

# 17 Vegetable Fermentations\*

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# 1 Introduction

The preservation of vegetables by fermentation is thought to have originated before recorded history and the technology developed by trial and error. PEDERSON (1979) presumed early man to observe that when vegetables were flavored with salt or brine and packed tightly in a vessel, they changed in character but remained appetizing and nutritious. He concluded that the Chinese were the first to preserve vegetables in this manner and assumed that fermentation in salt brines occurred first and that dry salting came later. The Chinese have been credited with introducing fermented vegetables into Europe.

Many, if not all, vegetables have been preserved by fermentation throughout the world. This chapter is devoted to summarizing the current scientific principles and technology involved in the commercial preservation of cucumbers (for pickles) and cabbage (for sauerkraut) by fermentation. The preservation of kimchi, a Korean fermented vegetable mixture of radishes, Chinese cabbage, cucumbers, and other components, is also summarized.

## 2 Cucumbers for Pickles

### 2.1 Raw Product

Various authors have attributed the origin of the cucumber (*Cucumis sativus* L.) to Africa, China, India, or the Near East (MILLER and WEHNER, 1989). Later domestication occurred throughout Europe, and cucumbers are now grown throughout the world using field or greenhouse culture, but with various characteristics, depending upon region.

Cucumbers are bred either for fresh market or processing (pickling). The fresh market varieties possess a relatively tough skin, which serves to extend their storage life as fresh produce. Pickling varieties, however, possess thin, relatively tender skin. Pickling cucumbers are harvested in a relatively imma-

ture stage, before the seeds mature and before the seed area becomes soft and starts to liquefy. The fruit contains an endo-polygalacturonase in the area surrounding the seeds which causes pectin hydrolysis and, thus, liquefaction in the seed area as the fruit matures (MCFEETERS et al., 1980). The value of pickling cucumbers to the processor varies inversely with fruit size, and growers are paid accordingly. Size grades are determined by fruit diameter, and grading devices sort the fruit by diameter. There are limited efforts to also grade the fruit by length, but it is a more common practice to cut overly long fruit to match jar sizes preferred by the processor/consumer.

Pickling varieties of cucumbers have been carefully bred to resist diseases and environmental stresses, grow well in the specific region for which they were developed, produce high yields, and possess the desired physical and chemical attributes (MILLER and WEHNER, 1989). Among the physical attributes desired are relatively small seed area, thin and tender skin, straight and uniform shape, a length to diameter ratio of approximately 3.0, firm texture, typical green color, and absence of internal defects. Comparatively little has been done to manipulate the chemical composition of cucumbers, although research has indicated several possibilities for consideration.

Cucurbitacins (ENSLIN et al., 1967) responsible for bitterness; sugar content (MCCOMBS et al., 1976; MCCREIGHT et al., 1978), important in fermentation; malic acid (MCFEETERS et al., 1982b), important in bloater formation during fermentation; and polygalacturonase activity (MCFEETERS et al., 1980), involved in softening as the fruit ripens, are some of the chemical constituents that have been considered for possible manipulation. Although most improvements in cucumber varieties to date have been accomplished by traditional breeding programs (MILLER and WEHNER, 1989), the tools of modern molecular genetics are in the early stages of application (STAUB and BACKER, 1995).

## 2.2 Processing

Cucumbers are harvested by hand or mechanical means, depending upon availability of labor, land size and conformation, and other factors. Cucumbers are a seasonal crop that is grown in various geographical regions and shipped to the processor. Great changes have occurred in the United States over the past 20 years as to origin of the fruit which a processor receives. While once a mainly regional and seasonal enterprise, some large processors now receive fresh cucumbers nearly the entire year. Figures of the production of cucumbers for pickles in the U.S. are shown in Tab. 1. The fruit are grown from Mexico to Canada and shipped fresh to processors according to their demands. Cucumbers grown near the processor may be processed within 24 hours. Cucumbers are shipped under refrigeration if grown at distant locations from the processor. The demand for a year-round supply of fresh cucumbers varies according to the types of products that the processors manufacture. Brined cucumbers, being more stable, are transported inter-continently.

Pickling cucumbers are preserved by three basic methods, fermentation (40% of overall

production), pasteurization (40%), and refrigeration (20%) (FLEMING and MOORE, 1983), as outlined in Fig. 1. Fermentation is the oldest method of preservation and was the only commercial method until about 1940. Pasteurization of fresh cucumber pickles was introduced into the United States industry in the 1940s and resulted in increased consumption of pickles because of their milder acid flavor and more uniform quality. The process involved heating properly acidified cucumbers to an internal temperature of 74°C and holding for 15 min (ETCHELLS and JONES, 1942; MONROE et al., 1969). Some processors deviate from this standard process, depending upon their products and experiences. Fermented cucumbers also may be pasteurized to increase shelf stability, but at lower temperatures and times (JONES et al., 1941). Refrigerated pickles were introduced on a national scale in the United States in the 1960s. Most of these products are preserved by addition of low concentrations of vinegar and a chemical preservative (e.g., sodium benzoate), in addition to refrigeration at 1–5°C. Microbial growth in these products is not desired. Non-acidified, refrigerated pickles, originally popular among certain ethnic groups, also are marketed in some metropolitan areas. These

**Tab. 1.** U.S. Production Statistics for Pickles and Sauerkraut for 1992

Crop/State	Harvested (1000 acres)	Yield per Acre (tons)	Total Production (1000 tons)	Total Value (\$1000)
<b>Cabbage for Sauerkraut</b>				
New York	1.4	25.0	35.0	1365
Wisconsin	2.6	38.8	100.8	3348
Other states	1.5	23.6	35.9	1799
Total U.S.	5.5	31.1	171.7	6512
<b>Cucumbers for Pickles</b>				
North Carolina	20.1	4.0	80.4	17125
Michigan	21.5	5.2	111.8	17776
Other states	61.6	—	397.4	85912
Total U.S.	103.2	5.7	589.6	120813

Source: ANONYMOUS (1993a)