# Comparative Effects of Plant- and Animal-Based Milks on Chronic Disease Management: A Narrative Review

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**Abstract**

**Background:** The global burden of chronic non-communicable diseases (NCDs) has intensified interest in dietary determinants of health. Milk whether animal-derived or plant-based constitutes a major dietary component across populations. With the rapid expansion of the plant-based milk alternative (PBMA) market and growing consumer concern regarding the health consequences of conventional dairy consumption, a rigorous comparative review of both milk types within a disease-management framework is both timely and necessary.

**Objective:** This narrative review aims to compare the nutritional profiles of plant-based and animal-based milks and critically evaluate their respective roles in the management of major chronic diseases, including cardiovascular disease (CVD), type 2 diabetes mellitus (T2DM), osteoporosis, cancer, and gastrointestinal disorders.

**Methods:** A comprehensive literature search was conducted across PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar using relevant Medical Subject Heading (MeSH) terms and Boolean keyword combinations. Studies published between 2010 and 2025, including systematic reviews, meta-analyses, randomized controlled trials (RCTs), and observational cohort studies were considered. Narrative synthesis was employed to integrate findings across disease categories.

**Results:** Animal-based dairy milk provides superior bioavailable protein, calcium, iodine, vitamin D, and B12, with well-established benefits for bone health and emerging protective associations with colorectal cancer and glucose metabolism. Plant-based milks offer advantages in lipid-lowering (particularly oat and soy milks) and glycemic management (unsweetened soy and almond milks), and are essential for lactose-intolerant populations. Soy milk most closely approximates dairy in protein quality among PBMAs, while almond, rice, and oat milks exhibit substantially lower protein content. Fermented dairy products demonstrate distinct immunomodulatory and gut microbiome benefits. Neither milk type is universally superior; clinical utility depends on disease context and fortification status.

**Conclusion:** Personalized, evidence-based dietary guidance is essential for selecting appropriate milk types in the context of specific disease conditions. Public health recommendations should move beyond dichotomous dairy vs. plant-based frameworks toward nuanced, disease-specific guidance. Future research should prioritize long-term RCTs directly comparing milk types in clinically defined disease populations.

**Keywords:** *plant-based milk; dairy milk; animal-based milk; chronic disease management; cardiovascular disease; type 2 diabetes mellitus; osteoporosis; colorectal cancer; gut microbiome; nutritional comparison; lactose intolerance; narrative review*

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## 1. Introduction

Milk has been a fundamental component of the human diet for millennia, providing essential macronutrients and micronutrients critical for growth, development, and the maintenance of physiological homeostasis. Conventionally, the term 'milk' has referred to the lacteal secretion of mammals most commonly cows (Bos taurus) though goat, sheep, buffalo, and camel milk are also consumed globally. In recent decades, a diverse array of plant-derived beverages, collectively termed plant-based milk alternatives (PBMAs), has entered the global food market at unprecedented scale, challenging the primacy of animal-based milk and fundamentally reshaping nutritional discourse [1,2].

The rapid expansion of the PBMA market has been driven by multiple converging factors: rising prevalence of lactose intolerance affecting approximately 65–70% of the global adult population [56]; increasing incidence of cow's milk protein allergy (CMPA); ethical and environmental concerns related to animal agriculture; and a broader cultural shift toward plant-forward dietary patterns [5,7]. PBMAs derived from legumes (soy, pea), cereals (oat, rice), nuts (almond, cashew, coconut), and seeds (hemp, sesame) now account for approximately 15% of retail milk dollar sales in high-income countries [5]. The global plant-based dairy alternatives market was valued at approximately US$28.55 billion in 2023 and is projected to grow at a compound annual growth rate of 9.9% through 2033 [10].

Simultaneously, the global burden of chronic non-communicable diseases (NCDs) continues to escalate. Cardiovascular disease (CVD) remains the leading global cause of death, accounting for over 20 million deaths in 2021 [26]. Type 2 diabetes mellitus (T2DM) affects over 537 million adults worldwide, with projections reaching 783 million by 2045 [31]. Osteoporosis affects an estimated 200 million women globally and is a major determinant of fracture risk in the elderly [41]. Cancer, across all forms, constitutes the second leading cause of mortality. Diet is a primary modifiable risk factor for each of these conditions, and the specific role of milk type plant-based or animal-based in disease management remains an underexplored and clinically important question.

Although existing literature has examined plant-based dietary patterns broadly, and individual studies have investigated dairy consumption in relation to specific diseases, a focused comparative narrative review evaluating different milk types specifically within a disease-management framework is lacking. The present review addresses this gap by synthesizing current evidence across nutritional composition, cardiovascular disease, type 2 diabetes, osteoporosis, cancer, gastrointestinal health, and special population considerations, to generate clinically actionable conclusions [79,80].

## 2. Methods

A narrative review methodology was employed, consistent with established approaches for synthesizing heterogeneous bodies of evidence where formal meta-analytic methods are not feasible owing to diversity in study designs, populations, and outcome measures. Literature searches were conducted independently across PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar in February–April 2025. MeSH terms and free-text search strings included: 'plant-based milk', 'plant-based milk alternatives', 'dairy milk', 'cow's milk', 'soy milk', 'almond milk', 'oat milk', 'rice milk', 'non-dairy beverages', combined with 'chronic disease', 'disease management', 'cardiovascular disease', 'type 2 diabetes mellitus', 'osteoporosis', 'bone mineral density', 'cancer', 'gut microbiome', 'lactose intolerance', 'inflammation', 'clinical outcomes', 'nutritional composition', and 'protein quality'. Boolean operators (AND, OR) were used to combine terms.

Inclusion criteria: (1) peer-reviewed original research articles, systematic reviews, meta-analyses, narrative reviews, and evidence-based clinical guidelines; (2) published in English between January 2010 and May 2025; (3) adult human populations (age ≥18 years) or studies with relevance to specific populations (infants, elderly, pregnant women); (4) reporting quantitative or qualitative data on the association between milk type and nutritional outcomes or disease parameters. Exclusion criteria: animal studies (unless mechanistic basis for human inference),

conference abstracts, grey literature, and studies with insufficient methodological reporting. A total of 112 records were initially retrieved, of which 80 met full inclusion criteria after title, abstract, and full-text screening. References were managed using a standardized reference database. No ethics approval was required for this review.

**3. Nutritional Comparison: Plant-Based vs. Animal-Based Milk**

A rigorous understanding of the compositional differences between plant-based and animal-based milks is foundational to interpreting their distinct disease-management implications. Table 1 presents a comparative overview of major nutrients across commonly consumed milk types per 240 mL serving based on published compositional analyses [2,9,11].

**Table 1. Comparative Nutritional Profile of Common Milk Types (per 240 mL serving, approximate values)**

| Nutrient | Cow's Milk (whole) | Soy Milk (fortified) | Almond Milk (unsweet.) | Oat Milk | Rice Milk | Coconut Milk |
|---|---|---|---|---|---|---|
| Energy (kcal) | 149 | 80–110 | 30–50 | 120–130 | 113–120 | 45–75 |
| Protein (g) | 8.0 | 7.0–8.0 | 1.0–1.5 | 2.5–4.0 | 0.7–1.0 | 0.5–1.0 |
| Total Fat (g) | 8.0 | 4.0–4.5 | 2.5–3.0 | 4.5–5.0 | 2.3–2.5 | 4.5–5.0 |
| Saturated Fat (g) | 4.6 | 0.5–1.0 | 0.2–0.3 | 0.5 | 0.3–0.5 | 4.0–4.5 |
| Carbohydrate (g) | 11.7 | 8.0–9.0 | 1.0–2.0 | 16.0–22.0 | 22.0–25.0 | 1.0–2.0 |
| Dietary Fiber (g) | 0 | 0.5–1.0 | 0.5–1.0 | 1.5–2.0 | 0.3 | 0 |
| Calcium (mg)* | 276–300 | 280–320 | 200–450 | 350 (fort.) | 250 (fort.) | 450 (fort.) |
| Vitamin D (IU)* | 115–124 | 100 (fort.) | 100 (fort.) | 100 (fort.) | 100 (fort.) | Variable |
| Vitamin B12 (mcg)* | 1.1 | Var. (fort.) | 0 | Var. (fort.) | 0 | 0 |
| Iodine (mcg)* | ~56 | Low/absent | Low/absent | Low/absent | Low/absent | Low/absent |
| PDCAAS score | ~1.0 | ~1.0 | ~0.4 | ~0.5 | ~0.5 | ~0.3 |

**Values vary by brand and fortification status. Fort. = fortified; Var. = variable; Unsweet. = unsweetened. PDCAAS = Protein Digestibility-Corrected Amino Acid Score. Sources: [2,9,11,12].*

**3.1 Protein Quality and Quantity**

Cow's milk contains approximately 8 g of high-quality complete protein per 240 mL serving, comprising ~80% casein and ~20% whey proteins. Its Protein Digestibility-Corrected Amino Acid Score (PDCAAS) approaches 1.0 the maximum value indicating full amino acid completeness and high digestibility [12,13]. Among PBMAs, soy milk most closely approximates cow's milk in protein content (7–8 g per serving) and quality, possessing a PDCAAS comparable to animal protein owing to its balanced essential amino acid profile, including adequate lysine content [11,13]. Oat milk provides a moderate 2.5–4 g protein per serving with an incomplete amino acid profile, while almond, rice, and coconut milks contain substantially lower protein (0.5–1.5 g per serving) with poor amino acid scores [4,6]. This heterogeneity has critical implications for populations with elevated protein requirements, including the elderly, growing children, and those with catabolic disease states [70,71].

**3.2 Calcium, Vitamin D, and Iodine**

Cow's milk is among the richest dietary sources of bioavailable calcium, providing 276–300 mg per 240

mL with an intestinal absorption rate of approximately 30–32%, facilitated by lactose and casein phosphopeptides [14,15]. Vitamin D, naturally present at 115–124 IU per serving in whole milk, enhances calcium absorption and supports immune function. PBMAs, unless fortified, contain negligible calcium and no vitamin D [16]. When fortified with calcium carbonate, PBMAs can achieve calcium contents comparable to dairy, though bioavailability studies yield variable results: tricalcium phosphate-fortified milks may exhibit ~25% lower absorption relative to dairy calcium [15]. Critically, iodine present at ~56 mcg per 240 mL in cow's milk and essential for thyroid function and fetal neurodevelopment is largely absent from PBMAs unless specifically fortified, representing a significant public health concern for populations relying exclusively on plant-based alternatives [68,69].

### 3.3 Bioactive Components and Phytochemicals

Animal-based milk contains a complex array of bioactive components including lactoferrin (antimicrobial, immunomodulatory), immunoglobulins (IgA, IgG, IgM), conjugated linoleic acid (CLA; anti-atherogenic and potentially anti-carcinogenic), milk fat globule membrane (MFGM; neurodevelopmental roles), and whey-derived peptides with antihypertensive and insulinotropic activities [21,79]. Conversely, PBMAs are rich in plant-specific bioactives: soy milk contains isoflavones (genistein, daidzein) with phytoestrogenic activity and lipid-modulating properties; almond milk is a source of vitamin E (alpha-tocopherol) and polyphenolic antioxidants; oat milk provides beta-glucan, a viscous soluble fiber with well-established LDL cholesterol-lowering properties [23,24,25]. These compositional differences fundamentally underlie the divergent clinical effects of different milk types across disease categories.

## 4. Disease-Specific Evidence: Management Implications

### 4.1 cardiovascular disease

Cardiovascular disease remains the leading global cause of mortality, and dietary fat composition particularly saturated fatty acid (SFA) intake is a primary modifiable risk factor [26]. Full-fat cow's milk contains approximately 4.6 g SFA per 240 mL, predominantly palmitic acid (C16:0) and myristic acid (C14:0), both of which raise LDL cholesterol concentrations [17]. However, the relationship between dairy fat and CVD is complex. A systematic review and meta-analysis by Chen et al. (2022) encompassing data from prospective cohort studies found that total dairy consumption was associated with modestly lower risks of hypertension (RR: 0.91, 95% CI: 0.86–0.95), coronary heart disease (RR: 0.96, 95% CI: 0.92–1.00), and stroke (RR: 0.90, 95% CI: 0.85–0.96), suggesting a favorable or neutral CVD effect when dairy is considered as a food matrix rather than as isolated SFAs [17].

The landmark PURE (Prospective Urban Rural Epidemiology) study, involving 136,384 participants from 21 countries, reported that higher total dairy intake was associated with lower risk of major CVD events and total mortality, with no significant increase in CVD risk even with full-fat dairy [20]. More recently, a dose-response meta-analysis by Hu et al. (2026) of 29 prospective cohort studies encompassing 1,680,651 participants confirmed heterogeneous associations across dairy subtypes, with fermented dairy (yogurt, cheese) demonstrating more consistently favorable associations than plain whole milk [18]. A parallel umbrella review and updated meta-analysis published in Nutrients (2025) confirmed a weak inverse association between total dairy and CVD risk (pooled RR 0.96, 95% CI: 0.93–0.99) [22].

Among PBMAs, oat milk is distinguished by its beta-glucan content (0.5–1.5 g per serving), which has been demonstrated in RCTs to reduce LDL cholesterol by approximately 5–10% through upregulation of hepatic LDL receptors and increased fecal bile acid excretion [23,24]. A meta-analysis of 28 RCTs found that ≥3 g oat beta-glucan daily significantly reduced LDL cholesterol by −0.25 mmol/L and total cholesterol by −0.30 mmol/L compared to control [24]. Soy milk isoflavones have demonstrated modest improvements in endothelial function and reductions in total and LDL cholesterol, particularly in hyperlipidemic postmenopausal women [25,27]. For patients with established dyslipidemia or atherosclerotic CVD, fortified oat or soy milk represents a clinically relevant dietary substitution [26].

### 4.2 Type 2 Diabetes Mellitus

Despite containing lactose (~11.7 g per 240 mL), cow's milk has a relatively low glycemic index (GI ~31–40) attributable to the insulinotropic properties of whey protein, which stimulates insulin secretion via incretin pathways independently of blood glucose elevation [32]. A systematic review and dose-response meta-analysis by Slurink et al. (2024) of 18 prospective cohort studies found that dairy intake particularly yogurt was associated with modest reductions in prediabetes risk and improved fasting glycemic markers [29]. Total and low-fat dairy were inversely associated with a 3–4% lower T2DM risk per 200 g/day increment [35]. A notable mechanistic finding by Luo et al. (2024) in Nature Metabolism identified a variant in the lactase LCT gene as a potential mediator of the milk-T2DM association, highlighting a gene-diet interaction that may explain heterogeneity in observational studies [34].

PBMAs vary substantially in their glycemic profiles. Unsweetened soy milk (GI ~34) and unsweetened almond milk (GI ~25) have very low

carbohydrate content and minimal postprandial glucose impact, rendering them suitable for individuals with T2DM or insulin resistance [32]. Oat milk, however, exhibits a higher GI (~60–79 in commercial preparations) due to its elevated starch content, and may produce greater postprandial glucose excursions compared to cow's milk or lower-carbohydrate PBMAs [32]. Rice milk carries the highest GI (~79–92) of commonly consumed milk types and is generally inadvisable for glycemic management [32]. A larger systematic review and meta-analysis from Harvard found that adherence to plant-based dietary patterns was associated with a 23% lower risk of T2DM incidence, though the specific contribution of individual milk types independent of overall dietary pattern requires further elucidation [31].

For patients with established T2DM, the clinical recommendation should stratify milk selection by carbohydrate content and GI. Unsweetened soy and almond milks are preferred PBMA choices; oat and rice milks should be used with caution or avoided as primary milk sources. Low-fat dairy milk, consumed in appropriate portions, remains a viable and nutritionally superior option when tolerated. Whey protein-enriched dairy formulations may offer additional glucose-modulating benefits through incretin stimulation [32,33].

**4.3 Osteoporosis and Bone Health**

The relationship between dairy consumption and bone health is one of the most extensively studied in nutritional epidemiology. Cow's milk provides a triad of nutrients calcium, vitamin D, and high-quality protein that are collectively critical for peak bone mass attainment and the attenuation of age-related bone loss [14,40]. A meta-analysis by Malmir et al. (2020) published in Critical Reviews in Food Science and Nutrition found that dairy consumption was positively associated with bone mineral density (BMD) at the hip, spine, and forearm, with consistent inverse associations with osteoporosis risk across prospective cohort studies [38]. An updated analysis by Hidayat et al. (2022) confirmed that milk supplementation significantly improved BMD at the lumbar spine and hip in intervention studies [42]. A recent RCT by Zhao et al. (2025) in 97 postmenopausal women demonstrated that daily consumption of 400 mL high-calcium milk for one year significantly increased lumbar spine BMD (L1-4), elevated serum 25-hydroxyvitamin D, and modulated bone formation biomarkers compared to regular milk [39].

The National Osteoporosis Foundation (NOF) and multiple international consensus bodies affirm that adequate calcium (1000–1200 mg/day for adults >50 years) and vitamin D (800–1000 IU/day) are essential for fracture prevention, with dairy as the most practical dietary source for most populations [41]. The dairy food matrix encompassing not only calcium and vitamin D but also phosphorus, potassium, magnesium, whey-derived insulinotropic peptides, and MFGM is hypothesized to exert synergistic bone-protective effects that cannot be replicated by simple calcium supplementation alone [14,40].

For PBMAs, calcium-fortified products can theoretically provide adequate elemental calcium, but bioavailability data remain heterogeneous [15,37]. Calcium carbonate-fortified soy milk demonstrates comparable fractional calcium absorption to cow's milk in controlled studies; however, the bioavailability of tricalcium phosphate used in many commercial PBMAs may be approximately 25% lower than dairy calcium [15]. Critically, many individuals consume PBMAs without adequate verification of fortification status, and the absence of naturally occurring iodine and B12 in PBMAs further compounds nutritional risk. For patients with established osteoporosis, evidence supporting dairy milk particularly low-fat and fortified variants substantially exceeds that available for PBMAs [38,42].

**4.4 Cancer**

The relationship between milk consumption and cancer risk is site-specific and mechanistically complex. For colorectal cancer (CRC), dairy milk demonstrates a consistently protective association: a dose-response meta-analysis found that each 400 mL per day increment in dairy consumption was associated with an 8–11% reduction in CRC risk [45]. Proposed mechanisms include calcium's capacity to bind mutagenic secondary bile acids and ionized fatty acids in the colonic lumen, promoting differentiation and apoptosis of colonic epithelial cells, thereby suppressing neoplastic transformation [46]. This dairy-CRC protective association represents one of the most robustly reproduced diet-cancer relationships in the nutritional epidemiology literature and is endorsed by the World Cancer Research Fund [54].

Conversely, a meta-analysis by Deng et al. (2022) in Frontiers in Nutrition, analysing prospective cohort data, reported that high milk consumption was associated with higher cancer mortality in females (RR: 1.10, 95% CI: 1.01–1.21) and elevated risks of prostate (RR: 1.23, 95% CI: 1.02–1.48), liver, and ovarian cancer-specific mortality [47]. Proposed mechanisms for the prostate cancer association include elevated circulating insulin-like growth factor-1 (IGF-1) which promotes androgen-sensitive prostate cell proliferation and potential suppression of anti-proliferative 1,25-dihydroxyvitamin D by high calcium intake [49]. Sex steroid hormone residues in modern commercial dairy milk represent an additional concern that warrants further investigation [49]. A meta-analysis of childhood milk intake found no statistically significant associations with later-life breast, prostate, or colorectal cancer risk, though significant heterogeneity limited conclusions [48].

Among PBMAs, soy milk's isoflavone content (genistein, daidzein) has been extensively studied in the context of hormone-sensitive cancers. Current evidence including an updated meta-analysis [52] and a systematic review by Messina (2016) [53] supports the safety of moderate soymilk consumption (1–2 servings/day) for women with estrogen receptor-positive (ER+) breast cancer at typical dietary intake levels, with some studies suggesting modest protective associations. The American Cancer Society and major oncology dietetics bodies do not recommend against soy food consumption in cancer survivors at dietary quantities. Anti-proliferative and antioxidant bioactive components in almond and hemp milks (vitamin E, polyphenols, omega-3 fatty acids) may confer general chemoprotective properties, though direct human evidence for disease management remains limited [50,51].

**4.5 Gastrointestinal Health and Lactose Intolerance**

Lactose intolerance resulting from insufficient intestinal lactase enzyme activity affects approximately 65–70% of the global adult population, with markedly higher prevalence in East Asian (90–100%), West African (>70%), and Indigenous populations [56]. Gastrointestinal symptoms including bloating, flatulence, abdominal cramping, and diarrhoea following dairy consumption represent a direct and significant barrier to conventional milk use in these populations [58]. PBMAs are inherently lactose-free and are the primary dietary alternative. Among PBMAs, soy, oat, almond, and rice milks are all well-tolerated by lactose-intolerant individuals and provide an effective substitution strategy, provided adequate nutritional fortification is ensured [57]. Emerging evidence from Mendelian randomization studies further implicates gut microbiota composition specifically Bifidobacterium abundance as a modulator of lactose intolerance symptom severity, independent of lactose intake per se [59].

Fermented dairy products yogurt, kefir, and cultured buttermilk represent a nutritionally superior option for many lactose-intolerant individuals because microbial beta-galactosidase activity partially pre-digests lactose, markedly reducing symptom burden while preserving nutritional density [57,61]. A recent comprehensive review by Jiang et al. (2025) in Nutrients synthesized mechanistic and clinical evidence demonstrating that fermented dairy products modulate gut microbial diversity, enhance production of short-chain fatty acids (SCFAs), reinforce epithelial tight junction proteins, and reduce systemic inflammatory markers in metabolic syndrome, hypertension, and irritable bowel syndrome (IBS) cohorts [64]. Yogurt supplemented with Bifidobacterium animalis subsp. lactis BB-12 has demonstrated significant increases in beneficial gut Bifidobacterium populations and improved lactose metabolism at the functional level in clinical trials [62].

Cow's milk protein allergy (CMPA) an IgE- or non-IgE-mediated immunological reaction to bovine caseins or whey proteins, distinct from lactose intolerance requires complete avoidance of all bovine milk proteins. In infants with CMPA, extensively hydrolyzed formulas or amino acid-based formulas are preferred over direct PBMA substitution, as most commercial PBMAs are nutritionally inadequate for infants [65,66]. The prebiotic properties of beta-glucan in oat milk and resistant starch in certain plant milks may support Bifidobacterium and Lactobacillus proliferation, though commercial pasteurization and processing may attenuate inherent fermentable fiber benefits [60,63].

**4.6 Special Populations**

In infants and young children, PBMAs are nutritionally inadequate as primary milk replacements. WHO and ESPGHAN guidelines recommend exclusive breastfeeding for the first six months of life, followed by complementary feeding; commercial dairy-based infant formulas are the standard of care when breastfeeding is not possible [65]. PBMAs should not be used as primary milk sources for infants under 12 months owing to inadequate protein content, inappropriate carbohydrate and energy composition, and absence of essential micronutrients including vitamin B12 and iodine [65,77]. Soy-based infant formula, regulated to meet nutrient standards by the FDA and EFSA, is an appropriate alternative for infants with CMPA or galactosemia [66].

For elderly individuals (≥65 years), protein and calcium requirements are elevated relative to younger adults. Sarcopenia age-related loss of skeletal muscle mass and strength is a major clinical concern affecting physical function and independence [71]. Dairy milk's superior protein quality and leucine content a primary activator of the mechanistic target of rapamycin complex 1 (mTORC1) anabolic signaling pathway support muscle protein synthesis in older adults more effectively than equivalent servings of most PBMAs [70,71]. The ESPEN Expert Group recommends protein intakes of 1.2–1.5 g/kg body weight per day for elderly adults at risk of sarcopenia, a target that is difficult to achieve with low-protein PBMAs as the primary milk source [71]. For lactose-intolerant elderly individuals, lactase enzyme supplements or commercially available lactose-free dairy products represent a clinically preferable option over switching to low-protein PBMAs [37].

During pregnancy, requirements for iodine, calcium, choline, vitamin B12, and vitamin D are substantially elevated [68]. Cow's milk provides approximately 56 mcg iodine per 240 mL a critical nutrient for fetal thyroid development and neurological maturation that is typically absent from PBMAs unless specifically fortified [68,69]. Iodine deficiency during

pregnancy is the leading preventable cause of intellectual disability globally. Pregnant women following plant-based dietary patterns and relying on PBMAs as their primary milk source should be carefully monitored for iodine, B12, and vitamin D status and receive supplementation as clinically indicated [69].

**Table 2. Summary of Clinical Recommendations: Milk Type by Disease Condition**

| Disease Condition | Preferred Milk Type(s) | Use with Caution | Key Evidence Basis |
|---|---|---|---|
| Cardiovascular Disease (CVD) | Low-fat dairy; oat milk; soy milk | Full-fat dairy (high SFA) | Beta-glucan LDL lowering [23,24]; dairy food matrix [17,20] |
| Type 2 Diabetes Mellitus | Unsweetened soy/almond milk; low-fat dairy | Oat milk (high GI); rice milk | Glycemic index data [32]; whey insulinotropic effect [33] |
| Osteoporosis / Bone Health | Fortified dairy; low-fat dairy; fortified soy milk | Low-protein PBMAs (inadequate Ca/protein) | Ca bioavailability; BMD evidence [38,42]; protein for bone [40] |
| Colorectal Cancer | Low-fat dairy (protective) | High-fat dairy (neutral/uncertain) | Calcium antiproliferative mechanism [45,46] |
| Prostate Cancer | Plant-based alternatives; low-fat dairy | High dairy volume; high-fat dairy | IGF-1; calcium-vitamin D interaction [47,49] |
| Lactose Intolerance | All PBMAs; lactose-free dairy; fermented dairy | Regular cow's milk | Lactase deficiency prevalence [56]; symptom management [57] |
| IBD / Gut Health | Fermented dairy (kefir/yogurt); oat milk | High-fat dairy (may exacerbate) | Probiotic/prebiotic effects [62,64]; SCFA production [63] |
| Sarcopenia (Elderly) | Fortified dairy; lactose-free dairy | Low-protein PBMAs (<2g protein) | Leucine-mTOR pathway; ESPEN guidelines [71] |
| Pregnancy | Dairy milk (iodine, B12 source) | Unfortified PBMAs (iodine deficit) | Iodine for fetal neurodevelopment [68,69] |
| Infants (<12 months) | Breast milk; regulated infant formula | All PBMAs (nutritionally inadequate) | ESPGHAN/WHO guidelines [65,66] |

## 5. Limitations and Research Gaps

This review has several important limitations that should be considered when interpreting its conclusions. First, as a narrative review rather than a systematic review with formal meta-analytic synthesis, this work is inherently subject to selection bias in the choice of included literature. Studies reporting significant associations are more likely to be indexed and retrieved, constituting a potential publication bias that may inflate observed effect sizes [74]. Second, the preponderance of existing evidence derives from studies examining overall plant-based dietary patterns or total dairy consumption rather than isolating the effects of specific individual milk types. Attributing effects to individual milk types within complex dietary patterns remains methodologically challenging.

Third, the nutritional composition of PBMAs is highly variable across brands, geographic markets, processing methods, and fortification practices [4,9]. Findings from studies conducted with one commercial product may not generalize to the category as a whole. Fourth, the impact of ultra-processing on PBMA health outcomes including the addition of stabilizers, emulsifiers, added sugars, and flavor modifiers has not been adequately characterized in long-term human

studies [7]. Fifth, the majority of included evidence was derived from Western, high-income country populations, limiting applicability to diverse global populations with differing baseline nutritional status, disease burdens, dairy fermentation traditions, and fortification regulations [5,31].

Critical research gaps include: (1) long-term RCTs directly comparing specific plant-based and animal-based milk types in well-defined disease-management populations; (2) standardized bioavailability studies of fortified PBMAs for calcium, iodine, and vitamin B12 across different product formulations; (3) mechanistic studies examining how PBMA ultra-processing components affect gut microbiota, inflammation, and metabolic biomarkers; (4) adequately powered studies in pediatric, elderly, and pregnant populations; and (5) exploration of gene-diet interactions (e.g., lactase polymorphisms, APOE genotype) that may modify individual milk type responses.

## 6. Conclusion

This narrative review demonstrates unequivocally that neither plant-based nor animal-based milk is universally superior in the context of clinical disease management. The evidence base supports nuanced, disease-specific, and patient-centered recommendations rather than blanket endorsements of either dairy or plant-based alternatives. Animal-based dairy milk provides bioavailable protein, calcium, iodine, vitamin B12, and vitamin D a nutritional combination that is difficult to replicate with unfortified PBMAs and that underpins dairy's well-established benefits in bone health, particularly for osteoporosis prevention and sarcopenia management in elderly populations. Dairy also demonstrates protective associations with colorectal cancer through calcium-mediated mucosal antiproliferative mechanisms, and a neutral to modestly favorable relationship with cardiovascular disease when consumed as part of a balanced diet.

Plant-based milks particularly oat and soy milks offer significant advantages in lipid management through beta-glucan and isoflavone pathways, and unsweetened soy and almond milks are the preferred options for glycemic management in T2DM. PBMAs are the primary dietary solution for lactose intolerance affecting the majority of the global adult population, provided adequate fortification is ensured. Fermented dairy products (yogurt, kefir) occupy a distinct clinical niche through their probiotic properties and gut microbiome modulating effects.

For clinical practice, dietary counseling regarding milk selection should be individualized to the patient's specific disease condition, age, reproductive status, genetic lactase persistence, comorbidities, and access to adequately fortified products. Wholesale replacement of dairy with unfortified PBMAs in vulnerable populations infants, elderly, pregnant women without appropriate nutritional monitoring and supplementation carries real and quantifiable nutritional risk. Conversely, for cardiovascular and glycemic management in lactose-intolerant adults, judicious selection of fortified oat or soy milk represents an evidence-based dietary strategy. Future research should prioritize well-designed, long-term RCTs comparing specific milk types in disease management settings, standardization of PBMA fortification requirements, and personalized nutrition approaches informed by individual metabolomics and gut microbiome profiles.

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