BALANCING MACROMINERAL COMPOSITION OF FRESH-PACK CUCUMBER PICKLES TO IMPROVE NUTRITIONAL QUALITY AND MAINTAIN FLAVOR[1]

R.F. MCFEETERS[2] and H.P. FLEMING

Food Fermentation Laboratory, U. S. Department of Agriculture
Agricultural Research Service and
Department of Food Science
North Carolina State University
Raleigh, NC 27695-7624, USA

Accepted for Publication February 29, 1996

ABSTRACT

The macromineral nutritional balance of fresh-pack dill cucumber pickles was improved without loss of flavor quality. A product with flavor acceptability equal to the original product was obtained if NaCl was reduced by 40%, from 2.0% to 1.2%. To replace the 0.8% reduction in NaCl 0.8% KCl was added. $CaCl_2$ and $MgCl_2$ were added proportionately to match the daily value (DV) of the added KCl. In addition to changes in mineral composition, low levels of both citric acid and hot pepper sauce were added to improve flavor acceptability. The flavor acceptability of dill pickles was rated higher ($P < 0.05$) than the 2.0% NaCl control when the NaCl concentration was reduced 20% from 2.0 to 1.6%, and 0.4% KCl was added to replace the NaCl. Again, $CaCl_2$ and $MgCl_2$ were added at a level which gave the same proportion of the DVs of these minerals as 0.4% KCl. The highest flavor acceptability in the product with 20% less NaCl was obtained when only citric acid was added as a flavor modifier.

[1]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or North Carolina Agricultural Research Service, nor does it imply approval to the exclusion of other products that may be suitable.
[2]To whom inqueries should be directed: Telephone 919-515-2979.

Journal of Food Quality **20** (1997) 81-89.

INTRODUCTION

Pickle products traditionally have had 2-4% NaCl to produce the flavor that consumers expect. While a few no-sodium or low-sodium products have been marketed for people who must severely restrict dietary sodium (Bell *et al.* 1972), these products do not have the expected flavor of a pickled product. Pickle products made with equal amounts by weight of NaCl and KCl also have been investigated by processors (Strietelmeier 1986), but commercial production has been very limited, presumably because the salty flavor is not close enough to products with 100% NaCl. However, Matsumoto *et al.* (1986) reported that for some Japanese pickled vegetables 20% replacement of NaCl with KCl gave products with improved flavor; products with 40% NaCl replacement had a flavor quality equivalent to the full sodium product, and a 60% replacement gave a product inferior in flavor acceptability. These products are very different in flavor and character compared with the cucumber products typically consumed in the United States, but, if a similar result was found for cucumber pickle products, a moderate reduction in sodium would be possible.

One characteristic of the mineral composition of diets in the United States is that sodium consumption is typically many-fold greater than is required. The other three essential macrominerals, potassium, calcium and magnesium, are consumed in amounts close to recommended levels (Koop 1988). The exception is that calcium intake tends to be low for women. Though the available experimental evidence is far from conclusive, there are some indications that, in contrast to sodium, there may be a tendency for increased intakes of the other macrominerals to lower blood pressure as intake increases (Koop 1988). Therefore, the intent of this work was to improve the macromineral balance of pickle products, rather than just sodium reduction.

The objective of this study was to determine whether sodium levels in a typical fresh-pack cucumber pickle product could be reduced and the other macrominerals increased by nutritionally significant amounts without reducing the flavor acceptability of the product.

MATERIALS AND METHODS

Preparation of Pickle Products

Size 2B cucumbers were washed and either packed (816 +1 g/jar) whole or as 4 mm thick slices in 1360 mL jars (46 oz). Cucumbers were covered with 544 mL brine to give a 60:40 pack-out ratio. After closing, jars were heat processed in a 76C water bath until the temperature reached 74C in the center of the jar. The water bath was then cooled to 74C and the temperature held at that level for 15 min. The jars were cooled in tap water to less than 40C. Temperature in the

middle of a test jar was monitored by placing a thermometer through a rubber septum in the lid such that the tip of the thermometer was inside a cucumber in the center of the jar. After processing, samples were stored at least 4 weeks at room temperature to allow equilibration prior to sensory analysis.

A commercial dill brine formula was used to make the reference product for comparisons of flavor changes resulting from the modification of mineral composition. A liter of the cover brine contained 50 g NaCl, 109 g vinegar containing 13% acetic acid, 20 g high fructose corn syrup, 4 g $CaCl_2 \cdot 2H_2O$, sodium benzoate, FD&C No.5 yellow food coloring, and a dill spice concentrate. These components equilibrate with the cucumbers after packing to approximately 40% of the added concentration. For NaCl, this is a 2% equilibrated concentration. Reductions in NaCl concentration from the 2% level and additions of KCl, $CaCl_2$, and $MgCl_2$, and other brine modifications are indicated for the appropriate experiments.

Sensory Analysis

For experiment 1, whole dill pickles were prepared to contain the equilibrated concentrations of macrominerals shown in Table 1. Percentages of the daily value (DV) of the added minerals in a 30 g serving of pickles, as defined in current food labeling regulations, is given in Table 2. Natural levels of the minerals were not determined. Each of the six levels of sodium replacement from 0 to 60% were served to faculty, staff and students of the NCSU Food Science Department. Triangle tests were done with the 2% NaCl product as the reference (Larmond 1982) to determine whether the products differed. Tests were done with fluorescent room lighting. Panelists were given unsalted crackers and water to clear their palates. They did three triangle tests at each sitting.

Fourteen participants from experiment 1 were found to consistently differentiate samples with potassium, calcium, and magnesium added. These people were selected as panelists for experiment 2. The objective was to determine whether the acceptability of a 40% reduced sodium product could be improved for this selected group if 10 mM of an organic acid and a low level of hot pepper sauce were added in addition to the changes in mineral composition. The mineral composition was the same as the 40% sodium reduction shown in Table 1. Equilibrated concentrations of organic acids are shown in Table 3. A low level of hot pepper sauce (1.2 mL of Tabasco brand, McIlhenny Co., Avery Island, LA, per liter of the final product) was added to all treatments. Sensory analysis was carried out using a multiple paired comparison test (Larmond 1982) with the 40% reduced sodium product prepared as described in experiment 1 as the reference sample. Panelists were asked to rate the test samples relative to the reference on the basis of flavor preference. The adjectives used to rate the degree of flavor preference were none, slight, moderate, much, and extreme (Larmond 1982). The reference sample was included as an unknown with each set of samples. On a 9-point scale, a score of

5 was assigned if the flavor preference of a sample was judged to be equivalent to the reference. Higher scores indicated the test sample was preferred relative to the reference, lower scores that the acceptability was less than that of the reference.

TABLE 1.
EQUILIBRATED CONCENTRATIONS OF
ADDED MACROMINERALS IN FRESH-PACK DILL PICKLES

NaCl Reduction, %	0	10	20	30	40	50	60
Equilibrated Concentration, g/100 g of Product							
Sodium Chloride	2.0	1.8	1.6	1.4	1.2	1.0	0.8
Potassium Chloride	0.0	0.2	0.4	0.6	0.8	1.0	1.2
Calcium Chloride	0.0	0.08	0.17	0.25	0.33	0.41	0.50
Magnesium Chloride	0.0	0.05	0.09	0.14	0.19	0.23	0.28

Experiment 3 was designed to determine the degree of flavor acceptability of reduced sodium dill pickles containing citric acid and/or a low level of hot sauce in a general consumer population. Treatments were: (1) a reference sample made with the standard formula containing 2% NaCl; (2) 20% NaCl reduction with corresponding increases in KCl, $CaCl_2$, and $MgCl_2$ (Table 1), and 0.192% citric acid; (3) same as treatment 2, with 1.2 mL/L of product hot pepper sauce (Tabasco brand, McIlhenny Co., Avery Island, LA); (4) 40% NaCl reduction with corresponding increases in KCl, $CaCl_2$, and $MgCl_2$, (Table 3) and 0.192% citric acid; (5) same as #4 with 1.2 mL/L hot pepper sauce. Two lots of cucumbers were processed 1 week apart, with fresh brines prepared each time. Sensory analysis was done with 104 volunteers from faculty, staff and students in the Department of Food Science, Department of Horticultural Science and D.H. Hill Library at North Carolina State University. Sensory analysis was done with a multiple paired comparisons test with the 2% NaCl product as reference (Larmond 1982). The reference sample and the four treatment samples were evaluated and compared with the designated reference sample. Panelists were asked to compare each sample with the reference on the basis of flavor preference. They were asked to ignore perceived differences in texture or appearance. The order of sample presentation was varied. Panelists were given water and unsalted crackers to clear their palates between samples. Evaluations were done in normal room fluorescent lighting. Panel ratings were converted to a nine-point scale using the same adjective ratings as described above. Panelists were asked to give their age within 1 of 4 categories: <20, 20-39, 40-59, ≥ 60, so it could be determined if there was an age effect in flavor preferences.

TABLE 2.
PERCENT DAILY VALUE (DV) OF ADDED MACROMINERALS IN REDUCED SODIUM, FRESH-PACK DILL PICKLES COMPARED TO THE REFERENCE PRODUCT WITH 2% NaCl ADDED

NaCl Reduction, %	0	10	20	30	40	50	60
% DV/30 g of Product[a]							
Sodium	9.8	8.9	7.9	6.9	5.9	4.9	3.9
Potassium	0.0	0.9	1.8	2.7	3.6	4.5	5.4
Calcium	0.0	0.9	1.8	2.7	3.6	4.5	5.4
Magnesium	0.0	0.9	1.8	2.7	3.6	4.5	5.4

[a]Daily values are: sodium, 2400 mg; potassium, 3500 mg; calcium, 1000 mg; magnesium, 400 mg.

Statistical Analysis

Significance levels for the triangle tests were determined from the appropriate table (Larmond 1982). Analysis of variance was used to analyze the results of the multiple paired comparisons tests done for experiments 2 and 3. Calculations were done using the general linear models procedure in SAS (SAS Institute, Cary, NC). Significance levels for all comparisons were calculated.

TABLE 3.
ORGANIC ACIDS ADDED TO FRESH-PACK DILL PICKLES FOR FLAVOR MODIFICATION

	%, w/v
Tartaric Acid	0.150
Gluconic Acid Lactone	0.178
Succinic Acid	0.118
Adipic Acid	0.146
Lactic Acid, 88%	0.102
Fumaric Acid	0.116
Citric Acid	0.192

RESULTS AND DISCUSSION

Table 4 shows results of triangle tests performed on samples with 10% to 60% sodium reduction. The panel could not distinguish samples with sodium reduced 20, 30, or 40% from the control sample with 2.0% NaCl at the $P \leq 0.05$ level. Surprisingly, the panel could distinguish between the control and the 10% reduction. At the 50 and 60% replacement levels, the panel was also able to

distinguish the experimental samples from the control.

TABLE 4.
TRIANGLE TEST COMPARISON OF REDUCED SODIUM DILL PICKLES COMPARED TO THE 2.0% NaCl PRODUCT (EXPERIMENT 1)

Na Replacement, %	No. of Panelists	No. of Correct Responses	$P \leq 0.05$
10	35	20	Yes
20	34	16	No
30	35	17	No
40	34	14	No
50	35	23	Yes
60	34	26	Yes

It was observed that less than half the panelists were able to consistently make the correct selection in the triangle tests. However, some people were able to reliably detect the macromineral substitution in at least five of the six tested substitution levels. Mickelsen *et al.* (1977) commented that there appeared to be a segment of the population who can taste a 50% replacement of sodium chloride by potassium chloride in "lite salt" and strongly dislike the replacement. There were no comments in this study to indicate a strong rejection of samples with mineral replacement. However, at the higher replacement levels, nearly all of the panelists who made the correct selection of the odd sample picked the control sample which contained only NaCl as the more acceptable product. On the basis of this observation, it was decided to make an attempt to modify the reduced sodium product to see if the flavor acceptability could be improved among people who could detect mineral substitution based upon triangle tests. Fourteen people who could consistently identify the mineral substitution were identified. They were given fresh-pack dill pickle samples with a low level of hot pepper sauce added. The level added (1.2 mL/L of product) was so low that the product was not perceived to be hot, but a difference in flavor could be detected. The second modification made was to add 10 mM concentrations of several food-grade acids in addition to the standard 95 mM acetic acid. Table 5 shows the ratings of flavor preference for products with a 40% sodium reduction and the pepper sauce and organic acid modifications. Product with sodium reduced by 40% (Table 1) was used as the reference. Though the mean score for pepper sauce addition was lower than the reference, statistically it was not different from the reference. Among the organic acids tested, succinic and lactic acids significantly reduced the flavor acceptability. Only citric acid increased the flavor score compared with the reference. This increase was significant at the $P \leq 0.10$ level, but not at the $P \leq 0.05$ level. However, because the panel size was necessarily small, it was decided to test

the flavor acceptability of dill pickles with citric acid added with a larger, general population of panelists.

TABLE 5.
EFFECT OF ADDED HOT PEPPER SAUCE AND ORGANIC ACIDS TO DILL PICKLES WITH NaCl REDUCED 40% TO 1.2% (EXPERIMENT 2)

Treatment	Mean Panel Score[b]	Probability that Treatment is not Different from Reference
Reference A - 1.2% NaCl[a]	5.29	-
Pepper Sauce	4.50	0.190
Tartaric Acid	4.29	0.096
Gluconic Acid	5.21	0.905
Succinic Acid	3.56	0.002
Reference B - 1.2% NaCl[a]	4.92	-
Adipic Acid	4.38	0.385
Lactic Acid	3.54	0.027
Fumaric Acid	4.23	0.260
Citric Acid	6.00	0.084

[a]Reference product was included as one of the coded samples, so panalists compared the reference to itself. Reference product contains potassium, calcium, and magnesium chlorides, as shown in Table 1 for 40% sodium reduction.

[b]A score of 5 is equal to reference. Greater than 5 is preferred over the reference. Less than 5 is worse than the reference.

For the larger panel, a 20% sodium reduction and the corresponding increases in potassium, calcium, and magnesium was preferred to the 2.0% sodium chloride reference product when 0.192% citric acid was added in addition to the macrominerals (Table 6). The mean flavor score for the identical product with 1.2 mL/L hot pepper sauce was slightly lower so that it was not different from the reference at the $P \leq 0.05$ significance level. With citric acid added to the product, a 40% reduction in sodium was not statistically different from the reference with or without addition of hot sauce. The mean score for the product with added hot sauce was identical to that for the reference sample with 2.0% sodium chloride. Without hot sauce, the mean score was slightly lower. Significant differences were not found between lots of product or age of the panelists.

The primary conclusion of this study is that fresh-pack dill pickles can be prepared with moderately lower sodium levels and a better balance of the other macrominerals without reduction in the flavor preference of the product. The flavor judgments were made in a side by side comparison with the 100% sodium chloride product as the reference. This experimental design was chosen to maximize the likelihood that any deterioration in flavor that resulted when the

sodium levels were reduced would be recognized by panelists. In fact, a panel of 104 people found a small increase in flavor preference of a product with 20% reduction in sodium and 0.192% citric acid addition. The results are consistent with earlier studies of replacement of sodium chloride with potassium chloride in Japanese pickled vegetables (Matsumoto *et al.* 1986). It is impossible to predict the specific sensory responses that might be observed if this approach to improvement in the macromineral balance were used in the variety of commercially available pickled cucumber products. However, the fact that apparently similar flavor responses have been observed in very different pickled vegetable products suggests that moderate reductions in sodium levels and improvement in macromineral balance might be generally feasible. Table 2 shows changes in the percentages of the daily reference values of the macrominerals per 30 g of product that result from a 20% or 40% reduction in NaCl. The natural level of macrominerals in the cucumbers was not determined. However, based upon data in USDA Handbook No. 8 (Haytowitz and Matthews 1984), the DV of sodium would increase less than 0.04%/30 g of product if the natural level was considered. The DV for potassium would increase about 0.6%, while the DV for calcium and magnesium would increase slightly over 0.3%.

TABLE 6.
FLAVOR ACCEPTABILITY OF REDUCED SODIUM DILL PICKLES COMPARED TO A 2.0% NaCl PRODUCT AS JUDGED BY A CONSUMER PANEL
(EXPERIMENT 3)

Treatment	Mean Panel Score[b]	Probability that Treatment is not Different from Reference
Reference - 2.0% NaCl[a]	4.36	-
20% NaCl Reduction;[c] 0.192% Citric Acid	4.80	0.037
20% NaCl Reduction;[c] 0.192% Citric Acid; 1.2 mL/L Pepper Sauce	4.68	0.138
40% NaCl Reduction;[c] 0.192% Citric Acid	4.18	0.343
40% NaCl Reduction;[c] 0.192 % Citric Acid; 1.2 mL/L Pepper Sauce	4.35	0.972

[a]Reference product was included as one of the coded samples, so panelists compared the reference to itself.
[b] A score of 5 is equal to the reference. Greater than 5 is preferred over the reference. Less than 5 indicates the sample was less preferred than the reference.
[c]These products contain the amounts of added potassium, calcium, and magnesium chlorides shown in Table 1 for 20% or 40% sodium reduction.

This investigation was supported in part by a research grant from Pickle Packers International, Inc., St. Charles, IL.

REFERENCES

BELL, T.A., ETCHELLS, J.L., KELLING, R.E. and HONTZ, L.H. 1972. Low-sodium pickle products for modified diets. J. Amer. Dietetic Assoc. *60*, 213-217.

HAYTOWITZ, D.B. and MATTHEWS, R.H. 1984. *Composition of Foods: Vegetables and vegetable products.* Agriculture Handbook No 8-11. p. 178. U.S. Department of Agriculture. Human Nutrition Information Service. Washington, D.C.

KOOP, C.E. 1988. *The Surgeon General's Report on Nutrition and Health.* Publication No. 88-50210, pp. 69-70, 155-160. U.S. Public Health Ser.

LARMOND, E. 1982. *Methods for Sensory Evaluation of Food.* Publication 1637, Agriculture Canada, p. 20-23, 32-37, Ottawa..

MATSUMOTO, N., IKEDA, J. and SUGAHARA, T. 1986. Effect of potassium chloride added to kitchen salt used for preparing pickled vegetables. Eiyogaku Zasshi *44*, 27-33.

MICKELSEN, O., MAKDANI, D., GILL, J.L. and FRANK, R.L. 1977. Sodium and potassium intakes and excretions of normal men consuming sodium chloride or a 1:1 mixture of sodium and potassium chlorides. Amer. J. Clin. Nut. *30*, 2033-2040.

STRIETELMEIER, D.M. 1986. *Morton Salt Technical Information: Fresh-Pack Pickles.* pp. 1-2, Morton Thiokol, Morton Salt Division, Chicago, IL.