

A review on potato milk: A possible alternative for consumers allergic to cow milk proteins

Anitha S* and Manivannan A

PG & Research Department of Microbiology,
Hindusthan College of Arts and Science, Coimbatore 641028, Tamil Nadu, India

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Research and development in science and innovation have changed consumer awareness of conventional food sources to functional foods that provide more nutrition and health. On the other hand, there is an emerging no for cow milk due to environmental and ethical considerations. Plant-based milk alternatives emerged as a rising trend, serving as an inexpensive alternative to a poor economic group of developing countries and in places where cow's milk supply is insufficient. A functional food should promote cognitive response, an improved immune system, and general well-being. Though there are several plant-based milk substitutes, using vegetables to produce a novel milk substitute still needs to be considered. Hence, this review aims to incorporate potatoes to produce a milk-like substitute due to their high nutritious content, bioavailability, and environmental sustainability. Potatoes are a better source of protein, vitamins, and minerals than rice, wheat, sorghum, legumes, and corn, with a high number of antioxidants and phytochemicals. With consumers becoming increasingly aware of the association of diet, nutrition, and health, potatoes have the potential to become an important dietary source of bioactive ingredients, i.e., functional food.

Keywords: Lactose intolerance, Milk alternatives, Potato, Probiotics, Vegetable extract

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Introduction

With limited available natural resources and an ever-increasing human population, feeding all of them with vital nutrients is a great challenge faced in the 21st century. This, consequently, increased research of new natural components and the development of new products related to functional products¹. The global functional food and nutraceutical market is growing at a rate, taking over the traditional processed food market.

Canada Health defines functional food as “Functional foods are analogues in appearance to, or maybe, a traditional food, and consumed as a part of the usual diet, with physiological benefits of reducing the danger of chronic disease beyond basic nutritional functions. This urged the multi-stakeholders to divert the traditional food production approach by increasing the health benefits that make food products more functional.

The bioactive compound is the basis for the development of functional food because it can act as

an antioxidant, antidiabetic, source of fibre, and other health benefits. Bioactive components include a range of chemical compounds with varying structures, such as carotenoids, flavonoids, phytosterols, omega-3 fatty acids (n-3), allyl and diallyl sulfides, indoles (benzopyrroles), polyphenols. The long-term intake of a low-fat, whole-food vegan diet, with regular aerobic exercise and training, may increase maximal lifespan in humans; these are achieved by regulating the plasma level of insulin and free IGF-I².

Regarding world food production as an energy source, potato stands fourth following rice, wheat, and maize, and is the first non-grain food commodity. Potatoes are important and are a staple food since they contain 15% of dietary calories and functional ingredients like protein, starch, bioactive (e.g., vitamins, photochemical), and fibre. In the developed world, potatoes are the most eaten vegetable. However, though staple food is worldwide, many consumers are not aware of its health-benefiting properties. Comparatively, potatoes have higher protein and significant dry matter per unit of growing area than cereals. Potatoes are cost-efficient compared to other vegetables in terms of nutrient-to-priceratio³.

*Correspondent author
Email: anithasurendran625@gmail.com

To satisfy the increased demand for animal-derived products, novel plant-based food is being designed and available on the market. Though milk and its derivatives are considered a class of food with essential nutrition, there is a need for alternatives for those with health problems related to high cholesterol intake in the diet, lactose intolerance or malabsorption, and allergy to milk proteins.

Due to the increased demand of consumers, the products with nondairy-based probiotics have been increased. This shifted to using probiotics in fruits and vegetable beverages among the various functional foods, and products containing probiotics stand unique. Probiotic products have an improved lipid profile and immune system, help manage diabetes, have anticarcinogenic properties, and help with general well-being. This attracts vegans as they produce high nutritional status and health⁴.

Among the plant-based milk substitutes, potato milk is a newcomer. Potato milk is not only soy-free, gluten-free, and sugar-free but also an excellent replacement for dairy as it is relatively analogous to dairy milk". Potato milk stands out from the crowd as it is sustainable, environmentally friendly, uses less water and land area, and emits less greenhouse gas when compared with other plant-based milk. Hence, developing functional food will benefit the planet; on the other hand, the world food supply can be achieved by incorporating plant-based food, providing an opportunity to complement agriculture.

Therefore, the scope of this review encompasses the vegan way of living by eliminating dairy and its derivatives and shifting over to a plant-based diet. However, the substitutes for plant-based milk are legumes, nuts, cereals, and pseudocereals. This review will highlight the use of vegetables and potatoes in producing milk alternatives by enhancing their nutritional value by incorporating probiotics.

Veganism is not a trend. It is awakening

The advance of sustainable foods brings enormous benefits to the global population, and incorporating plant-based eating habits will represent an opportunity to complement traditional agriculture, resulting in a more efficient way to meet the world's food supply⁵.

The food we choose determines our identity, especially for those who identify themselves as vegetarian or vegan. Vegetarians generally do not eat products of animal origin. Veganism is an extreme type of vegetarianism that prohibits any animal product or by-products from being in one's diet. In

1944, the very first vegan society was established in the UK. Donald Watson, one of the founders, coined the term "vegan" from the word "vegetarian" with the motto of unifying the dairy-free vegetarians, furthermore describing this novel group as strict or total vegetarians. In 1962, the term "vegan" was introduced to the Oxford English Dictionary.

A vegan diet is solely based on foods of plant origin, which exclude meat, eggs, milk, and other dairy products. The Vegan Society (2018) defines veganism as "the approach of living that seeks to eliminate all forms of exploitation and cruelty done to animals for food, clothing, transportation or any other purpose. Vegans do not intake red meat, fish, birds, cow or goat's milk, eggs, honey, or foods made from animal sources such as gelatin or animal broths. Vegans don't wear animal by-products like silk, leather, wool, or fur. Vegans avoid products that are being tested on animals and avoid sports or entertainment that includes animals (e.g., zoos, animal harassment, and horse racing). They are physically more active, more likely to be non-smokers, and seldom drink alcohol (American Vegan Society, 2018). Although people following a vegan lifestyle form a minority in the economically developed world, emerging trends indicate notable growth in their numbers. In addition to animal welfare and environmental sustainability, plant-based eaters are increasing due to concern for human health. This is supported by recent clinical and observational research, which shows a plant-based diet will help to prevent many health-related problems, such as obesity and cancers, including breast and prostate cancers, while also lowering the risk of cardiovascular and chronic diseases. A plant-based diet can have positive mood benefits, reporting less stress and anxiety than omnivores⁶.

A further motivation of vegans is to participate in mitigating climate change by taking individual action to reduce carbon footprints by transferring to a plant-based diet. For some people following veganism, it is a philosophy extended to other areas of life that becomes a concept with specific ethical, environmental, and spiritual characteristics. Consequently, awareness about the environmental consequences of livestock production and slaughtering attracts greater visibility to vegan products that have emerged as an important response to the environmental crisis. The number of people consuming plant-based food is rapidly growing

worldwide, faster than they imagined. The American Dietetic Association prognosticated in 2009 that the number of vegans would probably double by 2020. However, two years later, the Vegetarian Resource Group stated that the number of vegetarians and vegans in the US had doubled in 2011. In 2016, of a total of approximately 8 million adults, half of them were vegetarian (4.3 million), and another half were vegan (3.7 million). On a global level, it is estimated that 1 billion people are following vegetarian and vegan diets.

Milk is unnecessary

Animal milk consumption existed from 8000 BC through the aurochs, the ancestors of cows, they domesticated the cows and used their milk for consumption. Since milk contains almost all the essential nutrients for the body, it is highly valued and plays a vital role in the human diet. Infants require their mother's milk for growth and nourishment. However, it is not necessary for humans after weaning, as the ability to digest lactose is inhibited by three-fourths of the population. Though milk is highly valued, people are moving towards a dairy alternative for several reasons. The most common reasons are allergies to milk protein, lactose intolerance, or lifestyle choices, such as vegetarianism⁷.

Health concerns about dairy milk

Cow milk protein allergy

Cow's milk protein allergy is one of the adverse reactions to human health due to the adverse response to the cow's milk dietary antigen. Casein, which makes up about 80% of milk proteins, initiates allergy. Casein is converted into opioid compounds called β -casomorphines when they are digested, causing allergy to the human body; this affects mainly children since the body's immune system does not recognize the cow's milk protein. Cow's milk allergy is an adverse reaction to milk proteins or lactose. The allergic reaction is caused mainly by the milk proteins casein, α -lactalbumin, β -lactoglobulin, globulin, and bovine serum albumin, which can cause IgE- and non-IgE-mediated allergic reactions⁸.

CMPA symptoms may include oral and perioral swelling (more evident in cutaneous manifestations — atopic dermatitis, urticaria, angioedema), gastrointestinal symptoms (eosinophilic esophagitis, reflux, vomiting, dyspepsia, rectal bleeding with or without malabsorption, food refusal, severe colic, constipation, and eosinophilic gastritis), and respiratory tract

symptoms (persistent asthma, allergic rhinitis, wheezing, or chronic cough); chest pain, arrhythmia (cardiovascular system), drowsiness, seizure, or mental confusion (nervous system) some serious cases result in anaphylactic shock⁸.

Lactose intolerance

The inability of the intestinal mucosa to digest and absorb lactose due to the low activity (hypolactasia) or low production of the β -D-galactosidase enzyme, popularly known as lactase results in lactose intolerance. The symptoms are characterized by flatulence, abdominal discomfort, diarrhoea, nausea, vomiting, and constipation⁹.

Veganism

Veganism is a growing trend that excludes the consumption of any type of red meat, chicken, or fish and products of animal origin, such as eggs, milk, and their derivatives. Adapting veganism not only supports the exclusion of animal foods from its diet due to the animal's suffering but also will present less environmental impact⁷.

Anticaries

Milk can cause cavities and tooth decay, especially in toddlers and younger children. Milk contains a decent amount of sugar and under the right environment, it will cause tooth decay. In addition to all the healthy vitamins and proteins, milk also contains natural sugars called lactose. Sugar in any form is always a catalyst for cavities in the right environment. If the child receives multiple servings of milk a day, the risks go way up with developing cavities if proper oral hygiene isn't practiced diligently. Regular intake of milk will make it potentially anti-cariogenic¹⁰.

Acne

Among more than 47,000 women in the U.S., those who drank at least two glasses of skim milk a day as teenagers were 44% more likely to have had acne this may be due to milk's influence on certain hormones, including insulin and insulin-like growth factor-1 (IGF-1)¹¹. IGF-1 gene polymorphism has been shown to increase susceptibility to acne and IGF-1 plasma levels correlate with acne severity as they stimulate the sebaceous gland that produces acne.

Skin allergy

Eczema, a skin allergy, is worsened by the intake of milk and its derivatives; during childhood, eczema is associated with increased milk sensitisation and risk of rhinitis and asthma in early childhood¹².

Bone fracture

Bone fractures are most prevalent where more dairy and animal protein-containing calcium are consumed. However, a high intake of milk might have undesirable effects because milk is the main salutary source of D-galactose. Indeed, a low dose of D-galactose induces changes like natural ageing in animals, including shortened life spans caused by oxidative stress damage, chronic inflammation, neurodegeneration, decreased immune response, and gene transcriptional changes¹³.

The World Health Organization (WHO) recommends increased intake of fruits and vegetables, increased physical activity, and reduced sodium and animal protein intake to promote healthy bones.

Diabetes

The prevalence of type 1 diabetes is highly correlated to the consumption of dairy products. This is due to the autoimmune reaction of the dairy protein, which inhibits the insulin-producing cells of the pancreas¹⁴.

Multiple sclerosis

High intake of dairy and derivatives will increase the extent of multiple sclerosis due to the presence of saturated fat¹⁵.

Cancer

The high calcium content in milk increases the risk of prostate cancer. Women who intake milk regularly are prone to ovarian cancer¹⁶.

Plant-based milk

Novel plant-based (PB) foods and beverages are being designed and made available due to increasing demand for alternative animal-based. Milk alternatives are presently attained from many plants like legumes, seeds, nuts, cereals, and pseudocereals. The demand for plant-based milk alternatives is driven by factors like lactose intolerance, milk allergies, consumer concerns about cow milk hormones and cholesterol, ethical disputes regarding the use of animals and slaughtering, environmental issues, changes in food lifestyle like veganism, presumably healthier diet, considering environmental issues, the dairy and meat sector accounts for the biggest greenhouse gas producers in agriculture. The use of water and human activities for milk and dairy products is notably higher than for fruits and vegetables¹⁷.

This plant-based milk should resemble cow's milk's texture, appearance, technical, nutritional, and organoleptic properties. It is a water-soluble extract

from vegetables, legumes, cereals, pseudocereals, and nuts. Plant-based milk substitutes such as cheese and yoghurt, made from plant-based milk instead of cow milk that is traditionally animal-based, were driven by the growing popularity of being dairy-free for both health and sustainability¹⁷.

Even more impressive is the growth in plant-based derivatives like plant-based yoghurts (+55%), plant-based cheese (+43%), and plant-based creamers (+131%) in the USA¹⁷. Plant-based milk alternatives are fluids that imitate cow's milk in appearance and consistency; they are functional foods with enormous health benefits that are produced from the breakdown of the raw material, which is extracted in water followed by homogenization resulting in particle size distribution in the range 5–20 nm. Furthermore, these plant-based fluids are broadly classified as cereal-based, legume-based, nut-based, seed-based, and pseudo-cereal-based¹⁷.

Plant-based milk lacks some nutrition and varies in composition. Therefore, strategies such as fermentation, the addition of enzymes, fortification with essential nutrients, and mixing two or more plant milk have been suggested to achieve a product with a high nutritive value equivalent to cow's milk¹⁸.

Application of novel technologies like ultrasound pulsed electrical field, high-intensity ultrasound irradiation, ohmic heating, and ultra-high and high-pressure homogenization play a vital role in improving the physical stability of the milk¹⁸.

Therefore, such conditions point to the need for plant-based milk and its derivatives to be obtained as a healthy alternative so that people who cannot consume an animal diet can digest the nutrients necessary for a good diet, in addition to other food alternatives that allow diversifying eating routines. Due to the shift to plant-based milk, there is increased research and development in producing plant-based milk and its derivatives, such as yoghurts, ice cream, and fermented beverages (Table 1).

The adverse effect of plant-based milk**Antinutrients**

The most important health concern due to the increased intake of plant-based proteins is the presence of antinutrients in plant foods. These are naturally produced by plants, which cause adverse effects by interfering with the digestion, absorption, or utilization of nutrients in food¹⁹. Animals fed with unprocessed plant protein had adverse antinutrient

effects, which triggered fear in people regarding the consumption of some plant foods (Table 2).

Plant-based protein and allergy

About 170 foods are identified as causing food allergies. Among those, peanuts, tree nuts, fish, shellfish, milk, egg, wheat, mustard, sesame seeds, and soy are significant allergens. Pea protein is potentially less allergenic than soy and wheat. However, peanut allergy has been proven to affect the intake of pea protein. Pea protein is considered a "hidden allergen"¹⁹. Almonds, on the other hand,

bear more water than any other dairy alternative, consuming 130 pints of water to produce a single glass of almond milk, according to the Oxford study. Bees pollinating on almonds die due to these pressures and other environmental threats. Some people are prone to almond allergies¹⁹.

Coconut milk lacks protein content and has a high amount of saturated fat. Since coconut tree habitats are in tropical climates, there is increased pressure to meet global demand, causing the exploitation of workers and the destruction of rainforests¹⁹. Rice

Table 1 — Plant-based fermented milk alternatives

Plant-based milk	Health benefit
Fermented oat-based milk ³⁹	Antioxidant capacity and phenolic content and no significant decrease of β -glucan. The main phenolic components that were detected in higher amounts in the methanol extracts were gallic acid, catechin, vanillic acid, caffeic acid, p-coumaric acid, ferulic acid, and sinapic acid.
Fermented coconut milk ⁴⁰	Lactic acid bacteria fermentation of coconut milk has a good effect on the nutritional, phytochemical, antibacterial, and sensory properties.
Fermented hemp milk ⁴¹	Hemp seed milk is one of a kind since it is enriched with high nutritive value.
Fermented soy milk ⁴²	Fermented soymilk has been reported for its antioxidant, antiproliferative, antidiabetic, hypolipidemic, immune-modulatory, memory improvement, and wound-healing activities.
Fermented chickpea milk ⁴³	The fermented chickpea milk exhibits potential health benefits that exert physiological effects in vivo, and it determines the molecular mechanisms underlying the protective effects of FCE against manganese-induced toxicity.
Fermented rice milk ⁴⁴	The work focused on developing fermented rice milk with probiotic bacteria and determining its stability.
Fermented peanut milk ⁴⁵	The successful application and consumer acceptability of peanut milk-based curd have the potential to increase the utilization of this crop and enhance its market value. It will certainly reduce the gap between the supply and demand of animal milk and will also help to overcome malnutrition.

Table 2 — Adverse effects of available plant-based milk¹⁸

Component	Dysfunctionality
Phytic Acid	They inhibit essential digestive enzymes like amylase, trypsin, and pepsin. They largely contribute to anemia (which emanates from an iron deficiency) and bone loss. Calcium bioavailability is highly altered by the significant binding of calcium with phytic acid.
Gluten	Gluten, an enzyme inhibitor, causes gastrointestinal distress, leaky gut syndrome, autoimmune disorders, allergic reactions, and cognitive problems. In more severe cases, they cause celiac disease; they also account for joint pain, headaches, fatigue, and poor memory.
Tannins	Tannins cause indigestion, protein deficiency, and gastrointestinal problems, causing bloating, diarrhoea, constipation, and other GI issues.
Oxalate	Oxalate is present in sesame seeds, almonds, cashews, soybeans, and black and brown varieties of millet. These antinutrients make plant (especially legumes) proteins of "poor quality," they inhibit the absorption of calcium, and play a key role in the formation of kidney stones.
Lectins	Lectins are highly present in soy, peanuts, and other beans; they have shown significant inhibition of glucose absorption in the intestine, affecting total caloric intake and resulting in indigestion, bloating, rashes, joint pain, and gas. Lectins penetrate the cell lining of the digestive tract, causing loss of gut epithelial cells, damaging the cell lining, and triggering autoimmune reactions.
Saponins	They enter the bloodstream and trigger immune responses, contributing to leaky gut syndrome and autoimmune disorders.
Trypsin inhibitors	Trypsin inhibitors cause mineral deficiency in children and people suffering from pancreatic dysfunction. However, they are degraded by cooking.
Isoflavones	Isoflavones have a chemical structure similar to estrogen, so some weakly bind with estrogen receptors. In vitro, cell culture, or rodent studies involving large doses of isoflavones might have endocrine-disrupting impacts on reproductive hormones. It is highest in soybeans, might cause hormonal changes, and contribute to digestive issues. It is recommended to avoid soybeans because isoflavones are capable of exerting estrogen-like effects.

offers little in terms of nutrition or environmental benefits when compared with other alternatives. They have an unbalanced diet and are rich in sugar. Rice is a water hog, and according to the Oxford study, the amount of greenhouse gas produced is higher than that of any other plant milk. A large amount of fertilizer used for rice breeding will pollute the waterway, and bacteria will pump methane into the atmosphere¹⁹. Soy, despite its nutritional content, has off-flavor. Isoflavones inhibit the thyroid peroxidase enzyme, which is important in synthesizing T₃ and T₄ hormones and iodine. Due to this, customers are hesitating to take soy protein as it affects thyroid function¹⁹ (Table 2).

Potato

Nutrition of potato

Potatoes are a wholesome, nonfattening, and highly nutritious food that plays an important role in a balanced diet. Potatoes, when freshly harvested, contain 75-80% water content, 16-20% carbohydrates, 2.5-3.5% protein, 0.8-1.2% minerals, 0.1-0.2% crude fats, 0.6% fibre, and essential vitamins and calcium. They have a fair amount of essential amino acids such as isoleucine, leucine, and tryptophan²⁰. According to FAOSTAT, Potatoes provide a fair amount of daily requirement values (DRV) of essential nutrients, e.g., potassium (plays an important role in acid-base equilibrium, promotes Na elimination; 26% of DRV), vitamin C (growth and repair of tissues, antioxidant; 28% of DRV), vitamin B6 (enzymatic functions of the body; 27% of DRV) and dietary fibre (bodyweight management (BMI); 15% of DRV), magnesium (cellular functions; 12% of DRV) and iron (enzyme metabolism, 10% of DRV).

Macronutrients

Potatoes are known as "starchy vegetables," accounting for their predominant macronutrient — carbohydrate — and pre-dominant type of carbohydrate — starch. Potatoes contain "resistant starch" in small amounts, which are fermented by the microflora in the large intestine, producing short-chain fatty acids that result in lowering the pH of the gut and reducing the level of ammonia, which is toxic in the intestinal tract; they function as prebiotics, which promotes the growth of intestinal bacteria²¹.

The protein quality is expressed as a "biological value" based on the amino acid content and bioavailability. Egg protein is the reference protein with a biological value of 100. Compared with other

plant protein sources, potatoes have a fairly high biological value of 90 (e.g., soybeans have a BV of 84, and beans have a BV of 73). Potatoes contain all the nine essential amino acids and are considered "complete" protein. Potatoes are the only staple food meeting the recommended lysine level compared to pasta, white rice, and whole-grain cornmeal. Patatin (up to 40%), protease inhibitors (50%), and other high molecular weight proteins (10%) are the three main proteins present in potato isolate. Patatin possesses antioxidant activity and lipid acyl hydrolase activity. They can exhibit foaming and emulsifying properties. The protease inhibitors are anti-carcinogenic, and anti-microbial, and have high satiety properties by releasing the hunger suppressant cholecystokinin²².

Micronutrients

Potatoes contain a wide range of essential vitamins and minerals, predominantly vitamins C and B6, as well as potassium, magnesium, and iron. A medium-sized (5.2 oz) potato provides 27 mg of vitamin C, making it an "excellent source" of vitamin C as per FDA guidelines. In Americans, diet potato stands 5th as a dietary source of Vitamin C. Potatoes provide a good source of B vitamins like riboflavin, thiamin, and folate, vitamin B6 (12% of the US daily value per serving). Potatoes provide a source of concentrated potassium higher than those foods commonly considered potassium-rich, such as bananas, oranges, and broccoli. A medium-sized (5.3 oz) potato provides 48 mg of magnesium. Vitamin C plays a major role in the production of collagen needed to support cardiovascular function, maintenance of cartilage, bones, teeth, and wound healing²³.

Phytonutrients

Potatoes provide phytonutrients, predominantly carotenoids and phenolic acids²⁴. Regarding vegetable phenolics, potatoes are the largest contributor to the American diet. Carotenoids, such as lutein, zeaxanthin, and violaxanthin, are present in wide varieties of potatoes²⁴. Zeaxanthin in potatoes contributes 13–20% to the diet and is the third main contributor after citrus fruits and green vegetables.

Chlorogenic acid is a colourless polyphenolic compound, constituting up to 80% of the total phenolic content of potato tubers. The highest concentration of chlorogenic acid reported in 100 g of cooked potato tubers is ten times higher than the maximum quantum handed by apples (38.5 mg/100 g FW). They play an important role in promoting healthy gut microflora²⁴.

Quercetin, a flavonoid in higher concentrations in red and russet potatoes²⁴, is vital in antioxidant and anti-inflammatory properties *in vitro* and *in vivo*. Anthocyanins play a significant role in preventing heart disease, obesity, and anti-tumor activity²⁴.

Antioxidant

Potatoes are an important source of antioxidants in the human diet. They reduce the toxicity of cells, resulting from induced protein, lipid, carbohydrate, and DNA damage, contributing to reducing the risk for cancers, cardiovascular diseases, and type II diabetes²⁴.

Glycoalkaloids

Glycoalkaloids present in limited amounts act as natural defences against bacteria, fungi, viruses, and insects of the tubers. When taken in a lower amount, it helps lower cholesterol and inhibits the growth of cancer cells in culture and tumour growth *in vivo*²⁵.

Disadvantage of potato

Nightshade family of plants, which include potatoes, are highly prone to glycoalkaloids; potatoes contain glycoalkaloid solanine and chaconine. When the potato is exposed to light, it produces chlorophyll, which turns it green; these green potatoes are toxic, containing a high amount of glycoalkaloids. They affect digestive health and cause inflammatory bowel disease; they also cause drowsiness, increased sensitivity, itchiness, and digestive symptoms.

They also impart a bitter taste. When consumed in normal amounts, they do not cause any negative effects; they also impart beneficial effects like lowering cholesterol²⁵ and inhibiting the growth of cancer cells in culture and tumour growth *in vivo*. Due to their starchy nature, they cause gas and bloating when consumed more. Storing potatoes at lower temperatures and away from light will minimize the glycoalkaloid content.

Potato and milk

The historical improvement in agricultural productivity within the Old World was an important factor due to the addition of nutrient-dense potatoes from the Americas. This was due to the nutritive superiority of potatoes compared to other staple crops²⁶.

According to the WHO (2009), the amino acid profile of milk complements those in grain and cereals, which benefits people where grains and cereals are predominant; the legumes and cereals will

increase soil nitrogen content; however, potato does not. This will benefit the farmers who use potatoes as rotational crops.

USDA 2020 and NIH data, on comparing a russet potato and whole milk 100 g each. The sugar content of Russet potato is 7.1 times less than that of whole milk. The russet potato is fat-free. Potassium content is higher in russet potatoes. Carbohydrate in whole milk is 73% less than in russet potatoes. Whole milk has riboflavin and vitamin B12 as predominant, while russet potato contains a high amount of niacin, Vitamin B6, and folate. Vitamin D and calcium are predominant in whole milk. Russet potato has 0 cholesterol, while whole milk has about 10 mg of cholesterol per 100 mL. Iron content is higher in potatoes than in milk. Whole milk has more beta carotene, while russet potato has a high amount of lutein and zeaxanthin²⁶ (Table 3).

Potatoes are highly nutritious compared to all the starchy food crops, with more protein, vitamins, and minerals than cereals and legumes. They are a good source of antioxidants and phytochemicals. Recently, people have become aware of diet, nutrition, and

Table 3 — USDA 2020 and NIH data on comparing a russet potato and whole milk (100g each)

Nutrients	Potato	Milk
Calorie (kcal)	79	61
Protein (g)	2.1	3.2
Fat (%)	0.03	1.9
Dietary fibre (g)	1.3	0
Sugar (g)	0.62	5.1
Carbohydrate (g)	18.1	4.8
Cholesterol (mg)	10	0
Vitamin C (mg)	5.7	0
Vitamin D (IU)	0	51
Vitamin E (mg)	0.01	0.07
Vitamin K (µg)	1.8	0.8
Vitamin A (µg)	0	46
Thiamin (mg)	0.046	0.082
Riboflavin (mg)	0.169	0.033
Niacin (mg)	0.089	1.035
Pantothenic acid (mg)	0.373	0.301
Vitamin b6 (mg)	0.036	0.345
Folate (µg)	5	14
Vitamin b12 (µg)	0.45	0
Calcium (mg)	13	113
Iron (mg)	0.86	0.03
Potassium (mg)	417	132
Beta-carotene (µg)	0	7
Lutein+Zeaxanthin (µg)	5	0
Linoleic acid (g)	0.032	0.12
Alpha linoleic acid (g)	0.01	0.075

health. Potatoes have the potential to become an important dietary source of bioactive ingredients and hence can be termed functional food.

Potato milk

Milk, an essential part of the human diet, has long been consumed as a beverage; however, many people say a strict no to dairy products. This triggers the emergence of plant-based drinks from non-dairy alternatives; potato milk will stand unique to all other non-dairy alternatives. Consumers demand innovative food products due to increasing population, household incomes, changing lifestyles, and health issues like malnutrition²⁷.

Potato milk is an upcoming trend in plant-based milk. Not only is the flavour said to be naturally mild (creamy from potato's natural starch), but the process for making it is much friendlier to the environment than dairy and other plant-based milk. (The U.K.'s Plant-Based News reports) Potato milk is very sustainable since it takes only fewer resources to produce a litre of potato milk than other milk. It requires half as much land as oat milk and 56 times less land than almond milk for production". The carbon footprint is increasing tremendously with dairy milk 3.0 kg CO₂ per litre, 0.9 kg CO₂ per litre for oat milk, and 0.7 kg CO₂ per litre for almond milk, a high amount of water is required to produce almond milk, 120liters to produce one glass of milk. On the other hand, soy production led to the clearance of the Amazon rainforest, destroying the vital ecosystem. When compared, potato milk produces the lowest 0.27 CO₂ per litre with less land area for harvesting, reducing the carbon footprint.

In European culture, the use of potato juice in treating gastrointestinal complaints can take us back to the 19th century. Due to their anti-inflammatory activity, potato juice is used as an additive in producing health-promoting food for patients with inflammatory bowel syndrome. Although synthetic medications are given to dyspeptic symptoms, freshly squeezed potato juice, due to its antispasmodic and antacid effect, is used traditionally for hyper-acidic stomach complaints in Germany and Switzerland²⁸.

Despite the white-fleshed potatoes, coloured potatoes like red, purple, blue, or orange varieties are produced; they are a good source of antioxidants like polyphenolics, which neutralize free radicals that can cause cancer, according to the (University of Maine), and have a high amount of nutrition compared to

white-fleshed potatoes. Potatoes also deliver magnesium, potassium, fibre, and even Vitamin C. Raw potato juice is regarded as an excellent food remedy for rheumatism. Due to the lack of product development and value addition, sweet potato production and marketing have been a huge challenge in Ghana; hence, RTIMP developed a potagurt, which is the processing of raw sweet potato into a value-added yoghurt²⁹.

Due to its high-fat content, milk yoghurt is usually not of interest to consumers; however, reducing the fat content can cause a change in texture and consistency. To avoid this, fat replacers are being employed. These fat replacers are incorporated into cheese, yoghurt, and functional food ingredients. The Hydrocolloids (gelatin, xanthan gum, carrageenan, and modified starch) will generally affect the texture, rheology, syneresis, and lubrication properties of potato set yoghurt. Hence, enzymatically modified potato starch is used as a fat replacer. The modified potato starch using amylosubtilin and amylase from *Bacillus licheniformis* has shown great results³⁰.

Ultra-high-pressure homogenization (UHPH) is a novel method to obtain plant-based yoghurt-like substitutes from potatoes. UHPH will relevantly increase the temperature (estimated at 14–25°C per 100 MPa), resulting in a combination of homogenization and thermal treatment. The application of UHPH (>200 MPa) before adding inoculums favoured rapid growth of the microbial starters due to the higher availability of nutrients³⁰.

Potato juice is of interest due to its protein nature; though present in small amounts, it is equivalent to animal protein, especially the substance patatin and protease inhibitors. Potato protein is nutritionally equivalent to egg white protein³¹. They provide as much calcium as cow's milk, and the iron content is higher than other non-dairy milk.

The potato protein isolate has gained significant interest due to its functionality. Potato proteins are considered GRAS (safe food ingredients), non-allergenic, and have been incorporated in upcoming commercial food products such as the Impossible™ Burger. Potato proteins are considered to contain antimicrobial, antioxidant, and anti-allergic when compared to proteins from other sources. Patatin exhibits gelling properties, whereas protease inhibitors are suitable for stabilization³¹.

For a high-quality food, the ability of the protein to produce stable foam is important. The smoothness and

froth produced are associated with bubbles, which improve the palatability and volatilization of flavor³¹. Several techniques can enhance the foaming ability of potatoes. Heat treatment will enhance the foaming ability. The moderate to semi-high heat of 50–80°C can be applied for 10 minutes, partially denaturing the potato protein and enhancing the foaming ability. Precipitation with ethanol can also enhance foam formation. The hydrolysis of protein will increase the foaming. pH can influence foaming ability by initially denaturing protein to pH3 and readjusting to pH7. The foaming stability was due to the reduction of electrostatic interactions, i.e., around the IEP of the potato proteins or in the presence of salts. Using probiotics in the produced potato milk substitute will enhance the nutritional value and eliminate the ant nutrients present, resulting in a value-added milk substitute³¹.

Probiotics

Probiotic-based foods and beverages are emerging functional foods with wide acceptability among customers and are termed future foods. The WHO (2001) defines probiotics as live microorganisms that benefit the host when administered in proper amounts. Probiotics are the advancement of lactic corrosive microorganisms, *bifidobacteria*, *enterococci*, propionic bacteria, and yeasts, which advance solid impacts when ingested³².

They provide health benefits like antimicrobial activity, improved lactose metabolism, reduced gastrointestinal infections, reduced serum cholesterol, anti-carcinogenic properties, anti-diarrheal properties, reduced diabetes, improved inflammatory bowel disease, lipid profile, and reduced *Helicobacter pylori*-associated diseases³².

Species of Lactic acid bacteria, *Bifidobacterium*, *Streptococcus*, *Bacillus*, and Yeast like *Saccharomyces cerevisiae* are Generally Recognized as Safe (GRAS) and used in supplements or food matrices. The most common mode of probiotic delivery is through dairy products; however, choleostromeia, veganism, and lactose intolerance demand a non-dairy matrix for delivery. There is currently a demand for probiotics in non-lactic matrices based on fruits, vegetables, and cereals. Implementing probiotics in fruits and vegetables provides a health benefit to the host because they are rich in antioxidants, vitamins, dietary fibres, and minerals. They do not contain any dairy allergens that might prevent their use by certain segments of the population³³ (Table 1).

The use of diary starters in plant-based milk will enhance the unpleasant flavour. Probiotics are effective only if they survive gastric transit and reach the small intestine. Hence, the viability of probiotics should be 8 log cfu/g or mL when the food is consumed and possess the ability to tolerate gastric and intestinal conditions (including acid, bile, and enzymes) and be able to attach to the gut epithelium. Due to the global attention to probiotics, it has gained attention in the food industry and researchers to produce new products containing probiotics³⁴.

Probiotic potential microorganisms isolated from vegetables and fruits will fit in with the gut environment of people following veganism compared to those isolated from a different source. The surface of vegetables and the plant phyllo sphere are natural habitats of many bacteria. Due to their high nutrient content, such as vitamins, minerals, high carbohydrate content, and acidic environment, vegetables favour the growth of microorganisms. LAB from an unconventional source will provide novel, industrial importance and be a potential strain with enhanced characteristics, or their metabolites could be useful in food production³⁵⁻³⁸.

Discussion

Plant-based beverages are frequently found in supermarkets beside dairy goods and are considered milk substitutes. They are frequently praised for being more sustainable, healthier, and tolerable than milk. It is critical to ascertain the precise quantitative makeup of the macro- and micronutrients in these plant-based beverages to evaluate their nutritional value to that of milk. They can be used to optimize dietary plans that sufficiently satisfy nutritional requirements and raise awareness of potential nutritional gaps while proceeding with the entire milk dietary exclusion. This is crucial for the general public's dietary guidance. However, it is especially crucial for those with certain clinical disorders (including lactose intolerance, allergies to cow's milk proteins, galactosemia, and diarrhoea following an illness).

As was previously noted, lactose intolerance is one of the main causes of the rise in demand for plant-based replacement milk. Patients with this illness cannot break down lactose sugar because there is insufficient lactase enzyme in their digestive system. Frequent symptoms associated with lactose intolerance include gas, tenderness in the abdomen, flatulence, and loose stools. There are additional instances where vomiting and nausea are reported. Even though a sizable section of the

population is lactose intolerant, cow's milk and other mammalian milk are frequently consumed because of their high nutritional value. Since mammalian milk is the only source of energy for mammals, it has the ideal nutritional makeup.

One of the main factors driving the rising demand for plant-based milk beverages is their noticeably lower calorie content. The discrepancy can be attributed to the sugars in cow's milk, often absent from plant-based milk. Since cow's milk comes from mammals, it contains substantial cholesterol. There would be no cholesterol in any plant-based milk beverage, an additional benefit and another reason for the rising demand.

Most plant-based replacement milk brands include calcium in their formulas to replicate the quantities found in cow's milk. However, more investigation is required to determine the effects of increased calcium in the human body. Vitamins can also be found in abundance in cow's milk. However, only soy milk has an equivalent nutrient content to substitute milk. Other milk's vitamin contents are not listed on labels; thus, they are either completely absent or present in tiny amounts.

Conclusion

Although bovine milk is a very important food for the human diet due to its supply of essential nutrients, which in some cases are not found in other foods, using vegetable-based substitutes is a viable alternative to offer consumers who cannot or do not choose to consume dairy derivatives. Plant-based milk substitutes are taking over the markets now for consumers suffering from dairy-related gastrointestinal disorders such as milk protein allergy or lactose intolerance or to have a vegan lifestyle. However, PBMS will not substitute nutrients in milk and its derivatives. In this case, probiotics can be used in the fermentation of the milk produced, resulting in a value-added product. Various strategies could mitigate these limitations, such as fortification and bio-fortification of nutrients, mixing different plant-based milk sources, and genome-wide association studies. Using vegetable potatoes can be a wide awakening for people who require a nutrient-rich diet. Potato milk will stand out from other plant-based milk in that it has homogenization, proper stabilization, and fortification; it can serve as an emerging functional food. Future prospects may formulate potato milk to stand out from all other nondairy alternatives and ferment it with probiotic bacteria to enhance its bio functionality. This will be followed by optimizing the formulated potato

milk using response surface methodology and industrialization of the developed product.

Conflicts of interest

The authors report no financial or other conflicts of interest in this work.

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