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Pickle Research at Michigan State University 1973-74
Michigan State University Agricultural Experiment Station and Cooperative Extension Service
Research Report

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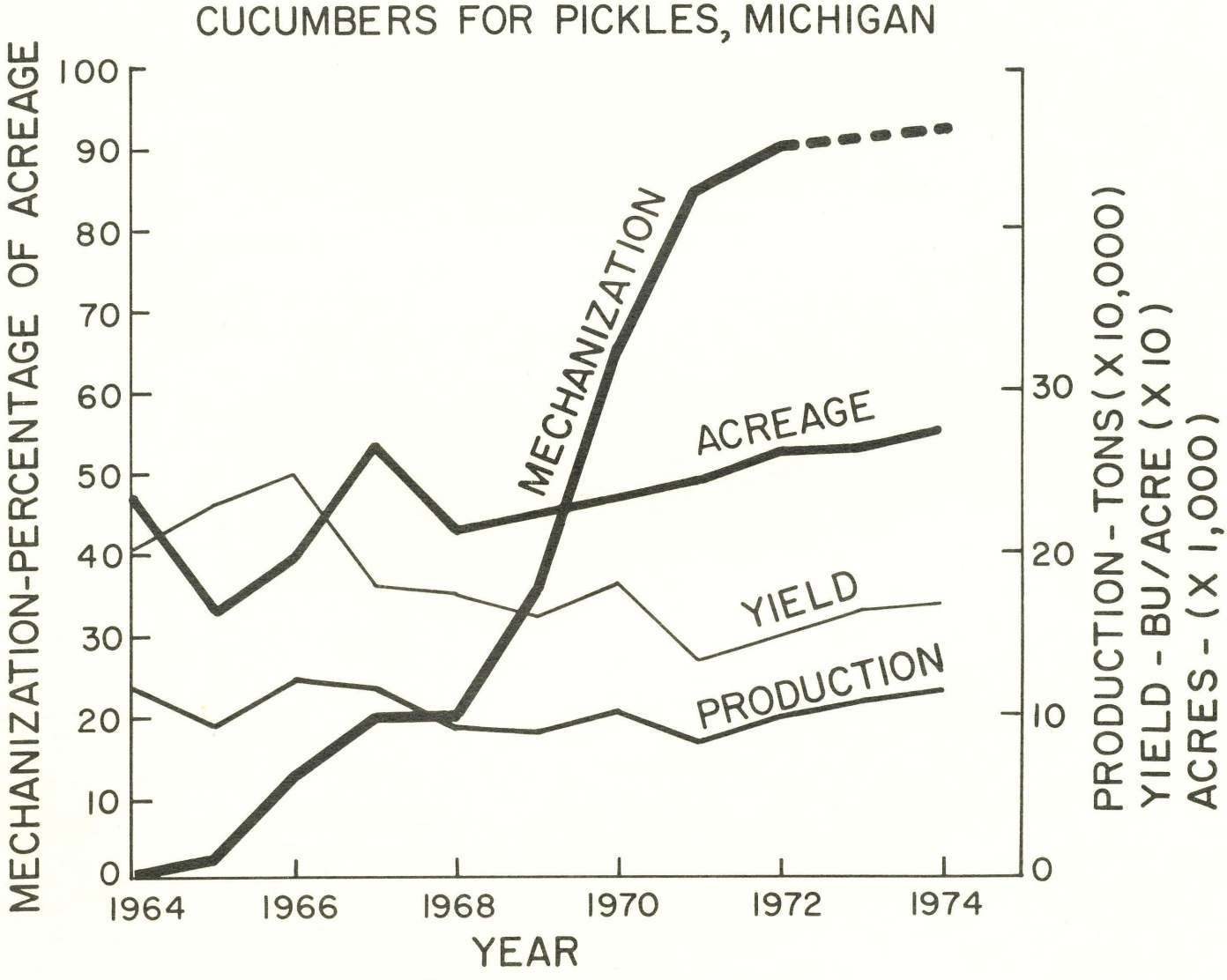
FARM SCIENCE

PICKLE RESEARCH AT MICHIGAN STATE UNIVERSITY — 1973-1974



CONTRIBUTORS

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PICKLE RESEARCH AT MICHIGAN STATE UNIVERSITY — 1973-1974

INTRODUCTION

The purpose of this report is to share research findings with other researchers and with the pickle industry to accelerate progress in the more efficient production and processing of improved pickles for the consumer. A "systems approach," started in 1972, coordinated projects between researchers of different departments and the USDA. An MSU Pickle Research committee and advisory industry Ad Hoc Committee for Pickle Research at Michigan State University were formed. Oral reports on MSU-USDA research are presented to industry members each November.

Subsequently, project proposals are made and critically reviewed by the combined committees to improve and coordinate research efforts. This year, traditional research on field production and mechanical harvesting was expanded and coordinated with research on brining, brine disposal and packaging.

Pickle technology continues in a phase of dynamic change. Examples include conversion from black to white spine hybrid varieties for production in the northern U.S., a trend toward more female varieties to further concentrate fruit set for mechanical harvest, and development of new brining techniques to improve salt stock quality.

The pickle is a relatively new cultivated species that responds markedly to research efforts. New, exciting developments occur every year, and researchers predict many more.

NECTAR SECRETION IN THE FLOWERS OF PICKLING CUCUMBERS[1]

Objectives: 1) to determine the quantity and quality of nectar in male and female flowers of pickling cucumbers under varying conditions, 2) to identify sugars present in cucumber nectar, 3) to compare nectar production in different cucumber cultivars, 4) to progress toward a practical system of monitoring attractiveness of cultivars to bees during plant breeding programs, 5) to provide information on the attractiveness of cucumbers to pollinating bees relative to other nectar plants competing for bee visits, and 6) to contribute to a basic knowledge of nectar production in plants.

This study, which was quite comprehensive in scope, will be briefly summarized in this report. Methods and techniques used included a scanning electron microscope comparative study of the nectaries of pistillate (female) and staminate (male) flowers (Figs. 1 and 2), measurement of water and sugar content of several thousand nectar samples removed from the flowers with microcaps (Fig. 3) and measured on an Abbé refractometer, measurements of the commencement of nectar production in a flower, amounts produced, and the influence of time, weather and other factors on the amount, concentration and termination of nectar production.

Nectar secretion in pickling cucumbers started the day of flower anthesis when the temperature reached 63°F, but measurable amounts were not obtained until the temperature reached 69°F. Basically, the cucumber flower secreted nectar only during the first day of bloom, although small amounts of more dilute nectar were present in the flower up to the third day. Apparently sugar of unused nectar was reabsorbed into the plant.

Pistillate flowers produced 1.5 to 2.3 times as much nectar as staminate flowers, but the nectar of staminate flowers averaged a higher sugar concentration (45% vs. 36%). Total sugar produced by both types of flowers was similar so bees were attracted equally to them. Water content of nectar varied from 40% to 87%, and this was influenced by relative humidity of the air and flower replacement of dilute nectar following its removal by bees.

If undisturbed, honey bees removed all the nectar from a flower in one visit. The flowers replaced

[1]Investigators: Clarence Collison and E. C. Martin.

Fig. 1. Pistillate flower of cucumber, cut open to show nectary. To reach nectar, bee must rub against the stigmas above and cause pollination.

about the same volume of nectar within 1 hr but the sugar concentration of the nectar dropped from 42% in the original nectar to 14% in the replaced nectar.

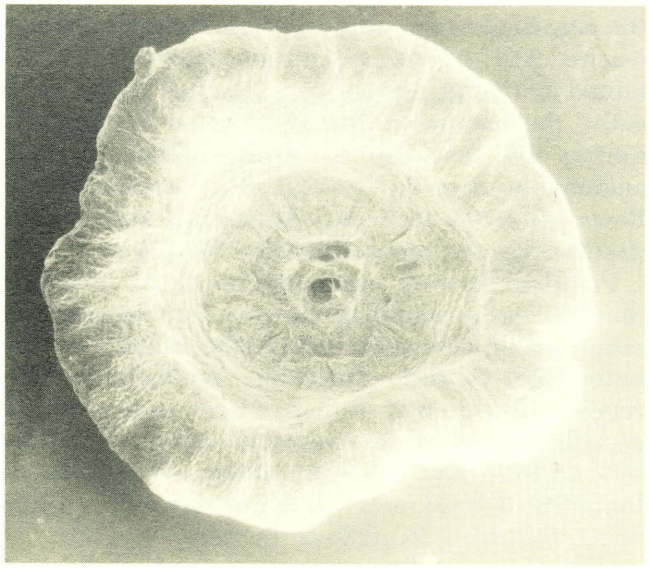

Fig. 2. Nectary of a pistillate flower.

In flowers from which bees were excluded, the sugar concentration of the nectar increased some 40% over those flowers with bee visits. Nectar removed from bees' honey sacs averaged about 25% sugar, which is a blend of concentrated original and dilute replaced nectar. All cultivars tested were quite similar in quantity and quality of nectar.

Honey bee visits to cucumber flowers were highest from 9:00 a.m. to 2:00 p.m. The decrease in afternoon visits coincided with a reduction in nectar sugar content. Tests indicated that fertilization of ovules took place about 7½ hours after pollination, and nectar secretion diminished after that time.

Using gas chromatography, the sugars of cucumber nectar were found to be sucrose, fructose and glucose. The major chemical constitutents were: water, 59.2%; sucrose, 24.7%; fructose, 10.2%; glucose, 5.9%.

Fig. 3. Nectar being removed from a cucumber flower by means of a "microcap" (fine capillary tube).

Summary

Based on sugar quantity and quality, cucumber nectar must be considered relatively attractive to honey bees, but major honey plants such as sweet clover and alfalfa have many times the number of flowers per acre.

The cucumber cannot be rated an important honey-producing plant. Lack of attractive pollen is a factor in reducing the cucumbers' ability to compete with other plants for visits of large numbers of bees. All cultivars tested produced a quantity and quality of nectar that were attractive to bees.

Techniques used in this study could be used to monitor the attractiveness to bees of new lines or cultivars during a plant breeding program. Although pistillate flowers contained more nectar, the nectar of staminate flowers was higher in sugar content, so bees visited both types of flowers indiscriminately. Nectar was readily replaced in flowers after removal by bees, but replaced nectar contained much less sugar. The sugars of cucumber nectar were: sucrose, 60.5%; fructose, 25.1%; and glucose, 14.4%.

HONEY BEE ACTIVITY IN PICKLING CUCUMBERS IN RELATION TO FRUIT PRODUCTION[2]

Objective: to develop more specific criteria for determining the amount of bee activity on flowers required to produce a crop.

The grower of a bee-pollinated crop usually wants to know how many colonies of bees are needed per acre to provide adequate pollination. In hybrid pickling cucumbers, we have suggested one colony to every 50,000 plants. Actually, this number would provide the right number of bees for the pollination job in some situations and not enough or too many in others. Some bee colonies may be much stronger than others; fields of clover or other attractive plants may draw bees away from the cucumbers; unfavorable weather may restrict bee flight. So, specifying the number of colonies per acre is a crude guideline to effective pollination.

We have made progress towards our objective by measuring bee activity on marked flowers and measuring the results in terms of fruit set, fruit shape, fruit inhibition and seed count.

For part of this project, we used seven rows of cultivar Piccadilly (Med I) planted 3 ft apart and 72 ft long. Pickles were planted June 27, 1974. Flowering began August 6; all flowers were picked through August 12 and observations were recorded August 13-24. An apiary of 13 colonies was .4 mi from the plot and on August 16 two colonies were placed alongside the plot.

To get an index of bee activity in the plot, five male and five female flowers were tagged each day and bee visits recorded for alternating 10-min periods from 8:00 a.m. to 5:00 p.m., D.S.T. In addition, a date tag was placed on every new flower in the plot every day during the observation period so fruit set, fruit inhibition and other data could be recorded later. Weather data in the field were also recorded.

Bees started to visit flowers shortly before 8:00 a.m., D.S.T. Visits peaked between 12:00 and 1:00 and ended soon after 5:00 p.m. Average total number of visits per flower for the 9 hours was 66. Between 12:00 and 1:00, bees visited flowers at the average rate of 13 visits per flower per hour (V/F/H). On August 22, a particularly good flight day, there were 90,000 visits to 900 flowers during 9 hours, which represents 11 V/F/H. At this rate, an acre with 50,000 plants would receive 630,000 bee visits per day. The number of bees present in the plot was greater than that usually found in commercial fields.

Bees visited male flowers at a slightly slower rate than female flowers until after 9:00 a.m. After 9:30, bees showed a slight preference for male flowers. From August 13 to 21, 1974, there was an average of one female to two male flowers in the plot. Later, the percentage of male flowers greatly increased; that is, the predominantly female characteristic desired for production of uniform fruit was not evidenced in this commercial cultivar.

From 692 plants in the plot, our harvest (at estimated optimum single destructive harvest time) was 1193 fruits or 1.7 fruits per plant. The presence of a single developing fruit on a vine inhibits development of fruit from fully pollinated flowers further down the vine. Development of a cultivar that would set and develop more fruit would be an obvious advantage.

Of 108 flowers pollinated on August 13, 90.7% set fruit. After 1 week, less than 20% of the pollinated flowers set fruit. This indicates that after about 1 week of good bee flight weather, effective pollination for a destructive harvest should be complete if enough bees were present and particularly if the plants had the predominantly female characteristic.

Fruits harvested averaged 230 seeds per fruit, with a maximum number of 540. There was no definite correlation between the number of seeds and fruit shape.

Summary

As a preliminary observation, we could say that if bees visited cucumber flowers at a rate of 13 V/F/H between 12:00 and 1:00 on a warm, good flying day and the field had adequate proportions of male and female flowers, optimum pollination would be accomplished.

[2]Investigators: E. C. Martin and Clarence Collison.

PICKLING CUCUMBER CHEMICAL DISEASE CONTROL RESEARCH (1973)[3]

Objective: to develop more effective methods of chemical protection against angular leaf spot and powdery mildew.

Field studies to develop improved methods for chemical control of pickling cucumber diseases were continued in 1973. Particular emphasis was on evaluating new bactefungicides, i.e., copper and hexachlorophene formulations for protection against angular leaf spot and powdery mildew.

Testing was done with the variety Pickmore. Plants were artificially inoculated and irrigated frequently (at night) to promote disease infection. The plots were hand harvested several times during the growing season.

Results indicate that hexachlorophene (Nabac 25 EC) at 0.5 pint is a satisfactory substitute for copper in combatting angular leaf spot, but may be somewhat less effective against powdery mildew (Table 1). Preliminary greenhouse tests have given some indication that the combination of copper and hexachlorophene may have greater bacteriocidal and fungicidal activity than either compound alone. Further investigation of this combination is warranted.

CHEMICAL CONTROL OF SCAB ON PICKLING CUCUMBER[4]

Objective: to evaluate Bravo (Chlorothalonil) at various rates as a protective fungicide for control of scab on pickling cucumbers. Special consideration was given to determining whether additives designed to extend the activity of organic compounds would permit lower rates of application without impairing control.

In 1974, Bravo at several rates alone and in combination with the extender Nu-film 17 was evaluated for protection against scab infection using the white spine, scab susceptible hybrid, Pickmore.

Tests were conducted in the greenhouse and on small field plots at East Lansing. Plants were artificially inoculated with the scab organism following application of protective sprays. Every effort was made to maintain conditions favorable to the spread of infection. Treatments in both tests were applied at a 4X concentration (25 gal/acre).

Greenhouse tests preceded those in the field, and were used to screen application rates. In these tests, evaluation was confined to seedling plants grown in flats. These were grown at 70° F under humid conditions and subjected to frequent overhead irrigation. Treatments were applied in a spray chamber with hollow cone nozzles mounted on an overhead moving carriage. Two applications were made at weekly intervals, and disease incidence was recorded a week after each spray.

Field plots simulated planting conditions for mechanical harvesting (approximately 60,000 plants/acre) and consisted of blocks six rows wide and 25 ft long separated by 8-ft alleys. Treatments were replicated four times and applied with a boom sprayer using hollow cone nozzles spaced 8 in. apart (one overhead and two drop nozzles per row). Applications were made weekly, starting when plants were approximately 3 in. high and continuing until harvest (six applications). Sprinkler irrigation was used frequently (at night) to promote the spread of natural infection.

Commercial field trials were conducted on the Clifford Harmsen farm in Allegan County to determine whether the high rate of Bravo approved for use on cucurbits was effective for controlling scab on pickling cucumbers.

The test site had been used to grow three successive crops of pickles. The last crop harvested in the fall of 1973 had been severely infected with scab and anthracnose. The 1974 planting was Pickmore

[3]Investigator: H. S. Potter.

[4]Investigator: H. S. Potter. Cooperator: Clifford Harmsen, grower.

Table 1. Disease treatment results in 1973[a]

Treatment	Foliage Disease Index [b] Angular leaf spot	Foliage Disease Index [b] Powdery mildew	Estimated harvested yield bu/acre	Cull [c] fruit %	Estimated marketable yield bu/acre
Nabac 25 EC 8 oz/acre	3.1 b	4.2 b	550.1 a	20.5 a	437.3 a
Nabac 25 EC 8 oz + M-45 80W 1.5 lb/acre	3.0 b	4.0 b	533.5 a	23.5 a	454.0 a
Cit Cop 4E ½ gal/acre	2.5 ab	3.4 ab	572.0 a	23.3 a	438.7 a
Kocide 404 ½ gal/acre	2.3 a	2.8 a	546.9 a	24.0 a	436.4 a
Copper Count N ½ gal/acre	2.8 b	3.1 a	595.1 a	24.0 a	452.3 a
No Treatment	6.9 c	6.0 c	399.8 b	33.3 b	266.7 b

(a) Small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.5 level.
(b) Index number range from 0 = no disease to 10 = complete defoliation.
(c) Includes diseased, misshapen and oversized fruit.

(approximately 70,000 plants/acre).It was irrigated at regular intervals or when necessary. Treatments were applied weekly with a brush boom sprayer at 50 gal/acre. Spraying was started when plants were only a few inches tall and continued on a weekly schedule until a week before harvest (six sprays).

Results of greenhouse tests indicate excellent control of scab on seedlings with Bravo alone at the 1½- and 2-lb rate (Fig. 4) and even at the 1-lb rate in combination with Nu-film 17 (Table 2).

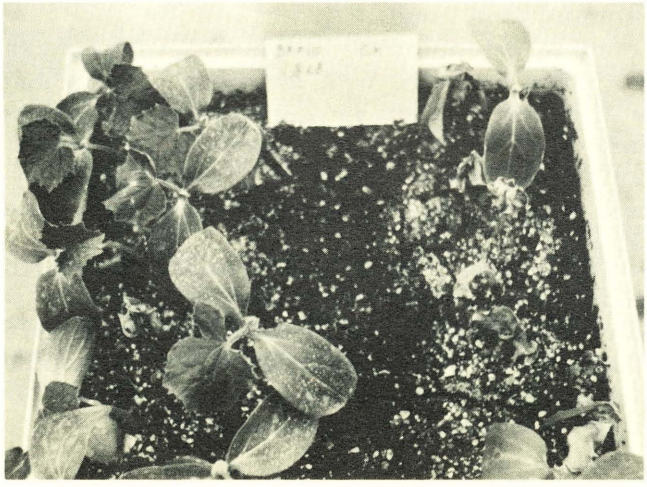

Fig. 4. Scab infection on Bravo treated and untreated pickling cucumber seedlings (Var. Pickmore).

In the field plot trials where plants were grown to maturity, control with Bravo alone at the 2-lb rate was significantly better than at 1½-lb alone. However, with the addition of Nu-film 17, the 1½-lb rate gave control comparable to the higher rate with and without the additive (Table 3).

In the commercial field trials, Bravo plus Cit Cop 4E reduced foliage infection by 79% and fruit infection by 84% (Table 4). The marketable yield was increased by 36% as a result of protective sprays (Fig. 5).

Table 2. Greenhouse studies for control of scab of pickling cucumbers (var. Pickmore), East Lansing, Michigan (1974)

Treatment		Disease Index [a] 7 days after first spray	7 days after second spray
Bravo 75W	½ lb/acre	4.9	6.5
Bravo 75W + Nu-film 17	½ lb + 8 oz/acre	2.2	3.8
Bravo 75W	1 lb/acre	3.4	4.2
Bravo 75W + Nu-film 17	1 lb + 8 oz/acre	1.2	2.2
Bravo 75W	1½ lb/acre	1.5	2.4
Bravo 75W + Nu-film 17	1½ lb + 8 oz/acre	0.8	1.8
Bravo 75W	2 lb/acre	1.2	1.9
Bravo 75W + Nu-film 17	2 lb + 8 oz/acre	0.9	1.4
No treatment		7.6	10.0
	LSD .05	1.3	2.2
	LSD .01	2.9	4.7

[a] Disease index ratings range from 0 (no disease) to 10 (100% infection, plants died).

Table 3. Field plot studies for control of scab of pickling cucumbers (var. Pickmore), East Lansing, Michigan (1974)

Treatment		% Infection Foliage	Fruit
Bravo 75W	1 lb/acre	10.7	19.2
Bravo 75W + Nu-film 17	1 lb + 8 oz/acre	8.4	20.7
Bravo 75W	1½ lb/acre	8.3	15.5
Bravo 75W + Nu-film 17	1½ lb + 8 oz/acre	5.6	10.3
Bravo 75W	2lb/acre	5.9	7.1
Bravo 75W + Nu-film 17	2 lb + 8 oz/acre	4.6	7.0
No Treatment		22.3	44.1
	LSD .05	2.3	5.1
	LSD .01	2.9	6.3

Table 4. Commercial field trials for control of scab pickling cucumbers (var. Pickmore), Clifford Harmsen farm, Allegan County, Michigan (1974)

Treatment		% Diseased Foliage	Fruit	Marketable yield bu/acre
Bravo 6F	2 pt/acre	10.3	12.0	176.6
Bravo 6F + Nu-film 17	2 pt + 8 oz/acre	7.5	8.1	185.1
No treatment		38.5	45.8	109.6
	LSD .05	3.5	3.7	9.6

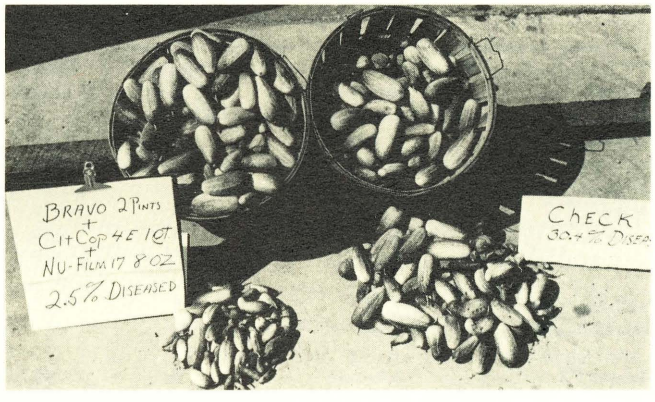

Fig. 5. Scab infection in Bravo treated and untreated pickling cucumber fruit (Var. Pickmore).

Summary

1. Bravo is an effective protectant against scab infection on pickling cucumbers.

2. In some instances, addition of the extender Nu-film 17 tended to increase the effectiveness of Bravo.

3. It is possible to grow scab-susceptible varieties of pickling cucumbers with minimum loss from scab infection if protective sprays of Bravo are applied.

4. Scab infection is likely to start in young plants, so effective control will often depend on early application of protective chemicals.

PICKLING CUCUMBER BREEDING RESEARCH[5]

Objective: to increase the yield, quality and disease resistance of varieties for once-over mechanical harvest.

Conventional Program

Average yields of pickles from once-over mechanical harvest have increased from approximately 100 bu/acre in 1971 to approximately 170 bu/acre in 1974. This increase has resulted from improvements in varieties, cultural practices and harvesters. Another important factor has been the conversion to white spine (WS) varieties. In 1972, less than 10% of the Michigan acreage was planted to WS varieties, whereas more than 50% was planted to WS varieties in 1974.

A number of hybrid varieties are suggested for once-over mechanical harvest based on the 1973 yield trial (Table 5). Yields were determined after harvest with a Wilde harvester of 1/50-acre plots. They ranged from 78 to 252 bu/acre. The time of harvest for each variety was subjectively determined by observation. Bloating of brine stock ranged from 2 to 88%, which may or may not be representative values.

Several breeding lines have been developed with WS color combined with resistance to cucumber scab, mosaic virus and angular leaf spot. These lines have been developed as gynoecious, monoecious and hermaphroditic sex types to accommodate hybrid seed production of both single and triple crosses.

Unfortunately, the 1974 trial was badly droughted and yield data were not obtained. However, 10 experimental hybrids will be tested further in 1975 (Table 6). All these hybrids are WS with multiple disease resistance and predominately female expression for once-over mechanical harvest.

[5]Investigators: L. R. Baker, J. Rudich, J. W. Scott and J. E. Wilson. Cooperators: R. C. Crum, D. J. deZeeuw, R. C. Herner and H. M. Sell.

Table 6. MSU experimental hybrids with white spine color for advanced trial

Pedigree	Diseases [a]			Fruit Characters		
	Scab	CMV	ALS	Type	Color	L/D
394 x SC 25	R	R	T-S	blocky	good	fair
394 x SC 38A	R	R	T	blocky	good	fair
(Gy14 x 4108)SC 38A	R	R	T-R	blocky	good	good
(394 x 4108)SC 38A	R	R	T	blocky	fair	fair
394 x 8519	R	R	T-S	blocky	good	fair
3488 x 8519	R	R	R-T	tapered	good	long
394 x 9429	R	R	R-T	blocky	fair	fair
(Gy14 x 4108)9429	R	R	R	tapered	fair	good
(394 x 4108)9429	R	R	R-T	blocky	fair	fair
(921 x 319)9429	R	R	R-T	blocky	fair	fair

[a] Disease rating: R = resistant, T = tolerant, and S = susceptible.

Table 5. Varieties suggested for once-over mechanical harvest in Michigan, (1973)[a]

Variety	Source	Spine Color	Yield (bu/acre)	Maturity	Percent Bloaters	Diseases Scab	CMV	ALS
Pioneer	Asgrow	B	86	Early	24	R	R	S
Bounty	Asgrow	B	208	Mid	88	R	R	T
XP 1040	Asgrow	B	140	Mid	66	R	R	T
Premier	Asgrow	W	154	Early	84	R	R	T
Score	Asgrow	W	134	Late	16	R	R	T-R
Carolina [b]	Asgrow	W	175	Mid	26	R	R	R-T
Perfecto Verde	N-K	W	252	Mid	12	S-R	R	T
Green Spear	N-K	W	171	Mid	2	R	R	T
Ranger [b]	Niagara	B	98	Early	86	R	R	T-S
La Salle	Ferry-M	B	78	Early	32	R	R	S

[a] Spine color: B = black and W = white; yield is bu/acre under 2 in.; bloaters are based on 50 grade no. 3B to 4 fruits; diseases are R = resistant, T = tolerant, and S = susceptible.
[b] Public releases developed by university plant breeders available from several seed companies.

Research to improve fruit quality has involved both improved brining techniques and varietal resistance to bloating in brine stock. The brining research is reported elsewhere in this report. Varietal resistance to balloon bloating is based on the high correlation (approximately 0.9) between carpel suture strength and the frequency of balloon bloating (see Research Report No. 213). Based on this correlation, a heritability study of carpel separation and nonseparation in mature fruits was conducted. Obviously, the fruits exhibiting carpel separation are presumed a result of weak carpel sutures which develop balloon bloating during the brining process. The heritability (narrow sense) estimates ranged from 39 to 45%, suggesting that selection for nonseparation would improve fruit quality via a reduction in balloon bloating.

With this basic information, varieties resistant to carpel separation and subsequent balloon bloating are being developed. Thus, genetic resistance to bloating in combination with improved brining methods should greatly reduce balloon bloating in brine stock.

Table 7. Sex expression of hybrids derived from different combinations of parental sex phenotypes

MSU pedigree	Gynoecious		PF		Total
	No.	%	No.	%	No.
Gynoecious x hermaphroditic crosses:					
713-5 x 4108H	128	100	0	0	128
921 x 4108H	120	100	0	0	120
394G x 4108H	140	100	0	0	140
Gynoecious x androecious crosses:					
713-5 x 1A	16	53	14	47	30
921G x 1A	—	—	—	—	—
394G x 1A	7	7	95	93	102
(Gynoecious x hermaphrodite) x androecious:					
(713-5 x 4108H)1A1	31	91	3	9	34
(921 x 4108)1A1	63	57	48	43	111
(394G x 4108H)1A1	62	65	33	35	95
(Gynoecious x hermaphrodite) x monoecious:					
(713-5 x 4108H)9429	—	—	—	—	—
(921 x 4108H)9429	12	14	76	86	88
(394G x 4108H)9429	19	22	68	78	87
Gynoecious x monoecious cross:					
Pioneer =Gy3 x SMR 18	65	17	320	83	385

Sex Expression

Female expression is an important economic trait because of concentrated fruit set and development necessary for once-over mechanical harvest. Research on sex has two main objectives: 1) enhance female expression of varieties to further concentrate fruit set and subsequent yield for once-over mechanical harvest, and 2) produce 100% gynoecious hybrids necessary for parthenocarpic seedless varieties.

The average hybrid variety exhibits some 10 to 20% gynoecious plants with the remainder predominately female (PF). This intermediate sex phenotype has been termed PF because it is easily influenced by environmental changes and is unstable for the ratio of male to female flowers. Genetic improvements in degree and stability of female flower expression under field conditions would increase yields for once-over mechanical harvest.

Several possibilities have been tested to enhance femaleness as compared to current PF hybrids. Recent attention has focused on the use of hermaphroditic and androecious phenotypes (Table 7). In brief, the cross of gynoecious x hermaphrodite results in gynoecious hybrid plants; i.e., hermaphroditic expression is completely recessive to gynoecious. Moreover, the female expression of these hybrid plants seems more buffered against environmental changes than gynoecious lines. This might be explained through complimentary gene action resulting in stronger female expression in the hybrid than either of the parent lines.

Gynoecious x androecious hybrid plants seem more female than present PF hybrids such as Pioneer. The frequency of gynoecious plants in the former hybrid is higher than most hybrids from gynoecious x monoecious crosses. Finally, the possibility of using hermaphroditic lines as the "second parent" in triple cross hybrids using either monoecious or androecious pollinators is promising. Several advantages are possible with triple crosses (as reported by Pike), but increased yields in seed production and improvement of concentration of fruit set and subsequent yield for once-over mechanical harvest are quite likely.

Parthenocarpic Cucumbers

The yield trial was conducted under good conditions in 1973, but the 1974 trial was lost to drought. A Stanhay planter was used to plant 1/50-acre plots (June 20) of 21 different hybrids using commercial practices. The plots were harvested with a Wilde harvester (August 17, 18 and 20). Yield and brine stock data were collected as in the conventional trial (Table 8).

Yields in this trial were improved, but too low for a once-over harvest system. Bloating was high, but all brine stock from the commercial tank used was bloated badly.

Table. 8. Evaluation of parthenocarpic gynoecious hybrids (1973)

MSU Pedigree	Spine Color	Yield bu/acre	% balloon bloat	Disease Scab	Disease CMV
92G x 4108H	W	134	82	R	T
368G x 4108H	W	184	68	S	T
394G x 4108H	W	145	56	R	R
921G x 4108H	W	223	70	R	R
364G x 4108H	W	156	40	S	R

The parthenocarpic expression of these experimental hybrids is "diluted" as the hybrid is heterozygous for parthenocarpy. Accordingly, a hermaphroditic line was backcrossed to a parthenocarpic recurrent parent to combine hermaphroditic expression with parthenocarpy. Hybrids from this hermaphroditic parthenocarpic pollen parent should be more strongly parthenocarpic with earlier fruiting and higher fruit numbers than hybrids heterozygous ("diluted" or weak) for parthenocarpy.

The first homozygous parthenocarpic hybrids were tested in 1974 under reasonable growing conditions (Table 9), but fruit yields would be improved under more ideal growing conditions. Nonetheless, earlier fruit set (node of first fruit) was obtained for parth-homozygous than parth-heterozygous hybrids. However, this earlier fruit set seemed to be at the expense of total fruit numbers. Such a response may be a deficiency in photosynthate related to a "source-sink" phenomenon. At any rate, research emphasis continues on development of hermaphroditic parthenocarpic pollen parents for the seed production of parthenocarpic hybrids.

Another reasearch area has been on the effect of nongenetic factors on parthenocarpic fruiting. First, the influence of daylength and night temperatures were determined (Table 10). Both night temperature and daylength were important. Overall, high night temperature and short daylength were more favorable for parthenocarpic fruiting than low temperature and long daylength. It requires fewer days to the first fruit under these conditions, with this fruit usually set on earlier nodes than with other growth conditions. Parthenocarpic fruit set was noted for Gy 3, a nonparthenocarpic line, under these conditions. This indicates that more genetic gain for parthenocarpy might be realized with selection under the opposite set of conditions — low night temperature and long daylength.

In the field, when the terminal apices of vines were run over by spray equipment, parthenocarpic fruiting was enhanced. A greenhouse experiment was designed to test this observation (Table 11). Removal of the apex ("pinching") enhanced both fruit numbers and earliness of fruit set in both gynoecious lines of nonparthenocarpic and parthenocarpic types. Again, this suggested a "source-sink" relationship with the apex competing with the fruit for photosynthate.

Earlier work (Sims and also Campbell and Pike) has suggested that mechanical clipping of plants and chemical killing of apices just prior to "tip-over" increased yields of conventional hybrids. This technique has not been used as a standard cultural practice, nor is it suggested for gynoecious parthenocarpic varieties (for mechanical harvest).

Finally, several reports of chemical induction of parthenocarpy prompted an evaluation of the more

Table 9. Comparison of pickling cucumber hybrids heterozygous and homozygous for parthenocarpy (1974)

Pedigree	Phenotype	No. of Plants	Node First Fruit	Total Early Fruit	Total Fruit
92G	Parth Parent	11	17.8	0.4	10.5
92G x 4108H	Heterozygous Parth F_1	15	19.8	0.5	7.9
92G x (364G x 4108H) 364 BC_3	Homozygous Parth F_1	25	6.2	1.8	4.4
364G	Parth Parent	36	10.6	1.5	6.6
364G x 4108H	Heterozygous Parth F_1	11	14.0	1.0	5.0
364G x (364G x 4108H)364 BC_3	Homozygous Parth F_1	94	5.9	2.2	4.4
921G	Parth Parent	36	19.1	0.2	16.3
921G x 4108H	Heterozygous Parth F_1	29	17.2	0.7	7.5
921G x (364G x 4108H)364 BC_3	Homozygous Parth F_1	31	15.8	1.7	6.4

Table 10. Effect of day length and night temperature on parthenocarpy of cucumbers (greenhouse conditions)

Treatment [a]		Pedigrees			
		Parthenocarpic		Non-partheno-carpic	Total across pedigrees
Night temp	Day length	MSU 364	MSU 394	Gy3	
				No. fruit/plant	
60	11	14.1	7.0	5.0	26.1
60	16	12.0	3.0	2.5	17.5
50	11	14.0	9.0	0	23.0
50	16	11.0	7.0	0	18.0
				Node no. first fruit	
60	11	2.8	17.0	17.0	36.8
60	16	5.3	18.3	17.2	40.8
50	11	4.8	9.6	(b)	—
50	16	6.5	10.6	(b)	—
				No. days to first fruit	
60	11	43	54	70	167
60	16	43	61	67	171
50	11	58	70	(b)	—
50	16	58	70	(b)	—

(a) All day temp were 75-80°F; data are average of five plants (reps).
(b) No fruit set in this treatment.

Table 11. Effect of "pinching" apices on parthenocarpic fruit set in nonparthenocarpic and parthenocarpic cucumbers (a)

Pedigree	No. of nodes before pinching	No. fruit set	Node of 1st fruit set
Gy3	Control	1.0	12.5
(nonparthenocarpic)	5	1.5	3.8
	7	2.0	5.3
	9	2.8	5.5
	11	3.2	4.2
MSU 364G	Control	1.7	3.5
(parthenocarpic)	5	3.2	2.7
	7	3.8	2.5
	9	3.0	2.7
	11	3.3	2.3

(a) Data are average of five plants (reps).

Table 12. Evaluation of chemical parthenocarpic agents under greenhouse conditions (1973)

Chemical	No. parthenocarpic fruit (a)	
	Pioneer	MSU 394G x 4108H
DPX 1840	0.7	3.2
TIBA	1.0	0.6
Morphactin	1.0	0.3
Control - none	0.0	0.0

(a) Averaged across ethrel treatment, stage of growth and replications; data for best concentration each chemical.

promising of these compounds. Three chemical parthenocarpic agents were experimented with in the greenhouse during the spring of 1973 (Table 12). The experimental design included plus or minus ethrel (50 ppm), two stages of growth and different rates. None of these treatment combinations resulted in reasonable numbers of parthenocarpic fruit production; all fruits were pointed to "nubby."

Field research with DPX 1840 was conducted, utilizing different concentrations and growth stages. Once again, parthenocarpic fruit production was not observed. A few nubby fruits were set on most plants, but not one marketable fruit was found in the treated plots. This included concentrations as low as 25 ppm, which only caused temporary phytotoxicity and epinasty. Unless better chemicals that cause the production of more parthenocarpic fruits with less damage to the foliage are discovered, chemical parthenocarpic agents for pickles seem unlikely.

Summary

Pickle yields produced using the technology associated with once-over mechanical harvest continue to increase. Yields in 1973 and 1974 averaged 163 and 169 bu/acre, respectively, with some yields as high as 450 bu/acre reported. Improved varieties, cultural practices, white spine varieties and machine improvements all contribute to this increase. Caution is required in the use of white spine varieties that do not carry resistance to scab, as an entire crop may be lost to this disease. Growers should be advised to plant only scab-resistant hybrids for Michigan production.

The hybrid variety situation continues to change each year as new and better varieties appear. The possibility of triple cross hybrids using monoecious and/or androecious pollen parents seems likely. Triple crosses increase seed yields for seedsmen and increase fruit yields for growers based on a stronger female expression. This changing variety situation will likely persist for 10 years or more. Accordingly, growers and processors should stay informed about varieties for production needs.

Finally, gynoecious parthenocarpic hybrids are still some time away from commercial use. The development of parthenocarpic hermaphroditic lines as pollen parents with parthenocarpic gynoecious seed parents will result in hybrids that are homozygous for parthenocarpy. Such hybrids express stronger parthenocarpic fruiting as determined by earliness of fruiting, but at the possible expense of high fruit numbers. Further testing may result in much higher-yielding varieties than with present conventional seeded hybrids, but requiring more days to maturity.

REDUCTION OF DIRT IN MECHANICALLY HARVESTED CUCUMBERS[6]

Objective: to reduce the amount of dirt in loads of mechanically harvested pickling cucumbers.

The problem of dirt and mud in cucumber loads is not a new one. Logical possibilities in the handling system to consider dirt removal are: 1) At the processing plant when it is unloaded (generally into water), 2) in the cucumber field, with a cleaner such as a rotary washer, 3) on the harvester, such as with a water tank, and 4) at the point of cutting the vine and its pickup on the front of the harvester. In 1973, problem areas were defined to plan research for 1974.

The 1973 research was concerned with the cutting and pickup of cucumber vines. The following approaches were tried under field conditions with moderate to no success. The first was to relocate a reciprocating cutter bar under the pickup in an attempt to cut the vines as they were picked up. Results were affected by many factors, such as cutter bar angle, clearance above and below the bar, forward speed and height stability.

The second was to use a 12-in. diameter rotary disc, which satisfactorily cut the vines in the row.

The third was to use the pickup principle in the USDA apple pickup machine. This unit used a drum with rubber fingers, which resulted in a stripping-lifting action. Cucumbers were successfully removed, but vine clogging of the machine was a problem.

Fourth was to attempt above-the-ground cutting with a high-pressure water jet. A pressure of 6,000 psi and a water flow of about 2 gpm were adequate to cut cucumber and weed stems up to 1 in. in diameter under simulated field conditions.

The 1974 research concentrated on the design and testing of an experimental one-row, trailer-model cucumber harvester to test different vine cutting and lifting concepts. Both a reciprocating sickle and high-pressure water jet which cut vines at or just above the ground surface were tested. Both were generally successful, but were not found feasible because the crown-set fruit (fruit set on or near the stem instead of out on laterals) are too close to the root to be lifted high enough to avoid being cut.

A completely different approach was tried by using a potato lifter and harvester. This approach, though very briefly tested, was promising. Recovery would be increased considerably because large cucumbers that are now lost at the pickup would be saved. Dirt would be shaken off through an open rod potato chain.

Another possibility under extremely wet field conditions is to go through the field with a puller or lifter prior to harvest. This would hasten soil drying and stop further development of fruit — generally preventing the field from being lost because of oversized cucumbers.

Summary

Four different approaches to harvester modification were tried under field conditions. While some success was obtained, none was found feasible. Direct or indirect principles used in potato harvesting look promising and will be investigated further.

INFLUENCE OF HANDLING ON CUCUMBER QUALITY (1973)[7]

Objectives: 1) to identify the handling steps between harvesting and processing of cucumbers that reduce quality, 2) to obtain specific information on the types of damage that occur during cucumber handling, and 3) to conduct laboratory experiments to explain the influence of handling on cucumber quality.

The field experiments involved collection of cucumber samples (150 fruit) at 7 to 10 stations between harvesting and the brine storage tank at the processing plant. Four different processing plants were included in the investigation. Samples were rated for visible damage, carpel strength and bloater frequency after laboratory brining.

Determination of visible damage provided an indication of both minor damage (abrasions) and major damage (broken or punctured). There was a general increase in damage as cucumbers moved from harvesting to brining tanks (10 to 75% damaged) (Fig. 6). When considering results from all four plant locations, the most significant increases in visible damage were produced at the sampling stations following harvesting, size grading and transportating into the brine tank. For this study, influence of handling on green stock carpel strength was not consistent with some indications that values increased with increased handling.

[6]Investigators: D. E. Marshall and J. H. Levin. Cooperators: D. R. Heldman, B. F. Cargill and L. R. Baker.

[7]Investigators: D. R. Heldman, L. J. Segerlind, L. R. Borton and D. E. Marshall.

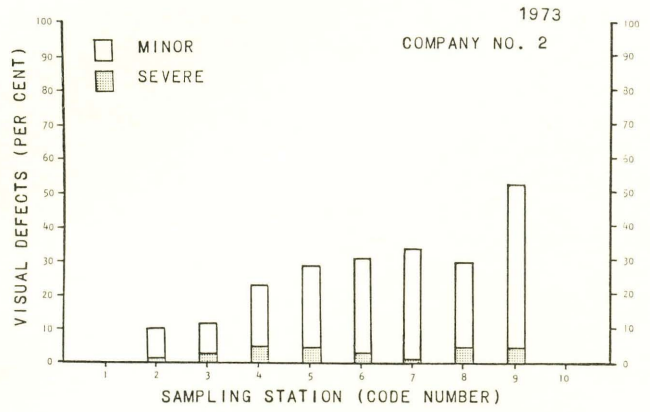

Fig. 6. Influence of handling between harvesting and brining on visible damage of cucumbers.

Handling increased bloater frequency (Fig. 7). For the situation illustrated, the first sample (No. 4) was obtained as green stock cucumbers arrived at the plant. Frequency of both balloon bloaters and total bloaters increased as the amount of handling increased. Results from all four processing plant locations indicated that size grading was the most consistent factor contributing to bloating.

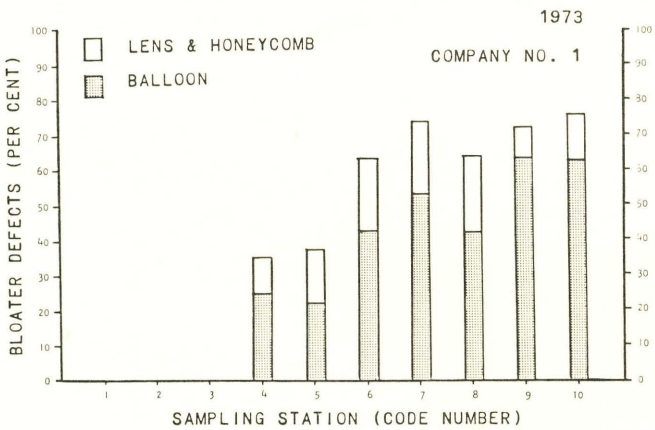

Fig. 7. Influence of handling between harvesting and brining on brine stock pickle quality.

Laboratory scale experiments involved drop tests and tumbling experiments. Single drops of green stock cucumbers of distances up to 2.5 ft did not influence bloater frequency. Greater distances caused increased internal fractures in the brine stock. Tumbling tests indicated that frequency of bloating was directly related to magnitude of handling (number of revolutions). The influence of frequency of small-magnitude drops was as follows:

No. of 1-ft drops (one 1-ft drop/rev)	% Balloon bloaters
0	21
25	39
50	56
75	84
100	88

Frequency of balloon bloaters increased with increasing numbers of 1-ft drops. Increased bloating resulting from handling may be due to large numbers of small-magnitude drops, which may relate to the size-grading operation.

Summary

Handling of green stock cucumbers between mechanical harvesting and brine tank storage usually results in various types of quality reductions. The harvesting, size grading and transporting steps seem to contribute most to visible damage. The frequency of bloaters is increased most consistently by the size-grading step. Laboratory scale experiments indicate that single drops of up to 2.5 ft do not cause detectable damage; high numbers (25 to 100) of 1-ft drops increase the frequency of balloon bloaters.

EFFECT OF HANDLING ON BRINE STOCK QUALITY (1974)[8]

Objectives: 1) to verify the 1973 results pertaining to increased bloating in cucumbers size-graded by vibratory systems, and 2) to identify the loading characteristic (vibration and impact) responsible for increased bloater formation.

The study consisted of both field and laboratory scale experiments. The field-scale experiments were carried out at Aunt Jane's processing plant in Croswell, Michigan, and involved sampling of green stock from: 1) a simplicity grader using a vibratory sizing principle, and 2) a Kerian grader representing a nonvibratory-type grader; in-plant handling was excluded (H in Fig. 8). Another set of samples was collected to evaluate the influence of superimposed impact loading encountered in the conventional handling-grading process on brine stock. They included green stock subjected both to the grading operation and preceding in-plant handling steps.

[8]Investigators: L. R. Segerlind and Y. Sarig. Cooperators: D. E. Marshall and J. H. Levin.

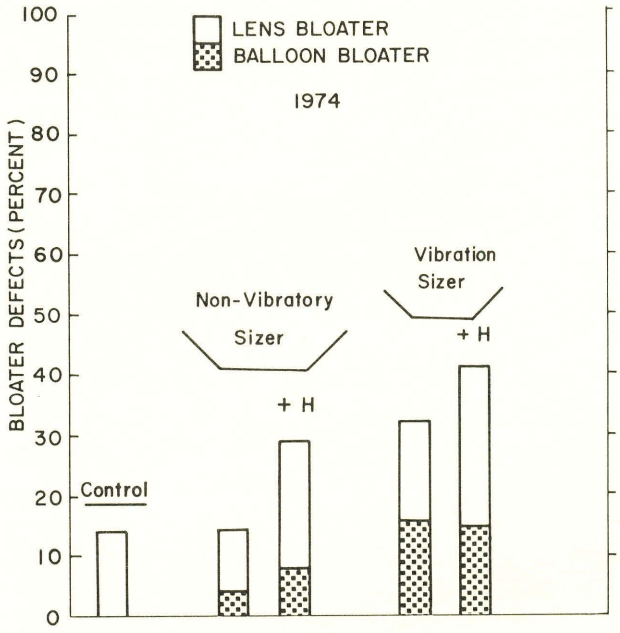

Fig. 8. Vibratory versus nonvibratory sizers as a function of bloater frequency in pickling cucumbers (in-plant study).

The laboratory experiments were conducted on an MTS vibration testing machine simulating actual conditions that prevail at the processing plant. To be comparable with field experiments, the loading simulation was tested as: 1) vibration and 2) vibration coupled with preceding impact loading tests.

Cucumber samples were obtained during normal plant operation and were mechanically harvested and handled prior to testing. The cucumber fruits were sized to what is commonly known as 3Bs and were density-sorted. The more dense were used in the tests. Twenty-five fruits were tested for carpel strength, and another 25 from the same sample were placed in a 10-gal plastic tank for laboratory brining. After appropriate fermentation and curing, the brine stock were evaluated to determine bloater formation. Defects were classified as lens or balloon type bloaters.

Results of the brine stock evaluation show a definite trend toward increased bloater formation with the increase in number of handling steps. The in-plant studies suggested that the high-frequency, low-amplitude loading (as manifested in the vibratory-type sizer) was the major cause of increased bloater formation. The damage is even more pronounced when vibration is coupled with preceding impact loading (Fig. 8). The effect of vibration was not evident in the laboratory studies, probably due to an insufficient duration of vibration. However, the impact effect was significant, resulting not only in a higher percentage of bloaters but also internal fractures of many cucumbers (Fig. 9).

Based on these results, and final studies in the next year, guidelines on the permissible energy impacts experienced in the handling and processing operations should be established.

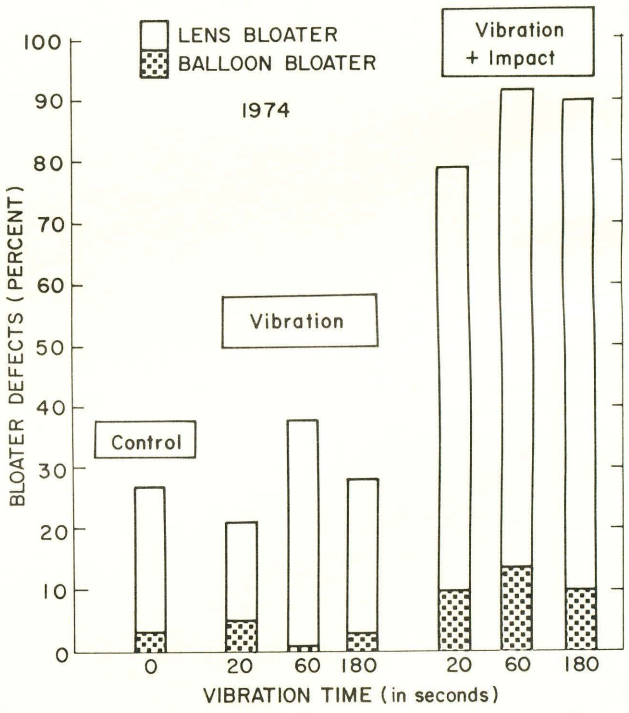

Fig. 9. Bloater frequency of pickling cucumber brine stock as a function of loading pattern (laboratory simulation studies).

DENSITY SORTING OF GREEN STOCK PICKLING CUCUMBERS TO REDUCE BLOATING[9]

Objectives: 1) to determine if green stock density is related to bloater formation in brine stock, and 2) to test the density-sorting principle under commercial conditions.

In 1973, the effect of density-sorting of pickling cucumbers on bloating was evaluated under commercial conditions for the second year. Size-graded No. 3 cucumbers were sorted by density into two groups — sinkers (most dense) and floaters (least

[9]Investigators: D. E. Marshall and J. H. Levin. Cooperators: D. R. Heldman and L. R. Baker.

dense), using a solution of approximately 25% ethanol in water (by volume). Two 300-bu tanks (replicates) were filled with green stock and brined according to commercial methods.

Bloater formation was evaluated about 100 days later. Frequency of bloating was similar to that in 1972: 1) As green stock density decreased, balloon bloating increased 2) lens bloating was unrelated to green stock density, and 3) when divided by density into 20% sinkers and 80% floaters, the sinkers had less balloon bloating than the floaters (Fig. 10).

Fig. 10. Reduction of balloon bloating by dividing into more dense (20% sinkers) and less dense (80% floaters) fruit — the latter to be fresh packed and the former to be brined. Samples from 300-bu tanks.

Variations in cucumber density are probably influenced by variety, cultural practices, growing locations and environmental conditions. Although more dense fruits are less likely to bloat, present methods of density-sorting are impractical on a commercial basis.

During 1974, specific gravity measurements were taken on 65 variety lots (55 different varieties) of cucumbers. Sample means had a range of .0240 (high .9822, low .9582). Statistical analysis showed that any variety mean that was different from another variety mean by .0087 or more was significantly different ($p<.01$).

Samples were brined in 5-gal plastic laboratory tanks. Bloater formation was so low generally that no relationship could be established between sample means and bloating for the varieties. However, density-sorting appears useful as a selection criterion for improving the brining of cucumber varieties.

Density-sorting is also a useful aid in brining research. It has been used to remove one more variable in brining studies such as cucumber handling research.

Summary

Based on two years of commercial testing, the frequency of balloon bloating in brine stock of pickling cucumbers was reduced by brining only the more dense fruits. No consistent relationship was found between lens bloaters and cucumber density. Density-sorting has been used to evaluate and compare experimental hybrids with conventional commercial varieties. Although the frequency of balloon bloating was reduced by this technique, present methods are not suited for commercial use, but are useful in research.

RECYCLED BRINES FOR CUCUMBER FERMENTATIONS[10]

Objectives: 1) to analyze the effects of alkali treatment on tankyard spent brines and 2) to evaluate the use of recycled brines in cucumber fermentations.

Analysis of Spent Brine

Geisman and Henne (1973a, b) reported a technique for clarifying spent brines by raising the brine pH to pH 10-11 with NaOH, removal of pre-

[10]Investigators: R. F. McFeeters and M. P. Palnitkar.

cipitate and neutralization of the treated brine with HCl. In 1973, spent brine samples were taken from six tanks in a commercial tankyard and treated according to Geisman's procedure. Organic matter, COD, protein, Kjeldahl nitrogen and mineral content were determined for each brine before and after treatment with NaOH. In addition, the precipitates were collected, dried and analyzed. Results are shown in Tables 13 and 14.

Table 13. Effect of base treatment of spent brines on brine composition [a]

	Precipitate (g)	Total organic matter (g)	Kjeldahl Nitrogen (mg)	Biuret Protein (mg)	COD ppm
Untreated spent brine	—	2.11	62.7	52.2	12600
Treated brine	—	2.03	56.2	41.7	12150
Precipitate from base treatment	0.19	.08	2.7	—	—
% Removed by base treatment	—	3.8	10.4	20.1	3.6

[a] All results are the mean of six samples; data are expressed as the amount per 100 ml spent brine.

Table 14. Mineral analysis of spent brine [a]

	Ca(%)	P(%)	Mg(%)	Fe ppm	Cu ppm	B ppm	Zn ppm	Al ppm
Untreated spent brine	.092	.017	.016	10.6	1.2	1.5	3.3	4.6
Treated brine	.051	.002	.00	1.5	1.3	1.3	2.4	13.8
Precipitate from base treatment	21.1	- 7.9	7.5	- 4900	98	65	568	1587
% Removed by base treatment	45	88	100	86	0	13	27	—

[a] Data expressed on the basis of liquid volume for the brine. The precipitate results are expressed on the basis of dry weight of precipitate.

The conclusions reached from this analysis are:

1. Very little organic matter is removed by base treatment.
2. It follows that BOD and COD are not significantly lowered. Therefore, this is *not* a suitable treatment for removal of organic material.
3. Only small amounts of protein and nitrogen are removed.
4. Mainly inorganic matter is found in the precipitate after base treatment. Significant amounts of calcium, magnesium, phosphorus and iron are removed from spent brine.
5. Since 2% of the spent brine is organic matter and only about 0.4% lactic acid is present, about 80% of the organic matter in spent brine consists of unidentified compounds.

Fermentation of Cucumbers in Spent Brine

Size 3B cucumbers were fermented in base treated, heat treated and untreated spent brine and control (fresh) brine. The salt concentration was maintained at 25° salometer during fermentation. The initial pH of the spent brine tanks was 4.0. Acid production in heated spent brine and fresh brine is shown in Fig. 11. Acid production in the other spent brine treatments was similar to that for the heated spent brine. Results indicate that:

1. The brine resulting from the fermentation of cucumbers in spent brine was higher in pH and titratable acidity due to the presence of buffering substances.
2. Slightly faster fermentation was evident with the spent brine.
3. There were no discernable differences in color, odor and texture between pickles fermented in spent brine and those fermented in fresh brine.

Repetitive Recycling

In one experiment, spent brine obtained from a commercial tankyard in which 1972 cucumbers

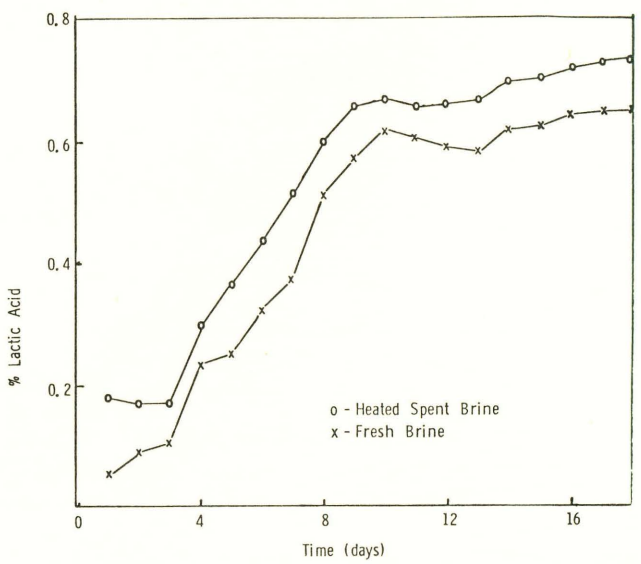

Fig. 11. Lactic acid production during fermentation of 3B cucumbers in heat treated spent brine and fresh brine.

were fermented was used as a starting point. During the 1973 season, cucumbers were fermented in the same batch of spent brine through four cycles. Each time the spent brine was treated with base and neutralized with acid according to Geisman's procedure. With each cycle, a control batch of cucumbers was fermented in a fresh brine. The spent brine resulting after the fourth laboratory fermentation represented its fifth recycling.

Results of the repetitive recycling indicated no significant difference in color, odor and texture of the fermented pickles after successive recycling in the spent brine, as compared to pickles fermented in a fresh brine. The titratable acidity, pH, BOD and COD values for the recycled brine increased with each cycle. This indicates that some buildup of organic matter can be expected when recycling brine. However, it may be feasible to utilize brine several times before it would be necessary to discard it. The maximum allowable number of brine cycles was not determined.

Bloater Reduction

Significant reductions in bloater numbers were observed between pickles fermented in spent brine compared to fresh brine. This was noted in an experiment with late season 3B cucumbers (Table 15).

Table 15. Fermentation of whole cucumbers in spent brine

	Fresh Brine Control	NaOH Treated Spent Brine	Heated Spent Brine
	Number of cucumbers from a 5-gal pail		
1. No defects	10	14	21
2. Advanced bloaters	18	9	2
3. Moderate bloaters	6	9	6
4. Slight bloaters	4	7	3
5. Advanced honeycombs	10	6	6
6. Moderate honeycombs	4	7	5
7. Slight honeycombs	8	9	16
No defects (% of 1)	16.7%	23%	35.6%
Some defects (% of 4, 6 & 7)	26.7%	38%	40.7%
Relish (% of 2, 3 & 5)	56.7%	39%	23.7%

Note the increase in good pickles obtained from spent brine and the large decrease in advanced bloaters. The results are summarized at the bottom of the table. It shows 57% relish stock with fresh brine compared to 24% with heated spent brine. The percentage of pickles free from defects is more than doubled. In this experiment, heat treated brine gave greater bloater reductions than base treated brine. The data are too limited to know whether this difference is significant.

When combined bloater data for the pickles fermented through four cycles in spent brine were compared with bloater data from the combined controls, the following results were obtained:

	Control	Recycled brine
No defects	67%	72%
Some defects	16%	23%
Relish	17%	6%

The reason for bloater reduction is not known. It is hoped that experiments during the 1974 season will lead to some understanding and control of bloaters.

Inactivation of Pectinase in Heated Brines

The cucumber fermentation experiments indicate that heat treatment of spent brines may be an alternative to base treatment. The major purpose for heating the brine is to be sure that pectinase, if present, is inactivated. To determine a reasonable heat treatment to assure enzyme destruction, commercially available pectinase from *Aspergillus niger* was heated in simulated brine. The simulated brine contained 0.6% lactic acid, pH 3.6, 0.1% calcium ion added as $CaCl_2$ and 50° salometer NaCl. The initial pectinase concentration was 2.00 mg/ml. Pectinase was inactivated at 176°F, 187°F and 199.4°F.

Incomplete inactivation of pectinase in 105 sec was observed at 176°F. The inactivation did not show first-order kinetics. At this time it is not possible to recommend a heating time at 176°F to assure enzyme inactivation. However, inactivation at 187°F and 199.4°F followed first-order kinetics. The time required to inactivate 90% of the initial activity (D value) was calculated at each temperature. The D values are 23.2 sec at 187°F and 11.6 sec at 199.4°F. To assure that 99.9% of the initial activity is destroyed, it will be necessary to heat brine for 69.6 sec at 187°F and 33.8 sec at 199.4°F.

The initial pectinase activity in these experiments was much higher than that occurring in brine tanks. However, in a first-order reaction, the initial enzyme concentration does not affect the percentage of enzyme destroyed. For example, with 2.0 mg/ml pectinase, heating at 199.4°F for 33.8 sec will inactivate all but .002 mg/ml of this enzyme. On the

other hand, if the initial active concentration was only 0.002mg/ml, the final concentration would be 0.000002 mg/ml.

If heat treatment of brine proves to be a useful procedure, more extensive information on heat inactivation of pectinase in salt brine will be required.

Summary

Results of experiments during the 1973 season indicate that either alkali or heat treated spent brine will give normal fermentations. Further experiments on the heat treatment technique will be required during the 1974 season to develop detailed recommendations for the procedure. The relative merits of the two procedures in terms of personnel safety, cost and simplicity of operation will need to be evaluated by each company.

The multiple recycling experiment indicates that brine can be recycled at least five times without loss of pickle quality. However, a reasonable degree of caution is advised. Studies on heavy metal (lead, cadmium, mercury) and possible pesticide accumulation in recycled brine should be evaluated during the initial years of recycling to be sure these materials do not accumulate to unacceptable levels in the brine.

The observation of significant bloater reductions in cucumbers fermented in recycled brines was an unexpected result of this investigation. This observation requires confirmation during the coming season. In addition, it would be very useful to determine the reason for this effect.

BRINE RECYCLING AND MANAGEMENT IN THE PICKLING INDUSTRY[11]

Objective: to develop inexpensive brine recycling and control methods adaptable to current industry operations. Approximately 300,000 tons of cucumbers are fermented annually during the harvest season and stored in a salt (NaCl) brine. Over the winter months, the salt stock cucumbers are desalted and processed into retail pickle products. The tankyard brine and desalting brine are discarded into streams and municipal waste treatment facilities. Management of brine disposal to meet EPA effluent guidelines is currently a crucial issue for processors.

Specific objectives of this project are: 1) to evaluate use of spent brines in cucumber fermentations, and 2) to evaluate the use of salt-free or low-salt solutions for cucumber storage.

In 1974, a repetitive cycling experiment through four cycles using 100% spent brine showed no observable differences in color, flavor, odor or firmness of pickles fermented in heat treated recycled brines compared to fresh brine. Therefore, dilution of spent brine may not be required for recycling.

Use of a 50° salometer cover makes it possible to use 100% recycled brine in fermentations. It is necessary to raise the pH of heated spent brine to 5.0 prior to reuse. If this pH adjustment is not made, excessive bloating will occur.

Organic matter determinations on recycled brines carried through four cycles do not show large increases in organic material in the brine. Theoretical considerations suggest that organic matter would not accumulate higher than the organic matter content of cucumbers. There will be migration of brine components into the cucumbers, as well as cucumber components into brine until equilibrium is reached.

Results of the 1974 experiments show that heat treated spent brine can be used for cucumber fermentations without loss in salt stock quality. Research during the past two seasons, including limited commercial trials, has shown that cucumber fruits can be fermented successfully in recycled brine.

In preliminary experiments conducted during 1973 and 1974, Lactobacilli grew in salt-free storage solutions containing low concentrations of acetic acid; thus the fruit had a fermented appearance. Some softening was noted in large overmature fruits, but the incidence of severe bloating was less than that in the brined controls.

In additional experiments, the addition of low salt concentrations (2-4%) enhanced the keeping quality of fruit in storage solutions containing 3-4% acetic acid.

Summary

The use of salt-free solutions for short-term storage appears feasible, especially if the fruit is processed during the first part of the storage season (September-December). Storage for only 2 months could result in a 20-25% reduction in salt disposal during the year.

Results of 1974 brine recycling experiments show that repetitive cycling with 100% treated spent brine gives salt stock that is normal with respect to

[11]Investigators: R. F. McFeeters and K. E. Stevenson.

flavor, color and texture. Both theoretical considerations and experimental results suggest that organic matter in spent brine will not accumulate higher than the organic matter content of cucumbers.

LABORATORY FERMENTATION OF CUCUMBER SLICES[12]

Objective: to evaluate parameters which affect product quality in slice fermentations.

Good quality pickle slices can be produced by slicing cucumbers prior to fermentation. This procedure completely eliminates the problem of bloating. Generally, over 90% good slices were obtained in laboratory fermentations.

Experiments on slice thickness show that slices down to ⅛ in. hold up well during fermentation. Yield of slices on a weight basis is lower than the yield of whole cucumbers. A 70-80% yield is usually obtained with slices compared to slightly over 90% yield on whole cucumbers. However, about 5-7% water uptake will occur when slices are desalted. In addition, there will be no slice loss from bloating.

Softening of slices will consistently occur if the NaCl concentration is allowed to fall below 5.5% at any time during the course of fermentation. Since slices take up salt much faster than whole cucumbers, care must be taken to ensure that the salt level is not allowed to drop at the beginning of fermentation.

Slices at the bottom of a 10-gal tank do not show a cured appearance as rapidly as slices on the top. However, the reducing sugar level is about the same as for cured slices. Therefore, this should not be a hindrance to processing as long as the gas which is the cause of the uncured appearance is removed prior to product shipment.

Summary

On the basis of laboratory scale experiments, slice fermentation appears to be a reasonable method to eliminate bloater problems without having to purge or do pure culture fermentations. There is now a need to transfer this process to a larger scale to develop salting and handling procedures for slices.

[12]Investigator: R. F. McFeeters.

FERMENTATION OF CUCUMBER SLICES[13]

Objective: to do preliminary feasibility studies on the fermentation of cucumber slices.

It has been known for many years that piercing or pricking cucumbers will solve the bloating problem since CO_2 cannot build up in a punctured fruit. About 20-25 years ago, Etchells and coworkers attempted to ferment pricked fruit in commercial tanks. The attempt was unsuccessful, largely because softening occurred in some experimental tanks. In addition, no commercially suitable machine for pricking the fruit was available.

Since bloating remains a serious problem and the advent of brine recycling means that procedures will be available in tankyards to destroy softening enzymes if they develop, a reinvestigation of the situation was undertaken. Fermentation of cucumber slices rather than pricked cucumbers was tried. Slicing converts the product to a usable form and eliminates the need for a pricking machine. It was anticipated that slice fermentation would be a more severe test of potential softening problems, since the tissue is more severely disrupted and the seed cavity more exposed to enzymatic softening than would occur by pricking.

Fermentations were done in 5-gal pails with commercially harvested, hand-sliced 3B cucumbers. Brine was added to give a 60:40 pack-out ratio. After 3-4 weeks, the fermented slices were removed from the brine and evaluated. Samples were stored in a dilute vinegar-salt brine without processing.

Slices did not soften during fermentation. Firm, good quality slices with characteristic color, flavor and odor were obtained after a 3-week fermentation. Slices stored in a fresh dilute vinegar-salt brine without processing showed no softening after 5 to 6 months. One pail was fermented with a 75:25 cucumber:brine ratio. These slices were equivalent in quality to those fermented using a 60:40 ratio.

Untreated brine was also used as the cover brine for cucumber slices. Again, no softening was observed either at the end of fermentation or after 5 months' storage of the unprocessed slices in a dilute vinegar-salt brine.

When over 80% of whole cucumbers fermented in fresh brine showed some bloating or honeycomb defects, only 5-6% of the slices from the same batch of fruit were judged unacceptable. Most defects present were holes from carpel separation which were already present in the green stock.

[13]Investigators: R. F. McFeeters and M. P. Palnitkar.

The yield of product from slices is 17-18 lb from 22 lb fresh fruit. This can be compared to a 20-lb yield from whole fruit. This is undoubtedly a result of greater water loss from slices during fermentation.

To evaluate the effect of pectinase on softening, fungal enzyme from Nutritional Biochemicals, Inc., was intentionally added at levels of 0.02g, 0.2g and 2.0g/pail. A concentration of 0.2g pectinase/pail reduces the viscosity of a 1% pectin solution by 50% in 15 min. Pectinase was intentionally added to pails containing whole cucumbers and slices.

No effect was observed with 0.02g/pail pectinase. The slices fermented in 0.2g/pail pectinase showed significant softening and seed sloughing. The high pectinase slices (2.0g/pail) showed extensive sloughing and softening. The slices were clearly unacceptable. No significant softening of the whole cucumbers was observed even at the highest pectinase level. The conclusion is that slices are more susceptible to pectinase softening than whole cucumbers. However, slices can be exposed to low enzyme levels without significant deterioration.

Summary

These results show that softening is *not* the inevitable result when slices are fermented. In fact, our limited results suggest that softening normally will not occur when commercial cucumbers are fermented.

These data suggest the possibility that a commercial procedure could be developed for fermentation of slices. Since slices are more susceptible to softening than the whole fruit, adequate tests would need to be developed for rapid detection of pectinase in the brine. In addition, a procedure to treat brines which develop excessive enzyme activity would be required.

Analysis of potential problems and the development of workable solutions will require a great deal of effort. However, the advantages of the procedure will include: 1) elimination of bloating, 2) easier handling during filling and emptying tanks, 3) rapid salt equilibration which will allow addition of all necessary salt before closing the tank, and 4) rapid desalting and a decrease in the volume of desalting brine generated. In view of these important advantages, a serious effort to develop a workable slice fermentation procedure appears to be warranted.

RESEARCH ON THE PURGING OF CUCUMBER FERMENTATIONS (1974)[14]

Objectives: 1) to test the efficiencies of different purging systems in the removal of CO_2 from fermenting brines, and 2) to determine whether it is possible to maintain low CO_2 levels in fermenting brines, and, if so, what effect it has on the percentage of bloaters.

The treatments used and their influence on bloater formation are given in Table 16. All experiments were conducted at the Heifetz Pickling Co., Eaton Rapids, Michigan. The tanks were 8 by 14 ft in size. Because of the unavailability of size 3B cucumbers, size 3A was used in all but three tanks. The purging system referred to as "sidearm" consisted of a 4-in. PVC pipe connected to the side of the tanks at the bottom and running up to and over the top to the opposite side. A ceramic gas dispersion tube was inserted inside the pipe at the bottom and the gas flow through the pipe resulted in brine circulation.

The gas flow rate was 20 to 30 ft^3/min, which was operated on a continuous basis for 14 days. The overhead purging system consisted of two plastic olive casks placed on top of the tanks. The brine was circulated through the casks by a pump and was purged in the casks on a continuous basis. A small ceramic gas dispersion tube was used on the bottom of each olive cask. The gas flow rate was 20 to 30 ft^3/hr, and the brine flow rate was about 10 gal/min.

The purging from the bottom was through polyethylene tubing. They were purged continuously for 14 days with 200 to 300 ft^3/hr nitrogen. Brine in one of the two tanks was recirculated continuously.

Carbon dioxide levels were measured twice each day for 14 days. Also, measurements were made of the temperature, salometer, pH, acidity and residual reducing sugars.

All types of purging had very pronounced effects on CO_2 levels in the brine; they were consistently below 80 mg/100 ml. However, none of the purging methods was successful in maintaining CO_2 levels as low as one would like except for the tank with the sidearm to which potassium sorbate was added after 5 days' fermentation. The CO_2 levels in this tank were usually below 20 mg/100 ml. These results indicate that it is very difficult to maintain low CO_2 levels when a yeast fermentation occurs. The potassium sorbate would prevent this.

[14]Investigators: Ralph N. Costilow, C. L. Bedford and David Black.

Table 16. Percentages of various defects in salt stock from control and purged fermentations in 1974

Tank No.	Date brined	Size cucumbers	Treatment	% with defects [a] Lens	Honey-combs	Carpel separation	Moderate bloat	Balloons	% Defective
215	8/25	3A	None	13	12	8	6	9	48 (26)[b]
217	8/28	3A	"Overhead," purged in barrels	12	3	0	0	0	15 (14)
219	8/24	3A	"Sidearm," air 3 days → N_2	19	2	5	2	2	30 (15)
220	8/29	3A	None	19	7	3	4	5	38 (54)
221	8/30	3A	None	26	2	13	10	16	67 (30)
216	9/08	3A	"Sidearm," + 0.033% sorbate 5 ½ days	2	2	0	0	0	4 (9)
218	8/29	3A	"Sidearm"	12	4	2	0	2	20 (19)
225	9/09	3B	None	24	7	9	18	28	86 (69)
223	8/28	3B	Bottom purging	17	24	16	16	14	87 (62)
224	8/26	3B	Bottom purging + circulation	18	10	12	10	3	53 (33)

[a] Based on random sample of 100 pickles from each tank.
[b] Numbers in parentheses are the results of the analysis of 50-lb samples by the staff of the Heifetz Pickling Co., Eaton Rapids, Michigan. These values represent percent bloaters.

As indicated in Table 16, we purged one tank with air for 3 days. At that time, this tank had 3 to 5 ft of foam on the surface and a high yeast population. Since we had softened a small lot of cucumbers in the laboratory by purging with air, we decided to change from air to nitrogen. Therefore, we think it is potentially very dangerous to use air for purging salt-stock fermentations.

The most efficient and practical purging system was the sidearm. While the bottom purged tanks had comparable CO_2 levels in the brine, enormous amounts of nitrogen were used in them. The sidearm system is more practical than the overhead because no pump is needed.

The effects of purging on bloater counts are evident in Table 16. The brine stock in the tank purged with the sidearm to which potassium sorbate was added was particularly good. Also, as noted above, CO_2 levels in this tank were consistently low. The two other tanks purged with sidearms and the one overhead purged tank also showed marked improvement in the salt-stock quality as compared to the controls. In contrast, one of the bottom purged tanks was no better than the control, and the other one reflected only about a 50% improvement.

Summary

While the data acquired this year were not conclusive with respect to the average reduction in bloaters from natural fermentations as a result of purging, they do point up that some system similar to the sidearm may be most efficient. It is hoped and expected that the sidearm system can be made more efficient and practical by further experiments in 1975. Such a system would be of value in removing CO_2 from either natural or controlled (inoculated) fermentations.

RESPIRATION OF CUCUMBER FRUIT[15]

Objective: to determine respiration rates of cucumbers of several varieties and breeding lines.

Since high CO_2 levels in the brine are an important part of the bloating problem, it was decided to determine the CO_2 production (respiration) for

[15]Investigator: R. C. Herner. Cooperators: L. R. Baker and C. L. Bedford.

larger-sized pickles (3As, 3Bs). Lines and varieties were selected to give a cross section of black and white spine types and susceptibility to bloating (Table 17).

Table 17. Lines and varieties

Pedigree	Spine color	Percent Bloat (1974)	Respiration rates (Mg CO_2/kg/hr) 1 day after harvest (Size 3B)
MSU 381M	black	44	44.75
MSU 394	white, black	—	44.80
MSU 394	black, white	—	46.65
SC 601H	white	4	43.40
MSU 921	black, white	—	32.40
Score	white	0	36.15
Premier	white	4	42.80
Green Spear	white	4	40.75
Pioneer	black	36	46.65

Summary

No significant differences in respiration rates between lines or varieties were detected. There were no differences between black or white spine types nor were there any large differences between 3As and 3Bs. Over a 5-day period from harvesting, respiration rates decreased about 40%. Mechanical harvesting increased respiration rates by 25 to 50%, which persisted over a 5-day period.

COST REDUCTION IN PICKLE PACKAGING[16]

Objectives: 1) to lower packaging costs to the pickle industry by improving current packaging techniques, 2) to investigate the possible use of plastic to replace the glass jars, and 3) to explore the development of individual packages for vending machines and fast-food extablishments.

Shipping containers must survive a long warehousing period and the distribution to retail stores. Five types of shipping containers for quart jars of pickles were studied and costs of materials determined (Table 18). Costs ranged from $205 per thousand containers to $101.40 per thousand.

[16]Investigator: Wayne Clifford.

Table 18. Cost of various shipping container alternatives for pickles (based on 1974 costs)

Cost	Cost/1000	Total
Top loaded RSC[a] for partitions L = 16; W= 11 15/16; D = 6 5/8; 7.528 sq. ft.	$159.41	
Partitions for above	$ 46.10	
Total cost, current standard shipping container		$205.51
End loaded RSC for partitions L = 11 15/16; W = 6 5/8; D = 16; 6.095 sq. ft.	$129.06	
Total cost with partitions		$175.16
Top loaded RSC for glass-to-glass L = 15; W = 11 1/4; D = 6 11/16; 6.848 sq. ft.		
Total cost		$145.01
End loaded RSC for glass-to-glass L = 11 1/4; W = 6 11/16; D = 15; 5.656 sq. ft.		
Total cost		$119.76
Tray for glass-to-glass L = 15; W = 11 1/4; D = 3; 2.616 sq. ft.	$ 55.40	
Overwrap film L = 41.25; W = 21.45 6.145 sq. ft.	$ 46.00	
Total shrink-wrapped tray		$101.40

[a] Regular slotted container.

Summary

A cost study of five types of containers showed that costs of materials could be reduced by over $100 per 100 units.

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