

VEGAN MILK -BURGEONING SECTOR OF FUNCTIONAL BEVERAGES: A COMPREHENSIVE REVIEW

Abstract

The market for plant-based or non-dairy milk substitutes is one of the fastest growing sectors in the functional and specialty beverage area of developing newer food products globally. These days, customers are more inclined to select alternatives to cow milk because of things like lactose intolerance, the incidence of hypercholesterolemia, cow milk allergies, and a preference for vegan diets. Plant-based milk substitutes are becoming more and more popular. They can be an economical option for those in low-income groups in developing countries and in places where there is a shortage of cow's milk. Even though there are a lot of innovative plant-based food and beverage items being utilised to replace cow's milk, a lot of them have technological issues, whether they are connected to processing or storage. While most of these milk replacements don't have the same nutritional balance as cow's milk, they do have elements that are both functional and health-promoting, which makes them appealing to consumers who are health-conscious. One major obstacle to the broad acceptance of legume-based milk substitutes is their sensory appeal. Innovative non-thermal processing methods, such as ultra-high temperature treatment, ultra-high pressure homogenization, and pulsed electric field processing, are being investigated by researchers to address problems with nutritional completeness, shelf life extension, emulsion stability, and sensory acceptability of the final product. In order to provide fresh goods that are both enjoyable and nutrient-appropriate, the functional beverage industry will require concentrated research effort in the coming years.

Keywords: cow's milk, functional beverage, lactose intolerance, plant-based milk, ultra-high temperature

Authors

Susmi Satheesh Kumar

Food Processing Technology and Management,
Hindusthan College of Arts & Science,
Coimbatore.

Dr. B. Premagowri

Assistant Professor,
Clinical Nutrition and Dietetics,
PSG College of Arts & Science,
Coimbatore.

I. INTRODUCTION

Over the past 10 years, research in all fields of food product development has placed a strong emphasis on the development of newer, healthier food options in order to meet shifting consumer preferences. Rising urbanisation has fuelled these desires, and the current trend in functional and specialty beverage research is centred on developing new products. Today's consumers demand their beverages to fit into their lifestyles and provide a particular efficacy; they no longer merely use them to quench their thirst. These drinks might be considered functional since they cater to different needs and lifestyles, give you a burst of energy, fight fatigue, ageing, and stress, and they also target specific diseases. Plus, the market for these drinks is still expanding. These modifications and advancements have resulted in more contemporary goods in the beverage industry.

Milk replacements are one such crucial functional requirement to address problems with cow milk allergy, lactose intolerance, calorie concern, and incidence of hypercholesterolemia (Valencia-Flores et al. 2013). A challenge is the production of plant-based milk that is equally nutritious as cow's milk. According to Romulo (2022), fortification is a production step required to produce plant-based milk with a high level of consumer appeal and sufficient nutritional value.

Ethnic origin affects the prevalence of lactose intolerance. The lowest rates among adults were seen in white people from northern Europe, North America, and Australia; they ranged from 5% in the UK to 17% in Finland and northern France. Lactase non-persistence affects more than 50% of people in South America, Africa, and Asia; in some Asian countries, this percentage is around 100% (Lomer et al. 2008). Plant-based milk has gained popularity because it is suitable for everyone and especially for those who are at risk of heart disease and lactose intolerance due to its lack of lactose and cholesterol.

The market for plant-based milk substitutes is expected to grow at a compound annual growth rate (CAGR) of 15% from 2013 to 2018, with a projected value of \$14 billion, according to Markets & Markets (2013). In western countries, plant-based milk substitutes are commonly utilised as a beverage and as an ingredient in a variety of dishes. This presents a chance to research plant-based substitutes for producing milk-like drinks. Furthermore, plant sources (such grains and legumes) are also regarded as functional foods and nutraceuticals because they contain components that are known to support health, like dietary fibre, minerals, vitamins, and antioxidants (Das et al. 2012). In this sense, plant-based milk substitutes that are healthy, non-dairy, affordable, and high in nutrients have largely relied on a small number of legumes and oilseeds (Sosulski et al. 1978). Table 1 below discusses the useful ingredients and health advantages of several vegan milks.

Table 1: Functional components and health benefits of various vegan milk

Varieties of milk	Active components	Health benefits
Soy milk	Isoflavones	Guards against osteoporosis, cardiovascular disease, and cancer
	Phytosterols	Diminishes cholesterol

Peanut milk	Phenolic compounds	Protective function against oxidative damage and guards against illnesses like stroke, heart disease, and some types of cancer
Rice milk	Phytosterols, sitosterol and oryzanol and β - γ	Cholesterol, hypertension, diabetes, inflammation, and oxidative stress reduction effects
Oat milk	β -Glucan	Changes the viscosity of the solution, prolongs the time it takes for the stomach to empty, and improves the gastrointestinal transit time. These effects are linked to a decrease in blood glucose and a hypocholesterolemic impact that lowers both total and LDL cholesterol.
Sesame milk	lignans like sesamin, sesamolin, sesaminol	Characteristics of nutraceuticals include antiviral, anticarcinogenic, hypocholesterolemic, and antioxidant effects.
Almond milk	Alpha-tocopherol	Strong antioxidant that is essential for preventing the effects of free radicals
	Arabinose	Prebiotic characteristics
Coconut milk	Lauric acid	Strengthens the immune system, fosters brain development, and keeps blood vessels pliable
	Vitamin E	Prevents ageing and replenishes skin

Source: Sethi et al., (2016)

Since soy milk is a healthy alternative to cow's milk, it has drawn a lot of attention in the past. Nonetheless, recent studies have concentrated on examining the potential novel food applications for cereals, oilseeds, and nuts based on their functional qualities, which illustrate the physical attributes of food ingredients and their interactions (Toma and Tabekhia 1979). Customers who are lactose intolerant or allergic to milk proteins prefer all plant-based milks over cow's milk because of their common benefits of being low in calories, cholesterol, and lactose free. To make plant-based milk substitutes, plant material is broken down, resulting in particles that are asymmetrically formed and sized. The size of the particles and the stability of the final product are influenced by the kind of raw material, the disintegration process, and the storage environment (Cruz et al. 2007).

A number of soy milk substitutes have been studied, including peanut milk, rice milk, oat milk, sesame milk, coconut milk, almond milk, hemp milk, hazelnut milk, tiger nut, lupin milk, and quinoa milk (Ukwuru and Ogbodo 2011). Technological obstacles need to be overcome in order to produce a plant-based milk substitute that is comparable to cow's milk in terms of appearance, flavour, taste, stability, and nutritional value. This article aims to give a summary of the technological advancements made to date to improve the quality of plant-based milk substitutes, as well as future research that can be done to produce high-quality plant-based milk substitutes (Penha et al., 2021).

II. PLANT-BASED/NON-DAIRY MILK ALTERNATIVES

The breakdown (size reduction) of plant material (cereals, pseudo-cereals, legumes, oilseeds, and nuts) extracted in water results in fluids that can be used as plant-based milk substitutes. Following homogenization, these fluids yield particles with a size distribution between 5 and 20 m that have an appearance and consistency similar to that of cow's milk. It has been attempted to categorise these plant-based milk substitutes broadly into the following five groups, notwithstanding the lack of an explicit description or classification of them in the literature:

- Cereal-based: rice, corn, oat and spelt milks.
- Legume-based: cowpea, peanut, soy, and lupin milks.
- Nut-based: Walnut, Hazelnut, Pistachio, Coconut, and Almond milks.
- Milks derived from seeds: Flax, Hemp, Sunflower, and Sesame.
- Based on pseudo-cereals: milk made from quinoa, teff, and amaranth.

The nutritive value of various vegan milk was given in below table-2

Table 2: Nutritive value of various vegan milk

Type of milk (per serving of 250 ml)	Calories (g)	Protein (g)	Fat (g)	CHO (g)	Dietary fibres (g)	Calcium (% daily value)	Iron (% daily value)	Vitamin A (% daily value)
Soy milk (Silk)	80	7	4	4	1	30	–	10
Quinoa milk (Ecomil)	104	4.5	6	9	–	–	–	–
Rice milk (Pacific)	130	1	2	27	0	30	6	10
Oat milk (Oatly)	80	2.5	4	16	2	15	0	10
Sesame milk (Ecomil, with agave syrup)	140	1.5	6	16.5	0.5	–	–	–

Almond milk (Silk)	40	1	3	2	1	20	2	10
Coconut milk (Silk)	80	<1	5	7	0	45	4	10
Hemp milk (Living harvest)	70	2	6	1	0	30	6	10
Hazelnut milk (Ecomil)	124	1.4	6	14	–	–	–	–
Multigrain milk (Pacific Organic 7 grain milk)	140	3	2	27	1	35	8	15
Cow's milk (Amul Gold standardize d UHT milk)	168	8	10	11	–	338 mg	1.25 µg	168 µg

Source: nutritional information available on respective product labels

Types of plant-based/non-dairy milk alternatives

- Oat Milk:** Oat milk is a recent addition to the market because of its potential health benefits. Oats have gained a lot of attention because of their high nutritional value, dietary fibre content, and phytochemical availability. Oats have several health benefits, such as their anti-inflammatory and hypocholesterolemic properties. The health benefits of oats are associated with dietary fibres such as -glucan, functional proteins, lipid and carbohydrate components, and phytochemicals contained in oat grains. These attributes make oats a prospective source of raw materials for the production of functional plant-based milk. Oats are a good source of well-balanced amino acid composition and high-quality protein. The first thing that attracted attention to oats was their functionally active component, glucan, which has nutraceutical properties. A soluble fibre known as -glucan has the ability to prolong gastrointestinal transit, postpone stomach emptying, and thicken liquids—all of which are associated with decreased blood sugar levels (Welch 1995). Oat fibres, according to Truswell (2002), have a hypocholesterolemic effect via reducing LDL and total cholesterol. They are also a good source of antioxidants and polyphenols. Oats include 60% carbohydrates, 11–15% total protein, 5-9% lipids, 2.3–8.5% dietary fibre, and 0.54% calcium, according to Rasane et al. (2015). The advantages of oats in gluten-free or celiac diets are widely recognised. To diversify the intake of oats, initiatives have been made to make oat-based beverages or oat milk. (Deswal et al. 2014; Zhang et al. 2007).

- 2. Peanut Milk:** It is believed that oilseeds have a lot of potential as a non-dairy beverage replacement. Like soy milk, peanuts are an oilseed that can be used to make plant-based milk, but their beany taste limits their application. Peanut milk has been widely utilised in developing countries by low-income groups, undernourished children, vegetarians, and people allergic to cow's milk (Diarra et al. 2005). The increased knowledge of plant-based milk's health advantages was the main driver of its increased usage. There are comparable volatile compounds in both peanuts and soybeans (Leu 1974). Peanuts are considered healthy since they include a large number of bioactive components that are known to have the potential to prevent disease.

Peanuts are an excellent source of proteins, fats, fibre, vitamins, minerals, antioxidants, phytosterols, and other nutrients that may support healthy blood lipid and blood sugar levels as well as longevity, according to Wien et al. (2014). Peanuts contain 21.5% carbohydrates, 49.6% lipids, 23.68% proteins, and 8% crude fibre, according to Settaluri et al. (2012). The main factor for peanuts' functional features is their inclusion of phenolic compounds, which are well known for their antioxidant properties and ability to prevent oxidative damage disorders such as heart disease, stroke, and other cancers. Numerous researchers have experimented with various treatment combinations in an attempt to produce peanut milk.

- 3. Soy Milk:** Soy milk was first recorded as being used in China over 2000 years ago. Soy milk was the first plant-based milk to accomplish the goal of feeding people in places where there wasn't enough milk available. Those who were allergic to milk proteins and lactose intolerant also thought highly of it. Soy milk is a great source of essential monounsaturated and polyunsaturated fatty acids, which are believed to be beneficial for cardiovascular health. It provides consumers with an inexpensive, nourishing, and hydrating beverage. Isoflavones, which seem to be soybean's functionally active ingredient, appeared to be the source of its beneficial effects. It is commonly known that isoflavones can prevent osteoporosis, cardiovascular disease, and cancer (Omoni and Aluko 2005). Genistein is the most common isoflavone in soybeans and is also believed to be the most biologically active, according to Cohen et al. (2000).

Soy proteins, in addition to isoflavones, are known to offer therapeutic and prophylactic benefits against a variety of illnesses. Furthermore, research has demonstrated that soy products have a high concentration of phytochemicals known to lower cholesterol, such as phytosterols (Fukui et al. 2002). Liu (2004) states that the usual composition of dried soybean is 40% protein, 20% oil, 35% carbohydrates, and 5% ash. Rahmati et al. (2014) substituted varying volumes of soy milk created with full-fat soy flour for the egg in their mayonnaise recipe, using the soy milk as an emulsifier. During sensory evaluation, no statistically significant difference was observed in the acceptability of samples with up to 50% replacement levels. There is only one disadvantage to drinking soy milk: because soy allergies are so common, it is not recommended for those who are sensitive to soy proteins. The process of making soy milk is depicted in the figure below.

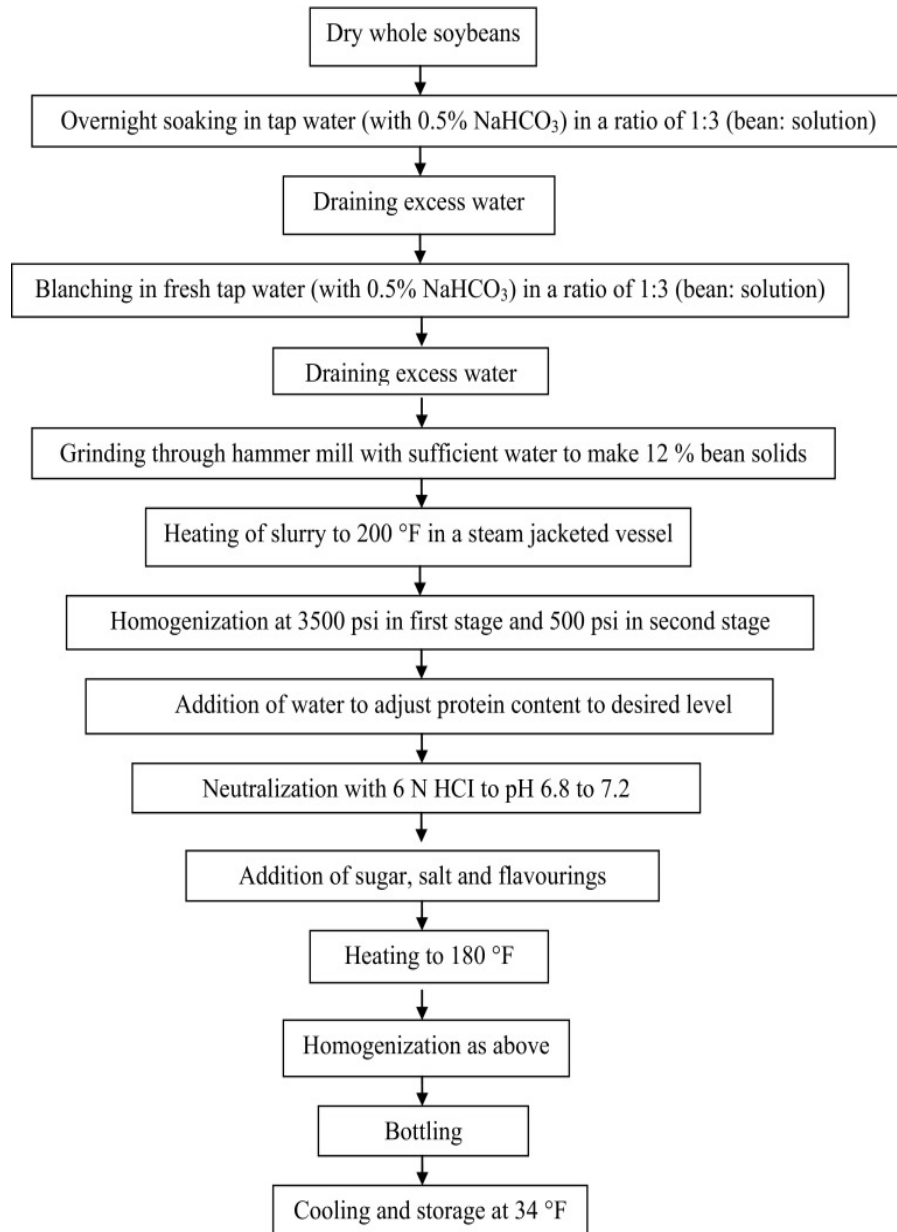


Figure 2: Illinois process for preparation of soy milk (Nelson et al. 1976)

- 4. Almond Milk:** Eating dried fruits and nuts has become an essential part of living a healthy lifestyle because of their possible health advantages. Almonds make up the majority of the nuts that are eaten. Almonds contain 25% protein, mostly in the form of amandin or AMP, according to Sathe et al. (2002). Almonds, a food high in nutrients, are also a fantastic source of manganese and alpha-tocopherol, a form of vitamin E. Compared to other plant-based milks, almond milk naturally has a higher vitamin content. This includes vitamin E, which the body has to get from diet or supplements because it cannot make it on its own. Alpha-tocopherol, a strong antioxidant that is necessary to stop

the production of free radicals, is the functionally active part of vitamin E (Burton and Ingold 1989).

Almonds are a great source of calcium, magnesium, selenium, potassium, zinc, phosphorus, and copper, among other nutrients. Apart from these many benefits, the pectic substances, such as arabinose, that are present in almond cell walls may also work as prebiotics by lowering blood cholesterol levels. It is well known that eating almonds has a variety of pharmacological benefits, such as laxative, antioxidant, cholesterol-lowering, and immunostimulant properties. The effects of high pressure processing (HPP) on almond milk amandin were investigated by Dhakal et al. (2014) at 450 and 600 MPa, 30 °C, and with varying holding durations (0, 30, 60, 180, 300, and 600 s).

- 5. Coconut Milk:** Coconut milk plays a significant role in South East Asian cooking. It is not only consumed as a beverage but also utilised as a component in many sweet and savoury cuisines. Coconut milk is commonly used in curries as a thickening agent to provide body, owing to its high fat content. A product high in nutrients and a good source of fibre is coconut. Coconut milk has an abundance of vitamins and minerals, including iron, calcium, potassium, magnesium, and zinc. Significant quantities of vitamins C and E are also present (Seow and Gwee 1997). Research has demonstrated the anti-viral, anti-microbial, anti-cancer, and anti-bacterial qualities of coconut milk. It contains lauric acid, a saturated fat associated with supporting brain development that is present in mother's milk (Belewu&Belewu 2007). Lauric acid also helps to maintain blood vessel suppleness and strengthen the immune system. Rich in antioxidants that help delay ageing is vitamin E, which can be found in coconut milk. Reactions to allergies are rarely associated with the use of coconut milk. Coconut milk also soothes the skin, helps with digestion, and has cooling properties. Saturated fats limit intake despite all of its health benefits.
- 6. Sesame Milk:** Sesame is one of the world's most important oilseed crops. It is consumed in a wide variety of recipes, including sweet meats and tahini. It is a good source of high-quality protein and has a unique amino acid balance. The beneficial properties of sesamin, sesamol, sesaminol, and other lignans present in significant concentrations in sesame seeds are well-established. Sesame lignans have anti-oxidative, hypocholesterolemic, anti-carcinogenic, anti-tumor, and antiviral properties, claims Namiki (2007). It contains a significant amount of antinutritional substances, including oxalates and phytates (Kapadia et al. 2002). Only the exterior hull contains oxalates, and most of them are removed during decortication. Additionally, decortication contributes to the increase of flavour since the compounds that give sesame seeds their bitterness are only found in their hulls.

The use of sesame proteins in the creation of plant-based milks is limited due to their susceptibility to heat denaturation and salt solubility. Therefore, functional modification of sesame protein is required prior to using it in plant-based milk. Because of this, research has been done on the potential to modify the functional characteristics of sesame proteins using a variety of processing methods, including soaking, roasting, defatting, germination, fermentation, and microwave heating (Quasem et al. 2009). The disadvantages of soy milk, including ingredients that can induce flatulence, a high incidence of soy protein allergies, and a beany or off flavour, can be overcome by consuming sesame milk (Zahra et al. 2014).

Several western countries produce and/or market other plant-based milks, despite the fact that there isn't much research on them in the scientific literature. Quinoa, hemp, cowpea, hazelnut, sunflower, and melon seed milk are a few examples (Bastolu et al. 2016).

III. CONCLUSION

It is essential to develop improved processing, technological interventions, and fortification procedures to produce a beverage that is both nutritionally full and well accepted by consumers. Plant-based alternatives to milk offer the health food industry substantial growth potential. Because of the previously mentioned benefits of plant-based milk substitutes, cutting-edge non-thermal technologies, like pulse electric field technology, can help identify barriers to the well-known processing of these plant-based milk substitutes, facilitating to afford more accessible, nutrientdense, and costeffective options for everyone who is allergic to cow's milk. Modern non - thermal technologies that are perfect for processing cow's milk need to be thoroughly studied for their potential in processing and storing plant-based milk.

Major research areas include maintaining the bioavailability of nutrients during storage and fortifying with an appropriate procedure of fortification using suitable technology to enable the population that is lactose intolerant to use plant-based milk as nutritionally equivalent substitutes for bovine milk. Furthermore, in order to get customer acceptability through technological interventions, plant-based milk substitutes will remain a major area of research in the more recent food product development field of food science and technology.

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Conflict of Interest

All authors has no conflict of interest or any affiliation or involvement in any organization academic, commercial, financial, personal and professionally relevant to the work.

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