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Potential Of Corn Silk In The Dairy Industry: A Review Of Its Benefits, Applications, And Challenges

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Abstract

Corn silk, a maize byproduct, comprises proteins, carbohydrates, vitamins, and minerals, with compositions varying by genotype and harvest stage. It is rich in bioactive compounds such as flavonoids and polyphenols, which have antioxidant properties. Several studies have suggested that incorporating corn silk extract can enhance the antioxidant properties of dairy products, addressing issues such as lipid oxidation and microbial spoilage. Currently, chemical preservatives are effective for the preservation of dairy products, but plant-based options are gaining traction due to various health concerns. Further research should focus on different dairy products, optimize extraction procedures and formulations, and evaluate market acceptance. Combining corn silk extract with other natural antioxidants may increase its efficacy and mitigate undesirable sensory effects. This review highlights the potential of corn silk extract as a natural additive in the dairy industry, promoting healthier and safer products while ensuring adequate shelf life and nutritional stability.

Keywords: Antioxidant, Corn silk, Paneer, Preservative, Natural alternative.

1. Introduction

India is an agronomic nation where majority of the population is vegetarian, and dairy products are vital to the country's overall nutritional and economic growth. Milk and its derivatives have been valued as complete food since Vedic times, as they are essential constituents of culture. The role of buffalo milk in total production is significant, as India, a leading producer of milk [1,2]. Approx 50%

of the milk produced in India is used to make traditional dairy products i.e. paneer, Dahi, khoa and ice-cream[2,3]. India ranks as the foremost milk producer globally, boasting an annual yield of 112 million tonnes in the mostrecent FISCAL year, indicating a 3.3% rise compared to the former year. Among the total yield, buffalo milk accounts for 55% (61.60 million tonnes). Nearly half of milk is utilized as liquid milk, whereas the remaining half is transformed into paneer, cheese, ghee, curd, khoa, chhana, ice cream, butter or milk powder [2]. These varieties are generally highly perishable because of their high-water activity and nutrient availability, which makes their preservation very important. The need for preservation arises from the perishable nature of dairy products and the need to maintain their quality and safety [3,5]. The spoilage of these perishable products is due mainly to bacterial action [2]. Traditional preservation methods are often insufficient, leading to the exploration of natural antimicrobial systems to increase shelf-life [1]. Since ancient times, the dairy sector has employed chemical preservatives, with formalin being the sole substance utilized for analytical objectives that is legally permitted in India [3,5]. Nonetheless, there are concerns that formalin may influence the accuracy of compositional analysis [6]. Dairy products, including paneer, can benefit from their extended shelf- life and the reduced health risks that natural alternatives such as plant extracts and essential oils have to offer [1]. According to the Food Safety and Standards Act Rules (FSSR, 2011), chemical preservatives in food serve to inhibit, delay, or prevent fermentation, acidification, and other forms of degradation. In dairy products, the "testability of a sample" refers to the minimum preservative concentration required to ensure effective chemical stabilization while maintaining product integrity [3]. The effectiveness of a preservative in dairy products is assessed on the basis of key criteria. It must successfully inhibit, delay, or prevent fermentation, acidification, and other degradation processes. Additionally, the original composition of the dairy sample from collection to analysis should be preserved, ensuring accurate results. A reliable preservative should also be effective across different types of milk, including both high-fat and low-fat varieties. Finally, its stability is crucial, with an ideal shelf life ranging from six months to one year to maintain long-term efficacy [7,8]. The commonly used preservatives in the dairy industry are shown in Table 1 [3].

Table 1: Commonly used preservatives in dairy products and their concentration.

S.no.	Preservative	Amount / Concentration	Findings / Effects	Products	References
1.	Formalin	0.4% (approximately 40% formaldehyde (CH2O) in aqueous solution) for milk & milk products, **0.6%** for ice cream samples, 0.1ml in every 25 gram	Antibacterial agent, kills spores, influence physiochemical qualities, preserves Dahi for 2 months.	Milk, ice cream, Chhena and Khoa, Dahi, paneer.	[3]
2.	Mercuric Chloride ($HgCl_2$)	0.05-0.4%, 0.4% and 0.6%	Satisfactory preservative for a period of month. Highly poisonous, used for cryoscopic examination. Effective for strengthening measurements of density and fat %.	Milk, Dahi	[5]
3.	Potassium Dichromate ($K_2Cr_2O_7$)	0.1-0.2%, 0.08-0.8%, 0.25%, 0.3 mL/100 mL milk	Gives specific color to the sample. Effective for fat measurement by milko tester for 5 days at 21 °C, Problematic due to production of allergen Chromium VI, improve density & fat %.	Milk, Dahi	[3,5]
4.	Hydrogen Peroxide (H_2O_2)	0.04%, 1 mL 23% H_2O_2 solution in 300 mL raw milk, 0.4%, 0.8%, and 1.2% by weight	Fat content decreased without affecting protein content at 20 °C, decreased bacterial counts during 6 days storage at 8–10 °C, keep milk at 5 °C for extended periods depending on concentration	Milk	[3]
5.	Bronopol	0.020 - 0.040 g/100 mL	Higher fat & protein content observed at 4 °C after 42 days, No	milk	[5]

			influence on fat, moisture for 90 days storage at 37 °C, Effective against all types of bacteria in milk		
6.	Methyl Paraben, Propyl Paraben	0.1 %	No effect on fat, TS or protein while lactose decreased after 21 days.	Milk	[3]
7.	Sodium Oma dine	0.4%	No effect on unprocessed milk held at 25°C for a duration of 7 days to test fat and protein levels.	Milk	[5]
8.	Sodium Azide, Azidol	0.02%-0.04%	At 4 °C and 20 °C, there is no influence on fat and protein levels.	Milk	[3,5]
9.	Dowicil	0.07%	No effects on fat up to 3 weeks.	Milk	[3,5]
10.	Bronopol and Kathon	0.4 %- 0.5 %	Effective in preservation of paneer and khoa for chemical analysis for 90 days at 30 °C	Paneer, Khoa	[3]
11.	Alcohol	-	Used as milk preservative.	Milk	[5]

Consumers are increasingly drawn to natural and health-focused foods, seeking options that promote well-being, prevent diseases, and provide functional benefits. This growing preference extends to natural food additives, particularly antioxidants derived from food sources. Concerns over the potential toxicity and carcinogenic risks of synthetic antioxidants have led to a stronger demand for safer, plant-based alternatives. Foods that are rich in high natural antioxidant content may lower the occurrence of certain diseases [9]. Natural antioxidants are safe and impart health benefits to consumers [10]. Due to their competence to combat oxidation, plant-derived extracts are increasingly employed as food additives in a range of food-related applications [6]. They can impede lipid degradation in products, aiding in food longevity by retarding spoilage and color alteration, and can be incorporated into diverse food formulations [9]. Antioxidants derived from plants can regulate the excessive production of free radicals and elevate antioxidant efficacy [6]. Fruit and vegetable processing results in substantial waste, which is an abundant source of antioxidant polyphenols [11]. Various plants are acknowledged as organic sources of antioxidants like flavonoids, polyphenols and vitamins, that can be obtained via the application of eco-friendly solvents like water, ethanol, or their combinations [6]. Medicinal plants rich in natural antioxidants and phenolic compounds are progressively incorporated in dairy product formulation to enhance nutritional value and health benefits [9].

Corn silk has a long and varied history of medicinal applications, particularly within traditional medicine systems [14,15]. Traditional Chinese medicine (TCM) first documented its use as early as 1476, and it was later officially recognized as a common herb in the Chinese Pharmacopoeia [15]. Throughout Asia and Africa, corn silk has been employed to address a range of ailments [16]. Notably, it has served as a folk remedy for hypoglycemia since ancient times [17]. Modern research is exploring its potential in managing different types of diabetes, cardiovascular diseases, hyperuricemia, alzheimer's disease, chronic nephritis, and related conditions [15,18]. The extensive farming and processing of Zea mays L. leads to a significant amount of corn silk. This plentiful supply makes corn silk an easily obtainable and readily at hand resource [15]. However, a significant portion is frequently discarded as agricultural waste [12,14,19]. This review highlights the opportunity to transform this by-product into value-added products and promote more sustainable agricultural practices [12,14]. Corn silk is not merely a repository of bioactive compounds; it also offers a valuable nutritional composition comprising carbohydrates, proteins, vitamins and minerals [12,16]. This review, provides an overview of several studies that investigated the incorporation of corn silk extract, a natural antioxidant, into dairy products to improve their shelf- life and reduce nutritional losses.

2. Composition and antioxidant profile

2.1.Nutritional composition

Maydis stigma, scientific name of corn silk refers to the stigmata of the female flower of corn (*Zea mays* L.) [13,14]. These are the silky, thread-like strands found extending from the tip of the corn cob that are pale green in color in its initial stages but turn red, yellow, or light brown during aging [12]. As a biological by-product of corn cultivation, corn silk represents a significant and often underutilized resource [12,13,15]. It is an annual grass widely distributed with a history of medicinal use. Often discarded as waste from maize cultivation, corn silk has gained attention because of the sustainable development of traditional medicine and modern technologies that allow for comprehensive analysis [15]. It is a natural powerhoupse, packed with nutrients and bioactive compounds that support healing and overall well-being. It is regarded as nontoxic and safe at the recommended dose only [12]. The nutrient profile of corn silk differs based on its genetic variety. Studies show that corn silk gathered during the silking phase has considerably elevated amounts of phenolic substances compared to those gathered at the fully matured phase [14]. Corn silk is composed of various biochemical nutrients, including proteins, carbohydrates, vitamins, mineral salts,alkaloids, tannins, volatile compounds, steroids, and flavonoids. Additionally, it is a rich source of vitamin A, B-complex, vitamin K, and essential minerals such as potassium and sodium. The major classes of bioactive components identified in maydis stigma are presented in Table 2.

Table 2: Phytochemical components of corn silk and their health benefits.

Class of bioactive compound	Phytochemical components	Health benefits	References
Flavonoids	Apigenin, Luteolin, Robin, Chrysoeriol, Flavonoid glycosides, Flavonols, Isoflavones, Maysin, Mirificin, Isoorientin 7-O-rhamnoside, Violanthin, Pectolinarin, 3'-O-methylmaysin, Flavones, Flavanols, Isoflavonoids, Flavone C-glycosides, Flavanol O-glycosides.	Antioxidant, anti-inflammatory, anticancer, improve T-cell mediated immune response, reduce inflammatory aspects, manage glycemic response.	[20,21,23]
Sterols	β-sitosterol, stigmast-4-ene-3β,6β-diol, Stigmast-5-ene-3β,7α-diol, Ergosterol endoperoxide, 7α-hydroxy stigmast-3-O-β-D-glucopyranoside, Stigmasterol-3-O-β-D-glucopyranoside, Stigmast-3-O-β-D-glucopyranoside.	β-sitosterol investigated for anticancer effect.	[20]
Terpenoids	Costunolide, Friedelin, α-amyrin, α-terpineol, citronellol, 6,11-oxidoacor-4-ene, trans-pinocamphone, neo-iso-3-thujanol, cis-sabinene hydrate.	Possess neuroprotective activities.	[15,19]
Saponins	7α-hydroxy stigmast-3-O-β-D-glucopyranoside, stigmasterol-3-O-β-D-glucopyranoside, Stigmast-3-O-β-D-glucopyranoside.	Suppress pro-inflammatory markers, prevent edema.	[17]
Organic acids	Amino acids (Leucine, Phenylalanine, Threonine, Valine, Glutamic acid, Aspartic acid), Long-chain organic acids (Linoleic acid, Lactic acid, Docosanoic acid, vanillic acid, stearic acid).	Reduce oxidative stress, anti-aging effects, supports kidney functions.	[15,17]
Polysaccharides	Mannose, Lactose, Galactose, Rhamnose, Arabinose, Xylose, Glucose.	Antifatigue, anti-obesity, antioxidant activity and anti-hepatoma activities, blood lipid regulating effects. (Singh et al., 2022; X. Wang et al., 2024; Y. Wang et al., 2024; Zhang et al., 2021)	[15,16,18,23]
Polyphenols	Tannins, alkaloids, steroids, cardiac glycosides, allantoins, saponins,	Protect against type 2 diabetes, heart diseases and cancer, boost	[12]

	flavonoids, anthocyanins, hesperidin and resins	digestion, improve brain health.	
Phenolic acids	Ferulic acid, Para-aminobenzoic acid (PABA), vanillic acid, caffeic acid, maizenic acid, hydroxycinnamic acid ester and 3-O-caffeoylquinic acid, p-coumaric acid, chlorogenic acid, protocatechuic acid.	Promote anti-inflammatory conditions, prevent cellular damage due to antioxidant activity.	[12]
Volatile compounds	Menthol, 6–11-oxidoacor-4-ene, citronellol, thymol, eugenol, trans-pinocamphone, cis-sabi nene hydrate, carvacrol, neo-iso-3-thujanol, cis-sabinene hydrate.	Improve human health, reduce use of chemical additives.	[12]
Vitamins	Vit. K, Vit.C and Vit. E	Boost immunity system, heal wounds.	[12]

Many studies have been conducted to determine whether the availability of flavonoids, anthocyanins, and phenolic compounds in maydis stigma contributes to its notable organic activities. In particular, the nutritional composition, mineral content, and antioxidant activity of corn silk become the subject of multiple investigations [14].

2.1.1. Flavonoids

Apigenin, isoorientin 7-O-rhamnoside, luteolin, mirificin, robin, chrysoeriol, flavonoid glycosides, flavonols, isoflavones, maysin, violanthin, pectolinarin, flavanols, 3'-O-methylmaysin, flavones, flavone c-glycosides and isoflavonoids, flavanol O-glycosides, which impart beneficial properties, such as antibacterial, antioxidant, antiviral, and antinflammatory properties are represented in Table 2 [25]. The studies on corn silk reveals the presence of 80 distinct flavonoid compounds, such as maysin, luteolin, apigenin along with various O-glycosides and C-glucosides which are flavonoid derivatives [15].

2.1.2. Sterols, terpenoids and saponins

Saponins are not commonly found in corn silk; however, three specific saponins stigmasterol-3-O-β-D-glucopyranoside, 7α-hydroxysitosterol-3-O-β-D-glucopyranoside, and 3-β-sitosterol-D-glucopyranoside have been identified. These compounds were successfully isolated from the ethyl acetate extract of maydis stigma via silica gel column chromatography [45]. Corn silk contains various volatile compounds, with terpenoids constituting more than 99% of the volatile extract. The key terpenoid constituents include trans-pinocamphone (5.86%), 6,11-oxidoacor-4-ene (18.06%), neo-iso-3-thujanol (2.59%), cis-α-terpinol (24.22%), citronellol (16.18%), eugenol (4.37%), and cis-sabinene hydrate (2.28%). These substances are frequently used in the flavor and fragrance industries for items such as soaps and cosmetic products [27]. Corn silk also contains rhamnose, cinnamic derivatives, glucose, and minerals such as potassium (15%), zinc (0.016%), sodium (0.05%), iron (0.0082%), and chloride (0.25%). Proximate examination showed that corn silk consists of 9.65% water, 3.91% mineral residue, 0.29% crude fat, 17.6% crude protein, and 40% crude fiber [28,29].

2.1.3. Polyphenols

Corn silk is packed with polyphenols and bioactive compounds, making it a valuable natural antioxidant with potential health benefits [12,20]. Its antioxidant power derived from various phenolic compounds, including flavones, flavanols, and glycosides [21]. The total phenolic content (TPC) varies with corn variety and maturity stage, with the Bisma variety from Indonesia showing particularly high levels (8262.93 µg GAE/g) [20]. Corn silk harvested at the silking stage contains more phenolics than those harvested at later stages do, increasing its antioxidant potential [21]. The extraction method also plays a key role, with ethyl acetate extracts demonstrating the strongest free radical scavenging activity [19]. Additionally, base hydrolysis can unlock even more antioxidants by releasing bound polyphenols. Studies have shown that corn silk powder has a TPC of 94.10 ± 0.26 mg GAE/g, reinforcing its value as a natural antioxidant source [16].

2.2. Antioxidant activity of corn silk

Corn silk exhibits significant antioxidant activity, making it a valuable natural resource [12]. This activity is linked to its rich composition of bioactive elements, including flavonoids, phenolic acids, polysaccharides, and other antioxidant substances [16,18]. Corn silk has strong antioxidant effects on several bioactive compounds [21]. Flavonoids like apigenin, luteolin, and maysin are among the primary contributors, while phenolic acids such as ferulic acid, chlorogenic acid and caffeic acid, further increase their antioxidant potential [17]. Additionally, polysaccharides in corn silk play a supportive role in increasing its overall antioxidant activity [24]. The antioxidant efficacy of corn silk is typically evaluated using different methods, including the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, the 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) assay, the ferric ion reducing power (FRAP) assay, and measurements of total antioxidant capacity [20]. These assays help quantify the ability of corn silk extracts to neutralize free radicals and prevent oxidative damage [12,22]. Corn silk exerts its antioxidant effects through multiple mechanisms. It directly scavenges free radicals, with its flavonoid glycosides playing a key role in neutralizing harmful molecules and preventing oxidative chain reactions. Additionally, it offers indirect antioxidant protection by reducing free radical formation and mitigating oxidative stress. For example, maysin, a flavonoid found in corn silk, helps lower intracellular reactive oxygen species (ROS) levels as well as regulates antioxidant enzyme expression [12,15]. Another important mechanism is metal chelation, where certain compounds in corn silk bind to metal ions, preventing them from catalyzing oxidation reactions [22]. Furthermore, bioactive compounds in corn silk can enhance the activity of the body's natural antioxidant enzymes, strengthening the overall cellular defense system against oxidative damage [12].

2.3.Factors influencing the antioxidant potential

Several features have been noted to influence the antioxidant competence of corn silk extracts, as illustrated in Fig. 1 [21,22].

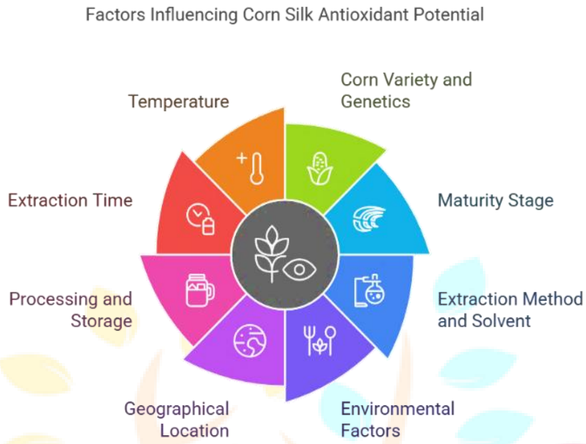

Figure 1: Shows the factors that influence the antioxidant activity of corn silk

Different corn varieties exhibit varying levels of antioxidant activity due to differences in their genetic makeup and bioactive compound profiles. The maturity stage at harvest significantly impacts the antioxidant content, with corn silk at the silking stage generally having higher phenolic and flavonoid contents than those at later stages [20]. The choice of extraction method and solvent affects the yield and composition of antioxidant compounds [12]. Compared with aqueous extracts, methanol and ethanol extracts often have greater antioxidant activity. Optimized extraction conditions, such as those achieved through alkaline hydrolysis, can enhance the recovery of bound phenolic compounds [19]. Environmental conditions including soil type, climate, and agricultural practices, can influence the phytochemical composition and antioxidant activity of corn silk [16]. Factors such as soil quality, climate, altitude, and farming practices play major roles in shaping nutrient profiles. Changes in temperature, sunlight exposure, and rainfall influence the levels of flavonoids and phenolic acids, which are key to their antioxidant properties. Increasing the extraction time can yield stronger ABTS radical scavenging activity [22]. Various other factors reported to influence antioxidant activity and stability include drying methods, storage conditions, and processing techniques [21].

3. Shelf -life stability of dairy products

Dairy products are a vital part of human nutrition, providing essential nutrients such as protein, calcium, fatty acids, amino acids, and vitamins. However, their shelf life and nutritional quality can be compromised by oxidation, microbial growth, and chemical degradation [30].

3.1.Oxidation

This process primarily involves lipid degradation, leading to undesirable taste change and a reduced shelf -life. Oxidation results in chemical spoilage, affecting nutritional value, flavor and texture. It is initiated by factors such as heat, light, and enzymes. Antioxidants can prolong the protein oxidation phase, limiting dityrosine formation [30,31].

3.2.Microbial spoilage

Bacteria, yeasts, and molds cause spoilage, compromising safety and sensory qualities. Spoilage in paneer is primarily due to bacterial action, leading to slime formation, discolouration, and off-flavors [2].

3.3.Chemical changes

The quality and stability of dairy products change over time because of both enzymatic and nonenzymatic reactions [30]. Enzymatic reactions involve natural or microbial enzymes breaking down proteins, fats, and lactose, which can affect texture, taste, and overall freshness. Nonenzymatic reactions, such as oxidation and the Maillard reaction, also play a role. Oxidation can cause fats to become rancid, leading to off-flavors, whereas the Maillard reaction, which occurs when proteins and sugars interact, can result in browning and flavor changes. These intrinsic processes affect the longevity and nutritional quality of dairy products [9].

Dairy product shelf-life hinges on factors such as raw material quality, storage temperature, hygiene practices, packaging, and processing techniques. Maintaining a cold chain (storage below 5 °C) is crucial for increasing shelf -life stability. The expected shelf -life of various dairy products under specific storage conditions is depicted in Table 3 [32].

Table 3: Shelf life of various dairy products under specific storage conditions.

Dairy Product	Viability period	Storage conditions (Maximum Temperature)
Raw milk	1–2 days	5 °C, dark place
Pasteurized milk	7–10 days	5 °C, dark place
Pasteurized and Microfiltered milk	14–21 days	5 °C, dark place
UHT Milk	At least 90 days	Room temperature
Yogurt, Sour milk	14 days	5 °C, dark place
Pasteurized sweet whipping cream	14 days	5 °C, dark place
UHT sweet whipping cream	At least 90 days	Room temperature
Sour cream	14 days	5 °C, dark place

Raw butter	60–90 days	5 °C or frozen
Fresh cheese	14 days	5 °C, shaded area
Paneer	Approx. 1 day 3 days	At room temp. 10 °C,

4. Antioxidants in dairy preservation

Different studies have analyzed the effects of adding natural additives to dairy products, which can enhance their antioxidant properties (Table 4).

Table 4: Different varieties of additives used in dairy products.

Additive	Dairy Product(s)	Antioxidant Activity/Effect	References
Plant Extracts	Yogurt, Cheese, Fermented Milks, Ice Cream	Enhance antioxidant and phenolic properties. Improve colour, sensory and nutritional characteristics.	[6,32]
Herbal Extracts	Yogurt, Cheese, Fermented Milks, Ice Cream	Increase antioxidant and total phenolic properties.	[6,30]
Fruit Peel Extracts	Dairy products	Microencapsulation enhances nutritional profiling and sensory attributes. Citrus peel, rich in phenolic compounds and carotenoids, acts as an antioxidant, preventing cells from free radical damage.	[32]
Black Rice and Purple Corn Extracted Residue	Cow milk	Increased DPPH antioxidant activity (6% additive concentration resulted in 9.27% activity).	[30]
Grape pomace extract	Cow milk	Folin–Ciocalteu antioxidant activity of 16.07 gAE mg/g.	[30]
Berries (Strawberry, Blueberry, Blackberry, Raspberry)	Fermented Milk Products	Substantially higher antioxidant capacity than other products.	[30]
Cudrania Tricuspidata Fruit	Fermented Milk	Enhanced antioxidant activity (DPPH, ABTS, FRAP)	[30]
Salal Berry and Black currant pomace	Yogurt	Black currant pomace addition inhibits α-glucosidase activity	[30]
Chestnut and Sulla Honeys	Yogurt	Increased antioxidant activity (ABTS and FRAP), especially with chestnut honey due to high phenolic acid and flavonoid content.	[30]

Allium Sativum (Garlic)	Yogurt	Increased DPPH antioxidant activity (37.9 ± 0.8% compared to control 26.4 ± 0.7%).	[30]
Sugarcane juice	Ice cream	Increased total phenolic content, DPPH free radical scavenging activity, nitric oxide free radical scavenging activity, and total antioxidant capacity.	[29]
Moringa Oleifera Oil	Butter Oil	Phenolic compounds enhance antioxidant perspectives and storage stability.	[29]
Vitamin C, Vitamin E, Beta-Carotene	Yogurt	Increased antioxidant capacity without affecting sensory properties.	[29]
Date Extracts	Paneer	Increased total phenolics, flavonoids, radical scavenging activity, trolox equivalent antioxidant capacity, and reducing power.	[33]
Corn Silk Extract	Dairy Products (General)	Contains polyphenols and flavonoids with antioxidant activity.	[6]
Benzoic Acid or its Sodium Salt (Benzoate)	Dairy products (General)	Exhibits antioxidant properties.	[34]

Scientists have examined various bioactive compounds, including polyphenols, flavonoids, vitamins, and plant extracts, highlighting their effectiveness in improving both nutritional value and functional properties. The review compiled data from multiple studies, and revealed that antioxidant activity increased by 15% to 80%, depending on the type of additive and dairy product. Additionally, Alenisan et al., 2017 explored how these additives enhance sensory characteristics and prolong shelf -life, with certain studies reporting as much as 50% heft in product durability. Constituents such as green tea extract and fruit powders not only improve antioxidant levels but also provide health advantages, including alleviating oxidative stress associated with illnesses such as cancer and heart disease. Nonetheless, the writers stress the importance of additional studies to standardize recipes and evaluate the lasting impacts on human health [9]. Corn silk extract can be incorporated into various food products, including dairy products, to enhance their nutritional profile and extend shelf life [20]. Corn silk is rich in polyphenols and flavonoids, serving as antioxidants. These compounds helps in neutralizing free radicals, reducing oxidative stress and preventing the breakdown of essential biochemical compounds [20,30]. Bioactive compounds in corn silk are associated with therapeutic roles in managing diseases such as diabetes, cancer, hypertension, obesity, and hyperlipidemia [20]. Owing to the increasing demand for natural and safe food additives, several natural alternatives are being explored to replace synthetic preservatives in dairy products [6,9,30]. Extracts from various plants and herbs can increase the antioxidant and antimicrobial properties of dairy products [38]. Granato et al. (2018), reported the use of herbal extracts to enrich dairy products, increasing their antioxidant and phenolic properties. Kandyliari et al., 2023 highlighted that the addition of *Hibiscus sabdariffa* extract to dairy products can improve their sensory profiles, shelf life and offer health benefits because of its bioactive components and high antioxidant activity. Gad & El-Salam (2010) explored the antioxidant characterstics of skim milk added with green tea and rosemary extracts [6]. Essential oils from plants such as rosemary, thyme, anise, and cinnamon are used in animal nutrition and can positively affect milk quality due to their antioxidant properties [31]. By leveraging natural preservatives such as corn silk extract and other plant-based additives, the dairy industry can meet the growing consumer demand for healthier and safer products while ensuring adequate shelf life and nutritional stability [9,30].

5. Application of corn silk in the dairy industry

The addition of corn silk aims to leverage its nutritional profile to develop functional and marketable food materials [12,36]. The specific application of corn silk extract in different products is depicted in Fig. 2.

Figure 2: Application of corn silk extract in different products

Several studies have explored the use of corn silk extract in dairy products, focusing on its potential to enhance nutritional content, antioxidant properties, and overall product characteristics. Corn silk, derived from the stigma of the *Zea mays* plant, contains bioactive compounds such as flavonoids and polyphenols, which contribute to its antioxidant and other beneficial properties [12,15]. Corn silk extract can be used in dairy products to increase their antioxidant content. Dairy products that undergo fermentation are particularly suitable for incorporating bioactive ingredients [33].

6. Future Perspectives

To address existing limitations and fully utilize the potential of corn silk extract in dairy products, future investigations should concentrate on essential areas:

6.1.Broadening research across dairy products:

A notable gap exists in research evaluating the impact of corn silk extract across different dairy items. Research should go beyond yogurt, cheese, and milk-based desserts to examine their interactions with diverse compositions and textures. Thorough evaluations should determine its influence on product quality, stability, and sensory characteristics to guarantee optimal incorporation.

6.2.Refining extraction and formulation techniques:

Additional studies are needed to improve extraction methods to maximize the yield of bioactive components from maydis stigma. Innovative technologies and the optimization of parameters such as selecting the correct solvent, temperature, and extraction time can improve bioactive recovery efficiency. Furthermore, initiatives should aim to create formulation strategies that enhance the stability and bioavailability of corn silk bioactives within dairy matrices.

6.3.Assessing commercial viability and consumer preference:

For effective commercial implementation, research should evaluate the scalability and cost-efficiency of integrating corn silk extract into dairy production. Market evaluations and consumer research are essential for comprehending acceptance rates. Sensory assessments, including taste trials and preference polls, should pinpoint formulations that resonate with consumers while preserving the functional advantages of corn silk.

6.4.Boosting efficacy through antioxidant collaborations:

Investigating the combination of corn silk extract with other natural antioxidants could further expand its functional advantages. Research should explore interactions with antioxidants derived from herbs, spices, or fruit extracts to create dairy products that exhibit increased antioxidant activity and health benefits. These combinations may also assist in alleviating any potential undesirable sensory impacts of corn silk extract on its own. By addressing these research deficiencies, the dairy sector can create groundbreaking, health-enhancing, and commercially viable products that align with consumer demands for quality and natural components.

7. Potential challenges and limitations

There are several potential challenges and limitations to consider when evaluating the use of corn silk extract in dairy products [33,36]:

Limited direct studies: There is a general lack of studies directly evaluating corn silk extract in various dairy products [36]. Many researches are required to explore the effects of maydis stigma extracts on various dairy matrices to fully determine their impact [37].

Variability in composition: The formulation and concentration of bioactive compounds in corn silk can depend on several factors such as biological, pedological, agronomical, and environmental conditions [16]. Variations in soil conditions, environmental factors, and cultivar can lead to large variations in corn silk nutrients and bioactives. Additionally, the stage of maturity of corn silk influences the levels of bioactive compounds [37].

Extraction and stability issues: It is essential to optimize extraction methods to maximize the yield of bioactive components from corn silk. Different extraction techniques, including solvent extraction, microwave-assisted extraction, ultrasonic-assisted extraction, and enzyme-assisted extraction, can be used [22]. Dairy products have complex matrices, and any treatment that does not respect this fact that destabilizes the milk and induces defects in the dairy products.

Sensory impact: The unique flavor of corn silk could have significant impact on taste and consumer acceptance. It may not be universally appealing, possibly changing the overall taste experience that may not be desirable for consumers. It is important to perform sensory evaluations by trained panellists to evaluate novel foods [36].

Regulatory Hurdles: Navigating regulatory and safety considerations is essential. Emerging practices in the dairy sector are constantly being researched and developed, so it is important to consider the European Food Safety Authority (EFSA) guidance focusing on the risk assessment of nanomaterials and other novel foods [37]. To address these challenges and limitations, more research is needed to enhance extraction methods, ensure the stability of bioactive compounds, assess sensory effects, and meet regulatory requirements [23,37].

8. Conclusion

The increasing consumer demand for natural and clean-label food additives offers corn silk a significant opportunity in the dairy sector. As an easily available byproduct of maize harvesting, maydis stigma is abundant in bioactive components such as antioxidant polyphenols and flavonoids, which can improve both the shelf life and nutritional value of dairy products.

Conventional preservation techniques frequently do not meet expectations, while synthetic preservatives are under growing scrutiny. In this context, corn silk extract appears to be a natural option for addressing lipid oxidation, microbial spoilage, and overall product decline. Its inclusion corresponds with industry needs for food safety compliance while meeting consumer desires for healthier choices. Nonetheless, moving from research to practical application necessitates overcoming various hurdles, including fluctuations in corn silk composition due to genetic and environmental influences, optimizing extraction processes to yield higher bioactive content and stability, minimizing sensory alterations in dairy products, and navigating through regulatory approvals. Future investigations should delve into its use across different dairy products, explore potential interactions with other natural antioxidants, and carry out market research to assess consumer acceptance. Addressing these issues will enable the dairy sector to convert corn silk from an agricultural byproduct into a valuable, sustainable ingredient.

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Conflict of Interest

The Authors have declared no conflicts of interest.

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