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Role of Plant Based Milk Alternatives as a Functional Beverage: A Review

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ABSTRACT

Plant based milk alternatives are emerging functional beverages. Dietary transition to veganism, rising prevalence of endocrinal disorders, lactose intolerance, cow milk allergies and intolerances, acne is an avenue for increasing need for milk alternatives. This review considered research papers from the past 11 years (2011 - 2022) from PubMed database, using keywords - plant based milk alternatives, plant based milk substitutes, plant based milk analogues, nutritional composition of plant based milk versus cow milk. Five commonly consumed plant milks were selected and discussed further. Coconut milk had highest and almond milk had lowest total energy. Total carbohydrate was highest in rice milk and lowest in almond milk, but oat milk had the highest sugar and coconut milk had no sugar. Soy milk and coconut milk had better protein content. Coconut milk had higher fat - lauric acid and MCTs. Vitamins A, D and E were found to be a good source in oat, soy and almond milk. All 5 plant milks were a good source of calcium. Plant milks were beneficial for lactose intolerance, reducing cholesterol, diabetes, CVD, cancer, and had immune boosting properties. Hence, it's a healthier functional beverage when cow milk needs to be replaced in the diet.

Keywords: plant based milk alternative, nutrition, health benefits

INTRODUCTION

Ever since humankind started rearing animals and embraced dairy, milk became an essential component of man's diet. Cow's milk has been consumed for hundreds of years all around the world as it is regarded as a complete food since it contains: proteins (of high biological value), lipids, carbohydrates (CHO), vitamins and minerals that are essential for human health. It also has anti-microbial properties and reduces the risk of respiratory infections and fever (Vanga and Raghavan, 2018: 10-20). India is the world's top producer and consumer of animal-derived dairy products. It is one of India's largest agribusinesses, accounting for 4% of the country's GDP. In the previous five years, the Indian animal-derived dairy business has risen by 12 %, with value-added products driving market development. Plant-based dairy, on the other hand, is gaining popularity across the world, albeit slowly (Narsaria and Rajyalakshmi, 2020). This is because beverages are no longer just thirst quenchers in today's world; consumers look for specific functionality that fits into their lifestyle. Functionality in these beverages may address various needs—boosting energy, combating aging, fatigue and stress, targeting specific diseases. Milk alternatives, for example, are a major functional requirement to address issues such as cow milk allergy, lactose intolerance, calorie concerns and

hypercholesterolemia (Sethi et al., 2016: 3408-3423).

These alternative milks are also called as plant extracts, 'non-dairy alternatives' (Silva et al., 2020: 131; Vanga and Raghavan, 2018: 10-20). Silva et al., (2020) described plant-based milk alternatives as water soluble extracts resulting from the breakdown of plant material (cereals, legumes, nuts and oilseeds) and then homogenizing it to make it look like cow milk (Silva et al., 2020: 131). In contrast to the above study, according to Pritulska et al., (2021) the term "plant-based milk" is incorrect, as this beverage is extracted from nuts, oilseeds, cereals and mixed with a specific proportion of water. This name can mislead the consumer thinking that it has similar nutritional value like the cow milk. Thus, it should be named as "plant-based milk analogues", as analogues seem to resemble or are similar to other things. And since these products have similar appearance and content, it is called milk. A general classification of the plant-based/vegetable milk alternatives is given in Table 1.

Plant-based milk such as soy milk, almond milk, and oat milk have recently made their way to the cafe menus and shopping lists of Indian consumers. Since around 2020, plant-based milk accounted for 15% of the total dollar sales in the United States (Narsaria and Rajyalakshmi, 2020). According to market research firm IRI, in the US 14% of the households buy vegan milk (Chiorando, 2020). According to the data below, it can be anticipated that Indian consumers may incorporate this product, along with animal-derived dairy (Narsaria and Rajyalakshmi, 2020).

Both in India and US consumers claim that they will be using both types of milk and cow milk being their staple. Even among those who purchased plant-based alternatives, 90% continued to purchase cow's milk. This clearly demonstrates that the potential for plant-based alternatives is increasing alongside cow milk rather than instead of it. However, the sales of cow milk are decreasing with the rise in plant-based milk options (Narsaria and Rajyalakshmi, 2020; Stewart, 2020).

The current review is being undertaken with the aim of understanding the various types of plant-based alternatives to milk as when compared to cow milk, most of the plant-based milk alternatives lack nutrient balance; however, they contain functionally active components with health-promoting properties, which attracts health-conscious consumers. And this study was also undertaken to understand the various kinds of plant-based milk alternatives and its nutritional content.

Articles from the past 11 years (January 2011-June 2022) were included for review. The search strategy for the review was as follows: a number of studies searched on engines such as PubMed, and ResearchGate. The key words used were Plant based milk alternatives, plant based milk substitutes, plant based milk analogues, comparison of plant based milk and cow milk, nutritional composition of plant based milk were the different search terms used to find the article.

Plant Based Milk alternatives

Plant-based or non-dairy milk substitutes are a rapidly growing market worldwide due to changing needs and urbanization (Park, 2021; Sethi et al., 2016: 3408-3423). Despite having fewer nutrients than cow milk, it is accepted due to its functional properties and the various downfalls of cow's milk. Firstly, due to the presence of various pathogens such as Salmonella, Escherichia it can cause widespread outbreak of diseases. Also because cow milk allergy is common in infants and children, likewise another widespread problem being lactose intolerance on consumption of cow milk, as it is the primary source of lactose in human diet, and yet other issues of cow milk consumption is higher calories and hypercholesterolemia, and thus plant-based alternatives can provide them another option. Few studies have also discovered a link between higher

cancer risks and milk consumption (Sethi et al., 2016: 3408-3423; Vanga and Raghavan, 2018: 10-20). Plant-based milk also contains functional properties that have health promoting effects (1,9). Veganism and vegetarianism have increasingly moved people and the food industry to seek plant-based alternatives (Vanga and Raghavan, 2018: 10-20).

According to the research done by Pritulska et al., (2021) in Ukraine, it was seen that the taste was the most important factor in choosing the product and almond milk (20.4%) was the most preferred plant-based milk analogue followed by oat (15.3%), soya (12.3%), rice and buckwheat (10.1%) each and 16.2% did not preferred plant-based milk analogues. The consumption of plant based milk analogues was highest among those who were 25-30 years of age followed by 18-24 years and then by above 50 years of age. In India, it was observed that the consumption of soy milk and almond milk was highest in the last 12 months (56% and 54%) respectively, followed by plant-based cheese (31%), oat milk (29%), and plant-based yogurt (21%). (Narsaria and Rajyalakshmi, 2020)

Types of plant based milk alternatives

Plant based milk are lactose and cholesterol free but have poor quality of protein and if these products are used as a protein source to replace cow's milk in the diet, they may pose a risk because they can cause protein deficiency and severe illnesses. Plant-based milk substitutes differ in nutritional value; therefore, fortifying with protein, adding enzymes, or combining two or more types of plant-based milk to obtain a product with a high nutritive value roughly comparable to cow's milk is an important step in the manufacturing process. But these processing treatments can destroy the micronutrients present in the product and thus, it needs to be supplemented through diet (Silva et al., 2020: 131).

Rice Milk

Rice (Oryza sativa) is a staple cereal that is consumed by about half of the population (Padma et al., 2018: 426-428). Rice milk can either be made from white or brown rice. Rice is rich in carbohydrates and thus during processing it is broken down to sugars and impart sweet flavor. However, consumption of rice milk instead of cow milk results in malnutrition as it is low in protein, lipids, vitamins and minerals (Karimdastjerd and Konsukan, 2021: 294-310; Vanga and Raghavan, 2018: 10-20). Amongst all milk substitutes rice milk contains the lowest amount of protein and soy milk contains the highest amount of protein (Aydar, 2020). Therefore, it needs to be fortified with vitamins and minerals (Karimdastjerd and Konsukan, 2021). The nutritional composition of rice milk in 240 ml is 130 kcal, 1.01g protein, 1.99g of total fat with no saturated fat, 27g carbohydrate, 300mg calcium, 1.08 mg iron, 101 IU vit D (Bridges, 2018). Rice milk has high selenium and magnesium content which helps increase immunity and provides resistance to pathogens (Karimdastjerd and Konsukan, 2021). It also contains a functional component- phytosterol like b-sitosterol and c-oryzanol which poses many health benefits like reducing cholesterol, has anti-hypertensive, anti-diabetic, anti-inflammatory and anti-oxidative properties (Sethi et al., 2016: 3408-3423). Since rice milk is not allergic and is lactose free, it is suitable for those who have an allergy to cow milk protein or have lactose intolerance (Karimdastjerd and Konsukan, 2021). Brown rice milk contains 2 to 3 times more nutrients and is low in starch and high in complex CHO, has low glycemic index compared to white rice and thereby aids in preventing T2DM (Karimdastjerd and Konsukan, 2021: 294-310; Vanga and Raghavan, 2018: 10-20). Romulo, (2022) discovered that black rice milk contains anthocyanin, phenols and ferulic acid, which contribute to antioxidant activity and DPPH inhibitory action.

Oat Milk

Oats also known as *Avena sativa*, contains functional component such as β-glucan, protein (with good quality protein and balanced amino acids) lipids, micronutrients like vitamin A, D, E and B1 and minerals like calcium, potassium, sodium, magnesium and iron, as well as antioxidants and phytochemicals (Ismail, 2015: 155-156; Syed, 2020). Thus due to its excellent nutritional composition oat milk is gaining importance in today's market. Thereby having potential health benefits such as helps reducing and maintaining weight, blood glucose, cholesterol and triglyceride levels that is due to the presence of soluble fiber which delays the gastric emptying time as well as increases the gastrointestinal transit time, has anticancer properties and also has beneficial effects on digestive health (Ismail, 2015: 155-156; Sethi et al., 2016: 3408-3423; Silva et al., 2020: 131; Syed, 2020). It is also suggested as a milk alternative for those who have irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD), as it is a part of an anti-inflammatory diet (Basinskiene and Cizeikiene, 2020: 63-69). The nutritional content of oat milk in 240ml milk is as follows: 130 kcal, 24g CHO, 4g proteins, 2.5g fats, 350mg calcium, 101 IU vitamin D, 499 IU vitamin A (Bridges, 2018).

There are some of the drawbacks of oat milk. Firstly, the lipase which is present can cause rancidity and also shortens shelf life of the product, but use of high temperature can denature the enzyme (4). Secondly, Phytic acid/ phytate- antinutritional factors are present in oat which hinders the absorption of some essential nutrients. They also attempted to replenish the nutrients that were lost during processing through enrichment (Silva et al., 2020: 131). Thirdly, using oat milk as a substitute for dairy milk can cause calcium deficiency, as oats are not rich in calcium. Thus, oats milk needs to be fortified with calcium, as it is important for growth and development before being used as a substitute (Sethi et al., 2016: 3408-3423; Silva et al., 2020: 131). Oat milk has more CHO than cow's milk, with starch and sugars (4g). One downside of drinking oat milk by diabetics is that it includes higher total carbohydrate per serving than cow's milk. All these drawbacks are overcomed by using proper processing methods to provide health benefits of oat milk (Cooper et al., 2020).

Soy Milk

Soyabean (Glycine max) and soy milk is widely consumed as an alternative to cow milk due to similar nutritional composition to cow milk and possessing various health promoting properties (Nowshin et al., 2018: 158-163). It is also extensively used as a milk alternative for those who have cow milk protein allergy and lactose intolerance. However, people who have cow milk protein allergy are highly probable to have soy allergy too (Silva et al., 2020: 131). Nevertheless, it is a good source of macro and micronutrients. It contains essential amino acids that are comparable to that of humans but low in CHO. It also consists of essential fatty acids: monounsaturated and polyunsaturated fatty acids (MUFAs and PUFAs), vitamins and minerals and no cholesterol; is rich in phytochemicals (like phytosterols, isoflavones, genistein, saponins, phytic acid etc) and have lipid lowering and antioxidant properties. All of the above properties make it suitable to have therapeutic benefits and provide protection against several diseases like: CVD, diabetes, BP, cancer, renal issues, osteoporosis (Anisur et al., 2016: 192-203; Eslami and Shidfar, 2019: 82-88; Nowshin et al., 2018: 158-163). Thereby soybean is also called "golden miracle bean" (Kant and Broadway, 2015: 1159-1162).

In Spite of many benefits, it also has few downsides. Firstly, because of its peculiar beany flavor but many techniques are utilised to reduce beany flavor and increase the shelf life. Secondly, it contains certain antinutritional components such as trypsin inhibitor, phytates, oxalates which form an insoluble complex and hinders mineral absorption. However, different processing

techniques are involved in removing anti-nutrients. Thus, its consumption declined and preference for almond milk increased. But at the same time it is widely consumed due to its nutritional content of soy milk in 240ml is 100 kcal, 7.9g CHO, 8g proteins, 4g fats, 299mg calcium, 501 IU of vitamin A, 119 IU of vitamin D; and also it is easily digested; is low in cost and has various health benefits (Bridges, 2018; Karimdastjerd and Konsukan, 2021: 294-310; Sethi et al., 2016: 3408-3423; Silva et al., 2020: 131; Vanga and Raghavan, 2018: 10-20).

Coconut Milk

Coconut (Cocosnucifera L.) is used in a variety of forms like from fresh to processed products - desiccated coconut, coconut milk and coconut oil. Coconut milk is being widely used at both household as well as industrial level for preparations of a variety of food products and also as a milk alternative (Alyaqoubi et al., 2015: 967-973). Coconut milk does not appear to cause allergic responses and is appropriate for those who are lactose intolerant. Although coconut milk is rich in calories and fats when compared with cow milk and other plant based milks, it mainly contains medium chain triglycerides, which are easily digested and also contains lauric acid which has been shown to cause apoptosis in breast and endometrial cancer cells, therefore boosting the immune system and maintaining blood vessels pliability. The lauric acid is converted to monolaurin which exerts anti-microbial, anti-bacterial, and anti-viral properties and protects against infections (Alyaqoubi et al., 2015: 967-973; Tulashie et al., 2022). Also consumption of coconut milk may reduce the risk for cardiovascular diseases and stroke due to the presence of lauric acid (Alyaqoubi et al., 2015: 967-973). It also contains some phenolic components and has antioxidant properties (contains vitamin E) which confers benefiting role against oxidative stress and damage, has anti-cancer properties, prevents against degenerative diseases, retards aging and nourishes skin and has soothing effects (Karunasiri et al., 2020; Tulashie et al., 2022). In a study it was found that on supplementation of coconut milk HDL levels increased and thereby being protective against CVD (Ekanayaka et al., 2013). The nutritional content of coconut milk in 100 ml is as follows: Energy - 60 kcal, CHO - 5.3 g, protein - 3.2 g, fat - 3.3 g, calcium - 113 mg (Tulashie et al., 2022).

Almond Milk

Almonds (Prunus dulcis) are the most widely consumed nut. This may be owing to its well-known therapeutic qualities, like: having good quality lipids, antioxidants like alpha-tocopherol and arabinose and have immune boosting properties (Kundu et al., 2018: 203-210). And also almond milk is getting more popular as it is low in calories (Torna et al., 2014: 215-222). It has 50% less calories when compared to cow milk and therefore is utlised by the people for weight reduction (Katz, 2018: 4-12). A study has found that daily consumption of almond milk for four weeks has shown to reduce weight, BMI and waist and hip circumferences (Zaidan and Tamimi 2016: 466-471). It consists of balanced nutrition with CHO, protein, fats with higher percentage of monounsaturated fatty acids and no cholesterol, fiber, vitamins and mineral like calcium, magnesium, phosphorus, potassium, sodium, selenium, zinc, vitamin C, B1, B2, B3, B6, B9 and vitamin E (Torna et al., 2014: 215-222; Savchuk et al., 2015; Zaidan and Tamimi 2016: 466-471). Almond milk has been demonstrated to lower blood vessel resistance and enhance the flow of blood, oxygen, and nutrients and maintain BP (Alozie, 2015: 117-121). It is also believed to enhance eyesight, help in the development of strong bones, and maintain proper renal function (Savchuk et al., 2015). It is also an appropriate alternative for people with lactose intolerance however, is not suitable for those who have nut allergy (Katz, 2018: 4-12). The nutritional content

in 240ml almond milk is as follows: Energy - 59kcals, CHO - 6g, Protein - 1g, Fats - 4g, calcium - 450mg, vit D - 100 IU (Bridges, 2018).

Table 1. Classification of Plant based milk alternatives based on food groups

Food group based milk alternative	Types of plant based milk alternatives
Cereal and pseudo cereal based milk	Oat milk, rice milk, corn milk, spelt milk, quinoa milk, amaranth milk
Legume based milk	Soy milk, peanut milk, cowpea milk, lupin milk
Nut based milk	Coconut milk, almond milk, walnut milk, hazelnut milk, pistachio milk
Seed based milk	Flax milk, sunflower milk, hemp milk

Sethi S, Tyagi SK and Anurag RK (2016) Plant-based milk alternatives an emerging segment of functional beverages: a review. Journal of Food Science and Technology 53(9): 3408–23.

Table 2a. Overview of nutritional composition of plant based milk alternatives (per 100ml)

Plant milk and Bioactive	Energy (kcals)	CHO (g)	Sugar (g)	Fiber (g)	Protein (g)	Fat (g)	Vitamins and Minerals
Rice milk	54	11.25	5.8	0	0.42	0.82	Calcium 125 mg, high in selenium and magnesium
Oat milk	54	10	7.9	1.9	1.6	1	Calcium - 145.8mg Vitamin A -207.9 IU,
Soy milk	42	3.29	2.5	1	3.3	1.66	Calcium - 124.5 mg, Vitamin A - 208.7 IU, Vitamin D2 - 49.5 IU
Coconut milk	60	5.3	-		3.2	3.3	Calcium - 133 mg, Vitamin E
Almond milk	25	2.5	2	0.9	0.41	1.66	Calcium-188 mg, Vit D2 - 41.6 IU, Vitamin E -

- Bridges M (2018) Moo-ove Over, Cow's Milk: The Rise of Plant-Based Dairy Alternatives the Rise of Plant-Based Milks. Practical Gastroenterology p:20–7.
- Tulashie SK, Amenakpor J, Atisey S, Odai R, Akpari EEA (2022) Production of coconut milk: A sustainable alternative plant-based milk. Case Studies in Chemical and Environmental Engineering 6:100206.

Table 2b. Bioactive compounds and their health benefits of plant based milk alternatives

Plant milk	Bioactive	Health benefit
Rice milk	Phytosterol - b-sitosterol and c-oryzanol	Reduces cholesterol, has anti-hypertensive, anti-diabetic, anti-inflammatory and anti-oxidative properties
Oat milk	β-glucan	Reduces and maintains weight, blood glucose, cholesterol and triglyceride levels, delays gastric and gastrointestinal transit time, used in IBS and IBD, has anticancer properties
Soy milk	Phytosterols, isoflavones, genistein, saponins, phytic acid	Lipid lowering and antioxidant properties, provides protection against several diseases like: CVD, diabetes, BP, cancer, renal issues, osteoporosis
Coconut milk	Lauric acid	Anti-microbial, anti-bacterial, and anti-viral properties and protects against infections Benefiting role against oxidative stress and damage, has anti-cancer properties, prevents against degenrative diseases, retards aging and nourishes skin and has soothing effects
Almond milk	Arabinose	Immune boosting properties, maintain BP, enhance eyesight, help in the development of strong bones, and maintain proper renal function

- Sethi S, Tyagi SK and Anurag RK (2016) Plant-based milk alternatives an emerging segment of functional beverages: a review. Journal of Food Science and Technology 53(9): 3408–23.

DISCUSSION

In this review, from the selected studies the nutritional composition and health benefits information was compiled and discussed.

The nutritional composition of five selected plant milk alternatives is summarized in Table 2. Almond milk was found to have lowest caloric content (25 kcals/100 ml), followed by soy milk (42 kcals/100 ml), oat milk and rice milk (54 kcals/ 100 ml) and with highest content in coconut milk (60 kcals/100 ml). Total carbohydrate content per 100 ml of plant milk was highest in rice milk (11.25 gm/100ml), followed by oat milk (10g), coconut milk (5.3g), soy milk

(3.29g) and was lowest in almond milk (2.5g). Of which, oat milk had the highest sugar (7.9g) and coconut milk had no sugar. Soy milk and coconut milk had better protein content compared to the other 3 plant milks. Coconut milk had higher fat content (3.3 g) but lauric acid and MCTs. Oat milk and soy milk had better vitamin A content. Vitamin D2 content was good in soy milk and almond. Nut milks - coconut milk and almond milk were good sources of vitamin E. All five plant milks were a good source of calcium. In addition, rice milk was a good source for selenium and magnesium.

The health benefits and bioactives of five selected plant milk alternatives are discussed as follows. Oat milk, rice milk and soy milk were found to be beneficial in reducing cholesterol, providing cardioprotective benefits and hence effective in CVD. Rice milk and soy milk have phytosterols, soy milk also has isoflavones and genestin. B-glucan soluble fibre from oat milk could be beneficial in managing diabetes, cholesterol and irritable bowel syndrome. Coconut milk contains lauric acid - MCT providing anti-microbial, anti-bacterial, and anti-viral properties, while its vitamin E provides antioxidant benefits. Almond milk contained arabinose and Vitamin E beneficial for immunity, eye health, bones and renal health. Soy milk and almond milk were reported to be useful for renal disorders. Also soy milk and coconut milk had anti-carcinogenic properties.

CONCLUSION

Plant milk alternatives are novel emerging functional beverages. These can prove to be a healthier alternative when cow milk needs replacement in the diet due to dietary preferences, intolerances and health issues. The nutritional composition and bioactive offer health benefits and may offer some preventive benefits in diseases. However, there is future scope for more research on plant based milk versus cow milk and in conditions such as acne, PCOS. Also, well designed RCT's and larger sample size could provide for stronger evidence on health benefits in humans.

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