BAG-IN-BOX TECHNOLOGY:
Preservation of Brined Vegetables Without Fermentation

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ABSTRACT

Acidification has been used in a variety of ways to safely preserve vegetables. The approach that we are taking is to systematically investigate the capabilities of traditionally used acids and preservatives to prevent growth of spoilage organisms and to kill acid-tolerant pathogens. We want to provide new opportunities to develop 'process-ready' vegetable ingredients for further processing. This is an update on the use of this approach for cucumbers and peppers. Cucumbers have been preserved on a pilot scale using the bag-in-box approach. However, we have some significant problems to overcome in making final products from the stored cucumbers. The work with peppers have given us new insight into how they soften and has led to the unexpected finding that sulfite helps to maintain the firmness of some peppers.

INTRODUCTION

Cucumbers and cabbage are unusual in that they are commonly fermented for bulk storage prior to further processing. Other vegetables, such as peppers and cauliflower, are brined in high salt concentrations to prevent fermentation during storage. There is very little published information on the best procedures for doing this type of vegetable storage. Historically, companies have developed in-house procedures that can be quite variable across the industry. This approach to brining typically results in a high salt, high biological oxygen demand (BOD) brine that must be disposed of in some way. Depending on the proportion of the brined ingredient used in a final product, it may be necessary to do a processing step to remove salt. This creates another higher volume waste stream with lower salt and BOD levels.

We have been investigating procedures to do bulk storage of cucumbers and peppers with brining conditions that will result in 'process-ready' vegetables, meaning they would be ready for use as an ingredient in institutional or retail products without further processing. Doing this will gain the same advantages of bulk storage for non-fermented vegetables that would result for fermented cucumbers. It will provide a reliable ingredient supply to the processor, and, since brining will be done with no salt or only that salt needed in the final product, smaller amounts of non-degradable salt would require disposal.

Vegetables such as pepperoncini peppers or small pickles from India are being preserved in bulk and shipped without fermentation. The pepperoncini peppers are low in acid, but are shipped with about 11% salt and 400-800 ppm sulfite, so they require washing out of salt and sulfite before being used in a final product. The small pickles from India contain 3-4% acetic acid, 4-8% salt, and up to 120 ppm sulfite, so brine ingredients must also be removed from this product. Our intent is to add no salt and keep the acid and preservative levels sufficiently low so that a washing step with the consequent high salt, high BOD waste stream would not be generated.

To develop long-term bulk storage with this concept, two major goals have to be realized. **First**, it is necessary to find combinations of the appropriate acids, acid concentration, equilibrated pH, and food-grade preservative(s) to assure that no microorganisms will grow during storage, and that acid-resistant pathogenic bacteria will rapidly die. **Secondly**, good texture, flavor, and color characteristics must be maintained during storage and any subsequent processing that might be done. Both goals are critical to success, but the goal of good quality with the different vegetables that might be preserved will undoubtedly take more time and effort than preventing growth of microorganisms. Our expectation is that the conditions that prevent microorganisms from growing in cucumbers will probably prevent organisms from growing in other commodities. However, important quality issues are often unique to a particular vegetable, so it is unlikely that one approach to assuring good retention of texture, flavor, and color will be successful across commodities.

We are working on this storage concept for cucumbers and peppers. In the case of peppers, our primary work has been on red bell peppers, with some more limited experiments with green bell peppers, jalapeno peppers, and banana peppers. Discussions with people who have brined peppers indicated that red peppers were very susceptible to softening problems. So the concept in concentrating on them was that if conditions could be found for successful extended storage of red peppers, those same procedures, perhaps simplified, would likely work for other types of peppers.

Cucumber Preservation

The initial impetus for pursing non-fermentation storage of vegetables was the idea that it might be feasible to preserve with a reasonably low levels of acid, use sulfite to prevent growth of microorganisms, and then remove sulfite at the end of storage by its reaction with food-grade hydrogen peroxide. Figure 1 shows that we were able to accomplish preservation of cucumbers with sulfite using only hydrochloric acid (Fleming et al., 2002c)[1] to lower the pH. It was also possible to remove sulfite to the point that it was not detectable (<3 ppm) by addition of hydrogen peroxide (McFeeters, 1998).

Bag-in-Box Non-Fermentation Storage

We used the pilot scale equipment described by Fleming et al. (2002a) to test the preservation of cucumbers in 250-300 gal bags. The process that has been successful in preserving cucumbers for 6 weeks (we have not attempted to hold them longer), as shown in Figure 2. Cucumbers (sizes 2B and 3A) were washed, but not blanched prior to putting them in a bag. No attempt was made to maintain aseptic conditions during transfer to the bag because the acid and sulfite in the brine were expected to kill the vegetative cells of the organisms naturally present on the green stock. A cover solution was added to give a pack-out ratio of either 50:50 or 55:45, and to

[1] Hydrochloric acid is a GRAS ingredient in the United States, and it is listed in the Codex Alimentarius. However, it may not be approved for use in all countries, Canada for example. Use of concentrated hydrochloric acid requires specific safety precautions. Consult your supplier.

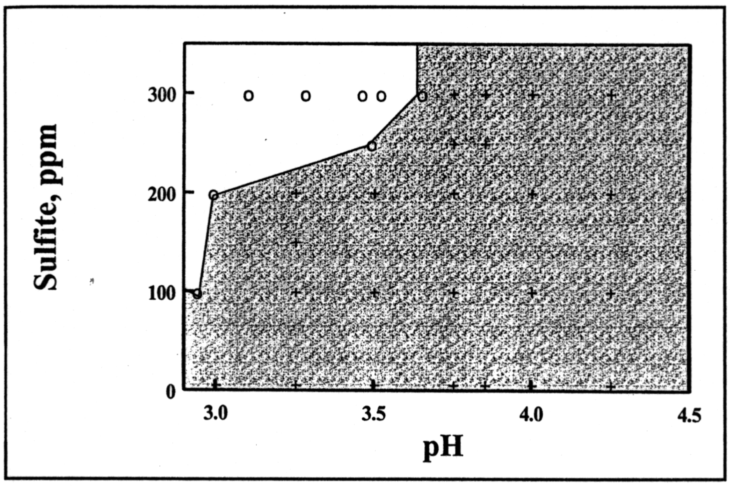

Figure 1. Preservation of cucumbers stored 6 months at room temperature with different pH/sulfite combinations (McFeeters, 1998). No microbial growth = 0 (white region); microbial growth = + (gray region).

equilibrate at 0.9% vinegar, 0.3% calcium chloride, and 450 ppm sulfite at pH 3.5. There was no salt added to the cucumbers, so the only chloride in any waste brine generated would come from the calcium chloride. Though it is not yet definitively proven, we think it is important to circulate the brine about 48 hr after brining. In our pilot experiments this was done by pumping cover solution through a 4-inch diameter capped opening in the bag into another container and then immediately pumping it back on to the cucumbers. Three boxes of cucumbers have been successfully stored in this way for up to 6 weeks without any microbial growth. In one experiment the same lot of 3A cucumbers was used for two boxes of cucumbers stored without fermentation and in one box that was fermented in 4% salt. After 6 weeks' storage, firmness of the non-fermented cucumbers was essentially the same (15.2 lbs on the fruit pressure tester) as the fermented cucumbers (15.0 lbs).

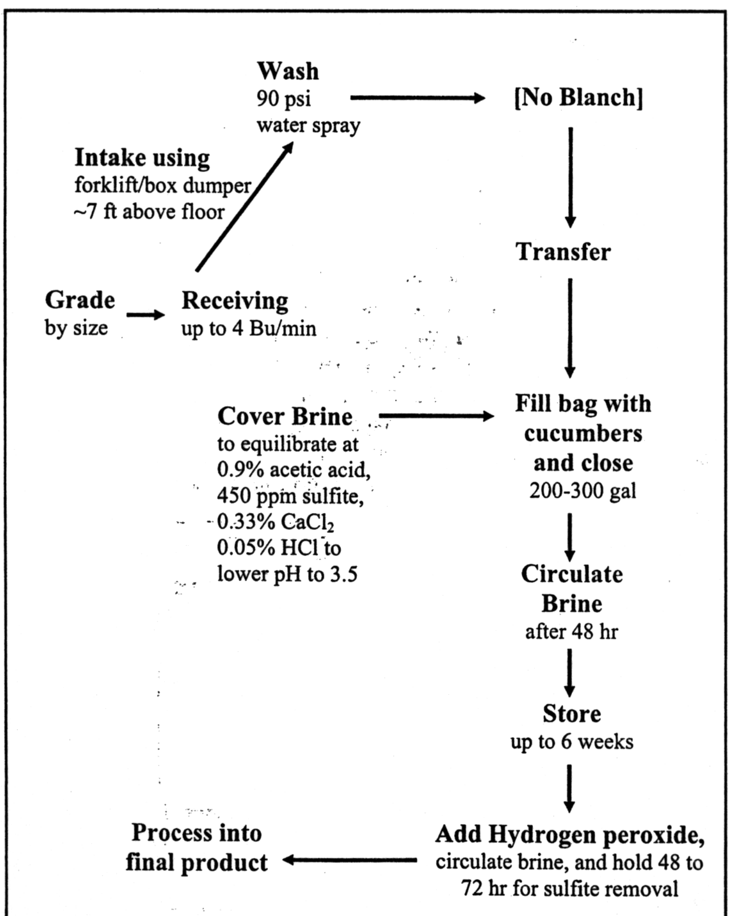

Figure 2. Flow diagram for non-fermentation preservation of cucumbers.

Sulfite Removal

Typically, some of the added sulfite reacted with components of the cucumbers and disappeared so that after 1 month to 6 weeks it had declined from an initial 450 ppm to about 300-350 ppm. Removal of sulfite was successfully accomplished to the point where it was non-detectable by using a sensitive chromatographic method to do the analysis. The objective was to add just enough food-grade hydrogen peroxide to remove all the sulfite, but not to add an excess that could cause quality problems. It was determined that 1.3 moles of hydrogen peroxide should be added for each mole of sulfite in a container of cucumbers. On a weight basis this was done by adding hydrogen peroxide equal to 70% of the weight of sulfite in a bag. So if there was 300 ppm sulfite in the cucumbers, sufficient hydrogen peroxide to equilibrate at 210 ppm was added. In the pilot experiments the brine was pumped off the cucumbers, hydrogen peroxide was then added to the brine, and then the brine was pumped it back onto the cucumbers. This assured that the hydrogen peroxide would be uniformly distributed in the bag. In all three boxes that have been stored successfully, sulfite removal has been complete with this procedure. The hydrogen peroxide must react with sulfite inside the cucumbers as well as the sulfite in the cover solution. For this reason, cucumbers were held 48-72 hr before emptying the box. Removal of sulfite was confirmed by HPLC analysis.

Recent Laboratory Results

We have investigated the use of benzoate instead of sulfite to prevent the growth of microorganisms in cucumbers. At pH 3.5, 0.17% sodium benzoate has prevented growth of the naturally present microorganisms in many lots of cucumbers. This is greater than the 0.1% allowed in final products. However, cucumbers can be stored in bulk with this level of benzoate and then the benzoate can be reduced to 0.1% or less by using a fresh cover solution that does not contain benzoate for the final product. This would provide an option for preserving cucumbers without using sulfite. Cucumbers preserved with benzoate maintained their firmness as well as or slightly better than cucumbers preserved with sulfite. We have observed that cucumbers developed a cured appearance more slowly with benzoate, where it was incomplete after 2 months. The change to a cured appearance is typically complete in less than 1 month with sulfite as the preservative.

Problems and Questions

Before the three boxes in which cucumber storage was successful, there were three boxes in which yeasts grew and badly bloated the cucumbers. After the first preservation failure in two boxes of 2A cucumbers, the sulfite added was increased to 450 ppm from the 300 ppm that had been successful in laboratory experiments. Unfortunately, the next attempt at preservation with 450 ppm sulfite also failed. This led to the conclusion that the problem was uneven distribution of the sulfite as liquid from the cucumbers created areas in the box where there was insufficient acid and sulfite to prevent yeasts from growing. The circulated boxes have been successfully preserved. The result of the initial preservation failures may be that we are now using more sulfite than is required. Also, the bags used in these experiments have high oxygen permeability (Fleming et al., 2002b). For longer term storage, bags with much lower oxygen permeability will be used.

The more serious questions about the use of bulk stored cucumbers occurred when fresh pack dill pickles were made from cucumbers stored for 2 months in 5-gal pails in the laboratory with either sulfite or benzoate as the preservative. Fresh cucumbers (size 2B) were made into fresh-pack dills and stored for 3 months. The same cucumbers were stored at pH 3.5 with 0.9% acetic acid and either 450 ppm sulfite or 0.17% sodium benzoate as preservatives. After 2 months of storage, sulfite was removed from the pails to which it had been added. Dill pickles were prepared with the same formulation as was used to make product from fresh cucumbers. The cover brines were adjusted to account for the vinegar and benzoate that were in the stored cucumbers. The products made from the bulk stored cucumbers were pasteurized at 165°F (74°C) for 15 min just as the jars prepared with fresh cucumbers had been 2 months earlier. One month after products were prepared from the stored cucumbers, we did sensory analysis of the pickles made with the stored cucumbers compared to those made from the fresh fruit. The panel found that the dills made from the stored cucumbers were softer and had a high level of oxidized off-flavor compared to product made from fresh cucumbers. The sulfite-preserved pickles were judged to be a little worse than the benzoate-preserved product, but both were clearly unacceptable in quality. This means there are some significant quality issues to deal with when making a final product. We have found the firmness of cucumbers stored with either sulfite or benzoate to be slightly softer, but close to the firmness of cucumbers fermented with calcium and 6% salt. It may be that greater softening occurs during pasteurization because the cucumbers are already equilibrated at low pH before heating. The reason for greater oxidized off-flavor remains to be determined.

Storage of Peppers

Papageorge (2000) did an M.S. thesis on preservation and storage of red bell peppers. Her results gave us the basis for substantially improving the firmness retention in salt-free peppers stored at pH 3.5. Not surprisingly, calcium helped maintain firmness, but the amount required was lower than that needed for cucumbers. Figure 3 shows the effect of calcium chloride on firmness retention. More significantly, it was found that blanching pepper pieces prior to brining was necessary to assure consistent firmness retention among different lots of peppers. Figure 4 shows that blanching at 167°F (75°C) gave the best retention of firmness during storage. The length of the blanch treatment did not appear to be too important provided it was long enough to allow the inside of tissue pieces to reach 167°F. The minimum blanch time that we have used for long term storage experiments is 90 sec. Changing the acid concentration while keeping pH constant did not significantly affect firmness retention. Switching between acetic acid and gluconic acid did not have any consistent effect on texture retention.

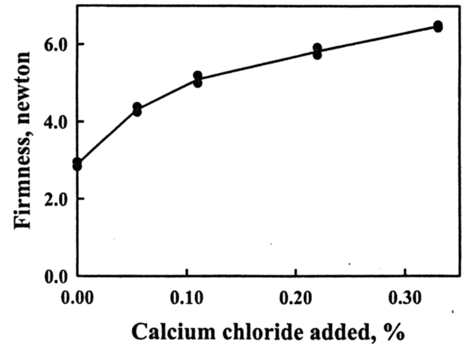

Figure 3. Effect of calcium concentration on the firmness of blanched (167°F for 3 min) red bell peppers stored for 4 months at 86°F (Papageorge, 2000). Peppers were stored at pH 3.5 in 0.9% acetic acid and 400 ppm sulfite.

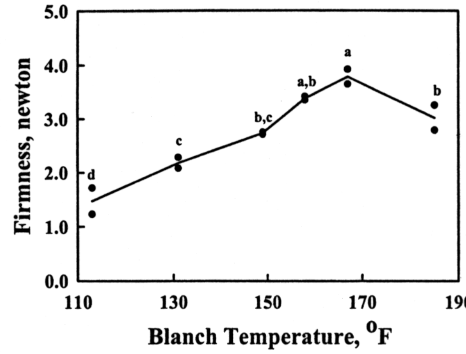

Figure 4. Effect of blanch temperature on the firmness of red bell peppers after 4 months storage at 86°F (Papageorge, 2000). Peppers were blanched for 3 min, stored at pH 3.9 with 0.6% acetic acid, and 400 ppm sulfite. No calcium chloride was added. Initial firmness 7.35 Newton. Data points with different letters are significantly different ($P \leq 0.05$).

The major surprise to come from her work was that red peppers softened much faster when sodium benzoate was substituted for sulfite to prevent microbial growth. Indeed, we found that red peppers would lose much of their firmness in a week or two if no sulfite was added to the cover solution. Figure 5 shows that low sulfite concentrations had a major effect on keeping peppers firm during a 1 month storage period. In more recent work, we found that the rapid softening that occurs in the absence of sulfite is caused by the presence of oxygen in the pepper jars. If the jars were filled inside an anaerobic hood to strictly exclude oxygen, the peppers remained just as firm as they did when we added 100 ppm sulfite to jars that were stored in air. In preliminary experiments we have observed that sulfite is also effective in slowing down softening of green peppers and jalapeno peppers. Green banana peppers do not undergo rapid softening in the first 2 weeks after packing in the absence of added sulfite, so they apparently are not susceptible to the same type of rapid

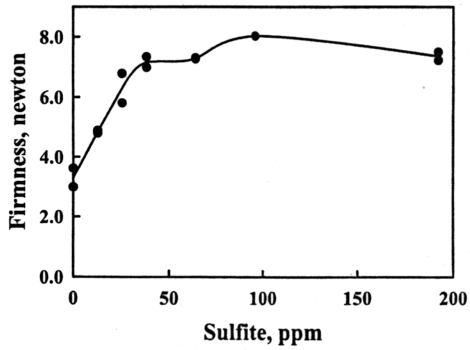

Figure 5. Effect of sulfite on the firmness of red bell peppers blanched at 167°F for 3 min and stored for 1 month at 86°F at pH 3.5 without added calcium.

softening when oxygen is present as red, green, and jalapeno peppers.

After looking at the effects of individual factors on firmness retention in red peppers, we combined the best results to determine how long peppers could be stored while still maintaining reasonable firmness. The following procedure was used for storage for 1 yr of five lots of red peppers grown in different parts of the country. Red peppers were cut into pieces about 0.5 to 0.75 inch on a side. The pieces were blanched for 90 sec in 167°F water and cooled for 3 min in cold tap water. They were covered with a brine solution to equilibrate with 0.9% acetic acid added as vinegar, 0.1% calcium chloride, 0.04% sodium benzoate, and 100 ppm sulfite added as sodium metabisulfite and stored in sealed 12- to 46-oz jars. Sufficient hydrochloric acid was added to lower the pH to 3.5. The peppers were stored in an incubator where the temperature remained at 86°F (30°C). Firmness was determined with a Texture Technologies texture analyzer (model TA-XT2, Scarsdale, NY) equipped with a 3 mm diameter stainless steel punch. Pieces of peppers were placed skin down on a metal plate, and the force in Newtons required to puncture the inner surface of pepper pieces was recorded. From each jar 15 pieces of pepper were punched and the average firmness was calculated.

The firmness of the peppers gradually declined (Fig. 6), but after 1 yr the peppers retained at least 40% of their initial firmness. The pieces were soft, but not mushy and retained their integrity when handled during evaluation. These results have shown us that red peppers can be preserved without salt and with relatively low concentrations of vinegar and standard preservatives. The softening that happens during a year of storage at 86°F is about the same as happens in a month or less if the peppers are stored without sulfite, calcium or blanching.

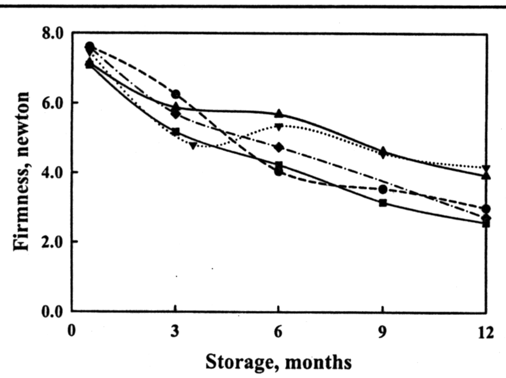

Figure 6. Firmness loss during 12 months' storage of five lots of red bell peppers stored at 86°F. Peppers were blanched for 1.5 min at 167°F, packed to give a 55:45, peppers:brine, pack-out ratio, and equilibrated at pH 3.5, with 0.9% acetic acid, 0.11% calcium chloride, 100 ppm sulfite and 0.04% sodium benzoate.

CONCLUSIONS

Acidification has been used in a variety of ways to safely preserve vegetables. The approach that we are taking is to systematically investigate the capabilities of traditionally used acids and preservatives to prevent growth of spoilage organisms and to kill acid-tolerant pathogens. We want to provide new opportunities to develop 'process-ready' vegetable ingredients for further processing. By understanding both the capabilities and limitations of acid preservation we think it is possible to minimize both the amount of ingredients required and the generation of waste from vegetable processing operations. From our experience in preservation of cucumbers and peppers it appears that maintaining high quality vegetables during extended storage periods is likely to be the greatest challenge as we proceed. In the case of cucumbers, we have been successful in maintaining the firmness of cucumbers during acidified storage, but we must also solve some problems that we have seen in converting the stored cucumbers into standard pickle products. The work with peppers has provided us new insight into how they soften. Given the fact that there are reasonable ways to slow the softening processes that occur, there is considerable promise that even red peppers can be stored with consistent firmness retention. It has also been an interesting finding that banana peppers, among those we have worked with so far, appear to be the least susceptible to the type of rapid softening that we first observed in working with red peppers.

ACKNOWLEDGMENTS

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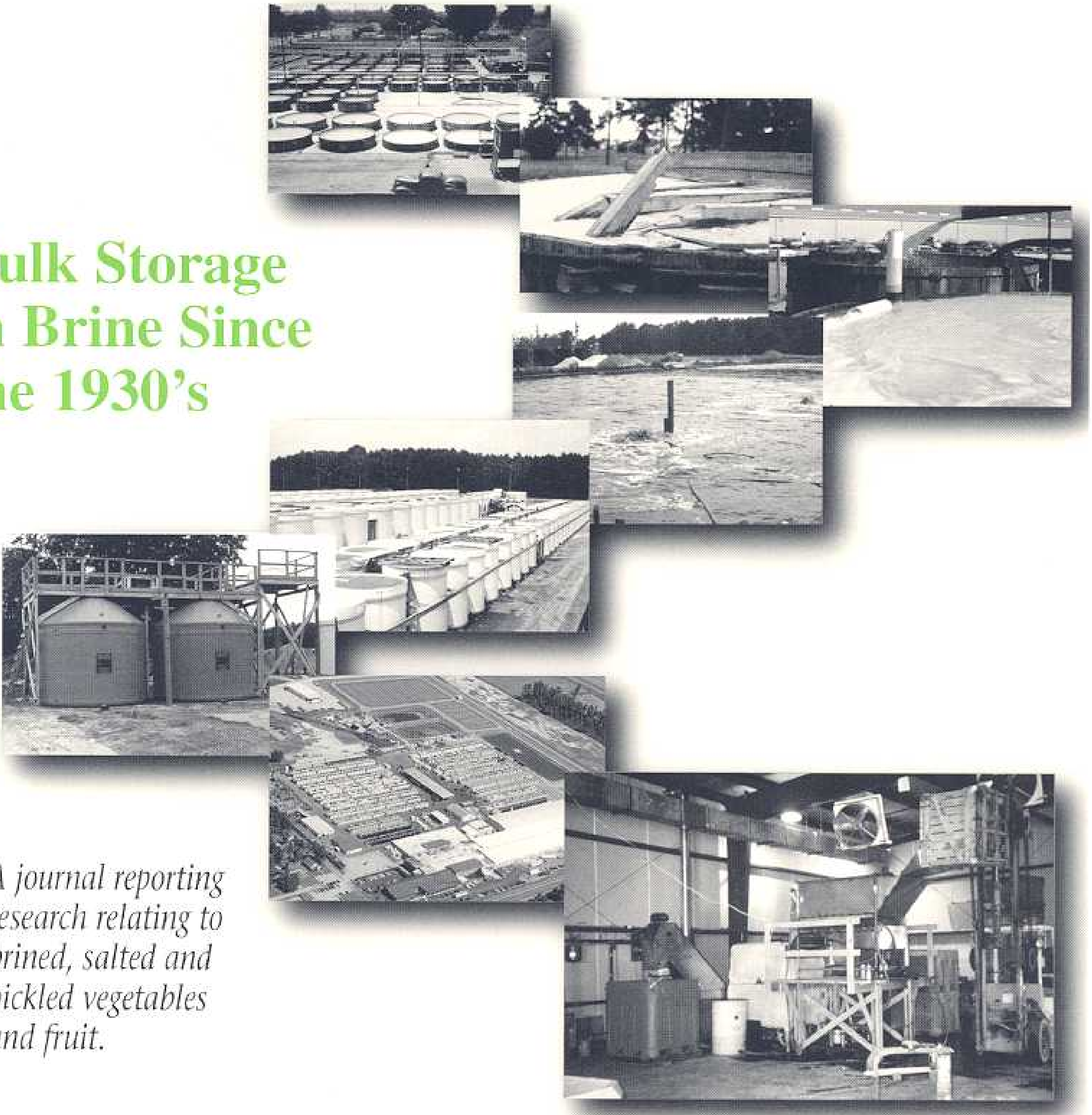
"For Those Who THINK PICKLES"

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.

Pickle Pak SCIENCE

Bulk Storage in Brine Since the 1930's



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