6 Plant-Based Milk Substitutes: A Novel Non-dairy Source

Sonika Pandey and Amrita Poonia

Abstract

Plant-based milk substitutes or non-dairy substitutes are among the fastest growing beverage segments worldwide. There are many reasons behind such growth. Lactose intolerance is one of the main reasons. Such milk substitutes are naturally free from lactose and have lower amount of cholesterol and fat than milk from animals. These substitutes are often more easily digested than dairy products and these also favor those people who do not suffer from lactose intolerance. Other than soy, which is the main driver of this growth instead, innovative beverages are made from nuts, grains, and seeds. These substitutes are manufactured by extracting the plant material in water, separating the liquid, and formulating the final product. Homogenization and thermal treatments are necessary to improve the suspension and microbial stabilities of commercial products that can be consumed as such or be further processed into fermented dairy-type products. The nutritional content depends on the plant source and further fortification.

Keywords

Non-dairy substitutes · Lactose intolerance · Homogenization · Thermal treatments · Fortification

6.1 Introduction

India follows a tradition of consuming milk that goes back to 2000 BC. Milk is mainly used in daily cooking and during festivals and is also offered as prasadam to deities in temples. Going dairy free through whole food and plant-based diet, though

S. Pandey (✉) · A. Poonia
Centre of Food Science & Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

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a relatively new concept in India, is steadily increasing in scope in the recent 4–5 years. It is very difficult to remove dairy from the diets of vegetarians, chiefly Indians. Nevertheless, over the years, dairy quality is deteriorating, as well as the overall health of people.

Dairy milk that comes from animals is a very good source of many vitamins and minerals including calcium. It is also sometimes fortified with vitamins A and D. Plant-based milk substitutes are the non-dairy beverages and may or may not be nutritionally equal to dairy milk. But they can be fortified with nutrients to make them nutritionally equal to dairy milk. Still, non-dairy beverages are good for those suffering with milk allergies or lactose intolerance. They are also very easily digested. Plant-based milk substitutes are boon for the countries where the supply of milk is not enough. The most broadly consumed plant-based milk substitute is soy milk. The first commercially booming product was launched in Hong Kong in 1940. The market grew rapidly during the 1970s and early 1980s in Asia after the technology for large-scale production of soy milk was developed (Chen 1989). The two major raw materials used for preparation of milk-like products are groundnut and soybean (Sangita et al. 2016). Overall, the dairy substitute market is still growing.

6.2 Types of Plant-Based Milk Substitutes/Non-dairy Alternatives

6.2.1 Almond Milk

Probably the most widely used milk substitute, almond milk, is a creamy, sweet, healthy, and nutritional powerhouse among foods. It is rich in omega-6 fatty acids. It is made from ground almonds and filtered water. It usually contains sweeteners and other ingredients. The shelf life can also be increased by the added ingredients. It may also be fortified with vitamins and minerals (Fleming 2008). This milk has alpha-tocopherol which is a powerful antioxidant and protects against harmful free radicals (Burton and Ingold 1989).

6.2.2 Soy Milk

Soy milk has the most of protein and in that view is comparable to cow's milk. It is made from ground soybeans and filtered water (Fleming 2008). It may contain sweeteners and flavors. It is very rich and creamy. Soy milk can be taken directly, with cereal or in coffee. The taste is nutty and slightly sweet. For the cooking purpose, soy milk is one of the best milks to choose. Its stability at high temperatures makes it a good choice for savory dishes and sauces. Soy milk because of its high protein content is best choice in baking. Soy milk has goodness of isoflavones and phytosterols which are effective against cancer, cardiovascular disease, and osteoporosis (Omoni and Aluko 2005).

6.2.3 Peanut Milk

It is produced by soaking and grinding full-fat raw peanuts with water to get a slurry subject to filtration. The milk-like product produced is further homogenized and pasteurized in the same manner as fresh milk and also fortified with vitamins and minerals and is at times flavored (Chan and Beuchat 1992). It has been well-known that peanut milk is rich in protein, minerals, and essential fatty acids such as linoleic and oleic acids, which are considered to be highly valuable in human nutrition. It is widely used in India and other emerging countries by vegetarian mass and in recent times by children allergic to cow's milk (Kouane et al. 2005). It is good in phenolic compounds and protective against diseases like coronary heart disease, stroke, and cancers (Wien et al. 2014).

6.2.4 Rice Milk

This is typically made from rice and filtered water. It may have some oil added. It also may be fortified with vitamins and minerals. It may be sweeter than cow's milk (Fleming 2008). It is commonly used milk which is a healthy and nutritious option for those looking for an alternative to dairy products. As compared to products like cashewnut milk and coconut milk that are more expensive, rice milk, made from one of the world's most common and frequently cultivated grains, is typically found at a cheaper price point than other non-dairy milks. It is a healthy blend of carbohydrates and protein, showing a very minimal amount of fat per serving. It is best in taste when mixed with the powerhouses of kale, berries, bananas, flax seeds, and avocados. Rice milk is rich in β-sitosterol and γ-oryzanol that lower cholesterol, hypertension, anti-diabetic, anti-inflammatory, and antioxidative effects (Biswas et al. 2011).

6.2.5 Coconut Milk

It is prepared by steeping of finely grated coconut meat in hot water and then filtering to get milk. It is rich in fat but low in proteins. Coconut milk is best for drinking straight from the glass, added to coffee or smoothies or poured over cereal. It works well in cooking and baking (Fleming 2008). It is found to be rich in lauric acid which stimulates brain development, lifts immune system, and sustains the elasticity of the blood vessels (Seow and Gwee 1997).

6.2.6 Hemp Milk

It is made from soaked hemp seeds and filtered water. It may also contain sweetener according to the requirement, followed by fortification with vitamins and minerals (Fleming 2008). Hemp milk has more protein than other non-dairy milks other than soy milk and is also rich in omega-3 fatty acids. It is thick and creamy. It has a strong taste that may be appropriate for making savory dishes, and its protein content is useful in baking.

6.2.7 Oat Milk

This is formulated with presoaked oat groats that are hulled grains broken into fragments. Oat milk is light with little sweet texture. It is compatible to low-fat or fat-free cow’s milk. It can be taken directly from the glass, over cereal or in smoothies. It can be applied for both sweet and savory dishes. Since it is light in texture, it is good for light cream soups and curries, while its sweet taste makes it work for baked goods. It has goodness of β-glucan that reduces the blood glucose level and hypocholesterolemic effect by lowering total and LDL cholesterol (Deswal et al. 2014).

6.2.8 Cashew Milk

Cashew milk is similar to almond milk in that it does not contain much protein. It is not only made from nuts, but also it is less known than rice, coconut, and oat milks. But due to its high nutritional content, it must be considered important. It is used in baking or making of sweets, directly consumed, or taken with cereal. Cashew milk is nutrient dense as compared to soy and dairy milks with less calories. It promotes cardiovascular health and reduces the deficiencies of trace mineral such as zinc and iron (Manzoor et al. 2017).

6.3 Process

Plant-based milk substitutes are colloidal suspensions or emulsions mainly containing dissolved and disintegrated plant substance. These are prepared firstly by grinding the raw material into slurry and then straining it to eliminate coarse particles. There are many kinds of methods of processing, but the general outline of a modern industrial-scale process is essentially the same. The plant material is both soaked and wet-milled to extract the milk constituents, or alternatively the raw material is dry milled, and the flour is extracted in water. The waste generated by grinding is separated by filtering or decanting. After standardization, the kind of additives and other ingredients, such as stabilizers, coloring agents, and sweetening agents, may be added, followed by homogenization and pasteurization/ultra-high-temperature treatment to improve suspension and microbial stabilities. Spray drying process is also useful for production of powder (Diarra et al. 2005).

6.4 Pre-treatment of Raw Material

Methods involved in pre-treatment include dehulling, soaking, and blanching (Debruyne 2006). To inactivate trypsin inhibitors and lipoxygenase, blanching is done; otherwise that would result in off-flavors in soy milk (Giri and Mangaraj 2012). On roasting of the raw material, it increases the aroma and flavor of the final product, but heating reduces the protein solubility and extraction yield (Rustom et al. 1991; Hinds et al. 1997a).

6.4.1 Extraction

As the temperature of extraction is raised, it increases the extractability of fat, but the denaturation of proteins decreases their solubility and yield (Rustom et al. 1991).

When the hot water extraction of cowpea milk was done, it decreased the yield and protein content as compared to the cold water extraction, but it slightly improves protein digestibility due to trypsin inhibitor inactivation and leads to a decreased extraction of phytic acid (Akinyele 1991). During extraction, alkaline pH increased the protein extractability, but a neutralization step may be required in the process (Rustom et al. 1991; Aidoo et al. 2012).

6.4.2 Separation

Once the extraction step is completed, coarse particles are removed from the slurry by filtration, decanting, or centrifugation (Lindahl et al. 2001; Diarra et al. 2005). Peanuts, as raw materials, has high amount of fat; the excess fat can be removed using a separator as in dairy processing (Diarra et al. 2005).

6.4.3 Formulation of Product

After separation of coarse plant material, other ingredient may also be added like vitamins and minerals for fortification, with sweeteners, flavorings, stabilizers, and emulsifiers. Since the suspension constancy is a problem in plant milk substitutes, hydrocolloids are often used to increase the viscosity of the continuous phase, and also emulsifiers have been proved successful in some beverages. Sodium stearoyl-2-lactylate (SSL), a lipid surfactant, has been found to bind particularly to partially hydrolyzed oat proteins and thus enhance the stability of oat protein suspensions (Chronakis et al. 2004). Rice-based beverage stability was increased by using pine nuts as these beverages contain proteins with good emulsifying properties (Lee and Rhee 2003).

By using a stabilizer mix for dairy products containing mono- and diglycerides, glyceryl monostearate, guar gum, and carrageenan, it gave the most stable peanut milk (Rustom et al. 1991), whereas good results were also found with 0.02–0.04% carrageenan and 0.2–0.4% mono- and diglycerides (Hinds et al. 1997c).

6.4.4 Homogenization

Homogenization decreases the particle size distribution and improves the stability of plant milk substitutes by disturbing aggregates and lipid droplets (Malaki Nik et al. 2008). Due to high quantity of lipids present, an emulsion is formed resulting in a creamier, more homogenous product. Homogenization as in the conventional dairy-processing pressure range (ca. 20 MPa) is reported to increase the suspension stability of at least soy, peanut, and rice milk substitutes (Rustom et al. 1991; Hinds et al. 1997b; Lee and Rhee 2003). Higher homogenization temperature has been reported to increase the stability of peanut milk (Rustom et al. 1991; Hinds et al. 1997a). When ultra-high-pressure homogenization (UHPH) of soy milk at 200–300 MPa was done, it reduced the particle sizes intensely and improved the stability compared with conventionally processed products. The treatment also reduced microbial counts and can be used for preservation (Rustom et al. 1996). A greater homogenization temperature has been reported to increase the stability of peanut milk (Rustom et al. 1991; Hinds et al. 1997a).

6.4.5 Storage and Shelf Life

A peanut beverage was treated for 4 and 20 s at 137 °C. The longer treatment time increased the taste and quality but decreased the suspension stability. Both the treatments increased the microbial shelf life, and no growth of spores and mold was seen (Rustom et al. 1996). The commercial plant-based milk substitutes are pasteurized or UHT treated to improve the shelf life. But the heat changes that occur in protein properties not only influence the stability but change the flavor, aroma, and color (Kwok and Niranjan 1995; Rustom et al. 1996).

To avoid UHT-related changes in flavor, Sikhye, a Korean rice beverage, is commonly sold frozen. However, *Bacillus cereus* spores are a risk, and their number has successfully been reduced by a procedure consisting of heating to 80 °C to activate spore germination, followed by heating to 95 °C known as tyndallization (with CO_2 injection) (Kim et al. 2012).

6.5 Acceptability

Now people around the world are accepting plant-based milk substitutes. The major problems in developing countries are due to the deficiency in protein intake by poor people. The quick solution for this problem is there should be the utilization of vegetable protein with low cost and good quality. Many a time the milk substitutes are blended together to improve taste and nutritional quality of the product. Based on

Table 6.1 Some plant-based milk fermented products

S. No.	Fermented products	Benefits	References
1.	Fermented soy milk beverage	Reduced the amount of flatulence-inducing oligosaccharides depending on the a-galactosidase activity of the strain and increased the angiotensin- converting enzyme (ACE) inhibitory activity	Donkor et al. (2007)
2.	Fermented oat milk beverage	Strains of *Leuconostoc mesenteroides*, *Leuc. dextranicum*, *Pediococcus damnosus*, and *Lactobacillus kefiri* produced the highest levels of lactic acid, resulting in a pleasant flavor	Martensson et al. (2000)
3.	Peanut milk with kefir	High minerals and essential amino acids content	Bensmira and Jiang (2012)
4.	Probiotic milk with added quinoa milk	Improved nutrition	Casarotti et al. (2014)
5.	Lupin milk-based cheese	Enhance taste, texture, flavor, and overall acceptability of both fresh and mature cheese	Elsamani et al. (2014)
6.	Fermented tiger nut milk	Enhanced the growth of the incorporated probiotic bacteria strains	El-Shenawy et al. (2016)

roasted peanut milk, a probiotic fermented beverage was developed. It was a blend of yellow millet and roasted peanuts (Kabeir et al. 2015). Two peanut-based beverages were formulated due to their good source of protein, wide offer, and low cost. The peanut milk was enriched with umbu and guava pulp (de Albuquerque et al. 2015). Flavored lactose-free milk, non-dairy powders, low-calorie cheese, and lactose-free ice cream are some non-dairy milk products (Dekker et al. 2019). Few plant-based milk fermented products are listed in Table 6.1.

6.6 Conclusion and Future Research

Plant-based milk substitutes represent a huge expansion for the healthy food market. In the future, we anticipate many different new product launches in this expanding section of the dairy industry. It needs a proper research through the development of advanced processing, technological interventions, and fortification techniques, for developing a complete nutritional beverage with high overall acceptability. To keep up with the competitive demand of the market, research is a true challenge: further studies on functional properties, stability, and sensory acceptance are needed while keeping up with the cost and environmental impact in mind.

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