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Oat milk analogue versus traditional milk: Comprehensive evaluation of scientific evidence for processing techniques and health effects

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ABSTRACT

Milk, enriched with high-quality protein, is a healthy and nutritious food that meets people's needs. However, consumers are turning their attention to plant-based milk due to several concerns, such as lactose intolerance, allergies and some diseases caused by milk; carbon emission from cattle farming; economical aspects; and low access to vitamins and minerals. Oat milk, which is produced from whole grain oats, is lactose free and rich in a variety of nutrients and phytochemicals. With the significant development of food processing methods and advancement in milk simulation products, the production of plant-based milk, such as cereal milk, has greatly progressed. This review described some features of oat milk analogue versus traditional milk and compared the properties, processing technologies, health effects, environmental friendliness, and consumer acceptance of these products. It is expected to provide a reference for evaluating development trends and helping consumers choose between oat milk and traditional milk.

1. Introduction

With the increasing awareness of environmental protection, green consumption has attracted more attention from consumers. Compared with animal-based products, plant-based products are ecological, produce low quantities of carbon, and are more suitable for sustainable development (McClements & Grossmann, 2021). The use of plant-based milk is increasing, and the industry is expanding to produce beverages with favorable features, including beverages that alleviate aging, prevent diseases, or improve nutrition, which can meet different people's needs.

Recently, the plant-based milk market has rapidly grown. The global total retail market for plant-based food was approximately $5 billion, of which milk products accounted for 40% in 2019 (McClements & Grossmann, 2021). Compared to other plant-based foods, including meat, cream, yogurt, and eggs, dairy products have the largest share of the market (McClements & Grossmann, 2021). It is expected that in 30 years, people's demand for food will increase by 70%, dietary structures will change as protein consumption significantly increases (80%), and dairy and meat products will be replaced by plant-based proteins (Jeske et al., 2018). Hence, the plant-based milk market should be very prosperous and shows great development prospects.

Currently, commercially available cereal-based milk can be classified into two broad categories based on processing and product characteristics. One category is cereal-based milk beverages that are similar to milk, such as corn milk, in which the cereal's initial texture and color are preserved; the other category includes beverages that are more milk-like in appearance and texture, such as oat milk (Xiong et al., 2022). Recently, the plant-based milk market has grown, which was worth over $17 billion in 2018 and is expected to reach $18.9 billion by 2023, while the volume of sales of oat milk increased by 71% from 2017 to 2018 (Aydar et al., 2020). In addition, oat milk sales have increased by more than $60 million (by nearly 700%) annually from 2018 to 2019 (Ramsing et al., 2023). Oat milk was first developed by Swedish scientists, who created the world's first oat milk brand, Oatly, in the 1990s; this brand was developed to create an environmentally friendly alternative to traditional milk that addresses lactose intolerance and reduces carbon emissions associated with traditional animal milk (Krampe & Fridman, 2022). In Oatly's oat milk recipe, 1 kg of oat milk is generated from oats (0.20 kg) and rapeseed oil (0.035 kg) (Röös et al., 2016). Oat

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milk is not milk but a water extract of oats, which has a smooth, milk-like taste and is not only a simple plant-based nutritional drink but also contributes to a healthy lifestyle (Bocchi et al., 2021). Currently, oat milk is a successful commercial cereal milk and has become an important substitute for plant-based milk in mainstream consumption. In addition to Oatly, many other brands are sold worldwide, such as Vitasoy (China), Alpro (UK), Pacific (US), Simpli (Finland), and Pureharvest (Australia) (Xiong et al., 2022). Oat milk contains a good quantity of fatty acids, protein, minerals, vitamins, dietary fiber, and a variety of micronutrients and provides several health benefits, as it reduces blood sugar, lowers cholesterol, and prevents cancer (Jeske et al., 2018). Therefore, oats are a promising alternative to traditional milk. Although the nutrients in oat milk are mostly the same as in oats, some nutrients are lost during processing and the product must be enhanced by improved processing techniques or through fermentation and other technologies (Sethi et al., 2016). However, technical problems must be solved to produce plant-based milk substitutes that are equivalent to cow milk in terms of physical and chemical sensory properties and nutritional value.

This review provides a comparative evaluation of oat milk and traditional milk in terms of properties, processing technology, nutrition and health, and carbon neutrality, as well as the science and technology in the optimization of oat milk, to provide a comprehensive scientific basis for the comparison between oat milk and traditional milk (Fig. 1).

2. Comparison of properties, composition and structure

Currently, the market is flooded with a variety of dairy products; however, the term "milk" can refer only to milk from healthy animals, rather than colostrum from "early" milk produced shortly after labor, as nutrition and immune ingredients are very different (Kelly, 2003; Pereira, 2014). Moreover, using "milk" for plant-based beverages to traditional milk, such as soy milk, coconut milk, oat milk, almond milk, etc., is controversial (Mcclements et al., 2019). Thus, determining the composition, structure, and characteristics of traditional milk is essential for improving the development, design, and production of commercial plant-based milk, the milk analogue.

Milk is a complex colloidal dispersion, which is a kind of oil-in-water emulsion. It is composed of two colloidal systems suspended in a watery medium, namely, casein micelles and fat globules, which form a uniform colloidal emulsion (Jukkola & Rojas, 2017; Mcclements et al., 2019). Fat globules composed of triacylglycerol contain almost all the fat in milk, with an average diameter of 4 μm (Truong et al., 2016). Milk fat globules are the most complicated entity in milk; thus, the surface properties of milk fat globules are unique to other biological lipid export systems through which fat is delivered (Argov et al., 2008). Structurally, the globule consists of a three-layer membrane structure that encloses the central layered triglycerides (Smoczyński et al., 2012). The milk fat globule membrane (MFGM), which surrounds each fat globule and exhibits an average thickness of 10–50 nm, plays a crucial role in dairy product function and quality, as its composition and properties are changed through processing (Jukkola & Rojas, 2017; Lopez et al., 2011). Previous studies indicated that the addition of MFGM to plant beverages improved the bioavailability of plant sterols (Alvarez-Sala et al., 2016). In our daily life, we can observe that milk boils but does not clump. This is because casein micelles are stable proteins and their structures are not easily broken (Holt, 1992). Casein micelles are spherical nanoparticles in which casein and calcium phosphate form an aggregation that contains thousands of individual protein molecules by hydrophobic and electrostatic forces, with an average diameter of 150–200 nm (Dalgleish & Corredig, 2012; Lucey & Horne, 2018). Various conditions, such as environmental conditions, nutritional status, and animal genetics, can impact the chemical composition of milk (Kalac & Samkova, 2010). On average, milk is composed of water (87%), lactose (4–5%), fat (3–4%), protein (3%), minerals (0.8%), and vitamins (0.1%) (Haug et al., 2007; Lindmark-Mansson et al., 2003). Thus, the composition and unique structure of milk determine the function of dairy products. Simulating the desirable characteristics of milk is necessary for the development of plant-based milk.

Plant-based and traditional milks differ in their functional properties, such as their ability to foam during cooking and their stability in hot drinks (Mcclements, 2020). In terms of sensory qualities and physical and chemical properties, plant-based milk is expected to be comparable to traditional milk. The physical properties of cow's milk and oat milk are shown in Table 1. Plant-based milk, which mimics milk in appearance and consistency, is prepared by breaking down plant materials (grains, nuts, oilseeds, legumes, and pseudograins) to form oil bodies and other colloids or by hydrate plant components to create simulated fat globules to form oil-in-water lotions (Do et al., 2018; Sethi et al., 2016). This is performed to simulate the most important component of

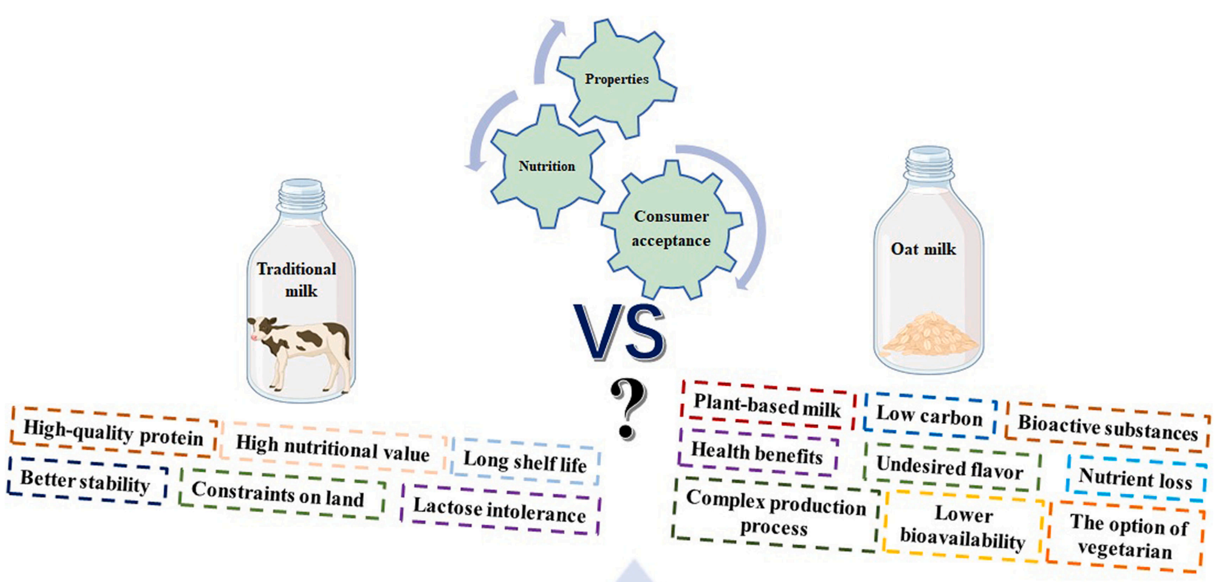

Fig. 1. Comparison of traditional milk and oat milk There are some differences between traditional milk and oat milk in properties, processing technology, nutrition and health, bioavailability, carbon neutrality, and consumer acceptance. This review made a comprehensive and scientific analysis and comparison between traditional milk and oat milk, providing a reference for people to consume.

Table 1
Comparison of physical properties of cow's milk and oat milk.

Type of milk	Viscosity [mPa·s]	Whiteness index (L * A * B *)	Flow index	D32 [μm]	D43 [μm]	Separation rate (%h)	Shelf life	Flavor	Cites
Cow's milk	3.15	81.89	1.00	0.36	0.6	3.9	Refrigerate at 4 °C for 24–120 h	A mild flavor and a creamy mouthfeel	(Jeske et al., 2017; Mccarthy et al., 2017; Mcclements, 2020; Paul et al., 2020)
Oat milk	6.77	60.21	0.89	1.7	3.8	40.1	Refrigerate at 4 °C for 28 days	Oat flavor	

milk, milk fat globules, so that plant-based milk exhibits a similar quality, taste, and appearance to traditional milk. Due to differences in raw material properties and processing technologies, the particle size is uneven and ranges from 5 to 20 μm. Plant-based milk is classified into five categories according to the products currently on the market, including nut milk, cereal milk, seed milk, pseudocereal milk, and legume milk (Sethi et al., 2016). Among them, oat milk is a cereal-based milk. According to results obtained for sensory characteristics of several commercial plant-based milks, it was found that in the overall preference, oat milk is better than rice, soybean, almond, lentil, etc., indicating that oat milk is the most promising plant-based milk and is comparable to traditional milk (Mcclements, 2020). The variety of oats and the method of raw material processing determine the composition and properties of oat milk (Aparicio-García et al., 2021; Yue et al., 2021). Oat milk is distinguished from conventional milk in its quality properties by providing a nutrient-rich, lactose-free alternative to dairy products.

3. Overview of the process

Milk is obtained from healthy animals during lactation, and the processing procedures include separation, heat treatment, and homogenization. Raw milk must often undergo heat treatment (pasteurization or sterilization) before being placed on the market due to the health hazards posed by potential pathogenic microorganisms (Mcclements et al., 2019). Since the fat globules in raw milk are lighter than water, they can float on the water's surface, which is the main reason that milk undergoes delamination (Lopez et al., 2015). Milk stability can usually be improved by homogenizing the fat globules to decrease their size. Understanding the process of milk production is very helpful for developing oat milk. Plant-based milk is not true milk but exhibits a similar texture and appearance to milk; thus, the production and processing technology is somewhat scientific. Plant-based milk is produced through the following methods: (1) directly destroying and decomposing plant tissue into small particles through mechanical crushing, soaking, hydrolysis, separation, heat treatment, and homogenization unit operation, which is a relatively traditional method; and (2) mixing and separating plant components, such as emulsifiers, thickeners and oils, with water, which is then heat treated and homogenized to produce an emulsion with small droplets (Mcclements et al., 2019). The nutritional properties of oat milk, such as fat, protein, carbohydrate, and energy, vary with different processing methods, as well as the function of bioactive compounds (Babolanimogadam et al., 2023). Processing technology affects the quality of oat milk, and the setting of process parameters, such as temperature and concentration, affects rheological properties (Deswal et al., 2014). As a result, only by carefully controlling these processing processes can more stable milk analogs be produced.

Generally, oat milk is constructed through a series of unit operations, which are mainly divided into physical chemical, and mechanical operations, to construct an efficient production process. The preparation of oat milk can be roughly divided into the following steps: first, the oats are broken down by milling, then water extraction, enzymatic hydrolysis, and finally filtration and homogenization (Deswal et al., 2013; Xiong et al., 2022). The overall process of generating oat milk is shown in Fig. 2.

As mentioned above, fat globule preparation is essential for plant-based milk to successfully simulate milk in appearance and properties. Fat globules can usually be prepared in two ways, either by directly constructing them from plant materials or by isolating oil bodies from plant sources (Do et al., 2018; Sethi et al., 2016). Nuts and legumes are good natural sources of oil bodies, and the production of soy milk, almond milk, and coconut milk is suitable for this method, while oat milk is unsuitable (Nikiforidis et al., 2014). The fat globules in oat milk can be prepared using the second method, which consists of water, oil, emulsifiers, and additives (Clements, 2005). The water used to prepare oat milk usually must be treated (heating, reverse osmosis, or filtering) to remove certain organic matter that affects the properties of the emulsion, as well as minerals and pH (Mcclements et al., 2019). Emulsions can be made from olive oil, corn oil, coconut oil, sunflower oil, soybean oil, and other plant oils (Granger et al., 2005; Marquez & Wagner, 2012). Different oils have different components and properties,

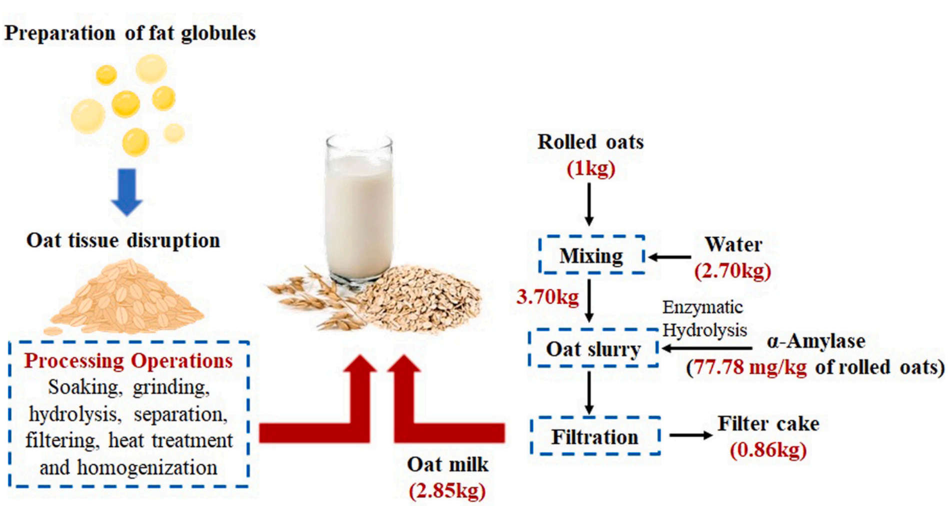

Fig. 2. The process flowchart for the production of oat milk (Deswal et al., 2013). The preparation of milk fat globes from oat milk could be accomplished by directly destroying the oat tissue. The processing included soaking, grinding, hydrolysis, separation, filtering, heat treatment, and homogenization. After mixing 1 kg rolled oats with water, α-Amylase was used to obtain oat slurry through enzymatic hydrolysis, and then 0.86 kg filter cake was obtained after filtration, and 2.85 kg oat milk was finally gained.

which have a certain impact on the stability and formation of emulsions and affect health. Olive oil is high in oleic acid and exhibits anti-inflammatory and antioxidant properties due to its high content of phenols (Martin-Pelaez et al., 2013). Coconut oil is not easily oxidized and is very stable because it is composed of saturated fatty acids; however, coconut oil can also lead to heart disease (Ludwig et al., 2018). Emulsifiers, which play a crucial role in emulsion stability, include phospholipids, polysaccharides, proteins, and biosurfactants such as soy lecithin, monoglycerides, and sucrose esters, which are derived from natural plants such as rice, oats, soybeans, peas, and flaxseeds (Mcclements, 2020; Mcclements et al., 2017; McClements & Gumus, 2016). In addition, other additives, such as thickeners, have been added to oat milk to improve emulsion properties (Mcclements et al., 2017). Compared to cow's milk, oat milk lacks some nutrients; thus, it is necessary to add some nutrients, such as vitamins, calcium carbonate, and minerals (Singhal et al., 2017).

4. Prospects for oat milk production and quality improvement

4.1. Fermentation technology

Fermentation technology is a natural and economical food production technology that can enrich biologically active ingredients, enhance nutrition, and improve food quality and sensory properties (Zhu et al., 2020). Probiotic foods based on milk are common in the fermented food market, and probiotic foods account for approximately 70% of the total functional food market; however, these foods are high in saturated lipids and cause lactose intolerance, allergy to β-casein and cholesterol, etc. (Maekinen et al., 2016; Salmeron et al., 2015; Singhal et al., 2017). Nevertheless, limited attention has been given to plant-based foods. Previous studies have indicated that fermented foods based on legumes (such as soy milk) could produce fermented soy milk rich in B vitamins for the development of functional soy milk (Zhu et al., 2020). There have been few attempts to develop functional probiotics or nutrient-fortified foods using other plant-based fermentation substrates, such as cereals (Sharma et al., 2022b). Although cereals are rich in nutrients, compared to milk, they are less plentiful and high in nutrients. However, through fermentation, their nutritional value can be improved by enriching vitamins, minerals, and amino acids (Ray et al., 2016). Grains are prebiotics because they contain substances that promote the growth of probiotics, such as protein, dietary fiber, and lipids (Dong et al., 2017; Zhu et al., 2016). The ability to produce bacteriocins is an important feature of probiotic strains, such as lactic acid bacteria used in fermented oat drinks, a kind of safe, efficient, and nontoxic natural food preservative, during the fermentation process (Angelov et al., 2018; Messaoudi et al., 2013). At present, studies have been performed on oat fermented beverages. Nionelli et al. (2014) fermented oats with strains of *Lactobacillus paracei*, *Lactobacillus casei,* and *Lactobacillus plantarum* to obtain an oat fermented beverage (Nionelli et al., 2014). Previous studies have suggested that *Lactobacillus plantarum* strains can be used to obtain fermented oat beverages. The specific process was to heat the mixture of oats and water to 95 °C, cool it to 37 °C and then add the strain, which was found to increase the riboflavin content when fermentation was carried out for 16 h at 37 °C (Russo et al., 2016). Studies on germinated oat beverages fermented by *Lactobacillus reuteri*, *Lactobacillus plantarum* B28, and *Streptococcus thermophilus* concluded that probiotic strain fermentation did not affect β-glucan content and that fermentation combined the health benefits of oat dietary fiber β-glucan with probiotic culture (Angelov et al., 2006; Bernat et al., 2015a). In addition, due to the high protein content in oats, the digestibility of protein can be improved for better absorption and utilization (Karlund et al., 2020). Previous studies have shown that lysine and alanine contents in oat drinks could be increased by fermentation with *Lactobacillus plantarum* LP09 (Luana et al., 2014). The characteristics of metabolites in oat milk fermented *in vitro* after gastrointestinal digestion have also been reported. *Lactobacillus* and *Bifidobacterium* strains were used to coferment oats, and after *in vitro* digestion and fermentation, the levels of phenolic compounds were significantly different. The content of avenanthramides in oats decreased after fermentation but increased after digestion, which indicated that the bioavailability of phenolic compounds could be improved by fermentation (Bocchi et al., 2021). Thus, the sensory and nutritional properties and bioavailability of the products can be improved by adding probiotics to oat beverages for fermentation while preserving the potential of the active ingredients as prebiotics.

4.2. Enzymatic production process of oat milk

The main component of oats, starch, has an important influence on the fluidity of the liquid, which becomes sticky during the hot processing of oat milk (Tester & Karkalas, 1996). Enzymatic hydrolysis technology can generate more glucose and maltose by means of amylase, which not only prevents the formation of colloids with high viscosity but also improves the sweetness of oat milk. It has been reported that the optimal enzymatic hydrolysis conditions for preparing a compound oat drink were as follows: cellulase added with 40 U/g enzyme, enzymatic hydrolysis temperature of 65 °C, and enzymatic hydrolysis time of 60 min (Ying-Run et al., 2021). Previous studies have shown that 2.85 kg oat milk could be obtained by mixing 2.7 kg water into 1 kg rolled oat milk, adding α-amylase to the resulting oat milk, and then filtering it after hydrolysis. The best conditions for preparing oat milk were as follows: the slurry concentration was 27.0% (w/w) and the enzyme concentration was 2.1% (w/w), liquefying for 49 min (Deswal et al., 2013). However, the solubility of proteins in oat milk has a high pH requirement and is soluble only under alkaline conditions (Brückner-Gühmann et al., 2019). After α-amylase–alkali treatment of oat milk, Babolanimogadam et al. (2023) discovered that compared with the untreated group, oat milk yield, and protein extraction increased significantly, especially the protein extraction rate, which was approximately 80% and 60%, respectively, and the protein concentration was significantly higher than that of other treatments (Babolanimogadam et al., 2023). Similarly, β-glucan, a dietary fiber rich in oats that exhibits an effect on the sensory properties of oat milk to some extent, increases the viscosity of oat milk, and β-glucan with high molecular weight (Mw) tends to form a semisolid (Lyly et al., 2003; Rosa-Sibakov et al., 2022). Therefore, it is necessary to depolymerize β-glucan by enzymes to generate a suspension of β-glucan with low viscosity and high concentration (Sibakov et al., 2013). It was found that more phenolic compounds were detected in urine after β-glucan was ingested with a low Mw (82 kDa) compared to a high Mw (1000 kDa) and a medium Mw (524 kDa) (Hakkola et al., 2020). It has been demonstrated that the Mw of β-glucan could be significantly reduced from 2748 kDa to 893 kDa and 350 kDa with the treatment of oat bran concentrates with β-glucanase, reducing the concentration of concentrate and improving the water holding capacity (Rosa-Sibakov et al., 2022). Therefore, the selection and technology of enzymes affect the taste, flavor, and nutritional properties of oat milk. Processing with enzyme preparation causes the originally rough oat particles to become smooth and delicate, and the release of smaller molecular flavor substances is more conducive to the sensory smoothness of oat milk, which is comparable to that of traditional milk.

4.3. Other quality improvement aspects

4.3.1. Improved stability

The stability of the emulsion can be affected by the size of the grain particles. After comparing the stability of animal and plant-based milk processed by commercial ultrahigh temperature (UHT), it was found that oat milk was much more stable than rice milk but less stable than soy milk and bovine milk (Durand et al., 2003). In the production process, high-intensity ultrasound irradiation, ultrasonic homogenization, and ultrahigh-pressure homogenization (UHPH) can be used to solve the stability problem (Paul et al., 2020). Microorganisms could be inactivated by UHPH treatment at 350 MPa and 85 °C, and the nanoemulsion formed by crushing to enhance stability (Briviba et al., 2016). Jeske et al. (2019) and Xia et al. (2019) found that the appearance and flavor properties of the emulsion, which was similar to milk, could be improved after treatment at 175 MPa and 900 bar at 85 ℃, respectively (Jeske et al., 2019; Xia et al., 2019). Cortes-Munoz et al. (2009) demonstrated that during the construction of whey protein concentrate oat milk, ultrahigh-pressure homogenization treatment could effectively reduce the number of microorganisms and the aggregation of fat globules (Cortes-Munoz et al., 2009). In addition, at a parameter setting of 500 W with 20 kHz input power, ultrasonic treatment reduced the size of the fat globules, reaching a size in the submicron range and enhancing liquid fluidity (Abdullah et al., 2018; Lu et al., 2019). Other operations to improve emulsion stability include colloid milling, heat sterilization, and adding an emulsifier (Paul et al., 2020).

4.3.2. Removal of off-flavor

The undesired flavor in oat milk may be caused by a lipid reaction, which is associated with the oxidation of unsaturated fatty acid chains (Lehtinen & Laakso, 2004). The most direct way to address this issue is by adding additives to mask the smell. The most direct way to address this issue is masking the off-flavor by adding natural or synthetic additives, such as benzaldehyde, methyl anthranilate, diacetyl, cinnamaldehyde, allyl hexanoate, limonene, etc. (Paul et al., 2020). Additionally, the flavors can be removed through cold plasma, a pulsed electric field, and high-pressure processing. A new nonthermal food processing technology called cold plasma is used to inactivate various enzymes (α-chymotrypsin, polyphenol oxidase, peroxidase, alkaline phosphatase, and lysozyme) to eliminate food contamination (Han et al., 2019). Lipoxygenase activity could also be reduced by pulsed electric field processing by inhibiting *Escherichia coli* and *Staphylococcus aureus* (Li et al., 2013). The lipoxygenase activity was inhibited by controlling the exit temperature to 121 and 145 °C at 207 and 276 MPa pressures (Sidhu & Singh, 2016).

4.3.3. Extended shelf life

The shelf life of milk substitutes should be at least equal to that of milk. However, due to the abundant nutrients in plant milk, microorganisms easily breed, which affects the quality of products (Sethi et al., 2016). Ultrahigh-pressure homogenization and thermal treatment have been used to kill microorganisms for a long time (Paul et al., 2020). Studies have shown that a shelf life of three days can be extended to a maximum of 57 days after UHPH treatment (Codina-Torrella et al., 2018). Combining citral and linalool and heating at 55℃ for 15 min delayed the growth probability of wild *Saccharomyces cerevisiae* (Belletti et al., 2010). Other works have combined high-pressure homogenization with low heat treatment and found that the beverage exhibited the greatest stability under the condition of 172 MPa/85 °C/30 min (Bernat et al., 2015b). Moreover, shelf life can also be extended through ultrasonic processing technology by killing microorganisms or improving emulsion stability. The growth of *Listeria monocytogenes* and *Escherichia coli* O157:H7 was inhibited at a frequency of 20 kHz and an acoustic energy of 130 W to prolong the storage time at 4 °C for up to two weeks (Iorio et al., 2019). Salve et al. (2019) demonstrated that ultrasonication could improve the physicochemical properties and stability of emulsions, thereby extending their shelf life (Salve et al., 2019).

5. Comparison of nutrients and health benefits

5.1. Nutrient composition

For thousands of years, people have regarded milk as an indispensable part of their diet, and it is still widely consumed worldwide. As a healthy and nutritious food, milk is a good source of protein and provides the main nutrients.

The nutrients in oat milk are derived from oats, which are rich in various bioactive substances and nutrients and are a healthy source of functional proteins, lipids, vitamins, dietary fiber, minerals, flavonoids, tocopherols and avenanthramides (Xinping et al., 2022; Yu et al., 2022). A comparison of cow's milk versus several commercially available oat milk in terms of total nutritional value is presented in Table 2. The nutritional composition differs between oat milk and milk. The β-glucan component contained in oats, which is a water-soluble dietary fiber and the most abundant in oats and barley, has become the focus of attention for oat milk (Sharma et al., 2022a). β-Glucan plays a significant role in lowering cholesterol, blood lipids, and blood sugar, mainly because it can delay gastric emptying and reduce food intake by increasing the viscosity of food (Singh et al., 2013; Truswell, 2002). In addition to soluble dietary fiber, Avns, a unique alkaloid in oats, exhibits anti-inflammatory, antioxidant, anti-allergic, and antitumor biological activities, which can improve body function (Sang & Chu, 2017; Yu et al., 2022). Although oat milk is rich in a variety of nutrients and dietary fiber, it lacks certain amino acids, calcium, and vitamin A compared with milk, which is not suitable for children during their growth and development, so dairy products for children under 5 years old cannot be completely replaced with oat milk (Sethi et al., 2016). Moreover, nutrients can be destroyed when oats undergo a series of processing treatments that result in the loss of vitamins and minerals, which can be fortified by adding nutrients. Compared with milk, oat milk as a cereal drink is higher in carbohydrates, and only 4.2% of oat milk contains added sugar (Escobar-Saez et al., 2022). Furthermore, compared to cow's milk, oat milk is lower in fat, which conforms to the expectations of plant-based milk. At the same time, oats are rich in lipids, the content of which ranges from 4.9% to 10.5%, and the proportion of unsaturated fatty acids is as high as 78–81.5%, among which the content of linoleic acid is 34.6 to 38.2% (Kourimska et al., 2018). The protein content of oat milk is lower than that in cow's milk, and the digestible indispensable amino acid scores (DIAAS) of oat and milk were 57 and 116, respectively. The limiting amino acid in oat was lysine, while milk contained no limiting amino acids (Ertl et al., 2016; Herreman et al., 2020). In addition, the addition of plant protein to commercial protein milk has been found to improve the protein content (Lu et al., 2019). More nutritional comparisons between commercially available oat milk and cow's milk are shown in Table 3. Taken together, the results indicate that oat milk contains some healthy ingredients that milk lacks, such as dietary fiber and alkaloids, but from the perspective of the overall nutritional composition, oat milk has shortcomings. Therefore, if we replace cow's milk with oat milk entirely, it is necessary to consider whether these nutrients are fortified or obtain these nutrients from other foods.

5.2. Bioavailability

Bioavailability refers to the rate at which an active compound is taken up by the target site of action as it is released from the food matrix (Carbonell-Capella et al., 2014). Because processing processes, such as boiling and thermal application, cause loss and destruction of plant milk nutrients, some nutrients in oat milk have lower bioavailability, such as calcium, vitamins, and minerals (Aydar et al., 2020). It is necessary to increase the bioavailability of minerals such as calcium in the body; common sugars, such as starch, sucrose, glucose, and maltose, do not require supplementation, while lactose does (Miller, 1989). In oat milk, the lower bioavailability of calcium is due to absorption by oxalate and phytase, and insoluble calcium phosphate will eventually form due to the higher phosphate content; therefore, when the calcium and phosphate ratio is 2:1 or 1:2, calcium can be normally absorbed by the body (Dubey and Patel, 2018). Casein stabilizes calcium phosphate, which in turn helps to enhance the absorption and delivery capacity of the intestine, maximizing bioavailability, whereas casein micelles form gels at $pH < 7$, thus slowing digestion and enhancing satiety and nutrients in milk can be efficiently digested by the body (Lambers et al., 2013). In addition to calcium, the bioavailability of other minerals is also affected by phytic acid, which in oats reacts with iron and zinc cations to form

Table 2
Nutritional comparison between commercially available oat milk and cow's milk (per serving of 240 ml).

Type of milk	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrates (g)	Dietary fibers (g)	Fortification	Cites
Cow's milk	153.6	7.92	9.36	11.04	–	–	(Maekinen et al., 2016)
Oat milk (Oatly)	84	2.4	1.68	15.6	1.92	Ca, D_2, B_2, B_{12}	
Oat milk (Alpro)	158.4	0.96	3.6	30.48	–	Ca, D_2, B_2, B_{12}	
Oat milk (Hain Europe)	120	1.44	3.12	20.64	2.4	Ca, D_2, B_{12}	

Table 3
The nutritional composition of oat milk compared with cow's milk.

Nutrients	Component	Cow's milk	Oat milk	Cites
Amino acid (mg/100 g)	Histidine	15.0–26.0	2.85–3.68	(Mickowska et al., 2016; Rafiq et al., 2016; Sterna et al., 2016)
	Isoleucine	25.0–62.0	4.15–4.41	
	Leucine	90.0–108.0	7.89–9.17	
	Lysine	49.0–96.0	3.79–3.91	
	Methionine	17.0–27.0	1.73–1.93	
	Phenylalanine	38.0–56.0	5.46–5.48	
	Threonine	23.0–41.0	3.25–4.30	
	Tryptophan	–	3.61–4.09	
	Valine	33.0–53.0	5.34–6.01	
Lipids (g/240 ml)	Fatty acids (total saturated)	4.55	–	(Singhal et al., 2017)
	Fatty acids (total monounsaturated)	1.98	–	
	Fatty acids (total polyunsaturated)	0.476	–	
	Cholesterol	0.024	–	
Vitamins (μg/100 g)	C	202.3	–	(Walther et al., 2022)
	A	29.2	–	
	B1	11.9	25.2	
	B2	108.3	14.0[1)]	
	B6	20.1	5.0	
	E	89.1	513.7[2)]	
Minerals (mg/100 g)	Fe	0.07–0.08	6.40–7.40	(Paul et al., 2020; Sterna et al., 2016)
	Ca	122.0–134.0	84.3–85.6	
	K	152.0–181.0	669.2–671.6	
	Na	41.0–58.0	3.11–3.21	
	P	119.0–121.0	672.3–816.32	
Water-soluble dietary fiber (g/100 g)	β-Glucan	–	0.5	(Önning et al., 1999)
Phytosterols (mg/100 ml)	β-sitosterol	–	3.9	(Decloedt et al., 2018)

[1]Contains products supplemented with vitamins; [2]contains products supplemented with sunflower oil.

complexes that affect absorption (Gibson et al., 2006; Sethi et al., 2016). Since phytic acid is present in oats, higher levels of the nutrient should be consumed to prevent effects on bioavailability.

5.3. Effects on disease prevention

Epidemiological evidence has shown that the risk of Parkinson's disease, a common disease among elderly individuals, is associated with the consumption of dairy products, possibly because galactose causes neuropathological changes, and drinking two glasses of milk a day may reach the risk dose (Sarni & Baroni, 2019).

Compared to animal milk, oat milk exerts a positive effect on preventing cancer, cholesterol, diabetes, and cardiovascular disease due to its abundant functional active components (Paudel et al., 2021). In a study on the risk of chronic kidney disease and kidney stones due to the consumption of plant-based milk, oat milk was shown to have the lowest risk of kidney stones compared to almond and cashew milk and was superior to cow's milk (Borin et al., 2022). A daily intake of 0.75 L of oat milk containing 3.8 g of β-glucan for five weeks could reduce low-density lipoprotein (LDL) levels and serum total cholesterol, which may be a function of β-glucan (Önning et al., 1999). In another study on the effect of oat milk consumption on blood lipids and antioxidant capacity, after four weeks of consumption of 0.75–1 L of oat milk per day, plasma cholesterol was significantly lower compared with milk and was inversely related to antioxidant capacity (Onning et al., 1998). The unsaturated fatty acids in oats also reduce blood lipid levels (Kourimska et al., 2018). In summary, all the studies illustrated that drinking oat milk has a preventative effect on some diseases.

6. Effects on carbon peaking and carbon neutrality

6.1. Environmental effects

Regarding the environmental impact of animal milk and plant-based milk, environmentalists will choose plant-based milk without hesitation. A common adverse environmental impact caused by milk production is climate change. The environmental impact factors of milk production include water use land, demand, and greenhouse gas emissions (Naranjo et al., 2020). Greenhouse gas emissions account for 4% of total emissions, followed by meat products, accounting for 6% of acidification risk (Noya et al., 2018). Compared to milk, oat milk generates a much lower climate impact, with much lower direct greenhouse gas emissions (16–41%) but higher acidification potential (21–37%) (Röös et al., 2016). Under the background of "carbon peaking and carbon neutrality", plant-based food is more low-carbon and environmentally friendly and effectively saves resources. Therefore, the idea of introducing a carbon emission tax as a strategy to respond to climate change is being discussed in many countries (Huang, 2022). Taken together, the results indicate that oat milk plays a more crucial role in promoting carbon neutrality and carbon peak than that of animal-based milk.

6.2. Constraints on land

Considering the global restrictions on land, it is critical to reduce the consumption of land resources. Maximizing the utilization rate of land and reducing the cost of land use are crucial factors when evaluating food sustainability (Garnett, 2009). Further studies showed that 26–54 m^2 of land is only sufficient for 1 kg of protein production of milk, compared with 4–25 m^2 for plant protein, and comparing the protein delivery efficiency, the value of milk is 31 g and that of oats is 359 g (Nijdam et al., 2012; Smedman et al., 2010). From the limited literature, oat milk production requires less land compared to milk.

7. Opportunities for oat milk

7.1. The option of vegetarianism

In the mid-20th century, the concept of vegetarianism became popular worldwide, aiming to contribute to environmental protection and animal welfare (Allès et al., 2017). Recent publications have reported that less than 10% of the population in Europe are vegetarians, and the number of vegetarians is increasing globally (Baroni et al., 2019). Oat milk is an excellent choice for vegetarians because of its plant-based ingredients; however, special attention should be focused on how nutrient supplementation affects children and adolescents (Escobar-Saez et al., 2022). In addition, milk restrictions are necessary for people who are intolerant to lactose or allergic to milk, which is among the reasons vegetarians choose oat milk.

7.2. Lactose intolerance

Although milk and dairy products provide the main nutrients in the diet, they can also cause adverse reactions in some people, including allergies and lactose intolerance (Jeske et al., 2018). Research from the US National Library of Medicine (2020) suggested that nearly 70% of the global population has a decreased ability to digest lactose, while in East Asia, people with lactose intolerance can digest up to 70–100% lactose (Aydar et al., 2020). According to statistics, a number of factors can cause lactose intolerance: (1) the most common type, primary hypolactasia, usually appears at approximately 5–7 years of age and causes the greatest impact in adulthood; (2) a genetic disease, congenital lactase deficiency; and (3) developmental lactase deficiency, which is due to premature birth before lactase production (Jellema et al., 2010). In contrast, oat milk does not contain lactose, which can avoid symptoms such as diarrhea and flatulence, and the related population can consume oat milk instead of the adverse effects caused by animal milk.

7.3. Nutritional fortification of oat milk

In addition to health effects, the main factors people consider when choosing between cow's milk and plant-based milk are the content of nutrients. The main source of nutrition in the human body is mainly provided by milk, including calcium, protein, minerals, and vitamins A and B. Although some nutrients in oat milk are low in content or bioavailability, the milk can be fortified to improve the content. Recent publications about the design of the next generation of superfoods (foods with high levels of bioactive compounds and nutrients) suggested that activating secondary metabolites in plants through abiotic stress regulation exerted antioxidant, anti-inflammatory, and other health benefits, which could also be applied to the nutritional fortification of oats (Sharma et al., 2022a; Sharma et al., 2022c). Calcium fortification has been used to prepare oat milk because oxalates and phytates in oats form complexes with calcium and do not ionize or dissolve, which affects calcium absorption (Shkembi & Huppertz, 2021). Tricalcium phosphate and calcium carbonate are commonly used as fortifiers because their bioavailability is similar to that of calcium in milk, which is beneficial for human absorption because they can be dispersed throughout the product without causing the accumulation of anionic proteins in oat milk (Munekata et al., 2020). In addition, calcium bioavailability can also be fortified by the addition of probiotics because the production of short-chain fatty acids can improve calcium solubility (Aydar et al., 2020). For example, bifidobacteria and Lactobacillus can improve calcium bioavailability by hydrolyzing glycosidic bonds in the gut (Dubey & Patel, 2018).

8. Consumer acceptance

According to market research, people are increasingly consuming plant-based milk. The experimental results of Onning et al. (1998) showed that compared with medium-fat UHT milk, oat milk was more acceptable (Onning et al., 1998). When consumers choose dairy products, the first concern is the fat content; a lower fat content (1% or 2%) and sugar content will be preferred by consumers, and plant-based milk is more suitable for people who are lactose intolerant (Mccarthy et al., 2017). For children around the age of 10, the preference for plant-based milk is relatively low (Palacios et al., 2010). In addition, in terms of price, plant-based milk is much higher, which is caused by the high production cost of its processing.

9. Conclusion

Plant-based foods are becoming more popular as consumers focus on health, sustainability, and function. Comparing oat-based milk analogs and traditional milk, we found that from different perspectives, both have their own characteristics and are suitable for different populations. In the background of "double carbon", plant-based milk has a greater advantage from an overall environmental perspective and has a lower impact than dairy in terms of land use as well as water and greenhouse gas emissions. In terms of food properties, including texture, appearance, flavor, function, and taste, plant-based foods are expected to be comparable to animal foods. From the perspective of nutritional value, milk contains higher amounts of protein and is high-quality protein. However, the plant protein industry has recently experienced rapid growth with increased health awareness and consciousness of sustainable development (Kumar et al., 2020). For calcium supplementation, the calcium content can be increased by adding the calcium fortifier calcium carbonate/calcium phosphate to oat milk. Moreover, oat milk is richer in unsaturated fatty acids and contains a variety of bioactive components as well as dietary fiber, which have the effect of preventing disease. Plant-based milk was first produced to solve nutritional problems for lactose-intolerant people, then championed by vegetarians, and is now prized by environmental advocates who argue that it requires far less energy to produce than traditional milk. For those who are not suitable for milk, such as lactose-intolerant people and people with milk protein allergies, when we choose the plant-based milk we need, opting for oat base milk analogs that have been fortified with nutrients is a better option and to ingest enough nutrients from other diets.

With the continuous expansion of the market of oat base milk analogs and the wider consumption population compared with traditional animal milk products, there are still some technical problems to be solved in terms of production, processing, preservation, and nutritional composition. Therefore, in the future, the market will focus on nutritional, sensory, physical, and chemical properties and sustainable design to develop better-quality oat milk. In addition, standards for evaluating oat milk should be developed, and quantitative indicators should be established to provide consumers with better reference opinions for selecting dairy products.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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References

Abdullah, Z., Taip, F. S., Mustapa Kamal, S. M., & Abdul Rahman, R. Z. (2018). Effect of sodium caseinate concentration and sonication amplitude on the stability and physical characteristics of homogenized coconut milk. *Journal of Food Processing and Preservation, 42*(11), e13773. https://doi.org/10.1111/jfpp.13773

Allès, B., Baudry, J., Méjean, C., Touvier, M., Péneau, S., Hercberg, S., & Kesse-Guyot, E. (2017). Comparison of sociodemographic and nutritional characteristics between self-reported vegetarians, vegans, and meat-eaters from the NutriNet-Santé study. *Nutrients, 9*(9), 1023. https://doi.org/10.3390/nu9091023

Alvarez-Sala, A., Garcia-Llatas, G., Cilla, A., Barbera, R., Sanchez-Siles, L. M., & Lagarda, M. J. (2016). Impact of lipid components and emulsifiers on plant sterols bioaccessibility from milk-based fruit beverages. *Journal of Agricultural Food Chemistry, 64*(28), 5686–5691. https://doi.org/10.1021/acs.jafc.6b02028

Angelov, A., Gotcheva, V., Kuncheva, R., & Hristozova, T. (2006). Development of a new oat-based probiotic drink. *International Journal of Food Microbiology, 112*(1), 75–80. https://doi.org/10.1016/j.ijfoodmicro.2006.05.015

Angelov, A., Yaneva-Marinova, T., & Gotcheva, V. (2018). Oats as a matrix of choice for developing fermented functional beverages. *Journal of Food Science and Technology, 55*(7), 2351–2360. https://doi.org/10.1007/s13197-018-3186-y

Aparicio-García, N., Martínez-Villaluenga, C., Frias, J., & Peñas, E. (2021). Sprouted oat as a potential gluten-free ingredient with enhanced nutritional and bioactive properties. *Food Chemistry, 338*, Article 127972. https://doi.org/10.1016/j.foodchem.2020.127972

Argov, N., Lemay, D. G., & German, J. B. (2008). Milk Fat Globule structure & function; nanosciece comes to milk production. *Trends in Food Science & Technology, 19*(12), 617–623. https://doi.org/10.1016/j.tifs.2008.07.006

Aydar, E. F., Tutuncu, S., & Ozcelik, B. (2020). Plant-based milk substitutes: Bioactive compounds, conventional and novel processes, bioavailability studies, and health effects. *Journal of Functional Foods, 70*, Article 103975. https://doi.org/10.1016/j.jff.2020.103975

Babolanimogadam, N., Gandomi, H., Akhondzadeh Basti, A., & Taherzadeh, M. J. (2023). Nutritional, functional, and sensorial properties of oat milk produced by single and combined acid, alkaline, α-amylase, and sprouting treatments. *Food Science & Nutrition, 11*(5), 2288–2297. https://doi.org/10.1002/fsn3.3171

Baroni, L., Goggi, S., Battaglino, R., Berveglieri, M., Fasan, I., Filippin, D., … Antonio Battino, M. (2019). Vegan nutrition for mothers and children: Practical tools for healthcare providers. *Nutrients, 11*(1), 5. https://doi.org/10.3390/nu11010005

Belletti, N., Kamdem, S., Tabanelli, Giulia, & Fausto. (2010). Modeling of combined effects of citral, linalool and α-pinene used against Saccharomyces cerevisiae in citrus-based beverages subjected to a mild heat treatment. *International Journal of Food Microbiology, 136*(3), 283–289. https://doi.org/10.1016/j.ijfoodmicro.2009.10.030

Bernat, N., Chafer, M., Gonzalez-Martinez, C., Rodriguez-Garcia, J., & Chiralt, A. (2015a). Optimisation of oat milk formulation to obtain fermented derivatives by using probiotic Lactobacillus reuteri microorganisms. *Food Science and Technology International, 21*(2), 145–157. https://doi.org/10.1177/1082013213518936

Bernat, N., Chafer, M., Rodriguez-Garcia, J., Chiralt, A., & Gonzalez-Martinez, C. (2015b). Effect of high pressure homogenisation and heat treatment on physical properties and stability of almond and hazelnut milks. *LWT-Food Science and Technology, 62*(1), 488–496. https://doi.org/10.1016/j.lwt.2014.10.045

Bocchi, S., Rocchetti, G., Elli, M., Lucini, L., Lim, C. Y., & Morelli, L. (2021). The combined effect of fermentation of lactic acid bacteria and in vitro digestion on metabolomic and oligosaccharide profile of oat beverage. *Food Research International, 142*, Article 110216. https://doi.org/10.1016/j.foodres.2021.110216

Borin, J. F., Knight, J., Holmes, R. P., Joshi, S., Goldfarb, D. S., & Loeb, S. (2022). Plant-based milk alternatives and risk factors for kidney stones and chronic kidney disease. *Journal of Renal Nutrition, 32*(3), 363–365. https://doi.org/10.1053/j.jrn.2021.03.011

Brückner-Gühmann, M., Vasil'eva, E., Culetu, A., Duta, D., Sozer, N., & Drusch, S. (2019). Oat protein concentrate as alternative ingredient for non-dairy yoghurt-type product. *Journal of the Science of Food and Agriculture, 99*(13), 5852–5857. https://doi.org/10.1002/jsfa.9858

Briviba, K., Graef, V., Walz, E., Guamis, B., & Butz, P. (2016). Ultra high pressure homogenization of almond milk: Physico-chemical and physiological effects. *Food Chemistry, 192*, 82–89. https://doi.org/10.1016/j.foodchem.2015.06.063

Carbonell-Capella, J. M., Buniowska, M., Barba, F. J., Esteve, M. J., & Frigola, A. (2014). Analytical methods for determining bioavailability and bioaccessibility of bioactive compounds from fruits and vegetables: A review. *Comprehensive Reviews in Food Science and Food Safety, 13*(2), 155–171. https://doi.org/10.1111/1541-4337.12049

Clements, D. (2005). *Food emulsions: Principles, practices and techniques*.

Codina-Torrella, I., Guamis, B., Zamora, A., Quevedo, J. M., & Trujillo, A. J. (2018). Microbiological stabilization of tiger nuts' milk beverage using ultra-high pressure homogenization. A preliminary study on microbial shelf-life extension. *Food Microbiology, 69*, 143–150. https://doi.org/10.1016/j.fm.2017.08.002

Cortes-Munoz, M., Chevalier-Lucia, D., & Dumay, E. (2009). Characteristics of submicron emulsions prepared by ultra-high pressure homogenisation: Effect of chilled or frozen storage. *Food Hydrocolloids, 23*(3), 640–654. https://doi.org/10.1016/j.foodhyd.2008.07.023

Dalgleish, D. G., & Corredig, M. (2012). The structure of the casein micelle of milk and its changes during processing. *Annual Review of Food Science and Technology, 3*, 449–467. https://doi.org/10.1146/annurev-food-022811-101214

Decloedt, A. I., Van Landschoot, A., Watson, H., Vanderputten, D., & Vanhaecke, L. (2018). Plant-based beverages as good sources of free and glycosidic plant sterols. *Nutrients, 10*(1). https://doi.org/10.3390/nu10010021

Deswal, A., Deora, N. S., & Mishra, H. N. (2013). Optimization of enzymatic production process of oat milk using response surface methodology. *Food and Bioprocess Technology, 7*(2), 610–618. https://doi.org/10.1007/s11947-013-1144-2

Deswal, A., Deora, N. S., & Mishra, H. N. (2014). Effect of concentration and temperature on the rheological properties of oat milk. *Food and Bioprocess Technology, 7*(8), 2451–2459. https://doi.org/10.1007/s11947-014-1332-8

Do, D. T., Singh, J., Oey, I., & Singh, H. (2018). Biomimetic plant foods: Structural design and functionality. *Trends in Food Science & Technology, 82*, 46–59. https://doi.org/10.1016/j.tifs.2018.09.010

Dong, J.-L., Yu, X., Dong, L.-E., & Shen, R.-L. (2017). In vitro fermentation of oat β-glucan and hydrolysates by fecal microbiota and selected probiotic strains. *Journal of the Science of Food and Agriculture, 97*(12), 4198–4203. https://doi.org/10.1002/jsfa.8292

Dubey, M. R., & Patel, V. P. (2018). Probiotics: A promising tool for calcium absorption. *The Open Nutrition Journal, 12*(1), 59–69. https://doi.org/10.2174/1874288201812010059

Durand, A., Franks, G. V., & Hosken, R. W. (2003). Particle sizes and stability of UHT bovine, cereal and grain milks. *Food Hydrocolloids, 17*(5), 671–678. https://doi.org/10.1016/s0268-005x(03)00012-2

Ertl, P., Knaus, W., & Zollitsch, W. (2016). An approach to including protein quality when assessing the net contribution of livestock to human food supply. *Animal, 10*(11), 1883–1889. https://doi.org/10.1017/s1751731116000902

Escobar-Saez, D., Montero-Jimenez, L., Garcia-Herrera, P., & Sanchez-Mata, M. C. (2022). Plant-based drinks for vegetarian or vegan toddlers: Nutritional evaluation of commercial products, and review of health benefits and potential concerns. *Food Research International, 160*, Article 111646. https://doi.org/10.1016/j.foodres.2022.111646

Garnett, T. (2009). Livestock-related greenhouse gas emissions: Impacts and options for policy makers. *Environmental Science & Policy, 12*(4), 491–503. https://doi.org/10.1016/j.envsci.2009.01.006

Gibson, R. S., Perlas, L., & Hotz, C. (2006). Improving the bioavailability of nutrients in plant foods at the household level. *Proceedings of the Nutrition Society, 65*(2), 160–168. https://doi.org/10.1079/pns2006489

Granger, C., Leger, A., Barey, P., Langendorff, V., & Cansell, M. (2005). Influence of formulation on the structural networks in ice cream. *International Dairy Journal, 15*(3), 255–262. https://doi.org/10.1016/j.idairyj.2004.07.009

Hakkola, S., Nylund, L., Rosa-Sibakov, N., Yang, B., & Linderborg, K. M. (2020). Effect of oat β-glucan of different molecular weights on fecal bile acids, urine metabolites and pressure in the digestive tract – A human cross over trial. *Food Chemistry, 342*(7), Article 128219. https://doi.org/10.1016/j.foodchem.2020.128219

Han, Y., Cheng, J. H., & Sun, D. W. (2019). Activities and conformation changes of food enzymes induced by cold plasma: A review. *Critical Reviews in Food Science and Nutrition, 59*(5), 794–811. https://doi.org/10.1080/10408398.2018.1555131

Haug, A., Hostmark, A. T., & Harstad, O. M. (2007). Bovine milk in human nutrition - a review. *Lipids in Health and Disease, 6*, 25. https://doi.org/10.1186/1476-511x-6-25

Herreman, L., Nommensen, P., Pennings, B., & Laus, M. C. (2020). Comprehensive overview of the quality of plant- And animal-sourced proteins based on the digestible indispensable amino acid score. *Food Science & Nutrition, 8*(10), 5379–5391. https://doi.org/10.1002/fsn3.1809

Holt, C. (1992). Structure and stability of bovine casein micelles. *Advances in Protein Chemistry, 43*, 63–151. https://doi.org/10.1016/s0065-3233(08)60554-9

Huang, W. (2022). Demand for plant-based milk and effects of a carbon tax on fresh milk consumption in Sweden. *Economic Analysis and Policy, 75*, 518–529. https://doi.org/10.1016/j.eap.2022.06.011

Iorio, M. C., Bevilacqua, A., Corbo, M. R., Campaniello, D., Sinigaglia, M., & Altieri, C. (2019). A case study on the use of ultrasound for the inhibition of Escherichia coli O157:H7 and Listeria monocytogenes in almond milk. *Ultrasonics Sonochemistry, 52*, 477–483. https://doi.org/10.1016/j.ultsonch.2018.12.026

Jellema, P., Schellevis, F. G., van der Windt, D. A. W. M., Kneepkens, C. M. F., & van der Horst, H. E. (2010). Lactose malabsorption and intolerance: A systematic review on

the diagnostic value of gastrointestinal symptoms and self-reported milk intolerance. *Qjm-an International Journal of Medicine, 103*(8), 555–572. https://doi.org/10.1093/qjmed/hcq082
Jeske, S., Bez, J., Arendt, E. K., & Zannini, E. (2019). Formation, stability, and sensory characteristics of a lentil-based milk substitute as affected by homogenisation and pasteurisation. *European Food Research and Technology, 245*(7), 1519–1531. https://doi.org/10.1007/s00217-019-03286-0
Jeske, S., Zannini, E., & Arendt, E. K. (2017). Evaluation of physicochemical and glycaemic properties of commercial plant-based milk substitutes. *Plant Foods for Human Nutrition, 72*(1), 26–33. https://doi.org/10.1007/s11130-016-0583-0
Jeske, S., Zannini, E., & Arendt, E. K. (2018). Past, present and future: The strength of plant-based dairy substitutes based on gluten-free raw materials. *Food Research International, 110*, 42–51. https://doi.org/10.1016/j.foodres.2017.03.045
Jukkola, A., & Rojas, O. J. (2017). Milk fat globules and associated membranes: Colloidal properties and processing effects. *Advances in Colloid and Interface Science, 245*, 92–101. https://doi.org/10.1016/j.cis.2017.04.010
Kalac, P., & Samkova, E. (2010). The effects of feeding various forages on fatty acid composition of bovine milk fat: A review. *Czech Journal of Animal Science, 55*(12), 521–537. https://doi.org/10.17221/2485-cjas
Karlund, A., Gomez-Gallego, C., Korhonen, J., Palo-Oja, O. M., El-Nezami, H., & Kolehmainen, M. (2020). Harnessing microbes for sustainable development: Food fermentation as a tool for improving the nutritional quality of alternative protein sources. *Nutrients, 12*(4). https://doi.org/10.3390/nu12041020
Kelly, G. S. (2003). Bovine colostrums: A review of clinical uses. *Alternative Medicine Review, 8*(4), 378–394.
Kourimska, L., Sabolova, M., Horcicka, P., Rys, S., & Bozik, M. (2018). Lipid content, fatty acid profile, and nutritional value of new oat cultivars. *Journal of Cereal Science, 84*, 44–48. https://doi.org/10.1016/j.jcs.2018.09.012
Krampe, C., & Fridman, A. (2022). Oatly, a serious 'problem' for the dairy industry? A case study. *International Food and Agribusiness Management Review, 25*(1), 157–171. https://doi.org/10.22434/ifamr2021.0058
Kumar, S., Kumar, V., Sharma, R., Paul, A., Saini, R., and Suthar, P. (2020). Plant Proteins as Healthy, Sustainable and Integrative Meat Alternates. In, (pp. 1-19).
Lambers, T. T., van den Bosch, W. G., & de Jong, S. (2013). Fast and slow proteins: Modulation of the gastric behavior of whey and casein in vitro. *Food Digestion, 4*(1), 1–6. https://doi.org/10.1007/s13228-012-0028-7
Lehtinen, P., & Laakso, S. (2004). Role of lipid reactions in quality of oat products. *Agricultural and Food Science, 13*(1–2), 88–99. https://doi.org/10.2137/1239099041838085
Li, Y. Q., Tian, W. L., Mo, H. Z., Zhang, Y. L., & Zhao, X. Z. (2013). Effects of pulsed electric field processing on quality characteristics and microbial inactivation of soymilk. *Food & Bioprocess Technology, 6*(8), 1907–1916. https://doi.org/10.1007/s11947-012-0868-8
Lindmark-Mansson, H., Fonden, R., & Pettersson, H. E. (2003). Composition of Swedish dairy milk. *International Dairy Journal, 13*(6), 409–425. https://doi.org/10.1016/s0958-6946(03)00032-3
Lopez, C., Briard-Bion, V., Menard, O., Beaucher, E., Rousseau, F., Fauquant, J., … Robert, B. (2011). Fat globules selected from whole milk according to their size: Different compositions and structure of the biomembrane, revealing sphingomyelin-rich domains. *Food Chemistry, 125*(2), 355–368. https://doi.org/10.1016/j.foodchem.2010.09.005
Lopez, C., Cauty, C., & Guyomarc'h, F. (2015). Organization of lipids in milks, infant milk formulas and various dairy products: Role of technological processes and potential impacts. *Dairy Science & Technology, 95*(6), 863–893. https://doi.org/10.1007/s13594-015-0263-0
Lu, X., Chen, J., Zheng, M., Guo, J., Qi, J., Chen, Y., … Zheng, B. (2019). Effect of high-intensity ultrasound irradiation on the stability and structural features of coconut-grain milk composite systems utilizing maize kernels and starch with different amylose contents. *Ultrasonics Sonochemistry, 55*, 135–148. https://doi.org/10.1016/j.ultsonch.2019.03.003
Luana, N., Rossana, C., Curiel, J. A., Kaisa, P., Marco, G., & Rizzello, C. G. (2014). Manufacture and characterization of a yogurt-like beverage made with oat flakes fermented by selected lactic acid bacteria. *International Journal of Food Microbiology, 185*, 17–26. https://doi.org/10.1016/j.ijfoodmicro.2014.05.004
Lucey, J. A., & Horne, D. S. (2018). Perspectives on casein interactions. *International Dairy Journal, 85*, 56–65. https://doi.org/10.1016/j.idairyj.2018.04.010
Ludwig, D. S., Willett, W. C., Volek, J. S., & Neuhouser, M. L. (2018). Dietary fat: From foe to friend? *Science (New York, N.Y.), 362*, 764–770. https://doi.org/10.1126/science.aau2096
Lyly, M., Salmenkallio-Marttila, M., Suortti, T., Autio, K., Poutanen, K., & Lahteenmaki, L. (2003). Influence of oat beta-glucan preparations on the preception of mouthfeel and on rheological properties in beverage prototypes. *Cereal Chemistry, 80*(5), 536–541. https://doi.org/10.1094/cchem.2003.80.5.536
Maekinen, O. E., Wanhalinna, V., Zannini, E., & Arendt, E. K. (2016). Foods for special dietary needs: Non-dairy plant-based milk substitutes and fermented dairy-type products. *Critical Reviews in Food Science and Nutrition, 56*(3), 339–349. https://doi.org/10.1080/10408398.2012.761950
Marquez, A. L., & Wagner, J. R. (2012). Rheology of cream-like emulsions prepared with soybean milk and low trans vegetable fat. *Journal of the American Oil Chemists Society, 89*(10), 1857–1865. https://doi.org/10.1007/s11746-012-2093-z
Martin-Pelaez, S., Isabel Covas, M., Fito, M., Kusar, A., & Pravst, I. (2013). Health effects of olive oil polyphenols: Recent advances and possibilities for the use of health claims. *Molecular Nutrition & Food Research, 57*(5), 760–771. https://doi.org/10.1002/mnfr.201200421
McCarthy, K. S., Parker, M., Ameerally, A., Drake, S. L., & Drake, M. A. (2017). Drivers of choice for fluid milk versus plant-based alternatives: What are consumer perceptions of fluid milk? *Journal of Dairy Science, 100*(8), 6125–6138. https://doi.org/10.3168/jds.2016-12519
McClements, D. J. (2020). Development of next-generation nutritionally fortified plant-based milk substitutes: structural design principles. *Foods, 9*(4), 421. https://doi.org/10.3390/foods9040421
McClements, D. J., Bai, L., and Chung, C. (2017). Recent advances in the utilization of natural emulsifiers to form and stabilize emulsions. In M. P. Doyle & T. R. Klaenhammer (Eds.), *Annual Review of Food Science and Technology, Vol 8*, vol. 8 (pp. 205-236).
McClements, D. J., & Grossmann, L. (2021). The science of plant-based foods: Constructing next-generation meat, fish, milk, and egg analogs. *Comprehensive Reviews in Food Science and Food Safety, 20*(4), 4049–4100. https://doi.org/10.1111/1541-4337.12771
McClements, D. J., & Gumus, C. E. (2016). Natural emulsifiers-Biosurfactants, phospholipids, biopolymers, and colloidal particles: Molecular and physicochemical basis of functional performance. *Advances in Colloid and Interface Science, 234*, 3–26. https://doi.org/10.1016/j.cis.2016.03.002
McClements, D. J., Newman, E., & McClements, I. F. (2019). Plant-based milks: A review of the science underpinning their design, fabrication, and performance. *Comprehensive Reviews in Food Science and Food Safety, 18*(6), 2047–2067. https://doi.org/10.1111/1541-4337.12505
Messaoudi, S., Manai, M., Kergourlay, G., Prevost, H., Connil, N., Chobert, J. M., & Dousset, X. (2013). Lactobacillus salivarius: Bacteriocin and probiotic activity. *Food Microbiology, 36*(2), 296–304. https://doi.org/10.1016/j.fm.2013.05.010
Mickowska, B., Litwinek, D., & Gambus, H. (2016). Oat raw materials and bakery products - amino acid composition and celiac immunoreactivity. *Acta Scientiarum Polonorum Technologia Alimentaria, 15*(1), 89–97. https://doi.org/10.17306/j.Afs.2016.1.9
Miller, D. D. (1989). Calcium in the diet: Food sources, recommended intakes, and nutritional bioavailability. *Advances in Food and Nutrition Research, 33*, 103–156. https://doi.org/10.1016/s1043-4526(08)60127-8
Munekata, P. E. S., Dominguez, R., Budaraju, S., Rosello-Soto, E., Barba, F. J., Mallikarjunan, K., … Lorenzo, J. M. (2020). Effect of Innovative Food Processing Technologies on the Physicochemical and Nutritional Properties and Quality of Non-Dairy Plant-Based Beverages. *Foods, 9*(3), 288. https://doi.org/10.3390/foods9030288
Naranjo, A., Johnson, A., Rossow, H., & Kebreab, E. (2020). Greenhouse gas, water, and land footprint per unit of production of the California dairy Indust over 50 years. *Journal of Dairy Science, 103*(4), 3760–3773. https://doi.org/10.3168/jds.2019-16576
Nijdam, D., Rood, T., & Westhoek, H. (2012). The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes. *Food Policy, 37*(6), 760–770. https://doi.org/10.1016/j.foodpol.2012.08.002
Nikiforidis, C. V., Matsakidou, A., & Kiosseoglou, V. (2014). Composition, properties and potential food applications of natural emulsions and cream materials based on oil bodies. *RSC Advances, 4*(48), 25067–25078. https://doi.org/10.1039/c4ra00903g
Nionelli, L., Coda, R., Curiel, J. A., Poutanen, K., Marco, G., & Rizzello, C. G. (2014). Manufacture and characterization of a yogurt-like beverage made with oat flakes fermented by selected lactic acid bacteria. *International Journal of Food Microbiology, 185*, 17–26. https://doi.org/10.1016/j.ijfoodmicro.2014.05.004
Noya, I., Gonzalez-Garcia, S., Berzosa, J., Baucells, F., Feijoo, G., & Moreira, M. T. (2018). Environmental and water sustainability of milk production in Northeast Spain. *Science of the Total Environment, 616*, 1317–1329. https://doi.org/10.1016/j.scitotenv.2017.10.186
Onning, G., Akesson, B., Oste, R., & Lundquist, I. (1998). Effects of consumption of oat milk, soya milk, or cow's milk on plasma lipids and antioxidative capacity in healthy subjects. *Annals of Nutrition & Metabolism, 42*(4), 211–220. https://doi.org/10.1159/000012736
Önning, G., Wallmark, A., Persson, M., Akesson, B., Elmstahl, S., & Oste, R. (1999). Consumption of oat milk for 5 weeks lowers serum cholesterol and LDL cholesterol in free-living men with moderate hypercholesterolemia. *Annals of Nutrition and Metabolism, 43*(5), 301–309. https://doi.org/10.1159/000012798
Palacios, O. M., Badran, J., Spence, L., Drake, M. A., Reisner, M., & Moskowitz, H. R. (2010). Measuring acceptance of milk and milk substitutes among younger and older children. *Journal of Food Science, 75*(9), S522–S526. https://doi.org/10.1111/j.1750-3841.2010.01839.x
Paudel, D., Dhungana, B., Caffe, M., & Krishnan, P. (2021). A review of health-beneficial properties of oats. *Foods (Basel, Switzerland), 10*(11), 2591. https://doi.org/10.3390/foods10112591
Paul, A. A., Kumar, S., Kumar, V., & Sharma, R. (2020). Milk Analog: Plant based alternatives to conventional milk, production, potential and health concerns. *Critical Reviews in Food Science and Nutrition, 60*(18), 3005–3023. https://doi.org/10.1080/10408398.2019.1674243
Pereira, P. C. (2014). Milk nutritional composition and its role in human health. *Nutrition, 30*(6), 619–627. https://doi.org/10.1016/j.nut.2013.10.011
Röös, E., Patel, M., & Spångberg, J. (2016). Producing oat drink or cow's milk on a Swedish farm — Environmental impacts considering the service of grazing, the opportunity cost of land and the demand for beef and protein. *Agricultural Systems, 142*, 23–32. https://doi.org/10.1016/j.agsy.2015.11.002
Rafiq, S., Huma, N., Pasha, I., Sameen, A., Mukhtar, O., & Khan, M. I. (2016). Chemical composition, nitrogen fractions and amino acids profile of milk from different animal species. *Asian-Australasian Journal of Animal Sciences, 29*(7), 1022–1028. https://doi.org/10.5713/ajas.15.0452
Ramsing, R., Santo, R., Kim, B. F., Altema-Johnson, D., Wooden, A., Chang, K. B., … Love, D. C. (2023). Dairy and plant-based milks: Implications for nutrition and

planetary health. *Current Environment & Health Reports*. https://doi.org/10.1007/s40572-023-00400-z

Ray, M., Ghosh, K., Singh, S., & Chandra Mondal, K. (2016). Folk to functional: An explorative overview of rice-based fermented foods and beverages in India. *Journal of Ethnic Foods, 3*(1), 5–18. https://doi.org/10.1016/j.jef.2016.02.002

Rosa-Sibakov, N., de Oliveira Carvalho, M. J., Lille, M., & Nordlund, E. (2022). Impact of enzymatic hydrolysis and microfluidization on the techno-functionality of oat bran in suspension and acid milk gel models. *Foods, 11*(2), 228. https://doi.org/10.3390/foods11020228

Russo, P., de Chiara, M. L. V., Capozzi, V., Arena, M. P., Amodio, M. L., Rascón, A., … Spano, G. (2016). Lactobacillus plantarum strains for multifunctional oat-based foods. *LWT-Food Science and Technology, 68*, 288–294. https://doi.org/10.1016/j.lwt.2015.12.040

Salmeron, I., Thomas, K., & Pandiella, S. S. (2015). Effect of potentially probiotic lactic acid bacteria on the physicochemical composition and acceptance of fermented cereal beverages. *Journal of Functional Foods, 15*, 106–115. https://doi.org/10.1016/j.jff.2015.03.012

Salve, A. R., Pegu, K., & Arya, S. S. (2019). Comparative assessment of high-intensity ultrasound and hydrodynamic cavitation processing on physico-chemical properties and microbial inactivation of peanut milk. *Ultrasonics Sonochemistry, 59*, Article 104728. https://doi.org/10.1016/j.ultsonch.2019.104728

Sang, S., & Chu, Y. (2017). Whole grain oats, more than just a fiber: Role of unique phytochemicals. *Molecular Nutrition & Food Research, 61*(7), 1600715. https://doi.org/10.1002/mnfr.201600715

Sarni, A. R., & Baroni, L. (2019). Milk and Parkinson disease: Could galactose be the missing link. *Mediterranean Journal of Nutrition and Metabolism, 12*(1), 91–118. https://doi.org/10.3233/mnm-180234

Sethi, S., Tyagi, S. K., & Anurag, R. K. (2016). Plant-based milk alternatives an emerging segment of functional beverages: A review. *Journal of Food Science and Technology-Mysore, 53*(9), 3408–3423. https://doi.org/10.1007/s13197-016-2328-3

Sharma, D., Shree, B., Kumar, S., Kumar, V., Sharma, S., & Sharma, S. (2022a). Stress induced production of plant secondary metabolites in vegetables: Functional approach for designing next generation super foods. *Plant Physiology and Biochemistry, 192*, 252–272. https://doi.org/10.1016/j.plaphy.2022.09.034

Sharma, K., Kaur, R., Kumar, V., Kumar, S., Singh, A., & Gautam, N. (2022b). Prebiotic and probiotic potential of cereals. In S. Punia Bangar, & A. Kumar Siroha (Eds.), *Functional cereals and cereal foods: Properties, functionality and applications* (pp. 163–188). Cham: Springer International Publishing.

Sharma, S., Shree, B., Sharma, D., Kumar, S., Kumar, V., Sharma, R., & Saini, R. (2022c). Vegetable microgreens: The gleam of next generation super foods, their genetic enhancement, health benefits and processing approaches. *Food Research International, 155*, Article 111038. https://doi.org/10.1016/j.foodres.2022.111038

Shkembi, B., & Huppertz, T. (2021). Calcium absorption from food products: Food matrix effects. *Nutrients, 14*(1), 180. https://doi.org/10.3390/nu14010180

Sibakov, J., Anu, K.-N., Kaisa, P., Olavi, M. K., Pekka, L., & Tapani, S. (2013). Comparison of acid and enzymatic hydrolyses of oat bran β-glucan at low water content. *Food Research International, 52*(1), 99–108. https://doi.org/10.1016/j.foodres.2013.02.037

Sidhu, J., & Singh, R. (2016). Ultra high pressure homogenization of soy milk: Effect on quality attributes during storage. *Beverages, 2*, 1–17. https://doi.org/10.3390/beverages2020015

Singh, R., De, S., & Belkheir, A. (2013). Avena sativa (Oat), A potential neutraceutical and therapeutic agent: An overview. *Critical Reviews in Food Science and Nutrition, 53*(2), 126–144. https://doi.org/10.1080/10408398.2010.526725

Singhal, Y., Baker, R. D., & Baker, S. S. (2017). A Comparison of the nutritional value of cow's milk and nondairy beverages. *Journal of Pediatric Gastroenterology and Nutrition, 64*(5), 799–805. https://doi.org/10.1097/mpg.0000000000001380

Smedman, A., Mansson, H. L., Drewnowski, A., & Edman, A. K. (2010). Response-letter to the editor regarding nutrient density of beverages in relation to climate impact. *Food & Nutrition Research, 54*. https://doi.org/10.3402/fnr.v54i0.5732

Smoczyński, M., Staniewski, B., & Kiełczewska, K. (2012). Composition and structure of the bovine milk fat globule membrane—some nutritional and technological implications. *Food Reviews International, 28*(2), 188–202. https://doi.org/10.1080/87559129.2011.595024

Sterna, V., Zute, S., & Brunava, L. (2016). Oat grain composition and its nutrition benefice. In *, 8. 1st Florence Sustainability of Well-Being International Forum (SWIF) on Food for Sustainability and not Just Food* (pp. 252–256).

Tester, R. F., & Karkalas, J. (1996). Swelling and gelatinization of oat starches. *Cereal Chemistry, 73*(2), 271–277.

Truong, T., Palmer, M., Bansal, N., & Bhandari, B. (2016). An overview of milk fat globules. In T. Truong, M. Palmer, N. Bansal, & B. Bhandari (Eds.), *Effect of milk fat globule size on the physical functionality of dairy products* (pp. 5–9). Cham: Springer International Publishing.

Truswell, A. S. (2002). Cereal grains and coronary heart disease. *European Journal of Clinical Nutrition, 56*(1), 1–14. https://doi.org/10.1038/sj.ejcn.1601283

Walther, B., Guggisberg, D., Badertscher, R., Egger, L., Portmann, R., Dubois, S., … Rezzi, S. (2022). Comparison of nutritional composition between plant-based drinks and cow's milk. *Frontiers in Nutrition, 9*, 988707. https://doi.org/10.3389/fnut.2022.988707

Xia, X. D., Dai, Y. Q., Wu, H., Liu, X. L., Wang, Y., Cao, J. P., & Zhou, J. Z. (2019). Effects of pressure and multiple passes on the physicochemical and microbial characteristics of lupin-based beverage treated with high-pressure homogenization. *Journal of Food Processing and Preservation, 43*(4), e13912. https://doi.org/10.1111/jfpp.13912

Xinping, L., Linyue, Z., Yonghui, Y., Jingjie, Z., Jing, W., & Baoguo, S. (2022). The potential functions and mechanisms of oat on cancer prevention: A review. *Journal of Agricultural and Food Chemistry, 70*(46), 14588–14599. https://doi.org/10.1021/acs.jafc.2c06518

Xiong, Y., Zhang, P. Z., Warner, R. D., Shen, S. B., & Fang, Z. X. (2022). Cereal grain-based functional beverages: From cereal grain bioactive phytochemicals to beverage processing technologies, health benefits and product features. *Critical Reviews in Food Science and Nutrition, 62*(9), 2404–2431. https://doi.org/10.1080/10408398.2020.1853037

Ying-run, F., Yu, S., Rong-chuan, L., Xiao-jing, S., Jiang-ping, F., Xiao-lin, L., & Jia-shun, G. (2021). Study on the optimization of oatmeal coffee beverage formula by box-behnken design. *Food Research and Development, 42*(22), 131–136. https://doi.org/10.12161/j.issn.1005-6521.2021.22.020

Yu, Y., Zhou, L., Li, X., Liu, J., Li, H., Gong, L., … Sun, B. (2022). The progress of nomenclature, structure, metabolism, and bioactivities of oat novel phytochemical: Avenanthramides. *Journal of Agricultural and Food Chemistry, 70*(2), 446–457. https://doi.org/10.1021/acs.jafc.1c05704

Yue, J., Gu, Z., Zhu, Z., Yi, J., & Rao, J. (2021). Impact of defatting treatment and oat varieties on structural, functional properties, and aromatic profile of oat protein. *Food Hydrocolloids, 112*, Article 106368. https://doi.org/10.1111/jfpp.13912

Zhu, F., Du, B., & Xu, B. (2016). A critical review on production and industrial applications of beta-glucans. *Food Hydrocolloids, 52*, 275–288. https://doi.org/10.1016/j.foodhyd.2015.07.003

Zhu, Y.-Y., Thakur, K., Feng, J.-Y., Cai, J.-S., Zhang, J.-G., Hu, F., & Wei, Z.-J. (2020). B-vitamin enriched fermented soymilk: A novel strategy for soy-based functional foods development. *Trends in Food Science & Technology, 105*, 43–55. https://doi.org/10.1016/j.tifs.2020.08.019