Vegetable Fermentation

Joell A. Eifert, Food Safety Extension Agent, Virginia Cooperative Extension, Renee R. Boyer, Associate Professor, Food Science and Technology, Virginia Tech, Robert C. Williams, Associate Professor, Food Science and Technology, Susan S. Sumner, Associate Dean Academic Programs, College of Agriculture and Life Sciences

Introduction

People have been fermenting vegetables for centuries to increase the stability of fresh foods, to make the foods safer to eat in the absence of refrigeration and to enhance their flavor. Today, vegetable fermentation is done on a large-scale setting in factories as well as in households across the world. In the United States, the primary vegetables fermented are cucumbers (pickles), cabbage (sauerkraut and Kimchi) and olives. In many parts of the world, especially in developing countries where refrigeration is not common, fermented foods constitute a major portion of the diet.

During vegetable fermentation, mainly bacteria and, at times, yeast break down vegetable sugars into acid, carbon dioxide gas and other flavor compounds. The acid produced gives the vegetable tartness and also keeps the food safe by preventing harmful bacteria from growing. The acid and carbon dioxide also keeps spoilage microorganisms from growing so fermented vegetables can last much longer than their fresh counterparts. Fermentation changes the flavor of vegetables as well as increases the nutritional content by producing B-vitamins and increasing the digestibility of the vegetable by breaking down vegetable fiber.

What is Fermentation?

Fermentation is a process that occurs in low or no oxygen conditions. Fresh vegetables naturally contain bacteria, yeast and mold that will eventually spoil them. But, some bacteria, yeast and mold present on the vegetables are key players in the fermentation process but are present in low numbers as compared to those microorganisms that spoil the vegetables. Commonly in fresh vegetables, the spoilage organisms are higher in number and grow faster than fermenting organisms, resulting in rotting vegetables. However, salting or brining vegetables as well as controlling the atmosphere around the fermentation favors the growth of the fermenting organisms so that they can overpower and outgrow the organisms that are harmful to you or spoil the food.

The Fermenters

Of the many groups of fermenting bacteria, those from the lactic acid bacteria family (lactics) are the most important in vegetable fermentation – specifically *Leuconostoc,*

Lactobacillus and *Pediococcus* species. These three groups of microorganisms are mainly responsible for producing the characteristic by-products of fermented vegetables that include lactic and acetic acids, carbon dioxide and ethanol (ethyl alcohol) from the natural vegetable sugars. The natural acids and other antimicrobial compounds produced by the fermenting organisms inhibit other bacteria that could be harmful to you as well as inhibit bacteria, molds and yeasts that spoil the vegetable. The carbon dioxide produced helps maintain the low-oxygen conditions that fermenting bacteria need as well as stabilizes the flavor and color of the vegetables.

During most vegetable fermentations, the fermenting bacteria usually do not grow and produce compounds at the same time in the product. Instead these organisms grow in a sequential order, with each group of bacteria providing the next group of bacteria the needed environment and food to continue the fermentation. This sequential growth of fermenting microorganisms provides for acid and flavor development of the final fermented product. The sequential growth can be broken into specific stages of fermentation: initiation, primary and secondary fermentation. In the initiation stage, the fermentation begins with organisms that can grow easily in the vegetable and are salt tolerant. If a fermenting culture is added, the fermenters in the culture will usually grow first in the initiation stage.

Specifically, *Leuconostoc mesenteroides* (in sauerkraut, kimchi, olives and low-salted pickles) and *Pediococcus cerevisiae* (in high-salted pickles and olives) are important in the initiation of fermentation since they grow much more rapidly than other bacteria due to their tolerance to a wide variety of temperatures and salt concentrations.

In the primary stage, the main fermentation occurs. This is when the fermenters that started growing in the initiation stage grow rapidly and produce acids and carbon dioxide. These acids and carbon dioxide favor the growth of more fermenting organisms and stabilize the product so that the product does not spoil. At the end of the primary stage and in the beginning of the secondary stage, the primary fermenting bacteria die as more acid is produced.

Finally, secondary fermenters that can withstand the high acid conditions take over in the secondary stage, finishing the fermentation process adding more acid and other flavor components.

Acid-tolerant *Lactobacillus brevis* and *Lactobacillus plantarum* are responsible for the secondary fermentation of many vegetables with *Lactobacillus plantarum* finishing the fermentation process as the acid accumulates in the product. Fermentation is usually stopped when acid accumulates and kills or slows the growth of the secondary fermenters. The graph shows an example of sequential growth in sauerkraut where various fermenting

organisms are present and growing at different stages.

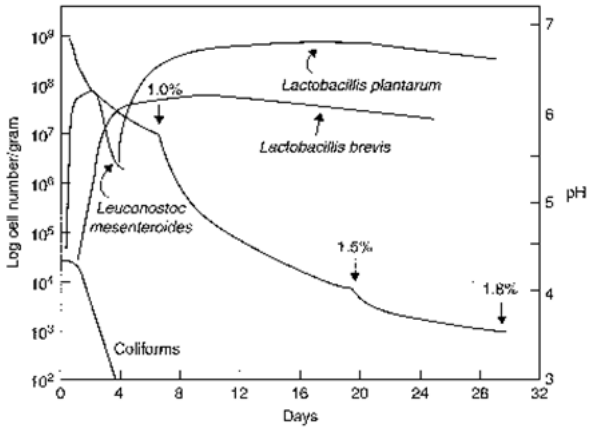

Figure 1. Sequential Growth of Fermenting Microorganisms in Sauerkraut. (Adapted from Handbook of Vegetable Preservation and Processing 2010)

During the fermentation stages, certain bacteria produce many end products when fermenting vegetable sugars. These fermentation products include natural acids such as lactic acid and acetic acid as well as carbon dioxide, ethanol and other flavor compounds. Other fermenting organisms strictly produce only acid in the fermentation process. While only a few microorganisms have been discussed, there is recent evidence that there is a great amount of fermenting microorganisms present especially during natural fermentation of vegetables. The more diverse and complex the fermentation population, the more by-products are produced and the more complex tasting the product. In comparison, if only a few organisms are present and growing in the fermentation, fewer by-products are produced and less flavor complexity results. Fermenting populations are affected by the type of organisms present at the initiation stage, salt amount and temperature.

Unlike other food fermentations, yeast and molds are lesser microorganisms participating in vegetable fermentation and are considered sources of fermentation problems and spoilage in many cases.

Fermentation Components

Culture

Starting fermentation growth can be accomplished in three basic ways:

- Spontaneous or natural – allowing the natural fermenting microorganisms on the vegetables to grow. This technique allows for the natural sequential growth of fermenting organisms. It can be the most unpredictable method but can allow for the most developed and complex flavors since more fermenters are present.
- Back-slopping – adding live bacteria from a fermented product to start other batches. In back-slopping, the initial fermentation stage is shortened since fermenting microorganisms are already growing and the risk of fermentation failure is lower. However, the natural sequence of fermentation is disrupted and flavor development may not be as complex. The acidity of the back-slop can also affect the success of fermentation initiation with the high acidity leading to

poor fermentation or producing softer textured product.

- Culture Inoculation – a specific bacteria culture is added to start the fermentation. Culture inoculation is done less in home-based fermentations and more in the industry to ensure consistent fermentation. Vegetables are usually heat treated prior to inoculation to ensure only starter culture bacteria are present and growing. If a culture is used in home fermentations, be sure to follow the directions accompanying the culture. However, culture inoculation may result in a less complex flavored product especially if the culture contains only a few fermenters.

Salt

Salt provides many functions in the fermentation process:

- Allows needed water and sugars to be pulled from the vegetables which are used as nutrients by fermenting organisms.
- Favors the growth of fermenting organisms over spoilage bacteria, yeast and mold as well as harmful bacteria.
- Allows for crisper vegetables by hardening the plant pectins and decreases the activity of pectinase, an enzyme that makes vegetables mushy.
- Allows for longer fermentation by slowing the fermentation process and decreasing the chance of undesirable mold growth.
- Gives flavor to the final product.

Salt concentration is very important in fermentation, therefore salt amounts should be measured carefully and a tested recipe should be followed. Salt concentrations in vegetable fermentations can vary from 1-15% and are specific for the vegetable being fermented. Sauerkraut fermentation, for instance, occurs ideally under salt concentrations of 2.25–2.5% while pickle fermentation is achieved in salt concentrations of 3-5% for low-salt pickles and 5-16% in high-salt pickles.

In general, lower salt percentages will favor the growth of more types of fermenting organisms, especially in a natural fermentation, leading to faster acid production and a more acidic product. But, lower salt concentrations can allow for mold and other contaminant growth resulting in a softer texture or off-flavored final product. Higher salt concentrations, in general, favor growth of only certain salt-tolerant fermenting microorganisms and slow the progression of fermentation.

Salt additions are done by two basic methods:

1) Direct or dry-salting - salt is added directly to the vegetables. With this technique, it is best to allow the vegetable/salt mixture to stand so that water from the vegetables is released forming a brine that will cover the vegetables when packed into the fermentation container. Chopping or

shredding the vegetables will increase the speed of water release and allow for better fermentation initiation.

2) Brining - mixing salt and water to form brine before adding to the vegetables. This technique can allow for better coverage of the vegetables which lessens the risk of fermentation failure.

Salt quality: The salt used in fermentation should contain no additives. Anti-caking additives in table salt will cause cloudy brine. Iodine in iodized salt can cause browning of vegetables and slow fermentation. Impurities found in natural salts (sea salt for example) can also affect the fermentation process. Lime impurities can reduce the acidity and the safety of the final product. Iron impurities can blacken the vegetables. Magnesium impurities can cause bitterness while carbonates can result in softening especially in pickles. Natural salts also vary in weight and can alter the brine solution percentage which can affect the safety and quality of the fermentation. Use of reduced-sodium salt in fermented pickle recipes is also not recommended. Canning or pickling salt is recommended since it contains no impurities and has a consistent granular size and weight.

Vegetables

Choose vegetables that are free from damage and disease. Damaged areas on the vegetables are susceptible to bacterial, yeast and mold contamination and growth. Growth of these unwanted microorganisms can negatively affect the quality of the product and the fermentation process.

Certain vegetable varieties and sizes will ferment better than others. For instance, small pickling cucumbers will ferment more efficiently than larger cucumbers. Large salad cucumbers do not ferment well and do not make good quality product.

Selection of cucumbers: Select a variety of unwaxed cucumbers intended for pickling. Use 1½ inch cucumbers for gherkins; 4 inch for dills. For optimum quality, pickle the cucumbers within 24 hours of harvest. Otherwise refrigerate the produce where it will be well ventilated and remain cool. Before fermenting, wash the cucumbers thoroughly, especially around the stem area to remove soil containing bacteria. Remove the blossom end to prevent softening by enzymes naturally contained in the blossom.

Selection of cabbage: King Cole, Bravo, Krautman, Sanibel and Danish hybrids of cabbage are better for making sauerkraut as they contain larger amounts of sugar for fermenting. In general, larger heads of cabbage contain more sugar and would be more suitable for fermenting. However, smaller heads of cabbage can also be used successfully. Mature heads weighing 6 to 15 pounds with a solid, white interior are most desirable. Use only clean cabbage, removing the outer leaves and any spoiled or damaged spots. The cabbage core should be removed since the fermented core can cause sliminess.

Selection of spices: It is important that you follow tested and proven recipes. Many of the tested and proven recipes have spice addition options that will allow you to personalize your fermentation. Choose whole fresh or freshly dried spices. Ground and flaked dried spices can be difficult to use since they can float to the top of the fermentation and may mold over time. Older dried spices have a higher chance of mold content when compared to fresh spices or newly dried spices.

Container Choice

Not all container materials are suitable for fermentation. Fermentation occurs in salty, acidic conditions. Metal, except for high-grade commercial stainless steel, can degrade and pit so is usually not recommended. Ceramic crocks and plastic containers are more suitable.

Any food container chosen should be easy to clean and free from deep scratches, chips or pits that can harbor harmful bacteria or can affect the fermentation. Wooden containers have been used to ferment vegetables but can be difficult to keep clean and sanitary. Containers and other equipment should be washed in hot soapy water before using. Do not use chlorine bleach to sanitize the equipment as the remaining chlorine and chloramine residues on the equipment could inhibit the growth of fermenting organisms. If chlorine bleach is used, the equipment should be rinsed thoroughly to remove any residual chemical.

Ceramic Crocks

Ceramic crocks come in various sizes and shapes. When choosing a crock, it is important to ensure that the paint or glaze does not contain lead, especially in older crocks made before the 1970's. Lead from paint or glaze can leach into the food especially under acidic conditions. When choosing a crock, both size and shape should be considered. For food safety and proper fermentation, it is important to have the brine/juices stay 1-2 inches above the fermented vegetables. Vegetable submersion allows for the product to stay under anaerobic conditions (without oxygen) that favors the growth of the lactic acid bacteria and other fermenting organisms. Keeping the vegetables covered allows for salt to cover the product which also gives the lactic acid bacteria a competitive edge. So it is important to choose a fermenting container that will allow for vegetables to be completely submerged under the brine fluid. In general, allow one-gallon of crock for each 5-pounds of product.

The shape or style of crock does not affect product safety but could affect quality. Many crocks are simple cylinders with or without fitting lids. If a fitting lid does not accompany the crock, a plate or similar cover can be used. It is important to cover the product for both safety and quality. Other crocks have specialized rims with grooves or gutters in which a lid fits snuggly within. The groove or gutter must also be kept constantly filled with water to provide a seal that keeps oxygen out. These specialized crocks ferment better if the lids are not

removed or disrupted which may be difficult for curious cooks.

Figure 2. Examples of a simple cylindrical ceramic crock (left) and a specialized fermentation crock (right).

Plastic Containers

Plastic containers can also be used successfully for fermenting vegetables. Look for high-density polyethylene containers (HDPE- #2 Plastic) that are phthalate and bisphenol free. Phthalates and bisphenol are chemicals added to some plastics to increase their elasticity and flexibility. There is evidence that repeated exposure to these compounds could have an effect on health especially the young. Given the acidic and salty nature of fermented products and the fact that the vegetables will be fermenting in the container for weeks, it is advisable to avoid plastics containing these compounds. Plastic containers should also be food-grade which means that they are made of plastic that can be safely used for food preparation. Other 1- to 3-gallon non-food-grade plastic containers may be used if lined inside with a clean food-grade plastic bag. Garbage trash cans and trash bags are not considered food grade and are not suitable for fermentation.

Glass containers:

Glass containers can also be used but care should be taken to ensure they are not broken, cracked or chipped. Half gallon or quart canning jars can be used but spoilage may be more of an issue since it can be more difficult to keep vegetables submerged. Use of wide-mouth jars allows for better filling and vegetable submersion. Use of plastic jar lids rather than metal lids is advisable since metal lids will degrade under acidic and salty conditions. Jar lids should be kept loose to ensure that gases produced can escape.

Other Equipment

Weights

For safety and proper fermentation, it is important that the vegetables be submerged 1-2 inches below juices and brine in the fermentation container. Weighting the vegetables ensures that:

- Vegetables are submerged in a salt solution.
- Vegetables are covered with liquid, keeping oxygen away.

Specific weights are available in various sizes for keeping vegetables submerged. If purchasing weights, choose a size that completely fills the inside of the container and covers the vegetables as completely as possible. Weights are available in ceramic and glass materials. Choose weights that can be cleaned and are food-grade. Do not use

weights that are not intended for food use as they may contain harmful compounds such as lead. Rocks should never be used as weights because they may contain heavy metals and limestone that can degrade under salty and acidic environments and can become part of the food.

Figure 3. Ceramic Fermentation Weights

A suitable sized clean plate or glass pie plate can also be placed on top of the vegetables inside the fermentation container. The plate must be slightly smaller than the container opening, yet large enough to cover most of the vegetables. The plate can be weighted down with 2-3 sealed quart jars filled with drinkable water or heavy-duty plastic food bags filled with a brine solution. Brine solution is recommended in plastic bags to assure that the fermentation brine is not diluted should the bag leak or break. The brine can be made by mixing 4 ½ tablespoons of salt for every 3-quarts of drinkable water. Covering the fermentation container opening with a clean, heavy bath towel or lid helps prevent contamination from insects and molds while the vegetables are fermenting.

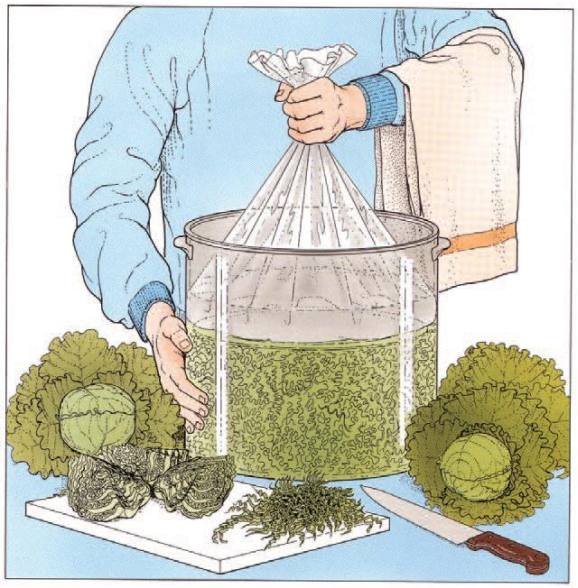

Figure 4. Weighting sauerkraut with food-grade plastic bag and plate. (Adapted from USDA 2009)

Chopping and Cutting Tools

Evenly chopped or shredded vegetables will ferment more efficiently. Chopping and cutting will help release juices from the vegetables and allow the vegetables to become more evenly brined. Knives, mandolins and kraut boards can be used to cut vegetables. Ensure that all cutting devices can be easily cleaned and are not made of materials that harbor microorganisms. Kraut boards and mandolins should be used with care as these devices are very sharp. Wearing metal mesh or cut-resistant gloves can add another level of safety when using these pieces of equipment beyond using the vegetable holders and safety guards provided by the utensils.

Figure 5. Mandolin. User is wearing a cut resistant glove.

Figure 6. Kraut Cutter or Kraut Board

Pounding Tools

While vegetables can be allowed to rest after brining and before packing to allow water to be naturally released from the vegetables, there are tools that can help extract the juice from vegetables quicker. Crushers, pestles and sauerkraut pounders crush the vegetable tissue so that the juices will be released more readily. When choosing any cooking tool, ensure that it can be easily cleaned. Cleaned and gloved hands can also be used to mix and squeeze brined vegetables to release water and juices. Shredding, chopping and slicing will also help liberate vegetable juices.

Figure 7. Vegetable Pounding Tool

Thermometer

Proper fermentation temperatures allow for the beneficial fermenting microorganisms to grow and prevent growth of spoilage and disease causing bacteria. Fermentation is best achieved at 68-72°F, although the range from 60-78°F can work. At ideal temperatures, fermentation may take 3-4 weeks, at lower temperatures fermentation may take 5-6 weeks or longer. Generally, lower temperatures produce higher quality products. Higher fermentation temperatures create a fast fermentation where some types of lactic acid bacteria cannot grow at all, resulting in less fermentation by-products and a less complex flavor. If the temperature is too high, spoilage bacteria may take over and ruin the fermentation leading to spoiled and softened vegetables. Using a thermometer

to measure room and storage temperatures will allow you to monitor for proper fermentation.

Fermentation Troubleshooting

Vegetable fermentation does not require an abundance of sophisticated equipment or involve complicated procedures. However, following recipes to ensure proper salt concentration and proper fermentation temperatures along with using proper hygiene and clean equipment will lower the risk of fermentation failure.

Use fresh vegetables that are free from damage and spoilage. It is also important to use vegetables that have been grown using good food-safety practices that include proper manure management, use of clean water and use of proper hygiene before, during and after vegetable harvest. These practices will lower the risk of harmful bacteria contaminating the vegetables. Even though fermenting organisms can compete with harmful and spoilage organisms during fermentation, lowering the initial competition number of those bad organisms will increase the chance of successful fermentation.

Mold growth on the surface of the brine/liquid can occur. Monitoring for mold growth and scum formation on the surface and quick removal will ensure quality vegetable fermentation.

Occasionally, even when the recipe is followed, fermented cucumbers undergo an undesired secondary fermentation during storage, which is characterized by a decrease in acidity, the disappearance of lactic acid, and the formation of undesirable smelling propionic and butyric acids which smell like rotting vegetables and rancid dairy products. This incidence of fermented cucumber spoilage tends to increase at the beginning of the spring season, when the temperature increases. For safety precautions, do not taste and discard any fermentation batch that has bad or off-odors.

For more help, consult Table 1 for solutions to possible problems.

Preservation after Fermentation

Once fermentation is complete, you can process them in a boiling water canner so containers can be stored at room temperature. Canning should be done according to a tested and proven recipe. For more information on boiling water bath and pressure canning, consult the following Virginia Cooperative Extension Publication:

Boiling Water Bath Canning Including Jams, Jellies, and Pickled Products, Publication 348-594.

You may skip the boiling water bath process and store the fermented product in the refrigerator, but product texture and flavor will suffer over time since fermenting bacteria will continue to grow, produce by-products and alter the flavor and texture of the vegetables. Eventually, fermented bacteria will die due to the build-up of acid by-products. Fermented vegetables with 1 to 2 percent salt should keep well for four to

nine months, respectively, in a refrigerator. A two percent salted version should keep well in a dark, cool area such as a root cellar for at least three months, if the vegetables are kept submerged under liquid. However, refrigerated storage is recommended.

You can successfully freeze sauerkraut. Fill pint- or quart-size bags to about 3 inches from the top of the bag. Squeeze out air out of the bag to limit freezer damage, label and freeze flat. Bags may be placed inside rigid plastic containers for extra protection from leakage. Be sure that your freezer temperature remains steady. Fluctuation (freeze, thaw, refreeze) in temperature will adversely affect the quality of the food. Pickles can also be frozen but tend to lose their texture. Some of the beneficial bacteria may die during the freezing process but freezing will not kill all of the bacteria.

Table 1. Causes and Possible Solutions for Problems with Commonly Fermented Foods

Problem	Cause	Prevention
Soft or slippery pickles (If spoilage is evident, do not eat.)	Insufficient amount of brine.	Keep cucumbers immersed in the brine. Add more boiled and cooled brine if necessary.
	Blossom ends not removed from cucumbers. Blossom end contains enzymes that soften pickles.	Slice at least 1/16th inch off blossom end of cucumbers and discard.
	Low salt concentration. Softening occurs because of overgrowth of spoilage microorganisms that have enzymes that soften the cucumber.	Follow tested recipe that has proper salt concentration. Salt concentration for cucumber fermentation should be at least 6% for good cucumber texture. Use canning or pickling salt that has a consistent size and weight.
	Using natural salts with impurities. Carbonate impurities can cause product softening.	Use canning or pickling salt.
Soft Sauerkraut (If spoilage is evident, do not eat.)	High fermentation temperature. Above 75° F, sauerkraut may become soft.	Store the fermentation container at 68-75° F while fermenting.
	Aerobic environment where oxygen is allowing spoilage organisms to grow.	If juice does not cover the cabbage, add boiled and cooled brine (1½ tablespoons of salt per quart of water).
	Spoilage organisms growing due to uneven salt distribution.	If using the dry-salting method, ensure salt and cabbage is mixed evenly. Allow the mixture to sit before packing into the fermenting container. If making large batches, mix cabbage and salt in 5-lb. amounts before combining into the fermentation container.
Shriveled Pickles	Placing cucumbers in too strong brine.	Follow tested recipe and use amounts of salt called for in a recipe. Use canning or pickling salt that has a consistent size and weight.
Pickles Have Internal Air Pockets (Bloaters)	Yeast build-up caused by low salt concentration.	Follow tested recipe and use amounts of salt called for in a recipe. Use canning or pickling salt that has a consistent size and weight. A recipe using added acids prior to fermentation helps reduce pickle bloating.
Off-color Sauerkraut (Pink, brown or black color)	Spoilage organisms (bacteria, yeast and mold) growing due to aerobic environment. Brine not properly covering sauerkraut.	If juice does not cover the cabbage, add boiled and cooled brine (1½ tablespoons of salt per quart of water).

Problem	Cause	Prevention
	Spoilage organisms growing due to aerobic environment. Salt may not have been properly distributed.	If using the dry-salting method, ensure salt and cabbage is mixed evenly. Use gloved or cleaned hands to massage the salt and cabbage. Allow the mixture to sit before packing into the fermenting container. If making large batches, mix cabbage and salt in 5-lb. amounts before combining into the fermenting container.
	High fermentation temperature.	Store the fermentation container at 70 to 75° F while fermenting.
Mold Growth on Surface	Mold spores on garlic or spices	Use fresh spices.
	Low salt concentrations.	Follow tested recipe that has proper salt concentration. Use canning or pickling salt that has a consistent size and weight. Use canning or pickling salt that has a consistent size and weight.
Cloudy Brine	Spoilage bacteria and yeast growth. Usually accompanied by off-odors or yeasty odors. Salt levels too long to prevent growth of spoilage organisms.	Follow tested recipe that has proper salt concentration.
	Anti-caking agents in salt.	Use canning or pickling salt.
Strong, bitter taste	Using salt substitutes and natural salts. Potassium chloride, the ingredient in most of salt substitutes, causes bitterness. Magnesium impurities in natural salts cause bitterness.	Use canning or pickling salt.
	Dry weather.	No prevention. Bitter taste is usually in the peel or skin of fruits and vegetables.
Dark or discolored pickles	Minerals in hard water.	Use soft or filtered water.
	Ground spices used.	Use whole spices.
	Brass, iron, copper or zinc utensils used.	Use food-grade unchipped enamelware, glass, stainless steel, or stoneware utensils. (If brass, copper or zinc utensils and brining equipment were used, do not use pickles.)
	Iodized salt used.	Use canning or pickling salt.
Spotted, dull, or faded color	Excessive exposure to light.	Store processed jars in a dark, dry cool place.
	Poor vegetable quality.	Use produce of optimum quality, and grown under proper conditions (weather, soil, etc.)

Tested Recipes

These recipes are adapted from the "Complete Guide to Home Canning," Agriculture Information Bulletin No. 539, USDA, revised 2009.

DILL PICKLES

Use the following quantities for each gallon capacity of your container.

4 lbs. of 4-inch pickling cucumbers
2 tbsp. dill seed or 4 to 5 heads fresh or dry dill weed
1/2 cup salt
1/4 cup vinegar (5%)
8 cups water and one or more of the following ingredients:

2 cloves garlic (optional)
2 dried red peppers (optional)
2 tsp whole mixed pickling spices (optional)

Procedure: Wash cucumbers. Cut 1/16-inch slice off blossom end and discard. Leave 1/4-inch of stem attached. Place half of dill and spices on bottom of a clean, suitable container. Add cucumbers, remaining dill, and spices. Dissolve salt in vinegar and water and pour over cucumbers. Add suitable cover and weight. Store where temperature is between 70° and 75°F for about 3 to 4 weeks while fermenting. Temperatures of 55° to 65°F are acceptable, but the fermentation will take 5 to 6 weeks. Avoid temperatures above 80°F, or pickles will become too soft during fermentation. Fermenting pickles cure slowly. Check the container several times a week and promptly remove surface scum or mold.

Caution: If the pickles become soft, slimy, or develop a disagreeable odor, discard them.

Fully fermented pickles may be stored in the original container for about 4 to 6 months, provided they are refrigerated and surface scum and molds are removed regularly. Canning fully fermented pickles is a better way to store them. To can them, pour the brine into a pan, heat slowly to a boil, and simmer 5 minutes. Filter brine through paper coffee filters to reduce cloudiness, if desired.

Fill hot jar with pickles and hot brine, leaving 1/2-inch headspace. Remove air bubbles and adjust headspace if needed. Wipe rims of jars with a dampened clean paper towel. Adjust lids and process as below, or use the low temperature pasteurization treatment.

Recommended process time for **Dill Pickles** in a boiling-water canner.

		Process Time at Altitudes of		
Style of Pack	**Jar Size**	**0 - 1,000 feet**	**1,001 - 6,000 feet**	**Above 6,000 feet**
Raw	Pints	**10 min**	15	20
	Quarts	**15**	20	25

SAUERKRAUT

25 lbs. cabbage
3/4 cup canning or pickling salt

Quality: For the best sauerkraut, use firm heads of fresh cabbage. Shred cabbage and start kraut between 24 and 48 hours after harvest.

Yield: About 9 quarts

Procedure: Work with about 5 pounds of cabbage at a time. Discard outer leaves. Rinse heads under cold running water and drain. Cut heads in quarters and remove cores. Shred or slice to a thickness of a quarter. Put cabbage in a suitable fermentation container (see page 6-6), and add 3 tablespoons of salt. Mix thoroughly, using clean hands. Pack firmly until salt draws juices from cabbage. Repeat shredding, salting, and packing until all cabbage is in the container. Be sure it is deep enough so that its rim is at least 4 or 5 inches above the cabbage. If juice does not cover cabbage, add boiled and cooled brine (1-1/2 tablespoons of salt per quart of water). Add plate and weights; cover container with a clean bath towel. Store at 70° to 75°F while fermenting. At temperatures between 70° and 75°F, kraut will be fully fermented in about 3 to 4 weeks; at 60° to 65°F, fermentation may take 5 to 6 weeks. At temperatures lower than 60°F, kraut may not ferment. Above 75°F, kraut may become soft.

If you weigh the cabbage down with a brine-filled bag, do not disturb the crock until normal fermentation is completed (when bubbling ceases). If you use jars as weight, you will have to check the kraut two to three times each week and remove scum if it forms. Fully fermented kraut may be kept tightly covered in the refrigerator for several months or it may be canned as follows:

Hot pack—Bring kraut and liquid slowly to a boil in a large kettle, stirring frequently. Remove from heat and fill hot jars rather firmly with kraut and juices, leaving 1/2-inch headspace.

Raw pack—Fill hot jars firmly with kraut and cover with juices, leaving 1/2-inch headspace.

Remove air bubbles and adjust headspace if needed. Wipe rims of jars with a dampened clean paper towel. Adjust lids and process.

Recommended process time for **Sauerkraut** in a boiling-water canner.

		Process Time at Altitudes of			
Style of Pack	**Jar Size**	**0 - 1,000 feet**	**1,001 - 3,000 feet**	**3,001 - 6,000 feet**	**Above 6,000 feet**
Hot	Pints	**10 min**	15	15	20
	Quarts	**15**	20	20	25
Raw	Pints	**20**	25	30	35
	Quarts	**25**	30	35	40

References

Breidt, F., McFeeters R. F., Perez-Diaz I., and Lee C. 2013. Food Fermented Vegetables Microbiology: Fundamentals and Frontiers, 4th Ed. Edited by M. P. Doyle and R. L. Buchanan: ASM Press, Washington, D.C.

Handbook of Food Science, Technology, and Engineering, Volume 2. 2005. Edited Y. H. Hui: CRC Press.

Handbook of Food Science, Technology, and Engineering, Volume 4. 2005. Edited Y. H. Hui: CRC Press.

Handbook of Plant-Based Fermented Food and Beverage Technology. 2012. 2nd Ed. Edited by Y. H Hui and E. Özgül Evranuz: CRC Press

Handbook of Vegetable Preservation and Processing. 2003. Edited by Y . H . Hui , S. Ghazala , D. M . Graham , K . D . Murrell and W. Nip: CRC Press.

National Center for Home Food Preservation (NCHFP). www.uga.edu/nchfp/index.html.

USDA. 2009. USDA Complete Guide to Home Canning. U.S. Department of Agriculture National Institute of Food and Agriculture. Agriculture Information Bulletin No. 539. www.uga.edu/nchfp/publications/publications_usda.html.