BAG-IN-BOX TECHNOLOGY:
Pilot System for Process-Ready, Fermented Cucumbers

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ABSTRACT

A pilot system was designed, constructed, and tested for preserving fermented cucumbers without generation of excess salt and organic wastes. The cucumbers are washed, blanched, cooled, aseptically transferred to a bag-in-box (250-330 gal) containing cover brine (salt to equalize at ca. 4%), inoculated with a special culture of lactic acid bacteria which does not produce CO_2 from malic acid, and allowed to ferment. The system has potential benefits to the grower (marketing flexibility, value enhancement) and processor (waste elimination, improved product quality/uniformity).

INTRODUCTION

Brining is a means for temporary preservation of pickling cucumbers before they are processed into finished products. Once properly brined, the cucumbers undergo fermentation by naturally occurring lactic acid bacteria. The cucumbers traditionally have been preserved in open-top tanks by a combination of added salt and lactic acid produced by the fermentation. Vegetables and other foods have been preserved by fermentation for centuries. All pickling cucumbers in the United States were commercially preserved by fermentation until about 1940, when pasteurized (fresh-pack) pickles were introduced. Refrigerated pickles were introduced on a national scale in the 1960s. Today, we estimate the approximate relative volumes of commercially processed pickles in the United States to be 35% brined, 40% pasteurized, and 25% refrigerated.

Although brining is still an important method for preserving cucumbers, the traditional process has resulted in environmental concerns due to excess salt and organic wastes that are generated. Strict environmental regulations have resulted in some companies having to abandon brining operations, and others having to pay sizeable expenses for discharge into municipal wastewater or install expensive lagoons and equipment for waste handling. In addition, there is growing demand from the food industry for high and uniform product quality in an increasingly competitive market.

Our laboratory has developed a palletized system for temporarily storing "process-ready" brine-fermented cucumbers. By "process-ready" we mean that the salt concentration is sufficiently low that excess salt does not have to be leached out before making the brine-stock cucumbers into finished pickle products. The system is designed for use by growers and processors of brined cucumbers. Potential advantages of the system to growers include: (1) an increase in marketing flexibility and (2) value addition to their crop. Potential advantages to processors include: (1) elimination or significant reduction in salt and organic wastes, and (2) improved quality and uniformity of finished products. In addition, the cucumbers are fermented and stored in closed containers, isolating the product from the environment and protecting the product from chance or intentional contamination.

MATERIALS AND METHODS

Chemical Analyses

Lactic, acetic, and malic acids; ethanol; and glucose and fructose were measured by HPLC with an HPX-87H column (Bio-Rad, Richmond, CA) with 0.03N sulfuric acid as the eluant. The column was heated to 140°F (60°C) at a flow rate of 0.8 mL/min. A photodiode array detector (model UV6000, Thermal Separations, Schaumburg, IL) set at 210 nm (Frayne, 1986) was used for the detection of the organic acids. Dissolved CO_2 was measured as described by Fleming et al. (1974). Salt (NaCl) was measured by titration (Fleming et al., 2001).

Product Evaluation

Fermented cucumbers were evaluated for bloater damage, which was expressed as "bloater index," as described by Fleming et al. (1977). Cucumber firmness was measured by a USDA Fruit Pressure Tester, as described by Bell et al. (1955).

Procedure

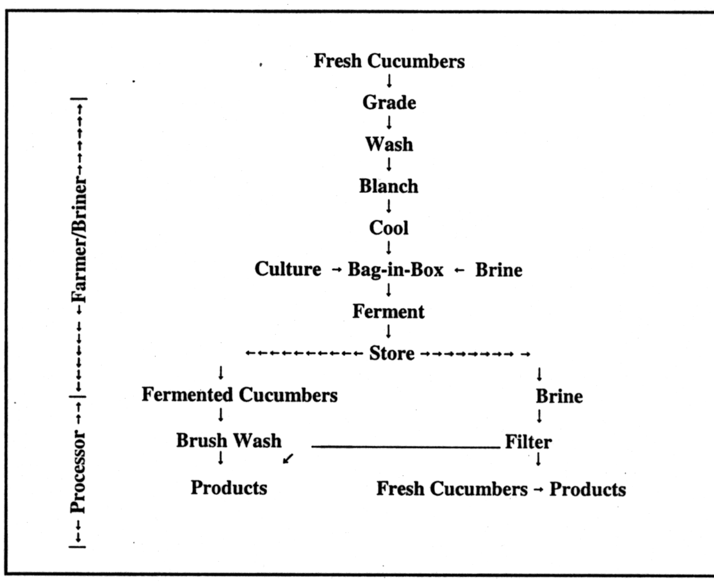

Figure 1. Flow diagram for process-ready, fermented cucumbers.

The overall procedure for producing process-ready, brine-fermented cucumbers is outlined in Figure 1. Steps through storage are proposed for the farmer/briner. Steps after storage are proposed for the processor. The processor, of course, may choose to do the entire process.

FRESH CUCUMBERS are harvested and GRADED to size. For best results, the cucumbers should be graded and brined according to the steps in Figure 1 immediately after harvest. This will allow greater retention of original quality of the fruit. Quality deteriorates with holding time, especially under conditions of high temperature and humidity.

GRADED CUCUMBERS are WASHED to remove loose soil, flowers, and foreign material. Use of a high pressure spray, as described below, may be adequate for most purposes, but a brush washer may be preferred in some cases. The cucumbers eventually will be brush-washed by the processor just before manufacture into finished products.

The cucumbers are then BLANCHED in 175-180°F (79-82°C) water for 1/2 to 3 min, depending upon size and other factors. This kills most of the bacteria and inactivates microbial softening enzymes on or near the surface of the cucumbers. Then the cucumbers must be COOLED before or after they are added to the bag-in-box. The objective is to have the cucumbers and brine equilibrate to 90°F (32°C) or less. In this pilot system, the cucumbers were cooled by dropping them into potable water that had been circulated through crushed ice (34-40°F, 1-4°C), and then they were transferred to the bag containing room temperature brine. For a commercial unit, we propose that the cover brine be cooled to 32-34°F (0-1°C), which will more closely result in the desired temperature after equalization with the blanched cucumbers, depending upon cucumber size and blanching time/temperature. More details on this subject are given in the paper by Fasina et al. (2002b). The purpose of cooling is to provide a temperature suitable for the added bacterial culture to survive and ferment and to avoid textural degradation of the cucumbers that prolonged high temperature could cause.

The BAG-IN-BOX is palletized for ease of handling by a forklift truck. Various types of bags and boxes may be used, some of which are described below. Those tested to date vary in volume, 250-330 gal. The COVER BRINE contains the compounds given in Table 1 at concentrations depending upon the pack-out ratio (pounds cucumbers/ pounds brine) to equalize with cucumbers at the desired final concentration. The blanched and cooled cucumbers are transferred to the bag-in-box in a manner to avoid contamination and in sufficient amounts to fill the container. From the weight of cucumbers and knowing the predetermined total weight of water that the bag will hold, one can calculate the pack-out ratio. These concentrations of components were determined based on research. The 4% salt is needed to help assure microbial stability of the fermented cucumbers. The acetic acid, present in vinegar, serves to acidify the brine. The $Ca(OH)_2$ reacts with the acetic acid to form a buffer which helps assure complete conversion of the sugars to lactic acid. The calcium supplied in the $Ca(OH)_2$ and $CaCl_2$ acts as a firming agent for the

Table 1. Cover brine composition for different pack-out ratios (cucumbers:brine).

Brine Component	Desired final concentration % (mM)[2]	% in brine for pack-out ratios[1]			
		50:50	55:45	60:40	65:35
NaCl	4.00 (684.3)	8.00	8.88	10.00	11.43
Acetic acid	0.32 (53.0)	0.64	0.71	0.78	0.91
$Ca(OH)_2$	0.13 (18.0)	0.27	0.30	0.33	0.38
$CaCl_2$	0.13 (12.0)	0.27	0.30	0.33	0.38

[1]Calculated as weight cucumbers: weight brine.
[2]mM is another way of expressing concentration that most scientists use, but for the rest of the table concentrations are expressed only as % by weight. The ingredients and concentrations listed were justified in the paper by Fleming et al. (1988).

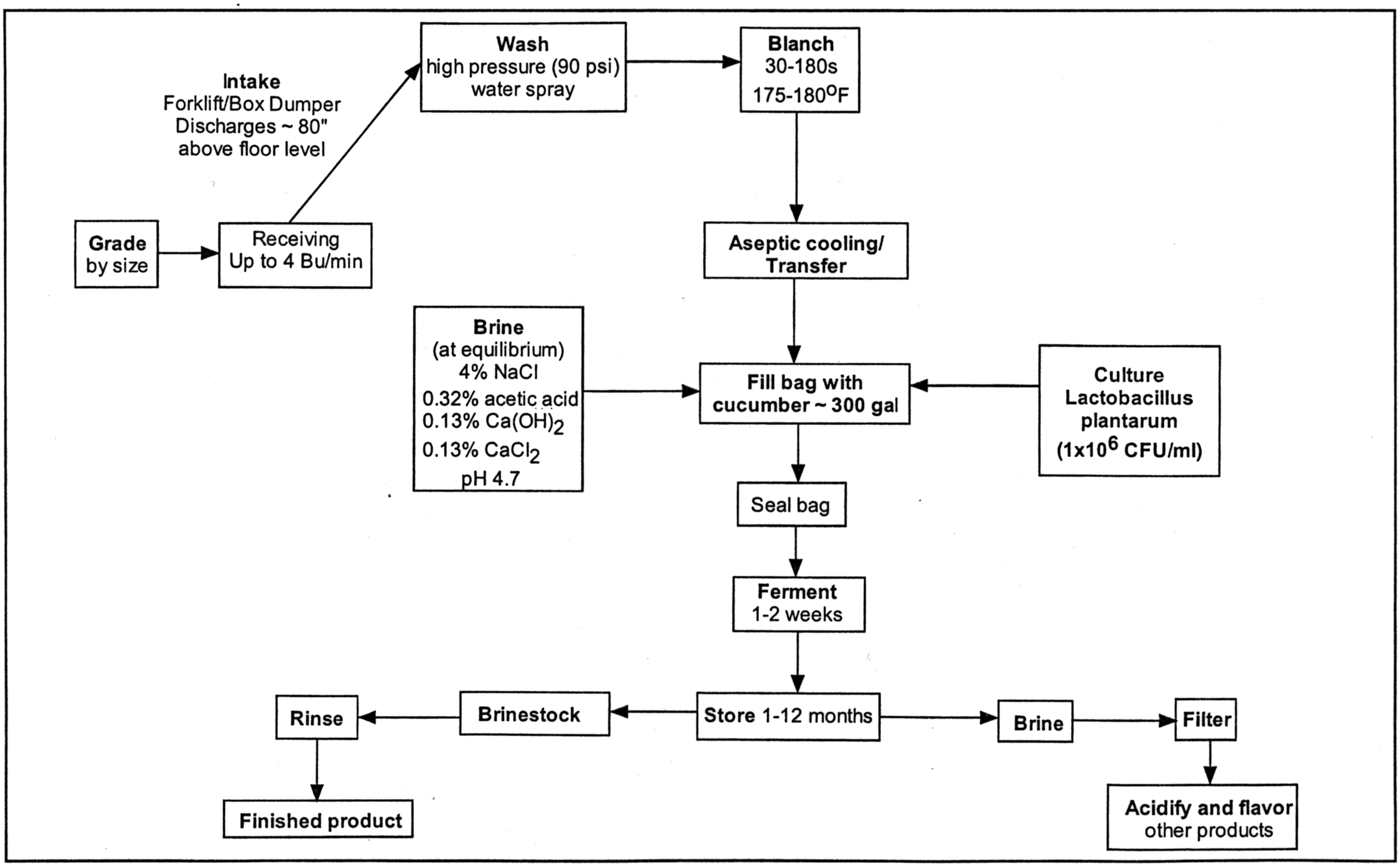

Figure 2. Block diagram of overall process with operating parameters and equipment items.

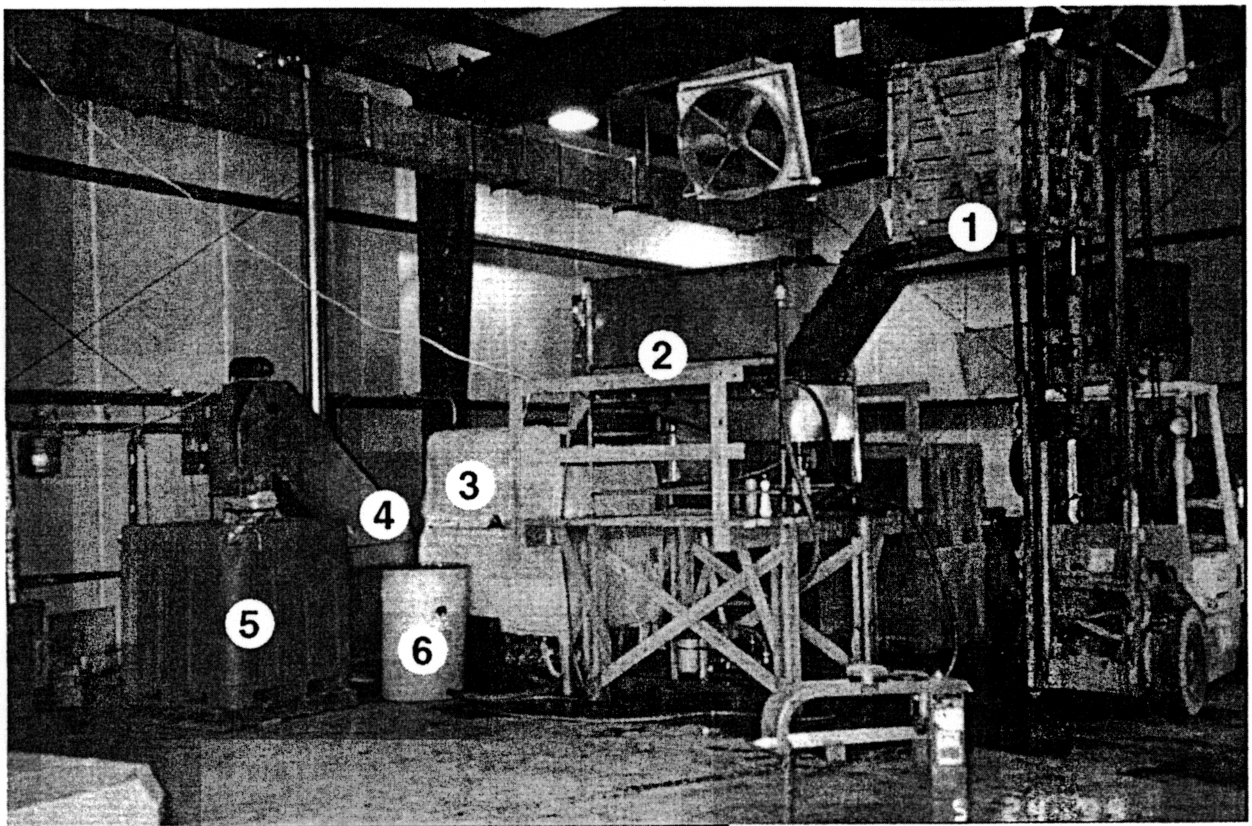

Figure 3

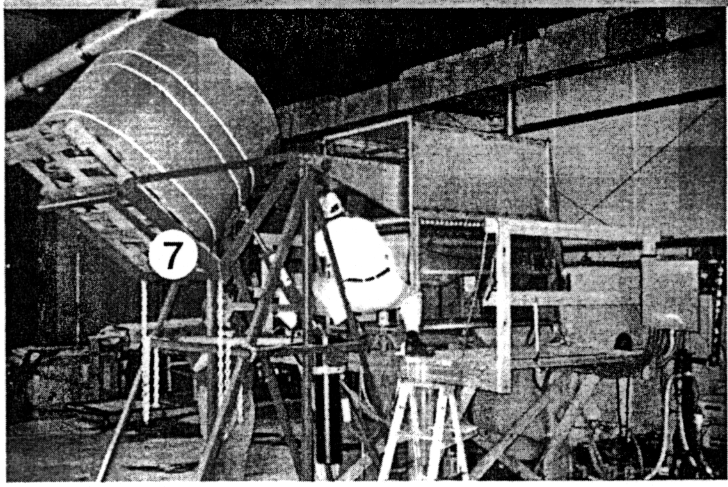

Figure 3A

Figure 3. Pilot processing equipment illustrating forklift delivery (1) to the stainless steel washer unit (2), the insulated blancher (3), the cooling and transfer conveyor (4), the fermentation/storage container (5), and an ice barrel for cooling water (6). Fig. 3A. A pallet box dumper (7) was substituted for the forklift in later trials.

cucumbers and helps retain the texture. About half of the cover brine is added to the bag before cucumbers start to be introduced through the snout. After cucumber addition starts, the culture is added through the sampling port.

The CULTURE consists of a bacterium, *Lactobacillus plantarum*, grown in a medium to provide very large numbers. The culture may be purchased in dried or frozen form. The dried form is more convenient, but must be mixed with a small amount of brine immediately before adding to the brined cucumbers. The culture is added to represent about four billion cells per gal of cucumbers/brine. This culture ferments all of the sugars of the cucumbers to lactic acid and traces of other compounds, with the production of very little gas (carbon dioxide).

The cucumbers are allowed to FERMENT, which normally requires 1-4 weeks, depending on cucumber size, at about 80°F (27°C). Lower temperatures will require a longer time to complete conversion of all the fermentable sugars to acetic acid and traces of other compounds. Processors may require that all fermentable sugars be fermented, depending upon the product they make therefrom. For example, they may not want residual sugars in the hamburger dill chips, which may not be pasteurized. Residual fermentable sugars could lead to yeast growth and gaseous spoilage.

The fermented cucumbers should be STORED in a cool, dry place. They should be stable for up to 6 months, and perhaps longer, depending upon oxygen transmission rate of the bag and other factors (Fleming et al., 2002). The bag-in-box procedure allows brined cucumbers to be stored indoors, in contrast to the traditional open-top tanks that must be held outdoors so that sunlight can prevent growth of yeasts and molds on the brine surface.

FERMENTED CUCUMBERS and brine are separated by the processor. The cucumbers are BRUSH WASHED to remove cells and foreign material from the surface. They are then made into sweets, dills, relishes, etc., without the need to remove excess salt. The BRINE may be cloudy due to bacterial cells from the fermentation. This brine must be filtered (Fasina et al., 2002a) before it can be added back to fermented cucumbers, or used to acidify and flavor fresh-pack cucumber products.

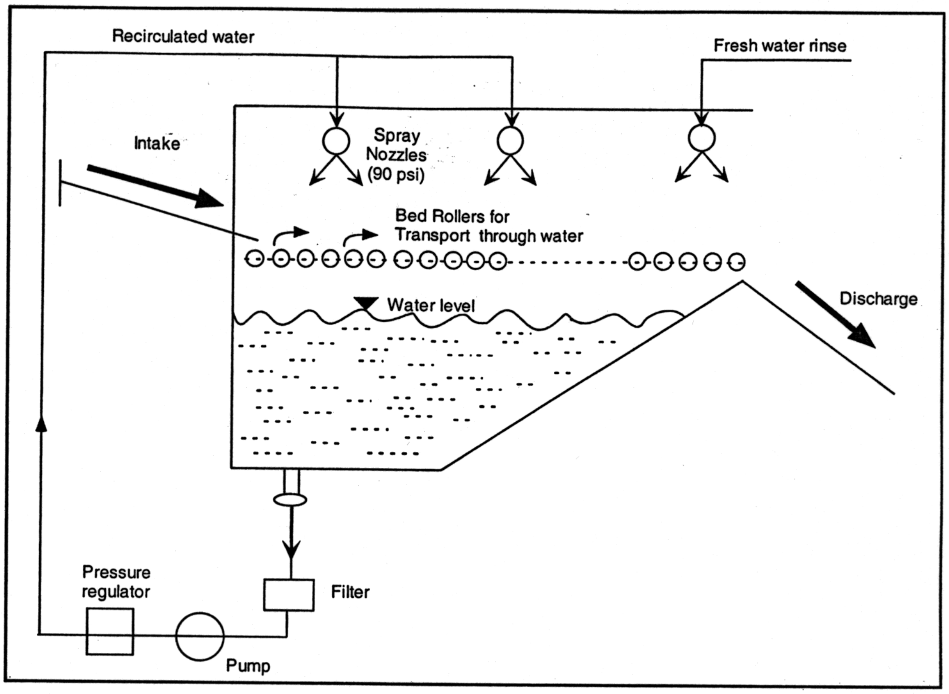

Figure 4. Washer schematic illustrating bed rollers, spray nozzle placement, pump, and freshwater intake.

Equipment

Major elements of the pilot processing equipment (PPE) include a washer, blancher, combined cooler/bin filler, and the fermentation/ storage container. Accessory conveyors and transport devices include a box dumper, water level and temperature controls, circulating pumps, and a propane-fired hot water heater for heating the blanching water. Figure 2 is a flow chart of the equipment system with important operating parameters; the actual equipment is pictured in Figure 3. The through-put rate of cucumbers for the system varies, depending upon submersion heating time in the blancher. These rates (lbs/min) are 33, 50, 100, and 200 when heated for 3, 2, 1, and 1/2 min, respectively. The minimum heating times for cucumbers of various sizes are yet to be determined.

Washer. Cucumbers are introduced into the PPE at the washer entry by means of a forklift truck equipped with a rotating head, or a box dumper especially built for the system (Fig. 3A) capable of rotating a wooden field box or cardboard shipping container through an angle of 140°. The washer is mounted on a platform in order to raise its discharge height to correspond to the intake of the blancher, thereby enabling the use of gravity transfer between them. Consequently, entry into the washer is about 80 inches above floor level.

The rotating head forklift can be used to raise and slowly rotate conventional 20-bushel field boxes of cucumbers to pour them into the washer. However, flow rate into the washer was found to be erratic. This prompted the design and construction of a box dumper mounted on an angle iron frame and powered by a 2 1/2-inch diameter hydraulic cylinder with a 30-inch stroke. Hydraulic power is supplied by a commercial power pack (Barnes Hydraulics, model 4F67A, 2 HP, 1900 psi) capable of executing small incremental angle changes of the box dumper, resulting in more uniform feeding of cucumbers into the system. The box dumper can be operated with conventional 20-bushel field boxes or larger (40 bushels) cardboard shipping containers commonly employed in the industry.

The washer is constructed of 18-gauge stainless steel sheeting on a stainless steel angle frame and is basically a tunnel 38 inches wide by 60 inches long. A bank of six high pressure, square pattern flood nozzles (Spraying Systems, 1/4 HH10SQ) is mounted 20 inches above the cucumbers. Figure 4 is a schematic cross-section of the washer, illustrating its essential features. Nozzle pressure is maintained at 90 psi on the first two rows by a booster pump (STA-RITE Industries, model HP20F-01, 1.5 HP) and 40 psi on the freshwater rinse nozzles. The wash water is re-circulated from the washer tank through a filter system (Amtek, model HD-10-R50-BBS) to the high pressure wash nozzles.

A series of 30 fixed axis bed rollers mounted on 1 7/8-inch centers provides transport of the cucumbers through the washer. Rollers are constructed of Schedule 80 PVC pipe which is 1.660 inches in diameter (nominal 1 1/2-inch pipe), 37 7/8-inches long and mounted on 3/8 inch diameter stainless steel shafts. These shafts are supported by bronze bushings (3/8 x 5/8 x 1/2 inch) mounted in 6 x 58 x 1/2 inch PVC sections attached to each side wall of the washer. The rollers are driven by no. 35 ANSI roller chain sprockets (11 teeth) mounted on one end of each roller shaft. An adjustable rate drive unit (Dayton, model 4Z370, 1/2 HP) for the rollers is coupled to the rollers through a reducing chain drive that enables roller speed to be varied between 40 and 90 rpm.

Blancher. The blancher is a stainless steel, ferris wheel-type device with ten sections or pockets that forcibly submerge cucumbers under the blanching water surface as illustrated in Figure 5. The water level is maintained about 7 1/2 inches below the center of the 44-inch diameter wheel by addition of makeup water controlled by a float valve (Gentech International LTD). Cucumbers are gravity fed into the blancher from the washer discharge, collected in a blancher pocket, submerged, and discharged by gravity to the cooling/transfer conveyor. Rotational speed of the blancher wheel is variable through the 1/2 HP gear head motor and Zero-Max drive (model W3-0-20). The final drive is a no. 40 ANSI roller chain operating on 18 and 48 tooth sprockets, respectively. Submergence in the blanching water can be varied from 18-200 seconds by changes in the Zero-Max or final drive ratio.

Blanching water temperature in the 190-gal, urethane-insulated blancher tank is controlled by a three-way regulator valve (Hoffman Specialty, series 1140) that operates in a diverting service mode. Water is heated by a 270,000 BTU propane-fired hot water heater

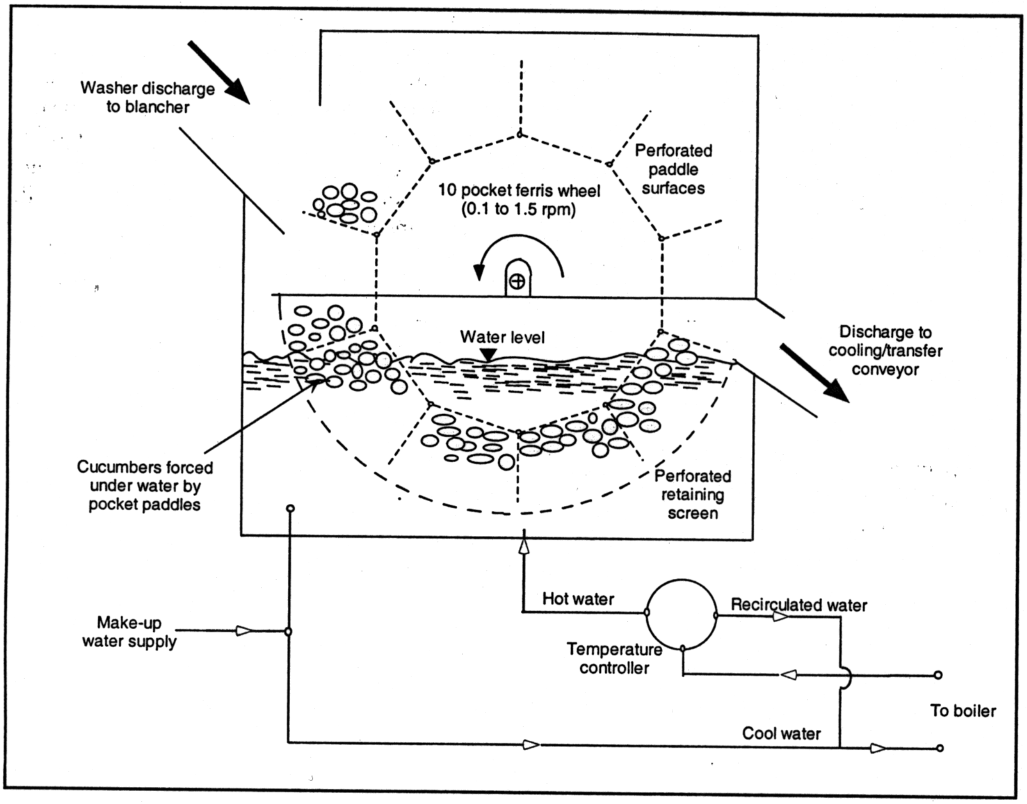

Figure 5. Blancher schematic, including plumbing connections to the boiler (hot water heater) and water supply, ferris wheel pockets for submersion of cucumbers in blanching water.

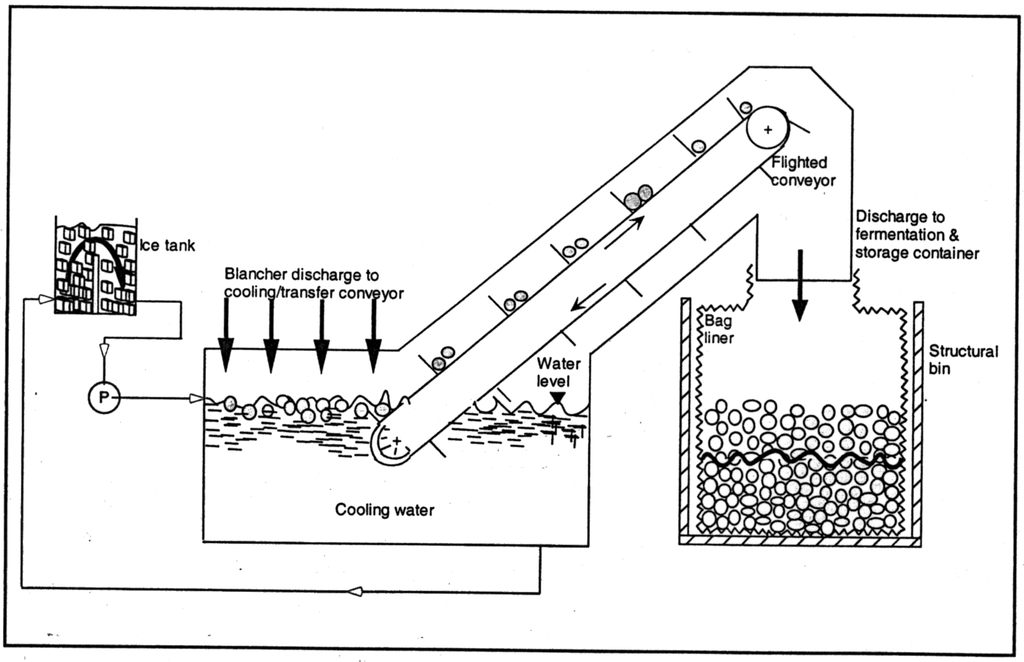

Figure 6. Schematic of cooling and transfer conveyor with external ice barrel and delivery of cucumbers to the fermentation storage container.

(Lochinvar, model RB270) that supplies a continuous flow of water to the diverting value. If the blanching tank temperature, as sensed by the temperature bulb of the diverting value, is below the set point, hot water (≈190-200°F, 88-93°C) from the water heater is diverted to the tank. If the blanching tank temperature is above the set point, the water heater supply is simply recycled to the heater. The schematic shown in Figure 5 illustrates this operation; temperature sensitivity in the blancher tank was ±3°F when operated at a 178°F (81°C) set point. Makeup water to compensate for that lost from the blancher in the normal course of operation is added to the system from ordinary tap water.

Cooling and transfer conveyor. The blancher discharges by gravity directly into a transverse unit that serves as a cooling tank and transfer conveyor. A schematic of this unit shown in Figure 6 illustrates its delivery of cucumbers to a bag/box combination for fermentation and storage. The tank section of the 18-gauge stainless steel unit is 72 x 19 x 12 inches and operates with cooling water at a depth of 14 inches. Cooling is provided by crushed ice in an external reservoir (55-gal, polyethylene tank) through which the cooling water is continually circulated by a 1/2 HP pump (Fig. 6). Water temperature in the cooling tank is typically about 40°F, but is subject to wide variations, depending on the flow rate of the cucumbers, cooling water, and the quantity of ice in the system.

The conveyor component consists of an endless, stainless steel ladder chain (Cambridge Wire Cloth Company, Sani-Grid, 1/2 inch pitch) 12 inches wide equipped with 2-inch high rubber flights (Tatch-A-Cleat) spaced 10 inches apart. The belt is indirectly driven by a 1/2 HP gear head motor at a belt speed of 60 ft/min. The chilled water circulating pump discharges from the tank end opposite the conveyor (Fig. 6) and tends to push the cucumbers into the conveyor. Water drains from the cucumbers as they are elevated and discharged to a box/bin containing a polyethylene liner (bag) attached to the conveyor discharge. The system is isolated from the atmosphere from the point of entry to the blancher to the bag. Although not hermetically sealed, the isolation provides an acceptable degree of protection from contamination.

Cleaning and sanitizing. The blancher and cooling and transfer conveyor should be thoroughly cleaned and sanitized after each day of operation. This is necessary to prevent build-up of microorganisms that may contaminate subsequent runs. This is particularly important in the cooling and transfer conveyor. Two different formulations are required. The cleaning compound is used to remove organic and other adhering materials from the equipment surface. After applying the cleaning compound by pressure spray, it is washed from the surface with clean water. Then a food-grade sanitizing compound is sprayed onto the equipment surface and allowed to drain. The sanitizer is not washed from the surface since it is approved as food-grade. At the beginning of the next run, the cooling and transfer conveyor are again sanitized before entrance of blanched cucumbers into the system. Various types of cleaning and sanitizing compounds are commercially available. The manufacturer of the compounds used should be consulted to confirm their appropriateness for their intended use.

Bags and boxes/bins. Several combinations of bags and boxes have been employed in the PPE system. In most of our runs, the bag was a commercially available, 3-ply (each ply 4 mils thick), ultra-low density polyethylene (ULDPE) liner having a volume of 250-330 gal. There is some evidence that oxygen transmissibility of this type of liner may exceed acceptable limits for storage periods greater than 1 month (Fleming et al., 2002). Excessive oxygen allows growth of film yeasts or molds that may survive the blanching operation. A nylon-coated outer liner (PNEP, Custom Packaging, Manistee, MI) providing greater resistance to oxygen transmission is an alternative for long-term storage. A more complete discussion of bag composition is given by Fleming et al. (2002).

In practice, about half of the cover brine is added to the bag after placing it in the outer box that provides structural strength. Shortly after cucumbers begin to arrive from the PPE system, the fermenting culture is poured into the bag by hand. A 3-inch access port in the top of the bag is convenient for this step, and also provides a means of sampling at later times. In the absence of a port, the culture may be poured in through the fill snout. After filling with cucumbers and adding the remainder of the brine, the top filling snout is folded and heat-sealed for fermentation and storage. A portable hand-held unit (Vertrod Thermal Impulse Sealer, model 12H/H, 1/4) with a 12-inch sealing section is employed. Two overlapping applications are necessary to cover the 15 to16-inch wide filling snout.

The outer structural shell or box that contains the liner can take several forms. Its primary function is to provide the structural strength necessary to contain the bag. To date, both rigid and flexible or collapsible pallet boxes constructed of plastic, wood, synthetic fibers, or cardboard have been utilized as liner containment devices. It appears that most of the commercially available shells utilized to ship liquid products (paint, food purees, juices, oil, etc.) in bulk quantities utilizing bag-in-box methods could be utilized. Filling the bags uniformly and maintaining a level fill, especially at the end of the fill, will require some mechanical means of distributing the product over the entire area to obtain a level fill. Since cucumbers tend to float in brine, they must be physically restrained by a header board or structure that can be strapped to the top of the box to positively submerge the top layer of product. A flat PVC sheet with simple wooden restraints as shown in Figure 7 has been used. Further improvements in the restraining cover are expected.

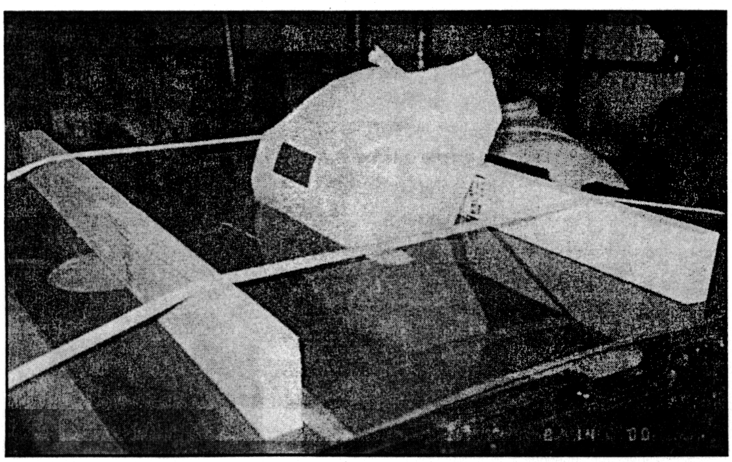

Figure 7. Sealed bag-in-box with restraining cover and straps. Moderate production of fermentation gas (CO_2) causes expansion of the filler snout of bag. Note the patch on the expanded filler snout, which was used to cover the needle puncture from sampling of gas.

RESULTS

Product Quality

Characteristics of the fresh cucumbers used in this study are summarized in Table 2. Five different lots of cucumbers were used. The quality of cucumbers fermented by the procedure described herein for the five different runs is summarized in Table 3. Bloater damage was slight to negligible in all runs, and firmness was acceptable. The cucumbers were not fully cured visually, which has little practical significance but distinguishes them from traditionally fermented cucumbers. Sizes of cucumbers fermented were 2b and 3a, and storage time in the bag-in-boxes varied from 13-161 days.

Product Chemistry

The chemical composition of the fermented cucumbers in the five runs reported herein is summarized in Table 4. The levels of lactic acid produced (104-120 mm) are important in flavoring of the finished products, as is described in a following paper by

Table 2. Characteristics of fresh cucumbers in this study.

Run no.	Cucumber size[1]	pH	Concentration, mM		
			Malic acid	Glucose	Fructose
1	2b	6.1	17.7	45.6	56.1
2	2b	6.1	17.5	46.5	54.3
3	2b	5.9	18.4	53.5	63.7
4	3a	5.7	15.6	41.4	45.6
5	2b	6.0	15.7	48.5	60.6
5	3a	5.8	13.9	46.9	56.2

[1]Cucumber size 2b = 15/16 to 1-1/16; size 3a = 1-1/2 to 1-3/4 inches diameter.

Table 3. Quality of fermented cucumbers.[1]

Run no.	Storage time (days)[2]	Cucumber size	Cure (%)	Bloaters (BI)[3]	Firmness (FPT, lbs)
1	13	2b	45	0.5	18.8
2	48	2b	55	4.8	16.3
3	42	2b	55	2.8	18.8
4	48	3a	75	3.0	15.3
5	161	2b	50	0.0	15.6
5	161	3a	50	0.8	14.7

[1]The cucumbers were blanched for 3 min at 175-180°F before brining for all runs listed.
[2]Storage time in the plastic bag before opening. See Fleming et al. (2002) for extended storage time in glass jars.
[3]BI = bloater index.

Table 4. Composition of brined cucumbers after fermentation.

Run no.	Storage time (days)	CO_2 (mg/100 mL)	pH	Salt (%)[1]	Concentration, mM[2] Lactic acid	Acetic acid	Ethanol	Malic acid	Glucose	Fructose
1	13	41	3.52	2.0	116	51	5.67	9.47	ND[3]	ND
2	48	67	3.63	2.0	104	43	0.6	0.79	ND	0.58
3	42	44	3.52	2.0	114	64	ND	0.40	ND	ND
4	48	76	3.41	2.0	120	48	8.36	4.64	0.63	ND
5	161	52	3.36	4.0	104	42	9.20	9.74	0.11	0.30
5	161	68	3.29	4.0	97	47	18.0	5.57	1.13	ND

[1]These are the intended salt concentrations at equilibrium. The salt concentration was stratified as given in Table 2 of Fleming et al. (2002).
[2]These are concentrations near the center of the bag. These concentrations were stratified also, as was the salt. See Table 2 of Fleming et al. (2002).
[3]ND - none detected.

Johanningsmeier et al. (2002). The level of acetic acid approximates that which was projected based on that added in the cover brine. The CO_2 levels in runs 1 and 3 (about 40 mg/100 mL brine) were about what was expected for the special culture of lactic acid bacteria used in the fermentations. The CO_2 for runs 2, 4, and 5 was higher than desired, but the bloater damage in these runs was not severe. Note that none of these fermentations were purged, so the CO_2 levels reported are an accumulated total from the cucumbers and the fermenting bacterium.

DISCUSSION

In this paper we have summarized our efforts to construct and evaluate a pilot system for the application of bag-in-box technology for the fermentation and temporary storage of fermented cucumbers. We think enough information is provided for enterprising companies or individuals to seriously consider the potential of the system. A diversity of considerations is required before the system can be applied at the commercial level, and our efforts have uncovered many such considerations, some of which are discussed below.

Equipment

While the equipment described is suitable for pilot- or small-scale operations, the entire system must be scaled up for serious commercial operations. Of particular interest is the blanching and cooling system. The cucumbers must be heated sufficiently to inactivate undesired microorganisms and enzymes located on the fruit surface, and then quickly cooled sufficiently to avoid excessive temperatures in the bag containing the cucumbers, which could adversely affect survival of the added culture and result in excessive temperatures of the bulk cucumbers with deterioration of texture and other quality factors.

Blanching Time and Temperature

The optimum times and temperatures for blanching cucumbers of various sizes have not been established, but are probably lower than 3 min at 175-180°F, as reported in this paper. Our basic studies have shown that >99% of total microorganisms of fresh cucumbers are killed in less than 1 min at 176°F (80°C; Breidt et al., 2000). Basic studies also indicate that fungal softening enzymes representing those found on cucumbers are >99% inactivated in 36 sec at 167°F (75°C; Chavana and McFeeters, 1977). Only experience will reveal if these data can be used to predict the minimum heating necessary to assure microbial and textural stabilities of fermented cucumbers.

Then there is the softening activity of enzymes native to fresh cucumbers, which increases in larger fruit (McFeeters et al., 1980). It is important that these enzymes not be active, and is the reason larger fruit are susceptible to soft center development. Since it may be impractical to blanch cucumbers sufficiently to inactivate these enzymes within the fruit, larger fruit (>size 3A) may be unsuitable for low-salt brining, as described herein.

Bag Composition

The oxygen transmission rate of the bag used to contain the brined cucumbers is crucial, as is more fully explained later (Fleming et al., 2002). We found that sufficient oxygen diffused into the bag to permit the growth of oxidative (film) yeasts. These types of yeasts do not grow in the absence of oxygen, but in the presence of oxygen can utilize the lactic acid for growth and result in a rise in pH, with potential growth of undesirable bacteria, as well as cause off flavors from their own growth. Also, oxygen can cause off flavor development from chemical reactions.

Storage Stability

The conditions previously found (Fleming et al., 1996) to be optimum for long-term (12 months) storage stability (microbial and textural) of fermented cucumbers were shown to be 4.4% salt, pH 3.5, and absence of oxygen and fermentable sugars. The addition of 0.1% sodium benzoate after fermentation was beneficial to microbial stability. In the present study, we took brine-stock samples at the time the bags were emptied and the product evaluated for storage studies under laboratory conditions. Results of these storage studies are reported later (Fleming et al., 2002).

Fermentation Culture

Commercial cultures of lactic acid bacteria for use in the fermentation are available, including a special culture (Daeschel et al., 1984) that does not produce CO_2 gas from malic acid (the major acid in cucumbers). However, we grew the culture in our laboratory for use in these studies. Two concerns need to be addressed concerning commercial availability of this culture.

First, most commercial firms that produce lactic acid bacteria cultures for the food industry grow them in a medium containing dairy-based components. Such cultures do not meet kosher food law requirements for use in fermenting pickles because of this. Although the culture can be grown in media that do not contain dairy components, we are unaware of any current commercial firm that does so. Commercial firms have indicated a willingness to provide such a culture, but will do so only if sufficient volume of culture is needed for economic justification. We are making efforts to assess the potential demand for the culture by the pickle industry.

Second, the culture can be made available in frozen or dehydrated form. We think that the dehydrated form provides convenience that may be desirable for use in fermenting cucumbers.

Cost Analysis

A comprehensive cost analysis of the proposed bag-in-box system has not been done. Costs for scale-up of the system for commercial use must be addressed, and economic and other benefits of the system considered. Potential advantages of the system were summarized in the Introduction.

CONCLUSIONS

The system for preserving "process-ready" brined cucumbers, as described in this paper, offers an approach for technological advancement of the pickle industry, with potential benefits to producers and processors of pickling cucumbers. Details of the system require optimization for maximum potential benefits, some of which are addressed in the other papers in this issue dealing with bag-in-box technology.

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Pickle Pak

SCIENCE

Bulk Storage in Brine Since the 1930's








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

Pickle Pak **SCIENCE**

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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PREFACE

This issue of *Pickle Pak Science* contains a collection of six papers describing our efforts over the past five years to develop a procedure for producing process-ready, brined cucumbers and other vegetables using bag-in-box technology. The technology has the potential to benefit both farmers (market hedge, value enhancement) and processors (higher and more uniform quality, waste elimination) of brined vegetables.

The first paper describes the pilot system used to preserve process-ready, brined cucumbers. By process-ready we mean the use of a sufficiently low concentration of salt to preserve the cucumbers, but not so high as to generate wastes created when excess salt must be washed from the brine-stock before their manufacture into finished products. The cucumbers are removed from the brine, briefly washed to remove bacterial cells, and incorporated into finished products. The brine is filtered and used as an acidulant for fresh-pack and other products. The paper on brine membrane filtration (#4) and the one on sensory quality of pickles using this brine (#5) explain how this new technology can be applied by the pickle industry

The paper on predicting equilibrium temperatures of blanched/brined cucumbers (#2) can be useful in several heat transfer applications to the pickle industry, in addition to optimizing the conditions for bag-in-box technology. Conditions affecting storage stability of bag-in-box brine-stock are given in paper #3. The use of preservatives to preserve brined vegetables without fermentation is given in paper #6.

Thus, this collection of papers is intended as an introduction to a potential new era for the preservation of brined vegetables. The technology for this new era will require a careful cost analysis to determine if the savings in waste elimination, improved product quality/uniformity, and greater security from contamination are sufficient to offset the expenses involved in implementing the new technology.

In addition to the above six papers, two other papers are included in this issue. One relates to the use of hydrochloric acid to acidify brines in traditional, commercial bulk tanks of cucumbers to an optimum pH of 3.5 for microbial and textural stability. The other paper relates to the use of an air-lift pump to move brine-stock pickles in a commercial operation.

Henry P. Fleming

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