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Application of Bioactives from Herbs and Spices for Improving the Functionality and Shelf Life of Dairy Products-A Review

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Abstract: Historically, humans are aware of the positive potential of different herbs and spices to prevent pathogenic and spoilage microflora. Herbal foods are valued for their antimicrobial, antioxidant, nutritional, and medicinal properties. Due to the current corona pandemic, people worldwide have become more conscious about their health. Herbs and spices have been found to be beneficial to one's health. Milk is a highly perishable commodity. Many dairy products deteriorate within days of their production. To ensure that processed dairy products remain safe and uncontaminated, the use of the natural preservative is necessary; therefore, herbs and spices added in dairy products can give value-added products with prolonged shelf life.

Keywords: bioactives; herbs; spices; dairy; preservative; antimicrobial; antioxidant.

1. Introduction

Spice and herbs have been an important part of our diet for centuries. They have been used for many years to improve the taste, color, and aroma of food products [1-5]. Apart from taste enhancement, herbs and spices are also recognized for their preservative effect and possess antioxidant, anti-inflammatory, antitumorigenic, anticarcinogenic properties [6-16]. In recent years, many people have shifted to herbal lifestyles to maintain their health. Due to the current corona pandemic, people worldwide have become more conscious about their health, and an increased interest in the inclusion of herbs and spices in the diet has been observed owing to their functional and health attributes and boosting immunity. Herbs and spices contain certain bioactive compounds which play a prime role in the growth and development of humans and have been shown to provide health benefits. Some examples of bioactive found in herbs and spices are polyphenols, carotenoids, and nonflavonoid phenolics. The effect of these bioactive components on diseases such as cardiovascular disease, diabetes, hypertension, obesity, and osteoporosis has been well documented [17-20]. India is regarded as the "Botanical Garden of the World" and "Land of spices" as it is the world's largest producer of traditional medicinal herbs [21]. India is the world's largest milk-producing country and utilizes significant quantities of liquid milk to manufacture various traditional dairy products. Many dairy products are highly perishable. Because dairy products are now frequently sold in regions far from their manufacturing plants worldwide, there is a need to provide these products

with longer shelf life. To ensure that processed foods remain safe and uncontaminated, natural preservatives are used. Hence, the addition of herbs and spices to food and dairy products seems to be a good alternative to chemical preservatives to improve the functionality and prolong the shelf life of dairy products.

2. Classification of Herbs and Spices

According to their usage, the herbs can be classified into four classes- Aromatic herbs, Culinary herbs, Medicinal herbs, and Ornamental herbs. Based on the active components present in them, the herbs can be categorized into five categories- Aromatic (volatile oils), Astringents (tannins), Bitter (phenol compounds, saponins, and alkaloids), Mucilaginous (polysaccharides), and Nutritive (foodstuff). Based on their different flavor and color, the herbs and spices can be categorized into various groups- aromatic herbs (basil, bay leaf, garlic, marjoram, thyme, onion, and shallot), astringent herbs (bayberry, peppermint, red sage, red raspberry), aromatic spices (cinnamon, clove, cumin, dill fennel, nutmeg, mace,), hot flavor (black & white peppers, Cayenne pepper, chilies, mustard) and mild flavor (coriander, paprika), color (turmeric), paprika (red and orange), saffron and herbaceous (sage, rosemary) or based on their taste – bitter, spicy, sour, sweet [22]. Based on the period of life, herbs can be classified into- Annual herbs, Biennial herbs, and Perennial herbs. The major bioactive constituents and potential beneficial effects of the prominent spices and herbs are presented in Table 1.

Table 1. Bioactive constituent and beneficial effects of major spices and herbs [23-42].

Spices & Herbs	Botanical name	Major Bioactive Constituent	Potential Beneficial effects	Reference
Cloves	*Syzygium aromaticum*	Eugenol, gallic acid, flavonoids, phenolic acids	Antioxidant and antimicrobial	[23]
Cinnamon	*Cinnamomum zeylanicum*	Cinnamaldehyde and trans-cinnamaldehyde	Antioxidant, anti-inflammatory, antidiabetic, antimicrobial, anticancer, lipid-lowering, and cardiovascular-disease-lowering	[24]
Coriander	*Coriandrum sativum L.*	Linalool, α-pinene, γ terpenene, camphor and limonene	Antimicrobial, antioxidant, antidiabetic, antimutagenic and antidepressant	[25,26]
Saffron	*Crocus sativus L*	Crocin, crocetin, safranal, and picrocrocin	Antioxidant, antiinflammatory, anticonvulsant, satiating, antihistamine	[27]
Turmeric	*Curcuma longa L.*	Curcumin, demethoxycurcumin and bisdemetoxicurcumin	antioxidant, anti-inflammatory, antibacterial, antifungal, antidiabetic	[28]
Ginger	*Zingiber officinale*	Gingerols, shogaols, paradols, quercetin, zingerone, gingerenone-A, and 6-dehydrogingerdione, terpene compounds	Antioxidant, anti-inflammatory, antimicrobial, cardiovascular protection, antiobesity activity, antidiabetic	[29]
Curry	*Murraya koenigii*	Gallic acid, and flavonoids (myricetin, epicatechin, and quercetin)	Hypoglycemic and antidiabetic, hepatoprotective, anticancer, antibacterial, antioxidant, chemo modulatory, immunomodulatory, antidiarrheal, and anti-inflammatory	[30]
Fenugreek	*Trigonella foenum-graecum*	Sesquiterpenes, aromatic aldehydes, terpenes	Anticarcinogenic, antidiabetic, antioxidant, hypocholesterolemic, anti-lithogenic antimicrobial	[31]
Black pepper	*Piper nigrum*	Camphene, isoquercetin, limonene, piperine, pinene, terpenes, piperidine, sarmentine	Antioxidant, anti-inflammatory, anti-microbial	[32]
Basil	*Ocimum basilicum L.*	Apigenin, catechins, quercetin, rutin, kaempferol,	Anti-oxidant and anti-microbial	[33]

Spices & Herbs	Botanical name	Major Bioactive Constituent	Potential Beneficial effects	Reference
		anthocyanins, eugenol, limonene, terpinene, carvacrol, geraniol, menthol, safrole, tannins, ursolic, p-coumaric, rosmarinic acids		
Dill	*Anethum graveolens L*	Quercetin, kaempferol, myricetin, catechins, isorhamnetin, carvone, limonene	Antimicrobial, antihyperlipidemic, and antihypercholesterolemic	[34]
Garlic	*Allium sativum L.*	Allicin, alliin, diallyl sulfide, diallyl disulfide, diallyl trisulfide, ajoene, and S-allyl-cysteine	Antioxidant, anti-inflammatory, antimicrobial, immune modulation, cardiovascular protection, anticancer	[35]
Rosemary	*Rosmarinus officinalis L.*	caffeic acid, rosmarinic acid, luteolin-7-O glucoside, carnosic acid, ursolic acid, and carnosol, di- and triterpenes	Anti-oxidant, anti-inflammatory, anti-microbial, cardiovascular protection	[36]
Sage	*Salvia officinalis L*	Geraniol, pinene, limonene, carnosol, saponin, catechins, apigenin, luteolin, rosmarinic, carnosine, vanillic, caffeic acids	Anticancer, antiinflammatory, antioxidant, antimicrobial	[37]
Shatavari	*Asparagus racemosus*	Steroidal saponins, alkaloids, flavonoids, dihydrophenanthrene derivatives, furan derivatives	Antioxidant, antibacterial, Cardioprotective effect, Anti-cancer, Antidepressant	[38]
Ashwagandha	*Withania somnifera*	Glycowithanolides, alkaloids, steroidal compounds such as ergostane type steroidal lactones, withaferin A, withanolides A–Y, withasomniferin A, withasomnidienone, withasomnierose A–C, withanone	Antioxidant, antibacterial, Anti-cancer, cardiovascular protection	[39]
Black Cumin	*Nigella sativa L*	Thymoquinone, thymol, and α hederin	Antioxidant, antibacterial, Anti-carcinogenic, anti-hypertensive, anti-inflammatory, anti-diabetic	[40]
Thyme	*Thymus vulgaris L.*	carvacrol, thymol, and p-cymene, α-pinene, 1,8-cineole, camphor, linalool, and borneol	Antioxidant, antimicrobial	[41]
Oregano	*Origanum vulgare L.*	γ-terpinene, p-cymene, thymol and carvacrol methyl ethers, thymol and carvacrol acetate	Antioxidant, antimicrobial, antiinflammatory, antiviral, antispasmodic, antiproliferative and neuroprotective	[42]

3. Functional Properties of Herbs & Spices

The consumption of herbs and spices has been shown to provide certain health benefits. Herbal foods are valued for their antimicrobial, antioxidant, nutritional, and medicinal properties. Some bioactive constituents of herbs and spices include carotenoids, coumarins, curcumins, flavonoids, lignans, phenolic acid phthalides, polyphenols, saponins, sulfides, terpenoids, and plant sterols. These bioactive components have been shown to prevent the occurrence of degenerative diseases such as cancer, cardiovascular diseases, diabetes, and obesity [21]. The main functional properties of the herbs and spices are discussed hereunder.

3.1. Antioxidant properties.

The antioxidants are the compounds that inhibit or prevent oxidation in food products. These can be natural or synthetic in origin. Examples of commonly used synthetic antioxidants include butyl hydroxyanisole (BHA) or butylhydroxytoluene (BHT). Their addition to the food products in measured proportion prevents the degradation of carbohydrates, lipids, and proteins. However, these synthetic antioxidants decompose at elevated temperatures and cause serious health concerns.

Contrary to this, herbs and spices contain high amounts of bioactive components which possess natural antioxidants. When added to food products, these natural antioxidants prevent food spoilage by delaying the development of rancidity. Bioactive molecules from spices and herbs act mostly as free radical scavengers by donating a hydrogen atom to free radicals. These natural antioxidants obtained from herbs are in great demand nowadays among health-conscious consumers due to synthetic antioxidants' safety issues.

Because of synthetic antioxidants' toxicity and harmful effects, herbal phytochemical-based natural antioxidants are in great demand among consumers. Phenolic compounds have demonstrated antioxidant activity in herbs [43]. They play the role of antioxidants by scavenging the free radicals and protecting the body against different ailments such as asthma, cancer, cardiovascular disease, diabetes, and infections. A lot many researchers have worked on the different anticancer effects of herbs through mechanisms such as increasing endogenous cancer-preventive enzymes, inhibiting nucleic acid synthesis, protecting DNA from free radical-induced structural damage, induction of apoptosis, and inhibiting tumor growth; while the cardiovascular protective effects of herbs are due to their anti-thrombotic and anti-platelet aggregation activity and anti-diabetes activity. Recently, different studies have revealed that the inclusion of polyphenol-rich herbs in the diet can prevent the occurrence of cardiovascular disease, reduce the growth of cancer cells, and exhibit antidiabetic effects [44].

3.2. Antimicrobial properties.

The herbs have been shown to possess antimicrobial properties, which can be effectively used to prevent the growth of spoilage causing micro-organisms in dairy products and enhance the shelf life and stability of dairy products. Several herbs and spices exert antimicrobial activity against different bacteria, yeasts, and molds [45,46]. The first scientific study on the preservative effects of spices was conducted in the 1880s and showed the antimicrobial effect of cinnamon oil against *Bacillus anthracis* spores [47]. Different types of spices have been categorized based on their antimicrobial activities into strong (cinnamon, clove, mustard), medium (allspice, bay leaf, caraway, coriander, cumin, oregano, rosemary, sage, thyme), and weak (black pepper, red pepper, ginger) [48]. The active components present in the herbs and spices include phenols, alcohols, aldehydes, ethers, ketones, and hydrocarbons. Allicin, isolated from garlic, can restrict the growth of both gram-negative and gram-positive bacteria. The main antimicrobial compounds present in herbs are phenolic compounds such as oleuropein, tea catechins, ellagic acid, ferulic acid, and coumaric acid. These can effectively replace the artificial antimicrobial agents in food products. These phenolic compounds have been found to be effective in inhibiting some common pathogenic bacteria such as *Salmonella enteritidis, Staphylococcus aureus*, and *Listeria monocytogenes* [49]. Further, the essential oils present in herbs also contain certain bioactive compounds that show antimicrobial properties

and anticancer, anti-inflammatory, antioxidant, and other beneficial health-promoting aspects [50].

4. Application of Herbs and Spices in Dairy Products

4.1. Ghee (clarified butter).

Ghee, a type of clarified butterfat, has been produced and utilized in India from ancient times. Shingala *et al.*[51] evaluated the cholesterol-lowering property of ajwain, betel, and curry leaves added @ 0.5% in ghee. Their addition to ghee lowered cholesterol content by 4.63%, 10.53%, and 4.50% for ajwain, betel, and curry leaves. They concluded that the herbs could be used to develop low cholesterol ghee. Deshmukh *et al.* [52] carried out studies on the herbal ghee prepared with ethanolic extract of *Asparagus racemosus* (*Shatavari*) and *Withania somnifera* (*Ashwagandha*). The addition of these herbs into ghee at different concentrations increased the phytosterol of the ghee. They suggested that the ethanolic extract of *Asparagus racemosus* and *Withania somnifera* could be used as an antioxidant and enhance the phytosterol content in ghee. Arjuna ghee prepared by incorporating functional attributes of *Terminalia arjuna* has been found to possess beneficial effects against cardiovascular diseases, is more stable towards oxidative degradation than control ghee, and is sensorially acceptable [53]. Further, adding alcoholic and aqueous extracts of Satavari herb to ghee increases its oxidative stability [54]. Moreover, the addition of coriander extract to ghee improves the antioxidant activity of ghee and offers better oxidative stability to ghee during storage compared to control ghee [55]. Further, there is an increasing trend to use herbal extracts of sage (*Salvia officinalis*), and rosemary (*Rosmarinus officinalis*) to stabilize fat-rich dairy foods like butter, butter oil, ghee, etc. These extracts have greater antioxidant activity than synthetic antioxidants like BHA or BHT [56].

4.2. Ice cream.

Ice cream is widely consumed worldwide but is devoid of natural antioxidants, colors, and polyphenols. Therefore, there is scope for improving the nutritional value of ice cream by incorporating natural bioactive from herbs and spices into it. The antioxidant activity of herbal ice cream prepared by the addition of varying concentrations of selected medicinal herbs can be determined using DPPH (2,2-diphenyl-1-picrylhydrazyl) testing. Ali *et al*. [57] prepared herbal ice cream by including herbs powder (asparagus, green asparagus, salep orchid, and pomegranate) in the ice cream. The addition of herbs (@4%) increased the antioxidant properties of the ice cream significantly, as indicated by DPPH and FRAP activity. Similarly, other researchers [58] have also reported that the antioxidant activity and total phenolic compounds of ice cream increase upon the addition of herbs.

Gremski *et al*. [59] prepared antioxidants-rich ice cream containing herbal extracts and Fructo-oligosaccharides of *Ilex paraguariensis, Melissa officinalis,* and *Cymbopogon citratus*. The extract was found to possess antidiabetic, antihypertensive, and antioxidant activity using in vitro protocols and overall increased the total phenolics and antioxidant activity of developed herbal ice cream. Paul *et al.* [60] quantified functional ice cream's antioxidant and phenolic properties by adding 0.5% (w/v) basil oil microcapsules. The percentage of DPPH scavenging activity in basil oil was 94.14% because of phenolic and terpenoid compounds, while that of the functional ice cream prepared by the inclusion of basil oil microcapsules was 94.57%. The total phenolic compounds of the ice cream increased upon the addition of basil oil

microcapsules in the formulations. A higher value of phenolic content in the ice cream would help fight against diseases caused by reactive oxygen stress properties.

4.3. Cheese.

Herbs and spices also find their applications in the preparation of cheese as an antioxidant, antimicrobial, and flavoring ingredients, as well as to improve the functionality and stability of cheese [61]. Mahgoub *et al.*[62] investigated the effect of adding 0.1% and 0.2% (w/w) of *Nigella sativa* oil on inhibiting foodborne pathogens (*Staphylococcus aureus, Salmonella enteritidis, Escherichia coli, Listeria monocytogenes*) and the storage stability of Domiati cheese. They reported that the addition of 0.2% oil improved the physicochemical and sensory characteristics of the cheese and was most effective in restricting the growth of pathogens. El-Kholy *et al*. [63] studied the effect of the addition of essential oils (@ 0.1%) from cumin, rosemary, and thyme on the antioxidant and antimicrobial activity of the UF (ulfiltrated) soft cheese. They reported that the inclusion of essential oils increased the antioxidant activity of the resulting UF soft cheese. The antioxidant activities, relative to BHT, were 33.85, 66.83, 65.73, 77.34, and 70.42% for the control cheese and cheese containing cumin, rosemary, thyme, and the mixture essential oils, respectively. After 28 days of storage, there was a gradual decrease in the antioxidant activity of all the cheese samples. Further, the microbiological studies revealed that the addition of essential oils to cheese decreased the total viable count (TVC) due to the antimicrobial effect of essential oils. Moreover, no yeast and mold growth was observed in the cheese samples with essential oils after 28 days of storage, while growth was observed in control cheese after 14 days of storage. The researchers concluded that including essential oils into UF-soft cheese would help extend its shelf life.

Bin *et al.* [64] studied the antibacterial potential of five spices and herb extracts, namely clove, cinnamon stick, grape seed oregano, and pomegranate peel, restricting the growth of *Salmonella enterica, Staphylococcus aureus,* and *Listeria monocytogenes* in cheese stored at room temperature. They found that all five plant extracts selected in the study inhibited the growth of the three foodborne pathogens in cheese. The addition of spices and herb extracts improved the stability of cheese against lipid oxidation. They concluded that clove was the most effective antibacterial and antioxidant, and thus, its extract can be used as a natural food preservative.

Furthermore, Mohamed *et al.* [65] reported that the addition of *Moringa oleifera* extracts to cream cheese at different ratios (2.00, 3.00, and 4.00 g/100 g) extended its shelf life up to four weeks and also increased the probiotic counts, total phenol content and antioxidant activity of resulting cheese. Similarly, Kose & Ocak [66] investigated the changes in total phenolics, antioxidant, and antimicrobial activities of Herby cheese prepared from sheep milk with added herbs- Sirmo (*Allium vineale L.*), Mendi (*Chaerophyllum macropodum Boiss.*), and Siyabo (*Ferula rigidula DC.*) and reported that the three herbs added to prepare Herby cheese increased the total phenolic compounds and antioxidant activity of cheese, respectively. Yeriikaya *et al.* [67] investigated the antioxidant, antimicrobial activities, total phenolic content, and microbiological quality of Mozzarella cheeses added with medicinal and aromatic plants, namely rosemary (*Rosmarinus officinalis L.*), basil (*Ocimum basilicum L.*), peppermint (*Mentha piperita L.*), and Turkish oregano (*Origanum onites L.*). They reported that the added herbs and spices increased the antioxidant and antimicrobial activities of the Mozarella cheese. The prepared mozzarella cheese samples exhibited antimicrobial activities against *Escherichia*

coli, *Listeria monocytogenes*, *Enterococcus faecalis*, *Staphylococcus aureus*, and *Bacillus cereus*.

4.4. Butter.

The butter gets spoiled due to auto-oxidation of fat, which leads to deterioration of flavor and development of flavor defects in butter, usually after 1 month to 2 years of cold storage. The extent of deterioration depends upon the storage temperature, quality of raw milk, and the processing parameters involved in butter manufacturing. Along with off-flavors, hydroperoxides are also formed in butter as storage progresses. The process of fat oxidation can be prevented by adding natural or synthetic antioxidant substances. The inclusion of herbs in butter offers a possible solution to prevent the auto-oxidation of fat.

Souza *et al.* [68] studied the effect of the addition of herbs on the physicochemical parameters of butter. They reported that the addition of oregano, parsley, basil, and rosemary did not affect the percentage of moisture and fat content of butter. Vidanagamage *et al.* [69] studied the effect of adding cinnamon extract on the functional properties of butter. They reported that adding 3% cinnamon extract to butter lowered the microbial count, peroxide value, and free fatty acids value compared to control. Ozkan *et al.* [70] conducted studies to determine the antioxidant activity of essential oil of *Satureja cilicica* in butter. When added @ 0.5%, 1.0%, and 2.0% in butter, the essential oil of *S. cilicica* displayed a strong antioxidant activity. They concluded that the essential oil of *S. cilicica* could be used as a natural antioxidant and aroma enhancer in butter.

4.5. Yogurt.

Yogurt is a fermented dairy product and is widely consumed in many countries. Adding herbs and spices to yogurt helps to improve its functional properties and shelf life. Maji *et al.* [71] prepared *lassi* (Indian yogurt) by incorporating turmeric at the level of 1% (v/v) and reported that the prepared *lassi* possessed high phenolic content than control *lassi* and was sensorially acceptable up to 9 days upon storage at 7°C in a glass bottle. Husain & David [72] developed aloe vera fortified functional *lassi*. The functional *lassi* possessed better immunoprotective effects as revealed by animal studies compared to control lassi. Similarly, Govindammal *et al.* [73] reported that the addition of 15% aloe vera gel to yogurt increased its protein, fiber, and phytonutrients content (such as anthraquinones, phlorotannins, saponins and steroids, and) and also increased its vitamin C content. Ghosh [74] observed that tulsi and beetroot extract added @ 5% to yogurt displayed more nutrients than control yogurt. The addition of tulsi and beetroot extract improved the folic acid and riboflavin content of the yogurt. Moreover, tulsi also displayed higher antiradical activity in yogurt. Azizkhani and Parsaeimehr [75] reported that incorporating essential oils from herbs, such as peppermint, basil, and Zataria, to probiotic yogurt enhanced its antioxidant activity, antiradical property, and consumer acceptance. Similarly, turmeric, sage, or marjoram water extract (10%) was added to skimmed milk yogurt (@1%). The addition of turmeric extract increased the acid production level and bacterial growth in yogurt compared to sage or marjoram. The addition of the herbal extract increased the antioxidant activity of yogurt [76]. Similarly, Yangilar and Yildiz [77] also reported that adding the essential oil of ginger and chamomile oil @ 0.2% and 0.4% respectively into yogurt improved the preservation activity due to the antimicrobial and antioxidant properties of the herbs. Maji *et al.* [78] conducted a study on the development of

herbal *lassi* by the inclusion of ginger, turmeric, and carrot extracts @ 2 % (v/v), 1% (v/v), and 15% (v/v), and reported that the prepared samples exhibited good antioxidant activity.

Assem *et al.* [79] incorporated eugenol in carnation essential oil to milk at varying concentrations of 0.2, 0.4, 0.6, and 0.8 µl/ml milk, respectively, and used this milk for the preparation of herbal yogurt. They reported that eugenol in carnation essential oil displayed an antimicrobial effect against the selected pathogenic bacterial strains at varying concentrations. They concluded that 0.6 µl/ml eugenol could be applied to improve the storage stability of yogurt for more than 15 days. Tizghadam *et al*. [80] used the dill extract to prepare functional yogurt. The investigation results showed that the inhibition activity percentage and amount of total phenolic compounds increased with the increase in the amount of dill extract added to yogurt.

5. Conclusions

Herbs and spices have been known to humankind for ages. In the present scenario, where people have become health conscious and looking for potential alternatives for chemical preservatives and antimicrobial agents, the bioactive components from herbs and spices seem to provide a possible solution. These bioactive compounds in herbs possess antioxidant and antimicrobial properties, preventing dairy products' deterioration and extending their shelf life. Moreover, their consumption is also associated with certain health benefits. Though several researchers have researched the possible application of herbs and spices in dairy products; however, more research is required to optimize extraction procedures of bioactives from herbs & spices and improve their availability and efficiency in fortified dairy products.

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Conflicts of Interest

The authors declare no conflict of interest.

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