BULK TANK TECHNOLOGY:
Acidification of Commercially Fermented Cucumbers in Bulk Tanks to Increase Microbial Stability

H. P. Fleming,* E. G. Humphries, R. L. Thompson, and R. F. McFeeters

U. S. Department of Agriculture, Agricultural Research Service,
and North Carolina Agricultural Research Service,
NC State University, Raleigh, NC 27695-7624, USA

ABSTRACT

Ten commercial fiberglass tanks (8,000 gal) of size no. 1 fermented cucumbers were acidified with 3.21N HCl to lower the brine pH to 3.5 from the pH that resulted at the end of fermentation (3.65-3.70). The volume of hydrochloric acid required to do this varied from 8.9-14.8 gal per tank. The rate of attainment of pH equilibrium after acid addition varied by tank location, but was complete within about 4 hr. Samples of brine-stock and cover brine from each of the 10 tanks were adjusted to pH 3.5, 4.0, and unadjusted and were stored in glass jars under laboratory conditions. Over a 14-month storage period at room temperature, the brines adjusted to pH 3.5 were more stable in chemical composition than the unadjusted, and much more so than the pH 4.0-adjusted samples, based on chemical changes. Chemical changes that indicated microbial instability were characterized by a rise in pH and CO_2 and acetic acid concentrations, and a reduction in lactic acid concentration. The data indicated that lowering the pH of the brine to 3.5 after fermentation from higher levels can help to increase microbial stability of brined cucumbers at relatively low salt concentrations without serious adverse effects on cucumber firmness.

INTRODUCTION

Commercially fermented cucumbers held in bulk tanks are subject to various types of quality loss, including bloater damage, softening, off-flavor development, and others. These problems can be greater with cucumbers which are held at low brine strengths, and is why high salt concentrations (8-16%) have been used by some commercial firms for many years. Regulatory pressures to limit food processing and other wastes have increased over the past 30 yr. Of particular concern to the pickle industry was the issuance of a guideline limit of 230 ppm chloride in freshwater bodies by the U.S. Environmental Protection Agency (EPA, 1987). Brine recycling and reduction of salt concentrations for cucumber fermentation and storage are being increasingly used by many pickle companies to meet regulatory pressures and to avoid surcharge expenses. The frequency of spoilage due to microbial instability may have increased in recent years due to efforts to meet regulatory guidelines.

Microbial instability of fermented cucumbers has been associated with a decrease in lactic acid and an increase in pH, acetic acid, carbon dioxide, and, in extreme cases, the production of propionic and butyric acids (Fleming et al., 1989; 1996; 2002a; 2002b). Carbon dioxide production during storage can cause serious bloater damage since purging to remove it is normally done only during the fermentation period (first 10 days after brining). In extreme cases where propionic and butyric acids appear, off-flavor development can cause the entire tank to require disposal. If the pH rises above 4.6, food safety of the pickles becomes an issue because of potential growth and toxin production by *Clostridium botulinum*. It has been reported that an optimum pH of 3.5 will help ensure microbial and textural stability of fermented cucumbers at relatively low (4.4%) concentration of salt (Fleming et al., 1996). Considerably lower concentrations of hydrochloric acid are required to lower the pH of fermented cucumbers, compared to either acetic or lactic acid (Fleming et al., 1996).

In this paper we demonstrate how the addition of hydrochloric acid (HCl, i.e., muriatic acid) can be used to acidify commercially fermented cucumbers to help increase microbial stability at relatively low concentrations of salt (4.6-5.6%).

MATERIALS AND METHODS

Hydrochloric Acid

Hydrochloric acid (also called muriatic acid) has many commercial applications, including some in the food industry, but, being a hazardous chemical, must be handled with due caution. Hydrochloric acid is considered to be a multiple purpose GRAS (Generally Regarded As Safe) food substance within the meaning of section 409 of the Federal Food, Drug, and Cosmetic Act under 21 CFR, paragraph 182.1057 (Vulcan Chemicals, 1996). Thus, the chemical does not pose a health concern when present in appropriate levels in food, but handling of it in concentrated form can be hazardous. It should be handled so as to avoid inhalation, skin contact, or ingestion by use of safety devices such as protective gloves and masks. Handling instructions supplied by the manufacturer or seller should be carefully followed.

Acidification of a Commercial Tank of Fermented Cucumbers—Concept

Conventional "side-arm" purging units, as employed by the industry, operate as gas-lift pumps and have been described in detail (Costilow et al., 1977). Generally, brine is pulled from the bottom of a tank into a 4-6 inch diameter PVC eduction pipe located near the tank wall, raised to the tank top by the action of the gas (air or nitrogen), and discharged through a short horizontal section at the tank top as illustrated in Figure 1. Thus, a pattern of liquid (brine)

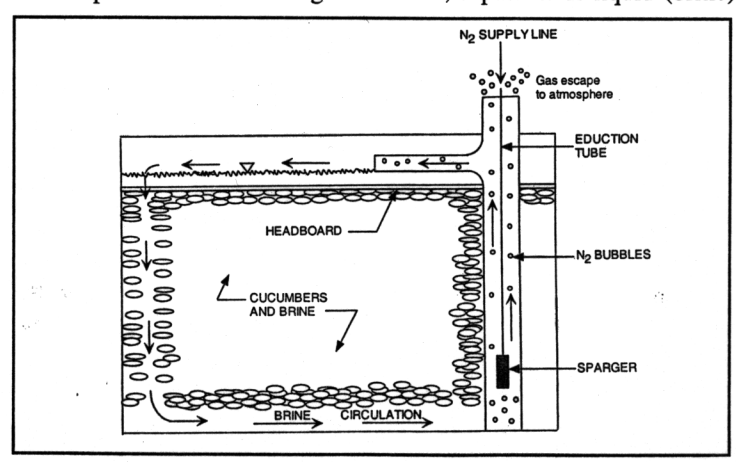

Figure 1. Model cucumber brining tank illustrating the brine circulation pattern when being purged.

circulation is established in the tank that may resemble that illustrated in Figure 1. The flow pattern at the tank top can be visually discerned, as represented in Figure 2A; however, the flow pattern at successive depth intervals is not visible and has not been measured. A liquid zone of 6-20 inches in depth is established at the tank bottom as a result of cucumber buoyancy in the brine. Liquid flow patterns in this zone of the intake of the eduction pipe are most likely as shown in Figure 2B. A transition shift in flow patterns between the top and bottom zones must exist. This paper deals with measurement of pH change at various tank locations (as a result of acid addition via the purging system) and the time required for uniform mixing throughout a tank.

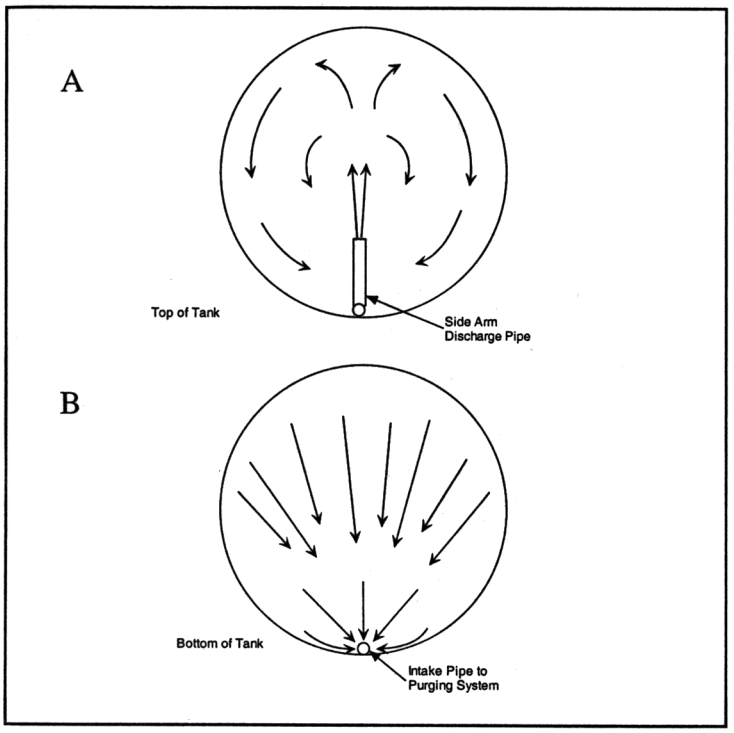

Figure 2. Theoretical brine circulation pattern at the top and bottom of the nitrogen-purged tank of brined cucumbers.

Procedure

A local processor's tank (~8,000 gal) containing no. 1 size (up to 1-1/16 inches diameter) cucumbers and brine was employed to measure mixing response and uniformity. The cucumbers were fermented to completion (no residual sugar) and 20° salometer 1 month prior to acidification on 7/28/1992. The tank purging system was operated at 35 SCFH for 24 hr prior to acidification to assure uniform conditions throughout the tank. The volume flow rate of brine circulated by the purging system was determined by placing a plastic bag over the purging discharge pipe and catching the brine flow for timed intervals. Replicate measurements indicated 46.2 and 45.5 gal/min. At a nominal pack-out of 50% brine and 50% cucumbers, the 4,125 gal of liquid in the 8,351 gal (actual volume of tank occupied by brine and cucumbers) tank would require only 90 min to turn over.

Twelve sampling positions were established throughout the tank at locations indicated in Figures 3-5. Each sample position was established by installation of an appropriate length of 3/8-inch stainless steel tubing with eight 1/8-inch diameter holes within its bottom 6 inches. The bottom end of each tube was plugged with a

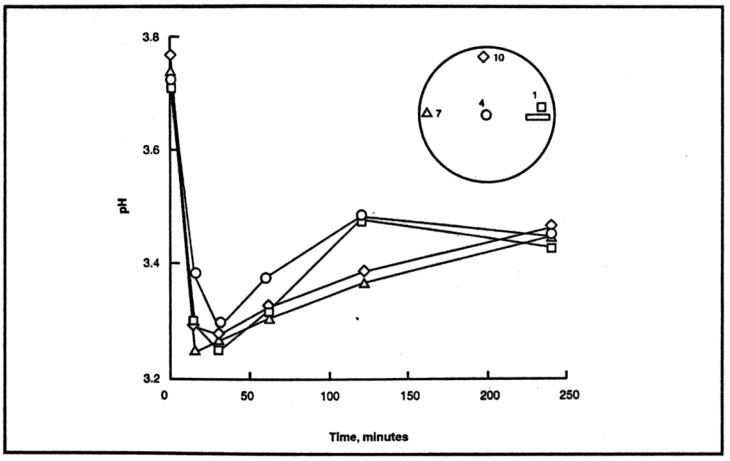

Figure 3. Acidification rate of the brine in the top of the brined cucumbers. The circular diagram represents a tank viewed from the top. The numbers within the diagram represent the locations from which brine samples were taken. The side-arm discharge pipe is illustrated under the □ sampling location.

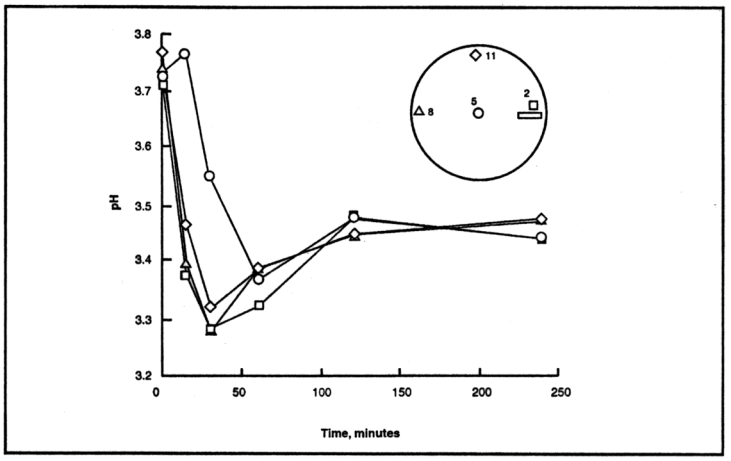

Figure 4. Acidification rate of the brine in the middle of the brined cucumbers. See Figure 3 caption for explanation of the circular diagram.

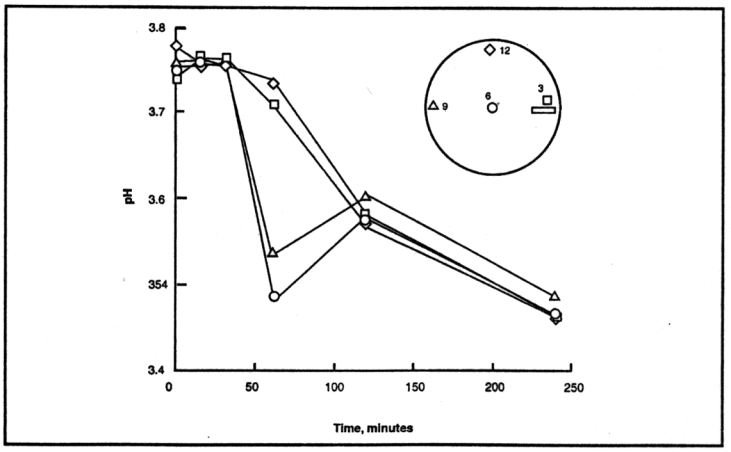

Figure 5. Acidification rate of the brine in the bottom of the brined cucumbers. See Figure 3 caption for explanation of the circular diagram.

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ABOUT THE COVER:

Bulk storage in brine has been an economic means of extending the processing season of pickling cucumbers since before the 1930's (1). When larger sizes of cucumbers began to constitute a higher proportion of the crop in the 1960's, bloater formation resulted in buoyancy force sufficient to rupture tank heading timbers (2), but purging of CO_2 from the brine reduced bloater damage and buoyancy forces within the tank (3). However, use of high concentrations of salt in brine storage requires washing of the excess from the brine-stock before conversion to finished products, which requires the use of aeration ponds to biodegrade the organic matter (4), but still results in problems in the handling of salt and other non-biodegradable wastes. The use of fiberglass and polyethylene tanks (5) has reduced salt leakage that was prominent with wooden tanks (1-3), but relatively high salt concentrations are still used to serve as insurance against vagaries of nature due to tanks being open to the atmosphere. Closed tanks have been considered by the industry (6), but various factors have resulted in modernized brine yards of open-top, fiberglass and polyethylene tanks and a waste handling system (7). This issue of the journal is devoted largely to summarizing efforts to design and test a pilot system (8) for preserving "process-ready," brined cucumbers with improved quality and reduced wastes, and with intended benefits to the producer and processor of pickling cucumbers.

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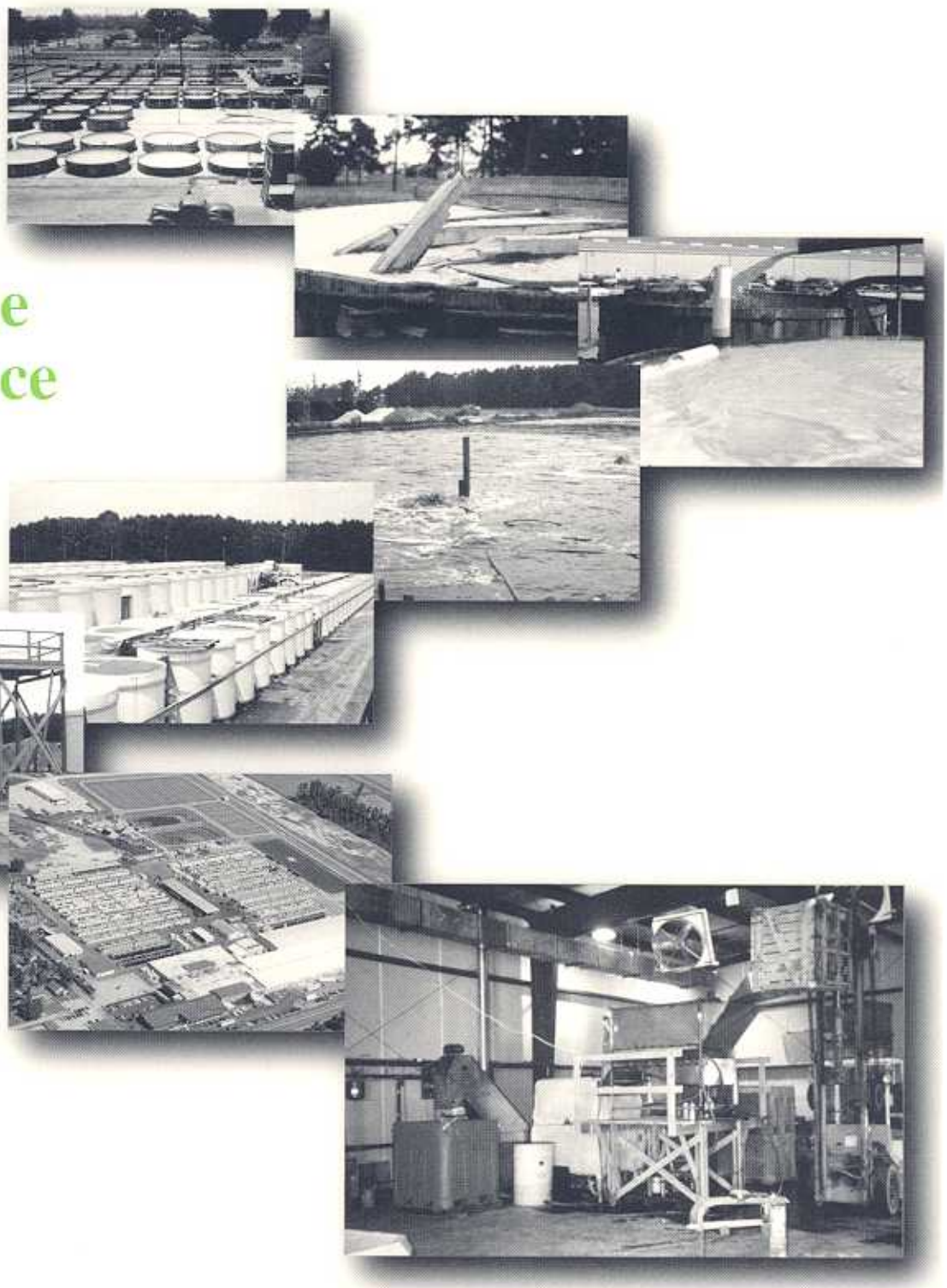
Bulk Storage in Brine Since the 1930's



A journal reporting research relating to brined, salted and pickled vegetables and fruit.