

This document (based on publications in the scientific literature, media, and other sources) provides a general overview of plant-based cheeses (PBC), including their ingredients, quality, food safety risks, sales volumes, and regulations. This review does not discuss plant-based soft cheeses (such as cream cheese, cottage cheese, etc.).

Definition of Plant-based Cheeses (PBC)

Plant-based cheeses (PBC) are also known as vegan cheeses, non-dairy cheeses, cheese analogs, and other names. Although U.S. regulations define “cheese” as a product made from milk and/or cream (7 CFR Part 58.405(a) and 21 CFR Part 133), the use of the word “cheese” is commonly used for plant-based cheese analogs at this time but may change (Zeltzer et al., 2022).

Ingredients of PBC

Many different formulations of PBC have been created and marketed. Most are based primarily on soy, nuts (mostly cashews), grains (for example, oats), seeds (hemp, for example), other plant proteins, starches and/or oils. Other ingredients included in formulations may include water, cultures, carrageenan, vegetable gums, salt, flavorings, colorings, preservatives (lactic acid, citric acid, sorbic acid, sodium lactate, lemon juice, cultured sugar), and vitamins. See the table on Page 2 for a list of ingredients in some representative retail products.

Soy tofu has been considered by some to be the first PBC, and it can be made to mimic certain mold-ripened cheeses or cream cheeses (Feder, 2014). A recent review discusses soy cheeses (Jeewanthi and Paik, 2018), which are relatively inexpensive and are rich in isoflavones, but may have a beany taste and grainy texture.

Nuts, especially cashews are commonly used to make PBC (British Columbia Centre for Disease Control, 2017; Chen et al., 2020). Nut PBC products may be fresh or fermented. The fermented cheeses made from nuts often use a starter culture derived from sprouted grains known as rejuvelac; this starter culture has been identified as potential food safety concern (British Columbia Centre for Disease Control, 2017).

The stretchability of melting cheese has been hard to replicate in plant-based cheeses. Casein-casein interactions are primarily non-covalent, and cheeses made from proteins that have natural disulfide bonds or other covalent linkages do not melt like conventional cheeses (Lucey et al., 2003). In an attempt to replicate the flowing properties of cheese, some PBC have been formulated with significant amounts of plant fats that have melting temperatures near room temperature (coconut, palm oil, etc.) and starches, gums, and gels, leading to products which are lower in protein than natural cheese (Mattice and Marangoni, 2020).

One plant protein that shows some promise in mimicking the functionality of casein is the corn protein zein. Zein is considered GRAS for certain food applications (although not for this

application currently), and it is currently more expensive than other plant-based proteins that have been used in PBC. The sensory properties of zein-containing cheeses have not yet been evaluated (Mattice and Marangoni, 2020).

Although it does not appear to be used in any products yet, [lab-grown casein](#) is being developed to make a vegan cheese that more closely mimics real cheese.

Starches are used in some formulations to help trap fat globules within a protein matrix, and gums help to enhance texture and shear properties of cheeses (Feder, 2014).

A survey of ingredients listed on labels of a variety of commercially available PBC products is shown in the following table:

Product	Ingredients
Daiya Cheddar-style Shreds	Filtered Water, Tapioca Starch, Coconut Oil, Expeller Pressed: Canola and/or Safflower Oil, Vegan Natural Flavors, Chickpea Protein, Salt, Potato Protein, Tricalcium Phosphate, Lactic Acid (Vegan), Konjac Gum, Yeast Extract, Xanthan Gum, Annatto Color, Turmeric Color, Inactive Yeast, Potassium Chloride
Daiya Cheddar-style Slices	Filtered Water, Potato Starch, Coconut Oil, Expeller Pressed: Canola and/or Safflower Oil, Tricalcium Phosphate, Vegan Natural Flavors, Salt, Pea Protein, Xanthan Gum, Lactic Acid (Vegan), Konjac Gum, Fruit and/or Vegetable Juice Color, Annatto Color, Yeast Extract, Vegan Enzyme, Vitamin B12
So Delicious Cheddar Flavored Shreds	Organic Coconut milk (Filtered Water, Organic Coconut Cream), Palm Oil, Modified Starches (Potato, Corn), Contains 2% Or Less Of: Salt, Navy Bean Flour, Yeast Extract, Cultured Sugar (To Retain Freshness), Cultures, Natural Flavor, Xanthan Gum, Konjac Gum, Lactic Acid, Annatto Extract (Color), Cellulose (To Prevent Caking)
Treeline Aged Artisanal Plant-based Cheese Wheel	Cashew nuts, filtered water, vegan lactic acid, vegan <i>L. Acidophilus</i> , hickory smoked sea salt
Treeline Plant-based French-style Cheese	Cashew nuts, filtered water, sea salt, lemon juice, green peppercorns, vegan <i>L. Acidophilus</i>
Field Roast Vegan Chao Slices	Filtered water, coconut oil, modified corn and potato starch, potato starch, fermented tofu (soybeans, water, salt, sesame oil, calcium sulfate), sea salt, natural flavor, olive extract (antioxidant used as a preservative) and beta carotene
Follow Your Heart Dairy-Free Cheddar Shreds	Filtered Water, Organic Palm Fruit Oil, Modified Food Starch, Natural Flavors (Plant Sources), Less than 2% of: Pea Fiber, Pea Starch, Bamboo Fiber, Nutritional Yeast, Calcium Phosphate, Rice Flour, Vegetable Glycerin, Sunflower Lecithin, Sea Salt, Sunflower Oil, Lactic Acid (Vegetable Source), Carrageenan (Vegetable Source), Calcium Sulfate, Citric Acid, Enzymes, Annatto (for color), Xanthan Gum, Disodium Phosphate, Sodium Citrate
Follow Your Heart Medium Dairy-free Cheddar Slices	Filtered Water, Coconut Oil, Modified Potato and Corn Starches, Potato Starch, Sea Salt, Lactic Acid (Plant Sources), Citric Acid, Natural Flavor (Plant Sources), Yeast Extract, Olive Extract, Annatto Extract and Beta Carotene for Color
Follow Your Heart Parmesan	Filtered Water, Organic Palm Fruit Oil, Modified Food Starch, Canola Oil, Natural Flavors (Plant Sources [Contains Autolyzed Yeast]), Vegetable Glycerin, Less than 2% of: Lactic Acid (Vegetable Source), Calcium Lactate (Vegetable Source), Sea Salt, Sodium Phosphate, Carrageenan, Bamboo Fiber, Nutritional Yeast, Calcium Phosphate, Organic Chickpea Miso (Organic Handmade Rice Koji, Organic Whole Chickpeas, Sea Salt, Water, Koji Spores), Sunflower Lecithin, Citric Acid, Annatto

Product	Ingredients
Teese Vegan Mozzarella cheese	Filtered Water, Coconut Oil, Tapioca Maltodextrin, Carrageenan, Salt, Pea Protein, Natural Flavors, Lactic Acid, Natural White Color
Teese Vegan Cheddar cheese	Filtered Water, Coconut Oil, Tapioca Starch, Tapioca Maltodextrin, Carrageenan, Salt, Pea Protein, Yeast Extract, Lactic Acid, Natural White Color, Annatto, Natural Flavors, Citric Acid
Violife Epic Mature Cheddar Flavor Block	Filtered Water, Coconut Oil, Food Starch-Modified (Potato & Corn), Potato Starch, Salt (Sea Salt), Organic Ground Sunflower Kernel, Mature Cheddar Flavor (vegan sources), Lactic Acid, Olive Extract, Beta Carotene (Color), Vitamin B12
Violife Just Like Mozzarella Shreds	Filtered Water, Coconut Oil, Food Starch-Modified (Potato & Corn), Corn Starch, Salt (Sea Salt), Mozzarella Flavor (Vegan Sources), Olive Extract, Beta Carotene (Color), Vitamin B12, Powdered Cellulose Added to Prevent Caking
Sister River Foods Vegan Parmesan Original	Nutritional Yeast, Organic Sunflower Seeds, Walnuts, Himalayan Crystal Salt, Organic Hemp seeds
Miyoko's Fresh Vegan Mozz	Filtered Water, Organic Cashews, Organic Coconut Oil, Organic Tapioca, Agar, Organic Cultured Sugar*, Sea Salt, Organic Sunflower Lecithin, Cultures
Dr. Cow Aged Cashew Cheese	Raw cashew nuts, acidophilus, Himalayan pink salt
Tofutti American Cheese Slices	WATER, MAY CONTAIN ONE OR MORE OF THE FOLLOWING OILS (SOY, CORN OR PALM), NON-GMO (TOFU, SOY PROTEIN), MALTODEXTRIN, APPLE CIDER VINEGAR, CORN STARCH, CALCIUM PHOSPHATE, POTATO FLAKES, SEA SALT, POTASSIUM PHOSPHATE, NON-DAIRY LACTIC ACID, ADIPIC ACID, SOY, AND NATURAL COLORS
Oatzarella	Water, organic steel cut oats, organic extra virgin olive oil, organic tapioca flour, natural flavors, sea salt, organic agar, lactic acid (vegan)
Esti Plant-based cheddar-style	Coconut oil, filtered water, starch, non-GMO modified starch, sea salt, extra virgin olive oil, olive extract, citric acid, vegan flavoring, beta-carotene and paprika extract (vegan color)
Good Planet Dairy-free Cheddar	Water, refined coconut oil, modified potato starch, modified tapioca starch, sea salt, tricalcium citrate, vegan flavor, sorbic acid (natural preservative), beta carotene (natural color), paprika extract (natural color)
Nafsika's Garden Swiss Style	Water, refined coconut oil, modified potato starch, modified tapioca starch, sea salt, natural vegan flavors, sorbic acid (natural preservative), beta carotene (color)
Nuts for Cheese Chipotle Cheese Wedge	Organic cashews, organic coconut oil, organic quinoa rejuvelac (water, organic quinoa), water, nutritional yeast, sea salt, organic chickpea miso (organic rice, organic chickpeas, sea salt, water, koji spores), organic chipotle peppers in adobo sauce (organic onion, organic tomato paste, organic chipotle peppers, organic maple syrup, organic apple cider vinegar, organic olive oil, organic garlic), fermented organic oregano extract (water, organic oregano, organic raw cane sugar, active cultures), organic spices
Mozzarisella Organic Smoked Mozzarella	Organic BioSuRice (water, organic sprouted brown rice, organic apple cider vinegar, salt), water, organic cold-pressed coconut oil, organic lemon juice, agar agar, gum arabic, xanthan gum, carob bean gum, natural smoke flavoring, organic turmeric

Quality

PBC is less like real cheese than other plant-based dairy products (milk and yogurt) are like their natural counterparts. As described in one article: “In contrast, currently available plant-based cheeses (sometimes referred to as non-dairy cheeses) leave something to be desired in terms of the functionality and sensory properties. Specifically, the property that many plant-based

cheeses lack is high temperature melt, stretch and flow functionality which is desirable particularly in plant-based cheddar and mozzarella alternatives”(Mattice and Marangoni, 2020).

In a comparison of plant-based cheeses (including those made at home), cashew-soy, cashew, cashew-coconut oil, and almond-based cheeses were rated the highest in terms of consumer preferences based on mining of YouTube, Blogposts, and Amazon product reviews (Satwani et al., 2020).

While the scientific literature does not appear to contain head-to-head sensory analysis comparisons between PBC and natural cheeses, an [informal blinded comparison online](#) showed that PBC and natural cheeses were readily distinguished; however, the quality of PBC may be suitable for some applications. Many reports in the popular media [such as this one](#) claim that the quality of PBC has greatly increased in recent years.

Food Safety Risks

Many different ingredients, formulations, and processes are used in making PBC, so different types of hazards may exist for different PBC products. However, as a starting point, many of the same hazards outlined for processed cheeses could be considered for PBCs (Glass and Doyle, 2013).

Very little information related to the pH or water activity of PBC is currently found in the literature. One paper did give a pH of 2.8 to 2.9 for fermented cashew-based cheeses (Chen et al., 2020), while another suggests that the water activity of fermented nut cheeses is likely to be higher than 0.94 (British Columbia Centre for Disease Control, 2017). These values are likely to vary significantly because of the significant differences in formulations between products and manufacturers.

Because they are likely to be present in the raw ingredients, pathogenic sporeformers including *Clostridia* and *Bacillus* spp. could be a concern, depending on the production method, formulation, packaging, and storage of a product.

Salmonella is commonly associated with nuts and other raw plant products. At least two *Salmonella* outbreaks have been attributed to fermented cashew cheeses, including a [2014 outbreak of *Salmonella* Stanley in the U.S.](#) attributed to a retail product and a 2017 outbreak of *Salmonella* Weltevreden in Victoria, British Columbia, attributed to a restaurant-made product (Schmitt et al., 2018).

Listeria monocytogenes is a possible post-processing hazard for PBC, with a recommendation for products to achieve a pH of ≤ 4.4 to ensure safety from this pathogen (Schmitt et al., 2018). *Staphylococcus aureus* could also be a concern as a post-processing hazard.

The use of lactic acid bacterial fermentation and clean-label preservatives appear to be commonly used in currently marketed PBC products.

In addition to microbiological concerns, certain components of PBC (nuts, some seeds) may be allergens. Also, some plant-derived ingredients such as cashews can be associated with [chemical toxicities](#).

Finally, because those with allergies to milk may assume that non-dairy cheeses contain no milk protein, it is important that all ingredients used in plant-based cheeses be free from milk protein or appropriate labeling used to prevent anaphylactic reactions. [At least one person with a milk allergy has died as a result of eating a food containing a plant-based dairy analog that contained traces of milk protein.](#)

Sales of Plant-based Cheeses

U.S. consumers who identified as vegan increased from 1 to 6% between 2014 and 2017 (Satwani et al., 2020).

Plant-based milk represents 13% of all dollar sales of retail milk, but one source states that [“Although dollar sales of plant-based cheese grew 19% in the past year and 69% over the past two years, it still accounts for less than 1% of all dollar sales of retail cheese”](#), lagging behind other plant-based dairy products in terms of market share.

Globally, the vegan cheese market is expected to reach \$4.42 B by 2027 (Allied Market Research, 2020). In the U.S., the Good Food Institute cites the following numbers for PBC in recent years:

2017 sales of PBC: \$125,377,000

2018 sales of PBC: \$159,783,000

2019 sales of PBC: \$189,099,000

Source: <https://www.gfi.org/marketresearch>

One CEO of a vegan food company predicts [PBC will represent](#) 5% of the market in 5 years and 10% in 10 years. Other officers in vegan food companies [caution](#) that PBC will appeal to vegans but may not appeal to flexitarians, who may be more likely to consume other plant-based dairy products such as plant-based milks.

One PBC company, Daiya, reports that its sales have increased from \$17M to \$127 million between 2012 and 2019.

Regulations

Currently, few if any regulations related to PBC appear to exist except for some considerations related to labeling.

The U.S. standards of identity for cheese types, found in [21 CFR Part 133](#), make it clear that all products identified as cheese must contain milk. The FDA [requested comments](#) on the use of

names of dairy foods in the labeling of plant-based products including cheeses in 2018. The comment period [was extended](#) until 2019, and the [docket for comments](#) (which has so far accumulated more than 14,000 comments) appears to still be open.

So far, based on the names of products cited in the table on Page 2 above, there appears to be a lot of freedom in how PBC are labeled in the U.S., but this may change. Individual states may restrict usage of certain dairy terms, however, as discussed [here](#) and [here](#).

In Canada, one vegan company [was ordered](#) to eliminate the word “cheese” from its marketing, but this decision appears to [have been changed](#) (McClintock, 2020).

In Europe, the U.K., and Australia, it appears that there is [far less tolerance](#) at this time to the use of “cheese” for PBC products (see also [here](#)) (Sinnott and Kotsios, 2020).

Comparison to Natural Cheese

Sensory comparisons: As discussed above, there appears to be very little information about this in the scientific literature. The popular media contains very limited and potentially quite biased comparisons:

- Comparison to natural cheddar cheese in a grilled cheese sandwich: <https://www.cnet.com/health/vegan-cheese-is-it-just-as-good-as-the-real-thing/>
- Video with side-by-side taste tests: <https://sea.mashable.com/science/9569/vegan-cheese-isnt-living-up-to-the-real-thing-heres-why>
- Taste test of vegan cheeses: https://www.huffingtonpost.com.au/2016/10/18/we-taste-tested-8-vegan-cheeses-heres-what-we-think-of-them_a_21585540/

Nutrition: For the most part, PBC are nutritionally very different from natural cheeses. Some PBC have fewer calories and lower sodium content than do natural cheese; however, they may have lower protein (or proteins with a nutritionally inferior amino acid composition) and lower calcium, vitamin D, and mineral levels. PBC may also contain plant-based compounds which can inhibit absorption of essential minerals in the intestine (Jeewanthi and Paik, 2018). The fat composition of PBC is generally quite different from that of natural cheeses. Some PBC have significant levels of carbohydrates compared to natural cheeses.

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