Safety of Fermented Foods

Assessing risks in fermented food processing practices and advice on how to mitigate them

BC Centre for Disease Control · Alberta Health Services · Saskatchewan · Manitoba · Public Health Ontario · Santé publique Ontario · New Brunswick · Nouveau-Brunswick · Nova Scotia · Prince Edward Island · Newfoundland & Labrador · Agriculture and Agri-Food Canada · Agriculture et Agroalimentaire Canada · BIO | FOOD | TECH

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Section 3 | Food safety reviews of fermented foods

A national working group of health inspectors, food safety specialists, and industry fermentation experts reviewed this food safety guidance.

Each fermented food review includes:

- background on the food,
- a description of the food preparation,
- a food flow chart,
- a review of the potential issues with the food preparation, and
- food safety control points.

Foods covered in this guidance are sorted in order of increasing complexity and fermenting agent.

Figure 1 | Fermented foods described by fermentation agent and complexity

Complexity	Foods	Fermenting Agent	Section
high ↑	Sausage	Added LAB[1], wild moulds & yeasts	3.13
	Kefir, Kombucha	SCOBY[2] based: *Acetobacter*, yeast & mould	3.11-3.12
	Koji, Miso	*Aspergillus*, wild or added yeast & LAB	3.10
	Tempeh	*Rhizopus*	3.9
	Natto	*Bacillus*	3.8
	Yogurt, Plant-based cheese	Added LAB	3.6-3.7
	Dosa, Idli, Fesikh	Wild LAB and Yeast	3.4-3.5
↓ low	Vegetables, Sauerkraut, Kimchi	Wild or added LAB	3.1-3.3

[1] – LAB-lactic acid bacteria; [2] – SCOBY-symbiotic culture of bacteria and yeast

A non-fermented, high alkalinity processed food is also included in this guidance: pidan century egg (Section 3.14).

Box 1 | How to use the information in this food safety review

The information presented here lays out best practices for a variety of fermented foods, however, it does not replace or supersede federal and provincial guidance or regulatory requirements for fermented foods. Health inspectors, food safety staff, owner and operators of food processing facilities should follow federal and provincial food safety requirements. This work intends to assist food safety staff (health inspectors) to evaluate the safety of fermented foods and fermentation processes encountered during inspections. Owners and operators of food processing facilities may also find this guidance helpful as it reviews critical control points and measures recommended to produce safe fermented foods. The best available evidence guided this work at the time of publication. The application and use of this document is the responsibility of the user.

This guidance does not include information about good manufacturing practices, labelling practices, or management control programs for cleaning and sanitation, pest control, employee training etc. It is expected that operators will follow approved guidance and seek this information elsewhere.

3.7 | Fermented plant-based cheeses made from nuts

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Overview

Description	Plant-based, vegan cheeses are made from tree nuts and nut milks, lactic acid bacteria starter culture and other ingredients. Plant-based cheeses (PBC) can be made with vegetable rennet, and a variety of thickening agents such as starches (starch agar, tapioca, potato), gums (xantham, guar) and seaweed powder (carrageenan). PBC may be made as fresh spreads, or moulded and aged for short or long-term by air drying in similar fashion to dairy-based cheeses. 
Starter culture	Lactic acid bacteria (LAB). Commercial source required. Wild ferments, i.e. not adding starter culture, rejuvelac, backslopped culture and other starters derived from kefir, probiotic capsules, and other fermented product starters are not recommended.
Key features	PBC made with nuts are different from blended nut pastes because blended nut pastes are not fermented. Both are considered refrigerated, ready-to-eat foods. PBC made with nuts may be fermented and aged at non-refrigerated temperatures, but most require refrigeration following the fermentation and drying process. Manufacture of PBC made with nuts is novel, emergent among vegan consumers, and not based on ethnic or traditional methods.
Hazards of concern	• *Salmonella* • *Listeria*
Important control points	• Rehydration of nuts should occur in acidified or refrigerated potable water. • Raw nuts should be sourced from a company that provides a certificate of assurance (COA) that testing of nuts verified an absence of pathogens. Alternatively, nuts should undergo a process control step that allows for a minimum 5-log reduction in *Salmonella* and pathogenic microbes of concern prior to fermentation. • Commercial LAB must be used. • pH should drop below 4.4 to prevent the growth of *Listeria* during storage. • Ingredients added before or after fermentation must be assessed and processed to remove

Background

Plant-based cheeses (PBC) made from nuts are prepared with plant-based ingredients and do not contain dairy products (milk or cream) sourced from animals. It is suitable for vegetarian and vegan diets and marketed as dairy free. Blended or liquid nut ingredients are fermented with LAB to make a product that is similar in taste, texture and shape to dairy cheeses. Fermented plant-based nut products may be formed into a spread or a cheese-like product. Other plant-based nut spreads or dips are not fermented and are typically refrigerated immediately after preparation and through-out their shelf-life. Other recipes may involve cooking the blended nut mixture, including adding thickening agents to make a firmer spread. These products should be treated like any other perishable, refrigerated food and will not be reviewed here.

In contrast, PBC fermentation steps are done at room temperature, drying and aging processes may also be done at temperatures above 4°C. This review is focused on PBC made with nuts. PBC made with beans, soy and other legumes require extensive processing and are not reviewed here. A review of PBC alternatives made with legumes report the industry is still in development, as the flavour and texture of these products are not yet acceptable, being 'chalky, pasty and plastic-like.'[1] In comparison to dairy cheeses, nut-based PBC, are lower in protein than dairy cheeses and some other legume based cheeses. In a study done in Spain, cashew nut PBC contained 11% protein,[2] another study of commercial purchased coconut and legume PBC found protein content ranged from 0.11 to 0.6% in coconut PBC, was 3% in legume PBC, and 25% in dairy cheddar cheese.[3] Typically, dairy cheeses range from ~10% protein (in cottage cheese) to ~25% protein (cheddar, swiss cheeses).[4] In addition, PBC made from nuts are more expensive as nuts are comparatively higher priced, suggesting that markets for these products are less traditional, confined to Western and European vegan populations. Unlike all other foods reviewed in other sections of the fermented food guidance, PBC made from nuts are not based on traditional, ethnic based recipes. As relative newcomers, processes for making these foods are in development, with knowledge about food safety concerns lagging behind.

Box 2 | Use of the word milk and cheese when describing plant-based products

The Codex Alimentarius is an international body that defines food standards. The standard created for milk defines milk as a "normal mammary secretion of milking animals…".[5] This definition was adopted in 1999. How this ruling is interpreted is further explained in the General Standard for the Use of Dairy Terms (GSUDT) guidance.[6] Non-milk products, including non-milk cheese products should not be described using the terms "milk" or "cheese" as these terms are misleading to the consumer. This is also to allow fair practices in food trade among countries. The distinction is important because proteins made via genetic engineering culture methods are commonplace in many countries, and also represent misuse of the term "milk" and "cheese". Consumers expect milk and dairy products to be made from the "normal mammary secretions of milking animals", not from nuts or in a laboratory.

In Canada, the following response was communicated on the issue of labelling of plant-based foods: "the common name selected to describe an unstandardized food product is subject to the requirements of subsection 5 (1) of the *Food and Drugs Act* and subsection 6 (1) of the *Safe Foods for Canadians Act* which prohibit the use of a common name that is false, misleading, deceptive or that creates an erroneous impression regarding the product."[7,8] The common name chosen to describe an unstandardized food must be suitable for the product. It should adequately describe the true nature of the product and it should not be misleading to the consumer. Any words or descriptors used in the common name of an unstandardized food product should be appropriate and they should accurately describe the product as it is sold to the consumer.

Regulated parties responsible for selling non-dairy type foods that resemble standardized dairy products must ensure that the common names used to describe these types of food products are suitable and will prevent these products from being mistaken for foods with compositional standards established in the regulations, such as in the case of standardized cheeses and milk. In some cases modified standardized common names may be used to describe such foods if the following conditions are met:

- It must always be clear to consumers that the food so described does not meet the standard.
- The consumer is told, in all respects, on the label and in advertisements, the way in which the food does not meet the standard. This information must always be in evidence in a clear and prominent manner as part of the common name on labels and in advertisements.[9]

In the context of the fermented food reviewed here, which may be made with coconuts, cashews, almonds and other types of nuts, the use of the words "milk" and "cheese" by themselves on labels is inappropriate. In recent years, Canadian governing bodies have accepted the use of dairy terms in advertising when the description clearly includes the product is derived from plants, for example "100% dairy-free, plant-based cheese".[10] GSUDT explains that commonly used marketplace terms in each country may be allowable if there is long and established use of the term in the country.[6] Operators making fermented plant-based products will also need to comply with provincial labelling practices that may be tied closely to compositional requirements. In the context of dairy products made with animal milk, this may mean use of words like "cheese" and "milk" and not allowable in that province unless they contain animal milk. Operators in Quebec are instead advised to review requirements with authorities to ensure compliance with Loi sur les produits alimentaires. In this guidance, we have decided to refer to all fermented plant-based products using the consumer recognized name for the product with the added description of what type of plant was used in the manufacture. For example, instead of the more misleading term, "cashew cheese", we describe this as a "plant-based cheese made from cashews", and abbreviate this as PBC made from cashews. Nut milks, such as coconut milk, are additionally differentiated from true milk by using the term plant-based milk, abbreviated as PBM.

Outbreaks and Recalls

Similar to dairy cheeses, PBC made from nuts are at risk of contamination from source ingredients (e.g., raw nuts) or from cross contamination in processing facilities. There have been documented outbreaks of salmonellosis linked to these products in Canada and the US.[11–13] In 2021, a recall of PBC made from cashews (see Table 1 for recalls and Table 2 for a list of outbreaks) was implicated in 20 illnesses with four different serotypes of salmonellosis.[12] In a warning letter sent to the processor by the US Food and Drug Administration,[14] non-compliance was noted in two areas: (1) lack of cleaning and sanitation of a food contact table (*Salmonella* Leiden found in surface swab); and (2) failure to eliminate *Salmonella* as a hazard on the ingredients. *Salmonella* Urbana was found in raw cashews and finished plant-based brie cheese made from cashews; *Salmonella* Chester and *Salmonella* Vinohrady were found in multiple varieties of ready to eat (RTE) plant-based brie cheeses made from cashews.

Table 1 | Recalls related to PBC from nuts

Year(s)	Hazard Category	Hazard detail	Number Recalls	Country (s)	Product Description
2021[15]	Biological	*Salmonella*	1	U.S.	Cashew PBC (brie style)

Two other outbreaks are also documented with PBC made with cashews. One occurred in Canada (2017) and another in the U.S. (2013).[11,13] In Victoria, BC a PBC spread made with cashews was implicated in 23 illnesses.[11] The product was not fermented with a commercial starter culture, instead a culture of fermented sprouting seed water was used, called rejuvelac.[11] Although this and temperature control during the nut cheese processing were found to be unsatisfactory, it was hypothesized that the strain of *Salmonella* found in the nut spread, *S*. Weltevreden, originated on the cashews and was amplified through the processing steps.

Table 2 | Outbreaks related to PBC from nuts in Canada and elsewhere

Date	Country	Pathogen causing illness[1]	No. Ill (no. hospitalized)	Premises where outbreak occurred	Reason
2013[13]	U.S.	*Salmonella* Stanley	17 (3)	Retail product	Cashew PBC (raw)
2017[11]	Canada (BC)	*Salmonella* Weltevreden	23 (NR)	Restaurant	Cashew PBC spread
2021[12]	U.S.	*Salmonella* multiple serotypes (4)	20 (NR)	Retail product	Cashew PBC (brie style)
2022[16,17]	France	*Listeria monocytogenes*	5 (NR)	Retail product	Cashew or almond PBC

NR=not reported

In addition to outbreaks caused by PBC made with cashews, other nut varieties causing illnesses have been linked to consumption of nut pastes and spreads include almonds, hazelnuts, walnuts, peanuts, sesame seeds (tahini) and soy nuts (plant-based butter).[18] Outbreaks have also been linked to non-fermented plant-based nut butters.[19,20]

Description of food preparation for fermented PBC made from nuts

Nuts and plant-based milk (PBM) made from nuts (e.g., coconut PBM or almond PBM) are used as base ingredients. Additional ingredients or flavouring agents may be added before or after the fermentation period to thicken the product, add texture or flavour. Typical ingredients involved in production of PBC made from nuts are listed in the table below.

Table 3 | Examples of ingredients used in manufacture of PBC made with nuts

Nut and nut PBM[1]	Fermentation ingredients and thickening agents	Other ingredients	Spices
Cashews	Starter culture	Maple syrup	Salt
Almonds	Agar	Dried fruits	Pepper
Coconuts	Cider vinegar	Flavoured oils	Poppy seeds
Tree nuts	Starch		Parsley (fresh/dried)
	Vegetable rennet		Thyme

[1]-PBM: plant-based milk

When nuts are used, these must be soaked and blended (chopped into finer fragments) before the fermentation step. Additional ingredients and starter culture may be added before or after the blending step. The mixture is fermented at room temperature for one or more days. The recommended final pH for fermented PBC made with nuts is pH 4.4 to control for *Listeria*.[21] Following the fermentation, when PBC like spreads are made, the mixture is put into containers for refrigerated storage. Other PBC products are shaped and dried to more closely resemble dairy cheese. The PBC products may be wrapped in cheese cloth or put into containers with a perforated bottom that allows excess fluids to drain away. Drying can be sped up by putting fermented PBC into a dehydrator for short periods of time. During drying periods other flavouring agents may be added to impart other flavours to the cheese, for example, rubbing in flavoured oils, doing salt brine washes, or adding fresh or dried spices and herbs to the outer layer of the PBC.

Fermented vegetables, for e.g., sauerkraut and kimchi, have centuries-long histories that include traditional cultural processing methods and practices with ethnic roots based in their country of origin, Germany and Korea. In contrast, PBC made with nuts have arisen more recently, in the last few decades, as vegans and vegetarian populations demand to have foods that look and taste like animal-based products, but are plant-based. Very few publications exist in the public record from the scientific community regarding manufacture of fermented PBC;[21] therefore there is little information to provide best practices or to advise on quality issues. However, there is a good historical record for tree nuts as a causative agent for many foodborne outbreaks.[22] Because PBC products have been linked to outbreaks in Canada, France and the United States, careful examination of food safety risks in the processing steps is recommended.[13–15] Recommendations are to manage the ingredient risks in PBC products in a manner similar to what is expected of dairy cheese products, as they are both potentially hazardous foods. The recommendations provided here for food safety control are consistent with best practices used for manufacturing dairy cheeses.[23,24]

Strict control over the ingredients at all stages of fermentation is necessary to prevent cross-contamination and potential microbial growth.[23,24] Ingredients added to PBC before the PBC has achieved a pH of 4.4 or less during the fermentation process must be managed so as to not increase risk. For example, see Box 3 using the example of a recipe that declares coconut milk is used to make the plant-based cheese, more granular detail is required to assess risk.

Soaking of nuts is a high risk step. Before soaking, nuts should receive a process to reduce pathogen load, such as a heat pasteurization or treatment with periacetic acid. During the soak step to prevent pathogen growth, water should be acidified or the nuts soaked under refrigeration. Hygiene and premises control should be in place to reduce risks of cross contamination in the processing facility that can introduce pathogens during soaking and subsequent process steps. The source of each ingredient must be specified and information about how the ingredient is processed provided. For incoming nut ingredients, a certificate of assurance (COA) is often requested to demonstrate absence of pathogens from a log-reduction treatment and/or testing. Of note: blanching of nuts is a process applied by the nut industry to remove the thin pellicle (skin) layer from the kernel. The process can differ among different types of nuts. Blanching should not be viewed as a validated pathogen reduction step unless this is explicitly stated in the product certificate of assurance.

Figure 2 | Coconut as an ingredient

Box 3 | Verify ingredient sources to determine if further process control is required

The recipe states that coconut milk is used. Ask the operator more about the coconut milk and where it came from. You might also request who it was purchased from or who the supplier is. The important information to find out is whether this PBM is a canned product or fresh product? The risk is very different depending on the answer.

If the coconut milk is from a canned commercial source further documentation and processing would not be required, as we can accept that a canned supplier of coconut milk has sufficiently processed the product to control for microbes (similarly, if coconut milk was purchased in shelf-stable cartons). However, if the coconut milk came from a batch of raw coconuts, and it was the operator who split open the nuts to freshly extract the milk, the risk is greater, and further processing is required. In this example, the possibility of *Salmonella* on the surface of the coconut exists. *Salmonella* could enter the nut meats and milk from cross-contamination of the knife when slicing or chopping open, transferring bacteria from the exterior to the interior of the coconut.

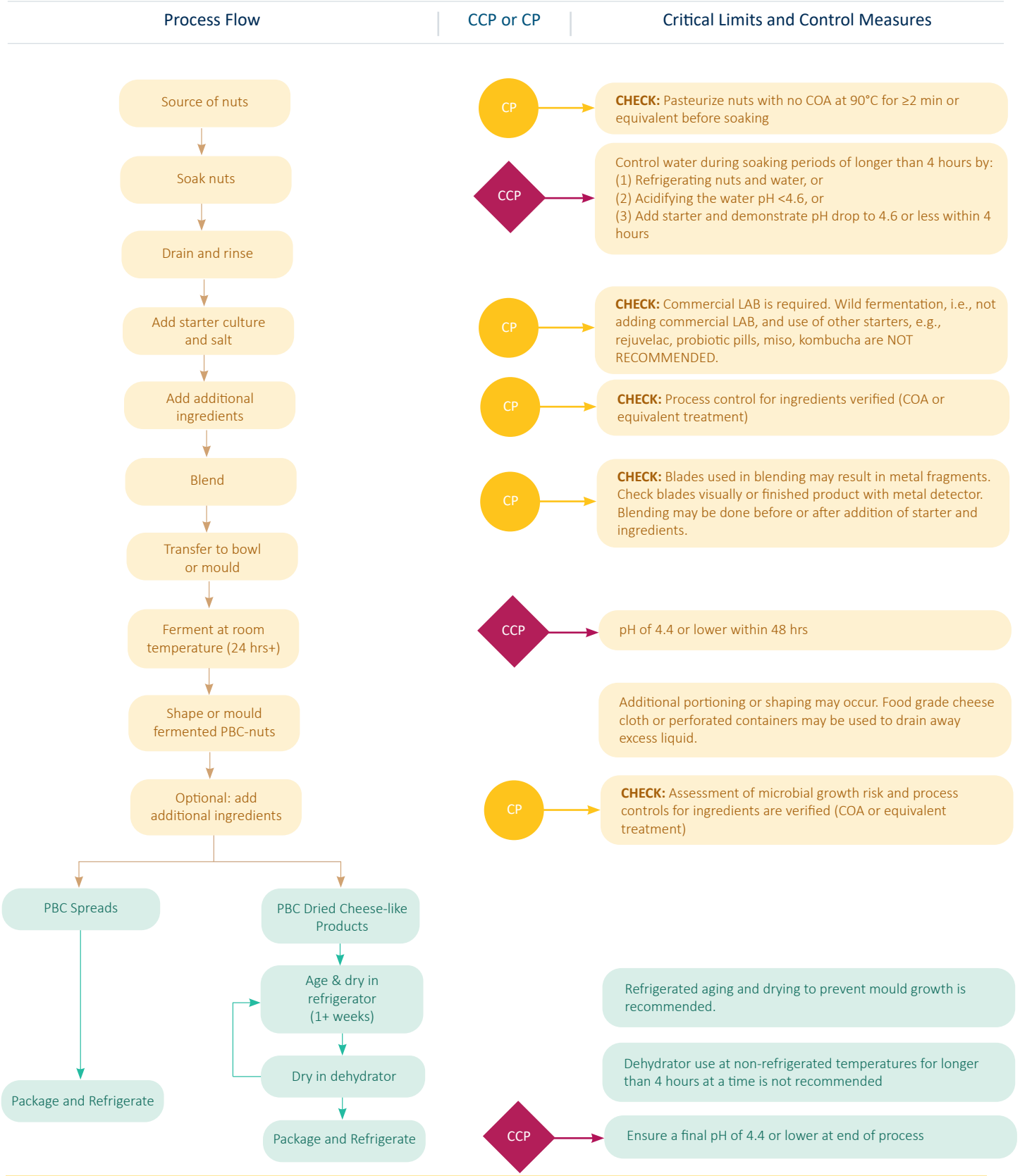
To control for this possible contamination an additional process step by the operator is required to control this hazard. For example, a heating step sufficient to impart a minimum 5-log *Salmonella* reduction would be required.[24]

In the dairy cheese industry, herbs and flowers added to cheeses following fermentation and ripening likewise go through a sanitizing process before being added to the outside of the finished product.

This guidance is focused on processes that will limit growth of microbial hazards that may be present on nuts or arise from cross contamination with the environment, food handlers or other ingredients when making PBC. Additionally, other chemical and physical hazards associated with PBC cheeses made with nuts include those hazards that should be controlled by the supplier and manufacturer of nut ingredients. Chemical hazards associated with nuts include mycotoxins (aflatoxins), pesticides, heavy metals, and sulfites.[25] Physical hazards associated with nuts include stones, shell casings and other items associated with nut processing.[25] Because control of most physical and chemical hazards associated with nuts rest with the manufacturer, we recommend that high quality nut ingredients are used, preferably sourced from a supplier who can provide a COA that includes testing for chemical hazards like aflatoxins and microbial hazards (*Salmonella*) to assure these contaminants are absent. We recommend all nuts receive a log reduction process, such as heat pasteurization, prior to the fermentation.

Allergen labelling in PBC made with nuts is self-evident, nonetheless, it is important to ensure that adequate labelling makes it clear that although these products look like animal dairy based cheese, they are in fact plant-based, are made from nuts, and contain nuts. This is consistent with allergen labelling requirements specified by the *Food and Drug Act* and the *Safe Foods for Canadians Act* and regulations.[9,10]

Fermented PBC made from nuts food flow chart | Process flow and controls



Potential issues with fermented PBC made with nuts food preparation

Issue	Description
Raw nut ingredients	Raw tree nuts have been linked to outbreaks including PBC made with cashews. Nuts should be heat-treated to allow for a 5-log reduction of *Salmonella* prior to soaking, blending and fermentation steps. This can be done by pouring boiling water over the nuts to provide a minimum temperature of 90°C for 2 minutes or other equivalent time and temperatures to ensure a 5-log reduction.[25] Nuts taken directly from freezer or refrigerator will take longer to come up to room temperature so ensure that if a boiling water method is used, that 90°C or higher is maintained for a full 2 minutes. Note: this process was validated for almonds. Chemical sanitizers such as periacetic acid are also acceptable.
Soaking of nuts	All nuts must be soaked in refrigerated (<4°C) or acidified potable water (pH <4.6) to prevent bacterial growth and toxin formation (including roasted nuts or raw nuts with COA verifying absence of pathogens). The concern is that cross-contamination may occur in this process step that would allow introduction of pathogens. Preventing growth through acidification of water to pH <4.6 or via refrigeration to temperatures <4°C will mitigate this risk. Some recipes add starter culture at this step. If this option is chosen, verify a pH drop to a pH of 4.4 or below within 48 hr as per fermentation process control verification. Other control measures include limiting soak time to 2 hr or less or any equivalent process.
Non-commercial starter cultures	PBC-nut recipes suggest a variety of starter cultures may be used, such as miso paste, coconut yogurt, probiotic pills or rejuvelac (fermented seed water). *Enterobacteriacaea* (not further speciated) and *Bacillus* were detected in rejuvelac starter prepared from quinoa seeds during manufacture of cashew nuts in one study of PBC-cashew nuts prepared by an Ontario manufacturer.[26] It was suspected that the quinoa seeds were likely contaminated by *E. coli*. The final PBC-cashew was not found to be contaminated with *Enterobacteriacae*, speculation was that these bacteria were destroyed by the LAB activity and the acidity (final pH 2.9) of this batch of PBC.[26] The predominant cultures in the rejuvelac were determined to be *Leuconostoc*, *Weisella*, and *Pediococcus*.[26] In this same study, miso was found to be contaminated by *Staphylococcus* and *Streptococcus*.[26] Rejuvelac and other non-commercial sources are not recommended as a starter culture or source of LAB for PBC.
Ingredients used prior to fermentation step	Many different types of ingredients can be used to make a fermented PBC made with nuts. When an ingredient is contaminated by a pathogen, risk exists for that pathogen to multiply or grow during the fermentation process. To reduce risk, process controls should be applied to ingredients to demonstrate risks are managed. This can come from a supplier in the form of a certificate of assurance that the product is pathogen free. Otherwise the operator is expected to assess ingredient ability to support microbial growth, and if needed to apply a process control to the ingredient to manage the risk. Options for process control: boil spices for 30 minutes; soak in bleach (200ppm for 2 min); immerse in food grade hydrogen peroxide following manufacturer's specifications; evaluate manufacturing process of the ingredient is acceptable and low-risk (e.g. dried fruits added are at a_w of 0.85 or less), or use other acceptable process controls (e.g., frying, use of irradiated spices, steam treating).[24]
Ingredients used after fermentation step	Spices, fresh herbs, fruits or other ingredients added to PBC or pressed onto the PBC still pose risk even if PBC is at a pH of 4.4 or less. This is because the ingredients added may not equilibrate to this acidic pH or create a microenvironment where pathogen growth could still occur. Risk is reduced if aging occurs under refrigerated conditions of 4°C or less. It is still recommended spices, herbs and other ingredients be treated (as above) to reduce risk.
Rind-washing	PBC made with nuts that are washed with salt brine or other flavours (wine, beer, oils) must be assessed for pH and potential pathogen risk. The ingredients used should be commercially purchased otherwise be evaluated for safety as described (examine process control methods for safety.[24]
Aging and drying	Drying and aging in refrigerated conditions is recommended. The use of dehydrators operating at low temperatures should be limited to short periods, no longer than 2 to 4 hours.

Food safety control points for PBC made with nuts

- For ingredients to be exempted from a process control the ingredients **must** meet certain conditions;
    - be sourced from a supplier that subjected ingredients to a process control that has inactivated pathogens, e.g., irradiated spices or commercially canned nut milk;
    - be sourced from suppliers that can verify products are testing free of *Salmonella*, *Listeria*, *E. coli* and other microbial hazards (a COA should come with the ingredient)
- However, subsequent CCPs (e.g., control of soaking) still apply, and
- We recommend all nuts receive a log reduction process (e.g., heat pasteurization by adding boiling water) or be treated with a chemical sanitizer such as peracetic acid, prior to the soaking / fermentation step;
- Sanitary facilities and handling are required for the manufacturing of this product. If the cashews or other nuts are mechanically chopped / blended there must be a sanitation plan in place to limit contamination from this processing and handling step;
- Commercial lactic acid bacterial starter culture is recommended to make PBC made with nuts;
    - Wild or natural fermentation is not recommended.
- Rejuvelac water is not recommended for the manufacture of PBC. Biological hazards (e.g., *Salmonella*) are difficult to control in sprouted seeds and significant risk of illness exists associated with sprouted seeds, wild fermentation cultures that are created through soaking of wheat berries or other seeds to create rejuvelac;
- Back-slopping (using a previous culture), use of kombucha, yogurt, miso paste, probiotic pills, or pickling brine as a starter culture is not recommended;
- After heat pasteurizing, nuts should be cooled from 60°C to 20°C in two hours, and further cooled from 20°C to 4°C in four hours (per normal guidance)[27];
    - Nuts soaked in water **must** have an additional control step to minimize growth of *Salmonella* by either (1) refrigeration, or if soaking nuts at room temperature (2) acidification of the water to below 4.6, or (3) addition of LAB starter culture with verification of pH reduction to 4.6 or less after 4 hours;
- Fermentation verification: pH tests of the initial cashew ferment (0 hrs), and ferment process (at 24 and 48 hours) must be provided, and sufficient to show an active fermentation with 2 days is established with pH dropping to below 4.4 by end of 2nd day. Use of a pH meter is recommended.
- Reduced oxygen packaging, if used, packaging should comply with products according to the pH and a_w of the final product.
- Allergen labelling of nut cheese products is required, although it has been demonstrated that fermentation reduces allergenicity by up to half in final products.[26]

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