# FDE 437
# FERMENTATION TECHNOLOGY

## Sauerkraut Production

# Other Pickles

- Pickles made from pepper, tomato, carrot, cabbage, and eggplant are very common besides cucumber pickles in some countries including Turkey.

- Apart from these, a mixed pickle product, which contains a few types of pickles, is preferred by the consumers. This is generally produced by mixing every fermented vegetable such as carrot, pepper, cucumber, tomato, cabbage at certain ratios after they are fermented individually.

- The other commonly consumed fermented vegetables in the world are sauerkraut, kimchi, and capers.

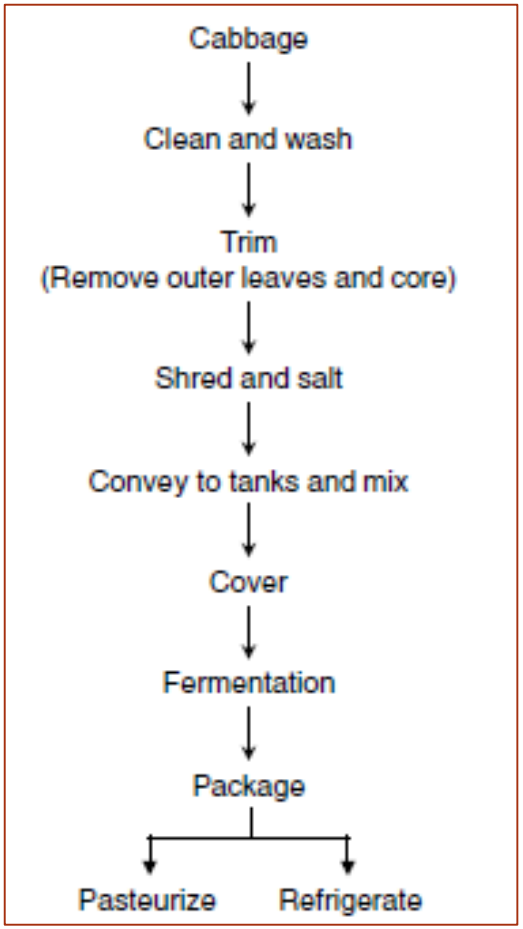
# Sauerkraut

- Sauerkraut is the fermented cabbage, which is very popular in European countries, especially in Germany.
- Sauerkraut is produced by the fermentation of cabbages, *Brassica oleracea*. In other words, Sauerkraut is pickled cabbage (*Brassica oleracea*).
- Similar to pickles, sauerkraut fermentation is usually conducted by the natural microflora. However, starter culture can also be used to control the fermentation process.
- The mature white cabbage that is used in the production of sauerkraut has a mild, slightly sweet flavor and contains 5% or more fermentable sugars.
- Dry salt is mainly used for salting in this type of product.
- After shredding of cabbage, salting step is performed. The amount of salt is around 2%–2.5% that is less than the salt used in the pickle fermentation.

# Manufacture of Sauerkraut

- Sauerkraut is produced in a simple process.
- Only two ingredients, cabbage and salt, are necessary to produce sauerkraut and once these ingredients are properly mixed and placed into suitable fermentation vessels, there is little that the manufacturer needs to do until the fermentation is completed.
- The simplicity of the process is reflected by the US Standards that states that sauerkraut is the "product of characteristic acid flavor, obtained by the full fermentation, chiefly lactic, of properly prepared and shredded cabbage in the presence of not less than 2 percent nor more than 3 percent of salt."
- When properly fermented, sauerkraut should contain not less than 1.5% acid (expressed as lactic acid) and have a pleasant tart flavor.

# Manufacture of Sauerkraut



# Manufacture of Sauerkraut

- The manufacture of sauerkraut starts with the selection of the raw substrate material.

- Although various cabbage cultivars exist, **white cabbage** is typically used because it has a mild, slightly sweet flavor and contains 5% or more fermentable sugars.

- The fermentable sugars are comprised mainly of nearly equimolar amounts of **glucose** and **fructose**, with a very small amount of sucrose.

- Cabbage used to make sauerkraut should be fully mature, and should contain few outer leaves. The cabbages of choice will have large heads that are compact (dense), contain few outer green leaves and have desirable flavour, colour and texture.

# Manufacture of Sauerkraut

1. **Shredding and salting:**

- The outer leaves and any spoiled leaves are removed from the cabbage heads and the core is removed.
- The cabbage is shredded (to a diameter of approximately 1 mm) to make a slaw. In other words, the cabbage is sliced into thin pieces known as slaw.
- Shredded cabbage is placed in a container and salt is added.
- Cabbage is dry salted to about 2-3% by weight and allowed to self-brine through its own moisture.
- Mechanical pressure can be applied to expel the cabbage juice, which contains fermentable sugars and other nutrients suitable for LAB activity.

# Manufacture of Sauerkraut

- The amount of salt added is critical. Usually, between 2% and 3% salt is added (by weight). This is a fairly narrow range, with about 2.25% generally considered to be the optimum.

- Because salt performs several essential functions during the sauerkraut fermentation, problems are almost certain to occur if too much or not enough salt is added or if the salt is not uniformly distributed.

- Very soon after the salt is mixed with the shredded cabbage, water begins to diffuse out from the interior of the plant tissue to the exterior medium, due to simple osmosis. The brine that forms also contains sugars and other dissolved nutrients that diffuse out with the water. Thus, it is this water phase that ultimately serves as the location for most of the microbial activity.

# Manufacture of Sauerkraut

- The salt dissolved in the brine also provides the selective conditions that discourage growth of most of the non-lactic microorganisms that would otherwise compete with the lactic microbiota.

- Although salt at concentrations ordinarily used, is by itself, not sufficient to inhibit all of the indigenous, non-lactic bacteria, it is enough to provide the lactic acid bacteria with a substantial growth advantage.

- Furthermore, combined with other environmental factors, the selective effects of this relatively moderate salt concentration can be increased appreciably. Thus, once the pH has been decreased by fermentation and the ensuing production of organic acids, the combination of salt plus acid contributes significantly to the long preservation properties of the finished product.

- Finally, salt imparts a desirable flavor to the product and helps to maintain a crisp texture by inhibiting pectinolytic enzymes responsible for softening of the tissues.

# Manufacture of Sauerkraut

## 2. Mixing:

- The shredded and salted cabbage is then placed into tanks and mixed well to distribute the salt.
- Mixing is an important step, because localized regions within the rather heterogeneous material may contain more or less than the 2–3% salt that was added to the bulk mixture. Within those pockets, therefore, it is entirely possible that the salt concentration may vary by as much as 0.5–1%. This may result in either too little or too much inhibitory control over the organisms that reside in that microenvironment. If spoilage organisms were able to grow, their products (e.g., slime, pigments, off-flavors) could accumulate in those pockets. Then, when the sauerkraut is mixed prior to packaging, the entire batch of product would be contaminated with those products.
- The sauerkraut fermentation was traditionally performed in wooden barrels.
- Wood-stave tanks are still used; however, concrete vats are now common.
- The cabbage is covered with a plastic, tarp-like material, large enough to drape over the sides of the tank.

# Manufacture of Sauerkraut

## 3. Fermentation:

- The manufacture of sauerkraut and other fermented vegetables depends on a succession of organisms that are naturally present in the raw material.

- The lactic fermentation in sauerkraut occurs in a series of overlapping stages or sequences.

- **The first stage, variously referred to as the initiation, heterofermentative, or gaseous phase, is marked by growth of *Leuconostoc mesenteroides* subsp. *mesenteroides***. This organism is salt-tolerant and has a relatively short lag phase and high growth rate at low temperatures (15°C to 18°C). Importantly, it metabolizes sugars via the heterofermentative pathway, yielding lactic and acetic acids, $CO_2$, and ethanol.

- (A low salt concentration (ca. 2%) and the low temperature (18◦C) favour heterofermentative organisms. Conversely, a high salt content (3.5%) and high temperature (32◦C) promote homofermentative fermentation. The normal sequence is heterofermentation first, followed by homofermentation. The main sugars in cabbage are glucose and fructose and, to a lesser extent, sucrose. They are converted to acetic acid, mannitol and ethanol in the first week, together with $CO_2$ which is important for establishing anaerobiosis. After a week or so, the brine becomes too acidic for the heterofermentative organisms and the fermentation is continued by the homofermenters, notably *Lb. plantarum*. Production of lactic acid continues until all the sugars are consumed and the pH has dropped from around 6 to 3.4.)

- Ultimately, the acidic environment (0.6% to 0.8%, as lactic acid) created by growth of these heterofermentative bacteria not only inhibits non-lactic competitors, but it also favors other lactic acid bacteria. The production of $CO_2$ also contributes to making the environment even more anaerobic (as low as –200 mV), which again favors the more anaerobic lactic acid bacteria. Eventually, however, as the acid concentration approaches 1.0%, *L. mesenteroides* is, itself, inhibited, and within four to six days, this organism is barely detectable.

# Manufacture of Sauerkraut

- **In the next stage – the so-called primary or homofermentative phase** – the decrease in the *Leuconostoc* population coincides with the succession of several other lactic acid bacteria including *Lactobacillus plantarum* and *Lactobacillus brevis*.

- Although ***L. plantarum*** is a facultative heterofermentor (meaning it has the metabolic capacity to ferment different sugars via homo- or heterofermentative pathways) and *L. brevis* is an obligate heterofermentor, both organisms are strong acid producers, nearly doubling the acid content to about 1.4% to 1.6%. They are also quite stable in this acidic environment and dominate the fermentation during this period (especially *L. plantarum*).

- Finally, as the acidity approaches 1.6% and the pH decreases below 4.0, the acid-tolerant ***L. plantarum*** dominates the finished product.

- The entire process can take up to one to two months, and the fermentation is generally considered complete when the acidity is at about 1.7%, with a pH of 3.4 to 3.6.

# Packaging and processing

- In the United States, commercial products are usually thermally processed, much like other high-acid foods (about 75°C), prior to packaging in cans or jars. Such products are essentially commercially sterile such that they are stable at room temperature.

- There is also an emerging market for non-pasteurized, refrigerated sauerkraut that is packaged in glass jars or sealed plastic bags. The latter products may still evolve $CO_2$, which may build up pressure inside the package. Recently, plastic pouches have been developed that contain venting systems that release the accumulated $CO_2$.

# Differences between pickle and sauerkraut fermentations

- The actual process steps used for the manufacture of fermented pickles are similar to those used for making sauerkraut. Both rely on salt, oxygen exclusion, temperature, and anaerobiosis to provide the appropriate environmental conditions necessary to select for growth of naturally-occurring lactic acid bacteria.

- There are, however, several differences between pickle and sauerkraut fermentations.

1. First, a brine, rather than dry salt, is used for pickle fermentations.

2. In addition, the salt concentration is higher than that used for sauerkraut, in part because the water in the cucumbers dilutes the salt level in the brine. Still, the final salt concentration will be higher resulting in development of a less diverse microbiota.

3. Finally, the pickle fermentation process, unlike sauerkraut, is amenable to the use of pure starter cultures and a more controlled fermentation. Indeed, such cultures are now available and some pickle manufacturers have adopted controlled fermentation processes.