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# Can Plant-Based Beverages Truly Replace Milk? A Nutritional Reality Check

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### Abstract

The growing popularity of plant-based beverages (PBBs) such as soy, almond, and oat drinks reflects a global shift toward sustainable and health-conscious food choices. However, their nutritional equivalence to traditional bovine milk remains debated. This article critically compares milk and PBBs in terms of macronutrient and micronutrient composition, protein digestibility, antioxidant capacity, and sensory quality. Cow's milk continues to offer a superior balance of essential amino acids, digestibility, and fatty acid diversity. On the other hand plant-based beverages are lactose- and cholesterol-free and often require fortification to achieve comparable nutritional profiles. Soy beverages emerge as the closest nutritional substitute, followed by oat drinks, while almond beverages rank lowest unless fortified. The discussion also emphasizes regulatory frameworks, environmental sustainability, and future prospects of blended dairy-plant innovations. Overall, PBBs complement rather than replace dairy, contributing to dietary diversity and consumer choice in evolving nutritional landscapes.

**Keywords:** Plant-based beverages, Bovine milk, Nutritional comparison, Protein digestibility, Functional properties

### Introduction: The Rise of Plant-Based Beverages

In recent years, the food and beverage landscape has witnessed a remarkable shift. Supermarket shelves once dominated by dairy products now feature a colorful array of plant-based beverages from almond and soy to oat, rice, and coconut drinks. Health consciousness, environmental sustainability, ethical concerns about animal farming, and the rise of vegan lifestyles are the main factors responsible for this shift. In India the market for plant-based alternatives is also increasing rapidly. Although India is largest producer of milk, urban consumers are experimenting with dairy-free options, particularly among lactose-intolerant and health-conscious groups. However, as consumers pour plant-based beverages into their morning coffee or cereal, a scientific question arises can these products truly replace milk nutritionally?

### What Makes Milk Unique?

According to the Food Safety and Standards Authority of India (FSSAI, 2011), milk is defined as the normal mammary secretion obtained by complete milking of a healthy milch animal, free from

colostrum and adulteration. Beyond this simple definition, milk is a remarkably complex biological fluid containing balanced proportions of proteins, fats, carbohydrates, vitamins, and minerals. Its unique feature lies in the nutrient synergy milk’s proteins (caseins and whey) interact with fats and minerals to make nutrients more bioavailable and digestible. This biochemical harmony is what makes cow’s and buffalo’s milk a “gold standard” for human nutrition, particularly for infants, children, and the elderly.

**What is Plant-Based Beverages (PBBs)?**

Plant-based beverages are water extracts made from cereals, legumes, nuts, and seeds such as soybeans, oats, almonds, rice, and coconuts that are processed to mimic appearance and texture of milk (Sethi *et al.*, 2016). These products are emulsions of plant-derived solids and oils, often fortified with vitamins, minerals, and stabilizers to improve texture and nutritional profile. Their appeal lies in being cholesterol-free, lactose-free, and often perceived as eco-friendly. However, these beverages differ widely in nutrient composition depending on their source and processing.

**Nutritional Composition: A Closer Look**

When compared nutritionally, the gap between dairy milk and plant-based beverages becomes evident.

**Protein:** Cow’s milk contains around 3.4% protein, mainly casein and whey, which are complete proteins containing all essential amino acids. Plant-based beverages vary widely soy drinks (3.2%) come closest, while almond and oat drinks are far lower (0.5-1.0%) (Vashisht *et al.*, 2024).

**Fat:** The lipid fraction in milk is unique, with more than 50 different fatty acids, including short-chain fats like butyric acid and conjugated linoleic acid (CLA) that are known for their metabolic benefits (Antunes *et al.*, 2024). In contrast, plant beverages contain only about 15 fatty acids, dominated by unsaturated fats but lacking CLA and butyric acid.

**Carbohydrates:** Milk contains lactose (4.9%), which supports calcium absorption. In plant drinks, carbohydrates vary often added sugars or starch hydrolysates are used to improve taste and texture.

**Micronutrients:** Cow’s milk is a natural source of calcium, phosphorus, potassium, and vitamins A, D, and B12. Plant beverages need fortification to match these levels (Smith *et al.*, 2022).

Overall, while plant beverages can mimic milk’s appearance, they fall short of its nutrient density and bioavailability. Table 1 summarizes the average nutritional composition of cow’s milk compared with popular plant-based beverages such as soy, almond, and oat drinks.

Component	Bovine Milk	Soy Beverage	Almond Beverage	Oat Beverage
<b>Protein (%)</b>	3.4	3.2	0.5	1.1
<b>Fat (%)</b>	3.7	1.8	1.5	1.5
<b>Carbohydrate (%)</b>	4.9 (lactose)	2.5	1.3	7.1
<b>Calcium (mg/kg)</b>	1067	260	214	139
<b>Vitamin D (µg/100 gm)</b>	1.0	0.45-2.5	0.45-3.3	1.6

**Table 1. Comparative Nutritional Composition of Cow’s Milk and Major Plant-Based Beverages** (Vashisht *et al.*, 2024 and Smith *et al.*, 2022)

**The Protein Puzzle: Digestibility Matters**

Beyond protein quantity, protein quality measured by the Digestible Indispensable Amino Acid Score (DIAAS) is a key factor. Using dynamic digestion models (such as the TIMsg system simulating stomach and intestinal phases), Khamzaeva *et al.* (2024) reported that:

- Cow’s milk had an ileal protein digestibility of 90.4%,
- Oat drink: 87.5%,
- Almond drink: 85.8%,
- Soy drink: 80.7%.

These results show that even the best-performing plant beverage, soy, lags behind dairy milk in amino acid bioaccessibility. Casein and whey proteins are efficiently digested and absorbed, while plant proteins often contain anti-nutritional factors (phytates, tannins) that reduce absorption. Table 2 presents a comparative overview of protein digestibility and antioxidant potential of cow’s milk and major plant-based beverages.

<b>Beverage Type</b>	<b>Ileal Protein Digestibility (%)</b>	<b>Relative Antioxidant Capacity (%)</b>	<b>Key Observation</b>
<b>Cow’s Milk</b>	90.4 ± 0.7	100	High digestibility & balanced amino acid profile
<b>Oat Drink</b>	87.5 ± 2.2	≈ 50	Moderate protein quality but lower antioxidants
<b>Almond Drink</b>	85.8 ± 1.3	≈ 50	Low protein content & limited bioaccessibility
<b>Soy Drink</b>	80.7 ± 0.8	109-110	Slightly lower digestibility but higher antioxidant potential

**Table 2. Protein Digestibility and Antioxidant Capacity of Milk and Plant-Based Beverages** (Khamzaeva *et al.*, 2024)

**Antioxidants and Functional Aspects**

Interestingly, not all comparisons favor dairy. Some plant-based beverages demonstrate antioxidant properties due to phenolic compounds naturally present in soy, almond, or oats. According to Khamzaeva *et al.* (2024), antioxidant capacity (measured by Oxygen Radical Absorbance Capacity and Trolox Equivalent Antioxidant Capacity assays) was 50% lower in oat and almond drinks compared to milk, but 9-10% higher in soy beverages. This suggests that while dairy milk offers superior bioavailable protein, certain plant beverages can contribute beneficial phytochemicals, giving them a functional beverage appeal.

**Sensory and Consumer Acceptance**

In terms of sensory attributes, dairy milk scores higher for creaminess, mouthfeel, and natural sweetness. Plant beverages often exhibit a chalky or beany taste (especially soy) or a watery texture (in almond and oat drinks). Manufacturers use emulsifiers, flavors, and stabilizers to improve sensory acceptability, but these may reduce the clean-label appeal that consumers seek (Prajapati *et al.*, 2025).

**Health Myths and Realities**

Plant-based beverages are often marketed as “healthier alternatives” to milk. While they are suitable for people with lactose intolerance, milk allergies, or vegan preferences, scientific evidence suggests they cannot fully substitute dairy in terms of nutrient completeness.

- **Calcium and Vitamin D:** Fortified plant beverages provide these, but absorption efficiency is lower than in dairy.
- **Protein quality:** Animal-derived proteins remain complete and more digestible.
- **Fatty acid diversity:** Dairy lipids contribute short- and medium-chain fatty acids critical for gut and brain health missing in plant drinks.
- **Vulnerable populations:** For children, elderly, and individuals with low animal-product intake, complete replacement may risk nutrient deficiencies (Smith *et al.*, 2022).

### **Environmental and Ethical Angles**

Plant-based beverages have an edge in environmental sustainability lower greenhouse gas emissions, reduced water use, and less land demand compared to dairy. However, the processing of nuts and cereals (e.g., almond farming’s high-water footprint) complicates this picture. Moreover, the protein yield per hectare for legumes like soy is higher than that for dairy, but milk’s nutrient density per liter remains unmatched. Hence, sustainability discussions must consider nutritional sustainability, not just carbon footprints.

### **Regulatory Framework**

In India, the FSSAI (2011) defines milk strictly as an animal-derived product and restricts labelling of plant-based beverages as “milk.” This has led to debates over nomenclature should terms like “soy milk” or “oat milk” be allowed? Current guidance recommends “soy beverage” or “plant drink.” At the same time, FSSAI and global agencies like Codex are exploring nutritional standards to ensure that plant-based beverages meet minimum levels of key nutrients, especially protein and calcium, if they are to serve as milk substitutes.

### **The Future of Milk and Its Alternatives**

The future may not be about replacement, but coexistence. Consumers are likely to continue mixing both categories based on preference and dietary needs cow’s milk for nutrition and satiety, plant beverages for variety, functionality, or ethics. Innovation is also moving toward blended beverages, combining dairy and plant ingredients to achieve better taste, texture, and nutrient balance. Research on fermentation and enzyme-aided extraction is helping improve protein solubility and sensory quality in plant drinks.

### **Conclusion**

No single plant-based beverage can replicate the complete lipid complexity, amino-acid profile, and digestibility of bovine milk. Even so, these beverages play a valuable role in diversifying diets and supporting individual health, lifestyle, or ethical preferences. Among them, soy-based beverages currently offer the closest nutritional match to dairy milk, followed by oat drinks. Almond drinks, while popular, are comparatively limited unless fortified. For consumers, the most effective approach is to examine labels carefully and focus on protein content as well as calcium and vitamin

fortification. Ultimately, milk and plant-based beverages need not be seen as competitors; rather, they can serve as complementary options within an evolving global diet. Ongoing scientific advancements continue to improve both categories, helping ensure that the glass we raise, whether dairy or plant-based, is genuinely nourishing.

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