The Pharma Innovation Journal 2023; SP-12(7): 2153-2159

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(7): 2153-2159
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www.thepharmajournal.com
Received: 28-05-2023
Accepted: 30-06-2023

**Navya Siby**
Student, M.sc Food Science and Technology, Department of Food Science and Nutrition, Lovely Professional University, Punjab, India

**Corresponding Author:**
**Navya Siby**
Student, M.sc Food Science and Technology, Department of Food Science and Nutrition, Lovely Professional University, Punjab, India

# Cereal-based unfermented beverages: Processing techniques and nutritional attributes

**Navya Siby**

**Abstract**
In recent times, there has been a notable surge in interest towards cereal-based unfermented beverages, which are increasingly recognized as a wholesome and viable substitute for conventional dairy milk. This review explores the processing methods and nutritional qualities of these beverages. The production process involves the extraction of nutrients from cereal grains to create a bioavailable product. Various techniques, such as homogenization and the use of hydrocolloids and emulsifiers, are employed to enhance suspension stability and maintain a smooth texture. Fortification with essential vitamins and minerals ensures that these milk substitutes meet dietary requirements. The challenges related to heat-induced changes in protein properties and Flavors are addressed through careful temperature control during pasteurization and ultra-high temperature treatment. As consumer demand for healthier and sustainable options grows, the future prospects for cereal-based unfermented beverages appear promising. Capitalizing on health and wellness trends, targeting the vegan and plant-based market, exploring innovative flavours, and emphasizing sustainable branding can all contribute to the success of these beverages in the evolving food and beverage industry.

**Keywords:** Cereals, unfermented beverages, functional drinks, bioavailability, oat milk, rice milk

## 1. Introduction

Cereal-based unfermented beverages encompass a diverse array of non-alcoholic drinks derived from cereals that have not undergone fermentation. While numerous cereal-based beverages are indeed fermented, the non-alcoholic options have gained prominence due to their economic feasibility and efficient utilization of various cereals and crops (Xiong *et al*., 2020) [41]. This category of beverages has a rich historical background, deeply ingrained in cultures worldwide. Their appeal lies in providing a refreshing and nutritious alternative to alcoholic drinks, catering to individuals of all age groups (Grosu-tudor *et al*., 2019) [19]. Traditionally, some of these beverages were prepared as alcoholic concoctions but have since transitioned into soft drinks and non-alcoholic beverages that are commercially accessible in the market (Amadou, 2019; Fidele *et al*., 2017; Soma *et al*., 2019; Wend-bénédo *et al*., 2018) [3, 16, 36, 39]. Cereal grains play a crucial role as a staple food source in diverse cultures, and the global food trade plays a vital role in making a wide array of cereals easily accessible for consumption worldwide (Ubwa *et al*., 2012) [37]. Cereal-based diets are widely embraced worldwide, serving essential sources of calories and protein. Maize, barley, wheat, rye, sorghum, rice, millet and oats, are particularly favoured and collectively contribute to approximately 56% of the total food energy and around 50% of the protein content consumed by global inhabitants (Cordain, 1999) [11]. Incorporating grains of cereal into our diets offers the body access to an array of bioactive substances with possible health advantages.

Cereal grains can also consider nutrient-rich packages containing indispensable macronutrients like carbohydrates, proteins, and lipids, as well as micronutrients such as minerals, vitamins along with various beneficial phytochemicals like phenolic compounds and carotenoids. The carbohydrates found in the food, which include simple sugars and digestible starch, play a crucial role as essential sources of energy (Arendt & Zannini, 2013) [4]. Additionally, indigestible carbohydrates contribute to dietary fiber, promoting digestive health. Certain cereal dietary fibers, like β-glucans found in oats and barley, have earned recognition for their potential health benefits and have garnered health assertions. Among the micronutrients found in cereals, B vitamins play crucial roles in supporting overall well-being (Vitaglione *et al*., 2008) [38]. Whole grains contribute significantly to the mineral content of human diets, encompassing essential minerals such as magnesium, copper, potassium, calcium, phosphorus, sulphur, zinc, iron, and manganese.

However, the presence and deposition of minerals within the grain tissue can impact their accessibility for absorption during the digestion process. (Gani *et al*., 2012) [18]. Phenolic compounds form the primary group of phytochemicals in grains, including phenolic acids, flavonoids, anthocyanidins, and phytosterols. Frequently, phenolic compounds are attached to cell-wall polysaccharides as a component of dietary fiber. Notably, ferulic acid stands out as a dominant phenolic antioxidant in cereals (Okarter & Liu, 2010) [28]. The health-promoting effects of antioxidants are attributed to their gradual release from dietary fiber within the gastrointestinal tract. Cereal grains also contain carotenoids, such as β-carotene, α-carotene, zeaxanthin, and lutein which exhibit antioxidant properties and pro-vitamin A activity, supporting overall well-being (Wu *et al*., 2013) [40]. Cereals have emerged as highly sought-after raw materials to manufacture non-alcoholic and functional beverages, garnering significant alertness in recent times. They can be utilized in various forms, serving as stimulants comparable to coffee and tea, refreshing beverages. Processing techniques of beverages may involve simple non-microbial approaches, includes the physical application methods, or more complex methods that include enzyme clarification and microbial fermentation (Blandino *et al*., 2003) [8]. Beverages can be categorized as either non-fermented or fermented, with the latter being further divided into alcoholic and non-alcoholic variants. Additionally, beverages can be classified based on their processing scale, distinguishing between industrially processed ones tailored to meet broader consumer needs and traditionally processed ones, reflecting regional and ethnic differences in the elements and consumption habits observed in different countries (Aka *et al*., 2014) [2]. Cereal-based beverages offer a natural and nutritious choice, predominantly containing natural sugars and boasting abundant vitamins, antioxidants, and health-enhancing elements. Versatility of products lies in their capacity to incorporate various functional constituents, yielding a wide range of characteristics. These beverages are derived from a grain suspension, and the extract itself can be consumed as a dietary supplement rich in dietary fibers. However, further processing steps such as sifting and filtering present exciting opportunities for crafting intriguing beverages. By introducing oil emulsions to the filtrate, beverages akin to milk or cream are produced, devoid of animal protein and lactose. This "cereal milk" proves to be highly suitable for individuals with lactose intolerance and cow's milk allergy. Additionally, by fermenting the extract with microorganisms, innovative Flavors can be achieved, further enhancing the appeal and diversity of cereal-based beverages (Zannini *et al*., 2012) [43].

## 2. Non-fermented cereal-based beverages

### 2.1 Milk substitutes based on cereal grains

Cereal-based milk substitutes are delightful liquid extracts obtained from a variety of cereals or pseudocereals, bearing a striking resemblance to the familiar appearance of cow's milk. These delightful beverages have been cherished in different regions across the globe for generations. For instance, one can *savor* the rich flavours of Sikhye in South Korea, skilfully prepared from cooked rice, malt extract, and a touch of sugar, while in Nigeria, the refreshing and nourishing *kunu (Kunun zaki)* awaits, lovingly crafted from sprouted millet, sorghum, or maize. These traditional concoctions not only captivate the taste buds but also offer a glimpse into the cultural richness and diversity of various countries and regions (Aung *et al*., 2022) [5].

#### 2.1.1 Milk extracted from rice grains.

Rice milk, a beloved liquid derived primarily from brown rice, is typically free of added sugars. Instead, its natural sweetness emerges through an enzymatic breakdown of carbohydrates, primarily yielding glucose. However, some rice milk varieties may be sweetened using alternative sources like sugarcane syrup or other types of sugars. Diverse commercial brands have introduced a wide range of flavours, including popular choices such as vanilla, chocolate, and almond, alongside the classic unflavoured version. Its versatility as a milk alternative has made it a preferred choice in various recipes, satisfying the needs of those seeking a non-dairy option in their culinary adventures (Achi & Asamudo, 2019; Freire *et al*., 2017) [1, 17].

#### 2.1.2 Milk extracted from oats

Oat milk is created by soaking whole oat grains to extract their nutritional goodness. It naturally boasts a velvety texture and a unique oatmeal-like taste. However, in the commercial market, oat milk is readily available in a delightful array of flavours, ranging from sweetened to unsweetened, vanilla, or chocolate-infused varieties (Deswal *et al*., 2014) [14]. While there may be some uncertainty surrounding its practicality as a complete dairy substitute, oat milk continues to prove its worth as a versatile ingredient. It can be successfully utilized in the creation of fermented milk products, such as yogurts, kefir, prebiotics, and probiotics, while preserving its characteristic nutrient-rich profile (Mäkinen *et al*., 2016) [24]. This plant-based beverage has found its way into the hearts of many, becoming a favourite among those seeking an alternative to traditional dairy milk, with its smooth texture and delightful flavour enhancing a wide range of recipes and culinary delights. Its versatility and nutrient content make it a compelling choice for health-conscious consumers and eco-conscious individuals alike (Deswal *et al*., 2014) [14], Oat milk continues to present itself as a practical and viable choice for crafting an array of fermented milk products, including yogurts, kefir, prebiotics, and probiotics. Even throughout the fermentation process, oat milk manages to retain its distinctive nutrient-rich composition, making it an excellent alternative to traditional dairy in the realm of dairy-free culinary innovations.

#### 2.1.3 Beverages prepared from roasted grains.

A delightful and comforting roasted grain beverage is crafted through the artful process of roasting one or more cereal grains and subsequently boiling or steeping them in hot water. This creates a warm and soothing drink that has gained popularity and is now readily available in crystal or powder form for convenient consumption. With the simple addition of hot water, these products can be effortlessly reconstituted, allowing anyone to savour their rich flavours (Dibaba *et al*., 2018) [15].

Roasted grain beverages have gained immense popularity in East Asian countries like Korea, Japan, and China. People in these regions commonly enjoy these warm or cold drinks, often replacing plain drinking water in households and restaurants. Among the most cherished varieties are barley tea, rice tea, corn tea, and buckwheat tea. Each region has its unique names for these beverages: barley tea is known as damai-cha´ or ma`i-cha´ in China, mugi-cha or mugi-yu in

Japan, and bori-cha and *Sino-Korean cha* in Korea. To balance the slightly bitter flavor of barley, roasted barley is frequently combined with roasted corn, resulting in a delicious tea known as oksusu-cha. Additionally, there are other popular roasted grain drinks enjoyed in Korea, such as hyeonmi-cha (brown rice tea) and memil-cha (buckwheat tea). Sungnyung, made from scorched rice, is also a traditional drink, where both the rice and liquid are consumed together after simmering the rice grains for a relatively long time (Basinskiene *et al*., 2016; Basinskiene & Cizeikiene, 2020) [7, 6].

## 3. Nutritional attributes

Milk extracted from rice and oat are popular choices for individuals with specific health conditions that do not react well to dairy consumption, such as cow's milk allergy, lactose intolerance, and individuals undergoing radioiodine cancer treatment or dealing with eczema. Oat milk, especially, comes highly recommended as an excellent alternative to dairy milk for individuals dealing with irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD) as part of an anti-inflammatory diet. Due to its soothing and anti-inflammatory properties, oat milk has become a popular choice among patients with IBS and IBD, leading to a substantial increase in its consumption compared to other beverage options. Embracing oat milk as a dairy substitute has proven to be a beneficial dietary choice for those seeking relief from gastrointestinal discomfort and inflammation (Olendzki *et al*., 2014) [9].

Unfermented cereal beverages, including cereal milk and roasted grain drinks, offer a range of valuable nutritional properties that vary depending on the grains used and the processing methods employed. These beverages are typically rich in carbohydrates, providing a significant source of energy for the body. In particular, when made from whole grains, cereal beverages can be an abundant source of dietary fiber, promoting digestive health, supporting healthy gut microbiome. The presence of dietary fiber in these drinks contributes to feelings of fullness, making them potentially beneficial for weight management. In addition to carbohydrates and fiber, cereal beverages contain varying amounts of protein, contributing to overall nutrition. These proteins can be especially valuable for individuals following plant-based diets or looking for alternatives to animal-based sources. Moreover, cereal beverages may contain essential vitamins, such as B-vitamins (B1, B2, B3, B6, etc.), which play crucial roles in various metabolic processes in the body. Additionally, certain cereal grains used in these beverages, provide antioxidants.

Furthermore, cereal beverages are often low in saturated fat, making them a healthier option compared to some other beverages with higher fat content. For individuals with lactose intolerance, cereal milk and roasted grain drinks offer a lactose-free alternative to cow's milk, ensuring they can still enjoy a nutritious beverage without discomfort. Additionally, these beverages are typically free from caffeine, making them suitable for those seeking to avoid or reduce their caffeine intake, including pregnant women or individuals with certain health conditions. For individuals with gluten sensitivity or celiac disease, there are gluten-free options available among roasted grain beverages. These gluten-free versions provide a safe and enjoyable alternative for those who must avoid gluten in their diet. It's essential to note that the specific nutritional content of cereal beverages can vary based on factors such as the types and proportions of grains used, any added ingredients, and the concentration of grains in the beverage. Therefore, when choosing commercial products, it is advisable to check the product labels for specific nutritional information.

On the contrary, research has shown that the roasting process of cereal beverages can significantly enhance their total phenolic compounds and antioxidant activity. Studies conducted by Papetti *et al*., (2007) [31] have revealed that barley coffee possesses remarkable antimicrobial and bactericidal properties, particularly against oral pathogens like Streptococcus mutans and Streptococcus sobrinus. Additionally, it exhibits high antiadhesive properties, which could potentially help reduce the accumulation of cariogenic bacteria on teeth. The presence of α-dicarbonyl compounds formed during the barley roasting process has been attributed to these antibacterial and antiadhesive properties (Daglia *et al*., 2007; Ragaee *et al*., 2014) [12, 32]

## 4. Production technology of unfermented beverages

The manufacturing process of cereal-based milk substitutes closely mirrors that of other plant-based milk alternatives. Traditionally, the raw cereal material undergoes grinding to form a slurry, which is then strained to eliminate any coarse particles. In modern industrial-scale processes, the raw plant material is soaked and wet-milled to extract the vital nutrients. Alternatively, dry milling the raw material produces flour, which is later extracted in water. The residue from the grinding process is then separated through filtering or decanting. Once the extraction is completed, standardization might be carried out to ensure uniformity in nutritional content. Moreover, additional ingredients such as sugar, oil, flavourings, and stabilizers could be incorporated to enhance taste, texture, and overall product quality. After these steps, the mixture undergoes homogenization, which helps create a uniform and smooth texture in the beverage. To ensure the product's microbial stability and prolong its shelf life, the milk substitute is subjected to pasteurization or ultra-high temperature (UHT) treatment. Through these carefully orchestrated production steps, cereal-based milk substitutes are created, offering consumers a nutritious and palatable alternative to traditional dairy milk. These processes ensure that the beverages are not only rich in essential nutrients but also possess desirable sensory qualities, making them suitable for various culinary applications and a preferred choice for individuals seeking lactose-free and plant-based options (Muyanja *et al*., 2003) [25].

### 4.1 Extraction

The extraction process plays a pivotal role in the production of cereal-based milk substitutes. Unprocessed cereal grains typically have indigestible outer hulls, making them unsuitable for consumption. Therefore, processing is necessary to make the nutrients in the grains. The extraction procedure begins with milling or grinding to break apart the tough outer hull of the grains. To obtain soluble grain material, two main methods are commonly employed. The first method involves grinding the plant material with water, creating a mixture that allows the soluble nutrients to be released and dissolved in the water (Decker *et al*., 2014) [13]. The second method entails the process involves wet-grinding soaked grains into a thick, smooth slurry, which effectively extracts the desired nutrients and compounds from the grains. Both techniques are essential to transform the raw cereal grains into a form that is not only more digestible but also releases valuable nutrients for the production of the cereal-based milk substitute. Through these extraction processes, the nutritional content of cereal becomes readily available for incorporation into the final product. This ensures that the cereal-based milk substitutes offer a rich source of essential nutrients and are suitable alternatives for individuals seeking plant-based and lactose-free options. During the manufacturing of cereal-based milk substitutes, the extraction phase is essential which can significantly impacts the composition of the final product. Enhancing the efficiency of this step can lead to increased yield and improved product quality (Deswal *et al*., 2014) [14].

Various methods can be employed to achieve this (Rosenthal *et al*., 2003) [33]:

**4.1.1 pH Adjustment:** Increasing the pH level during extraction, either with bicarbonate or NaOH, can enhance the extractability of proteins. However, in some cases, a neutralization step may be necessary to restore the pH to a more suitable level for subsequent processing.

Temperature Variation: Modifying the extraction temperature can expedite the reaction rate and enhance fat extractability. Nevertheless, it is crucial to be mindful that elevated temperatures can also cause protein denaturation, diminishing their solubility and overall output.

Cellulase Treatment: Employing cellulase treatment has been found to decrease particle size and result in a more stable suspension. This treatment contributes to the overall efficiency of the extraction step. By optimizing the extraction process with these methods, cereal-based milk substitutes can be produced with higher yields and improved compositional qualities. These techniques play a crucial role in ensuring that the final products offer the desired nutritional properties, taste, and texture, making them appealing options for consumers seeking healthy and flavourful alternatives to traditional dairy milk.

Cereal-based milk substitutes, when produced using cereals or pseudocereals, encounter a challenge with starch forming a thick slurry when heated above the gelatinization temperature (55 °C to 65 °C). To overcome this, the starch undergoes gelatinization, liquefaction, and saccharification in subsequent processing steps. Amylases or malt enzyme extracts are utilized to break down the starch into simpler sugars, with some processes employing both α-amylases and β-amylases. This enzymatic treatment continues until the desired level of sweetness and viscosity is achieved in the milk substitute. The saccharification step can occur either before or after removing coarse particles from the mixture. Temperature control during this process is crucial, as heating the slurry above 50 °C before filtration can adversely affect the mouthfeel of rice milk. By carefully manipulating starches through controlled enzymatic processes, cereal-based milk substitutes can attain the desired sweetness, texture, and viscosity, offering a palatable and nutritious dairy milk alternative while preserving valuable nutritional properties (Lindahl *et al*., 1995; Nissenbaum *et al*., 1981; Salmerón *et al*., 2015) [23, 26, 34].

**4.2 Product formulation**

Product formulation plays an important role in the progress of cereal-based milk substitutes, involving the addition of various ingredients to the base after removing coarse plant material. These additional components can enhance the taste of product, texture, and nutritional value, making it a suitable alternative to dairy milk. To fortify the milk substitute with essential nutrients, vitamins, and minerals are often added (Ogunremi *et al*., 2022) [27]. Cereal-based milk substitutes, by nature, may have lower levels of calcium, iron, and vitamin A compared to dairy milk. Therefore, fortification with these nutrients becomes essential to ensure the product meets the required nutritional standards and can serve as a viable dairy substitute (Xiong *et al*., 2022) [42].

In formulation of cereal-based milk substitutes, it is essential to ensure that the added nutrients are not only bioavailable but also stable enough to maintain product quality throughout processing and shelf life. Various factors during processing, such as heat and exposure to oxygen, can impact the stability of vitamins. Careful consideration is given to selecting nutrient sources that remain stable under these conditions (Zhang *et al*., 2020) [44]. In the case of minerals, mineral sources are carefully chosen to provide a suitable and bioavailable form of iron and calcium in the milk substitute. However, it is worth noting that metal ions from these minerals can potentially react with other components in the milk substitute, which may affect product quality and stability (Salvador *et al*., 2016) [35]. To counteract this, the use of sequestrants, such as citric acid, may be necessary. Sequestrants help prevent unwanted interactions between metal ions and other food components, ensuring the overall quality and stability of the product. By carefully selecting bioavailable and stable nutrient sources, and employing sequestrants when needed, cereal-based milk substitutes can be fortified with essential vitamins and minerals in a way that maintains the product's integrity and nutritional value. Consumers can enjoy these milk substitutes as a nutritious and reliable alternative to dairy milk, meeting their dietary needs while enjoying the benefits of a plant-based beverage option (Chavan *et al*., 2018) [9].

Cereal-based milk substitutes, due to their composition, may contain insoluble particles such as protein, starch, fiber, and other cellular materials. These denser particles tend to settle down at the bottom of the product, causing sedimentation, which can make the beverage unstable and uneven in consistency. Additionally, when subjected to heating, these particles can coagulate and form clumps, leading to an undesirable texture and appearance in the milk substitute. These challenges need to be addressed during the production process to ensure a smooth and consistent product for consumers. Methods such as proper mixing, homogenization, and stabilizers may be employed to enhance the stability and overall quality of the cereal-based milk substitutes and prevent issues related to sedimentation and coagulation. To overcome these challenges and ensure the suspension stability of the milk substitutes, various techniques are employed (Hoffmann & Amaral, 2009) [20]. One effective method to increase suspension stability is by reducing the particle size through homogenization. Homogenization disrupts aggregates and lipid droplets, leading to a more uniform particle size distribution and improved stability (Mäkinen *et al*., 2016) [24]. Additionally, hydrocolloids and emulsifiers can significantly contribute to suspension stability. Hydrocolloids, such as gums and pectin, help stabilize the milk substitute by forming a network that prevents particle settling. Emulsifiers, on the other hand, act as stabilizers by reducing the surface tension between water and fat, ensuring a stable dispersion of insoluble particles throughout the beverage (Chronakis *et al*., 2004) [10].

Moreover, pine nuts were creatively employed by Ignat *et al*., (2020) [21] to enhance the stability of a rice-based beverage. The proteins found in pine nuts possess remarkable emulsifying properties, making them a valuable addition to the beverage formulation. Pine nuts contain proteins with excellent emulsifying properties, which can contribute to stabilizing the milk substitute and preventing the coagulation of particles upon heating. By incorporating these techniques and ingredients, cereal-based milk substitutes can achieve improved suspension stability, ensuring that the product remains visually appealing and pleasant to consume over its shelf life. The utilization of homogenization, hydrocolloids, emulsifiers, and innovative protein sources allows manufacturers to create high-quality milk substitutes that offer a smooth and consistent texture, making them suitable alternatives to traditional dairy milk.

**4.3 Extension of shelf life**

During the commercial production of plant milk substitutes, pasteurization or ultra-high temperature (UHT) treatment is commonly employed to prolong their shelf life and ensure product safety. However, the application of heat during these processes can result in changes to the properties of proteins present in the milk substitute. Proteins are sensitive to heat and undergo denaturation during pasteurization or UHT treatment. Denaturation involves a change in the protein's three-dimensional structure, which can lead to altered functional properties. For instance, proteins may lose their emulsifying or stabilizing abilities, affecting the overall stability of the milk substitute. This can result in the separation of phases, where water and fat separate, causing the product to appear lumpy or curdled. Moreover, the changes in protein properties can also impact the flavours, aroma, and colour of the plant milk substitute. Proteins play a role in the perception of taste and contribute to the mouthfeel of the product. Alterations in protein structure may lead to changes in the sensory attributes of the milk substitute, affecting its overall taste and texture. Furthermore, proteins are involved in Maillard reactions, which are responsible for the development of brown colours and desirable flavours in heated food products. Changes in protein properties during pasteurization or UHT treatment can influence the Maillard reactions, leading to alterations in the colour and flavour profile of the milk substitute. To mitigate these effects, manufacturers may employ various techniques, such as optimizing the heating conditions, selecting suitable protein sources, or adding stabilizers to preserve the quality and stability of the plant milk substitutes while extending their shelf life. Careful consideration of the heat treatment process is essential to strike a balance between product safety, shelf-life extension, and maintaining desirable sensory attributes (Kwok & niranjan, 1995) [22].

Pasteurization involves heating the product to temperatures below 100 °C, which is sufficient to destroy most microorganisms. The UHT treatment effectively extends the shelf life of the milk substitute by eradicating any microorganisms that could cause spoilage or foodborne illnesses. The rapid heating and cooling during UHT processing prevent the growth of bacteria and ensure the product remains safe and stable at room temperature for an extended period. This makes UHT-treated milk substitutes convenient for storage and distribution, particularly in regions with limited access to refrigeration facilities. However, it's essential to note that the intense heat during UHT treatment can lead to some changes in taste and color, albeit minimal, compared to pasteurized products. Nonetheless, the benefits of extended shelf life and convenience make UHT-treated milk substitutes a popular choice for consumers and the food industry alike. While pasteurization and UHT treatment are widely used and effective methods for preserving plant milk substitutes, they can also lead to alterations in flavour and sensory characteristics due to heat-induced reactions (Mäkinen *et al*., 2016) [24]. To overcome this issue, some products, like *sikhye,* take an alternative approach. *Sikhye* is commonly sold frozen to avoid flavour changes associated with UHT treatment. However, a potential risk with frozen products is the presence of Bacillus cereus spores. To address this, a process called tyndallisation with $CO_2$ injection can be employed, which involves a two-step heating procedure (80 °C and 95 °C) (Kim *et al*., 2012) [45].

**5. Conclusion**

he manufacturing process of cereal-based milk substitutes involves careful formulation to achieve the desired taste, texture and nutritional profile. Fortification with essential vitamins and minerals are crucial to meet dietary requirements, especially as cereal-based milk substitutes may naturally contain lower levels of certain nutrients compared to dairy milk. However, challenges related to stability and suspension of insoluble particles are addressed through various methods. Homogenization, the use of hydrocolloids, and emulsifiers contribute to enhancing suspension stability and maintaining a smooth texture. Additionally, innovative protein sources like pine nuts or treatments like tyndallisation with $CO_2$ injection are utilized to preserve flavours and address potential risks, respectively. Commercially, pasteurization and UHT treatment are commonly employed to extend shelf life. These methods ensure the safety and preservation of cereal-based milk substitutes, although careful control of temperature and processing is necessary to prevent undesirable changes in product quality.

The future prospects for cereal-based unfermented beverages appear promising with the rising demand for healthier and sustainable food options. As health and wellness trends continue to shape consumer preferences, these beverages can capitalize on their natural nutrient content, positioning themselves as nourishing choices for health-conscious individuals. The growing vegan and plant-based mark*et al*so presents a significant opportunity, allowing brands to target this community seeking cruelty-free and sustainable alternatives. Flavour innovation can further attract a diverse consumer base, offering unique taste experiences. Additionally, emphasizing the functional benefits of cereal grains can resonate with health-seeking consumers. Convenient and eco-friendly packaging options can cater to busy lifestyles and environmentally conscious consumers. Utilizing online marketing and e-commerce channels can expand their reach, particularly among tech-savvy consumers. Partnerships with cafes and restaurants can increase visibility, and educational campaigns can raise awareness about the versatility and nutritional advantages of cereal-based unfermented beverages, solidifying their position in the evolving food and beverage landscape.

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