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Manasa R

Department of Biochemistry,
 JSS College for Women's,
 Mysuru, Karnataka, India

Harshita M

Department of Food Science and
 Nutrition, Yuvaraja's College an
 Autonomous constituent College
 under University of Mysore,
 Mysuru, Karnataka, India

Prakruthi M

Department of Food Science and
 Nutrition, Yuvaraja's College an
 Autonomous constituent College
 under University of Mysore,
 Mysuru, Karnataka, India

Shekahara Naik R

Department of Food Science and
 Nutrition, Yuvaraja's College an
 Autonomous constituent College
 under University of Mysore,
 Mysuru, Karnataka, India

Mahesh Shivananjappa

Department of Food Science and
 Nutrition, Yuvaraja's College an
 Autonomous constituent College
 under University of Mysore,
 Mysuru, Karnataka, India

Corresponding Author:

Mahesh Shivananjappa

Department of Food Science and
 Nutrition, Yuvaraja's College an
 Autonomous constituent College
 under University of Mysore,
 Mysuru, Karnataka, India

Non-dairy plant based beverages: A comprehensive review

Manasa R, Harshita M, Prakruthi M, Shekahara Naik R and Mahesh Shivananjappa

Abstract

Plant based/Non-Dairy beverages are in demand due to increase in cow's milk allergy, lactose intolerance, calorie concern and hypercholesterolemia. Many consumers demand plant-based milk alternatives for healthier diet, as a lifestyle or for vegan food, and it is inexpensive too, which can be afforded by the poor economic people and can be used in countries and in places, where cow's milk supply is insufficient. In this review, we mainly focus on the different varieties of Plant-based/non-dairy beverages available in the market, their nutritional composition and their health benefits as compared to cow's milk. Even though it contains added sugar, protein content, unsaturated fatty acids, antioxidant activity and bioactive compounds like phytosterols and isoflavones make plant-based substitutes as an excellent choice. In the recent years, these beverages have become a multi-billion-dollar business in the global market and it may reach a value of approximately 26 billion USD in next 5 years. But the problem is with the acceptability and the nutritional value of these plant-based beverages compared to cow's milk. Several researches are undergoing to overcome these problems and make plant based beverages more tasty filled with more bioactive compounds.

Keywords: Plant based beverages, Non-Dairy beverages, lactose intolerance (LI), cow's milk allergy (CMA), vegan milk

1. Introduction

The demand for Plant-based beverages is increasing in the recent years because of lactose intolerance (LI) and cow's milk allergy (CMA) ^[1, 2], calorie concern and prevalence of hypercholesterolemia ^[3], concerns about *phenylketonuria*, cholesterol, growth hormone or antibiotic residues in cow's milk ^[4-6], ethical disputes regarding the use of animals ^[7], environmental issues ^[8-10], changes in lifestyle towards vegetarian and vegan food, presumably healthier diet ^[11] and the marketed health-promoting properties of these products ^[12]. From the ecological perspective, plant-based sources are preferred as the dairy industry is responsible large share of greenhouse gas emission ^[13] and promoting awareness towards sustainable food systems due to climate change and global warming. On the other hand, bovine milk contains high saturated fat and high intake of this cause's cardiovascular diseases (CVD). Cow's milk restricts its recommendation as a complete food for infants older than a year due to the limited availability of iron, folate and some amino acids. Daily intake of cow's milk (2 glasses / day) results in an intake of D-galactose > 100 mg/kg which could cause *Parkinson's disease* ^[14].



Fig 1: Different Plant-based milks

Plant-based beverages does not contain lactose or cholesterol compared to cow's milk, this led to the increase in demand.

Plant-based beverages are usually fortified with calcium and vitamins. The main plant-based beverages used are soy milk, oat milk, almond milk, peanut milk, coconut milk, sesame milk, hemp milk, rice milk, lupin milk, hazelnut milk, tiger nut, quinoa milk [15-22]. In the recent year's cereals, oilseeds and legume-based plant sources are used as functional foods and nutraceuticals due to the presence of minerals, dietary fibers, antioxidants and vitamins [22-26]. Plant-based foods such as soybeans and nuts reduce the risk of neurodegenerative disorders such as *Alzheimer's disease* [27]. They are also rich in fatty acids and antioxidant activity which reduce the risk of cardiovascular diseases, cancer, atherosclerosis, and diabetes [28]. The plant-based beverages market was valued at USD 11.16 billion 2017 and projected to reach USD 19.67 billion by 2023, growing at a CAGR (Compound Annual Growth Rate) of 12 % during the forecast period 2018-2023 [29] (Figure 1). The veganism trend has jumped 360 % in ten years, and it is estimated that there are now 500,000 vegans in the UK [30]. However, plant-based milk substitute products also have various negative health effects including lack of protein content, low bioavailability of minerals and vitamins, because of some anti-nutrients and polyphenols; can be overcome by fermentation [31-33]. But there is still a need to improve the stability, texture, nutritional aspects and sensory problems.

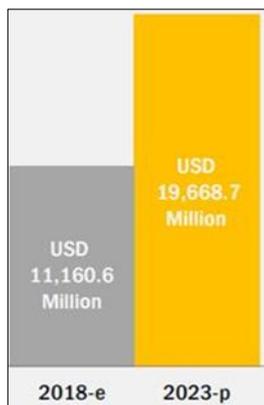


Fig 2: Estimated CAGR of plant-based beverages [29]

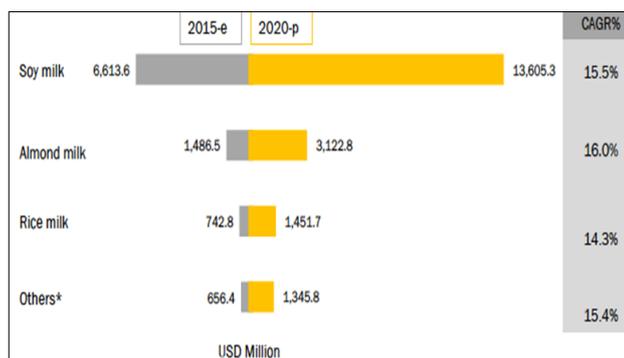


Fig 3: Plant-based beverages global projection [34]

2. Need for non-dairy beverages

2.1 Prevalence of lactose intolerance

Lactose intolerance (LI) is the decreased ability to digest the lactose (sugar found in dairy products) [35]. Lactose intolerance is due to the lack of the enzyme “lactase” which breaks down lactose into glucose and galactose. The main symptoms are abdominal pain, bloating, diarrhoea and nausea [36-37]. About 33% of the global population is affected by lactose intolerance with highest percentage in Africa, South

and East Asia. In India, 60-70% are lactose intolerant [38]. LI can also be caused by untreated celiac disease, gastroenteritis and cystic fibrosis [36, 39]. People with inflammatory bowel disease (10-20%) are sensitive for dairy products and are advised to avoid dairy products [40].

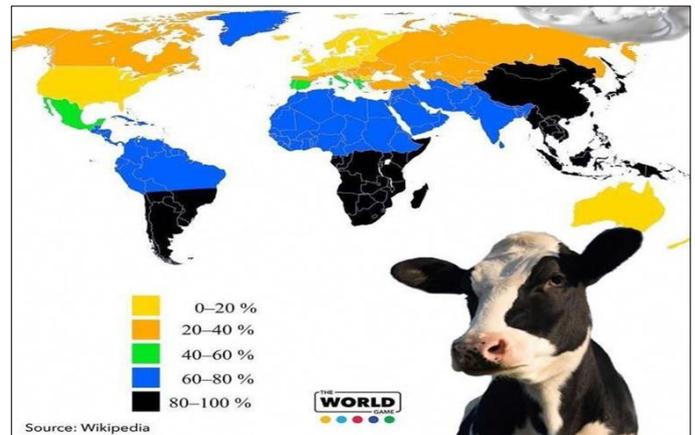


Fig 4: Worldwide Lactose Intolerance (Wikipedia)

2.2 Cow's Milk allergy (CMA)

Milk allergy is a type of food allergy, an adverse immune reaction to one or more of the constituents of milk, especially protein. This milk-induced allergic reaction can involve anaphylaxis, a potentially life-threatening condition. Approximately 2.5 % of children younger than three years of age and 0.3 % of adults are allergic to milk [41]. Nearly all infants who develop an allergy to milk do so in their first year of life. The allergic symptoms are asthma, cough, rhinitis and gastrointestinal problems. This CMA will be normalized in the first year of life, but 15% of children remain allergic [42]. The major whey proteins are α -lactalbumin and β -lactoglobulin which are responsible for the milk allergy [43]. The complete avoidance of milk and milk products is the only treatment to avoid milk protein allergy [42].

3. Plant-based / non-dairy milk alternatives:

Plant-based milk beverages are prepared by extracting them by water. In literature there is no any stated definition or any particular classification available [44]. Generally, it may be classified as follows:

- (a) **Cereal based:** Oat milk, Rice milk [45], Barley milk, Corn milk.
- (b) **Legume based:** Soy milk [46], Peanut milk, Lupin milk [47], Cowpea milk [48].
- (c) **Nut based:** Almond milk [49], Coconut milk [50], Cashew milk, Tiger nuts, Hazelnut milk, Pistachio milk, Walnut milk.
- (d) **Seed based:** Sesame milk [51], Flax milk, Hemp milk [52], Sunflower milk [53].
- (e) **Pseudo-cereal based:** Buckwheat, Quinoa milk [54], Teff milk, Amaranth milk.
- (f) **Fruits and vegetable juices:** Cranberry, Pineapple, Mango juice etc.

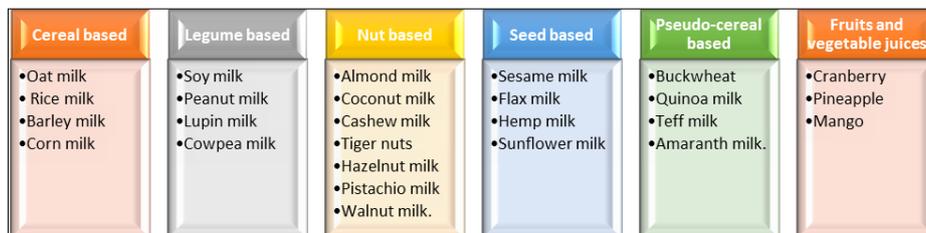


Fig 5: Types of Plant-Based Beverages

3.1 Overview of the process of plant based beverages

Plant-based milks are prepared by different process depending on the manufacturers. Some common steps used in the wet processing methods are as follows (Figure 4). Soaking is done to soften the plant tissues and disrupt it by grinding the plant tissues. Then separate the large insoluble particles by filtration or centrifugation. Next step is to hydrolyse the starch, fiber and other materials by enzymatic or chemical hydrolysis. Blanching is done to inactivate the endogenous enzymes present in it by heating. Then thermal processing is done to inactivate the spoilage and pathogenic bacteria. Homogenization is done mechanically breakdown particulate insoluble matter. Last step is formulation to add functional ingredients, flavours, thickeners, colours, preservatives, stabilizers, proteins, vitamins, minerals and lipids [55].

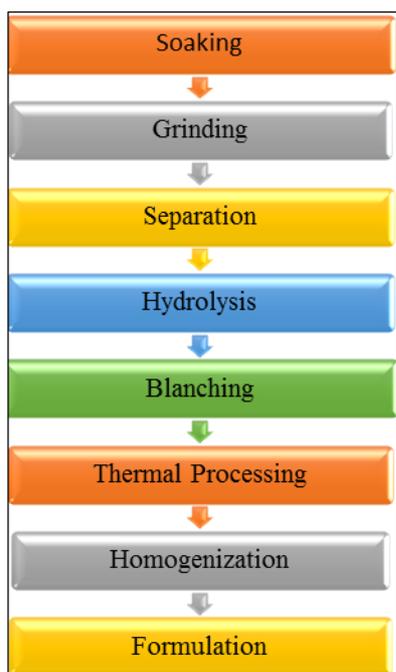


Fig 6: Overview of the preparation of plant-based milks. Adopted from McHugh (2018)

3.2 Cereal based: Cereals are one of the staple foods consumed throughout the world [25]. They are the important source of macro and micronutrients, bioactives, photochemicals and antioxidants [56]. It also contains fiber which has prebiotic effects [57]. Commonly used cereals based milks are oat, rice, barley and corn.

3.2.a Oat Milk

Oats is gaining prominence in the recent times. Various processed forms of oats are available which reduce cooking time and easy to consume. There are different types of oats depending on the thickness of the flakes like rolled oats, quick oats and instant oats [58]. Oat milk is prepared using the oat

groats, water and addition of some grains like barley, soybean, triticale, etc. [20, 59]. Oats mainly contain sugars (60-70%), protein (15-17%), dietary fiber (~12%), fat (~5%), β -glucan (2-6%) [60]. Oats also contains phytic acid (an antinutrient) (Frolic and Nyman 1988; Lolas *et al.*, 1976), phytochemicals, polyphenols (avenanthramides) [61] and a good amino acid balance. The intake of oats helps to reduce the cholesterol levels and blood glucose levels [44, 62-64]. The cholesterol lowering property is due to the presence of β -glucan (soluble fiber) [65-70]. The study reported that the intake of oat milk for 5 weeks reduces LDL cholesterol and serum cholesterol in men with moderate hypercholesterolemia [71]. Another study reported that compared to control, 5 g of β -glucans from oats significantly lowered total-cholesterol by 7.4% and postprandial concentrations of glucose and insulin [68]. The main drawback of oat milk is that it lacks calcium, which is essential for the growth and development; therefore it is to be fortified with calcium during processing. Oat milk is available under various brand names such as Alpro (UK), Pacific (USA), Oatly (Sweden) etc. It is also available in tetra packs which is UHT (Ultra High Temperature) treated.

3.2.b Rice Milk

Rice is the consumed by nearly one-half of the world population as it is less allergenic food compared to others. Rice is available in different varieties based on their physical and biochemical properties [72]. Rice mainly contains starch (90%) but less protein content (10%) which lacks threonine and lysine [73]. The most notable is the pigmented rice (red, black, brown, dark purple), the colour is imparted by the Anthocyanins. Red rice contains proanthocyanidins, whereas black rice contains both anthocyanidins and proanthocyanidins [74]. Red rice is known to have a pleasant nutty flavor [75]. Rice milk can be an alternative to people allergic to soybean and almonds [76-77]. This coloured rice has antioxidant and anti-carcinogenic activities which may help in preventing diabetes, cardiovascular diseases and cancer. Rice is widely accepted because it has no cholesterol, phytoestrogens and lactose [78]. It contains sterols, essential oils, amino acids, flavones, phenolic, tannin and tocopherols [79]. Brown rice contains tocotrienol, starch, oryzanol and GABA (Gama Amino Butyric Acid). As it is too hard, brown rice cannot be consumed as such. To overcome this, beverages made from "Rice slurry" is used instead of rice flour, it is named as "Rice Milk". Wet stone milling is used to prepare rice slurry using brown rice. But rice milk lacks minerals and vitamins like calcium and B-12 [80-81].

3.2.c Barley Milk

Barley is an ancient crop in Middle East, Europe, northern Africa and Asia. Barley was primarily used as animal fodder and for malting purposes [82]. Barley mainly contains beta glucan (which has nutraceutical properties) and phenolic compounds which are effective against diabetes and

cardiovascular diseases [83-84]. Barley has lost its prominence during 19th and 20th century due to the introduction of other crops like wheat and rice. However, because of the health benefits of barley, especially the beta glucan, food processing techniques have been improving to incorporate barley in various foods [85]. In western countries pearled / flaked / ground barley is used in soups, stews, and whole, pearled or ground barley is used in breakfast cereals. In North African countries ground pearled barley is used in the preparation of soups, porridge and flat bread [86].

3.2.d Corn milk

Maize is also known as Indian corn, sweet corn, sugar corn, pole corn or even just corn. Maize is one of the major food crops in India. Corn grains are rich in carbohydrates (starch) and sugar (sucrose) [87]. It also contains pentosan, and fiber but low protein with poor amino acid profile. Therefore, it should be supplemented with high grade protein like soybean. *Soy-corn milk* is highly preferable than the soy milk alone [88] in the ratio of 3:1 (soy milk: corn milk). The corn milk contains saturated fatty acids (palmitate and stearate) and unsaturated fatty acids (oleate and linoleate) which impart aroma and sweet taste to it. Corn milk attracts the health-conscious consumers as it has low cholesterol and saturated fat compared to the cow's milk [89]. Corn grains can be processed into corn milk, corn milk powder, corn-yoghurt, corn flakes, etc. The combination of 80 % sugar and 0.3 % CMC (Carboxy Methyl Cellulose) is the best accepted formulation of sweetened condensed corn milk.

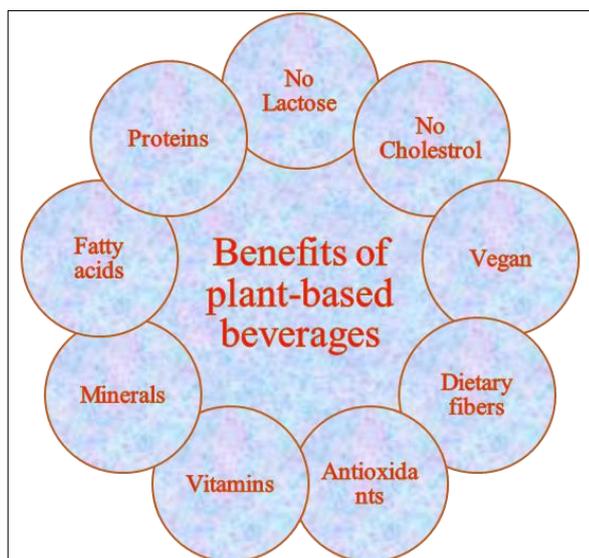


Fig 7: Benefits of plant-based beverages

3.3 Legume based

Legumes are highly nutritious and economical too. After cereals, legumes are a source of energy and protein in human diet. Legumes are rich in carbohydrates, vitamins, protein, minerals phytochemicals and fiber which protects against cancer and CVD. Minimum water is sufficient for legume cultivation than the cereals and used in crop rotation with cereals to control diseases and pests. Soybean, peanut, lupin and cowpea are the legume-based beverages used.

3.3.a Soy Milk

Soy milk is the most widely accepted non-dairy beverage alternative for the cow's milk. Soy milk contains fiber,

omega-3 fatty acids, magnesium, manganese and same amount of protein as that in a cup of cow' milk. It also contains, Trans fat, MUFA and PUFA. Dry soybeans contain protein (40%), carbohydrate (35%), oil (20%) and ash (5%) [90-91]. The isoflavones present in it is effective against cardiovascular disease, cancer osteoporosis and phytosterol has cholesterol-lowering properties [92]. The most abundant isoflavone is Genistein which is biologically more active and exhibit anti-cancer properties [93-94]. The high acceptancy of soybean milk is due to the absence of cholesterol and lactose as that of cow's milk, and because of high protein content, high nutritive value and is easily digestible. In addition to this it also contains phytic acid (anti-nutrient), which binds with some minerals and makes them unavailable for absorption. Above all it is fortified with vitamin D, A, B12 and also calcium during processing. But the major drawback of soy milk is its beany flavour and soy protein allergy which may cause flatulence [44, 95]. FDA approved health claim of soybean for lowering the risk of coronary heart disease in 1999, after which 2700 new products were introduced in the market [96]. Commercially it is available under the brand name Vitasoy (Hong Kong), Silk (USA), Alpro (UK), Tesco (UK) etc.

3.3.b Peanut milk

Peanuts are widely used by the low-income people in the developing countries as it is available at low cost. It is mainly used by the undernourished children, vegetarians and people allergic to cow's milk [55]. Peanut milk is prepared using yellow peas which are milled into flour and the protein content is separated from starch and fiber. Then the protein is purified and fortified with other ingredients like addition of calcium (150% more than cow's milk). Peanut mainly contains fats (49.6%), carbohydrates (21.5%), protein (23.8%), and fiber (8%) [97]. In addition, peanuts also contain phytosterols, minerals, vitamins, antioxidants, etc which helps to maintain blood sugar level, blood lipid level and provides protection against stroke, CVD and various cancers [98]. Peanuts contain many volatile compounds which are similar to soybeans [99]. Peanut milk and butter are rich in protein, minerals and fatty acids like linoleic and oleic acids [100]. Peanuts are rich in campesterol (198.3 mg/g) and stigma sterol (163.3 mg/g). Peanuts contain almost all 20 amino acids with rich in arginine [101]. But the drawback is its beany flavour to overcome this, many flavouring agents are added. Peanut allergy also sets back its use. It contains 8 peanut allergens namely *Arachis hypogaea* (Ara) h 1 to h 8 [102], among which h2 and h6 are the potent allergens [103]. Peanut also contain phytic acid (anti-nutrient) and insoluble fiber [104]. To improve the stability of the emulsion, gelatin, or alginates (1% by weight) may be added. Peanuts are available under the brand name Signs and wonder (USA), Sweety, etc. [44].

3.3.c Lupin milk

Lupin is widely cultivated in temperate climate zones like Russia, Poland, Australia, Chile etc. Lupin is cost-effective compared to soybeans, which helps the poor economic people. Australia is the leading producer of lupin with annual production of one million metric tonnes. Australian sweet lupin (ASL) is the most popular lupin produced in Western Australia which are of the other two types (white lupin and yellow lupin). This Australian lupin has high protein content (29-44%), dietary fiber (30%) and fat (6%). ASL contains low glycemic index, so it can be used in fermented food products (Tempe, Meso), bakery products, pasta, noodles etc. Lupin milk is prepared by fortifying with methionine (0.1%) to

increase the nutritional value ^[21] and it is spray-dried at 170 °C to improve the storage life. Lupin is rich in protein (35-40% w/w), oil (11% w/w), unsaturated fatty acids (78% w/w), soluble fiber but no starch ^[105]. Lupin is widely used as animal feed, however, due to its nutritional benefits it is gaining importance as a beverage and it will be a major plant-based beverage in the future. In Europe in the recent year's lupin is being used as an ingredient in human foods ^[106].

3.3.d Cowpea milk

The largest producer of cowpea in the world is the Nigeria, with 2.1 million tonnes. India leads its production in Asia. Seeds are a major source of dietary protein in most developing countries ^[107]. It contains carbohydrate (50–65%), protein (20-30%) and fat (2.71-2.96%) ^[108]. It is a good source of lysine and tryptophan but deficient in cysteine and methionine. It also provides adequate amount of mineral and vitamin ^[109]. Due to the presence of low fat it can prevent CVD by lowering the LDL levels ^[110]. The cowpea seeds contain lignan, which helps to prevent osteoporosis and certain cancers. Furthermore, Consumption of cowpea seed was found to reduce the risk of hypertension because of the presence of β -sitosterol ^[111].

3.4 Nut based

The consumption of dried fruits and nuts has become an essential part of healthy living owing to their potential health benefits. Nuts are rich in dietary fiber, vitamins and phytochemicals and low caloric content due to which it is widely consumed in recent years ^[44,46,92]. Commonly used nuts are almonds, coconut, cashew, hazelnut, pistachio, walnut etc.

3.4.a Almond milk

Almonds contribute to the largest share in total nuts consumption. In the recent years almonds are the most popular plant-based alternative to milk in North America and Australian beverage markets ^[112]. Almonds are rich source of vitamin E (alpha-tocopherol), which is a powerful antioxidant which protects against free radical reactions ^[113] and high protein content (25%) majorly in the form of amandin ^[114]. Almonds also contain nutrients like manganese, magnesium, phosphorus calcium, potassium, selenium, zinc and copper ^[115-116]. It is also rich in MUFA which helps to lower the LDL levels ^[117]. Apart from these almonds contain arabinose (cell wall pectic substance) which reduces the serum cholesterol level. But during processing the protein content is strained out along with the pulp, which reduces the protein content to only 1 g per 8 oz. cup but in cow's milk it is 8 g. The other limitation is its tree nut allergy and high cost limits its use as a beverage ^[92]. Almond milk is commercially available under brand names Alpro (UK), Pacific (USA), Silk (USA), Pure harvest (Australia), Hiland (USA), Almond breeze (USA) etc.

3.4.b Coconut milk

Coconut milk plays an important role in the south East Asian cuisine ^[118]. It is not only consumed as a beverage but used as an ingredient in number of sweet and savoury recipes. Coconut milk is rich in fat content which is used as a thickening agent in the curries ^[44]. It is also a good source of fiber, vitamins and minerals such as iron, calcium, potassium, magnesium and zinc. It is rich in antioxidants such as vitamin E which helps fighting against ageing. It is also rich in vitamin C and E ^[119]. The use of coconut milk is associated with health benefits such as anti-carcinogenic, anti-microbial, anti-bacterial, and anti-viral. The coconut milk contains Lauric acid (as that present in mother's milk) which promotes the development of the brain, ^[120], boosts the immune system and also maintains the elasticity of the blood vessels. The

consumption of coconut milk increases the HDL levels, which in turn helps to reduce the harmful LDL levels ^[121]. The various components present in it also affects the growth cells ^[122-123]. Coconut milk consumption is rarely associated with allergenic reactions. Other benefits of coconut milk includes: helps in digestion, nourishes skin and has cooling properties. The main drawback of coconut milk is the presence of the saturated fat, which limits its consumption and the nutritional value is reduced if the storage time is exceeded ^[124]. It is available under brand names, Blue almond (USA), Alpro (UK), Silk (USA) etc.

3.4.c Cashew Milk

Cashews are preferred for their taste and rich creamy texture with no saturated fat or cholesterol (only 60 calories per cup). They are rich in protein content (23%), lipids (44%), MUFA and PUFA ^[125-126]. Cashew milk is prepared by water-soaked cashews which is blend with water. Like almond milk, cashew milk also losses its vitamins, minerals and protein content during straining which can be regained through fortification ^[127]. Fortified cashew milk are 50% rich in calcium than cow's milk and also rich in vitamin D and E. It may boost immunity and improve heart, eye, and skin health ^[92].

3.4.d Tiger nut

Tiger nuts is an edible perennial grass like plant that belongs to the old world, it is also known as earth almond, 'chufa' (in Spanish), earth nut, yellow nut, sedge, groundnut, rush nut, edible galingale and nut grass ^[128-130]. The tiger nut plant produces sweet, nutlike tubers which are energy dense ^[131]. Tiger nuts are rich in sugar, protein, fatty oil, fiber and in minerals such as sodium, calcium, potassium, phosphorus, magnesium, zinc, traces of copper, vitamins E and C ^[130-133]. Their fatty acid profile is similar to olive and hazel nuts ^[131,134-135]. Tiger nuts have anti-inflammatory properties ^[133]. It is an underutilized tuber in many parts of the world but is used to prepare a cold beverage called Horchata in Spain ^[132]. Tiger nuts are suitable for people with diabetes, digestive disorders and cardiovascular diseases ^[131]. Tiger nuts are a popular snack in Ghana. They are either eaten raw, roasted or the milk from the nuts is boiled into porridge. They can also be ground to make beverages ^[136]. They can be processed into flour for baking ^[135]. Tiger nut milk is the aqueous extract obtained from the tiger nut tubers ^[137]. Tiger nut milk is made up of 0.91% protein, 0.25% ash, 3.09% fat and 1.03% dietary fibre ^[120]. It is available under the brand name, Chufi (Spain), Isola Bio (UK), Amandin (Canada).

3.4.e Hazelnut milk

Hazelnut has a unique flavour and highly nutritious ^[138]. It is consumed all over the world as bakery, dairy and chocolate products. Hazelnut milk is produced by hazelnut cake which is cold pressed and homogenized at 150 MPa pressure. Different 17 hazelnut varieties are compared with other nuts and showed that it progressively enhances the human health ^[139]. It is noted that if the hazelnut is consumed 5 times a week, it reduces the 50% risk for CVD ^[140]. Hazelnuts are rich source of minerals like manganese and copper and vitamin E (antioxidant) ^[141] and high content of omega-6, omega-9 fatty acids. The vitamin E helps to increase the antioxidant activity. They are known to reduce the blood sugar level, blood lipid level and high blood pressure. Hazelnut milk is usually fermented with kefir grains. However, the potential benefits of hazelnuts are to studied and proved yet. The drawback is, it

may be allergic to some people. Above all hazelnuts are an excellent source of nutrients and can be used in our diet.

3.4.f Pistachio milk

Pistachios are the most nutritious nuts in the world. It contains many nutrients like vitamin E, B6, and K, copper, phosphorous, omega-3 fatty acid, magnesium, calcium, lutein, phytosterol, dietary fiber^[142-146]. It is also rich in protein, fat, carbohydrates, water, and minerals as that of almonds, peanuts and sesame seeds^[147-150]. It is a good alternative for the people with lactose intolerance and milk protein allergy. It also has some health benefits like it reduces the serum lipid levels and bad cholesterol, CVD, diabetes and gall stone^[142,146, 151-153]. Pistachio milk is prepared by soaking the pistachios, milling, centrifugation, homogenisation, clarification and pasteurisation process. The most accepted formulation is the combination of 5% sugar, 0.02% vanilla, 0.0% salt.

3.4.g Walnut milk

Walnut is one of the most widely cultivated nuts in the world. It is well known for its nutritional, health and sensory attributes. It is consumed as whole nuts or used in many confectioneries. Researchers are trying to ferment walnut with LAB (Lactic Acid Bacteria) to produce walnut-milk based beverages^[154]. Usually Kefir grains are used to ferment walnut-milk^[155-158]. Walnut is mainly used with soybeans to produce **soy-walnut milk**, which is very popular than the soy milk alone. Soy and walnut milk can be blend in various proportions (10:90, 30:70, 50:50)^[159]. But the soy-walnut milk produced from 10% un-malted and 30% malted soymilk was most preferred by the consumers. Soy-walnut milk can solve the problem of protein malnutrition and micronutrient deficiency.

Table 1: Brand names of commercially available plant milks

Plant milk	Brand name	Country
Oat Milk	Alpro	UK
	Pacific	USA
	Oatly	Sweden
	Pureharvest	Australia
	Bioavena drink	Italy
	Simpli	Finland
Soy milk	Vitasoy	Hong Kong
	Silk	USA
	Alpro	UK
	Tesco	UK
Peanut milk	Signs and wonder	USA
	Sweety	
Almond milk	Alpro	UK
	Pacific	USA
	Silk	USA
	Pure harvest	Australia
	Hiland	USA
	Almond breeze	USA
Coconut milk	365	USA
	Blue almond	USA
	Alpro	UK
	Silk	USA
Tiger nut	Pacific	USA
	Chufi	Spain
	Isola Bio	UK
Sesame milk	Amandin	Canada
	Vegemil	South Korea
	Ecomil	Ecomil

3.5 Seed based

Seed-based milks are gaining importance in recent years due to their nutrient composition and health benefits. Commonly used seeds are sesame, flax, hemp and sunflower.

3.5.a Sesame milk

Sesame is one of the important seed-based beverages used in the world. It is considered to be present since 1600 B.C.^[160]. Popular as 'queen of oilseed' is also known with certain other names in different parts of world such as gingelly (India), benni seed (Africa), benne (Southern United States), gengelin (Brazil), and tila (Sanskrit). Sesame plant is majorly produced for its invaluable oil as it procures number of health and therapeutic properties^[161]. The presence of natural antioxidants and certain bioactive compounds like sesamin, sesamol, and tocopherols homologues makes it highly resistant to oxidation and rancidity, thus elevating keeping quality of the oil^[160]. It is also been evidenced to procure anti-oxidative, anti-cancer, anti-hypersensitive, anti-immunoregulatory actions. Beside this it also acts to escalate taste and flavor of various food products^[161]. On examining the chemical composition of the plant, it is observed to have oil content ranging from 50-60% followed by 18- 25% protein, 13-14% carbohydrate and 5% of the ash content. This composition itself confirms that it is rich source of oils and fats. Not only rich in major nutrients it is also significant in trace materials like phosphorus, iron, magnesium, calcium, manganese, copper and zinc^[160]. Sesame milk consumption can overcome the allergies and beany flavour of soybeans^[162]. It also contains oxalates and phytates (anti-nutritional factors)^[18]. But the oxalates are removed during decortication as it is present in the outer hull. As sesame proteins are salt soluble, they are susceptible to heat denaturation, which limits its use in the preparation of plant-based milk. Therefore, sesame protein must be modified before its use^[163]. Sesame milk is sold under the brand name Vegemil (South Korea), Ecomil (Spain) etc.

3.5.b Flax milk

Flaxseed, popular as Linseed is also named as Alsi, Jawas, Aksebija, in several parts of India belongs to the family of Linaceae. The blue flowering Rabi crop is believed to be native of Eastern Mediterranean, extending itself to Western Asia, and the Middle East to India^[164]. Flaxseed is majorly used for industrial purpose for extraction of its edible oil that is being utilized in production of natural health products^[165]. Traditionally, flaxseed is being reported to be used in paints and coatings, printing inks, soaps, core oils, etc but the presence of significant bioactive compound like linolenic acid, linoleic acid, and lignans make it useful for medicinal and therapeutic purpose^[165]. In recent researches it is being proved to procure anti-tumoral and anti-inflammatory properties and also effective in treatment of cardiovascular diseases, various cancers and diabetes^[166]. On examining the chemical composition of flaxseed, it was observed to be very rich source of fat accounting up to 41% followed by total dietary fiber content constituting about 28%, with 20% protein content and 3.4% of the ash constituents. Utilization of the flaxseed is new to food prospect because of increasing awareness among consumer towards functional food. Because of presence of effective bioactive component, it is now being used for the preparation of certain salad dressings, food additive, and substitute for milk^[166]. Flax milk is low in proteins and calories (25 kcal/cup unsweetened) compared to

that of almonds. It also contains omega-3 fatty acids (1200 mg) and phytoestrogens. Flax milk is prepared by cold-pressed flax oil with water, emulsifiers and thickeners. The pros and cons of this flax milk are yet to be proved. It is being researched extensively.

3.5.c Hemp milk

Hemp milk is highly suitable for the people with gluten allergy, or who are on starch-limited diet or must avoid oligosaccharides. Hulled seeds of hemp plant are used to prepare the hemp milk, which has an earthy taste that may be masked by the addition of vanilla and sweeteners. Other products like flour, oil and protein powders are prepared from hemp seeds [167]. Hemp seeds are richest source of PUFA such as α -linolenic acid and linoleic acid. Cannabidiolic acid (CBDA) is the most predominant bioactive constituent present in it [168]. It contains all essential amino acids, lipids (25-30%), proteins (20-25%), fibers (10-15%), carbohydrates (20-30%), vitamin E (90 mg-100 gm), minerals and fatty acids like omega-6 and omega-3 fatty acids (3:1 ratio) [169]. Hemp milk is highly unstable; hence emulsifiers or stabilizers are added to overcome this.

3.5.d Sunflower milk

Sunflower seed milk is more sustainable compared to almonds and cashews as it requires less amount of water to produce. Sunflower seeds are rich in magnesium, selenium and vitamin E. But the limitation is its earthy taste, to overcome this it is fortified with some sweeteners and vanilla extract. Sunflower seed milk is prepared by lactic acid fermentation [170]. It is superior in taste and stability. It is rich in linolic acid and α -tocopherol.

3.6 Pseudo-cereal based:

Pseudo-cereals are rich in high-quality protein, minerals, carbohydrates and fiber than the cereals Quinoa and amaranth have good health benefits but rarely used [171]. As they do not contain gluten as most other cereals, they are used to prepare gluten-free products [172]. Quinoa is the only pseudo-cereal which contains all the essential amino acids [173].

3.6.a Buckwheat:

It was originated from central and European countries; due to its high nutritive value it is now gaining prominence in other countries also [174]. Common (*Fagopyrum esculentum* Moench) and tartary (*Fagopyrum tataricum* Gaertn) buckwheat are mostly used as a source for bioactive compounds [175-176]. Buckwheat is very rich in starch (59-70%) in which amylose and amylopectin are found in equal amounts, lipids (1.5-4%), dietary fiber (7%) of the dry mass [177]. Salt-soluble globulins are the main proteins present in the buckwheat seed. These proteins have same content of all amino acids as that present in wheat. Important amino acids present are glutamic acid, aspartic acid, arginine and lysine (2.5 times higher than wheat flour). The fatty acids present are linoleic acid, oleic acid and palmitic acid accounts for 88% of total fatty acids [178]. Buckwheat is rich in all the important minerals than many cereals except for the calcium [179]. It has high concentration of tannins and flavonoids (rutin). Rutin is a flavanol glycoside which acts as an antioxidative, anti-inflammatory and anti-carcinogenic agent and can reduce the hypertension also helps in haemorrhagic disease by reducing the fragility of blood vessels. [180-181]. It also contains orientin, vitexin, quercetin, isovitexin and isoorientin [181]. Unhulled

buckwheat is used than the hulled as it is more advantageous. Absence of gluten (gliadin and glutenin) in buckwheat is the reason for its use in gluten-free products [182-183].

3.6.b Quinoa milk

Quinoa is rich in protein content which may vary from 8% - 20% which is higher than that present in wheat, oats, rice etc [184]. It contains all the essential amino acids required by the body with highest content in lysine (which is not abundantly found in other vegetables) (4.5-7.0%) [185] and methionine [184]. Quinoa is also rich in fatty acids like oleic acid, palmitic acid and linoleic acid. The quinoa is referred to as a pseudo-oilseed and it has a well-balanced protein and fat content. The polyphenols present are mainly kaempferol and quercetin glycosides [186]. Quinoa (whole seeds) also contains between 0.03 and 2.05% of bitter tasting saponins [187] and 0.1-1.0% phytic acid [188]. It helps to lower CVD and type-2 diabetes [189]. Quinoa is a good source to people with gluten allergy or celiac disease [184] and it can be used as an alternative to other cereals [190].

3.6.c Teff milk

Teff milk is high nutritious and gluten free cereal [191] makes it an alternative for wheat and other gluten containing cereals. It contains high fiber and good amino acid profile equivalent to egg in its nutritional value [192-193]. It is very rich in calcium which helps to reduce osteoporosis, weakening of teeth and skeleton etc. The unique quality is its antioxidant activity which helps to control many diseases. The high carbohydrate content, malt quality, high germinative energy and lack of gluten makes it suitable raw material for brewing industries for preparation of gluten free beverages. The major drawback of gluten-free cereals is its inferior taste which fails its acceptance by many people [194]. However, use of teff grain with falling number higher than 250 seconds at the moment of grinding solves these problems [195]. Teff as a food is mainly used in some countries like Netherlands, Ethiopia, and North America etc. In the future days no doubt it will be introduced to other parts of the world due to its nutritious properties.

3.6.d Amaranth milk

Amaranth is a nutritious and gluten-free grain which is best suited for people with celiac disease (gluten allergy). Both grain and leaves are used for human and animal food [196-197]. It is very rich in protein, fiber, calcium, iron, phosphorous, sodium, manganese, magnesium [198-202]. Amaranth also contains many antioxidants like vanillic acid, gallic acid, and p-hydroxy benzoic acid, which protects against many diseases. It helps to reduce the total and LDL cholesterol levels. The high protein and fiber content present in it help to reduce the appetite which in turn helps in the weight loss. Amaranth seeds contain polyphenols like rutin, nicotiflorin and isoquercetin and with some amides and phenolic acids. It contains amino acids like tryptophan, methionine and lysine [203]. Aqueous extracts of amaranth show anti-fungal, anti-malarial and anti-diarrheic properties; whereas, methanolic extracts of amaranth shows anti-diabetic, anti-helminthic and anti-hyperlipidaemic properties. In the recent years, amaranth has gained prominence due to its high grain yield, short production time and resistance to drought [204]. Some research says that nutritional value of amaranth grain improves during cooking [205-206].

3.7 Fruits and Vegetable Juices

Fruits and vegetables are widely accepted by the people of all ages as it is non-allergenic and healthy as it contains various antioxidants, phytochemicals, vitamins, minerals and dietary fibers [207]. Unlike dairy products the lack lactose, allergens and cholesterol. They are healthy, and have appealing flavour and taste which attracts more people [208]. Fruits and vegetable juices are fermented with microorganisms to make it an ideal functional beverage. They are rich in vitamins, minerals, dietary fibers, and antioxidants. To improve the desired flavour and to enrich with some metabolites, it is fermented with LAB (Lactic Acid Bacteria). Different strains of LAB are used for different fruits like: *Lactobacillus casei*, *L. rhamnosus*, *L. paracasei* for orange, cranberry and pineapple juices, *L. plantarum* for mango juice, *L. acidophilus*, *L. casei*, *L. delbrueckii*, for tomato juice etc. [209]. Among vegetables potato milk is gaining prominence in recent days.

4. Conclusion

Over the last decade, CM consumption per capita has progressively decreased along with increased availability and consumption of plant-based beverages. Non-dairy beverages continue to show an increasing sales trend in westernized countries because foods labelled as natural are perceived to be the healthiest and appropriate nutritional choice by most consumers. The nutritional profile of each type of "milk" depends not only on the plant source, but also the manufacturing process and the degree of fortification. These factors are especially important when considering the protein, vitamins, minerals, and sugar in each serving. The non-dairy beverages are usually fortified with calcium, vitamin D and other nutrients to cope up the loss during the manufacturing process. Therefore, it is the responsibility of the consumers to be aware of these plant-based beverages to replace it with the cow's milk.

5. References

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