. The technique of inclusion is determined by a variety of criteria, including the type of the herbal extract, the target dairy product, processing needs, and desired shelf life.

**5.2.1 Direct Infusion/Extraction**

Direct infusion is a simple and popular method for adding herbal solutions or infusing herbs directly during processing. It provides control over bioactive concentration and even distribution in dairy matrices (Bellary and Rastogi, 2016). Herbs can be added to milk before or after pasteurization, and yogurt before fermentation to allow for probiotic interaction. Its benefits include low cost and simplicity, but it also faces potential changes in flavor, color, and stability (Mehra *et al.,* 2022).

**5.2.2 Microencapsulation of Herbal Compounds**

Microencapsulation technology is a sophisticated method for adding herbal extracts into dairy products, providing higher stability, controlled release, and increased bioavailability of bioactive chemicals (Mehta *et al.,* 2022). Yogurt is a popular dairy product due to its unique flavor and health-promoting properties. Nonetheless, yogurt has been enriched with several nutrients. This method encapsulates herbal chemicals within protective matrices that safeguard them from environmental causes while allowing for their release under certain conditions (Wazzan *et al.,* 2024).

**Spray drying**, common for powdered herbal extracts, enhancing shelf life and handling (Ghosh *et al.,* 2017). Microencapsulation drying procedures frequently include freeze-drying and spray-drying. Freeze-drying has been the usual drying procedure for encapsulation and manufacture of bacterial cultures in dried form; nevertheless, it has significant limitations, such as low production yield and extended drying time(Meena *et al.,* 2023).

Coacervation is the process of creating microcapsules containing plant extracts by separating the liquid phases. This approach is very beneficial for encapsulating oil-soluble chemicals, as it offers excellent protection against oxidation and degradation. The resultant microcapsules can be included into dairy products without significantly altering sensory properties (Carvalho *et al.,* 2022).

**5.2.3 Use of Herbal Powders vs. Herbal Extracts**

The choice between powders and extracts depends on processing compatibility, cost, bioactivity, and sensory impact.

Herbal powders preserve the entire plant matrix, providing fiber, minerals, and overall nutrition, but they may change texture or flavor (Aguilera, 2019).

Herbal extracts are more concentrated and easier to include into smooth dairy products, however some plant ingredients may be lost during processing (El-Aziz *et al.,* 2023a).

Powders are often less expensive and more stable, whereas extracts have more bioactivity and are easier to standardize. Sensory evaluation is important since powders might have a greater impact on flavor and texture than extracts (El-Aziz *et al.,* 2023b).

**6. Technological Implications of Herbal Fortification**

**6.1 Impact on Physico-Chemical Properties**

The addition of herbal extracts to dairy products can drastically alter their physicochemical qualities, such as pH, moisture content, fat content, protein structure, and textural characteristics. The interaction of herbal substances and dairy components can produce both positive and negative effects, which must be carefully handled during product creation.

pH modification is one of the most significant physicochemical changes that can occur when herbal extracts are added to dairy products. Many herbal extracts have naturally acidic or basic properties, and their addition might change the pH of the dairy matrix, thereby influencing protein stability, microbial development, and overall product qualities. For example, including citrus-based herbal extracts can drastically lower the pH of milk-based products, potentially inducing protein precipitation or interfering with the action of beneficial bacteria in fermented goods (Rashidinejad *et al.,* 2022).

When herbal extracts are included into dairy products, moisture content might change, especially when liquid extracts are used or herbs impact the dairy matrix's water-holding capacity. Changes in moisture content can affect product texture, shelf life, and microbiological stability. Some herbal components may function as humectants, boosting water retention, whereas others may have dehydrating effects, affecting product quality (Wazzan, 2024).

The addition of herbal extracts, particularly those containing lipophilic chemicals or essential oils, can have an effect on fat content and distribution. The combination between herbal lipids and dairy fats can affect the melting, texture, and taste release properties of butter, cheese, and ice cream. Understanding these interactions is critical for retaining optimal product properties while increasing the inclusion of beneficial herbal ingredients (Kulshrestha *et al.,* 2008).

**6.2 Sensory Characteristics**

The sensory features of herbal-fortified dairy products are important variables in determining customer acceptance and commercial success. The use of herbal extracts can have a major impact on flavor, color, scent, and texture, necessitating careful optimization to produce products that are both functional and appealing to customers.

Flavor alterations have the greatest immediate sensory impact of herbal fortification, with the potential for both good and negative effects on customer acceptability. Many plant extracts have different flavors, which can range from pleasant and aromatic to bitter and astringent. Understanding the flavor profiles of various herbs and selecting combinations that compliment rather than compete with the natural flavor of dairy products is critical for successful flavor integration (Cashman *et al.,* 2024).

Color changes caused by herbal fortification can be both beneficial and troublesome for product development. Natural herbal colors can provide visually appealing messages to customers about health advantages and natural components (Thakur *et al.,* 2011).

Texture alterations caused by herbal fortification can have a substantial impact on consumer approval, especially in goods with predicted texture features. Herbal powders can add grittiness or impact the smoothness of milk and yogurt, whereas herbal extracts can change the viscosity, gel strength, or mouthfeel of many dairy products (Granato *et al.,* 2018).

**6.3 Shelf-Life Enhancement**

One of the key technological advantages of herbal fortification in dairy products is the possibility for increased shelf life due to the inherent antioxidant and antibacterial characteristics of herbal components. This natural preservation effect can reduce the need for synthetic preservatives while increasing product freshness and safety, benefiting both businesses and consumers. Herbal extracts' capacity to suppress lipid oxidation, protein breakdown, and microbiological development makes them useful functional additives for increasing product stability (Teshome *et al.,* 2022).

Studies on herbal-fortified butter and ghee have shown that adding turmeric, rosemary, and other antioxidant-rich herbs can increase shelf life by several weeks over unfortified goods. The efficiency of various plants as natural antioxidants varies greatly, with certain herbs offering more strong protection than others (Paswan *et al.,* 2021).

The antimicrobial activities of herbal extracts can help to extend shelf life by suppressing the growth of spoilage bacteria, yeasts, and molds. Many herbal substances have broad-spectrum antibacterial properties, which can help prevent microbial contamination and growth during storage. This antibacterial action can be especially useful in fermented dairy products, where controlling unwanted microbes is critical for maintaining product quality and safety (Barak and Mudgil, 2022).

**6.4 Challenges in Processing and Stability**

Despite the obvious advantages of herbal fortification, several technological hurdles must be overcome to ensure effective product development and commercialization. These obstacles include oxidation of sensitive compounds, off-flavor development, consistency issues, and ensuring the stability of both herbal compounds and dairy components during processing and storage.

Oxidation is one of the most major obstacles in keeping herbal ingredients stable in dairy products. Many therapeutic chemicals in herbal extracts are extremely sensitive to air, light, and heat, leaving them susceptible to deterioration during processing and storage (Dhulipalla *et al.,* 2023).

To prevent oxidation, manufacturing characteristics such as inert atmospheres, low oxygen packaging, and temperature control must be carefully considered. The use of appropriate antioxidants and stabilizers can help safeguard sensitive chemicals, while optimizing processing conditions can reduce oxidative stress (Musakhanian *et al.,* 2022).

Bitterness and astringency development are two major sensory problems related with herbal fortification. Many medicinal components found in plant extracts, including polyphenols and alkaloids, can produce bitter or astringent flavors that consumers may dislike. The intensity of these flavors frequently rises with storage, perhaps rendering items less appealing over time (Lemieux and Simard, 1992).

Physical stability issues may include precipitation, phase separation, or texture changes when herbal substances combine with dairy components. Some herbal components may be incompatible with certain dairy proteins or undergo chemical changes that impair product stability (Sikorski *et al.,* 2007).

**7. Nutritional and Therapeutic Benefits of Herbal-Enriched Dairy Products**

**7.1 Improved Nutritional Profiles**

The addition of herbal extracts to dairy products can greatly improve their nutritional profiles by raising amounts of vitamins, minerals, antioxidants, and other beneficial substances. This nutritional enhancement results in products that deliver more health advantages than traditional dairy products while retaining the familiar taste and texture that customers anticipate (Mehwish *et al.,* 2023).

One of the most notable nutritional benefits of herbal fortification is an increase in antioxidant content. Many herbal extracts contain polyphenols, flavonoids, vitamin C, vitamin E, and other antioxidant components that can protect against oxidative stress and lower the risk of chronic diseases (Vishwakarma *et al.,* 2022).

Herbal extracts that are naturally high in vitamins and minerals can be used to boost their levels. Moringa extract is extremely high in vitamin A, vitamin C, iron, and calcium, making it an ideal fortification additive for increasing the nutritional content of dairy products (Oyeyinka and Oyeyinka, 2018).

The combination of herbal vitamins and minerals with those naturally found in dairy products can result in nutritionally complete products that satisfy many dietary needs at once. This comprehensive nutritional approach is especially beneficial for populations at risk of nutrient deficiencies, such as youngsters, the elderly, and those on restrictive diets (Shlisky *et al.,* 2017).

**7.2 Studies Linking Herbal Dairy Products to Disease Prevention**

Numerous studies in the scientific literature show that herbal-enriched dairy products have the ability to prevent disease and improve health. These studies provide important evidence for the creation and use of functional dairy products as part of a balanced diet. The study includes a variety of investigations, such as in vitro tests, animal studies, and human clinical trials, all of which help us understand the therapeutic potential of these drugs (Epstein *et al.,* 2010).

Cancer prevention is one of the most important areas of research for herb-enriched dairy products. Many herbal substances have anticancer effects that can help prevent the onset and progression of certain cancers (Abdulridha *et al.,* 2020).

Clinical research has shown that consuming herbal-fortified dairy products can help improve a variety of cardiovascular risk factors, including blood pressure, cholesterol levels, and inflammatory markers (Giosue *et al.,* 2022). The effectiveness of these products appears to be dependent on the herbs utilized, the concentration of bioactive chemicals, and the length of ingestion. Long-term research are required to identify the best formulations and intake patterns for maximal cardiovascular protection (Biesalski *et al.,* 2009).

**8. Consumer Perception and Market Trends**

**8.1 Consumer Acceptance Studies**

Consumer approval is critical for the success of herbal-enriched dairy products. Sensory qualities like as flavor, scent, and texture have a substantial influence on purchasing decisions. Products with mild, complimentary herbal flavors are chosen over those with strong, medicinal notes. Consumer acquaintance with specific herbs improves acceptance (Fiorentini *et al.,* 2020).

Health awareness is important; informed consumers are more willing to try herbal products, even if they come with sensory drawbacks. Educational activities and health claims can help increase acceptance (Mena *et al.,* 2024). Demographics such as age, income, education, and cultural background influence customer opinions. Younger, healthier, and higher-income groups are more likely to be responsive (Eze and Mena, 2024).

**8.2 Market Growth Predictions and Opportunities**

The herbal-enriched dairy market is quickly expanding as people become more health conscious, interested in natural foods, and have more discretionary means. Global trends indicate significant growth, particularly in the Asia-Pacific area, where traditional herb use aligns with current health demands (Zamani *et al.,* 2025). Developed regions, such as North America and Europe, prefer expensive, scientifically supported products, whereas emerging markets prefer affordable solutions that combine traditional and modern nutrition (Enthoven and Broeck, 2021).

Innovation is propelling growth, with prospects for new product development, individualized nutrition, and novel delivery technologies. The organic and clean-label segments are expanding, making room for premium, environmentally responsible options. E-commerce and direct-to-consumer channels are critical for reaching niche and premium markets (Peter, 2025).

Targeted products that target health issues such as diabetes or immunological support have great potential. Technological breakthroughs in extraction, microencapsulation, and digital marketing are allowing for more efficient product development and consumer involvement. Collaboration among dairy producers, herbal suppliers, and research institutes is critical for health claim invention and validation, which increases consumer trust and accelerates market penetration (Obahiagbon and Ogwu, 2023).

**9. Global trends of the functional foods market**

The global market of functional foods in recent years is growing as is evident in Fig. 1. Steady real term growth of 7.2% is expected to continue to 2017 (Euromonitor, 2013).

Fig. 1 : Global trends of the functional foods market (Euromonitor, 2013).

## 9.1 Future Outlook for Herbal-Fortified Functional Dairy Products

The future of herbal-fortified functional dairy products appears to be quite promising, with a number of convergent trends driving ongoing expansion and innovation. Technological advances in extraction processes, microencapsulation techniques, and analytical procedures will allow for the creation of more effective and stable pharmaceuticals with higher bioavailability and therapeutic efficacy (Mehta *et al.,* 2022). The introduction of personalized nutrition concepts opens up possibilities for designing targeted products based on specific health issues and nutritional requirements (Verma *et al.,* 2018).

Market development into emerging nations, combined with rising global health consciousness and an aging population, will fuel demand for functional dairy products that promote healthy aging and illness prevention (Halder *et al.,* 2021).

However, fulfilling this potential involves overcoming existing hurdles such as standardizing herbal extract quality, developing evidence-based dose recommendations, and conducting rigorous clinical validation of health claims (Mukherjee *et al.,* 2022). Industry standards, regulatory frameworks, and quality assurance methods will be required to ensure customer safety and product efficacy (Kabir *et al.,* 2024).

The future success of herbal-enriched dairy products is dependent on sustained investment in R&D, which fosters collaboration among industry partners, academic institutions, and regulatory bodies. The development of strong scientific evidence through well-designed clinical trials will be critical for supporting health claims and winning consumer trust (Tunis et al. 2003). As these issues are overcome, herbal-fortified functional dairy products are poised to become key components of preventive healthcare initiatives, providing consumers with easy access to therapeutic nutrition in familiar and appealing food formats (Peckenpaugh *et al.,* 2009).

# Conclusion

The incorporation of herbal extracts into dairy products marks a significant step forward in functional food development, integrating ancient therapeutic expertise with modern food technology. These products include improved nutritional profiles, natural preservation benefits, and demonstrated health-promoting qualities such as antioxidant, anti-inflammatory, and immunomodulatory activities. While technological obstacles like as flavor optimization, stability maintenance, and standardization persist, novel technologies such as microencapsulation and sophisticated processing techniques show promise for overcoming these barriers. Growing consumer awareness of health and wellness, combined with rising demand for natural functional foods, places herbal-fortified dairy products as a rapidly growing market category. The convergence of scientific validation, technical innovation, and consumer acceptance indicates that herbal-enriched dairy products will become increasingly essential in preventive healthcare and functional nutrition. Future success is contingent on ongoing research, regulatory framework development, and industry partnership to set quality standards and evidence-based health claims. These products offer a viable path to accessible, therapeutic nutrition that combines ancient knowledge with modern food science to improve public health outcomes.

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