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REVIEW



Lactose Intolerance and Its Dietary Management: An Update

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ABSTRACT

Milk is the most common food consumed worldwide and is also a major ingredient in the preparation of various dairy products. However, despite the high production and consumption of milk and milk-based products, there is a large percent of the world's population that suffer from allergies to milk solids and lactose intolerance. Lactose intolerance specifically means the inability of the body to breakdown the sugar to its simplest form for assimilation and it is due to the inefficiency or lack of the enzyme in the human body. The most convenient prevention method for the affected population is to avoid milk and milk-based products but this may be a cause of development of other health related issues that result from inadequate nutrient consumption. To help find an alternative to this problem, this study aims at first studying the underlying information on lactose intolerance and then studying plant-based beverages as a possible alternative to milk and milk-based products.

KEY TEACHING POINTS

- Lactose intolerance specifically means the inability of the body to breakdown the sugar to its simplest form for assimilation and it is due to the inefficiency or lack of the enzyme in the human body.
- Consumption of probiotics may help relieve the symptoms of lactose intolerance.
- Soy beverage can be an economical alternative for lactose intolerant populations and has calcium content comparable to bovine milk.
- Calcium absorption in fortified plant based beverages depends upon type of calcium salt used.

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beverages; lactose free
alternatives

Introduction

Milk, produced by the mammary glands of mammals, is considered to be a complete and balanced food. It is highly nutritious and its main constituents (with approximate amount) are water (more than 80%), fats (more than 3%), protein (more than 3%), lactose (more than 4.5%) and ash content (more than 0.5%), micro and macro-elements (1,2). The dairy industry has been extensively exploited to developed a range of products with various nutritional benefits from raw milk; butter, cheese, ghee, whey, ice-cream, yoghurt etc. In the food industry, lactose (extracted from milk) is also used in the production of confectionary, bread and even sausages because it enhances the texture of the product and also the color. The sugar is approximately a third as sweet in the case of saccharose sugar and less than half sweet as glucose sugar (3).

Milk consumption from domesticated animals can be traced back to Northwestern Anatolia during the 7th millennium BC and its consumption and use especially as a food ingredient has been widespread ever since contributing to the nutritional requirements of humans (4). Currently, for approximately 6 billion people worldwide, milk and milk products constitute a major fraction of their diet, however, the other portion of the population suffer from lactose

intolerance and hence cannot consume such products (5). According to US National Institutes of Health and (6) around 65% of worldwide human population has reduced ability to break down the lactose sugar after childhood. Welsh et al. (7) stated that the lactose non-persistence is related to the ethnicity among various populations. Lactose intolerance in children will start to manifest at the age of 2-3 years and fully be expressed by 5 to 10 years of age but may vary also among various populations. Among adults the lactose intolerance is more among individuals of East Asia origin with more than 70% people diagnosed with this ability and communities that have been consuming milk-based products that are not fermented, the intolerance level is approximately 5% e.g. North European populations, hence the dire need to provide lactose free alternatives to this population (8).

For lactose intolerant people, their only treatment is their lactose free diets which lessens the long-term complications that arises due to untreated lactose intolerance (9,10) and plant-based beverages being lactose free is a feasible alternative. These plant-based beverages are being consumed worldwide because of lifestyle choice where a consumer desires a healthy lifestyle, to avoid any animal cruelty, milk allergies and intolerances and also environmental awareness

Table 1. Lactose content in various types of commonly consumed milk.

Type Animal of Milk	Mean lactose content (g/100g)	Reference
Cow milk	5	Heine et al. (15)
Buffalo Milk	4.69	Rasheed et al. (16)
Goat milk	4.33	Rasheed et al. (16)
Sheep milk	4.76	Rasheed et al. (16)
Camel milk	3.65	Khaskheli et al. (17)
Mare milk	6.75	Mariani et al. (18)
Donkey milk	6.6	Guo et al. (19)
Reindeer milk	2.5	Gjølstein et al. (20)
Human milk	7.5	Heine et al. (15)
Yak milk	5.03	Li et al. (21)

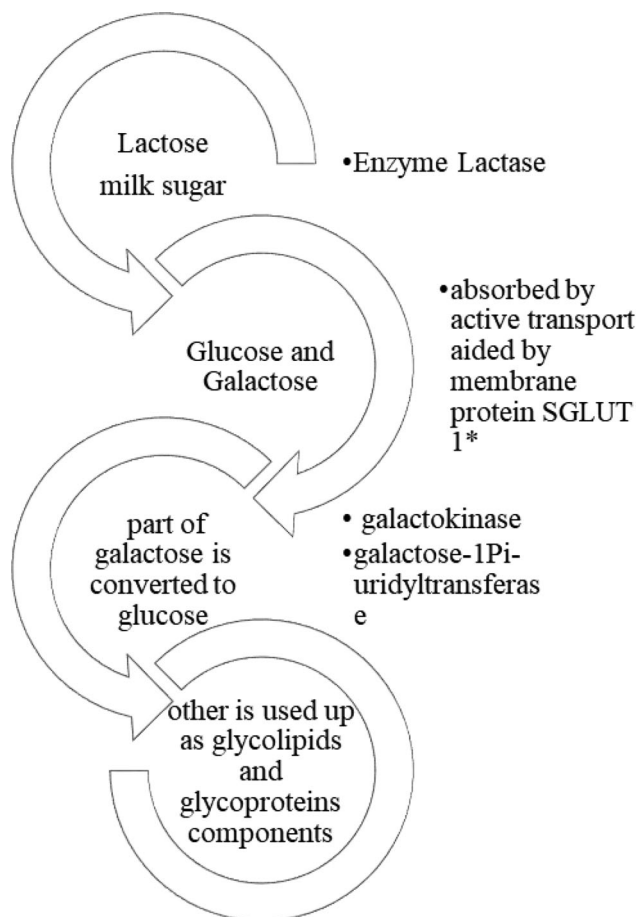
(11). These beverages have the ability to replace the bovine milk with possible fortifications based on their types and can prove to be even more beneficial.

Lactose digestion and intolerance symptoms

Lactose sugar (β -galactosyl-1,4 glucose) is the main carbohydrate found in milk and human milk constitutes around 7% and 4.8% in bovine milk by weight of total milk (12). It is hydrolyzed to glucose and galactose by lactase enzyme produced in the lining of the small intestines in the human body (13,14). The amount of lactose sugar varies highly among various types of milk and also among dairy products as shown in Table 1. Lactase enzyme is a β -galactosidase (EC 3.2.1.108) found majorly in the mid-jejunum and located on the enterocyte surface of the microvilli in the small intestine. After the breakdown of the lactose to its monosaccharide sugars, it is easily absorbed by the enterocyte cells and used up by the body. The fate of lactose sugar after breakdown is shown in Figure 1.

The occurrence of lactose intolerance can be detected by its symptoms. The symptoms normally occur within 30 minutes to few hours after consumption of food or drink containing lactose. However, the symptom intensity differs with the amount consumed, i.e. consumption of 10 g of lactose shows fewer symptoms as compared to consumption of 20–40 g of lactose (22). Other factors that determine fatality include gut transit, microflora in the gut, lactase expression and sensitivity to fermented products. Lactase expression is dependent on the genetic expression of an individual which further affects the enzyme expression. The colonic microflora is the one responsible for the fermentation of the undigested lactose (23).

Patients having lactose intolerance may show either gastrointestinal or extra-intestinal symptoms (24). The gastrointestinal symptoms vary among diarrhea, nausea, bloating and abdominal pains (25). A major contributor to these symptoms is the gut microbiota that ferments lactose sugar causing bloating. Bloating can also occur due to the osmotic potential of the lactose molecules in the gut. Constipation may also be felt by some patients that can be as a result of the activity of some micro-organisms to reduce carbon dioxide to methane (26). The extra-intestinal symptoms mostly seen in the patients are headache, weakness, joint or pain in the muscle, weak concentration and mouth ulcers (24).

**Figure 1.** Fate of lactose sugar in the body.

*SGLUT 1, sodium- glucose linked transporter 1, is coupled with glucose or galactose and Na^+ to the enterocyte from the intestinal lumen.

Lactose intolerance types and causes

Lactose intolerance can be broadly classified into three types, congenital lactase deficiency which is the rarest of the types and is caused by the inheritance of the defective alleles of the gene. There is no or reduced activity of the enzyme from birth. It is mainly characterized by diarrhea after feeding on breast milk. The low lactase enzyme activity may be due to pre-mature birth (28–32 weeks), in normal babies, the expression and activity of the enzyme would gradually increase after 34 weeks upto birth (27). Primary lactase deficiency or adult-type hypolactasia which is the most common type and is caused due to the progressive decline of the enzyme activity due to age. The most common time it occurs is from 5–7 years and has the maximum effect at the age of 30 to 40 years. 70% of the world lactose intolerant individuals have been estimated to suffer from this type of deficiency. Secondary lactase deficiency emergence may be due to interference by other diseases, i.e. Celiac disease and Chron's disease which damage the microvillus site of enzyme activity (28,29).

According to the intensity of symptoms and absorption, it can also be referred to as; lactose maldigestion which is the inability of the lactose sugar to be inefficiently digested and can be due to absence or inefficiency of lactase enzyme. If the sugar is not absorbed in the small intestines then the

condition is known as lactose malabsorption. The emergence of the symptoms after lactose malabsorption is lactose intolerance (27) however, a person having lactose malabsorption need not be lactose intolerant (30). Also, insufficiency of the lactase enzyme does not necessarily mean a person is lactose intolerant since only about 50% activity of the enzyme is required for the breakdown of the sugar (31) and the enzyme activity is usually retained to 5-10% (28). Based on the activity of lactase enzyme, the lactose intolerance can be divided into two types: alactasia which has no lactase activity and hypolactasia, which shows reduced activity of the enzyme and therefore causing an imbalance between the lactose consumed and its breakdown ability (32).

The study of genetic expression is also valuable in the case of congenital type of lactose intolerance. The gene responsible for encoding the enzyme lactase is in the 2nd chromosome, long arm at the 21st position (2q 21) and has 17 coding regions (32). The enzyme is made up of 1927 amino acids from the lactose (LCT) gene and has two activities, Lactase hydrolase activity in which it breaks down the lactose to glucose and galactose and also cleaves other substrates, i.e. cellobiose, cellotriose etc. and Phlorizin hydrolase activity – responsible for the breakdown of β -glycosidases by large hydrophobic alkyl chain (28)

Enhattah et al. (33), gave two different polymorphisms that affected lactase enzyme expression. The first one was on minichromosome maintenance complex component 6 (MCM6) that is located near the lactose gene (LCT) but has an indirect effect. The gene overlaps a segment of the lactose gene affecting the activation or inhibition of the expression of the lactase enzyme (34). The other most frequent single nucleotide polymorphisms (SNP) are the C/T-13910 and G/A-22108 that is found at 14kb and 22kb position respectively. It mainly deals with either cytosine, C location or thymine, T at the position 13910 or Guanine, G and Adenine, A at 22108 position. An individual having CC or GG is an intolerant phenotype whereas CT/TT or GA/AA is associated with continuous expression of the enzyme (35,36).

Clinical diagnosis of lactose intolerance

Initially, lactose intolerance was deduced by measuring the serum glycemia after 30 mins on consumption of 50g of lactose containing foods. Digestion of lactose would raise the glycaemic index to more than 20 mg/100 mL and therefore the presence or absence of the enzyme could be concluded (27). A modification was then made to this process such that the enzymatic activity in the small intestinal mucosal membrane was determined. This method was not only expensive but also the enzyme distribution may be irregular in the mucosal membrane of the small intestines (37).

Hydrogen breath test (HBT) is one of the methods developed later for intolerance detection; it is highly sensitive and specific, has relatively lower cost and is noninvasive. This test is done orally and is dependent on the amount of hydrogen expelled and collected after every 20-minute

interval for 2 hours on the administration of lactose (1 gm/kg of the body weight and is dissolved in a solution of 20% water concentration) (38). Hydrogen is produced by the gut microbiota when the lactose has not been absorbed or digested. Some amount of the hydrogen produced is released by the respiratory system and is hence collected by the air exhaled. The results are positive if the hydrogen level is greater than 20 parts per million or if there is an increase in hydrogen or methane in the breath for three continuous samples. Most studies show that the HBT has a sensitivity of more than 76% and specificity of more than 90% (39,40). There might be a possibility of a false negative scenario that may arise due to presence of bacterial overgrowth in the small intestines or antibiotic administration before taking the test hence low production of hydrogen. Some recommendations given are to avoid the use of antibiotics four weeks prior to the taking of the test, consumption of complex carbohydrates a day before the test and on the day of the test, a 12 hour fast is also done, avoidance of any physical activity or smoking is mandatory (27).

Another method for detection is the genetic method in which single nucleotide polymorphism (SNP) C/T-13910 that is related to lactase persistence is done especially among the Caucasian population where it is more prevalent. In this, the genotype CC represents individuals with lactose intolerance and genotype TT are for those with lactase persistence. If compared to the HBT, it has 97% sensitivity and 95% specificity (40,41).

Lactose tolerance test (LTT) is also another method by which hypolactasia can be detected. 50g of lactose is dissolved in water and given to the patient to consume after which blood samples are then collected after a 15 mins time gap for a period of one hour. The plasma glucose concentration is determined from the blood sample and a concentration of more than 1.4 mmol/L or more can be inferred that the lactose is being digested whereas no increase in the plasma glucose levels can be due to the fact that lactose is not being absorbed in the small intestines (42).

Current management of lactose intolerance

The major and most common treatment of lactose intolerance is avoidance of food containing any amount of lactose. Some foods also contain hidden lactose and caution should be taken while consuming them and they include bread and bakery products, breakfast cereals, pancake, biscuit and cookies mix, instant soups, breakfast drinks and potatoes, margarine, salad dressings and certain candies and sweets (43). However, some studies show that patients can tolerate about 12g of lactose that is equivalent to 1 glass of milk and 12-18g of lactose may also be tolerated if is taken at different time intervals, i.e. in different gapped meals (44,45).

Individuals with primary lactose intolerance can restrict taking foods containing lactose for 2 to 4 weeks to trigger remission and lactose containing foods can be gradually given to the patients (40). However, complete cutoff of milk and milk-based products may reduce the levels of calcium, phosphorus and some vitamins in the body and this may

Table 2. Lactose free alternatives available for the common lactose containing products

Lactose containing product	Alternatives available	Remarks	References
Dairy Milk	- Plant based beverages - Lactose free milk	Prepared from plant sources and are not similar nutritionally to dairy milk but can be fortified. Lactose is hydrolyzed and the resultant product is nearly similar to bovine milk.	Aydar et al. (11) Facioni et al. (50)
Ice- cream	Plant based frozen dessert	Prepared from extracts obtained from plant sources, i.e. soy milk,	Raja et al. (51)
Cheese	Lactose free cheese	The cheese milk is incubated with lactase enzyme before renneting resulting to break down the lactose sugar.	Facioni et al. (50)
Paneer	Plant based paneer, i.e. Soya Paneer	Prepared from soymilk or blended with dairy milk and has a high protein content.	Raja et al. (51)
Infant formulae	Lactose reduced or free formulas	The lactose in these formulas are reduced to tolerable amounts or completely removed but may be expensive.	Lasekan et al. (52)
Yoghurt	Yoghurt prepared from plant-based beverages	Yoghurt is prepared from the plant extract and the carbohydrate source is different and does not contain any amount of lactose. Can be prepared from soy milk, corn milk etc.	Favaro et al. (53)
Sweets i.e. Guabjamun and Shrikhand	Sweet prepared from plant-based beverages	These products can be prepared from either blending plant extracts with dairy milk or complete use of plant-based milk and can be cheaper.	Padghan et al. (54)

lead to the reduction in the bone density hence it should only be recommended to patients showing severe symptoms (46). Lactase can also be administered to a patient by enzymatic supplementation of diet to aid in the hydrolysis of the lactose. They can be given in the tabular form or by drop wise and is administered 5 to 30 mins before consuming a lactose diet (47,48). The effect though is short-lived and not much evidence has been given to this treatment method.

Continuous administration of lactose in an increasing fashion can improve the tolerance levels among the patients through colonic adaptation (45,49) but not many studies have been done to further support this finding. Lactose intolerance symptoms can merely be avoided by consuming lactose free foods or avoidance of lactose containing foods. Table 2 shows possible feasible alternatives of lactose containing products. Due to the numerous advantages of dairy milk, i.e. calcium content, there are several studies that show the development of lactose free milk which is produced by the pre incubation of β -galactosidase that digests the lactose in milk (56,57). Hydrolysis of the sugar also enhances the sweetness of the milk similar to adding 2% of normal sugar (58).

For the preparation of lactose free milk, there are two main processes involved. The first process is a batch process where the lactase enzyme is incubated in milk for 24 hours with continuous stirring to avoid cream formation. The incubation is also done at 4-8 °C to stop microbial action and these enzymes possess a high activity at these temperatures. The milk thereafter undergoes the normal processing steps and the enzymes are inactivated during the pasteurization or sterilization stages. The hydrolysis of the lactose

sugar causes an increase in sweetness of the milk; techniques such as ultra-filtration, nano-filtration and some chromatographic techniques are used to reduce the sugar content hence producing a drink that is similar to the dairy milk. The second process is the aseptic post-hydrolysis process. In this method, after milk has been processed by UHT treatment, a lactase solution is added to the milk before it is packed. The UHT milk is normally kept for 3 days before it is distributed and this time period is sufficient for the hydrolysis. The time and temperature duration are favorable for the enzyme activity hence it is required in relatively lesser quantities as compared to the batch processing (50).

Consumption of fermented foods and drinks containing active cultures helps increase the digestion of the lactose sugar. These products are rich sources of calcium, vitamins like B6, B12, riboflavin, proteins and are rich probiotic sources (58). The cultures of *Lactobacillus delbrueckii* sub sp. *bulgaricus* and *Streptococcus thermophilus* improve digestion if their amount is 10^8 Colony Forming Units (CFU) per gram (59). Use of probiotic strains especially those that can synthesize β -galactosidase enzyme could be administered to lactose intolerant patients (27). Patients that reported irritable bowel syndrome when administered *Lactobacillus plantarum* and *Lactobacillus acidophilus* for a duration of four weeks showed relief from this symptom especially bloating and abdominal pain (60,61). *Lactobacillus* and *Bifidobacterium* strains have shown specific advantages to the lactose intolerant patients because of their β -galactosidase activity (62). *Bifidobacterium longum*, *Bifidobacterium animalis* and *Lactobacillus rhamnosus* specially has shown to reduce the symptoms of lactose intolerance and has been shown to modify the colonic environment (63) hence probiotics or

Table 3. Various types of plant-based beverages.

Source	Examples	References
Cereal based beverages	Oat milk	Helsing (65)
	Rice milk	Sethi et al. (66)
	Corn milk	Supavititpatana et al. (67)
	Spelt milk	
Legume based beverages	Soy milk	Helsing (65)
	Peanut milk	Sethi et al. (66)
	Lupin milk	
	Cowpea milk	
Nut based beverages	Almond milk	Sethi et al. (66)
	Coconut milk	Xiaoli (68)
	Hazelnut milk	
	Pistachio milk	
	Walnut milk	
Seeds based beverages	Sesame milk	Sethi et al. (66)
	Flax milk	
	Hemp milk	
	Sunflower milk	
Pseudo-cereal based beverages	Quinoa milk	Sethi et al. (66)
	Teff milk	
	Amaranth milk	

fermented foods rich with these strains prove helpful to the patients.

Plant based alternatives

One probable substitute for dairy milk is the plant based beverages. Plant based beverages can be defined as fluids that are obtained from the crushing or size reduction of plant material e.g. cereals, nuts, that is then obtained by mixing or soaking in water with homogenization which further gives a particle size distribution of 5-10 μm similar in appearance and texture to dairy milk (64). The plant-based beverages be classified into 5 sub-groups according to their source of extraction as shown in Table 3. Recently, the acceptance of plant sources, i.e. cereals and legumes as functional foods and nutraceuticals because of their health benefits, i.e. rich source of dietary fibers, minerals, vitamins and antioxidants (69) has also enhanced the research on the development of variety of plant-based beverages and contributed to its acceptance. This has led to the development of various products such as fermented products - yoghurt, dahi, sweet dishes - Shrikhand, Gulabjamun (54) or ice-creams (55,70). These products can be developed by complete use of the obtained plant beverage or by addition of some percent of dairy milk.

To act as a replacement of bovine milk, the plant-based beverage must match the following energy requirements; 64kcal of energy, 4.65 g carbohydrate (29% energy), 3.66 g of fat (46% energy) and 3.28 g of protein (21% energy). The plant-based beverages with such comparable energy distributions are almonds, rice and coconuts (71). These plant-based beverages have been fabricated in a manner such that they can be used similarly as the bovine milk and are comparable in their look, feel, taste and shelf-life (72). The plant-based beverages and animal milk production and manufacturing processes are quite similar following a same pattern. The animal-based milk preparation follows the standard separation, standardization, homogenization and pasteurization or sterilization or UHT treatment. A large-scale plant-based beverages preparation is majorly dependent on plant type

and maximum yield. The general processing steps of the plant-based beverages is as shown in Figure 2. The production process of plant-based beverage is first (for shelled products, i.e. in coconut, peanut), removal of the shell or dehulling (products that have hulls or chaff). One commonly used method is by soaking in hot water (73). The flesh obtained is then dried and also for the products that do not have a shell or is fresh (74). Some raw material like peanut, almond, hazelnut, sesame and grain (75-77) are subjected to roasting and this process is done to increase the emulsion stability index and the solubility of the protein (78).

The next process is peeling that can either be done by use of acid, base or by water. The most preferable one is the acid-base peeling because it is faster, i.e. peeling done in walnuts or almonds in water is an overnight process roughly taking up 18-20 hours whereas use of 2% citric acid at 90 °C can be done within 2-3 minutes (68,79,80). The next step is soaking the product in water and for different raw materials it serves different purposes, i.e. in tiger nuts, it is done so as to increase the yield of the beverage obtained (81) or it is used to get rid of the toxins in the raw material because of lesser apparent amylose and can be used to soften the raw material, i.e. in rice kernels hence reducing the blanching time (82). This process is then followed by blanching that is done mainly to inactivate the enzymes and also reduce the number of micro-organisms in the raw material (66). Wet milling is then done by addition of a certain amount of water to the raw material and then ground together followed by filtration to separate the beverage and the cake. After obtaining the raw beverage, other ingredients, i.e. lecithin, Gellan gum, can be added so as to enhance the stability of the solution. Others such as cane sugar and sea salt can be added to enhance flavor and improve its acceptance. Fortification and enrichment with other minerals and nutrients, i.e. calcium, vitamins, proteins can be done so as to match the dairy milk properties. This product can then be sterilized to enhance its shelf life and is then packed (11).

The plant-based beverages are a richer source of fiber, unsaturated fatty acids and are cholesterol free as compared to bovine milk (11). The complete removal of milk and milk-based products could lead to the emergence of various deficiency diseases, it can promote poor bone health (83), high blood pressure (84) and diabetes mellitus (85) hence it is necessary to find a suitable alternative providing the same benefits. Figure 3 shows best type of plant-based beverages for various types of populations.

Soy beverage is the most common and widely consumed among all the plant-based beverages among most nondairy consuming populations because of its high protein content, per 8 ounces (236.6 ml) of soy beverage there is 7 g of protein which is quite similar to bovine milk (86). For children within 1-8 years, apart from cow's milk, soy beverage is the only plant-based beverage considered nutritious enough. Children at that age group if given a continuous diet of plant-based beverages are usually found to have a shorter height and most suffer from kwashiorkor (50). Soy beverage despite being rich in protein among the other plant-based

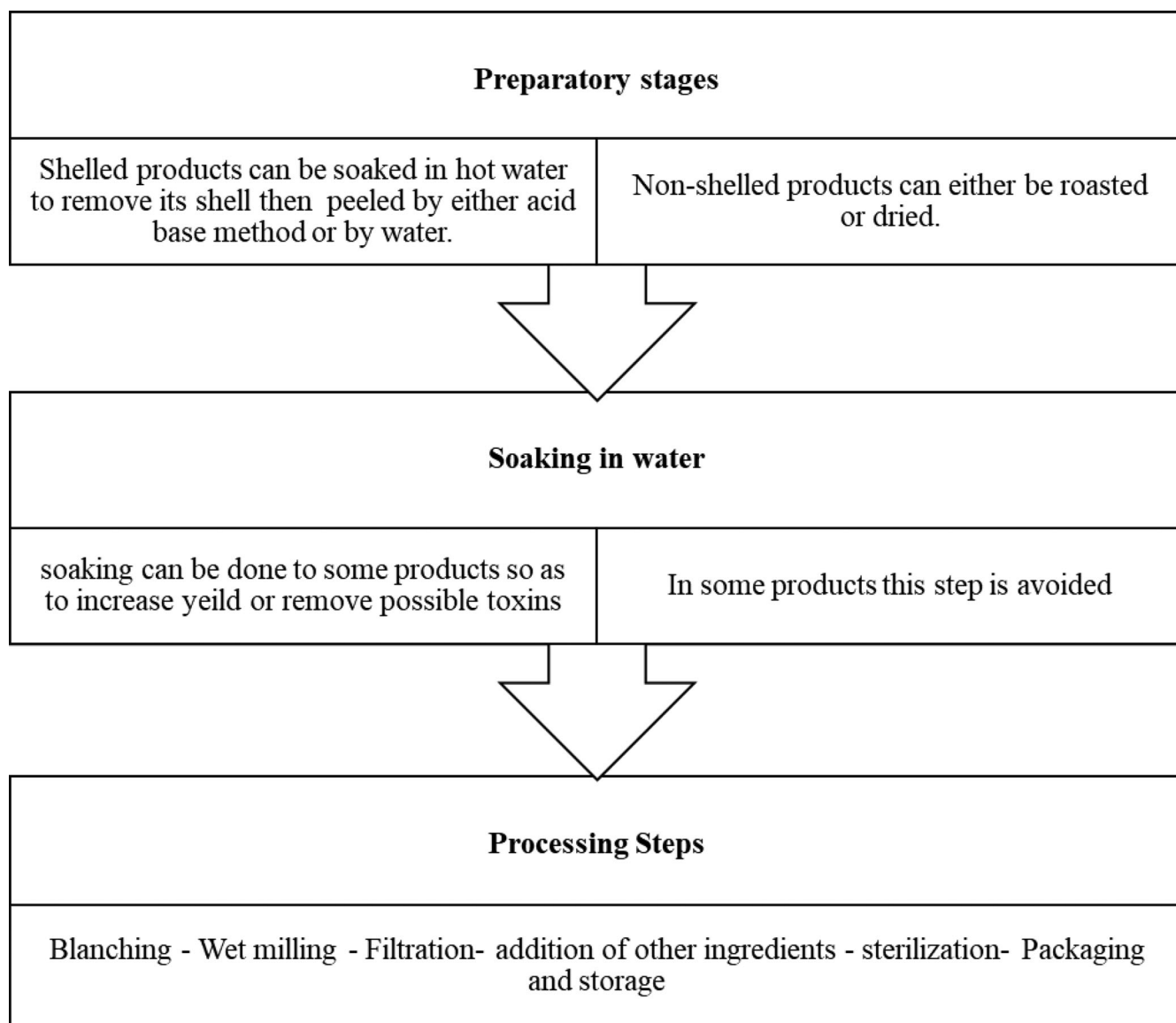


Figure 2. General process of preparation of plant-based beverages.

beverages, contain isoflavones (in 200 g of soy beverage approximately contains 9.96 mg genistein, 6.68 mg daidzein and 0.94 mg glycitein), phytic acids, sterols and saponins that contribute to its numerous health benefits (87). The anti-nutritional factors present in soy can also be reduced by the help of fermentation hence bioavailability of the bio-molecules is maximum (86).

For lactose intolerant patients, the most advised plant-based drink is almond beverage (88) over soy beverage. Almond beverage is a colloidal dispersion that is procured from filtering a solution of water and powdered or pasted almond solution (89). The beverage is also a good source of anti-inflammatory, anti-tumor, anti-hyperlipidemic and antioxidant bioactive compounds (90). The major downside of almond beverage is its allergic properties (tree nut allergy) because of amandin, legumin (11s) and prunin proteins (91), also due to its high fatty acids content it has the ability to harbor pathogenic micro-organisms (*E. coli* O157: H7 and *L. monocytogenes*) that can cause serious health implications. Although processing can be used to reduce the

microbial load, the high temperatures can reduce the nutritional value to the beverage (92,93).

Rice beverages have less allergenic properties with less than 1% among children hence it can be administered over the other allergen containing beverages. It is also a low-fat beverage having unsaturated fatty acids mainly (94). It contains more starch (approximately 90%) than protein (approximately 10%) (95) and is also a rich source of vitamins A and E. These drinks however, may contain some amount of arsenic hence it has been suggested to avoid giving the beverage to babies and younger children (94) and they need to be fortified with iron since it is lost during processing where the rice bran is removed (bran has most of the iron, approximately 85%) (96). Another beverage with low allergenicity is hemp beverage which is also a rich source of poly-unsaturated fatty acids (predominantly linoleic and α -linolenic acid –80-90 g/100g of total fatty acids present). The beverage is also good for patients suffering from obesity, rheumatoid arthritis, Alzheimer's and inflammatory bowel syndrome because of the presence of

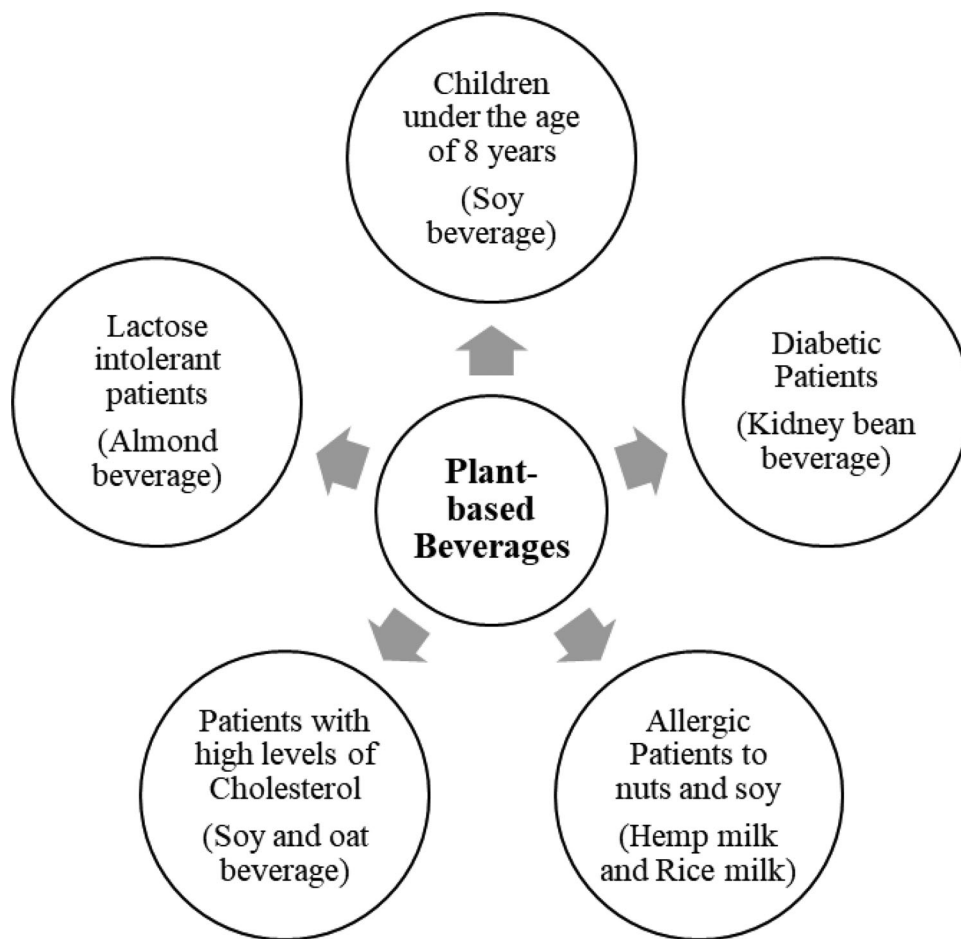


Figure 3. Best plant-based alternatives for various types of populations.

Table 4. Comparison between the plant-based beverages and dairy milk.

Nutritional information (per 100g)	Plant-based beverages (Range – highest to lowest)	Bovine milk	References
Energy (kcal)	Coconut milk- 92 Hemp milk-15	47	USDA (98) Astolfi et al. (99)
Fat (g)	Coconut milk- 6.0 Rice milk- 0.9	1.5- 6.0	Chalupa-Krebzdak et al. (72)
Carbohydrates (g)	Coconut milk-9.41 Almond milk-0.58	4.9	Mäkinen et al. (100)
Proteins (g)	Soy milk-3.16 Almond milk-0.59	3.57	
Calcium (mg)	Almond milk-197 Hemp milk-118	163	

cannabidiolic acid. Hemp beverage is also highly unstable because it is oil in water emulsion but use of high-pressure homogenization has been the most economical method against this issue (86). Kidney beans beverage because of its low glycaemic index (less than 27) has been proven good for diabetic patients (97).

On the basis of nutrient composition, the plant-based beverages do not have adequate nutrient composition as that of dairy milk. Table 4 gives a numerical nutrient comparison between the bovine milk and plant-based beverage. Fortification of the plant-based beverages can be used to overcome the inadequacy and nutrients such as calcium and vitamins such as A, B2, B12, D2 and E are the possible minerals and vitamins that can be added in the beverages (66).

When fortifying plant-based beverages with calcium the type of salt used should be taken into consideration. When the beverage is fortified with tricalcium phosphate, 75% absorption is noted when compared to bovine milk and with calcium carbonate, no difference in absorption rate is noticed (72). When the calcium salt is exposed to heat, the calcium precipitates the proteins especially in soy beverages which may reduce the calcium content and its absorption. Centrifugation at 3740 g can also separate 82% to 89% calcium in the beverage while cow's milk only precipitates 11% of the total calcium (100). Shaking of the beverage pack is highly emphasized among various studies because unshaken packs only provided 31% of their claim and approximately 59% when the pack was shaken (72). Studies indicate the

use of mixtures of hydroxycarboxylates increase the solubility of calcium to avoid its precipitation and increase its bioavailability (101).

The presence of inhibitors like phytic acid reduces the absorption and bioavailability of major minerals and nutrients, i.e. calcium is hindered by phytates and oxalates (102). The bioavailability of the major minerals can be increased by; allowing the seeds to germinate, fermentation of the beverages, using chelating agents (citric acid for iron bioavailability) or exogenous phytase (103). There is also deterioration in the oral health because of the addition of the sweeteners which may cause tooth decay or dental caries among other diseases (104). The plant-based beverages also possess a beany flavor like in soy beverage or chalky mouthfeel due to the presence of large insoluble particles that contribute to its reduction in consumer acceptability but a repeated consumption and exposure to these beverages boosts its acceptability among the consumers (100). These disadvantages do not have a major impact on its sales, a study on the North American market of these plant-based alternatives by Research and Markets gave that these beverages alone accounted for \$6 billion in the 2016 US sales and a projection was given of about \$28 billion by 2021 (105).

Conclusion

Lactose intolerance is a common disease worldwide and may manifest at the early stages of childhood or developed gradually through adulthood. Even with the growing lactose intolerant populations, most packaging does not give a lactose free label; hence care should be excised by the patients on the products they purchase. Complete exclusion of milk and milk-based products from the diet is not only a difficult task but also can lead to emergence of various diseases, i.e. poor bone health as a result of reduced calcium intake. Plant-based beverages is a common replacement and even though it cannot completely tally the nutrient content of bovine milk but by the help of fortifications, it may be able to give the required nutrition to match dairy milk i.e. on the case of calcium where calcium carbonate should be the preferred choice.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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