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Natural ingredients and probiotics for lowering cholesterol and saturated fat in dairy products: an updated review

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REVIEW ARTICLE

Abstract

Dairy products play a crucial role in ensuring healthy lives and promoting the well-being of people. However, they normally contain high levels of saturated fat and cholesterol which are related to the risk of noncommunicable diseases and other health issues. Our review focuses on the effectiveness of added natural ingredients and probiotics in dairy products for replacing or lowering cholesterol and saturated fat. This narrative review was conceptualized to describe: (i) natural ingredients for cholesterol and saturated fat substitution, and (ii) probiotics for lowering both cholesterol and saturated fat. Promising techniques for cholesterol and saturated fat replacement by healthy plant oils, carbohydrate, and protein co-products and their effect on product qualities are discussed. In addition, various probiotics inoculated in dairy products exhibiting effect on saturated fat and cholesterol are also addressed.

Keywords: dairy products; natural ingredients; probiotics; cholesterol-lowering; saturated fat reduction; functional foods

Introduction

Dairy industry is an integral part of food sector as it plays a pivotal role in the growth of global agricultural economy and in delivering nutrition for humans (Kaur *et al.*, 2020). In 2021, global milk production was ~928 million tons, which was an increase of 1.5% from 2020 estimates, and is expected to exceed 1 billion tons by 2025 (Canton, 2021). Dairy products, such as milk, cheese, and yogurt, are part of a healthy diet. They provide essential macronutrients, such as protein, carbohydrate and fat, vitamins, such as vitamins A, B complex, C, and D, minerals, such as calcium, potassium, sodium, magnesium, and iron, and fiber. All micronutrients are

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important for maintaining healthy bones, muscles, and the immune system (Chalupa-Krebzdak *et al.*, 2018) from the childhood.

However, consuming dairy products has been debated for many years because of the high levels of saturated fats and cholesterol, which can negatively affect human health (Lordan *et al.*, 2018). Figure 1 demonstrates the general complications on human health caused by the intake of cholesterol and saturated fats. One of the main concerns of consuming high levels of saturated fats and cholesterol is their association with heart disease and stroke (Givens, 2017). Saturated fats and cholesterol can increase the levels of low-density lipoprotein (LDL) cholesterol, known as "bad" cholesterol in the blood. High concentration of LDL cholesterol can lead to the formation of plaques in the arteries, which can increase the risk of heart disease (Zhang *et al.*, 2022a).

Various researchers have also found that intake of foods rich in saturated fat and increased blood cholesterol is positively correlated with a high risk of systemic inflammation (Alston *et al.*, 2022; Fan *et al.*, 2019), obesity (Alston *et al.*, 2022; Fan *et al.*, 2019), cancer (Ding *et al.*, 2019; Garcia-Estevez and Moreno-Bueno 2019; Mayengbam *et al.*, 2021), ischemic stroke (Hackam and Hegele, 2019), impaired cognitive function (Granholm *et al.*, 2008; Kalmijn *et al.*, 2004), and hypertension (MacDonald *et al.*, 2022). Moreover, saturated fats are high in calories and can contribute to weight gain, a significant risk factor for type 2 diabetes. Additionally, high cholesterol levels in the blood can affect the body's ability to use insulin, a hormone responsible for blood sugar levels (Kris-Etherton and Krauss, 2020).

In order to address the adverse effects of saturated fats and cholesterol in dairy products on health, it is important to consider sustainable development goals (SDGs). SDGs 2 and 3 aim to ensure healthy lives and promote well-being in all age groups (Mensi and Udenigwe, 2021). Globally, 70% of all deaths are attributable to noncommunicable diseases (NCDs), and hence some countries lose more than 5% of their gross domestic product (GDP) annually (Mensi and Udenigwe, 2021). Moreover, growing adolescents and middle-age people are now-a-days aware of health and prefer their diet to be low in calories and fat to lead a better lifestyle. This scenario has anticipated current world low-calorie food market to bypass US$16.0 billion by the end of 2027, because these foods are correlated with the management of obesity and cardiovascular diseases (Genovese *et al.*, 2022).

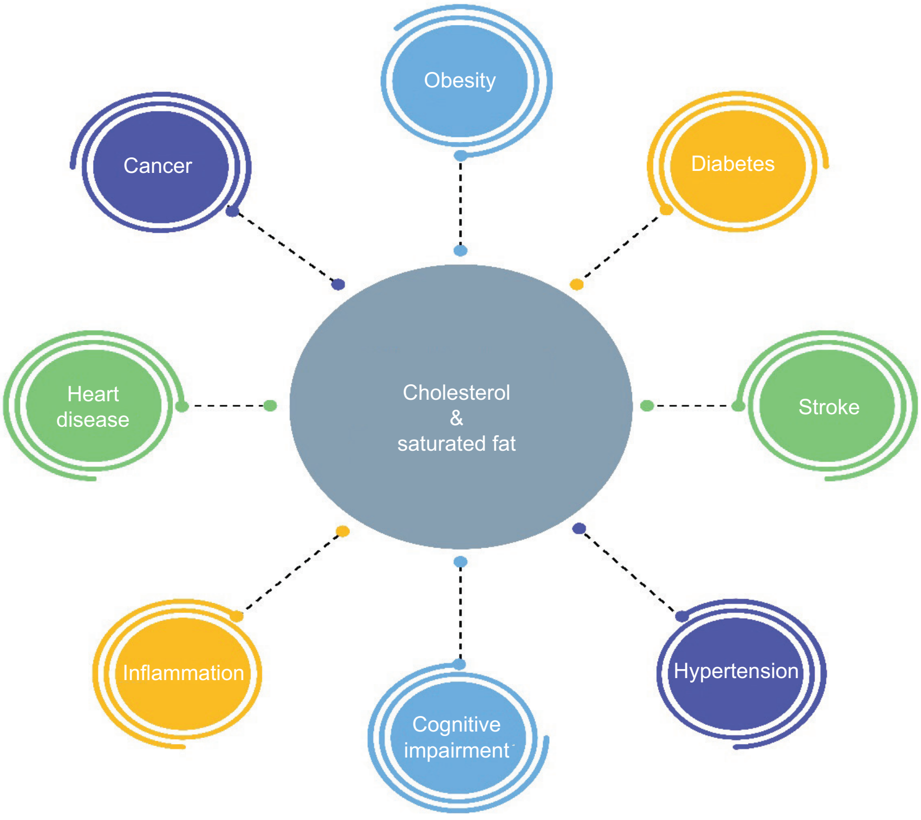

Figure 1. General health complications caused by the intake of cholesterol and saturated fat.

Although reducing the overall intake of dietary fat appears to be a feasible approach to control the risk of diseases, it is very challenging to remove fat from dairy products, as it would severely affect the overall quality of food, such as viscosity, texture, and sensory properties (Chen *et al*., 2020). Thus, the application of fat replacers has emerged as a promising tool to minimize fat without compromising food quality. Therefore, a practical approach to encourage sustainable and healthy eating practices is to reduce or substitute fat in dairy products with natural ingredients. Saturated fat replacement by healthy and high-quality plant oils, carbohydrates, and protein co-products, such as hydrocolloids, gum, fiber, and prebiotics, has been exercised in the food industry (Yu and Hu, 2018). Besides, fermentation of dairy products with probiotics is a healthy mode to reduce saturated fat and cholesterol levels. In addition, fermented dairy products with probiotics would also assist in the production of flavor compounds, enhancing of bioavailability of nutrients, and the overall improvement of nutritional value of foods (Parvez *et al*. 2006).

This review paper focusses on the current research summarizing the following two types of approaches for lowering both cholesterol and total fat, and replacing saturated fat in dairy products: (1) Natural ingredients for cholesterol and saturated fat substitution, and (2) probiotics for lowering of both cholesterol and saturated fat. The conceptual framework of natural ingredients and probiotics for lowering cholesterol and saturated fat in dairy products is presented in Figure 2. The effect of the natural ingredients and probiotics on the nutrition, properties, and application of products is presented and discussed in this review.

Natural ingredients for cholesterol and saturated fat replacement in dairy products

The role of natural ingredients in replacing saturated fat and lowering cholesterol in dairy products is increasingly important in today's health-conscious society (Kris-Etherton and Krauss, 2020). The high content of fat and saturated fatty acids (SFAs) is mainly associated with an increased risk of high blood cholesterol, cardiovascular diseases, and obesity (Gebreyowhans *et al*., 2019). This could be due to the fact that SFAs are usually less oxidized than unsaturated fatty acids (USFAs); in addition, fat thermogenesis is lower than other nutrients, such as carbohydrates and proteins, thus favoring fat deposition and leading to complications (Deus *et al*., 2019). Hence, reduction or substitution of saturated fats in dairy products with either high-quality plant oils rich in essential fatty acids or simple carbohydrates, such as hydrocolloids, gums and fibers, or protein co-products, such as soy and whey proteins, could minimize the complications in humans (Yu and Hu, 2018).

Generally, fat replacers are categorized broadly into either (1) plant oils-, (2) carbohydrate-, or (3) protein-based materials. Unlike healthy plant oils, which are lipid-based

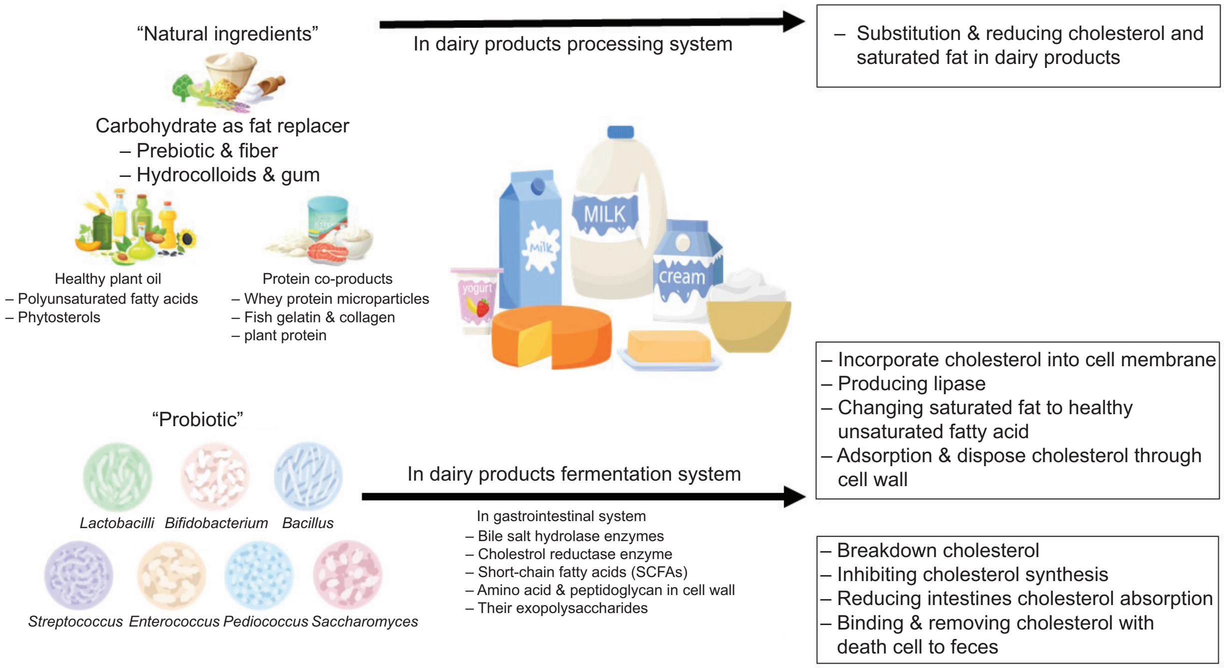

Figure 2. Conceptual framework of natural ingredients and probiotics for lowering cholesterol and saturated fat in dairy products.

fat substitutes and have structural similarity with fats, the carbohydrates- and protein-based fat replacers are considered as fat mimetics (Chen *et al.*, 2020; Peng and Yao, 2017). A summary of different studies that investigated a wide variety of natural ingredients used to reduce or partially replace content of saturated fats in dairy products and their effect on product quality are presented in Table 1.

Healthy plant oils

Healthy plant oils, as the name suggests, have become increasingly popular ingredients for substitution of dairy fat because of their enrichment in USFAs, which comprise monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs), and for being low in SFAs. Examples of the source of these oils include sunflower, corn, soybeans, linseed, flaxseed, cottonseed, and canola seeds (Jurić *et al.*, 2022; Tang *et al.*, 2021).

USFAs are healthy lipid molecules consisting of MUFAs, with one double bond, and PUFAs with two or more double bonds in their chemical structure. Although these double bonds make MUFAs and PUFAs less stable than SFAs and make them more reactive and prone to oxidation, they provide several important health benefits (Jurić *et al.*, 2022). However, only PUFAs are popular in consumers as they contain two healthy essential fatty acids, namely α-linolenic acid (ALA, 18:3n-3) and linoleic acid (LA, 18:2n-6). Both these essential fatty acids are not produced in the body and must be obtained through diet for numerous health benefits (Mantzouridou *et al.*, 2019; Romanić *et al.*, 2021).

ALA and LA, which belong to omega-3 (Ω-3) and omega-6 (Ω-6) fatty acids, respectively (Timilsena *et al.*, 2017), have been shown to possess anti-inflammatory effects and may help to maintain immune functions and reduce the risk of chronic diseases, including heart disease and stroke (Gebreyowhans *et al.*, 2019). However, a balanced ratio of Ω-3–Ω-6 fatty acids is important because these fatty acids have different effects on the body and their imbalance could lead to increased risk of chronic diseases (Abdelhamid *et al.*, 2018; Patel *et al.*, 2022). Thus, a suitable ratio of Ω-3–Ω-6 fatty acids is essential while formulating low-fat dairy products in order to maintain good health. Many studies have suggested that a lower ratio of Ω-6–Ω-3 fatty acids is more desirable for reducing the risk of many of the chronic diseases of high prevalence (El-Assar *et al.*, 2019; Modzelewska-Kapituła *et al.*, 2009; Patel *et al.*, 2022; Singh, 2017).

In addition, phytosterols, which are plant-derived steroids found in various plant-based oils (He *et al.*, 2018), can benefit human health. As phytosterols are structurally similar to cholesterol, they have been shown to reduce absorption of cholesterol from diet by 30–50% and decrease blood cholesterol levels (Ferguson *et al.*, 2016). When phytosterols and cholesterol are present in the intestines, the phytosterols compete with cholesterol for absorption, resulting in less cholesterol being absorbed by the body (Kozłowska *et al.*, 2016). In addition to their cholesterol-lowering effects, phytosterols also possess anti-inflammatory and antioxidant properties (He *et al.*, 2018). These effects could be beneficial in preventing chronic diseases, such as heart disease and cancer (Fidalgo Rodríguez *et al.*, 2020).

Plant-based oils can be used in dairy products in different modes to reduce content of saturated fat and in lowering cholesterol. Some researchers have developed low-fat cheese analogs from skimmed milk by replacing milk fat with canola oil, virgin coconut oil, or olive oil in the original formula, as they were generally less expensive than milk fat and have a higher proportion of healthy polyunsaturated Ω-3 fatty acids (Aini *et al.*, 2020; Leong *et al.*, 2020; Ramel and Marangoni, 2018). In another study, when sunflower oil blended with milk fat was used in some products, such as butter and spread, it significantly increased USFAs, such as oleic acid and LA, by 20–60% and improved the hardness and spreadability of products in cold temperatures without the requirement of chemical modifications (Viriato *et al.*, 2019). Derewiaka *et al.* (2019) attempted to study the effect of chia seed oil on fatty acids and sterol composition of yogurt. The authors found that yogurt fortified with 2% chia seed oil was found to have 57.0% low saturated fat and 2.3-fold escalation in USFAs, compared to natural yogurt. Similarly, grape seed oil (GSO) as a fat replacement was studied for preparing yogurt and analyzing various quality attributes, such as viscosity, textural properties, and sensory characteristics. The results demonstrated a 73.2% decrease in the composition of fatty acids, such as SFA. A 2.43-fold increase in PUFAs was observed with the yogurt fortified with 3% grape seed oil, compared to the control yogurt. The modified yogurt also had high viscosity, water-holding capacity, and improved textural and sensory properties (Kokabi *et al.*, 2021). In a study conducted by Ullah *et al.* (2020), olein fraction from chia seed oil was used to substitute milk fat in ice cream, showing a significant improvement in the concentration of Ω-3 fatty acids.

Dairy products greatly vary in microstructures, with all of them containing a significant proportion of milk fat distributed either in the bulk or dispersed in phases (Patel *et al.*, 2020). As fat contributes to taste, texture, mouthfeel, flavor, viscosity, and other organoleptic properties, a fat replacer must have the same functional properties as that of milk fat and convey the desired quality attributes (Genovese *et al.*, 2022). Thus, it is a challenging task to replace milk fat with liquid oils without compromising the quality attributes of products (Moriano and Alamprese, 2017; Patel *et al.*, 2020).

Table 1. **Summary of fat reduction or saturated fat substitution by natural ingredients in dairy products.**

Type	Sample	condition	Nutritional value output	Key effect	References
Healthy Plant oil	Spread	Mixing high oleic sunflower oil (HOSO) (30–50% w/w) with anhydrous milk fat (AMF) in lipid bases of product.	Unsaturated fatty acid was increased = 38–46% (w/w) (control = 32%).	Adding sunflower oil that has high amount of oleic acid (80% w/w) resulted in spreads with significantly higher unsaturated fatty acids concentration.	Viriato *et al*. (2019)
	Butter	Encapsulating chia oil with chitosan by spray drying before adding them (2–8% w/w) to the butter.	The amount of Ω-3 fatty acids increased up to 17% (w/w), total antioxidant capacity up to 55%.	Chia oil had high amount of alpha linolenic acid (66% w/w) and encapsulated chia oil can protect Ω-3 fatty acids and the antioxidant capacity of butter during storage time.	Ullah *et al*. (2020)
	Cheddar cheese analogues	Adding canola oil in skimmed milk via two-step emulsification (final fat content = 3.87% w/w).	The fat content of the cheese was reduced to 25% (w/w).	The double emulsion cheeses has a distinct microstructure with tiny skimmed milk droplets in the skimmed milk phase encapsulated within the emulsified oil droplets.	Leong *et al*. (2020)
	Yogurt	Adding 2% (w/w) of chia seed oil to natural yogurt.	The phytosterols were increased to 3.34% (w/w), linoleic fatty acids were increase to 12.93% (w/w).	Chia oil has high amount of alpha linolenic acid (66% w/w) and phytosterols (4.5% w/w).	Derewiaka *et al*. (2019)
Carbohydrate	Yogurt	Adding basil seed gum (BSG) solution to reduced-fat or nonfat yogurt at a concentration of 1% (w/v).	The saturated fat content of the yogurt was reduced to 0.5–1% (w/w) and antioxidant activity increased by 1.75 times of control.	The basil seed gum has flavonoid and phenolic acid, so BSG addition enhanced antioxidant activity in yogurt.	Kim *et al*. (2020)
	Yogurt	Adding 7.5% (w/v) chia seed mucilage to a skimmed yogurt formula.	The saturated fat content of the yogurt was reduced by 3.5% (w/w) and fiber contents increased by nine times of control.	Fiber of chia seed mucilage led to a highly structured network that provides samples with good yogurt gel strength and makes them more viscous.	Ribes *et al*. (2021)
	Labneh cheese	Adding of 0.8% (w/w) inulin into reduced-fat and low-fat milk for Labneh cheese processing.	The saturated fat content of the cheese was reduced to 6% (w/w) and prebiotic increased to 0.8% (w/w).	Inulin is prebiotic in cheese that interacted with skimmed milk casein chains and gave rise to new structures and matrices of cheese.	Aydinol and Ozcan (2018)
	Mozzarella cheese	Mixing 250 mL of 0.5% (w/v) konjac glucomannan (KGM) solution with 4 L of skimmed milk or low-fat milk for cheese processing.	The saturated fat content of the mozzarella was reduced by 27% (w/w).	KGM is a fat replacer that can breaks protein matrix to provide a softer texture, great meltability, and stretchability of cheese.	Das *et al*. (2019)

	Processed cheese	Adding inulin as fat replacers at a concentration of 3–7% (w/w).	The saturated fat content of the mozzarella was reduced to 50% (w/w).	Inulin can form complexes with dairy protein aggregates via hydrogen bonds, becoming part of the structural network, the higher the emulsion stability and gel formation tendency, and reduction in flowability.	Schädle (2022)
	Ice cream	Adding 1.2–3.0% (w/w) of agave fructans in low-fat ice cream formula.	The saturated fat content of the ice cream was reduced to 3% (w/w) and 2% (w/w) sugar reduction.	Agave fructans used in ice cream to reduce fat and sugar because of their capacity to form aggregates that trap free water, reducing the ice crystal size during freezing that reflected in good texture and consumer acceptance.	Jardines *et al.* (2020)
	Ice cream	Substituting inulin (4.02% w/w) in the formulation of low-fat reduced-sugar ice cream.	There are 4.02% dietary fibers in ice cream. The fat content of the ice cream was reduced by 2.3% (w/w).	Inulin is a fat replacer that plays an important role in improving ice cream texture because its good ability to bind water molecules and form a gel network.	Samakradhamrongthai *et al.* (2021)
Protein co-products	Yogurt	Adding whey protein microparticles for the adjustment of protein level to a total of 4.25% and 5.0% (w/w) protein in low fat yogurt (0.5% fat).	The protein content of the yogurt was increased by 1.5% (w/w) and 3% (w/w) fat reduced.	Whey protein microparticles improve more compact protein network and interconnected with whey protein serum and casein, resulting in decreased serum separation of yogurt.	Torres *et al.* (2018)
	Yogurt	Implementing thermal-denatured whey protein-milk fat emulsion gel microparticles as fat replacers at 26.5% (w/w) in low-fat yogurt.	The fat content of yogurt was reduced by 2.7% (w/w).	Thermal-denatured whey protein enhanced the three-dimensional structure forming of the protein, firmness, and yogurt gelation.	Li *et al.* (2021)
	Yogurt	Adding 0.4% (w/w) fish gelatin-xanthan gum mixture (99:1) in yogurt formula.	Low-fat yogurt with 0.4% fish collagen.	Fish gelatin-xanthan gum mixture contributes to the formation of casein network that best mimicked the storage moduli of milk gels with porcine gelatin in low-fat stirred yogurt.	Yin *et al.* (2021)
	Cheddar cheese	Adding fish gelatin and Arabic gum (1:1; 2% w/w) mixing with olive oil at a ratio of 30:70 (w/w) in milk cheese.	Low-fat cheese (6% w/w fat).	Fish gelatin-gum Arabic emulsion provided a greater casein network discontinuity and increased open spaces that make the softer and less rubbery texture of low-fat cheese.	Anvari and Joyner (Melito) (2019)
	Ice cream	Adding soy protein hydrolysates (5SPH, 5% degree of hydrolysis) and xanthan gum (XG) mixing at a ratio of 96:4 (w/w) in ice cream mixture.	50% fat-reduction in ice cream.	5SPH and XG mixing enhance the appearance, taste, and texture similar to 10% full-fat ice cream. Mixing XG with 5SPH can increase the consistency of ice cream, because XG delays soy protein molecular movement, stabilizes the protein, and protects aggregation in the ice cream matrix.	Liu *et al.* (2018)
	Milk dessert	Substituting pea and potato protein microparticles in fat-reduced milk desserts (50% w/w) in the formulation.	50% fat reduction in milk desserts.	Pea protein enhances the gelling properties, adhesiveness, and creaminess than potato protein due to higher disulfide bonds.	Tanger *et al.* (2022)

A promising approach is to apply double emulsions technique, in which emulsion droplets contain an inner emulsion of the opposite phase and form a water-in-oil-in-water emulsion. Double emulsions have been studied to improve stability and mechanical properties, in addition to reducing the fat content of various dairy products, including cheese (Leong *et al.*, 2020), yogurt (Lobato-Calleros *et al.*, 2009), and ice cream (Tekin *et al.*, 2017). In a study conducted by Leong *et al.* (2020), ultrasonication was used to form canola oil double emulsions to replace dairy fat in cheddar cheese. Double emulsions significantly reduced the fat content without altering cheese structure, and the resultant cheese had a distinct microstructure with tiny skimmed milk droplets in the skimmed milk phase encapsulated within the emulsified oil droplets. Moreover, the modified cheese showed improved stability and textural properties during aging process (Leong *et al.*, 2020).

In another study, low fat yogurt was formulated by making water-in-oil-in-water multiple emulsions using skimmed milk and canola oil and stabilized with carboxy methyl cellulose and amidated low-methoxy pectin. The results suggested that yogurt prepared from multiple emulsion had better microstructure and rheological properties, compared to a full-fat control yogurt (Lobato-Calleros *et al.*, 2009).

A direct replacement of USFA-rich oils in dairy products could cause rapid oxidation, rancidity odors, and inhomogeneous food matrices (Gebreyowhans *et al.*, 2019), which would affect the quality of products during storage. As lipid oxidation is unavoidable with reduced SFAs and increased USFAs during fat substitution, novel techniques must be developed to protect healthy plant oils that remain intact during processing and storage (Zhang *et al.*, 2022b). A potential solution to overcome this problem is to use microencapsulation, in which plant oils are effectively protected against environmental factors, such as heat, light, moisture, and oxygen.

The use of oil microcapsules as potential fat replacers has recently been shown to have great potential in different food products (Alasalvar *et al.*, 2022; Ullah *et al.*, 2020). Ullah *et al.* (2020) studied the effect of chia oil encapsulated within chitosan to prepare butter to increase Ω-3 fatty acids and to improve oxidative stability. The results of the conducted study by Ullah *et al.* (2020) showed that addition of microencapsulated chia oil could increase the concentration of Ω-3 fatty acids in butter by up to 17% w/w with reasonable oxidative stability without causing adverse effects on sensory characteristics during 90 days of storage.

Wang *et al.* (2022) applied soybean oil body (SOB), which are lipid-storing organelles in soybean with a particle size in the approximate range of 0.4–2.0 μm, as a milk fat substitute for the low-fat preparation of ice cream and analyzed for viscosity, melting, texture, and sensory properties. The results showed that the modified ice cream prepared with SOB at 50% substitution had 7.4% less total fat with 3.7- and 6.8-fold increase in LA and ALA, respectively, compared to control ice cream. The ice cream possessed high viscosity, droplet uniformity, better melting properties, and texture characteristics with good sensory acceptability.

Another strategy to improve the structural properties of dairy products to be incorporated with healthy plant oils is introducing oleogelation. Oleogelation is an innovative technology that structures liquid plant oil into a gel-like material. Through oleogelation, liquid plant oil can maintain a self-standing solid structure, although it contains a lot of USFAs. A widely used oleogelators are natural waxes, mono diglycerides, alcohols or esters of fatty acids, phospholipids, and phytosterols (Pehlivanoğlu *et al.*, 2018). Different studies have investigated the application of oleogelators in the preparation of dairy products to improve structure and desirable physicochemical properties (Bemer *et al.*, 2016; Moriano and Alamprese, 2017; Santos and Lannes, 2022).

As described above, different incorporation strategies have been followed to fortify dairy products with USFAs and reduce the content of SFAs. Researchers have even attempted to feed dairy cows with specially formulated diet rich in USFAs for a certain period to obtain modified milk. Dairy products, such as ultra-high temperature (UHT)-processed milk, cheese, and butter prepared from modified milk, resulted in high USFAs and low SFAs (Kliem *et al.*, 2019).

In another study conducted by Kliem *et al.* (2019), the above-mentioned products, such as UHT milk, cheese, and butter prepared with 23%, 38%, and 8% lower SFA and 71%, 43%, and 84% higher MUFA, respectively, compared to control products, were consumed by participants. The results showed that after 12 weeks of consumption, serum total cholesterol and LDL cholesterol were significantly reduced in case of participants who had consumed modified dairy products, compared to participants of the control group (Vasilopoulou *et al.*, 2020). A recent review focused on the fortification of USFAs into dairy products reported about different strategies, including feeding of cows with USFAs-rich feeds, direct incorporation of oils and their emulsions, and encapsulation of USFAs-rich oils (Villamil *et al.*, 2021).

Carbohydrates as a fat replacer

Carbohydrates have long been used in the food industry to improve the texture and consistency of various products. Recently, a growing interest has been shown in using carbohydrates as fat replacers in dairy products (Akbari *et al.*, 2019). Their functionalities are related to stabilizing, thickening, and emulsifying of proteins and fats in the food system (Munekata *et al.*, 2020). Carbohydrate-based fat replacers are "fat mimetics," which exhibit polar and water-soluble characteristics, and bind more water, provide lubricity, and mimic mouthfeel of fat; however, unlike healthy plant oils, they do not have functional properties of fat, such as flavor-carrying ability (Aydinol and Ozcan, 2018).

Carbohydrate-based fat replacers are hydrocolloids, which include gums, carrageenan, arabinoxylans, β-glucans, dextrins, pectins, mucilages, modified starch, and inulin. Hydrocolloids are complex carbohydrates characterized by their hydrophilicity and can form a gel-like structure when added to dairy products (Pirsa and Hafezi, 2023). They can be derived from natural sources, such as seaweed and plant gums, or synthesized in laboratory (Li and Nie, 2016). When using hydrocolloids as fat replacers in dairy products, it is important to consider the type and the amount used (Yousefi and Jafari, 2019).

Different types of hydrocolloids have different rheological texture properties, such as gelling and thickening properties (Li and Nie, 2016; Pirsa and Hafezi, 2023). Therefore, choosing the right type for the desired application is important. For instance, in yogurt, decrease in fat content could affect rheology and microstructure, such as syneresis and phase separation, because of loss of water-holding capacity (Laiho *et al.*, 2017). To solve these problems, hydrocolloids obtained from plants, such as basil seed gum, chia seed mucilage, or xanthan gum, have been investigated as alternative fat replacers in yogurt. The results established that adding hydrocolloids to yogurt could mitigate the degree of syneresis during storage and enhance the consistency, network structure, firmness, and viscosity of reduced-fat yogurt. In addition, adding hydrocolloids can improve nutritious value of yogurt. Bioactive compounds, such as adding basil seed gum, can enhance the total content of phenols and flavonoids as well as antioxidant activity, or chia seed mucilage can improve content of dietary fibers in yogurt (Kim *et al.*, 2020; Ribes *et al.*, 2021).

Aziz *et al.* (2018) investigated the effect of okra gum as a fat replacer in the preparation of ice cream and found that addition of okra gum as 44–55% fat substitution resulted in acceptable melting, textural, and sensory properties. However, the authors observed that complete substitution of fat with 100% okra gum had negative influence on quality attributes because of poor structural network (Aziz *et al.*, 2018). The authors also suggested that use of a single fat replacer is not sufficient to fulfill the characteristics of milk fat, and thus combination of fat replacers are recommended for enhancing overall quality. Therefore, hydrocolloids are usually formulated with other fat replacers to achieve desirable performance in low-fat foods (Peng and Yao, 2017). For instance, in the preparation of low-fat yogurt using canola oil and skimmed milk to form water-in-oil-in-water emulsion, hydrocolloids, such as carboxy methyl cellulose and amidated low-methoxy pectin, were used as stabilizers. These hydrocolloids provided gel-like structure to yogurt and compensated the functioning of fat globules while improving microstructure and rheological properties (Lobato-Calleros *et al.*, 2009).

In addition to gums, starch-based fat replacers have been largely implicated in dairy processing (Chen *et al.*, 2020). Different methods, applying chemicals and enzymes, have been used to modify starch to enhance functional properties, such as water-holding capacity and improved thickening if used as a fat replacer. A study investigated the effect of modified sweet potato starch by acid treatment on quality parameters during the production of ice cream. The results revealed that the incorporation of 1% modified starch as a fat replacer improved sensory and textural attributes at the end of storage period and found to be as acceptable as high-fat ice cream (Babu *et al.*, 2018). Similarly, in another study, starch in different concentrations modified by enzymatic treatment was used for producing ice cream. The results suggested that modified starch at 20% level resulted in significant reduction of fat content and calories of ice cream (Kale *et al.*, 2020).

Hydrocolloids are also used for the preparation of cheese analogues to improve their structural properties. For instance, a low-fat Halloumi cheese prepared using modified maize starch as a fat replacer showed improved textural and sensory properties while decreasing the period of rennet coagulation, compared to control cheese (Basiony and Hassabo, 2022). In another study, the effect of native and modified starch was compared as a fat replacer in the preparation of cheese. Modified starch exhibited higher viscosity and water-holding capacity, compared to native starch, indicating that some type of modifications of starch is required to enhance gelling properties (Diamantino *et al.*, 2019).

Further, Bagheri *et al.* (2018) evaluated 5–15% high and low amylose cross-linked rice starches as a fat replacer in reduced fat cream preparation. The results indicated that sensory and physicochemical characteristics of cream were not affected with 5% cross-linked starch. However, the cream prepared with any concentration of cross-linked starch possessed less swelling property. The authors suggested that cross-linking of starch to make it as a fat replacer might have affected the granule diameter and resulted in poor swelling.

A recent review focused on the use of starch-based fat replacers in foods has reported the types and functions of starch-based fat replacers, their applications in various foods, and their current and the future market scenario (Chen *et al.*, 2020). Among the carbohydrate hydrocolloids, arabinoxylans, β-glucans, pectins, gums, mucilages, and inulin are considered as soluble dietary fibers, as they are neither digested by human digestive enzymes nor absorbed in the small intestine. Instead, they enter the large intestine undigested, where they are fermented by gut microflora and promoted the growth and activity of beneficial bacteria in the colon. Owing to this, upon consumption, they exert prebiotic effect and other metabolic activities, including delayed absorption of glucose, increased immune functioning, lowering of cholesterol, enhanced digestive health, and promoting cardiometabolic and mental health and mineral bioavailability (Gibson *et al.*, 2017; Holscher, 2017; Hurtado-Romero *et al.*, 2020; Schädle, 2022). Thus, soluble dietary fibers being used as fat replacers in dairy products are also popular for their prebiotic effects (Farias *et al.*, 2019).

Various food researchers have investigated the beneficial addition of dietary fibers in the formulation of reduced-fat food products (Akbari *et al.*, 2019; Farias *et al.*, 2019; Karimi *et al.*, 2015; Kawee-ai *et al.*, 2018). In a research study, El-Assar *et al.* (2019) investigated the effect of inulin, a known prebiotic dietary fiber at 5–9% (w/w) on functional and organoleptic properties of low-fat cheese spread. The results showed that addition of 5% inulin enhanced the physicochemical, rheological, and sensory characteristics of low-fat processed cheese, while stability of inulin was affected during storage. El-Assar *et al.* (2019) suggested that reduction in stability of inulin could be due to partial hydrolysis during processing at high temperatures.

Similarly, the addition of inulin in reduced-fat ice cream was studied by Samakradhamrongthai *et al.* (2021), who observed that the addition of inulin influenced the firmness, hardness, and melting rate. It had an important role in improving ice cream texture because of its good ability to bind water molecules and form a gel network. The optimized content of inulin in ice cream was 4.02% (w/w) and the fat content was decreased to 2.3% (w/w) with excellent sensory acceptance.

In contrast, the low-fat yogurt prepared with 0.5% fat content and 2.7% inulin received slightly less score, compared to full-fat yogurt in terms of sensory properties and viscosity (Modzelewska-Kapituła and Kłębukowska, 2009). The authors concluded that both inulin concentration and fat content could have influenced viscosity in low-fat yogurt, and the quantity of prebiotic should be considered while designing low-fat yogurt in order to have acceptable quality. Consistent with the above research, some researchers suggested that addition of more than 1% inulin in the manufacture of low-fat yogurt negatively influenced few physical and sensory parameters, while yogurt prepared with 1% or less showed acceptable properties, compared to control (Aslam *et al.*, 2015; Guven *et al.*, 2005). It is anticipated that consumption of reduced fat dairy products fortified with inulin promotes the growth of healthy bacteria in the gut and enhances mineral absorption, immune function, and decreases serum cholesterol. Moreover, inulin fermentation might induce the production of short chain fatty acids, such as acetate, propionate, and butyrate to produce beneficial effects in the body (Guven *et al.*, 2005). However, the quantity of prebiotics, such as inulin, to be used in the manufacture of low-fat dairy products has to be optimized in order to have favorable effects, including rheological, sensory, and physicochemical properties.

To improve sensory attributes, some researchers utilized multiple fat replacers, such as microencapsulated chia oil and inulin, for producing processed cheese (Cardoso *et al.*, 2020). The results showed that the resultant cheese had 36% reduced fat, compared to the control cheese, and microencapsulation had better sensorial characteristics, compared to the formulation without encapsulation and the control (Cardoso *et al.*, 2020). Other dietary fibers, such as fructans and glucomannan, were also used in the formulation of low-fat dairy products. Jardines *et al.* (2020) utilized agave fructans for preparing ice cream with the aim to reduce fat and sugar in the final product while maintaining its quality attributes. The results demonstrated that ice cream prepared with less than 1.2% agave fructans resulted in poor texture and sensory attributes. In contrast, concentration of 1.2–3.0% agave fructans produced smooth, creamy, and fluid-textured ice cream.

In another study, a dietary fiber, konjac glucomannan, which is claimed to be beneficial to human health because of its prebiotic activity, was used as a fat replacer to produce low-fat and skimmed Mozzarella cheese, and to evaluate functional and pizza bake properties. The addition of 0.5% (w/w) glucomannan could reduce cheese fat by 27% (w/w). Further, the results showed the desirable pizza bake characteristics with higher meltability, greater stretchability, and enhanced microstructure properties to provide a softer texture (Dai *et al.*, 2019). Peng and Yao (2017) have recently reviewed carbohydrates as fat replacers. The authors provided information about nature, type, and functioning of fat replacers, starch, maltodextrin, polydextrose, gums, and fibers-based fat replacers, and the mechanism of fat replacement with carbohydrate-based fat replacers.

Protein co-products

Similar to carbohydrate-based fat replacers, protein-based materials are also used as "fat mimetics." They also minimize negative impact of protein interactions in low-fat foods and play a major role in fat replacement of oil-in-water emulsion food products (Yashini *et al.*, 2019). Different types of proteins are commonly used as a fat replacer. These include animal proteins, such as whey, casein, egg white, and plasma proteins, collagen, and gelatin, and plant proteins, such as soy, rice, potato, corn, wheat gluten, and pea proteins. Proteins that influence solubility, viscosity, gelling, and emulsifying properties, flavor, and textural properties are better fat replacers of the food system (Yashini *et al.*, 2019). Each type of protein has unique properties, which affect the texture and flavor of the final product. For example, soy protein has a slightly nutty flavor, and whey protein has a more neutral flavor (Shi and Li, 2021). Although protein-based fat replacement has some advantages over carbohydrate-based fat replacement in terms of lowering both fat and cholesterol, calorie reduction, flavor enhancement, and health benefits, their high cost restrict their usage in the manufacture of dairy products (Kew *et al.*, 2020; Yashini *et al.*, 2019). Thus, protein co-products recovered from the food industry could be the suitable candidates to be used as fat replacers, as they are cost-effective with value-added benefits (Álvarez-Castillo *et al.*, 2021). Moreover, this minimizes the complications involved in their disposal from the industry in the environment (Papademas and Kotsaki, 2020).

Protein co-products, such as milk protein concentrate or whey protein and whey protein microparticles recovered from the cheese processing industry, are usually used for fat reduction in dairy products (Akbari *et al.*, 2019; Wherry *et al.*, 2019). For instance, whey protein microparticles added to low-fat yogurt increased protein content and reduced fat. Besides, they improved the texture, increased the compact protein network, and decreased the serum separation of yogurt (Torres *et al.*, 2018). Moreover, when microparticulated whey proteins were added to reduced-fat yogurt, it improved important sensory attributes, such as creaminess and thickness of yogurt formulations (Hossain *et al.*, 2020). A relatively high native to denatured whey protein ratio of whey protein microparticles impacted the apparent viscosity and elasticity of yogurts (Ipsen, 2017; Torres *et al.*, 2018).

Li *et al.* (2021) studied the utilization of thermal-denatured whey protein isolate as milk fat emulsion gel in low-fat yogurt. Supplementing the thermal-denatured whey protein isolates emulsion gel at 26.5% (w/w) could replace 2.7% of dairy fat content in yogurt and improve the water-holding capacity, textural quality, and overall sensory property of low-fat yogurt. The addition of whey proteins not only reduced the fat content in dairy products but also provided the consumers added dietary protein with numerous health benefits (Genovese *et al.*, 2022). However, sole utilization of plant proteins has disadvantages of having shortage of certain essential amino acids (Yashini *et al.*, 2019). Thus, a combination of ingredients to produce low-fat dairy products is suggested for achieving more health benefits and acceptable sensory quality (Genovese *et al.*, 2022). Liu *et al.* (2018) investigated the effect of soy protein hydrolysate (5SPH) combined with xanthan gum (XG) when used as a fat replacer in the formulation of ice cream. Liu *et al.* (2018) found that 96:4 ratio of combined fat replacer had replaced 50% fat and maintained the textural and sensory quality similar to that of full-fat ice cream.

Other animal source proteins, such as collagen and gelatin, are also suitable fat replacers when used in combination with carbohydrate-based fat replacers in an emulsion system (Yashini *et al.*, 2019). For instance, fish gelatin, a partially hydrolyzed product from fish collagen recovered from fish processing industry, is one of the preferred choices of fat replacers in dairy products (Anvari and Joyner [Melito], 2019; Yin *et al.*, 2021).

Gelatin and collagen have excellent emulsion-stability, gel-formation, and water-holding properties. Owing to their unique properties, gelatin and collagen can substitute fat, as they can mimic fat's sensory characteristics, smoothness, and lubrication properties by "ball-bearing" effect (Nourmohammadi *et al.*, 2023). Gelatin chains create a sensation that mimics the melting point of natural fat under oral conditions, which is approximately 37°C (Godoi *et al.*, 2021). Considering collagen, it contains proline, hydroxyproline, and alanine as collagen peptides, and these properties of collagen make it a good fat replacer. It binds with water to form a glue-type viscous agent, resulting in higher water-holding and stronger emulsion capacities (Ibrahim *et al.*, 2018). In the yogurt system, fish gelatin modified with XG replaces mammalian gelatin in acid milk gels and low-fat yogurt. Moreover, increasing the mixing ratio of XG and fish gelatin results in a more homogeneous yogurt structure (Yin *et al.*, 2021). In the reduced-fat and low-fat Cheddar cheese processing, Anvari and Joyner [Melito] (2019) added a fish gelatin–Arabic gum emulsion as a fat replacer, resulting in a greater casein network discontinuity and increased open spaces in the modified cheese. The softer and less rubbery texture of the modified cheese was evident, compared to the conventional low-fat cheese.

Plant proteins have become increasingly popular as a healthy and sustainable alternative to animal proteins (Hu *et al.*, 2022), and can be used as a fat replacer in food products, thereby providing a healthier and more sustainable alternative to traditional fats (Hu *et al.*, 2022). Liu *et al.* (2018) substituted 0–100% fat with a 5% degree of hydrolysis of 5SPH and XG (mixing ratio 96:4 [w/w]) in ice cream mixture. Liu *et al.* (2018) found that 5SPH-XG mixture could be a good substitute for 50% fat in ice cream. The 5SPH-XG ice cream had an appearance, taste, and texture similar to that of 10% full-fat ice cream. This was due to 5SPH, which had a good emulsion stability and water-holding capacity. Moreover, XG delays soy protein molecular movement, stabilizes the protein, and protect aggregation in the ice cream matrix.

Tanger *et al.* (2022) produced fat-reduced milk desserts by substituting 50% (w/w) of fat content in recipe by pea and potato protein microparticles. It was found that the pea protein enhanced gelling properties, higher adhesiveness, and creaminess in a better manner than the potato protein. Potato protein microparticles have lower disulfide bonds than pea protein microparticles. The lower the number of disulfide bonds, the less stable is the particle. Thus, substituting saturated fat with higher cholesterol with plant protein resulted in lowering of cholesterol in food products.

However, reducing dairy fat by substituting with plant oil, carbohydrate, or protein could have adverse effects. The amount and bioavailability of dairy fat-soluble vitamins and essential minerals, such as vitamins A and D and calcium, would be lower if dairy fat is reduced (Moriano and Alamprese, 2017; Nourmohammadi *et al.*, 2023; Patel *et al.*, 2020). Moreover, addition of plant oil, plant protein, or fish protein negatively affected the sensory properties, such as fishiness, grassiness, greenishness, and bean-like off-notes, of plant proteins. Therefore, these challenging problem must be investigated in the future studies (Mayengbam *et al.*, 2021; Shi and Li, 2021; Tanger *et al.*, 2022).

The type and amount of fat replacers to be substituted for milk fat must also be considered. In this regard, a recent detailed review has been brought out by Genovese *et al.* (2022) on different types of fat replacers based on carbohydrates, proteins, USFAs, and their combinations for preparing functional ice cream. Thus, a number of factors, such as properties and combination of fat replacers, composition, and structure of dairy products, strongly influence the incorporation of fat replacers in dairy products. Therefore, understanding these factors and their mechanism is crucial in developing and achieving the best product quality with consumer acceptance.

Probiotics for lowering both cholesterol and saturated fat in dairy products

Probiotics are beneficial microorganisms that are found in human gut and have several health benefits (Tewari *et al.*, 2019). Common probiotics include lactic acid bacteria (LAB), *bifidobacteria*, and yeasts from sources, such as yogurt, cheese, kefir, sauerkraut, and human breast milk as well as digestive tract and feces. (Castellone *et al.*, 2021). These bacteria help to maintain the balance of microorganisms in the gut, thus promoting a healthy digestive system, boosting the immune system, and reducing the risks of NCDs (Khalil *et al.*, 2021).

How do probiotics lower cholesterol levels and reduce saturated fat?

Recently conducted studies have shown that probiotics help to lower cholesterol levels in both human body and dairy products; this is an essential factor for reducing the risk of NCDs (Fadl and Kamel, 2022; Frappier *et al.*, 2022; Ishimwe *et al.*, 2015; Sivamaruthi *et al.*, 2019). The mechanism of probiotics in lowering cholesterol levels (Figure 3) is as follows (Sun and Buys, 2015):

1. Probiotics help to produce bile salt hydrolase (BSH) enzymes in the gut. BSH promotes the breakdown of cholesterol by hydrolyzing conjugated bile acids. This process releases free primary bile acids (e.g., cholic acid and chenodeoxycholic acid) that are hardly reabsorbed by the intestines and excreted in faeces, resulting in decreased serum cholesterol levels (Pourrajab *et al.*, 2020; Romero-Luna *et al.*, 2021).

2. Probiotics increase the production of short-chain fatty acids (SCFAs) from oligosaccharides, bind to the peroxisome-activated proliferator in order to activate them. This helps to reduce cholesterol absorption in the intestines. Some SCFAs, such as butyrate and propionate, can inhibit enzyme reactions in the liver, resulting in cholesterol synthesis inhibition (Romero-Luna *et al.*, 2021).

3. Some probiotics, for instance, *Lactobacillus acidophilus*, have protease-sensitive receptors on their cell surface that bind tightly to exogenous cholesterol and incorporate them into their cell membrane (Ishimwe *et al.*, 2015; Mahmmodi *et al.*, 2021; Minj *et al.*, 2021).

4. LAB, such as *L. acidophilus*, *L. bulgaricus*, and *Lacticaseibacillus casei* ATCC 393, produce cholesterol reductase enzyme, which reduces cholesterol to coprostanol. This process lowers cholesterol levels because coprostanol is poorly absorbed by the intestines and is expelled through feces (Romero-Luna *et al.*, 2021).

5. Probiotics create strong interaction of their cell wall proteins and exopolysaccharides with cholesterol, thereby removing excess of cholesterol with cell

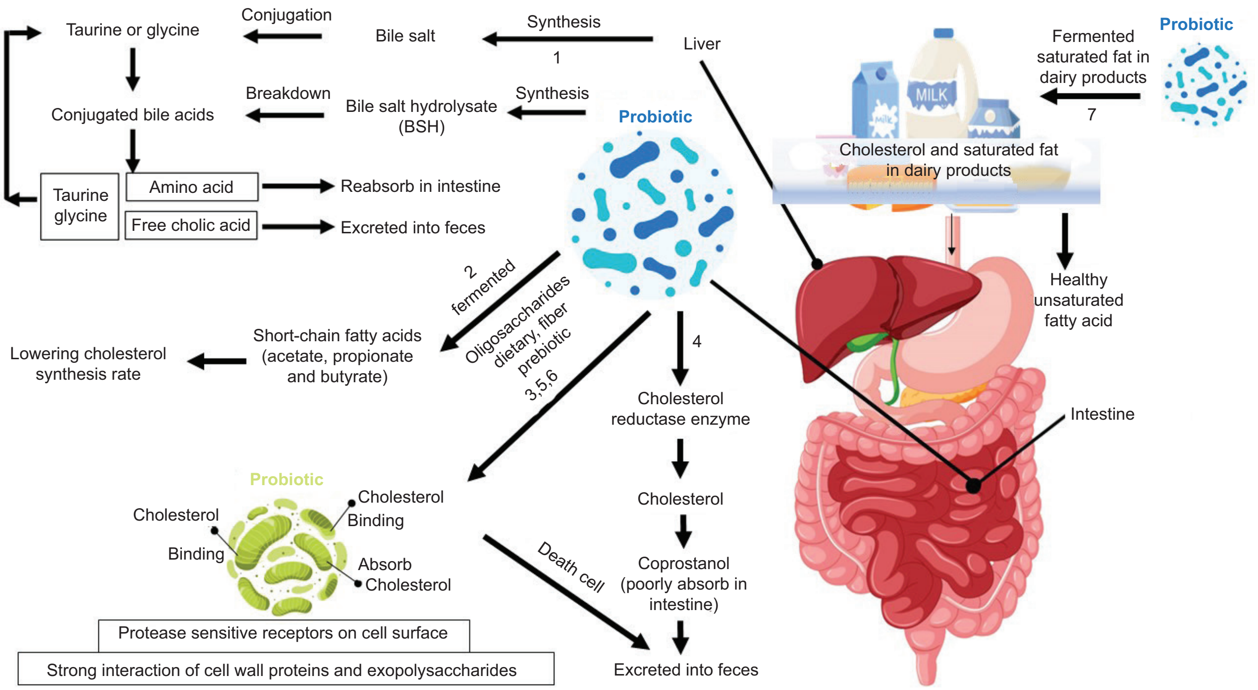

Figure 3. **Mechanism of probiotics in lowering cholesterol levels and saturated fat in dairy products.**

death in the body (Angelin and Kavitha, 2020; Korcz *et al.*, 2018).

6. Probiotic bacteria in dairy products remove cholesterol in milk and milk products through their cell wall adsorption (Sharma *et al.*, 2021).

7. Probiotics produce enzymes, such as lipase, during fermentation of dairy products, converting saturated fat into healthy USFAs (Ostadzadeh *et al.*, 2022).

Probiotics in dairy products and their impact on lowering both cholesterol and saturated fat

Probiotics reduce total cholesterol and LDL cholesterol levels more effectively when taken in fermented milk or yogurt rather than in capsule form (Sun and Buys, 2015). Several studies have investigated the effect of probiotics on lowering cholesterol in bacteria and culture media. However, only few studies have been conducted on the cholesterol- and saturated fat-reducing activity of probiotics in dairy products. Here, we focus on some research that investigated the effect of probiotics on cholesterol-lowering in dairy products. A summary of different studies that investigated the effect of probiotics on saturated fat reduction and cholesterol-lowering is given in Table 2.

Different studies aimed to isolate probiotics from traditional Thai fermented foods (Jitpakdee *et al.*, 2021), a traditional Korean fermented cabbage "Kimchi" (Kim *et al.*, 2021), Mongolian traditional dairy products (Cho *et al.*, 2020), or traditional Italian cheeses (Albano *et al.*, 2018), and screened them for lowering of both cholesterol and saturated fat. The favorite probiotics isolated from fermented food products are *Lactobacilli* (e.g., *Lacticaseibacillus rhamnosus, L. plantarum, L. acidophilus, L. casei,* and *L. paracasei*), *Bifidobacteria* (e.g., *Bifidobacterium lactis, Bifidobacterium bifidum,* and *Bifidobacterium breve*), Enterococcus species (e.g., *Enterococcus lactis* and *Enterococcus faecium*), and yeasts (e.g., *Kluyveromyces marxianus* and *Saccharomyces cerevisiae var. boulardii*) (Ansari *et al.*, 2021). Researchers have suggested that the final product must contain at least 10^7–10^9 CFU/g of viable probiotic bacteria in order to meet the minimum therapeutic requirements and consume more than 100 g/day to have supportive impact on health (Ahmed *et al.*, 2017; Albano *et al.*, 2018; Sohag *et al.*, 2019).

Yogurt is a fermented dairy product rich in probiotics (Das *et al.*, 2019). The current systematic review and meta-analysis (seven eligible trials with 274 participants) carried out by Pourrajab *et al.* (2020) confirmed that yogurt consumption could reduce cholesterol levels in the blood by up to -8.73 mg/dL. Similarly, Fadl and Kamel. (2022) found that probiotics from Egyptian yogurt, such as *L. casei*, *L. lactis*, and *L. acidophilus*, have the bile salt hydrolysis gene, which is related to cholesterol reduction effects in the blood.

Table 2. The effect of probiotics in dairy products on lowering saturated fat and cholesterol.

Dairy products	Probiotic	Key effect	References
Synbiotic yogurt	*B. lactis* plus *L. acidophilus* (3% v/v; 10^7 CFU/mL)	Lowering the serum total cholesterol levels 9.5–17% in mice	Ahmed *et al.* (2017)
Yogurt	*L. acidophilus* and *L. bulgaricus* (9.5 × 10^9 CFU/mL)	Decreasing total cholesterol 22–24% in diabetic mice	Sohag *et al.* (2019)
Yogurt	*B. coagulans GBI-30 6086*	Decreasing total cholesterol by 10% in mice	Almada-Érix *et al.* (2021)
Fermented milk	*P. pentosaceus* ENM104	Decreasing total cholesterol by 15.71% in fermented milk	Jitpakdee *et al.* (2021)
Minas Frescal cheese	*L. casei* 01 (1% v/v; 10^8 CFU/g)	• Improving higher PUFA values by 1.16 times compared to the control cheese • Reducing total cholesterol by 6.21%, LDL cholesterol by 6.85%, and triacylglycerides by 6% in the hypertensive overweighed women	Sperry *et al.* (2018)
Traditional Italian cheeses	*L. casei* VC199, *L. paracasei ssp. paracasei* SE160 and VC213, *L. plantarum* VS166 and VS513, *E. faecium* VC223, and *E. lactis* BT161	Reducing total cholesterol by 16–21% in cheese	Albano *et al.* (2018)
Coalho cheese	The probiotic mixture of *B. lactis* with *L. acidophilus*, *L. paracasei* (1:1:1; 0.01% w/v)	Lowering 2% of SFAs and increasing 2% PUFAs levels in cheese	Bezerra *et al.* (2017)
Butter	*P. acidilactici* LRCC5307 (8.74 log CFU/g)	Decreasing by 11% total cholesterol in butter	Kim *et al.* (2021)
Traditional Iranian butter	*L. pentosus* IBRC-M11045 (7.49 log CFU/g)	Reducing 10% of saturated fatty acids and increasing 10% of unsaturated fatty acids	Ostadzadeh *et al.* (2022)
Cream	*L. paracasei* (2.5 × 10^9 CFU/50 mL cream)	Decreasing saturated fatty acid (SFA) content in cream by 26.24% at light incubated conditions	Złoch *et al.* (2022)

Almada-Érix *et al.* (2021) studied the effects of food matrices, such as yogurt and orange juice, for their probiotic-delivering and cholesterol-lowering properties. The results revealed that yogurt was an effective carrier for the spore-forming probiotic bacteria *B. coagulans* GBI-306086, and the daily consumption of yogurt for 21 days decreased serum triglycerides (35%) and cholesterol (10%). Unlike orange juice, the fat and protein matrix present in the yogurt could have protected bacterial cells passing through digestive tract to reach the gut. This suggested that the type of food matrices and their composition are significant factors to consider for probiotic application in dairy products and need to be studied more in the future.

The application of a single or a mixture of probiotics in yogurt and fermented milk, and their effect on cholesterol and triglyceride levels, was discussed by several researchers. Sohag *et al.* (2019) investigated the effect of feeding single or combined probiotics (*L. acidophilus* and *L. bulgaricus*) in yogurt to diabetic mice. They found that yogurt containing *L. acidophilus* or *L. bulgaricus* alone or in combination (9.5 × 10^9 CFU/rat/day) decreased total cholesterol by 23%, 22%, and 24%, respectively. This demonstrated that the treatment with a combination of both probiotics had the lowest total cholesterol (105.67 mg/dL) in diabetic mice. The authors suggested that balancing microbiota with a combination of *L. acidophilus* and *L. bulgaricus* significantly reduced cholesterol and diabetic complications.

In contrast, the study conducted by Wa *et al.* (2019) found that when probiotics were administered to hyperlipidemic mice, no significant differences were observed between single (*L. rhamnosus* LV108) and combined probiotic-fermented dairy products (*L. rhamnosus* LV108, *L. casei* grx12, and *L. fermentum* grx08) on total cholesterol and triglycerides levels in the serum, liver, and small intestine. This could be due to inhibition of growth or activity of probiotics on each other (Ishimwe *et al.*, 2015). However, more studies are required to understand how different species of probiotics interact with each other for the overall beneficial effect on dairy products.

Some researchers have investigated the effect of yogurt with probiotics, prebiotics, or their combination (synbiotics) on the lowering of cholesterol (Ahmed *et al.*, 2017; Mofid *et al.*, 2020; Sarfraz *et al.*, 2019). The results demonstrated that synbiotic yogurt had greater potential for lowering cholesterol levels. Sarfraz *et al*. (2019) found that administration of synbiotic yogurt (2.5% w/v fructooligosaccharide plus 2.5% w/v isomalto-oligosaccharide and *L. acidophiluss* ATCC 4357^{TM}) to rabbit (15 g/kg body wt. per day for 4 weeks) could reduce 64–82% of total blood cholesterol. Similarly, Ribeiro *et al.* (2019) revealed that feeding synbiotic yogurt, containing *B. lactis* HN019 (1% w/v; 10^9 CFU/g) as a probiotic and 7% Jerusalem artichoke flour as a prebiotic, to New Zealand white rabbits (10 mL/day for 50 days) decreased 20% of total cholesterol levels, compared to non-synbiotic yogurt feeding. Moreover, the synbiotic yogurt group resulted in the total cholesterol levels of 40.33 mg/dL against 45.33 mg/dL with the probiotic yogurt group.

Ahmed *et al.* (2017) discovered that yogurt fermented with probiotic (3% v/v; 10^7 CFU/mL of *B. lactis* plus *L. acidophilus*), prebiotic (0.75% w/v barley β-glucan), and probiotic mixed with prebiotic, efficiently reduced the serum total cholesterol levels (9.5–17%) in mice. Besides, the yogurt fermented with probiotic mixed with prebiotic was more effective in lowering plasma cholesterol levels than yogurt non-probiotic or yogurt fermented with prebiotic or probiotic alone (120.7, 145.7, 126.6, and 131.8 mg/100 mL respectively). Probiotics and prebiotics can work synergistically to improve survival and promote the growth and activity of probiotic strains in the colon (Zepeda-Hernández *et al*., 2021). Specific prebiotics, such as fructans, inulin, and oligofructose, can increase the activity of probiotics and have cholesterol-lowering effects (Korcz *et al*., 2018). Therefore, suitable probiotic strains with specific prebiotics should be considered for improved health benefits.

Cheese is a dairy product that is the most widely used food matrix for probiotics (Rolim *et al*., 2020). Many studies have demonstrated different cheeses incorporated with the most varied probiotic strains and their cholesterol, saturated fat, and triglyceride-lowering properties (Albano *et al*., 2018; Kouhi *et al*., 2022; Sperry *et al*., 2018). In Minas Frescal cheese, the most popular cheese in Brazil, adding *L. casei* 01 (10^8 CFU/g) improved PUFA values by 1.16 times, compared to the control cheese. Besides, consumption of cheese inoculated with *L. casei* 01 for 28 days led to a reduction in total cholesterol (6.21%), LDL cholesterol (6.85%), and triacylglycerides (6%) levels, compared to 0 day consumption in hypertensive overweighed women. However, *L. casei* 01 did not affect physicochemical properties and microstructure of the cheese (Sperry *et al*., 2018).

Kouhi *et al*. (2022) isolated enterococcal species, such as *Enterococcus faecalis*, *Enterococcus hirae, Enterococcus avium*, *Enterococcus durans*, and *E. faecium*, from Iranian Motal cheese. Their findings demonstrated that these enterococcal species had adhesion ability toward epithelial cells along with high cholesterol assimilation (up to 67.4%) and good auto-aggregation activities by inserting cholesterol in cell membranes.

Bezerra *et al*. (2017) produced Coalho cheese by adding 0.01% of single and probiotic mixture with *L. acidophilus*, *L. paracasei*, and *B. lactis* (in a ratio of 1:1:1). The probiotic mixture produced the lower levels of SFAs (2%) and increased MUFAs and PUFAs (2%) as a synergistic effect, while individual strains did not exhibit this outcome. All the cheeses evaluated presented a satisfactory Ω-6–Ω-3 ratio (from 4:1 to 3:1) that complied with the values recommended for a healthy diet. Some research studies found that cheese ripening time and bacteria tolerance in food matrix could affect cholesterol reduction.

Albano *et al*. (2018) studied the effect of LAB strains isolated from traditional Italian cheeses on cholesterol-lowering of cheese. Various strains of bacteria (*L. casei* VC199, *L. paracasei ssp. paracasei* SE160 and VC213, *L. plantarum* VS166 and VS513, *E. faecium* VC223, and *E. lactis* BT161) were added to raw milk (10 L) at a concentration of 10^7 CFU/mL and allowed to ripen for 30 and 60 days. The authors found that after the 30-day of ripening, all strains decreased the cholesterol content of cheeses. The most significant cholesterol-reducing strains at 30-day period were *L. plantarum* VS513 (21%) and *L. paracasei ssp. paracasei* VC213 (18%). However, after 60-day ripening, *E. lactis* BT161 and *L. paracasei ssp. paracasei* VC213 showed the greatest cholesterol-lowering ability (up to 23%) in cheese. This was due to the persistence of enterococci and some lactobacilli in cheese matrix during the process of ripening. Some *Lactobacillus* spp. reached maximum activity at 30 days of ripening whereas *Enterococci* and *L. paracasei* spp. showed maximum activity by extending ripening to 60 days. Moreover, adding these strains had no negative impact on the sensory qualities of cheese (Albano *et al*., 2018).

Butter and cream are considered valuable dairy products because they contain essential fatty acids, such as linoleic acid, conjugated linoleic acid, or arachidonic acid. In contrast, butter and cream are also rich in SFAs related to NCDs (Bellinazo *et al*., 2019; Kim *et al*., 2021; Pandule *et al*., 2021). Some previous studies investigated the impact of probiotics on lowering of both saturated fat and cholesterol in butter and cream. Kim *et al.* (2021) isolated *Pediococcus acidilactici* LRCC5307 from "Kimchi," a traditional fermented Korean cabbage, and applied for manufacturing low-cholesterol butter. Kim *et al.* (2021) found that after butter fermentation at 42°C for 72 h (7.49 log CFU/g), *P. acidilactici* decreased butter cholesterol by 11% and could help in producing healthier dairy products.

Ostadzadeh *et al.* (2022) isolated LAB, such as *E. durans*, *Lactobacillus*, *Pediococcus*, and *Neoscardovia* from a traditional Iranian butter. They found that these isolated strains had cholesterol-lowering ability in butter. Among the strains, *Lactobacillus pentosus* IBRC-M 11043 and *Pediococcus. Pentosaceus* had a respective higher potential of 36.3% and 21.9% for lowering of cholesterol in butter. However, the butter sample with *Neoscardovia arbecensis* was more acceptable to consumers than *L. pentosus*.

Złoch *et al.* (2022) fermented cream by adding 2.5 × 10^9 CFU of *L. paracasei* to 50 mL of cream and incubating at light and night conditions for 48 h at room temperature. Adding *L. paracasei* in cream decreased SFA content by 17.68% at night and 26.24% under light conditions. This justifies that light is a source of energy for some probiotics and can activate oxygen, leading to lipid peroxidation caused by SFA reduction (Decimo *et al*., 2017; Gómez-Cortés *et al*., 2018; Złoch *et al*., 2022).

In contrast, Bellinazo *et al.* (2019) found that the addition of *L. casei* probiotic strains did not affect the composition of fatty acids in butter during 90-day storage at 4°C. It is important to consider the influence of fermentation conditions, for instance, light (day) or night, and the selection of probiotic strains for cream fermentation and butter production, because these conditions have a significant effect. Light leads to lipid peroxidation, and some probiotics, such as *L. plantarum*, showed strong antioxidant activity that inhibited lipid peroxidation (Złoch *et al*., 2022). Therefore, this factor should not be ignored when choosing the most appropriate LAB strains and fermentation conditions.

Conclusion and the Future Perspectives

Noncommunicable diseases are a leading cause of mortality worldwide. Being a crucial topic of every global sector, NCDs must integrate action and complementary interventions in agriculture and the food industry system. Major risk factors, such as high saturated fats, triglycerides, and LDL cholesterol in food, are significantly related to NCDs. In the dairy research and development sector, scientists continually investigate new approaches for solving these problems by fortifying natural ingredients to replace saturated fat and lowering cholesterol in dairy products, and by using probiotics in dairy products for reducing saturated fat, cholesterol, and triglycerides in both products and the serum. Overall, our review suggests that natural ingredients and probiotics have the potential to be effective in lowering both cholesterol and saturated fat in dairy products. However, the impact of unique ingredients on the dairy food matrix, nutrients bioavailability, optimal dosing, choice of probiotic strains, fermentation condition of probiotics, and toxicological effects must be further investigated. In addition, implementing the technology on an industrial scale is a challenge for further research. Finally, collaboration of researchers, dairy processors, stakeholders, and the government sector is a key for achieving SDGs.

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