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Originally sauerkraut was made only in the home because it provided a means for utilizing fresh cabbage which otherwise would spoil before it could be used. Now the commercial production of sauerkraut has become an important food industry. Even so, a significant quantity is still produced in the home, particularly in rural and suburban areas where home vegetable gardens still exist.

Cabbage varieties best suited for growth in the major production areas are used. Early, midseason, and late types are grown. Varieties formerly used such as Early Flat Dutch, Late Flat Dutch, Early Jersey Wakefield, and others have been replaced in part by new cultivars which have been bred to be well-adapted to mechanical harvesting and at the same time inherently contain less water, thus reducing the generation of in-plant liquid wastes (see Stamer 1975). Mild-flavored, sweet, solid, white-headed cabbage is the choice as it makes a superior kraut.

## Preparation for Fermentation

Properly matured sound heads of cabbage are first trimmed to remove the outer green, broken or dirty leaves. The cores are cut mechanically by a reversing corer that leaves the core in the head. Then the cabbage is sliced by power-driven, rotary, adjustable knives into long shreds as fine as 0.16 to 0.08 cm (1/16 to 1/32 in.) in thickness. In general, long, finely cut shreds are preferred, but the thickness is determined by the judgment of the manufacturer. The shredded cabbage (known also as slaw) is then conveyed by belts or by carts to the vats or tanks for salting and fermentation.

Salt plays a primary role in the making of sauerkraut and the concentrations used are carefully controlled. According to the legal standard of identity the concentration of salt must not be less than 2%, nor more than 3%. As a result most producers use a concentration in the range of 2.25 to 2.5% of salt. Salt is required for several reasons. It extracts water from the shredded cabbage by osmosis, thus forming the fermentation brine. It suppresses the growth of some undesirable bacteria which might cause deterioration of the product and, at the same time, makes conditions favorable for the desirable lactic acid bacteria. Salt also contributes to the flavor of the finished sauerkraut by yielding a proper salt-acid ratio (balance) if the cabbage is properly salted. The use of too little salt causes softening of the tissue and produces a product lacking in flavor. Too much salt interferes with the natural sequence of lactic acid bacteria, delays fermentation and, depending on the amount of oversalting, may produce a product with a sharp, bitter taste, cause darkening of color, or favor growth of pink yeasts.

Uniform distribution of salt throughout the mass of shredded cabbage cannot be overemphasized. In some factories the slaw is weighed on conveyor belt lines and the desired amount of salt is sprinkled on the shreds by means of a suitable proportioner as it moves along the conveyor to the vat. In other plants hand-carts are used to carry the shredded cabbage to the vat. Some prefer to salt the weighed cabbage in each cart. Others transport the

every 450 kg (1000 lb) of large cucumbers. When full, the tank is covered with a circular, slatted, wooden head until there is room for about 15 cm (6 in.) of brine above the cover. The slatted head is then secured with heavy cross timbers held at the ends with clamps. For convenience in handling, the slatted cover may be 2 semicircular pieces for large tanks or even 3 pieces when the largest diameter tanks are involved. If the brine formed by osmosis does not cover the cucumbers or cover when the tank is closed, 40° salometer brine is added to the desired level. The brine should be recirculated a day or two after the tank is filled in order to equalize the concentration of salt throughout the brine. On long storage the brine may be increased slowly until it is about 60° salometer.

In the brining industry the concentration of salt is expressed in degrees salometer which is % saturation of NaCl by weight. A saturated solution of pure sodium chloride (100° salometer) contains 26.359 g at 15.5°C (60°F). Thus, a salometer reading of 10° is equal to 2.64% NaCl by weight (rounded to the nearest tenth). Salt hydrometers are calibrated so that readings will cover several ranges of salt: low, medium, and high. Hydrometers also are available that are calibrated in % salt by weight.

**Brine Salting.**—Most picklers use the brine salting technique for fermenting cucumbers rather than the dry salting procedure just described. A "low" or a "high" brine process may be used. The low brine has a salt concentration of 25° to 30° salometer, whereas the "high" brine contains 40° or more salt by hydrometer.

The cucumbers are handled in the same manner as described previously for the dry salting process except that brine is used to cover the produce. The tanks are headed in the same way if they are of wood or concrete construction.

Recently, molded plastic and fiberglass tanks have been found useful for replacement of the wood or concrete containers lost by attrition. These plastic and fiberglass containers have several distinct advantages. They are not subject to the usual biological degradation of wood or chemical corrosion of concrete; they do not have to be maintained during the off season, as do wooden ones, to keep them from developing leaks which sometimes require extensive coopering to repair. The drain valves are plastic (polyvinylchloride), as are all other piping, so metal corrosion and resultant contamination of the cucumbers is eliminated. The greatest advantage of these newer containers, however, is that, if they are properly designed, the closures are nearly airtight so that former problems with loss of acidity caused by growth of aerobic yeasts is greatly reduced. With the use of plastic sheeting to cover the brine in open tanks, the problem of control of film yeasts in cucumber fermentations has, in recent years, been reduced to a minimum. Sheet plastic (polyethylene) may be used in the same manner as described previously with sauerkraut or as done with cucumbers and olives held in open tanks in California. In the latter case, the plastic film is floated on the surface of the brine over the false head and secured to the inside of the tank with pliable wood slats nailed so that the plastic is held in place at the

fermentation by *Leuconostoc mesenteroides* at lower temperatures and lower salt concentrations.

Once the lactic fermentation has an appreciable start, then the other species, *Pediococcus cerevisiae*, *Lactobacillus brevis*, and *Lactobacillus plantarum* begin to dominate the fermentation. The fermentation then is completed by the 2 species of *Lactobacillus, L. brevis* and *L. plantarum.*

Genuine dill pickles may be marketed in bulk in plastic containers of various sizes, or, as is done by some picklers, packed in glass, covered with an acidified brine, closed, and pasteurized at 74°C (165°F) for 15 min (*center* of jar temperature) and cooled rapidly to 37.8°C (100°F) or less (see Fabian and Wickerham 1935; Jones *et al.*, 1941). So far as is known, the refrigerated dills are always sold in bulk and held under refrigeration until consumed, because of their extreme susceptibility to spoilage.

## Deterioration of Pickles

Extensive study has been made of the spoilage of cucumbers during fermentation, curing, and storage. Most of the deterioration is caused by the activity of microorganisms, either by the elaboration of deteriorative enzymes or as the result of copious production of gaseous endproducts (carbon dioxide and hydrogen). Chemical defects are generally confined to metallic contamination or unanticipated alteration of flavor and aroma by the use of specific chemicals or undefined congenerics used for spicing purposes. Auto-chemical and physico-chemical reactions also have occurred.

The most damaging defect caused by microorganisms is tissue destruction resulting from cellulolytic or pectinolytic enzymes elaborated by a variety of organisms. Tissue destruction and loss of texture or firmness generally means nearly total economic loss to the pickler. Gaseous deterioration, resulting in the production of internal cavities or distorted stock caused by excessive gas pressure is another common spoilage caused by microorganisms. This defect is known as "bloater" or "floater" spoilage and is shown in Fig. 6.2. Affected pickles may have lens-shaped internal cavities or the locules may be slightly separated. In severe cases the locules become completely separated and the flesh in each locule is compressed so that the interior is completely hollow and the shape then is reminiscent of a balloon. The salt stock pickles damaged by destructive gas pressure generally may be salvaged by diverting them to relish type products. However, bloater spoilage of dill pickles may mean an economic loss at the present time.

## Softening

Softening occurs when microorganisms are capable of elaborating pectinolytic or cellulolytic enzymes under the conditions of salinity, acidity, etc., which exist in pickle brines. Softening is a progressive spoilage which occurs most frequently soon after the cucumbers are brined for production of dill or salt stock pickles. The skin of the cucumber is attacked first, usually at the blossom end. In a short time, the entire skin may be affected, become