**Plant based beverages: Types, process methods, nutritional value and consumer perspective**

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**Abstract**

 Concerns about sustainability, animal welfare, environmental impact, personal health issues and change in eating habits have increased consumer demand for non dairy plant based beverages. Moreover, non dairy plant based beverage consumption has increased due to the rise in allergenicity on cow’s milk, the prevalence of cardiovascular diseases, lactose intolerance and the flexitarian choice of food. Non dairy Plant-based beverages are gaining popularity among consumers who are seeking alternative and environmentally sustainable options to traditional dairy drinks. The food industry is therefore developing a range of affordable, convenient, desirable, nutritional, and sustainable non dairy plant based beverages. They are good alternatives instead of dairy milk due to the existence of functional components such as bioactive with health promoting functions. On the other hand, nutritional property and consumer acceptability in terms of taste, flavour of non dairy plant based beverages is lower than cow’s milk becoming a threat to its place in the food market. Therefore, this chapter provides an overview of the current knowledge on fundamental processing steps to convert plant material into plant-based beverages, types of plant based beverages, nutritional and sensory aspects of plant-based beverages.

**Keywords:** Plant based beverages, nutritional value, milk alternatives, functional beverages

1. **Introduction**

 Healthy nutrition is the consumption of necessary and sufficient nutrients for growth, development, maintenance of life and protection of health. Studies carried out in recent years; show that healthy nutrition has an important role in reducing and preventing the risk of some diseases (Type-2 diabetes, obesity, cardiovascular disease, etc.) [1,2,3,4,5]. With modern life, the increase in consumers' demand for ready-to-eat foods has negatively affected their eating habits, and decreased physical activity has led to an increase in health problems such as Type-2 diabetes, digestive system ailments, obesity and cardiovascular disease [6,7].

 The functional food sector is growing rapidly in parallel with the development of food and nutrition science, with consumers' understanding of the diet/disease relationship, the increase in the elderly population and treatment costs [2,8,9]. With the support of the development of the functional food sector by governments and the change in consumer awareness and production models, an increase in innovative food production is realized. One of the innovative food products is functional beverages, and the functional beverage market is growing by 10% every year worldwide [10]. Functional drinks can be classified as sports and performance drinks, energy drinks, milk-based drinks (with probiotic, protein and mineral additives), vegetable and fruit juices [11,12]. In recent years; due to reasons such as cow's milk allergy, lactose intolerance, hypercholesterolemia prevalence, calorie concerns, vegan/vegetarian diets preferred by consumers, plant based beverages have started to be used in the production of functional beverages and are rapidly growing in the new food product development category [13].

 In recent decades, the food industry aims to develop and produce alternative milk and dairy products with consumers' nutritional problems towards foods with improved functional properties because of the inadequacy of animal milk sources, together with their increasing awareness of demands, differences in dietary preferences (vegan / vegetarian diet, religious reasons) special diet), as in many foods, obtained from plant sources [14]. Plant based beverages are high in minerals and rich in health-promoting bioactive components such as vitamins, dietary fibers and antioxidants. They are accepted as functional foods because they are; similar to animal milk plant-based beverages or alternatives developed and marketed with the expression "milk". It takes place in the literature as a group under the name of milk drinks [15]. With the development of technology, plant based milk can be produced from legumes such as soybean, lupine, lentil, chickpea, pea; cereals like oat, rice, corn or nut based such as peanuts, coconuts, hazelnuts. Plant based milks have received more attention recently from consumers due to lactose free and cholesterol, vegetarians or people who prefer to not consume animal milk, deficiency of animal protein and awareness of allergy to animal proteins. Although the most common plant based milk is derived from soy, the demand for other plant based milks like almond, rice, oat and coconut milk, are also increasing [16]. Moreover, plant based milks, whose usage areas are gradually expanding; yogurt, cheese, kefir, pudding and desserts have been started and work continues in these areas. The worldwide plant-based food market is expected to grow by 12.5% annually from 2021 to 2028, reaching $20.5 billion [17]. To define this rises in the market, there are many factors which can be considered as reasons for the increase on the consumption of plant based beverages. The rise on the cases of lactoce intolerans with a prevalence of nearly 57% all over the world and cause to gastrointestinal symptoms is the main reason for consumption of the plant based beverages [18]. However, there are many benefits of plant based beverages, there is still concern about the nutritional value and consumer acceptance of plant based beverages compared to dairy products. Therefore, the aim of the present study give an overview of the production methods, type, nutritional properties and consumer preferences of plant based beverages.

**2. Processing Methods Employed to Manufacture Plant-Based Beverages**

 The processing methods employed to manufacture plant-based beverages vary depending on the specific type of beverage being produced and the final products. However, common processing methods include soaking or germination, extraction, filtration, homogenization, heat treatment, fermentation, fortification, packaging and quality control (Figure 1). Germination or water soaking, it is the first step for producing of some plant based milks like soybean, rice, hazelnut, almond, peanuts, sesame seed and tiger nut. This step can lead to swelling and softening of nuts and cereals, therefore, the apparent amylose content can be decreased [19]. Moreover, when tiger nuts, soybeans, peanuts and oats are soaked water extraction yield of milk is raised. In addition, blanching can be applied to almonds, soybeans, peanuts, coconuts, rice, quinoa and sesame lead to many advantages like inactivation of enyzmes like lipases, reduced microbial load and removal of undesirable flavour and taste [20].

 Extraction is extracting the desired components from the source material, such as fruits, vegetables, nuts, or grains. This can involve methods like juicing, grinding, wet milling, or blending to obtain the plant's liquid or pulp. For example, wet milling can be applied to cashew, tiger nuts, coconut, soy, cowpeas, almonds, peanuts, walnuts and hazelnuts. This step includes the addition of water throught griding of the raw materials. The type of feed rate and grinding, pH value and the amount of added water, grinding temperature can affect on nutritional, physicochemical properties and viscosity of plant based milks. For example, when increased amount of water can decrease the nutritional properties of plant based milk [21]. The filtration step involves after extraction the liquid or pulp is typically strained to remove any solids, fibers, or unwanted particles. This process helps improve the texture and clarity of the beverage. Homogenization is often employed to create a more uniform texture and prevent separation in plant-based beverages. This process involves mechanically breaking down the fat molecules in the beverage to distribute them more evenly, resulting in smoother and more stable products [20].

 Many plant-based beverages undergo heat treatment to pasteurize or sterilization them, extending their shelf life and ensuring their safety. This can involve techniques like high-temperature short-time (HTST) pasteurization or ultra-high temperature (UHT) processing. Glucosides and saponins are antinutrients due to their impacts the digestion of protein particularly soy proteins that are resistance to digestion. Whereas different kinds of seeds like oat and soybeans have different saponins, the applied heat treatment throughout the process during plant based beverages may decrease the content of these kinds of compounds [22].

 Consumers have nutritional concerns about the nutritional value of plant based beverages compare to animal milks. Especially, plant based beverages usually have deficiencies of important nutrients like high quality proteins, vitamins and minerals. The deficiencies of these nutrients can lead to some health problems especially the elderly and infants over time [23,24]. Therefore, it would be advantageous to add some nutrients (vitamins and minerals) to plant based beverages in order to avoid deficiencies. Plant-based beverages may also be fortified with various vitamins, minerals, or additives to enhance their nutritional value or improve their taste and texture. Common fortification ingredients include calcium, vitamin D, omega-3 fatty acids, and sweeteners. In addition, fortification of plant based beverages with nutrients like polyphenols and carotenoids can lead to enhance health benefits of these productions. Plant based beverages are a suitable production for vehicle for introducing essential nutraceuticals and nutrients into human diets. Plants based beverages are colloidal dispersion which can be fortified with bioactive ingredients with different molecular polarities; hydrophobic, amphiphilic and hyrophilic. Moreover, plant based beverages can be designed in order to raise the bioavailability of the bioactive agents [25]. On the other hand, plant based beverages have to be carefully designed in order that the bioactive components continue to remain stable during the shelf life of production, should not affect negatively production quality and are highly bioavailability after digestion. Once the beverage is processed and fortified, it is usually packaged in bottles, cartons, or aseptic containers to protect its quality and prolong its shelf life [26].

 Packaging materials and methods vary, but they generally aim to maintain product integrity and preserve freshness. During the manufacturing process, quality control measures are implemented to ensure the safety, consistency, and compliance of the plant-based beverages. This can include regular product testing, monitoring of processing parameters, and adherence to regulatory standards [27].

 Recently, eco friendly techniques like ultrasound, high pressure homogenization, fermentation and enzymatic process can reduce residuce and enhance extraction yield. Moreover, many studies have already reported that these kinds of techniques improve nutritional and sensorial properties of plant based milks [28]. These processing methods play a crucial role in transforming raw plant materials into palatable and commercially viable beverages, while also maintaining their nutritional value and ensuring consumer satisfaction and safety [29].



**Figure 1: Manufacturing process of plant based beverages starting from raw materials.**

**3.Application of Innovative Technologies For The Processing of Plant-Based Beverages**

Thermal and non thermal innovative technologies like microwave heating, ohmic heating, high pressure homojenization, pulsed electric field, ultraviolet raditaion, high intenstiy ultrasound, supercritical carbon dioxide have been researched as potential alternatives for production of plant based beverages. Productions of plant based beverages with these innovatives technologies may lead to enhancing the shelf life, protecting nutritional value and decreasing the loss of bioactive components.

**3.1. Thermal Innovative Technologies**

**3.1.1. Microwave heating**

 Microwave heating is an unconvential technique which is high effective tecnique to decrease microbial load and rise the shelf life of productions. The principle of this technique is based upon electromagnetic radiation that is frequency from 103 to 104 MHz that affects the dipole of the water molecules in production. The radiation enhances a rise in the intermolecular friction of the system because of forces and repulsion of these dipoles of water molecules delivering heat. Moreover, the rising of temperature is supported by ionic conduction due to the action of the electromagnetic area which providing to the displacement of the ions to areas that show opposite charges. Therefore, rising intermolecular collisions lead to disrupting hydrogen bonds in water [30,31,32]. (Cavalcante 2021, Costa 2021, hassan 2021). Researches have shown that the using of microwaves techniques increases digestibility, eliminated antinutrional components and increases protein yield compared to conventional techniques [33,34].

**3.1.2. Ohmic heating**

 Ohmic heating is an innovate thermal technique which is applied in the processing of unpacked or packaged plant based beverages. In this technique is an electrical current of 50 to 69 Hz is applied to the food matrix which discharges thermal energy because of electrical resistance. The advance of molecule’s agitation degree is increased by applied electrical energy to system to resistance medium. Thus, heat releasing contributes to molecules’ agitation [35,36]. The rising in the heat of medium supported by uniform heating which does not occur mechanical damage to production decrease the deteriorating and pathogenic microbial load from rupture of its cell membranes. Moreover, ohmic heating is suitable for enzymatic inactivation with enzyme denaturation [37,38]. Researches are showed that using ohmic treatment to soy products lead to decrease thiol loss and inactivation of antinutritional components such as chymotrypsin, trypsin. Compare to conventional techniques, ohmic heat treatment is sustainable and low-cost. On the other hand, ohmic heating may promote overheating of production, causing protein denaturation, nutritional and sensory alterations of plant based beverages [39].

**3.2. Non Thermal Innovative Technologies**

**3.2.1. High pressure homojenization**

 Ultra high presuusre homojenization and high presuure homojenization is an alternative non thermal innovative technique for production of plant based beverages. This high pressure which is between 200 and 600 MPa and temperatures from 30 to 80 C applied to food lead to develop stability of products by decreasing the particle size and promote uniform size particles. Moreover, a microbial load can be decreased by this technique [40]. A study conducted by Briviva et al., (2016) [41] has shown that besides a reduction in particle size, there is not any effect on vitamins of product. Furthermore, it is founded that there is a decreasing the protein antigens by applying ultra high presuure homogenization. Another study has shown that a remarkable reduction of particle size in ultra high pressure homojenization treated product sample compare to ultra high treatment treated product sample. While protein aggretiaon was observed after 200 MPa, ultra high pressure homojenization at 300 MPa cause similar protein aggregation [42]. Furthermore, applying ultra high pressure homojenization can contribute to physicochemical properties like colour during storage, minimize the effects on nutiritional properties and improve sensory properties [43,44].

**3.2.2. High intensity ultrasound**

 Ultra sound technique is an alternative innovative non thermal technique for plant based beverages. This technique is equal to wave with frequency from 20 kHz to 100 MHz. Ultrasound techniques can be divided into two according to the frequency employed for food or beverages high frequency (100kHZ to 1MHz) and low frequency (16 to 100 kHz) [45]. Productions of plant based beverages by applied of high intensity of ultrasound treatment provides an inactivation of pathogenic and endogenous enzymes. Moreover, the application of this treatment can allow rheological improvement [46]. A recent study have showed that the combination of thermosonication (heat) and ultrasound treatment results in better microbial stabilization of productions [47]. Besides, ultrasound technique is higher energy efficient compared to conventional heat treatment because of the short processing time. Furthermore, this technique is easy to use and providing volumetric heating led to minimal damage to the resistance of heat components of the productions [48].

**3.2.3. Pulsed electric field**

 Pulsed electric field technique has been used particularly for enzymatic inactivation and microbial stabilization of liquid productions involving plant based beverages. This technique is applied at low temperatures between 30 to 40 C less than 1 minute to products in order to prevent thermal degradation of food matrixs. The treatment of this innovative non thermal process provides a decrease in microbial load of productions with induction [49,50]. A study conducted by Li et al., (2008) [51] has shown that treatment of pulsed electric flied technique (100-600 Hz, at 25 ℃) leads to a decrease in lipoxygenase activity in soy products. On the other hand, this treatment can not inactive food spores so other components such as organic acids which lead to a rise in thermal energy and water activity should be added to pulsed electric field processing. Besides the reduction in microbial load, treatment of this technique contributes to the maintenance of nutritional properties of production because of its non-thermal technique. Whereas the investment cost of the pulsed electric field technique is expensive, there are many advantages such as high energy efficiency, shorter processing time and protect the vitamins, phenolic compounds, flavonoids and carotenoids [52,53,54].

**3.2.4. Ultraviolet radiation**

 Ultraviolet radiation technique attracts the attention of unconventional treatment for plant-based beverages. This technique relies on the germicidal impact provided by ultraviolet radiation. It provides mutation or disruption of deoxyribonucleic acid of microorganisms, changing morphological structure and reproduction function. Besides, providing microbial inactivation, ultraviolet radiation treatment effect enzymes [55]. This technique provides photochemical changing of protein so promoting enzymatic inactivation. Moreover, the ultraviolet radiation technique provides minimal altering to nutritional and sensory properties of productions. Once ultraviolent radiation applies at low temperatures and this does not provide thermal aggregation of the thermosensitive components in food [56]. On the other hand, the application of this technique is only useful for liquid media. The higher dose of radiation can be applied for cloudy liquids productions but it causes a decrease in the sensory properties of production [55].

**3.2.5. Supercritical carbon dioxide**

 Supercritical technology is non-thermal process that can apply plant-based beverages in order to extend shelf life. In this technology, food production is put into the reactor and saturated by injection of carbon dioxide. Carbon dioxide is a nontoxic, low cost and providing high extraction yields among supercritical fluids. Moreover, the critical condition of carbon dioxide is moderate which provided less damage to nutritional properties and a decrease in the process energy expenditure, compared to other fluids. Whereas the effectiveness and low cost of carbon dioxide, the application of this technology on an industrial food scale is difficult because of the high investment costs [56,57]. This technique decreases the load of endogenous enzymes and pathogenic microorganisms of production, providing its conservation. Supercritical carbon dioxide technique, in which the volume proportion of carbon dioxide (20 to 50%), the temperature at 35-55 ℃ and the impact of pressure (10-20 MPa), were evaluated on physicochemical and rheological properties of beverage [58]. This application did not provide remarkable changes in the physicochemical properties of the beverages whereas it changed the rheological properties of the coagulation of milk proteins by decreasing the pH during processing. Therefore, an additional homogenization process can be performed to improve kinetic stability [59].

**4.Types of Non-Dairy/ Plant-Based Beverages**

 Various plant based beverages are available in the market derived from legumes, cereals, seeds and nuts or a mixture of plant sources as an alternative to dairy milk. Whereas there is not obvious classifying and description of plant based beverages in published studies in literature, commonly plant based beverages can be divided into four broad categoris based on raw material (Figure 2).



**Figure 2.Categories of plant based beverages**

**4.1. Legume-based beverages**

 Legume-based beverages are drinks that are made from legumes, which are a type of plant from the Fabaceae family. Legumes are known for being a good source of protein, fiber, and various vitamins and minerals. Here are few popular types of legume-based beverages:

 **Soy milk:** Soy and soy productions have received attention from vegetarians because of its high protein content and protein quality. Made from soaked and ground soybeans, soy milk is a popular dairy milk alternative. A study has reported that soymilk contains 7/237 g/ml protein, the protein value of soymilk is nearly dairy milk protein [60]. Soy milk has a high amount of essential polyunsaturated and monosaturated fatty acids which are related to cardiovascular health. Soy milk is an cheap, nutritional and refreshing beverage with different functional properties which is beneficial for human health. For example, soy has contain huge amounts of isoflavones which have protective impacts against some diseases such as osteoporosis, cancer and cardiovascular diseases. In addition, it contains minerals, fiber, unsaturated fatty acids, phytochemicals (sterols, phytic acid and saponin) and vitamin B [61,62]. Soy milk products are often fortified with vitamin D and calcium.

 **Pea milk:** This type of milk is made from yellow peas. Peas have a high amounts of protein (%18-20) and is often suitable for those with nut, soy, or dairy allergies. Moreover, pea proteins are high quality related to essential amino acids and particularly high amounts of arginine and lysine. Pea proteins have benefical functional properties like emulsifying power, gelation proterties, foaming capacity and water solubility [63,64]. Pea proteins have higher digestibility and lower allergenic impacts, lower antinutritional factors like phytate than soy proteins. Moreover, peas have a great amounts of minerals and vitamins such as calcium, potassium, iron folic acid, vitamin B [65]. On the other hand, the unpleasant flavor of pea protein is the most limiting factor for using it in beverages [66].

 **Lentil milk:** Lentils are a nutritious legume and can be turned into a milk-like beverage. Lentil milk is known for its high fiber content and is often a good option for those following a vegan or plant-based diet. Moreover, lentil has vitamins (B and folate), minerals and complex carbohydrates (dietary fiber, starch and oligosaccharides) and its fat content is less than %1 [67,68]. The high protein level in lentil seeds makes it suitable for functional human foods. The studies have reported that firstly raw lentil seeds were cleaned and washed then washed seeds are kept in water for 14 hours. The shells of the softened seeds are removed by hand and then it is mixed with a blender by adding water for 3 minutes and filtrated [69].

 **Chickpea milk:** Chickpea is another legume that can be transformed into milk. Chickpea milk is an excellent source of protein and can be used as a substitute for dairy milk in various recipes. Chickpeas has one of the highest nutritional composition among legumes. It contains nearly % 23 protein, % 64 carbohydrate, % 6 fat and some minerals such as calcium, magnesium, phosphor, iron, zinc [70]. The presence of undesirable components in chickpea limits the wider use of chickpeas. However, undesirable factors can be reduced or eliminated with different cooking techniques. It has been reported that the starch content of different kinds of chickpeas varies from 41% to %50 [71]. The digestibility of chickpea carbohydrates is lower than other legumes. Chickpea milk has a darker and yellowish color than cow's milk. Chickpea is a food rich in folate content so reduces the risk of colorectal cancer in humans [72].

 **Lupin milk:** These legume-based beverages provide alternatives for those who are lactose intolerant, have allergies to common milk sources, or are following a plant-based diet. They offer a range of nutritional benefits and can be consumed on their own or used in cooking and baking. Lupin has a high amount of protein content (30%), fiber content (16%) and fat content (6%) [73]. Moreover, it has 18% and 33% of recommended daily intake of riboflavin and thiamine respectively. Lupin has a great amount of carotenoid, tocopherol, phytosterol, polyphenol and peptide with anticancer, antioxidant, anti-inflammatory and antimicrobial activities [74].

**4.2. Nut based beverages**

 **Almond milk:** Almond has a good amount of vitamin B complex comprising (B1,B2, B3, B5, B6), vitamin E, protein, dietary fiber, monosaturated fatty acids, phenolic compounds and minerals (Mg, P, Ca and K). Moreover, compared to other plant based milks, almond milk is a good source of vitamin E which can not be synthesized by the body and must be taken from diet [75]. Due to its high fiber, it is suitable for low sodium/high potassium diets. However, amandin which is a protein, is founded in almonds can cause almond allergy [76]. Almon milk after soaking in plenty of water for a while, it can be obtained by grinding, as well as directly grinding raw or roasted almonds into flour and diluting and then using plant based milk production methods can be produced. Compare to cow milk, the color of almond milk is darker and protein content is lower. The prevalence of nut allergy and the high cost of almonds limits their use as a beverage [77].

 **Peanut milk:** Made from ground peanuts and water, peanut milk is a rich and creamy alternative to cow's milk. It can be consumed on its own, used in cooking, or added to smoothies. Soaking raw peanuts is the first step for producing peanut milk, then grinding with water after that filtration and the last one is heat treatment. The processing conditions such as boiling or roasting have shown a rise in the amount of bioactive compounds. Peanut is used generally for nuts and oil production. Peanut contains functional components such as proteins, fibers, minerals, vitamins and antioxidants [21]. Recent studies have shown that peanut have a great source of Co-enzyme Q10 and involves all the essential amino acids with high level of arginine. Phenolic compounds which are flavonoid, resveratrol, phytosterols and phenolic acid are founded in peanuts and the study showed that prohibit the absorption of cholesterols from food [78,79,80].

 **Hazelnut milk:** One of the most notable plant based milk available in the market is hazelnut milk. Hazelnut milk has 0.6-0.8 g protein, 1.5-2.8 g fat, 6.5-8g carbohydrates in 100ml on average. Hazelnut milk can be produced with reduced fat, added sugar, unsweetened, flavored or on demand fortified formulations [81]. Although hazelnut gives flavor to the products, the minerals in its composition fiber, tocopherols and phenolic compounds play an important role in nutrition and health support. Hazelnut is preferable for its sugar effect due to its low glycemic index. Due to the high mineral content (K, Ca and P) in hazelnut milk, it suggests to pregnant women and against lactose an option for sensitive people to add to their diet instead of cow's milk [82].

 **Cashnew nut milk:** Cashew nut milk is a plant-based milk alternative made from creamy and mild-flavored cashew nuts. Cashew nut milk is made by blending cashews with water and then straining the mixture to remove any solids. The resulting liquid is a creamy, nutty milk that can be used as a dairy-free alternative. Cashew nut milk is low in calories and contains a good amount of healthy fats, protein, and carbohydrates. It is also a source of vitamins and minerals such as vitamin E, calcium, magnesium, and potassium. However, it is important to note that store-bought versions may have added sugars, so it is advisable to check the ingredient list [83]. Cashew nut milk is a popular choice for individuals who are lactose intolerant, allergic to dairy, or follow a vegan or plant-based diet. It can be used as a one-to-one replacement for dairy milk in various recipes, including smoothies, cereals, coffee, and baked goods. Cashew nut milk has a creamy and smooth texture, making it a great option for those who prefer a richer consistency in their beverages or recipes. It adds a subtle nutty flavor to dishes without overpowering the original taste [84]. Cashews used in cashew nut milk are a good source of healthy fats, including monounsaturated fats, which have been associated with lowering cholesterol level, controlling coronary heart disease and diabetes, continue healthy bones. They also provide dietary fiber, which can aid in digestion and promote satiety. Cashew nut milk is a dairy-free milk alternative with a creamy texture and subtle nutty flavor. It is a nutritious option for those following a vegan or plant-based diet and can be used in various recipes as a replacement for dairy milk [85].

 **Coconut milk:** Coconut milk is consumed mostly in Asian countries. It also is used as an ingredient like a sweetener in different recipes. Coconut milk, extracted from the solid endosperm of mature coconuts, is a liquid and can be mixed with water to be consumed as a beverage. Coconut milk is rich in minerals especially potassium, calcium, iron, zinc and magnesium [86]. Moreover, coconut milk contains high antioxidants like vitamin E. Coconut milk are high in saturated fat, healthier than other saturated fat products, and fat is easily metabolized by the body. The main saturated fat is lauric acid and it is also found in breast milk and promotes brain development and bone health, it strengthens our immune system and maintains the flexibility of blood vessels [87].

**4.3. Cereal-based beverages**

 **Oat milk:** Oats are good resources of dietary fibre such as b-glucan, phytochemicals, starch and lipid components. Oats have received interest due to b-glucan which is soluble fibre, can delay gastric empty time and arises gastrointestinal transit time that is related with blood glucose level [88]. However, a soluble fiber β-glucan tends to increase the viscosity of solutions. Oat milk has a benefical effects on human health like digestion systen regulation, control on body weight, type II diabetes. Although many health benefits of oat products, oat milk contains calcium, an essential nutrient for growth and development is poor; supplementation before consumption as a milk alternative to compensate for this deficiency needs to be done [89]. Oat milk is produced by UHT treatment and put into suitable packages in various sizes. Starch, which makes up the majority of oats (55-60%), has a gelatinization temperature range of 44.7-73.7 °C [90]. The existing high starch concentration of the oat drink in the preparation of a stable emulsion and the heat causes problems during processing. Starch with applied heat, starts to gelatinize and a high gel-like viscous structure formation which reduces the acceptability of oat milk is observed. Maintaining of the fluidity of oat milk during heat treatment in order to prevent starch hydrolysis method is applied [91].

 **Rice milk:** Rice contains various proteins, carbohydrates, vitamins B1-B2, iron, phosphorus, calcium and small amounts of vitamins A and C. Among plant-based dairy products, after soy milk and almond milk, rice milk is the third most popular alternative dairy product and the most hypoallergenic of these products. Rice milk does not contain saturated fat or cholesterol. Compare to other plant based milk, rice milk contain the least amount of fat [92]. Moreover, rice milk has rich in unsaturated fatty acids like oleic acid, riboflavin, niacin, thiamine, folate and β-carotene. Patients who have a cardiovascular disease can consume rice milk because of low saturated fat and cholesterol. Although the protein ratio is quite low compared to other plant based beverages, it is rich in complex carbohydrates and fiber content. Rice milk is rich in B vitamins and some of the vitamins can be lost during rice milk processing [93]. Rice milk also contains low levels of calcium so it needs to be fortified with calcium. Rice milk also supports the immune system, which helps prevent cancer. Moreover, it contains more magnesium and selenium than other plant based milks. Consumption of rice milk can lead to the production of red blood cells so that high iron and copper levels [94]. Rice milk is a rich source of carbohydrates, the sugar content is higher than cow's milk [95]. Therefore, people who have type 2 diabetes, should be carefully consume rice milk.

 **Wheat Milk:** Wheat milk, also known as kamut milk or spelt milk, is made by blending soaked wheat grains with water. It is similar in taste and consistency to rice milk but has a slightly nutty flavor [18].

 **Multigrain Milk:** Multigrain milk combines various grains like oats, rice, barley, and others, offering a unique flavor profile. It often provides a mix of nutrients from different grains [96,97].

**4.4. Seed-based beverages**

 Seed based beverages are drinks that are made from seeds, either as whole seeds or as seed extract. These beverages are often known for their nutritional benefits and can be consumed for various health purposes.

 **Sesame milk:** Sesame is one of the important oil seed crop all over the World. Sesame has high quality protein which has a good amino acid balance [96]. Its proteins are less soluble in water and susceptible to heat denaturation that limits sesame use in the preaperation of plant based milk. For this reason, modification in functionality of protein is required before use in plant based beverages. These modifications may be done with different types of processing methods such as roasting, soaking, germination, microvawe heating [98,99].

 **Chia seed beverage:** Chia seeds are soaked in water or other liquids to create a gel-like substance that can be enjoyed as a drink. It is often mixed with flavors such as fruit juices or milk alternatives to enhance taste [100].

 **Flaxseed beverage:** Flaxseeds can be ground into a powder and mixed with water or other liquids to make a drink. This beverage is known for its high omega-3 fatty acid content and is often consumed for its potential heart health benefits [101]

 **Hemp seed beverage:** Hemp seeds can be blended with water or other liquids to create a creamy and nutty-flavored beverage. Hemp seed beverages are a good source of plant-based protein and healthy fats [100] .

 **Pumpkin seed beverage:** Pumpkin seeds can be blended with water or other liquids to create a nutritious and antioxidant-rich drink. This beverage is nutrient-dense and may provide various health benefits, including supporting prostate health [102] .

 These seed-based beverages can be enjoyed on their own or used as ingredients in smoothies, shakes, or even baked goods. They offer a convenient way to incorporate the nutritional benefits of seeds into your diet.

**5. Nutritional Properties of Plant-Based Beverages**

 Plant-based beverages, also known as plant milks or alternative milks, are derived from a variety of plant sources and offer several nutritional properties. Some common plant-based beverages include almond milk, soy milk, oat milk, coconut milk, and rice milk. Here are some general nutritional properties of plant-based beverages:

1. Low in calories: Plant-based beverages are generally lower in calories than cow's milk. However, the calorie content can vary depending on the type and brand of plant-based beverage [26].
2. Low in saturated fat: Plant-based beverages are typically low in saturated fat, unlike dairy milk which contains significant amounts of it. This makes plant-based beverages a healthier option for individuals concerned about their saturated fat intake [102].
3. Source of vitamins and minerals: Plant-based beverages can provide valuable vitamins and minerals, depending on the plant source. For example, almond milk is a good source of vitamin E, calcium, and vitamin D (if fortified). Soy milk is naturally rich in calcium, vitamin D, and vitamin B12 [26,102].
4. Lactose-free: Plant-based beverages are naturally lactose-free, making them suitable for individuals who are lactose intolerant or have dairy allergies. This makes them a popular choice for those who cannot consume dairy products [102,103].
5. Cholesterol-free: Plant-based beverages are free of cholesterol, which is only found in animal-based products. This is beneficial for individuals looking to maintain heart health and lower their cholesterol levels [21,26,102,103].
6. Higher fiber content: Some plant-based beverages, such as oat milk, contain a higher fiber content compared to cow's milk. Fiber supports digestive health and can help regulate blood sugar levels [104].
7. Lower in protein: Most plant-based beverages are lower in protein compared to cow's milk. However, some brands enrich their products with additional protein from plant sources to help meet protein requirements [103,105].
8. Polyphenols: These are a group of antioxidant compounds found in plants. They have been associated with numerous health benefits, including reducing the risk of chronic diseases such as heart disease, certain cancers, and neurodegenerative disorders. Polyphenols are particularly abundant in beverages made from berries, grapes, green tea, and cocoa [105].
9. Carotenoids: These are pigments responsible for the vibrant red, orange, and yellow colors in fruits and vegetables. Carotenoids have antioxidant properties and are known to support eye health, reduce the risk of certain cancers, and boost the immune system. Plant-based beverages rich in carotenoids include carrot juice, tomato juice, and orange juice [26].
10. Phytoestrogens: These are naturally occurring compounds that have a similar structure to estrogen and can mimic some of its effects in the body. Phytoestrogens are found in soy-based beverages, flaxseed milk, and certain herbal teas like red clover and black cohosh. They are believed to have potential benefits for managing menopausal symptoms, reducing the risk of certain cancers, and maintaining bone health [26].
11. Alkaloids: These are nitrogen-containing compounds with diverse biological activities. Some alkaloids found in plant-based beverages include caffeine in coffee and tea, theobromine in cocoa, and nicotine in tobacco. Alkaloids can have stimulating or sedative effects on the central nervous system and may also have medicinal properties [19].
12. Omega-3 fatty acids: These are essential fatty acids that play a crucial role in brain health, heart health, and reducing inflammation in the body. While they are more commonly found in fish and seafood, some plant-based beverages like flaxseed milk and hemp milk can be fortified with omega-3 fatty acids derived from plant sources such as algae [21].
13. Variety of flavors and textures: Plant-based beverages come in a range of flavors, including vanilla, chocolate, and original, which can be appealing to individuals seeking variety in their diet. Some also have a creamy texture that is similar to dairy milk.
14. Fortified options: Many plant-based beverages are fortified with vitamins and minerals to make them nutritionally comparable to cow's milk. Common fortifications include calcium, vitamin D, and vitamin B12, which are often lacking in a vegan or vegetarian diet [106].

 It's important to note that the nutritional properties of plant-based beverages can vary depending on the brand, processing methods, and added ingredients. Therefore, it is always recommended to check the nutrition labels and choose fortified varieties when possible.

**6. Health Effects of Plant-Based Beverages**

 Plant-based beverages can offer numerous health benefits due to their natural compounds and nutrients. Some of the health effects include:

1. Nutrient-rich: Plant-based beverages such as almond milk, soy milk, and oat milk are often fortified with essential nutrients like calcium, vitamin D, and vitamin B12. These nutrients are beneficial for bone health, nutrient absorption, and energy production [107].
2. Heart health: Many plant-based beverages, particularly those made from soy and almonds, are naturally low in saturated fats and cholesterol. They can contribute to lower blood cholesterol levels and decrease the risk of heart diseases [16,108].
3. Digestive health: Some plant-based beverages contain high amounts of dietary fiber, which aids digestion and supports a healthy gut. For example, oat milk is known for its beta-glucan fiber, which can help regulate bowel movements and promote a healthy digestive system [106,109].
4. Antioxidants: Certain plant-based beverages, such as green tea or matcha tea, are rich in antioxidants. These compounds help to fight free radicals and reduce oxidative stress, potentially reducing the risk of chronic diseases like cardiovascular issues, cancer, and neurodegenerative diseases [110,111].
5. Reduced lactose intolerance symptoms: For individuals with lactose intolerance, plant-based beverages like almond milk or rice milk provide a dairy-free alternative. They do not contain lactose, a sugar found in dairy products that many people have difficulties digesting. 80% of the total protein in cow's milk is casein and the rest is whey protein. Individuals with cow's milk allergy are sensitive to various milk proteins such as casein, beta-lactoglobulin, alpha-lactalbumin, bovine serum albumin, bovine immunoglobulin and bovine lactoferrin, which are the main milk allergens [112]. Cow's milk allergy is a very common type of allergy among infants and children, and large-scale studies show that allergy that starts in infancy increases by 35% in advancing ages (5-6 years), and this rate increases to 80% when they reach the age of 16. has been emphasized in various studies [113,114,115].
6. Reduced allergies or intolerances: Plant-based beverages are suitable for individuals with allergies to common allergens like dairy, soy, or nuts. Beverages made from less common ingredients like hemp, flaxseed, or rice can provide a safe and nutrient-dense option [16,116].
7. Weight management: Plant-based beverages, especially those made from non-starchy vegetables or nuts, can be lower in calories compared to traditional dairy products. They can be used as a healthier substitute for high-calorie beverages, aiding in weight management or weight loss efforts. The majority (97-98%) of cow's milk fat consists of milk fat, which is triglyceride, and the remainder contains free fatty acids, mono-diglycerides, phospholipids and cholesterol. A cohort study of 80,000 people, it was stated that there is a significant relationship between the consumption of fatty cow's milk and the risk of coronary heart disease [117]. This situation is associated with an increase in the risk of coronary heart disease as a result of the intense consumption of dairy products increasing serum cholesterol [118,119]. In many studies investigating the effects of dairy products on health, it is emphasized that high-fat milk consumption has a negative effect on health [84,85]. This situation has caused consumers to negatively affect their consumption habits due to the high amount of saturated fat and cholesterol in cow's milk [120].

 It's important to note that the health effects may vary depending on the specific ingredients, processing techniques, and added sugars in plant-based beverages. Reading labels and choosing products without excessive additives or added sugars is recommended for optimal health benefits.

**7. Consumer Perspective**

 Consumer acceptability of plant-based milk has been growing steadily in recent years. The increasing popularity of vegetarian, vegan, and flexitarian diets, along with concerns about animal welfare, environmental sustainability, and health, have contributed to the rise in demand for plant-based milk. One of the main reasons for consumer acceptability is the taste and texture of plant-based milk. In the past, plant-based milk alternatives often had a different taste and texture compared to cow's milk, which deterred some consumers. However, advancements in manufacturing processes and ingredient formulation have allowed for a significant improvement in the taste and mouthfeel of plant-based milk [121,122]. Many brands now offer a wide range of options that closely mimic the taste and texture of cow's milk, such as almond milk, soy milk, oat milk, and coconut milk. Another factor driving consumer acceptability is the increased availability and variety of plant-based milk products [123,124,125]. Grocery stores now have dedicated sections for plant-based milk, with a broad assortment of flavors, types, and brands. This accessibility has allowed consumers to experiment with different options and find the ones that best suit their preferences.

 Health considerations also play a significant role in consumer acceptability. Plant-based beverages are often lower in calories, saturated fat, and cholesterol compared to cow's milk. They are also suitable for individuals who are lactose intolerant or have milk allergies [126]. Furthermore, many plant-based milk products are fortified with vitamins and minerals, making them a nutritionally balanced option. Environmental sustainability is another factor that drives consumer acceptability of plant-based milk. Cow's milk production is resource-intensive and contributes to greenhouse gas emissions. Plant-based milk, on the other hand, requires less water, land, and energy to produce, making it a more environmentally friendly choice. For individuals concerned about the environmental impact of their food choices, plant-based milk provides a viable alternative [122,125]. In conclusion, consumer acceptability of plant-based milk has increased due to factors such as taste improvements, increased availability, health considerations, and environmental sustainability. As more consumers embrace plant-based diets and look for alternatives to animal-based products, the popularity of plant-based milk is likely to continue to grow.

**8.Enviromental İmpacts and Sustainability Issues**

 A rising number of consumers, particulary the younger generation are concern about their food choices both healthy and sustainable, eco friendly. The research of the the sustainability of plant based beverages is not reported widely and its also effect on consumer beverages has not been studied. The sustainability problems of plant based beverages are vary among the category of plant based beverage and the problems differ in degree of magnitude [126, 127,128,129]. A study has reported that the production of plant based beverages like rice, soy, almond and oat milk, are related to nearly 22-38% of the greenhouse gas emissions of the level related to dairy products. Moreover, the using of water during production of plant based beverages is much less than for dairy products [130,131]. While almond and rice productions have a very high water usage, oat and soy productions are quite low water usage. For one liter of rice milk production, nearly 270 L of water are needed, 370 L of water are required for production of one liter of almond milk. However, rice and almond beverages are needed less water compare to production of cow’s milk. Moreover, cow’s milk is needed more land for its production compared any kind of plant based beverages [131].

 Almond farming has a disadvantageous impact on bees due to using pollination on almond trees [126]. However, compared to almond, hazelnut is pollinated by wind instead of honeybee and grow in humid regions where water is required much less [127]. Rice is not only required more water but also produces more greenhouse gas emissions than other crops which are used for plant based beverages [128,131]. Oat and soy milk are considered more eco friendly beverages compare to other plant based beverages because of less water needed and land usage [131]. As it is mentioned before beverages which are produced by rice, almond and soybean, have remarkably lower land usage, water usage and green gas emissions than dairy productions. There is still a gap about effects of plant based beverages on the enviroment, therefore more studies are needed for all kinds of plant based beverages to present their eco friendly and impacts on enviroment. Sustainability problems are very complicated and there may be huge variability in the environmental effect of not only types of plant based beverages but also in the same category, subject to the sustainability of farming technique used for growing crops.

**9. Advantages and Limitations**

 Plant-based beverages are often lower in calories, fat, and sugar compared to dairy-based beverages. They are also cholesterol-free and may contribute to a reduced risk of heart disease, obesity, and certain cancers [28,79,122,124]. Plant-based beverages come in a wide range of options such as almond milk, coconut milk, oat milk, hemp milk, and more. This diversity allows individuals to choose the flavor and consistency that suits their taste preferences and dietary needs. Many plant-based beverages, such as almond milk and soy milk, are fortified with essential nutrients like vitamins A, D, and B12, calcium, and protein. This makes them a good alternative for those who have dietary restrictions or are following a vegan or vegetarian diet [16,17]. Some people have difficulty digesting dairy products due to lactose intolerance or milk allergies. Plant-based beverages provide a lactose-free and dairy-free alternative that is easier on the digestive system [106,109]. Producing plant-based beverages requires fewer natural resources like water, land, and energy compared to dairy production. It can have a lower carbon footprint and contribute to reducing greenhouse gas emissions Plant-based beverages require significantly less water and land compared to animal agriculture. Choosing plant-based options can help conserve freshwater resources and reduce deforestation associated with animal farming. Plant-based beverages are a compassionate choice for those concerned about animal welfare. By choosing plant alternatives, individuals can avoid supporting the factory farming industry that often involves the mistreatment of animals [124]. Plant-based beverages are free from common allergens like lactose and casein, making them suitable for people with allergies, intolerances, or sensitivities to these substances [16,17]. Plant-based beverages can be used in various culinary applications, just like dairy milk. They can be consumed as a drink, used in cooking and baking, added to smoothies and shakes, or used as a substitute in coffee, tea, and other beverages. With the increasing popularity of plant-based diets, plant-based beverages are becoming more widely available in grocery stores, cafes, and restaurants. This accessibility makes it easier for individuals to incorporate them into their lifestyle.

 Plant-based milk substitutes may not be nutritionally identical to dairy milk. They might lack certain essential nutrients, such as calcium, vitamin D, and vitamin B12, which are naturally found in cow's milk [16,28]. Although some brands fortify their plant-based milk with these nutrients, there can still be variations in the amount and bioavailability of nutrients. Moreover, plant-based milk usually has a lower protein content compared to cow's milk. This can be a limitation for individuals who rely on milk as a significant source of protein in their diet, such as athletes or those following a high protein diet. Plant-based milk may not have the same creamy or rich taste as dairy milk. Some people find the flavor of plant-based milk substitutes less appealing, especially when used in beverages or in cooking and baking [127]. In addition, depending on the region, the accessibility and affordability of plant-based milk substitutes may be limited. In some areas, the variety of options might be restricted, making it difficult for individuals with specific dietary requirements to find suitable options. Furthermore, while plant-based milk can be a suitable alternative for individuals with lactose intolerance or milk allergies, some people may have allergies or intolerances to specific plant-based milks, such as soy, almonds, or nuts. This can restrict the options available for those individuals [128]. While plant-based milk substitutes are generally considered more environmentally friendly than dairy milk, some alternatives, such as almond milk, require large amounts of water and energy to produce. Additionally, the cultivation of certain crops for plant-based milk production can contribute to deforestation and other negative environmental impacts [129]. Plant-based milk substitutes often require processing to mimic the taste and texture of dairy milk, which can involve the addition of stabilizers, emulsifiers, and sweeteners. While these additives are generally recognized as safe, some individuals may prefer to avoid them for personal or health reasons. It is important to note that while plant-based milk substitutes have limitations, they can still be a suitable option for those who choose to avoid dairy milk due to personal preferences, dietary restrictions, or ethical reasons.

**10. Summary and Future Directions**

 The tendency towards plant-based foods, which is a new approach, has increased in recent years due to reasons such as the increase in the number of individuals with lactose intolerance and cardiovascular disease, the spread of vegan lifestyle, the replacement of animal-derived protein with plant-derived proteins may contribute to sustainability and climate change continues to increase day by day. Increasing world population combined with limited resources (arable land and fresh water) has created the need for alternative protein sources to meet global protein requirements. Plant food sources are accepted as inexpensive sources of both macro and micronutrients to manage malnutrition and improve the nutritional status of individuals in underdeveloped and developing countries. However, plant based beverages generally have lower protein content than dairy beverages. In the plant-based beverage industry, there is a need for nutraceutical-enriched beverages that are balanced in terms of nutritional content and can replace meals (protein quality and quantity). There is a need for research on preparing more nutritious and delicious personalized products for the functional plant-based beverage industry. In future studies, it is recommended to fortify the plant based beverage in terms of protein, calcium and vitamins. In addition, the sensory properties of the developed plant based beverages can be investigated by applying different flavoring agents. It is recommended to determine consumer preferences based on the glycemic index, shelf life and demographic characteristics of the product and to conduct in vivo studies.

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