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# 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 · Québec · New Brunswick / Nouveau Brunswick · Nova Scotia · Prince Edward Island Canada · Newfoundland & Labrador · Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada · Bio | Food | Tech

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Additional fermented food guidance can be accessed at: http://www.bccdc.ca/health-professionals/professional-resources/fermented-foods

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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], spontaneous moulds & yeasts | 3.13 |
| ↑ | Kefir, Kombucha | SCOBY[2] based: *Acetobacter*, yeast & mould | 3.11-3.12 |
| | Koji, Miso | *Aspergillus*, spontaneous 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 | Spontaneous LAB and Yeast | 3.4-3.5 |
| low | Vegetables, Sauerkraut, Kimchi | Spontaneous 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.

# 3.2 | Sauerkraut

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## Overview

| | |
|---|---|
| Description | <br>Cabbage is chopped, mixed with salt, and fermented for weeks to months. |
| Starter culture | Spontaneous lactic acid bacteria (LAB) present on ingredients.<br>Backslopping portion of old culture to new batch common practice. |
| Key features | • Sauerkraut can be served raw for refrigerated sale and storage, or be pasteurized and packaged for room temperature storage in shelf-stable containers.<br>• Fermentation is progressive lasting from 7 days to several months |
| Hazards of concern | • Spoilage yeasts and moulds that grow on surface<br>• *E. coli* from unsanitary conditions, and pathogens on raw materials including *Salmonella*, *Listeria* and *Clostridium* spp., however, these are unlikely to survive acidic pH development during fermentation<br>• Biogenic amine formation |
| Important control points | • Added salt to promote LAB fermentation, optimal 2.25% w/w (>0.7% NaCl <3.0% or in 5% salt brine solution)<br>• This is an anaerobic fermentation, so it is important to exclude air by (1) pressing down cabbage and squeezing to remove air bubbles and (2) to keep cabbage submerged below liquid to limit growth of spoilage yeasts and moulds |

**Background**

Sauerkraut is a LAB fermentation of cabbage and salt. It is commonly a spontaneous fermentation, without the use of a starter culture, although in commercial operations both starter and backslopping may be employed. Historically, sauerkraut can be traced back to the first century A.D. and gained prominence in 1775 when it was acclaimed by Captain James Cook as a food capable of preventing scurvy as sauerkraut is a good source of vitamin C, containing 300 to 700 mg/kg.[1] Sauerkraut and separately, sauerkraut juice, is sold.[2] The majority (up to 80%) of sauerkraut made in the United States (U.S.) is sold packed in cans, with the remainder marketed in bulk, or packed in glass jars or plastic bags.[3] Sauerkraut in glass jars or packed in plastic has an additional hurdle of refrigeration or preservative added, e.g., sodium benzoate.[3]

**Box 2 | Description of bacteria present in wild sauerkraut fermentations**

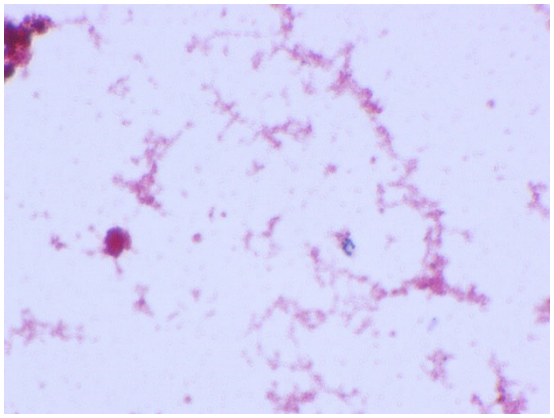
Spontaneous sauerkraut fermentations occur in four stages. (1) Aerobic bacteria present on the cabbage, e.g., *Pseudomonas*, *Flavobacterium*, *Acinetobacteria* will decrease in numbers once the cabbage is tightly packed into a container. Oxygen is used up by facultative anaerobic bacteria, after two to three days the pH decreases, as various organic acids are released.[2] *Leucononostoc* bacteria (*Lc. mesenteroides* primarily and also *Lc. fallax*) normally present on cabbage leaves in small numbers will rapidly increase in numbers up to $10^8$ CFU/mL in anaerobic conditions within 12 to 14 hours, lowering the pH in the brine by release of lactic acid and acetic acid bacteria.[1] *Leuconostoc* bacteria also release $CO_2$ into the brine establishing an anaerobic environment early in this process. Lactic acid content is usually <1% after one week. This stage is also known as the heterofermentative LAB stage.[3] In the second week, homofermentative lactobacilli bacteria then predominate (non-gas producers), along with streptococci and enterococci, converting the naturally occurring carbohydrates, for example, sugars of glucose, fructose and sucrose, to organic acids, for example lactic acid.[1,4] Other acids are also produced in smaller amounts. Lacticacid content will be 1.5 to 2%, and pH will be 3.8 to 4.1 (mild tasting sauerkraut).[4] After four or more weeks of fermentation, total acid content of up to 2.5% and pH decreases to a low of 3.4 occur (stronger, sharper sauerkraut).[1,4]

Commercial starter cultures are not typically used in sauerkraut production.[2]

In figure 2, home made sauerkraut is shown immediately after packing into a glass container. The sauerkraut is weighted down with a glass insert inside the jar, the lid has a vent, and the container is secured with a Mason ring. Before fermentation (Day 0) there is very little liquid in the jar and few bacteria. Liquid released from the cabbage rises above the glass weight within 24 hours, visible in Day 7 and 14 photos. Anaerobic microbial activity occurs, as observed by bubbles forming in the jar and in the microscopic examination of the fermenting liquid. At seven and 14 days into fermentation (Day 7 and Day 14) there are many gram positive cocci and rods observed (purple round and oval shaped bacteria), presumed to be LAB.

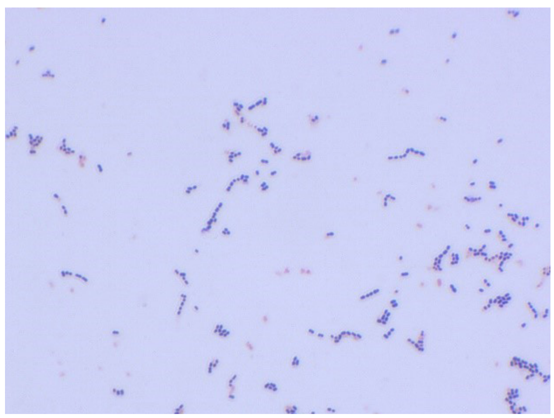
**Figure 2 | Sauerkraut appearance during fermentation**

Sauerkraut at Day 0



Gram stain 1000X

Sauerkraut at Day 7



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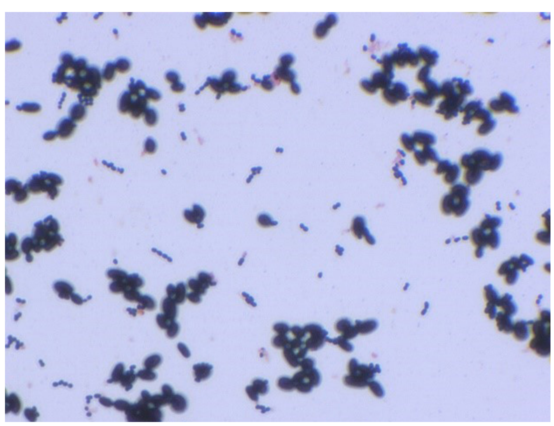
Sauerkraut at Day 14



Gram stain 1000X

### Outbreaks and Recalls

No foodborne illnesses or outbreaks were found linked to sauerkraut following reviews of the Publically Available International Foodborne Outbreak Database (conducted February 7, 2022).[5] A second review of foodborne illness statistics in the Centers for Disease Control database in the U.S., found sauerkraut is rarely reported as a food vehicle in illnesses, and to date no pathogens have been identified in sauerkraut, even though it is sometimes listed as a food consumed during a foodborne illness.[6]

Very few recalls of sauerkraut were found in Canada and elsewhere. Table 1 describes a series of allergen recalls for a fish based sauerkraut product in 2022. Physical hazards predominate in sauerkraut, glass fragments were detected in 2001 and 2011 in US and Canadian products, metal fragments were reported in plastic pouched sauerkraut in Luxembourg, stem pieces and unknown foreign bodies were also observed in sauerkraut products. No microbiological or chemical hazards were present in sauerkraut recalls.

**Table 1 | Recalls related to sauerkraut products in Canada and elsewhere**

| Year(s) | Hazard Category | Hazard Detail | Number Recalls | Country (s) | Product Description |
|---|---|---|---|---|---|
| 2022[7] | Allergen | Milk | 5 | Canada | Fish based (tilapia) |
| 2001-2011[8,9] | Physical | Glass | 2 | Canada, United States | Sauerkraut with carrots; sauerkraut in glass jars |
| 2021[10] | Physical | Physical | 1 | Luxumbourg | Pouched sauerkraut |
| 2021[11] | Physical | Foreign Bodies | NA | Germany | Pouched sauerkraut with ham ('dark foreign bodies') |
| 2016[12] | Physical (extraneous material) | Pieces of stem | 1 | Canada | Wine flavoured |

### Description of food preparation for sauerkraut

Fresh cabbage (*Brassica oleracea*, many varieties used) is prepared by removing outer soil and trimming away damaged leaves. The whole cabbage may be fermented, or it may be cored and sliced or shredded. Generally the cabbage is cored and chopped or sliced to 3 to 5 mm width.[3] Slicing releases and makes available the natural sugars in the cabbage that are rapidly digested by available bacteria. Following slicing and shredding it is important to add salt quickly to promote LAB growth and to create an anaerobic environment to begin the fermentation, otherwise spoilage bacteria may take hold. While sauerkraut fermentation is generally safe, process experts all agree spoilage issues usually occur at the beginning of the process.[3]

Salt is added, either by manual mixing or through addition of salt brine. Salt will promote release of water from the cabbage, so water is not usually added to the ferment. The cabbage is pressed down, covered and must be submerged below the liquid to prevent spoilage (moulds) and to create an anaerobic environment for LAB fermentation. The percentage of salt can vary from 0.7% to 3%, with optimal at 2.25% (w/w).[1] This range is important for selection and growth promotion of LAB. Salt concentrations above 3.5% should be avoided as higher amounts are detrimental to growth of *Leuconostoc* bacteria at the beginning of the fermentation process.[4] Quality issues may also occur if salt concentrations are too high or too low. When salt is added at too high of a concentration, "pink kraut", may result that is a discolouration due to formation of a water soluble red pigment.[4] Yeast growth from *Rhodotorula* causes the pink colour and creates a slimy sauerkraut from yeast pectinase activity.[2] When salt concentrations are too low, "soft kraut" may occur, when it takes too long for lactic acids to form.[4] The beginning of the fermentation process is critical to ensure spoilage microbes (yeasts, moulds, bacteria) do not become established, rapid pH drop is needed to prevent this.[2] Lowering the amount of salt (NaCl) by using some mineral salts is possible, and have been demonstrated in several experiments however, microbiological safety and sensory quality must be demonstrated for this to be an acceptable process.[2]

Fermentation temperatures should not generally be conducted at temperatures above 25°C or below 10°C as these favor the growth of spoilage organisms, affect flavour and may also result in poor LAB activity.[1,4] The initial pH of the cabbage and salt brine prior to fermentation beginning is usually 5.9 to 6.5; the initial sugar concentration in cabbage is 4 to 5% providing the carbohydrates necessary for LAB fermentation.[13] After one week, sauerkraut may be packaged, as long as the pH is below 4.2 and the total acids are >1% lactic acid.[1,13] At this pH the sauerkraut has a milder flavour. Extended fermentations from several weeks to several months will result in lower pH to 3.4; higher acid content from 1.5% to 2.0% (lactic and acetic acid) and provides a sharper flavour.[3] An acidity of 1.5% can occur in as little as 10 days depending on temperature.[3]

Commercial operations with large capacity fermentation tanks are capable of holding up to 100 tons of cabbage. Shredded cabbage is dry salted on conveyor belts and layered into a tank, covered with food grade plastic wrap and weighted down with water on top of the plastic. In the U.S. sauerkraut may sit in the tanks for up to a year waiting to be packed and sold, although the fermentation is generally completed in two to three weeks.[13] Commercial operations, to speed up the fermentation time, may also increase initial fermentation temperatures through use of heat and steam to raise temperatures of cold sauerkraut in holding tanks.[3]

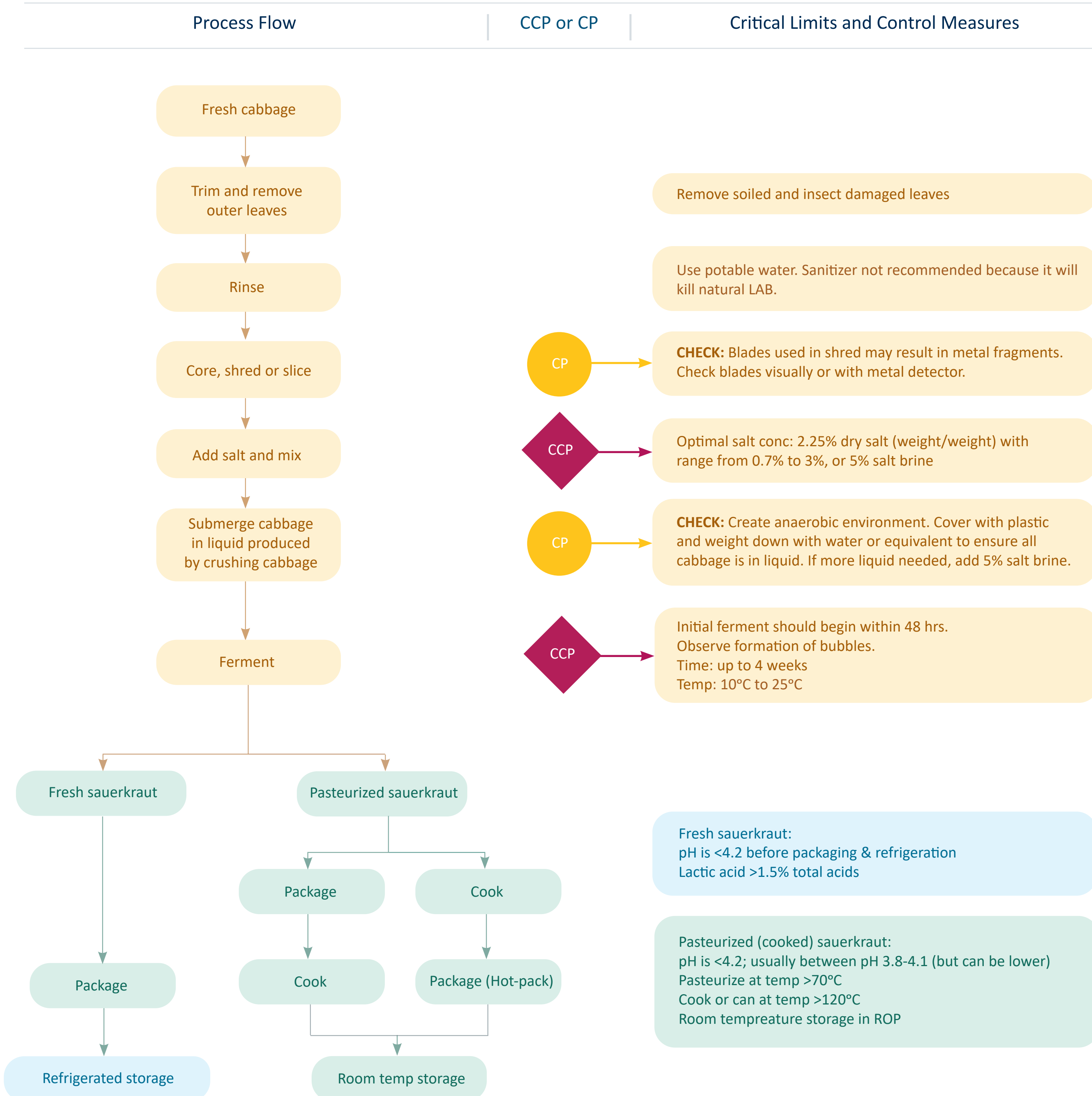
Fresh packed sauerkraut must be refrigerated; pasteurized sauerkraut is suitable for room temperature storage. Pasteurization should be at least to temperatures of 70°C, with a recommended temperature of 74°C in hot brine, then hot-packed.[4] The brine can be sourced from leftover sauerkraut juice or made with 2 to 3% salt.[3] Packaging may occur in cans, glass jars or plastic bags before cooling. As these products have low pH and high acid, up to 2.25% from lactic and acetic acids, boiling water methods are sufficient; pressure canning is unnecessary. Some commercial operations are able to market low sodium sauerkraut and sauerkraut juice using mineral salts, for example by adding potassium chloride (KCl).[2]

Approved preservatives, such as sodium benzoate, may be added as an additional barrier or hurdle for preservation, and is recommended for sauerkraut packaged in glass and plastic.[3,4] One study examining pathogen persistence in acidified (non-fermented) vegetables at a pH of 3.8 noted a time interval of 237 hours for pickled vegetables in citric acid and 282 hours for acetic acid pickled vegetables to achieve a 5-log reduction of *E. coli* O157:H7.[14] For sauerkraut sold fresh without pasteurization, operators are recommended to keep the product refrigerated after the fermentation period and to hold product for a minimum of two weeks once pH levels drop.

Adulteration by insects is regulated in the US – no more than 50 thrips per 100 g of sauerkraut should be observed.[3] In Canada, sauerkraut and other pickled vegetable products are not mentioned in the Guidelines for the General Cleanliness of Food although standards exist for other foods.[15]

Wastage in sauerkraut production occurs from cabbage coring, trimming and removal of excess liquid during initial stages of fermentation.[4] It's estimated that 100 tons of shredded cabbage will yield 20 tons of brine that can pose issues for municipal water treatment plants. Sauerkraut wastewater should be treated in a bioreactor before discharge to municipal waste treatment plants to remove high biological oxygen demand solids (BOD), acid and salt content. Yeast cells are used in bioreactors to remove in excess of 90% of BOD loads.[4]

# Sauerkraut food flow chart | Process flow and controls



**Potential issues with sauerkraut food preparation**

| Issue | Description |
|---|---|
| High salt >3.5%[1,2,16] | Slows growth of LAB allowing yeasts to grown, resulting in pink coloured sauerkraut and off flavours. Pectinases result in slimy sauerkraut. May also favor one type of LAB leading to poor flavours. |
| Low salt <0.8%[1] | Poor LAB growth resulting is soft sauerkraut |
| High temp >25°C[1] | LAB grows very fast with rapid acid production resulting in very poor flavour. During initial stages, before LAB population increase there is also risk of aerobic yeasts and moulds that also impart off-flavours before acid environment stops their growth. |
| Low temp <10°C[1] | Delay in start of fermentation that can lead to spoilage and off flavours. Cabbage should be at room temperature. |
| Heaving[13] | During initial fermentation (24 to 48 hr), carbon dioxide gas forms and pushes up cabbage, causing heaving. When CO2 is not removed or cannot escape (e.g., under the weight of plastic liner), cabbage may be pushed into aerobic environment allowing yeasts and moulds to grow. Vent gas, and/or drain brine to lower cabbage. |
| Delay between shredding cabbage and salting, packing and filling[2] | Shredding releases nutrients from the cabbage resulting in rapid microbial growth. Any delay following shredding allows aerobic yeasts, moulds, and potential pathogenic enteric microbes to grow. |
| Packing and filling is poor[1] | If shredded cabbage is not pushed down enough, two issues occur. Air is left between the layers of cabbage and salting doesn't result in water release from cabbage. This will allow yeast and mould growth. |
| Top of ferment container is not covered | When oxygen is not excluded, aerobic environments at the surface will allow growth of aerobic yeasts and moulds, causing spoilage. |
| Fermentation is incomplete[1] | Fresh sauerkraut is stored under refrigerated conditions. If it is not given enough time to completely ferment alcohol formation may result through the action of cold tolerant yeasts that convert remaining sugars. |
| Histamine formation[1] | Biogenic amines produced by aerobic microbes may form during initial stages of fermentation before LAB can grow. |

**Sauerkraut food safety control points**

Food safety points described in this section are shown in point form below:

- To limit microbial contaminants, cabbage must be prepared and trimmed by removing outer leaves, and rinsing off soils with potable water
- Following preparation, cabbage should be sliced, salt added, placed in a container with the top weighted down in a manner to exclude air, thereby creating an anaerobic environment for LAB fermentation to begin immediately
- Packing and filling of ferment container should be done quickly; cabbage should be adequately weighted down; cabbage and salt must be in contact to allow water from cabbage to enter into brine creating an anaerobic environment for optimal LAB growth
- Risk from metal blades and slicing of cabbage may be mitigated using metal detector prior to packaging
- Optimal salt concentration is 2.25% (range 0.8 to 3% NaCl)
- Optimal temperature is between 15°C to 20°C with upper limit of 25°C and lower limit of 10°C
- Initial fermentation ideally begins immediately with bubbles visible within 24 hrs and at latest 48 hrs

- Gas formation in the first 48 hrs may cause heaving, gas should be vented or purged or brine drained to allow cabbage to settle
- Fresh sauerkraut can be packaged when pH is below 4.2 and when total acidity (lactic acid) reaches 1.5% or higher.[3] Lactic acid content should be measured for fresh sauerkraut as this ensures there are no further fermentable carbohydrates, so that yeasts will not convert them to excess alcohol.[1]
- Fresh sauerkraut must be refrigerated, packaging into jars, cans, or vacuum packs are all considered a form of reduced oxygen packaging (ROP)
- Sauerkraut intended to be pasteurized (cooked) is finished when pH is 4.2 or below. It is room temperature stable once packaged. A boiling water bath method is sufficient to seal containers.

**Potential health issues with sauerkraut**

Biogenic amines may form in sauerkraut, although no reports of illness linked to biogenic amines were found in reports. Information about biogenic amines and how operators are recommended to manage this risk may be found in Box 3 below.

**Box 3 | Biogenic amines in fermented foods**

Biogenic amines (BAs) can be produced by microbes in fermented foods, such as fermented soybean products, vegetables, cheeses, sausage, and fish. Normal BA intake does not cause illness as intestinal amine oxidases break down and detoxify the BAs.[17,18] If large amounts of biogenic amines are ingested, or if amine oxidase activity is inhibited, then acute toxic symptoms can occur such as nausea, respiratory distress, hot flushing, sweating, heart palpitations, headache, bright red rash, burning sensations in the mouth, alterations in blood pressure, diarrhea and hypertensive crises.[17,19,20] The toxic effects of BA may vary between individuals as it depends on individual sensitivity and on the consumption of alcohol or drugs that are monoaminooxidase inhibitory.[21,22]

The main BAs are histamine, tyramine, β-phenylethylamine, putrescine, cadaverine and spermidine. Health Canada has set action levels for histamines in anchovies, fermented fish sauces and pastes at 200 mg/kg and for other fish and fish products at 100mg/kg.[23] However, there are no guidelines set for other fermented food products and BAs other than histamines in Canada, or elsewhere in the world. At present, the toxic doses in food are suggested only for three biogenic amines: 100-200 mg/kg for histamines, 100-800 mg/kg for tyramine and 30 mg/kg for phenylethylamine.[18]

Operators manufacturing fermented foods are not required to test for BAs in their products. Operators are recommended to list BAs as a potential chemical hazard in their food safety plan. Operators can address risks of BAs by:

(1) ensuring preventative measures are in place, the facility is clean and sanitary, handling practices are hygienic to limit bacteriophages and bacteria that interfere with the culture process;
(2) optimizing the fermentation: regulating time, temperature, moisture content, salt concentrations, and storage conditions; using good quality ingredients;
(3) purchasing commercial starter culture and/or verifying quality starter culture;
(4) monitoring that the expected culture activity occurs within correct timeframe; and
(5) monitoring for expected pH.

If a fermented food is linked to foodborne illness in consumers, inspectors are recommended to consider testing for BAs if symptoms and onset of illness in cases fit suspected BA illness. Further information about BAs and testing is found in Section 2 of this guidance.

The highest levels of histamine reported for sauerkraut were 37 mg/kg (below the illness threshold of 100 mg/kg), of tyramine were 206 mg/kg (within reported levels that cause illness between 100 and 800 mg/kg), and phenylethylamine of 0.18 mg/kg (below the illness threshold of 30 mg/kg).[24]

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