

The Role of Plant-Based Milk in Vegan and Vegetarian Diets: Nutritional Benefits and Challenges**Shrishti Joshi¹ and Shikha Mahajan²****¹Research Scholar, Department of Food and Nutrition, Punjab Agricultural University Ludhiana****²Assistant Professor, Department of Food and Nutrition, Punjab Agricultural University
Ludhiana****Abstract**

The increasing demand for plant-based milk results from health nutrition and environmental sustainability aspects in addition to follow-up choices for strict vegetarians and vegans. The analysis reviews both nutritional advantages and disadvantages of plant-based milk regarding its protein values along with vitamin and mineral content in addition to fortification methods versus conventional dairy products. Plant-based milk stands as an appropriate alternative but needs extra supplements consisting of calcium and vitamins D and B12 to reach dairy milk levels of nutrition. Evidence shows that plant-based milk generates reduced environmental impact through lower carbon emission because it needs less resources including land and water than traditional dairy milk. A life cycle assessment conducted by scientists determined that producing one liter of cow's milk leads to CO₂ emission of 3.2 kg but soy generates 1.0 kg emission while oat produces 0.9 kg and almond releases 0.7 kg and rice generates 1.2 kg. People continue to express doubts about how much water almond milk uses in production as well as whether vital nutrients remain accessible between various plant-based milk types. The ethical value of using plant-based milk rests in its cruelty-free nature because the dairy production system requires such practices as calf separation and hormonal manipulation of cows and the killing of male calves. The combination of sustainable and ethical issues push consumers toward making alternative dietary selections. The adoption of plant-based milk has met four essential hurdles which include how well nutrients are absorbed and requires improved fortification standards and how to reduce costs and improve market reach to consumers. The market sector for plant-based milk demonstrations ongoing expansion because consumers seek sustainable yet nutritionally rich ethical food items. Future scientific advancement needs to focus on plant-based milk improvements regarding nutrition value and sustainable availability and affordable cost to secure their status as attractive dairy substitute products.

Introduction

Vegan and vegetarian diets adopted plant-based milk as a fundamental component for people who need to replace traditional dairy milk. Several elements drive people to use plant-based milk as an alternative

to dairy products including lactose intolerance along with dairy allergies in addition to animal wellbeing beliefs and environmental preservation motivations (Mäkinen et al., 2016). Because vegan and vegetarian diets eliminate animal products completely or significantly most people need replacement substances for dairy-provided nutrients like calcium protein and vitamin B12 (Singhal et al., 2017). The plant-based milk industry has grown dramatically during recent times and soy milk alongside almond milk and oat milk and coconut milk and rice milk represent the main choices in the market (McClements et al., 2019). The nutrient content and functional characteristics of dairy milk substitutes differ significantly from each other because consumers need clear information to make proper choices for dairy milk replacement. Plant-based milks deliver advantages through cholesterol reduction and environmental benefits but the main drawbacks include the reduced protein content and potential nutrient deficiencies that can happen when proper fortification is not applied (Hansen et al., 2022). This review investigates plant-based milk nutrition and health benefits alongside their obstacles and practical solutions for enhancing vegan and vegetarian dietary intake. Knowing these principles helps provide a diet with the necessary nutrients that balanced nutrition needs.

2. Nutritional Composition of Plant-Based Milk

Plant-based milk gets its nutritional characteristics from what ingredients it uses as well as how it gets processed and which essential nutrients they add or not during production. Plant-based milk options need fortification because they lack the natural nutrient content of dairy milk and its triple benefits of high-quality protein and calcium along with vitamin B12 (Jeske et al., 2017).

- **Macronutrient Composition**

Soy milk proves to be superior among dairy substitutes for protein content because it offers 7-9 grams per serving while having similar amounts as cow's milk (Hansen et al., 2022). The protein quantity found in almond rice and coconut plant-based milk ranges between 0.5 to 2 grams when measured per cup (Vanga & Raghavan, 2018). Oat milk has protein compositions that fall between dairy milk and other alternatives delivering 2-4 grams per serving.

Plants used for milk production have different amounts of fat which leads to varying compositions. Each cup of coconut milk brings high levels of fat containing medium-chain triglycerides (MCTs) that deliver quick energy according to Lu et al. (2020). Almond and soy milk possess unsaturated fat as their main component and these heart-healthy fats are confirmed by Jeske et al. (2017).

Carbohydrate Levels in Rice Milk Result from Natural Starch Processing but These High Levels Make the Drink Not Suitable for Diabetic People (McClements et al., 2019). The carbohydrate level in oat milk rises but its beta-glucan component helps decrease cholesterol according to Whitehead et al. (2014).

- **Micronutrient Composition**

Unfortified plant-based milk products have lower calcium content than regular milk since dairy milk occurs naturally with 300 mg per serving (Weaver et al., 2016). The majority of plant-based milk brands use calcium carbonate or tricalcium phosphate for calcium fortification to reach dairy milk protein content.

Plant-based milks receive synthetic vitamin B12 as these products contain this micronutrient only in animal-based products. A vegan diet presents an elevated risk of vitamin B12 deficiency to people because fortified B12 is the only protection against neurological damage and anemia (Sakkas et al., 2020).

Vitamin D requirements must be met via dairy milk fortification since this nutrient helps bones absorb calcium for healthy development. Plant-based milks contain added vitamin D2 or D3 to combat deficiency mainly because vegans tend to lack adequate sunlight exposure according to Itkonen et al. (2018).

People need to choose plant-based milks according to their specific dietary needs since these alternative dairy products contain distinct nutritional values. Proper fortification represents a vital process for creating substitute dairy milk options that serve as adequate nutrition sources.

3. Health Benefits of Plant-Based Milk in Vegan and Vegetarian Diets

Plant-based milks provide significant health advantages which makes them suitable for both persons with vegan or vegetarian eating habits and those who avoid lactose consumption. Research shows that people who consume plant-based milk discover it helps their heart health and digestive system plus provides possible anti-inflammatory properties.

- **Cardiovascular Benefits**

The analysis of Rebello et al. (2020) proves that plant-based milk consumption specifically with soy milk leads to first a substantial reduction of LDL cholesterol and secondly retains or raises the HDL cholesterol levels in the body. Research shows that soy isoflavones function as cholesterol-lowering agents according to Messina (2016). The beta-glucan content in oat milk leads to cholesterol reduction and heart health enhancement according to Whitehead et al. (2014).

- **Lactose Intolerance and Digestive Health**

Diehard lactose intolerance disturbs a significant number of people across the world particularly inside areas that never maintained dairy as part of their standard dietary pattern (Montalto et al.,

2006). Plant-based milk functions as a complete lactose-free dietary choice thus serving people who face digestive problems after dairy consumption. Consuming oat milk results in prebiotic fiber benefits that stimulate beneficial gut bacteria development (Lu et al., 2020).

- **Weight Management and Metabolic Health**

The calorie content of almond and coconut plant-based milks falls below whole dairy milk levels thus making them a favorable choice for people monitoring their weight according to Vanga & Raghavan (2018). The addition of sweeteners in certain commercial plant-based milks requires healthcare attention since these sweeteners elevate calorie consumption and might negatively impact your metabolic health.

- **Skin and Anti-Inflammatory Benefits**

The skin benefits from vitamin E found in almond milk which is an antioxidant that helps fight oxidative stress and protects health (Jeske et al., 2017). Plant-based milk contains lower inflammation-inducing compounds than dairy milk because dairy milk contains both saturated fats and casein which link to inflammation (Lu et al., 2020).

The health advantages of plant-based milks establish them as essential food options for people who follow vegetarian and vegan dietary plans. The positive aspects of plant-based milk need thorough examination for the sake of creating nutritional balance.

4. Challenges of Plant-Based Milk in Meeting Nutritional Needs

The nutritional problems associated with plant-based milk are significant for individuals who use them instead of dairy products.

- **Lower Protein Content**

Plant-based milk faces the main issue of containing fewer proteins when compared to dairy milk. Plant-based milk varieties except soy milk have substantially low protein levels and may be harmful to individuals needing protein such as athletes along with children and elderly persons (Jeske et al., 2017).

- **Calcium and Vitamin D Deficiencies**

When plants lack natural dairy levels of calcium it becomes crucial to fortify plant milk to prevent deficiencies which raise osteoporosis risks and bone fracture possibilities (Weaver et al., 2016). Unfortified plant milks without vitamin D produce poor calcium absorption which consequently affects bone health according to Itkonen et al., (2018).

- **Nutrient Bioavailability and Antinutritional Factors**

Plants used to produce certain kinds of milk deliver antinutritional compounds that include phytates and oxalates which block essential mineral absorption including calcium and iron and zinc (Lonnerdal, 2000). The antinutrients phytates in almond and oat milk disrupt calcium availability because they create chemical bonds with this mineral thereby limiting its absorption process.

5. Fortification and Nutrient Bioavailability in Plant-Based Milk

The practice of adding essential nutrients represents an important strategy for achieving nutritional equivalence between plant-based milk and dairy milk. Manufacturers enhance the nutritional quality of plant-based milks by adding essential nutrient compounds including calcium and vitamin B12 and vitamin D since such nutrients are absent in these products naturally (Jeske et al., 2017).

Calcium Fortification

A cup of dairy milk contains authentic amounts of 300 mg calcium that supports bone structures and assists with muscle operations and nerve system transmission (Weaver et al., 2016). Plant-based milk products usually need additives of calcium carbonate or tricalcium phosphate because they contain limited natural calcium content yet these compounds absorb similarly to dairy milk calcium (Singhal et al., 2017). Plant milk based on almonds and oats contains antinutrients phytates that impair calcium absorption in the body (Lonnerdal, 2000).

Vitamin D Fortification

Bone mineralization and calcium absorption heavily depend on vitamin D consumption. Many plant-based milk producers add vitamin D2 (ergocalciferol) for fortification yet this version originates from plants whereas vitamin D3 (cholecalciferol) from animal sources demonstrates better absorbance (Itkonen et al., 2018). Several manufacturers now utilize animal-free D3 derived from lichen which enhances both its absorption and effectiveness as reported in Cashman (2020).

Vitamin B12 Fortification

The vegan and vegetarian lifestyle depends heavily on vitamin B12 since this nutrient exists naturally only in animal foods. The absence of B12 vitamin will create a deficiency that triggers anemia and neurological health problems and invokes cognitive decline (Sakkas et al., 2020). Plant-based milk manufacturers fortify their products with cyanocobalamin which stands as a synthetic form of B12 that people easily absorb into their bodies (Weaver et al., 2016). For people following vegan diets the regular

consumption of fortified plant-based milk acts as a crucial factor to minimize the risk of developing B12 deficiency (Tso & Forde, 2021).

Bioavailability and Absorption Factors

The amount of absorption determines the effectiveness of food-based nutrients in human bodies. Factors affecting bioavailability include:

- The addition of lecithin and guar gum in plant-based milk now becomes possible thanks to emulsifiers and stabilizers (McClements et al., 2019).
- When drinking plant-based milk with foods containing vitamin C (such as citrus fruits) you can boost the absorption of iron according to (Lonnerdal, 2000).
- The absorption of minerals in plant-based milks increases when these beverages undergo fermentation and undergo enzymatic treatments (Itkonen et al., 2018).
- Consumers need to pick fortified plant-based milk products with quality fortification standards while supplementing their nutrition with multiple essential nutrients from food sources.

7. Impact of Plant-Based Milk on Bone Health

Those who cut dairy from their diet need to consider bone health as a significant problem. The necessity of receiving adequate amounts of bone-density maintaining nutrients calcium and vitamin D makes it vital for plant-based milk products to deliver these important compounds.

- **Calcium and Bone Mineral Density**

Research indicates that those who drink unfortified plant-based milk tend to have lower bone mineral density measurements when compared to individuals who consume dairy milk per the findings of Knurick et al. (2017). Plants that incorporate additional calcium and vitamin D during fortification demonstrate an ability to protect bone health adequately according to Weaver et al. (2016).

- **Magnesium and Phosphorus**

Plant-based milks such as oat along with soy include moderate amounts of bone-metabolism essential minerals magnesium and phosphorus (Cashman, 2020). The proper consumption of minerals between these levels helps protect against osteoporosis for people following plant-based diets.

8. Future Perspectives and Innovations in Plant-Based Milk

The science of food has produced improvements that simultaneously enhance the nutritional content and flavor profile and environmental sustainability of alternative plant milk beverages.

Emerging Trends

- Fermentation techniques serve as a technology to improve proteins while removing antinutrients from food according to McClements et al. (2019).
- Pea milk together with hemp milk experience increasing demand because they contain elevated protein levels (Tso & Forde, 2021).
- The new generation of sustainable packaging techniques works to cut down environmental damage (Gephart et al., 2021).

Conclusion

The use of plant-based milk illustrates a revolutionary change in worldwide food consumption since it provides an auspicious replacement for conventional dairy products. The consumption of plant-based milk in vegan and vegetarian diets requires care since adequate nutrient intake relies on food source variety together with nutrient enrichment. Future research and innovation will play a key role in enhancing the nutritional quality, affordability, and sustainability of plant-based milk, making it an even more viable alternative for a growing population seeking healthier, ethical, and environmentally responsible food choices. By addressing these challenges through scientific advancements, sustainable production methods, and improved consumer awareness, plant-based milk can continue to evolve into an even more nutritionally complete and accessible alternative that supports both human health and planetary well-being.