BAG-IN-BOX TECHNOLOGY:
Sensory Quality of Pickles Produced From Process-Ready, Fermented Cucumbers

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ABSTRACT

Currently, most fermented cucumbers contain high levels of salt that must be washed out post-fermentation, creating a large volume of waste. Process-ready (PR) cucumber fermentations are carried out at a sufficiently low salt level, so no salt removal is required prior to making the finished products. This results in much less waste, as well as retention of lactic acid and other fermentation products in the PR fermented cucumbers. Our objectives were to evaluate the flavor impact of the additional lactic acid in PR fermented products, and to prepare and evaluate fresh-pack products using filtered fermentation brine (FFB) as an acidifying agent. Descriptive sensory analysis and measurements of consumer acceptability ("liking") were used to evaluate several pickle products prepared from PR fermented cucumbers and brine for individual flavor characteristics, as well as overall quality and acceptability. PR fermented cucumbers were successfully used for sweet and dill pickle products without salt and acid removal. All products tested were of high quality in both flavor and texture. Additionally, sourness equal to commercial products was achieved with substantially less vinegar. PR pickle products, which were balanced in acidity, and commercial products were liked equally. Furthermore, fresh-pack dills prepared with FFB (25% of total jar volume) as an acidulent were liked as well as those acidified with vinegar alone, indicating potential for use of all the products of the PR cucumber fermentation.

INTRODUCTION

Sensory quality of pickle products derived from the process-ready (PR) system using bag-in-box (BIB) technology for cucumber fermentation (Fleming et. al., 2002) is essential for the success of this low-waste technology. Currently, most fermented cucumbers contain high levels of salt that must be washed out post-fermentation, creating a large volume of waste. Before 1940, all commercially prepared pickles in the U.S. were preserved by fermentation (at high salt levels) and contained lactic acid. The cucumbers were desalted, but some lactic acid remained, depending upon the extent of leaching needed to reduce the salt to an acceptable level in the product. Vinegar (acetic acid) was added to many finished products from de-salted brine-stock and has been the primary acidulent for pasteurized "fresh-pack" (beginning in the 1940's) and refrigerated (beginning in the 1960's) pickles. PR cucumber fermentations are carried out at a low salt level, so no salt removal is required prior to making the finished products. This results in much less waste, as well as retention of high concentrations of lactic acid and other fermentation products in the fermented cucumbers.

Early pickle flavor research showed that, while acetic acid was generally more favorable for making pickles, small amounts of lactic acid gave a more desirable overall flavor (Fabian and Wadsworth, 1939a, 1939b, 1939c). Lactic acid was not suitable as the sole acidulent in sweet pickles or relish. However, sweet pickles were made successfully with the addition of small amounts of lactic acid, and consumers actually preferred sweet pickles with an acetic:lactic ratio between 4:1 and 9:1 over sweet pickles made with acetic acid alone. Additionally, a combination of lactic and acetic acids gave better-flavored, processed dill pickles than either acid alone (e.g., 1:0.2, 0.8:0.4, and 0.6:0.6 % acetic:lactic, respectively).

More recently, basic studies have been done to evaluate the taste properties of various acids in solution. Astringency of acids was directly related to pH and was not influenced by anion species (type of acid). Sourness of acids, however, was dependent on concentration, pH, and anion species (Sowalsky and Noble, 1998; Kallithraka et al., 1997; Lawless et al., 1996; Corrigan and Lawless, 1995; Rubico and McDaniel, 1992; Hartwig and McDaniel, 1995). At equivalent pH and concentration (wt/vol), acetic acid was perceived as the most sour acid, and lactic acid was found to be the least sour of several organic acids tested (Hartwig and McDaniel, 1995). However, when pH is not controlled, adding lactic acid lowers the pH more than adding the same amount of acetic acid, resulting in a more difficult comparison of the acids.

Taste interactions are also very important in making pickles. It has been known for years that the balance between salt, acid, sugar, and spicing is essential to desirable pickle flavor (Fabian and Wadsworth, 1939a, 1939b, 1939c; Pangborn and Vaughn, 1958). Basic flavor studies have shown that sweetness masks sourness to varying degrees, depending on the concentrations of sweetener and acid (Calvino and Garcia, 1998; Bonnans and Noble, 1993, 1995; Tuorila et al., 1993; King et al., 2000; Schifferstein and Frijters, 1990). Pangborn and Vaughn (1959) showed that adding 2% sucrose to dill pickles reduced undesirable flavors from high acidity and increased desirable flavors by enhancing spice flavors. Fabian and Blum (1943) also observed that even a sub-taste threshold level of sweetener decreased both salt and acid perception. Even aromas can alter the perception of sweetness and sourness (Stevenson et al., 1999; Baldwin et al., 1998).

Given the complex nature of pickle flavor and reported differences in flavor between acetic and lactic acids, research was conducted to evaluate the sensory qualities of products made from our pilot system BIB technology. We wished to determine how the entire contents of the bag could be used to make high quality finished products. Our objectives were to evaluate the flavor impact of the additional lactic acid in fermented products, and to prepare and evaluate fresh-pack products using filtered fermentation brine (FFB) as an acidifying agent.

MATERIALS AND METHODS

Pickle Products

Several types of pickles, including sweet pickle chips, hamburger dill chips, genuine dills (processed dills), fresh-pack dills, and fresh-pack bread and butter chips, were prepared from PR, fermented cucumbers and brine (Table 1). All products were prepared according to standard formulas and pasteurized. Some products were prepared with FFB (Fasina et al., 2002) as an acidulent. The chemical composition of the FFB is given in Table 2.

Table 1. Pickle products made and evaluated from process-ready (PR) cucumber fermentation.

Product type	Treatments			
	Cucumber source	Cover brine	Additional acetic acid	Sweetener
Sweet pickle chips	Fermented	Fresh	0, 33, 50, 67, 100% standard vinegar added	30 or 45% (wt/vol) HFCS[2]
Hamburger dill chips	Fermented	Fresh	None or reduced vinegar to account for increased concentration of lactic acid	None
	Fermented	FFB[1] (17 or 38%)		None
Genuine dills (processed dills)	Fermented	Fresh	None	None
	Fresh	FFB (38%)	None	None
Fresh-pack dills	Fresh	FFB (10, 25 or 38%)	Reduced vinegar to account for increased concentration of lactic acid	1.75% (wt/vol) HFCS
Fresh-pack bread and butter	Fresh	FFB (12%)	Reduced vinegar to account for increased concentration of lactic acid	32% (wt/vol) HFCS

[1]FFB = filtered fermentation brine used in varying amounts according to product type (% = percentage of total jar volume).
[2]HFCS = high fructose corn syrup

Table 2. Composition of filtered fermentation brine (FFB) used for making pickles.

pH	3.52
Salt (%)	1.98
Lactic acid, % (mM)	0.92 (102.5)
Acetic acid, % (mM)	0.38 (64.3)
Calcium (as $CaCl_2$), % (mM)	0.33 (30.0)

Instrumental Analysis

Chemical analyses of the finished products included pH and high pressure liquid chromatography (HPLC) for lactic acid, acetic acid, glucose, and fructose (McFeeters, 1993). Texture was evaluated using a Stable Micro Systems TA-TX2 Texture Analyser (Texture Technologies Corp., Scarsdale, NY), and maximum force (N) was recorded for 15 slices per jar.

Sensory Analysis Test Methods

Descriptive panel for sweet pickle analysis. Twelve volunteers from the Department of Food Science at North Carolina State

Table 3. Descriptive analysis reference sample attributes and established intensities.

Attribute	Definition	Sweet pickle chips (scale 0-14)	Fresh-pack dills chips (scale 0-15)	Hamburger dill (scale 0-15)
Sweetness	Taste stimulated by sucrose and other sugars such as fructose, glucose, etc.	10	1	0
Sourness	Taste stimulated by acids such as citric, malic, lactic, acetic, etc.	7	7	12
Saltiness	Taste stimulated by sodium salts such as NaCl and in part by other salts such as KCl	1	10	12
Spiciness	Combination of flavors elicited by sweet pickle spices in solution	7	NA	NA
Dill	Flavor elicited by dill oil	NA[1]	7	9
Vinegar	Aromatic flavor characteristic of vinegar or acetic acid	NA	3	5
Astringency	Shrinking, puckering, drying, or roughing of the tongue or other tissues of the mouth by substances such as alum or tannins	3	3	6
Bitterness	Taste stimulated by substances such as caffeine, quinine, and hop bitters	0	0	3.5
Overall intensity	The overall impact of the combined attributes of the product, reflecting the complexity of the flavor	NA	8	12
Other/ Off-flavor	This scale was added in order for panelists to account for any different flavors or off-notes that may present themselves in the samples that are not a normal characteristic of pickle products	0	0	3.5 (musty/dirty)
Crunchiness	Sound, feeling, and release of moisture associated with chewing raw vegetables	9	NA	9
Firmness	The amount of effort or force that it takes to bite through the pickle slice	NA	NA	6

[1]NA=not applicable.

University (NCSU) in Raleigh, North Carolina, were trained to evaluate sweet pickle products for several flavor attributes on a 15-point intensity scale: 0 = none to 14 = very strong. Panelists participated in eight 1-hr training sessions prior to evaluating samples. In the first training session, panelists were introduced to fundamental aspects of sensory evaluation, rules for tasting, general project goals, and training goals. The panelists then tasted five samples (sliced PR, fermented cucumbers with no flavorings added; commercial hamburger dill chips; commercial fresh-pack hamburger dill chips; commercial sweet slices; and commercial fresh-pack bread and butter chips), wrote down descriptors for each sample, and held a group discussion of the samples. A preliminary score sheet was developed. In training sessions 2-5, panelists were given solutions for the basic tastes and practiced scaling them according to their intensities. Solutions of lactic acid, acetic acid, lactic and acetic acid mixtures, and vinegar were used as sourness standards. Scaling of intensities, as well as description of each of the different acids (blinded), was done by the panelists. Sour, astringent, and bitter were the most commonly used descriptors for the various acid solutions. Solutions of high fructose corn syrup (HFCS), NaCl, pickle spices, alum, and caffeine were used for identifying and scaling sweetness, saltiness, spiciness, astringency, and bitterness, respectively. Panelists were also introduced to sweet pickle samples prepared especially for training to help anchor the endpoints of the sweetness and sourness scales. A commercial sweet pickle chip was established as the reference sample (Table 3). Training sessions 6-8 gave the panelists additional practice evaluating sweet pickle samples, followed by group discussion. Experimental sweet pickle samples and a commercial control sample were evaluated using a balanced block design in morning and afternoon sessions. Three replications of each treatment were completed over 4 days of testing. Each sample was coded with its own random three-digit number, and samples were presented in a random order for each panelist at each session. A commercial reference sample (Table 3) was provided at each testing session, along with water and unsalted crackers for palate-cleansing between samples. Analysis of variance was used to determine statistically significant differences using SAS statistical software.

Descriptive panel for dill pickle analysis. Eight volunteers from the Department of Food Science (NCSU, Raleigh, NC) were trained to evaluate pickle products for several flavor attributes on a 16-point intensity scale: 0 = none to 15 = very strong. Panelists participated in 15 or more 1-hr training sessions prior to evaluating samples. Training was similar to that of the sweet pickle panel, with more in depth training on each of the basic tastes and additional training with fresh-pack dill standards and hamburger dill chips. Fresh-pack dills with 0 (control), 10, 25, and 38% FFB and a commercial, fresh-pack dill were evaluated by the trained sensory panelists in a complete block design. Each sample was coded with its own random three-digit number, and sampling order was balanced across the panelists at each session. A reference sample (Table 3) was provided at each training and testing session along with water and unsalted crackers for palate-cleansing between samples. Five replications were completed over 2 weeks. Panel means were calculated for each replication and analyzed for statistically significant differences using analysis of variance with SAS statistical software. The same sensory panel and score sheet were also used to evaluate hamburger dill chips after additional training and practice with this type of product. A commercial hamburger dill chip was established as the reference sample (Table 3). A duplicate commercial reference sample, a PR hamburger dill chip processed by that same commercial facility on the same day, and a commercial hamburger dill chip of another brand were evaluated using a statistical design balanced for carry-over effects. This type of design allows determination and quantification of effects due to tasting order and fatigue. Two replications were completed on consecutive days. Each sample was coded with a random three-digit number, and unsalted crackers and water were provided at each session for cleansing the palate between samples. The commercial reference sample (Table 3) was provided at each session, and panelists were instructed to re-taste the reference sample before each coded sample. SAS statistical software was used to determine significant differences between treatments and any possible carry-over effects.

Hedonic testing ("liking" panels). A standard, bipolar, nine-point hedonic-type scale (Meilgaard et al., 1991) was used for testing acceptability of the PR pickle products. During evaluation, consumers were asked to taste the product and then indicate how much it was liked or disliked on a scale ranging from dislike extremely to like extremely. The responses were converted to numbers for data analysis, with dislike extremely = 1, dislike strongly = 2, dislike moderately = 3, dislike slightly = 4, neither like nor dislike = 5, like slightly = 6, ...like extremely = 9. Each treatment was coded with a random three-digit number. All possible serving sequences for each experiment were balanced across consumers. Analysis of variance was used to determine statistically significant differences using SAS statistical software.

Difference from control. The objective of this test was to determine if untrained tasters representing a lay population could tell a difference between commercial and PR hamburger dill chips that had a constant total acid concentration but varying lactic: acetic acid ratios. Fifty untrained volunteer panelists from the Department of Food Science (NCSU, Raleigh, NC) were presented with a commercial control sample labeled C and three coded samples (duplicate commercial sample, PR hamburger dill chip, and PR hamburger dill chip with 17% FFB). They were instructed to taste and compare each coded sample with the control sample and mark the amount of overall difference perceived on a 6-inch unstructured line scale with word anchors at each end, representing no difference and extreme difference (Meilgaard et al., 1991). Sample tasting order was balanced across panelists. Each panelist also received water and unsalted crackers and was instructed to use them to cleanse their palate between samples. The distance from the left end of the line scale to the panelist's mark, representing the magnitude of difference between the sample and the control, was measured and recorded. Analysis of variance was used to determine statistically significant differences using SAS statistical software.

RESULTS AND DISCUSSION

Fermented Products Flavor

Figure 1 shows a summary of sensory attributes for PR sweet pickles prepared with 45% (wt/vol) HFCS compared to a commercial sample. The attributes are located on radial axes, with the intensity ranging from 0 (none) at the center of the circle to 14 (very strong) at the outer circumference. This type of plot allows us to look at all sensory attributes tested for many samples at one time. At a glance, one can see that the PR products were of high quality—little to no bitterness or off-flavors and higher "crunchiness" scores than commercial samples. Treatments with 33 or 50% of the standard vinegar level scored the closest to the commercial sample in sourness and sweetness.

The level of sweetener and acetic acid in PR sweet pickle chips had the greatest effect on sweetness and sourness, respectively.

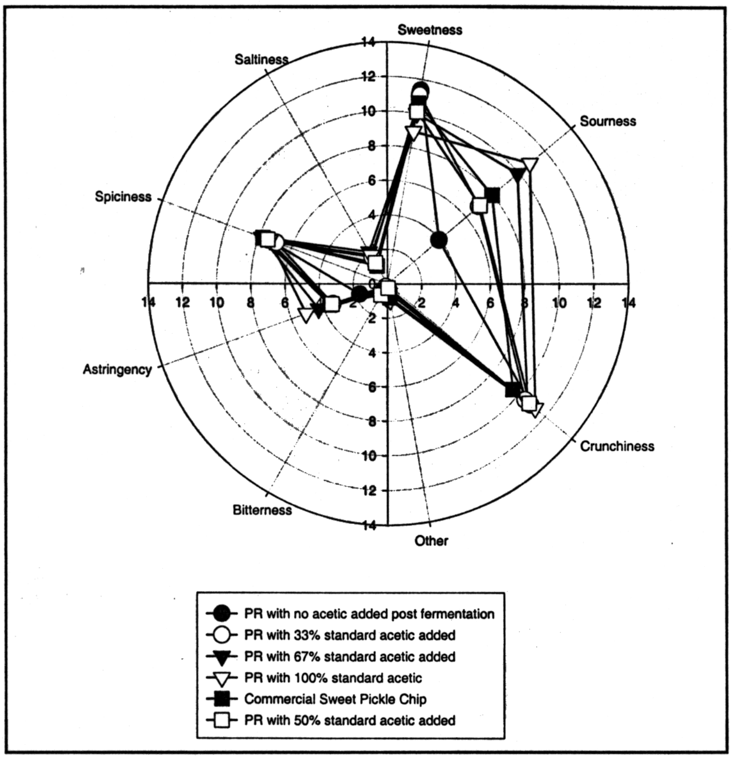

Figure 1. Flavor characteristics of process-ready sweet pickle chips (45% HFCS).

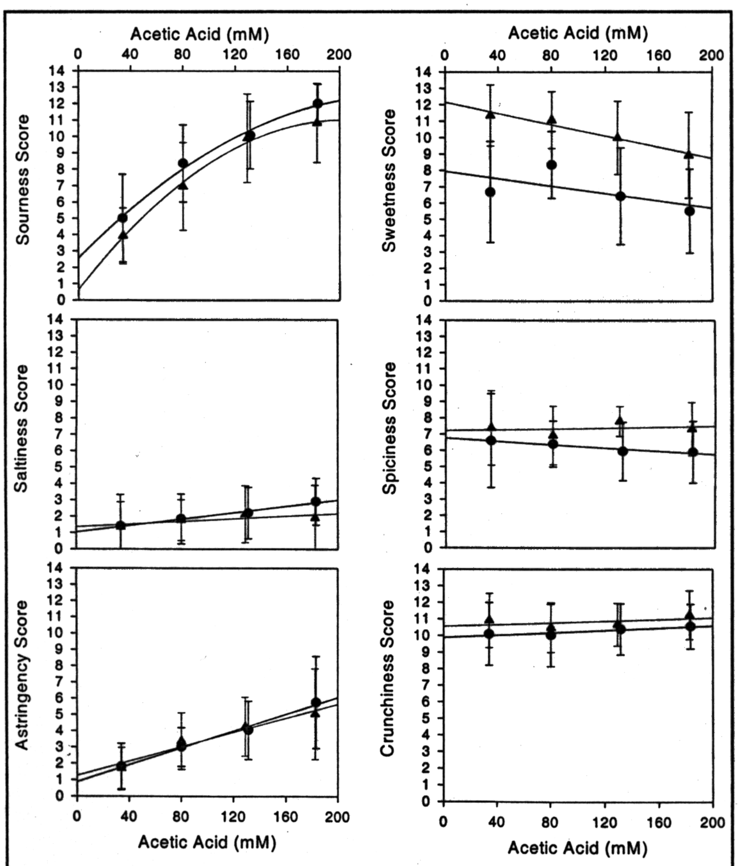

Figure 2. Mean attribute scores for process-ready sweet pickles prepared with varying levels of vinegar and high fructose corn syrup (circle = 30% wt/vol; triangle = 45% wt/vol).

Sourness scores for sweet pickle chips increased significantly with increasing acetic acid levels, as expected (Fig. 2), and the 30% HFCS treatments were significantly less sweet than the 45% HFCS treatments ($P < 0.05$). However, the level of sweetener also influenced perceived sourness, and acetic acid concentration influenced the perception of sweetness. Sourness scores for sweet pickles prepared with 30% HFCS were consistently higher than those with 45% HFCS over all levels of acetic acid, and sweetness scores decreased slightly with increasing acetic acid concentration for both 30% and 45% HFCS (Fig. 2). This was consistent with previous findings which showed that sweetness influenced perception of sourness and vice versa (Calvino and Garcia, 1998; Bonnans and Noble, 1993, 1995; Tuorila et al., 1993; King et al., 2000). All sweet pickle treatments were found to be only very slightly salty, which is typical of sweet pickle products. Nonetheless, saltiness scores increased slightly with increasing acetic acid concentration in 30% HFCS treatments (Fig. 2). The saltiness flavor component of acids described by Hartwig and McDaniels (1995) may be responsible for this increased slope. It is also possible that this flavor was masked completely at the 45% HFCS level, since it has been found that sweetness can mask both sourness and saltiness (Fabian and Blum, 1943). Spiciness was slightly higher in 45% HFCS treatments (Fig. 2), especially at higher acetic acid levels. It was not clear whether this trend was due to the enhancement of spiciness by sweetness (previously reported by Pangborn and Vaughn, 1959) or whether the spiciness was less noticeable due to the increased sourness of the 30% HFCS treatments. Since the two curves are farther apart at higher acetic acid levels, the latter explanation seems likely. Astringency scores increased with increasing acetic acid (Fig. 2) for both 45% and 30% HFCS treatments. However, even the most sour samples were only scored as having moderate astringency, and the level of sweetener had no effect on astringency. No significant bitterness or "other" flavors were noted in any of the samples, illustrating the high quality of the PR fermented cucumbers.

Sweet pickle treatments that had a standard amount of vinegar added to the cover brine in addition to the lactic acid present from fermentation (60-65 mM eq.) were extremely sour, indicating the need to reduce the vinegar level to compensate for the increased lactic acid concentration, even in the presence of a high concentration of sugar (45% (wt/vol) HFCS). The estimated ideal level of acetic acid from this experiment, based on equivalent sourness to commercial sweet pickle chips, was about 110 mM (0.66 %; 80 mM, 0.48%, added post-fermentation). This approximately 1:1 mM replacement of acetic acid by lactic acid was tested in hamburger dill chips, since there is no sugar masking effect in this type of product. The vinegar was reduced in order to keep a constant total acid concentration resulting in varying lactic:acetic acid ratios. A "difference from control" sensory test was done to see if the lactic for acetic substitution could be made without changing the overall flavor of the product. The "difference from control" test showed that even untrained panelists found experimental treatments to be slightly different ($P < 0.05$) from commercial hamburger dill chips, but not different from each other. Commercial hamburger dills, PR hamburger dills, and PR hamburger dills with 17% FFB had average distances of 1.66, 2.45, and 2.56 inches, respectively, on a 6-inch line scale. Descriptive sensory analysis showed that several flavor attributes differed between commercial and PR hamburger dill chips (Fig. 3). PR hamburger dill chips (as processed by a commercial facility) were less sour than both commercial samples that were tested ($P < 0.05$). They also scored lower than the commercial reference for dill flavor, vinegar flavor, astringency, and bitterness ($P < 0.05$),

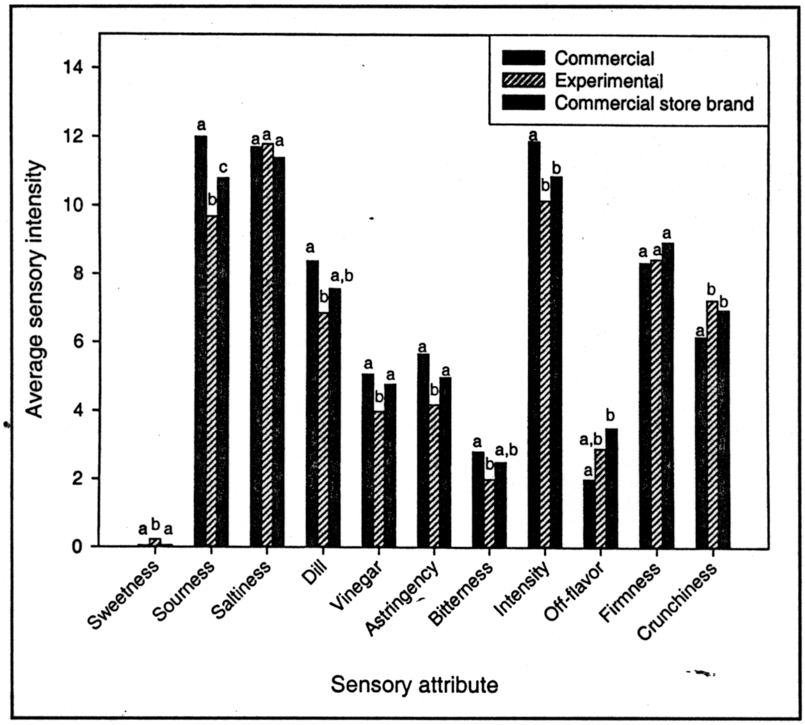

Figure 3. Flavor characteristics of commercial versus process-ready hamburger dill chips (different lowercase letters designate significantly different means, P <0.05).

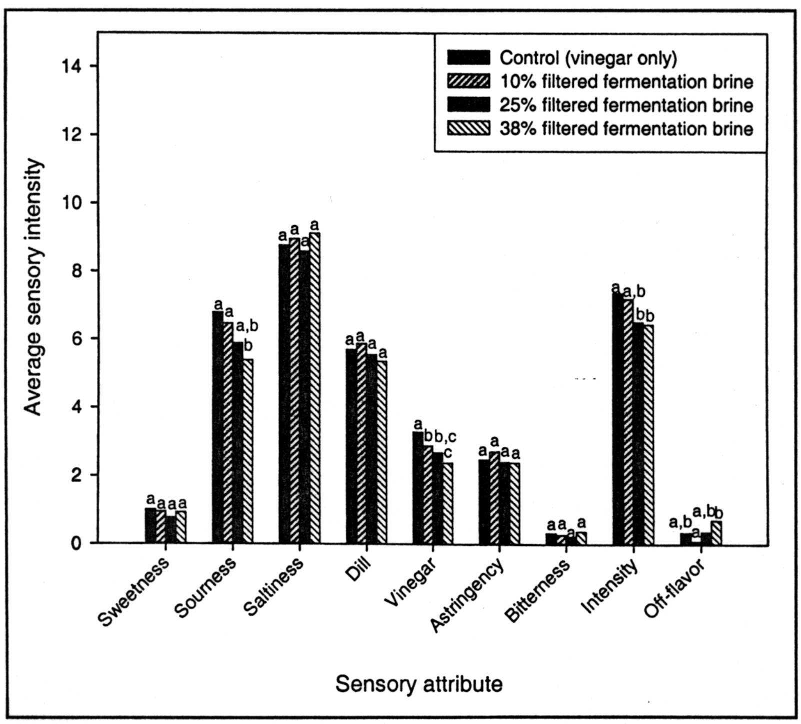

Figure 4. Flavor characteristics of fresh-pack dill chips prepared with varying levels of filtered fermentation brine as an acidulent (different lowercase letters designate significantly different means, P <0.05).

indicating an overall milder product that may be desirable to some consumers.

Fresh-Pack Product Flavor

Informal tasting of fresh-pack dills by experienced laboratory personnel revealed that pickles prepared with FFB had a slightly different flavor characteristic described by some as a fresher overall flavor. Descriptive sensory analysis using a group of trained panelists showed that increasing the substitution of FFB for vinegar decreased the sourness, vinegar flavor, and overall intensity of fresh-pack dill pickles (Fig. 4). Vinegar flavor was expected to decrease since less vinegar was added to these products. Lower sourness and overall intensity indicated that the lactic acid (added via FFB) provided less sourness than an equal amount of acetic acid (vinegar), which confirms findings by Hartwig and McDaniel (1995) that at equivalent pH and concentration lactic acid is less sour than acetic acid. Fresh-pack bread and butter chips were also evaluated informally by laboratory personnel. There was very little difference in the flavor of the two treatments, probably due to the low level of lactic acid (14.5 mM) compared to the amount of acetic acid (129.8 mM) that was present. Although the contribution of the lactic acid to the flavor was minimal in bread and butter type products, the FFB constituted approximately 30% of the cover brine. These experiments with fresh-pack products show great potential for use of the entire contents of the PR fermentation. It is easily conceivable that the entire PR fermentation can be used to make pickle products with minimal waste (Fig. 5).

Product Acceptability

A few products were chosen to be tasted for "liking" as an indicator of their overall acceptability. In all cases where acidity was balanced, PR pickle products were liked as well as a commercial pickle of the same type (Table 4). Some of the treatments that had either too low or too high total acid concentrations relative to a similar commercial product (Table 5) received lower "liking" scores (Table 4). PR sweet pickle chips receiving half the standard amount of vinegar were liked as well as a commercial sweet pickle chip by visitors to the Field Day in Clinton, NC (Table 4). The average score of seven corresponded to the category "like moderately," and experience suggests that this is a rather high score for a pickle of any kind. This same sweet pickle treatment was also the most well liked of the PR sweet pickles tested by the NCSU Department of Food Science, with an average score of 6.7, compared to 5.8, 5.2, and 6.0 for commercial, PR with no added vinegar, and PR with the standard vinegar addition, respectively. Commercial genuine dills and PR genuine dills were also equally well liked by visitors at the Field Day (Table 4). PR hamburger dill chips and commercial hamburger dill chips were not found to be different in "liking" by a group of pickle packers (Table 4), and there was no overall difference in "liking" found between fresh-pack dills with 25% FFB and the vinegar only control. Both treatments had an average score corresponding to "like moderately" on a nine-point hedonic scale (Table 4). These panels give strong indications that PR products, when balanced for acidity, are as acceptable as commercial products.

Texture

Instrumental texture analysis of sweet pickle chips after 10 months of storage showed that the PR pickles retained firmness at least as well as the commercial product (Table 6). All sweet pickle chip treatments received favorable texture ("crunchiness") scores

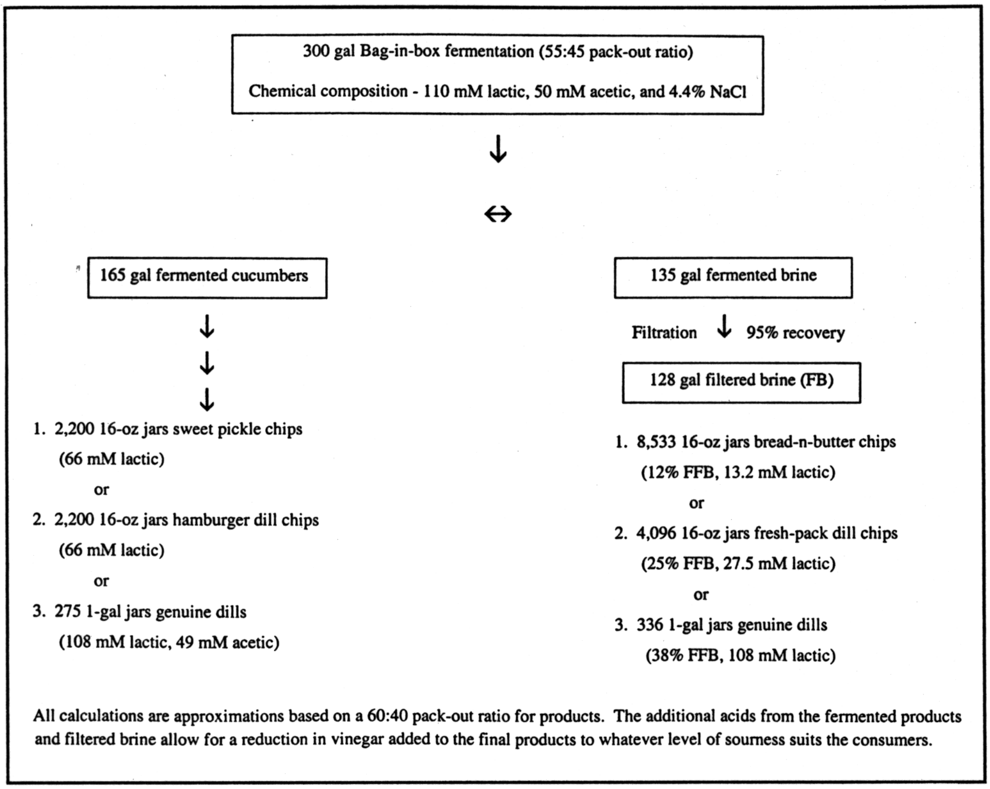

Figure 5. Flow chart for complete use of process-ready fermentation products in pickles.

(Fig. 2), indicating that the additional lactic acid from fermentation (Table 7) was not detrimental to the texture of the pickles. Furthermore, no significant difference was found in firmness (force, N) between the PR hamburger dills and commercial hamburger dills 11 weeks after processing, as well as 1 yr after processing (Table 6). PR hamburger dills were found to be equal in firmness and higher in crunchiness ($P < 0.05$) than commercial hamburger dills processed by the same facility on the same day (Fig. 3). Previous research has shown that lactic acid, when used as the sole acidulent, can result in softening of fresh-pack pickles (Bell et al., 1972; Fabian and Wadsworth, 1939a; 1939b; 1939c; Thompson and Fleming, unpublished). However, experimental fresh-pack products tested after 6 months of storage showed no significant differences in firmness among the treatments (Table 6), indicating that the addition of FFB containing lactic acid was not detrimental to texture. This could be due to several factors, such as the presence of a mixture of lactic and acetic acids, and/or constant pHs among the treatments due to the buffering capacity of the fermentation brine. Over many trials and various products, the texture of PR pickles or pickles made with FFB

Table 4. Process-ready (PR) pickles tested for "liking" on a nine-point bipolar hedonic scale.

Pickle type	Treatment	"Liking" score[1]	Consumers	No. of consumers
Sweet pickle chips	Commercial	5.8^{ac}	NCSU Food Science	60
	PR no added vinegar	5.2^{a}	NCSU Food Science	60
	PR 50% reduced vinegar	6.7^{bc}	NCSU Food Science	60
	PR standard addition of vinegar	6.0^{abc}	NCSU Food Science	60
Sweet pickle chips	Commercial	6.9^{a}	Field Day visitors, Clinton, NC	20
	PR 50% reduced vinegar	7.0^{a}	Field Day visitors, Clinton, NC	20
Hamburger dill chips	Commercial	6.0^{a}	NCSU Food Science	60
	PR no added vinegar	5.4^{ab}	NCSU Food Science	60
	PR with 38% FFB[2]	5.0^{b}	NCSU Food Science	60
Hamburger dill chips	Commercial	5.4^{a}	Pickle packers	41
	PR with reduced vinegar	5.7^{a}	Pickle packers	41
	PR with 17% FFB	5.7^{a}	Pickle packers	41
Genuine dill	Commercial	6.4^{a}	NCSU Food Science	60
	PR no added vinegar	5.7^{ab}	NCSU Food Science	60
	Fresh cucumbers with 38% FFB	5.5^{b}	NCSU Food Science	60
Processed dill	Commercial	6.9^{a}	Field Day visitors, Clinton, NC	20
	PR processed by commercial facility	7.0^{a}	Field Day visitors, Clinton, NC	20
Fresh-pack dill	Control (vinegar only)	6.7^{a}	Pickle packers	34
	Fresh cucumbers with 25% FFB and supplemental vinegar	6.7^{a}	Pickle packers	34

[1]Different lowercase letters within each grouping designate significantly different means ($P < 0.05$).

[2]FFB=filtered fermentation brine (% of total jar volume).

Table 5. Chemical analysis of process-ready (PR) pickles tested for "liking."

Pickle type	Treatment	pH	Lactic acid (mM)	Acetic acid (mM)	Total acid (mM)
Sweet pickle chips	Commercial	3.2	16.7	156.7	173.4
	PR no added vinegar	3.5	81.9	41.8	123.7
	PR 50% reduced vinegar	3.4	76.0	115.7	191.7
	PR standard addition of vinegar	3.3	76.1	194.9	271.0
Sweet pickle chips	Commercial	3.2	21.6	144.3	165.9
	PR 50% reduced vinegar	3.4	61.7	94.5	156.2
Hamburger dill chips	Commercial	3.4	38.2	99.9	138.1
	PR no added vinegar	3.7	75.2	42.7	117.9
	PR with 38% FFB[1]	3.7	116.0	70.9	186.9
Hamburger dill chips	Commercial	3.2	51.1	83.7	134.8
	PR with reduced vinegar	3.4	70.1	62.2	132.3
	PR with 17% FFB	3.4	89.4	41.9	131.3
Genuine dills	Commercial	3.5	37.9	73.1	111.0
	PR no added vinegar	3.6	76.2	41.7	117.9
	Fresh cucumbers with 38% FFB	4.1	47.0	34.8	81.8
Processed dills	Commercial	3.4	52.7	106.8	159.5
	PR processed by commercial facility	3.6	64.7	85.6	150.3
Fresh-pack dills	Control (vinegar only)	3.7	0	106.8	106.8
	Fresh cucumbers with 25% FFB and supplemental vinegar	3.8	27.3	61.2	88.5

[1]FFB = filtered fermentation brine (% of total jar volume).

has been at least of equal quality and frequently superior to that of comparable commercial products.

CONCLUSIONS

PR fermented cucumbers were successfully used for sweet and dill pickle products without the salt and acid removal that is customary with traditionally fermented cucumbers. All products tested were of desired quality in both flavor (no significant bitterness or other flavors) and texture (acceptable instrumental firmness and crunchiness scores ≥ commercial products). Additionally, sourness equal to commercial products was achieved with substantially less vinegar. In sweet pickles, it appeared that the sourness replacement value of lactic for acetic acid was approximately 1:1 on a mM basis, resulting in a 50% reduction in the amount of vinegar needed post fermentation. However, in dill pickles, where the total concentration of acids is lower and the potential for greater substitution of acetic acid with lactic acid exists, it appears that the sourness replacement

Table 6. Texture analysis of process-ready (PR) pickles.

Pickle type	Treatment	Storage time	Firmness (average maximum force, N)[1]
Sweet pickle chip	Commercial	10 months	8.00[a]
	PR 50% reduced vinegar	10 months	10.59[a]
Hamburger dill chips	Commercial	11 weeks	12.68[a]
	PR with reduced vinegar	11 weeks	14.21[a]
	PR with 17% FFB[2]	11 weeks	14.77[a]
Hamburger dill chips	Commercial	1 yr	10.41
	PR processed by commercial facility	1 yr	10.60[a]
	Commercial store brand		11.64[a]
Fresh-pack dills	Commercial	6 months	9.32[a]
	Control (vinegar only)	6 months	12.86[a]
	Fresh cucumbers, 10% FFB, and supplemental vinegar	6 months	12.98[a]
	Fresh cucumbers, 25% FFB, and supplemental vinegar	6 months	13.44[a]
	Fresh cucumbers, 38% FFB, and supplemental vinegar	6 months	14.21[a]

[1]Different lowercase letters within each grouping designate significantly different means.

[2]FFB = filtered fermentation brine (% of total jar volume).

Table 7. Chemical analysis of process-ready (PR) pickles evaluated by descriptive sensory analysis.

Pickle type	Treatment	pH	Lactic acid (mM)	Acetic acid (mM)	Total acid (mM)
Sweet pickle chips	Commercial lot #1 (reference)	3.2	19.9	135.9	155.8
	Commercial lot #2 (control)	3.2	22.1	148.9	171.0
	PR no additional vinegar	3.5	65.1	34.2	99.3
	PR 1/3 standard vinegar	3.4	62.9	80.3	143.2
	PR 1/2 standard vinegar	3.4	61.7	94.5	156.2
	PR 2/3 standard vinegar	3.4	64.8	129.2	194.0
	PR standard vinegar	3.3	63.3	182.6	245.9
Hamburger dill chips	Commercial (reference and control)	3.2	46.5	88.0	134.5
	PR with reduced vinegar	3.4	57.0	67.5	124.5
	Commercial store brand	3.3	50.4	77.2	127.6
Fresh-pack dills	Reference	3.8	0	98.6	98.6
	Commercial	3.8	0	96.2	96.2
	Control (vinegar only)	3.9	0	93.2	93.2
	Fresh cucumbers with 10% FFB[1] and supplemental vinegar	3.9	7.4	83.6	91.0
	Fresh cucumbers with 25% FFB and supplemental vinegar	3.9	21.0	59.2	80.2
	Fresh cucumbers with 38% FFB and supplemental vinegar	3.9	36.0	48.1	84.1

[1]FFB = filtered fermentation brine (% of total jar volume).

value of lactic acid for acetic acid is slightly less than one. PR pickle products that were balanced in acidity were liked equally as well as commercial products, and fresh-pack dills prepared with FFB as an acidulent were liked equally as well as those acidified with vinegar alone, indicating potential for use of all the products of the PR cucumber fermentation.

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Pickle Pak **SCIENCE**

ABOUT THE COVER:

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

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