THE SCIENTIFIC FRONTIERS

Popular Article

OPEN ACCESS

Health Benefits of Non-Bovine Milk: Approach towards green and sustainable life

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Abstract
Modern food technology allows designing products aiming to simulate and replace traditional food. In affluent societies there is a rising tendency to consume foods derived from plants including milk imitations or plant drinks based on cereals, nuts, legumes, oil seeds or other plant families. Herein we review production and composition of such drinks, summarize consumers' motivations to change from milk to plant drinks and highlight nutritional and health implications of consuming plant drinks instead of milk, in particular if non-fortified and if consumed by infants, children, adolescents and the elderly. These plant-based beverages can be made from nuts (e.g., almonds, cashews, hazelnuts), coconuts, grains (rice, oats), legumes (soy, peas), seeds (flax, hemp, sesame, chia), and fruits (banana). Almond, soy and coconut non-dairy beverages have been the recent market leaders, with the sales of oat-based beverages now experiencing a surge. This article will assist the readers in making informed decisions on which milk can be consumed based on their dietary as well as social factors. While among plant-based milks flavour masking was considered a viable option to meet the consumer preferences. Literature has reported lower environmental impact of plant-based milks however; broad sustainability evaluation is needed for a better comparison with dairy milk. Overall, preference between plant and dairy milk significantly relies upon a wide range of factors and consumer circumstances.

ARTICLE HISTORY

Received: October 10, 2025
Accepted: October 10, 2025
Published: November 1, 2025

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DOI: https://doi.org/10.5281/zenodo.19674742

KEY WORDS: Plant-based non-dairy beverages, plant-based milks, nutrient composition, fortification, calcium, vitamin D.

INTRODUCTION

Rising concerns regarding environmental sustainability, animal welfare, and personal health have significantly influenced consumer behavior, leading to a marked increase in the demand for dairy milk alternatives. Over the past decade, the popularity of these products has surged, particularly in Western nations, where a growing segment of the population intentionally limits or avoids cow's milk. This shift is largely motivated by several factors, including lactose intolerance, milk protein allergies, ethical considerations, environmental sustainability, and the adoption of plant-based or vegan lifestyles.

According to global market reports, the dairy alternatives industry was valued at approximately USD 12.1 billion in 2018 and is projected to more than double, reaching USD 25.1 billion by the end of 2026.

Currently, consumers can choose from over 20 varieties of plant-based beverages that mimic the sensory and functional properties of traditional dairy milk. Selection preferences are influenced by factors such as taste, texture, flavor, packaging, nutritional composition, price, and the presence or absence of organic or genetically modified (GM) ingredients.

Although research has largely focused on the nutritional comparison of plant-based beverages against cow's milk—often emphasizing vulnerable populations such as children and women—an emerging area of interest lies in the potential health benefits of non-bovine animal-derived milks. Evidence from compositional analyses, in vivo studies, and limited acute clinical trials suggests that milks from species such as sheep and goats may serve as viable alternatives

to cow milk, particularly in the context of cardiometabolic health.

Sheep milk, for instance, is notably rich in functional nutrients such as medium-chain triglycerides (MCTs), conjugated linoleic acid (CLA), branched-chain amino acids like leucine, and essential minerals. These components have been linked to beneficial effects on metabolic health, including improved lipid profiles and enhanced insulin sensitivity. Goat and buffalo milk also contain bioactive compounds with potential health-promoting properties, though typically at lower concentrations than those found in sheep milk.

Despite these promising insights, there remains a paucity of high-quality, long-term randomized controlled trials (RCTs) evaluating the health outcomes associated with non-bovine milk consumption. To substantiate any nutritional recommendations, future research must elucidate how the bioactive components of these alternative milks influence cardio-metabolic biomarkers and long-term disease risk in diverse populations.

COW MILK ALTERNATIVES

The worldwide commercial production of cow milk decisively eclipses the relatively minor contributions from alternative animal species. Nonetheless, these milks remain valuable primary sources of nutrition for many countries and communities globally. Owing to the specific make-up of proteins (e.g., β-lactoglobulin; β-lg) and sugars (e.g., lactose) within cow milk, the global prevalence of cow milk allergy and intolerance is notably high. Approximately 65% of adults worldwide have a suboptimal capacity to digest and absorb lactose. In Asian and American Indian populations, the reported prevalence of lactose intolerance is closer to 100%. However, with marked compositional differences, hypo allergenicity and improved tolerability have been indicated following the ingestion of goat, sheep, camel buffalo and donkey milk, as compared to cow milk. It should be noted that throughout this review buffalo milk refers to the produce of animals of the Bubalus genus. Lastly, non-dairy substitutes for milk, including soy, oat, rice, and nut 'milk beverages' have received growing attention. These plant-based alternatives are formulated through the disintegration of plant material, extraction in water, and subsequent homogenisation, which produces'milk' reminiscent of the consistency and appearance of animal milk. Despite a typically substandard macronutrient profile relative to mammalian milk, plant-based 'milks' possess distinct functional ingredients, lower allergenicity and greater affordability, which have impelled a noticeable surge in demand and production.

HEALTH BENEFITS OF NON-BOVINE MILK

Non bovine milk from animal sources contains substantial quantities of several nutrients such as oligosaccharides, lipids, bioactive peptides, high-quality protein, minerals, and vitamins with nutritional and health benefits. The types, concentration, and composition of these nutrients vary due to breed, animal age and season, feed type and quantity, and environmental conditions. Camel milk fats contain small size fat globules, high levels of lactadherin-like protein, essential fatty acids, unsaturated fatty acids, phospholipids, low amounts of cholesterol, and saturated fatty acids . Camel milk has a high digestibility; good nutritional value; and health effects such as anti-bacterial, anti-inflammatory, and anti-hyperlipidemia activities. The consumption of sheep milk by rats fed a diet restricted in calcium and phosphorous contents was found to increase the levels of calcium, phosphorous, and strontium in the bones of the rats, and thereby it has a good prospect of maintaining bone health in diets low calcium and phosphorous.

To overcome the known nutritional and sensory limitations, commercial plant-based milk alternatives are typically supplemented with sweeteners, artificial flavours, protein, amino acids, minerals (Ca^{2+}, Mg^{2+}, Fe^{2+} and Zn^{2+}), and vitamins (B12, B2, D and E) . Moreover, extended mechanical and thermal pre-processing (e.g. roasting, dehulling, blanching, soaking, cooking and sprouting) is applied to reduce anti-nutrients such as protease inhibitors, decrease and mask off-flavour and improve mouthfeel and colour. However, some anti-nutrients are very resistant. For example, phytates cannot be destroyed entirely even by heating to 100 °C.

FERMENTATION OF NON-DAIRY MILK SOURCES

Fermentation is capable of increasing the concentration or bioaccessibility of functional (bioactive) compounds. The fermentation of soy using bacteria with β-glucosidase ability enables the conversion of glucoside isoflavones into aglycone isoflavones of higher bioactivity and bioaccessibility, which has also been observed for seeds of kerandang, a flowering plant belonging to the legume family. Correspondingly, L. plantarum is able to transform sesaminoltriglucoside of sesame milk into bioactive sesaminol aglycone with enhanced radical scavenging activity. It was also reported that LAB fermentation of soy releases bioactive peptides, which inhibit angiotensin-converting enzymes that are related to the desired antihypertensive effect.

SOY MILK AS ALTERNATIVE

The protein content of soy milk is similar to bovine milk, with around 3.4 g of protein per 100 mL of product. The soymilk fat primarily contains unsaturated fatty acids. It contains nearly the same carbohydrate content as bovine milk but has complex carbohydrates like oligosaccharides and polysaccharides. It is naturally rich in potassium, phosphorus, and magnesium. It is a good source of

phytochemicals like isoflavones that have various health benefits, like reducing the risk of heart disease and cancer. It also contains prebiotic fibers called oligosaccharides that promote beneficial bacteria growth in the gut. The enzymatic population of this milk contains phytase that helps in breaking down the phytic acid, a compound that can hinder specific mineral absorption, such as iron and zinc. It is often fortified with calcium, vitamin D, and vitamin B12 to match bovine milk's nutrient content. The major amino acids present in soy milk are aromatic amino acids, tryptophan, threonine, and histidine .digestible score of soy milk is in the range of 78-116%.

ALMOND MILK COMPOSITION

For individuals seeking a low-calorie alternative to cow's milk, almond milk presents a viable option. This milk is derived from ground almonds and water. The nutritional composition of almond milk may vary based on factors such as processing methods and the inclusion of other ingredients, such as stabilizers or preservatives. Although almond milk has less protein than bovine milk, protein fortification can enhance its nutritional value. The fat content in almond milk is significantly lower than bovine milk. However, fat is healthier because it primarily comprises unsaturated fatty acids. Almond milk is rich in complex carbohydrates such as fiber, providing a sustained energy source. Furthermore, it constitutes a natural source of vitamin E, an antioxidant that can protect cells from harmful deterioration. It is also abundant in phytochemicals, such as flavonoids, that have been shown to reduce the risk of heart disease and certain types of cancer. It also contains prebiotic fibers, including inulin, that promote beneficial gut bacteria growth. Major amino acids in almond milk are aromatic amino acids, histidine, and tryptophan. Almond milk digestibility score was 85.8%.

OAT MILK BENEFITS

Oat milk is a recently popular substitute for bovine milk. It comprises oats and water and is a good source of protein, vitamins, and minerals. The composition of oat milk can vary depending on factors such as the processing method, the type of oats used, and any additional ingredients added. Oat milk has fewer calories (55 calories per 100 mL) and lower protein content (1.1 grams per 100 mL) than bovine milk. It contains higher levels of unsaturated fatty acids and lower total fat content than bovine milk. Although oat milk has similar carbohydrate content to bovine milk, the complexity of these carbohydrates is higher. Additionally, oat milk is naturally rich in vitamin B1, a crucial component of energy metabolism. It also contains phytochemicals such as betaglucans, which are linked to various health benefits, such as reducing cholesterol and supporting heart health. Periodic fibers are also present, which are like oligosaccharides, promoting the growth of beneficial gut bacteria, and enzymes like amylase, which aid in breaking down complex carbohydrates for easier digestion. Aromatic amino acids, sulphur amino acids and tryptophan are the major amino acids present in oat milk and this milk has a protein digestibility score of 87.5%.

HEALTH BENEFITS OF CONSUMING NON-BOVINE MILK

Non-bovine milk, such as almond, soy, oat, coconut, and goat milk, offers several health benefits compared to cow's milk. Here are some of the key benefits:

- Lactose-Free: Many non-bovine milks are naturally lactose-free, making them suitable for individuals who are lactose intolerant.
- Lower in Saturated Fat: Plant-based milks like almond and oat milk tend to have lower levels of saturated fat compared to cow's milk.
- Rich in Vitamins and Minerals: Non-bovine milks are often fortified with essential nutrients such as calcium, vitamin D, and vitamin B12. For example, almond milk is a good source of vitamin E, while soy milk is rich in protein and essential amino acids.

  Fewer Calories: Some non-bovine milks, such as almond and coconut milk, are lower in calories, which can be beneficial for weight management.
- Digestive Health: Plant-based milks like oat milk contain fiber, which is beneficial for digestive health.Lower Allergenicity: Goat milk is less allergenic than cow's milk and can be a better option for people with cow milk protein allergy.

  Heart Health: Plant-based milks often have lower cholesterol levels and may contain healthy fats, such as those found in coconut and almond milk, which can be beneficial for heart health.
- Antioxidants: Almond milk, for example, is rich in antioxidants, which can help protect the body from oxidative stress and inflammation.

  Environmental Impact: Non-bovine milks generally have a lower environmental impact in terms of greenhouse gas emissions, land use, and water use compared to cow's milk.

PLANT-BASED MILK (ALMOND, SOY, AND OAT MILK):

Advantages

Plant-based milk suits lactose-intolerant and dairy-allergic populations. They are comprised of complex carbohydrates, which give sustained energy. Among this milk, soy protein has been shown to lower LDL-cholesterol levels in the bloodstream and can slightly reduce blood pressure. Consumption of soy milk has hypolipidemic effects, which helps lower the concentrations of lipoproteins. These lipoproteins transport cholesterol and triglycerides in the bloodstream. Several research have shown that consumption of this milk aids in fighting chronic disease. Osteoporosis is a condition when bone density and bone mineral density decline. Soymilk

consumption is recommended as it can improve bone density and lower fracture This preprint research paper has not been peer reviewed. This milk is also known to have α-galactosidase, which helps in the digestion of complex sugar and fat. Almond milk's fat content is entirely comprised of unsaturated fatty acids, and it is a good option for those looking to reduce their saturated fat intake. Vitamin E, a powerful antioxidant that protects the cells, is abundantly present in almonds. It incorporates periodic fibers, such as inulin, which effectively promote the growth of advantageous gut bacteria. Due to its lower fat and protein content, it is also a low-calorie alternative to bovine milk. It contains a high concentration of phytochemicals, specifically flavonoids, which studies have indicated can help in lowering the chances of developing heart disease and some forms of cancer. Oat milk is known to have hypercholesterolemia activity, which helps reduce low-density lipoprotein (LDL) cholesterol levels and is associated with a reduced risk of heart disease. Oats contain a high amount of vitamin B1, essential for maintaining energy metabolism. Beta-glucans, a phytochemical found in oat milk, have been studied for their potential health benefits, including reducing cholesterol levels, and improving heart health. This milk has been found to contain periodic fibers such as fructo-oligosaccharides, which have been shown to promote the growth of beneficial gut bacteria and improve digestive health. Oat and almond milk had higher levels of vitamins and minerals, such as vitamin E, magnesium, and potassium, than bovine milk. This suggests that plant-based milk alternatives can provide valuable nutrients that may not be found in dairy milk. Further, plant-based milk alternatives are also more environmentally sustainable than dairy milk. Plant-based milk production requires fewer resources than dairy milk and produces fewer greenhouse gas emissions.

Disadvantages

A non-fortified and non-supplemented plant-based milk alternate consumption has the potential for nutrient deficiencies; these may not provide the same level of calcium, zinc, iodine, vitamins B12, B2, A, D, and indispensable amino acids as bovine milk . Plant-based milk may have various flavours that may not align with the consumer's taste preferences. Although it is controversial that consuming soy foods upset the hormonal balance, some studies have found that soy milk modifies estrogen concentrations in men, while others do not agree. Regular consumption of soy milk is associated with the development of hormone-responsive tissues. Most plant-based drinks have poor emulsion stability, ss Plant-based milk alternatives are a great source of nutrients, especially for those with a dairy allergy or lactose intolerance. Dairy milk is rich in calcium, vitamin D, and protein but may not be suitable for those who want to limit their saturated fat intake or have lactose intolerance. It is crucial for individuals to choose milk or milk substitutes that cater to their specific nutritional preferences and needs.

CONCLUSION

Many of the non-dairy plant-based beverages have significant health-promoting properties. Consumers need to be better informed regarding the nutritional content of non-dairy plant-based beverages as their nutrient profiles can vary greatly between the different types of beverages. Information about the health benefits. The rising popularity of a vegan lifestyle will continue to fuel the consumer demand for non-dairy plant-based beverages of the beverages may also help consumers make healthier choices. Bovine milk, with its inherent nutritional richness and superior functional properties, is a natural source of essential components. However, it is unsuitable for those suffering from milk protein allergy and lactose intolerance. In contrast, plant-based milk are suitable alternatives but require nutrient supplementation, and their sensory attributes may vary among consumers often necessitating flavor modifications. The environmental aspect adds another layer to the decision-making process, with plant-based milks gaining traction for their reduced environmental impact. However, a comprehensive assessment of sustainability is crucial, as existing studies may lack standardized methodologies. Overall, the choice between plant-based and dairy milk is dependent upon individual considerations, including nutritional requirements, taste preference, and environmental consciousness. Individuals are encouraged to select dairy milk or substitutes that align with their specific needs, fostering a more sustainable and health-conscious future.

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