REUSE OF FERMENTATION BRINES IN THE CUCUMBER PICKLING INDUSTRY

EXECUTIVE SUMMARY

U.S. ENVIRONMENTAL PROTECTION AGENCY
INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
-CINCINNATI-

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The Executive Summary is published with the intent of providing quick and concise information on the results and findings of this project. In this context, review has been kept to a minimum. The Final Report has been published under the same title as an ORD Series 2 report (600/2-78-207).

ACKNOWLEDGEMENT

This Executive Summary Report was prepared by SCS Engineers, Long Beach, California, under Contract No. 68-03-2578. The EPA Project Officer of the original grant was Harold W. Thompson. For further information on the project, contact the Food and Wood Products Branch, Industrial Pollution Control Division, Industrial Environmental Research Laboratory, Cincinnati, Ohio.

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- EXECUTIVE SUMMARY -

SIGNIFICANCE

The project evaluated on a commercial scale the technological and economic feasibility of recycling spent cucumber fermentation brine. Two brine treatment procedures, heat treatment and chemical treatment, were used. The results showed that brine recycling was practical. Either brine treatment procedure resulted in salt stocks which were equivalent in quality to control cucumbers.

An economic evaluation of the recycling procedures showed a small net savings for the heat treatment procedure and a small net cost for chemical treatment. Selection of the process for a particular plant will depend upon the local conditions.

PROJECT OBJECTIVES AND BACKGROUND

The commercial, technological, and economic feasibility of recycling spent cucumber fermentation brine by heat and chemical treatments were evaluated. Chemical treatment of spent brine was performed by the addition of Food Grade sodium hydroxide (NaOH) pellets to spent brine tanks to raise the pH to 11 or greater. A resulting precipitate was allowed to settle and was discarded. After settling, the clear brine was pumped into a clean tank, adjusted to pH 4.5 to 4.7 with 300 grain vinegar, and held until used in subsequent fermentation processes as a cover brine. In the heat treatment process, spent brine was heated to 90.5°C (195°F) and held at its original pH (3.2 to 3.5). Prior to use as a cover brine, the pH was raised to 4.5 with NaOH pellets.

To evaluate the effects of brine recycling it was necessary to compare the salt stock (fermented cucumbers) and brines from fermentations with recycled brines to control fermentations in which green stock cucumbers were covered with freshly prepared salt solutions. Control fermentations were performed according to normal commercial brining procedures. Beginning in 1975, experimental full-scale fermentation brines were reclaimed and reused through three complete fermentation cycles for both the heat and the chemical treatments. Figure 1 illustrates the experimental design used in evaluating brine recycling.

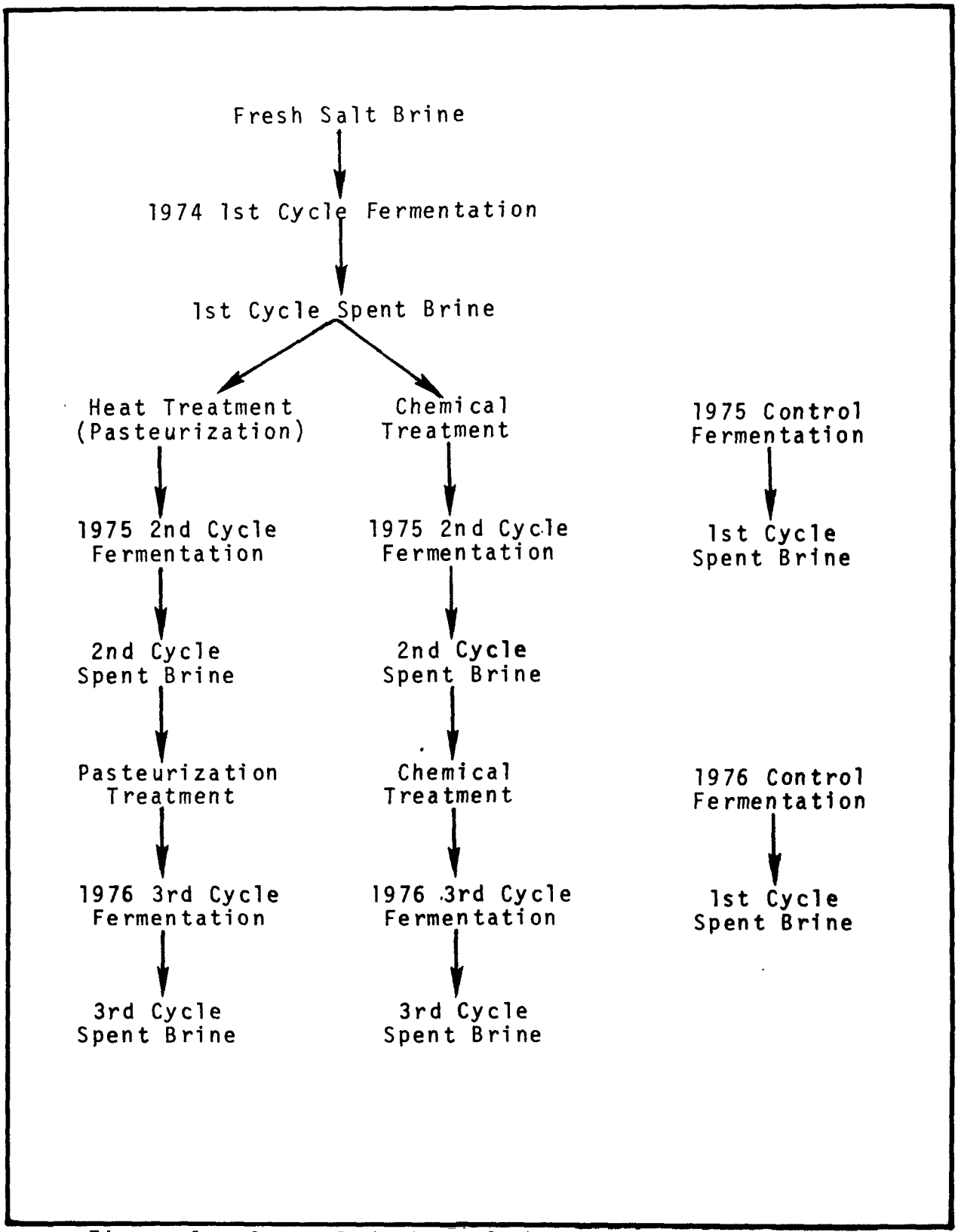

Figure 1. General design of the commercial evaluation of brine recycling.

In addition to the feasibility studies, separate experiments were conducted to evaluate potential difficulties in using recycled brine. These were:

- Evaluation of pesticide buildup with multiple use of brine
- Determination of thermal and pH stability of fungal pectinases (softening enzymes) which are most likely to occur in fermentation brines
- Measurement of lysinoalanine (an amino acid reported to be toxic to laboratory test animals) in chemically treated brine.

These experiments were performed with separate spent brine solutions from those used in the feasibility studies. The same procedures for heat or chemical treatment, however, were applied in these additional studies.

CONCLUSIONS

The following conclusions were made regarding the feasibility of brine recycling:

- Brine recycling is an effective procedure for reduction of waste in the manufacture of salt-stock pickles.
- Both the heat and chemical treatments for spent brine are practical for use in current commercial tank yard operations.
- Heating spent brine for 30 sec at 90.5°C (195°F) will assure at least 99.98 percent destruction of pectinases from fungi which were found to be common on cucumber fruits and flowers.
- Raising the pH of >72°F spent brine to 11.2 or higher for at least 37 hr will decrease Penicillium janthinellum pectinase activity in spent brines to ≤1 percent of its initial activity, a treatment considered adequate for brine recycling.
- Salt-stock cucumbers produced from fermentation using recycled brines are equivalent to control salt stock in bloater losses, texture, and flavor. Consumers have not detected any significant differences in products prepared from salt stock fermented in recycled brine.
- No significant accumulations of metals or pesticides occur as a result of brine recycling.

- The results show that brine can be reused for at least three fermentation cycles on a commercial basis. There were no indications of adverse effects of recycling on salt-stock quality or buildup of toxic constituents. This suggests that brine can continue to be reused beyond three cycles.

- Under the conditions of this project, heat treatment of brine resulted in a small net savings while there was a small net cost for chemical treatment. The relative economics of these two recycling procedures may vary with individual circumstances. However, the use of recycling is an economically feasible means of reducing the waste from tank yard operations.

A summary of these findings is provided in Table 1.

Characteristics of Recycled Brines

Heat treatment of the first cycle brine caused few changes. The pH and titratable acidity were increased and decreased, respectively, as the result of NaOH addition after heat treatment. Aluminum levels increased almost twofold.

Chemical treatment caused a number of changes in the brines. The pH and titratable acidity changed as expected. Reducing sugars declined under the alkaline conditions. Formation and removal of a precipitate reduced the suspended solids. The precipitate consisted primarily of mineral material. Aluminum was the only mineral component to show an increase. BOD and COD increased as a result of vinegar addition for pH adjustment.

Heat treatment of the second cycle brine resulted in no significant change in brine composition except for an increase in pH and decrease in titratable acidity. Chemical treatment (in 1975 and 1976) caused significant changes in the same components and in the same directions as noted above with the exception of BOD and Fe. In those two instances, the increase in BOD and the decrease in Fe were not significant.

Comparison of the heat-treated first- and second-cycle brines showed an increase in BOD from 9,700 mg/ℓ to 14,000 mg/ℓ and COD from 12,800 mg/ℓ to 19,300 mg/ℓ. In addition, there were small increases in the concentration of P, Ca, and Mg. For chemical treatment this first- and second-cycle comparison showed that BOD and COD increased. Though the levels of P, Ca, and Mg were lower in treated brines, the levels in 1975 were actually slightly higher than in 1976. This may have been a result of more efficient removal of precipitate in 1976.

Third-cycle brines were removed from cucumber fermentation tanks after the third-cycle fermentation. The concentrations of

TABLE 1. SUMMARY OF COMMERCIAL, TECHNICAL, AND ECONOMIC EVALUATION OF RECYCLING SPENT CUCUMBER BRINES

Treatment	Commercial Quality of Pickle Product	Technical Evaluation of Brine Recycling	Economic Cost Evaluation of Brine Recycling ($/1,000 gal)
Chemical Treatment	Final product commercially equivalent to controls regardless of brine cycle.	For all cycles fermentation proceeded normally. No significant buildup of toxic elements. Technologically practical.	$2.08 (-)* $4.27 (-)*
Heat Treatment	(Same as above)	(Same as above)	$12.84 (+)† $12.16 (+)†

*(-) Denotes net annual costs.

†(+) Denotes net annual savings.

minerals were similar to the concentration before treatment of the first- and second-cycle brines. Since the project was concluded at the end of the third cycle of fermentation, the third-cycle brines were not treated.

The results of these experiments showed that heat treatment had no effect upon the brine constituents, except for aluminum and the pH and titratable acidity, which were intentionally altered. Chemical treatment resulted in a decline in most of the mineral constituents of brine. The BOD and COD were increased as a result of vinegar addition. Aluminum levels increased after completion of brine treatment with both the chemical and heat techniques. It may be that the food grade NaOH, which was used in both procedures, contained some aluminum as an impurity.

Commercial Evaluation of Brine Recycling

Cucumbers fermented in recycled brine were judged to have normal texture, color, and odor. Pressure test evaluation of the desalted stock from second-cycle fermentations showed no significant differences in the stock from recycled brines.

Taste panel evaluations for texture, flavor, and overall quality done on hamburger dill chips showed no significant differences between control salt stock and from salt stock fermented in either heat-treated or chemically-treated recycled brine.

Based upon commercial experience, there does not appear to be any significant deterioration or improvement in the quality of products obtained from fermentation in recycled brine. There have been no complaints from either insititutional or individual consumers of these products which have been related to use of recycled brine.

Technological Evaluation of Brine Recycling

The data on the commercial quality of salt stock, on the composition of spent brines before and after treatment, on the course of fermentation, and on the mineral components of cucumbers before and after desalting led to the following conclusions regarding the technological aspects of brine recycling.

- Major changes in tank yard practice were not required for brine recycling.
- Fermentations proceeded normally. The same criteria used to judge completion of fresh brine fermentations could be used to judge fermentation with recycled brine.
- Treated brine which contained 12.5 percent NaCl could be used without dilution as a cover brine. This yielded salt stock equivalent in quality to control tanks.

- Changes in brine or cucumber composition as a result of recycling were small. There were no significant buildups of toxic elements in brines or cucumbers which would indicate that recycling should not be done or that the number of brining cycles would need to be limited.

- From a technical point of view, recycling the brine was practical and resulted in final products which were commercially equivalent to the controls.

Economic Evaluation of Brine Recycling

Brine treatment costs for chemical and heat treatment are shown in Table 2:

TABLE 2. ECONOMIC EVALUATION OF CHEMICAL AND HEAT TREATMENT (COSTS PER 1,000 GAL)

	Heat Treatment		Chemical Treatment	
	1975	1976	1975	1976
Total Treatment Costs	$ 6.37	$ 7.05	$21.29	$23.48
Total Savings from Recycling	19.21	19.21	19.21	19.21
Net Savings	12.84	12.16	0	0
Net Costs	0	0	2.08	4.27

Treatment costs for heat treatment were considerably lower than for chemical treatment. Although initial capital investment for a heat exchanger is high, estimates of the savings realized over a 5-yr period using heat treatment indicated that the heat treatment would be the procedure of choice.

In summary, the study indicated that either chemical or heat treatment can be utilized without making the cost of brine recycling prohibitive. It appears that in many situations, the heat treatment procedure would be economically advantageous. However, an analysis must be made for each particular situation considering local economic and physical conditions.

RESULTS OF SPECIAL STUDIES

Pesticide Distribution in Brine Recycling

Cucumbers raised on selected plots of land were treated with selected pesticides (chloronab, PCNB, PCA, Parathion, Paraoxon, Bravo, Dacthal, Difoltan, Endosulfan I, Endosulfan II, Endosulfan SO_4, and Carbaryl) at twice the recommended dosage and harvested at one-half the harvest interval recommended by EPA. Multiple reuse of recycled brine for the fermentation of these test cucumbers was evaluated for pesticide buildup.

Of selected pesticides, carbaryl was the only one which was accumulated in significant amounts in the brining solution. When green stock cucumbers low in pesticide residues were brined in tanks with higher pesticide concentrations than control brines, pesticide concentrations increased slightly in the brined cucumbers over the raw pesticide concentration. At the same time, as the raw cucumbers were absorbing the pesticides, concentrations in the initially elevated brines decreased to trace amounts.

Pectinase Inactivation

The possibility for introduction of pectinases into spent brines, either from the previous fermentation or during periods of brine storage, was a major concern in the development of recycling procedures. If these enzymes were not properly controlled, serious softening of cucumber salt stock could result.

Investigations were performed into the thermal stability of fungal pectinase enzymes under conditions which might occur during brine treatment. Heating at 79.4°C (175°F) for 30 sec was found to be sufficient to inactivate pectinase enzymes from *Penicillium janthinellum*, the most heat stable pectinase tested. Studies on the effects of differing pH levels at 22°C (72°F) on *Penicillum janthinellum* pectinase activity showed that pH should be raised to 11.2 or higher and held for at least 37 hr to assure 99 percent inactivation of pectinases.

It was not possible to evaluate the effect of heat and chemical treatments on the inactivation of pectinase as they occur in commercial brines since analysis of spent brines showed no measurable pectinase activity.

Lysinoalanine

Since it was known that base treatment of protein could lead to the formation of lysinoalanine (an amino acid that, when in the free state, has been shown to be toxic to rats), experiments were performed to determine whether lysinoalanine was formed during base treatment of spent brine. Results indicated that significant amounts of lysinoalanine were not formed as a consequence

of base treatment. The levels in pickle brine appeared to be considerably lower than levels reported in processed foods containing significant levels of protein.

RECOMMENDATIONS

As a result of this study, the following recommendations were made:

- Brine recycling should be adopted by the processed cucumber pickling industry as a means to reduce wastes.
- Both heat and chemical treatments of the spent brine are effective from a technical viewpoint. Selection of a procedure can be based upon economic considerations and upon the relative compatability of the procedures with each particular tank yard operation.
- Care should be taken to ensure proper design of a recycling system, proper training of operating personnel, and proper supervision of the procedure, since improper recycling techniques hold the potential for significant economic losses.
- Undertake an evaluation of calcium hydroxide as a partial or total replacement of sodium hydroxide in the chemical treatment procedure.
- Evaluate the need to remove the precipitate formed during chemical treatment.
- Efforts should be made to reduce tank leakage and overflow, since significant brine losses occur from these sources.
- A major effort is needed to develop salt-stock storage technology, which will allow reduction in the salt levels maintained in brining tanks, since wastes generated in the desalting operation are second only to spent brine as a source of waste in tank yard operations.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO	2.	3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE
REUSE OF FERMENTATION BRINES IN THE CUCUMBER PICKLING INDUSTRY - EXECUTIVE SUMMARY

5. REPORT DATE

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Pickle Packers International
108 East Main Street
P.O. Box 31
St. Charles, Illinois 60174

10. PROGRAM ELEMENT NO.
1BB610

11. CONTRACT/GRANT NO.
S-803825

12. SPONSORING AGENCY NAME AND ADDRESS

13. TYPE OF REPORT AND PERIOD COVERED
Final Report (5/75 - 12/77)

14. SPONSORING AGENCY CODE
EPA/600/12

15. SUPPLEMENTARY NOTES
The final report for this project, under the same title, is to be published as an ORD Series 2 report.

16. ABSTRACT

The project evaluated on a commercial scale the technological and economic feasibility of recycling spent cucumber fermentation brine. Two brine treatment procedures: heat treatment and chemical treatment, were used. The results showed that brine recycling was practical on a commercial scale. Either brine treatment procedure resulted in salt stock, which were equivalent in quality to control cucumbers.

Studies were conducted to determine the adequacy of the brine treatment procedures employed. The data confirmed that a heat treatment of 175°F for 30 sec was sufficient to assure inactivation of pectinases from molds found to be common on cucumber fruits and flowers. For effective chemical treatment, a brine temperature of 72°F or higher was required. In addition, the pH had to be maintained at 11.0 or higher for at least 36 hr to assure 99 percent inactivation of pectinases from the molds which were investigated.

An economic evaluation of the recycling procedures showed a small net savings for the heat treatment procedure and a small net cost for chemical treatment. Selection of the process for a particular plant will depend upon the local conditions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Food Processing Vegetables Brines Circulation Economic Analysis Treatment	Cucumber Brine Recycle Commercial Scale	68D

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to Public	Unclassified	12
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	