Flavor and Antibotulinal Evaluation of Sorbic Acid-Containing Bacon

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ABSTRACT

Bacon was prepared in a single pumping operation with a nitrite-free brine containing suspended, finely pulverized sorbic acid with the regular curing agents. The bacon, after being processed, was evaluated for susceptibility to *Clostridium botulinum* spore outgrowth and for taste panel acceptability using a 9-point hedonic scale. Sorbic acid levels of 0.13% or higher in the processed bacon gave nearly complete protection against spore outgrowth (as determined by gas production in aluminum cans) for the duration of the 6 months abuse period. The increase in antibotulinal efficacy with sorbic acid was generally associated with a lower pH. Flavor scores of control, nitrite-cured, and sorbic acid-cured bacon showed no significant differences among the three samples. After storage for 6 wk at 0–2°C, there was a decrease in the flavor scores, but the only statistically significant decrease was in the nitrite-cured bacon.

INTRODUCTION

SORBIC ACID and potassium sorbate are widely used in the food industry for inhibiting molds and yeasts. The compounds are generally recognized as safe (GRAS) by the Code of Federal Regulations (Section 121.101 of the Food Additives Regulations) and, at the levels used, do not unfavorably alter the taste or flavor of the foods. The undissociated form, sorbic acid, is more inhibitory to microorganisms than the salt (Robach, 1978; Huhtanen and Feinberg, 1980; Emard and Vaughn, 1952); however, it is less soluble than the salt, thus limiting its usefulness in some foods.

These compounds have been shown to be active against *Clostridium botulinum* in several meat systems. They prevented spores of the organism from germinating and forming toxin in poultry frankfurters and emulsions (Huhtanen and Feinberg, 1980; Sofos et al., 1979a, b, c); in comminuted pork (Ivey and Robach, 1978); in beef, pork and soy protein frankfurter emulsions (Sofos et al., 1979a); and in bacon (Ivey et al., 1978; Sofos et al., 1980). The latter workers used potassium sorbate in the curing brine, but because of greater efficacy, the free acid would be more desirable to use than the salt. One approach now under consideration is to utilize a double pump technique wherein a normal brine with nitrite is injected into the bellies followed by a second pump with a stable suspension of sorbic acid, guar gum, lecithin, and glycerol (Anon, 1980). This technique decreases the likelihood of formation of potentially carcinogenic compounds from the reaction of sorbic acid with nitrite (Tanaka et al., 1978) but is cumbersome and not readily adaptable to existing production lines.

Our work has concentrated on finding substitutes for nitrite in bacon for inhibiting *C. botulinum* spore outgrowth. Since sorbic acid is inhibitory to the organism and is GRAS, we attempted to develop a feasible single pump method for incorporating it into bacon. The results of our research are presented in this report. The flavor score of the resulting sorbic acid-cured bacon was also evaluated.

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EXPERIMENTAL

Preparation of bacon

Bacon was processed at two local plants, labelled A and B. The brine in use at plant A consisted of 12.5% salt, 0.860% sodium tripolyphosphate, 0.393% erythorbate, 0.108% liquid smoke, and 0.086% $NaNO_2$. The target pump at this plant was 14% with processing back to 4% above green weight. A total of 44 bellies were processed. A Belam model stitch pump was used; smoking and processing required 16 hr. The second plant, B, did not wish to have published the exact brine ingredient concentrations except the salt content which was 17.7%. Sugar, erythorbate, sodium tripolyphosphate, nitrite, and hydrolyzed vegetable protein were included in the brine. The target pump rate, obtained with an Anco stitch pump, was 11%; smokehouse time (artificial smoke) was 7–9 hr; and the final target process weight was 97% of the green weight. Fifteen bellies were processed in plant B. In both plants nitrite was omitted from the brine for the control bacon or was replaced with sorbic acid for the treated bacon. Weights were recorded for the individual green bellies and also for the bellies before entering the smokehouse and before being sliced. From these weights, the actual concentration of brine in the processed bellies was calculated.

After being processed, the bacon was sliced and packaged under vacuum following the normal procedure of the processing plant. The packages from each belly were separately labelled. In order to obtain uniform samples for the various studies, the packages were opened in a biohazard hood and the slices were sequentially rearranged to form new packages, each containing an equal number of slices from each original package. These were then resealed in plastic under vacuum and stored at 0–2°C until needed.

Sorbic acid

A commercial grade of sorbic acid (Aflaban®, Monsanto) was first used. This material, although it formed a suspension, clogged the filter of the stitch pump. Through the courtesy of Dr. K. Shaver of the Monsanto Co., we obtained a finer grade of sorbic acid which the company called "sorbic acid fines" (SAF). This material had an approximate particle size of 74 μm with 50–70% being retained by a USS 200 mesh sieve which is about 100 times smaller than commercially available sorbic acid. This material was used in the studies reported here.

Clostridium botulinum cultures

Eleven strains of type A *C. botulinum* and nine strains of type B were obtained from: the Center for Disease Control, Atlanta, GA [20 PLALCA(A), 174091A(A)]; Food Safety and Quality Service–USDA, Washington, DC [3(A), 4(B), 770B(B)]; US Army Natick Research & Development Laboratories, Natick, MA [53B(B), 33A(A)]; Northern Regional Research Center–USDA, Peoria, IL [B1218(A)]; Food & Drug Administration, Washington, DC [383(B), 999(B), 8688R(B), 78(A), 429(A), 62(A), 642(B), 69(A), 426(A), 169(B)]; and the American Type Culture Collection, Rockville, MD [7949(B), 25763(A)].

Heat shocked spores were prepared by inoculating cultures into brain heart infusion broth supplemented with 0.1% sodium thioglycollate and 5% tryptone. The cultures were incubated at 30°C in an anaerobic incubator (National Appliance Co.) in which a vacuum was drawn (24 in) with nitrogen replacement. After sporulation occurred, as evidenced by microscopic observation, the cultures were centrifuged at 10,000 RCF for 30 min, washed once with water, (1/5 the original volume), and heat shocked at 68°C for 30 min. Spore counts were made in 16 x 125 mm culture tubes (6 ml per tube) by serial dilutions in fluid thioglycollate medium, supplemented with 0.6% agar, and kept at 50°C. After solidification, 4 ml of 2% agar containing 0.1% sodium thioglycollate was overlaid on top of the diluting medium. The tubes were incubated at 30°C for 5 days, and spore counts were made by colony enumeration. A composite of the 20 strains consisting of equal quantities of spores from each of the suspensions was made. This composite contained a total of 2.8 x 10^5 spores per ml. One-tenth ml added to 70–75g bacon gave an inoculum concentration of approximately 400 spores per g.

Inoculated packs

One of the rearranged packages was used for determining *C. botulinum* spore outgrowth times. The slices were removed and placed in aluminum 208 x 107 tab cans, three slices (approximately 70–75g) per can, five cans per test. Prior to being vacuum sealed, the bacon slices were inoculated by touching 0.1 ml of inoculum onto the lean portions of the slices. After being sealed, the cans were heated to 68°C (at the center) and maintained at that temperature for 30 min. They were then cooled in tap water and incubated at 30°C for 180 days or until swelling was evident. Selected swollen and non-swollen cans were tested for toxin by adding an equal quantity of gelatin phosphate buffer to the bacon, allowing the mixture to stand 24 hr in a refrigerator, and injecting two mice intraperitoneally with 0.5 ml of the extract. Death of both mice within 3 days was considered presumptive evidence for the presence of toxin. If only one mouse died, the test was repeated. In practice, however, it was very rare for only one mouse to die. Samples were considered to be devoid of toxin if neither mouse died within this period.

Sensory evaluation

For the taste panel studies, bacon slices (stored in plastic packages under vacuum) were baked for about 12 min at 425°F in a Despatch model oven with a rotating shelf; we used baking instead of frying to ensure more even cooking. The exact time of baking was determined by visual examination of doneness. After baking, the slices were cut into 3/8" squares, thoroughly mixed, and reheated in an open kettle over hot water. Untrained judges, varying from 18–24 in number, were asked only for their opinion of the acceptability (flavor) of the bacon on a hedonic scale of 1 to 9, with 9 being the most acceptable score. Two to four samples were served at a session; only bacon from a single treatment was served each time.

Statistical significance

Significant differences between variables were determined by analysis of variance and the Student t statistic. Correlation coefficients were calculated to determine the degree of association between various parameters. In order to facilitate the statistical calculation of differences between mean swell times of cans, the figure of 180 days was used as an arbitrary swell time for those cans not swelling during this time.

Chemical tests

For pH measurements, made prior to canning, 5g uninoculated meat were placed in a 10 ml beaker and 5 ml H_2O was added. After the meat was minced with a stirring rod and left standing at room temperature 30 min, the pH's were recorded on an Orion model 601 meter. The pH values were rounded off to the first decimal. Sorbic acid was determined by the method of Robach et al. (1980).

RESULTS & DISCUSSION

TWO NEARBY PLANTS cooperated in a study of the feasibility of using the sorbic acid fines (SAF) on a small pilot plant scale. In the first of several experiments in plant A, the dry SAF was added directly to a nitrite-free curing brine. This dry material, however, created a dust that was irritating to the respiratory system. It would not form a uniform suspension; clumps of nonsuspended sorbic acid remained on the bottom of the brine tank even after vigorous stirring with paddles and air jets. The portion of the brine that was in suspension, however, pumped without difficulty and did not clog the needles or the filter. The results of this experiment are shown in Table 1. The mean swell times (MST) of the sorbic acid pumped bacons were greater than 180 days in six of the eight bellies. One belly, number 21, which contained the least sorbic acid (0.09%), showed the fastest MST and the highest pH, while bellies containing 0.13% or more sorbic acid showed the longest MST's and lowest pH's. We relied on MST as the main criterion for botulinal growth because of technical difficulties in performing the large numbers of toxin tests needed. This experiment indicated that a sorbic acid content of 0.13% would more effectively prevent spore outgrowth than 120 ppm nitrite. It is interesting to note in this table that the MST of nitrite cured bellies ranged from 8 to 29 days while nitrite free control bellies had MST's ranging from 6 to 52 days. Nitrite analysis indicated that there was less than 1 ppm residual nitrite in the nitrite-cured bellies. This may have been due to the long processing time used by this plant. Selected swollen cans from the control and nitrite bellies were all toxic. Both swollen cans from belly 21 were toxic, while the swollen can from belly 17, as well as one nonswollen can, were also toxic. None of the nonswollen cans from bellies containing 0.13% or more sorbic acid were toxic.

A second experiment was carried out in this plant; the results are shown in Table 2. The SAF was premixed with water to form a paste prior to addition to the brine; no problems were encountered either in mixing or pumping, and the material was kept in suspension during the pumping operation by the normal air jet stirring system in use at the plant. A target concentration of 0.1% sorbic acid in the processed bacon was not obtained because of insufficient pumping; this was not related to the use of sorbic acid per se but was a result of improperly calibrated pumping rates. Calculations of moisture phase NaCl in the finished sorbic acid bacon showed large variations ranging from 1.29–3.38%. Similar large variations were observed in the control bacons (1.62–2.52%) as well as in the conventional nitrite cured bacon (2.10–3.26%). In this experiment, the two bellies showing the longest MST's (no swelling in 180 days) were from the group that was pumped with sorbic acid. toxin tests of cans from these two bellies were negative. Less variation in the MST's of the control and nitrite cured

Table 1—Outgrowth of C. botulinum spores in bacon pumped with sorbic acid: [a]M First experiment, plant A

Belly[b] no.	pH	Sorbic acid (% wet basis)	Can swell time (days) Mean	Range	No./5	No. cans toxic/no. tested
1	5.8	–	14	12-15	5	2/2
2	5.8	–	8	7-9	5	2/2
3	5.8	–	20	18-22	5	2/2
4	5.9	–	9	9-10	5	2/2
5	6.1	–	13	13-14	5	2/2
6	5.9	–	7	6-7	5	2/2
7	5.8	–	6	6	5	2/2
8	5.9	–	6	6	5	2/2
9	6.1	–	6	6-7	5	2/2
10	6.1	–	52	42-70	5	2/2
11	6.0	–	29	18-42	5	2/2
12	6.1	–	18	12-36	5	2/2
13	6.0	–	8	7-9	5	2/2
14	6.2	–	13	13-14	5	2/2
15	6.3	–	27	20-42	5	2/2
16	5.1	0.38	>180	–	0	0/2
17	5.6	0.17	128	128	1	2/2
18	5.2	0.13	>180	–	0	0/2
19	5.5	0.14	>180	–	0	0/2
20	5.2	0.18	>180	–	0	0/2
21	5.7	0.09	13	11-18	5	2/2
22	5.2	0.51	>180	–	0	0/2
23	5.5	0.16	>180	–	0	0/2

[a] Sorbic acid was Monsanto's "Sorbic acid fines." It was added directly to the brine tank.
[b] Bellies 1—10 were prepared with the standard brine in use at the plant less nitrite; bellies 11—15 were prepared with 120 ppm (process target level) nitrite; bellies 16—23 were prepared with brine containing sorbic acid for a target level of 0.2% in the finished bacon.

bellies was noted in this experiment, although the MST's of these treatments overlapped considerably. The nitrite cured bellies appeared to show some correlation of calculated moisture-phase NaCl content with MST (bellies 12 and 13 had the highest salt content and longest MST). This may also have been a reflection of higher ingoing nitrite levels although the residual nitrite concentrations do not indicate this. The other treatments showed no such correlation. The statistical significance of this association was not determined.

Another experiment was conducted in plant B which used a brine higher in salt content than that of plant A. In contrast to plant A, plant B also used sugar and a hydrolyzed plant protein in its curing brine. The significance, if any, of the differences in the two brines was not apparent, however, from our limited studies. In plant B, sorbic acid was added to the brine as a premoistened paste. The target concentration in the finished bacon was 0.125% based on a 5.5% pumping rate and processing back to green weight. In this experiment, we wanted to determine the effectiveness of sorbic acid in a bacon containing less salt than that normally used in this plant; the sorbic acid bellies were compared with control and nitrite-cured bellies which were pumped to target levels of 11%. The results of this experiment are shown in the remaining Tables (3–6).

The MST's and other data from the control bellies from plant B are shown in Table 3. The calculated NaCl levels in these bacons were higher than from plant A due to the higher salt concentration in the brine (17.7% vs 12.5%). There were also large differences in the MST ranging from 11 days for bellies 8 and 11 (the two with nearly the lowest calculated NaCl levels) to over 180 days. There appeared to be a direct correlation between MST and calculated moisture phase NaCl. Thus, bellies 2, 3, 4, 6, 7, 10, 12, 13, and 15 all had NaCl concentrations greater than 6%; only 5 of the 45 cans from these bellies swelled during the test period. Conversely, of those bellies, containing 6% or less NaCl in the moisture phase, 28 of 30 cans swelled during the same period. The calculated correlation coefficient for this relationship was 0.62; this indicated a highly significant correlation ($p < 0.0001$) between MST and the process brine concentration. Toxin tests indicated general agreement with can swelling, although a notable exception was belly 7 which showed toxin in one nonswollen can. We found in other studies (unpublished observations) that 95% of the cans showing gas contained toxin; conversely, 16% of cans showing no gas were toxic. This lack of absolute correlation between toxin and gas formation was noted also by Sofos et al. (1980).

The nitrite-cured bacon from plant B (Table 4) was considerably more resistant to spore outgrowth than that from plant A. This is likely due to the higher salt content of this bacon, since it was shown by Roberts and Ingram (1973) that there was an additive effect of nitrite and sodium chloride on inhibition of *C. botulinum* spore outgrowth. There was one toxic nonswollen can in this group. Correlation coefficients were not calculated but there did not appear to be any relation between residual nitrite content, determined within 24 hr of packaging at the plant, and MST's.

The bellies prepared with the sorbic acid brine (Table 5) had a lower moisture phase NaCl content than that of the controls or nitrite pumped bellies. The actual pump rate for these bellies ranged from 3.5–10%. The sorbic acid content in the processed bacon varied from 0.07–0.16%. The pH's, which were between 5.4 and 5.8, also reflected the extra acidification caused by the sorbic acid. The MST ranged from 7 days for belly 6, which had the lowest sorbic acid content (0.07%), to over 180 days for bellies 11 and 12; these contained 0.14 and 0.16% sorbic acid. Belly 1, with 0.16% sorbic acid, showed only one swollen can during the abuse period; it was non-toxic. These results indicate that 0.14% sorbic acid was sufficient to give complete protection against spore outgrowth for the 6-month abuse period even when the moisture-phase NaCl was below 6.0%. The first experiment in plant A (Table 1) also showed that this level gave protection for the same amount of time. The second experiment in plant A (Table 2) indicated that in some bellies, even lower levels of sorbic acid prevented spore outgrowth for 6 months. Other workers (Sofos et al., 1979a, 1980; Ivey and Robach, 1978) found that levels of

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Table 2—Outgrowth of C. botulinum spores in bacon pumped with sorbic acid[a]: Second experiment, plant A

Belly[b] no.	NaCl[c] in brine	pH	Nitrite ppm (bellies 8—14) or Sorbic acid % (bellies 15—21)	Can swell time (days) Mean	Range	No./5 swollen	Toxic cans/ no. tested
1	2.5	6.4	–	21	19–21	5	2/2
2	2.3	5.9	–	9	7–10	5	2/2
3	2.2	6.2	–	11	10–13	5	2/2
4	2.3	6.4	–	11	10–11	5	2/2
5	2.1	6.4	–	9	8–10	5	2/2
6	2.1	5.9	–	10	10	5	2/2
7	1.6	6.4	–	7	6–8	5	2/2
8	2.2	6.4	9	15	14–17	5	2/2
9	2.4	6.3	9	15	13–17	5	2/2
10	2.3	6.4	15	16	14–17	5	2/2
11	2.1	6.3	15	21	17–21	5	2/2
12	3.3	6.5	18	30	24–43	5	2/2
13	3.3	6.4	18	35	24–50	5	2/2
14	2.2	6.5	30	13	10–17	5	2/2
15	3.4	6.1	0.08	>180	–	0	0/2
16	1.3	6.3	0.03	6	6–7	5	2/2
17	3.2	6.2	0.07	16	11–18	5	0/2
18	2.2	6.0	0.04	19	11–32	5	2/2
19	2.8	6.2	0.06	10	10–11	5	2/2
20	2.4	6.0	0.04	>180	–	0	0/2
21	2.8	6.0	0.04	100	64–146	2	2/2

[a] Sorbic acid was finely ground ("sorbic acid fines" - Monsanto). It was premixed with a small amount of water to form a paste before adding into the brine.
[b] Bellies 1—7 were prepared with standard brine (without nitrite) in use at the plant; bellies 8—14 were pumped with this brine including nitrite, (120 ppm target level), bellies 15—23 were prepared with sorbic acid to a process target concentration of 0.1%.
[c] Calculated from process brine concentration and moisture content of the bacon [original brine was 12.5% NaCl (w/w)].

Table 3—Analytical data on bellies prepared without nitrite or sorbic acid. Plant B.

Belly no.	pH	NaCl in water phase[a] (%)	Can swell time (days) Mean[b]	Range	No./5	No. cans toxic/ no. tested	Flavor score[c] Fresh	Stored
1	6.0	4.4	52	33-65	3	2/2	7.45	7.05
2	5.8	8.6	9	9	1	0/2	6.09	6.05
3	5.9	6.1	51	51	1	1/2	5.59	5.95
4	6.0	6.5	43	43	1	1/3	5.83	5.84
5	5.8	5.5	37	29-54	5	2/2	6.92	6.16
6	5.8	7.9	>180	—	0	0/2	5.71	5.68
7	6.1	7.4	>180	—	0	1/2	6.65	6.21
8	5.9	4.2	11	11-13	5	2/2	6.78	6.11
9	6.0	5.2	14	11-15	5	2/2	6.73	6.67
10	6.0	7.9	30	26-33	2	0/2	5.78	7.00
11	6.0	4.8	11	11	5	2/2	7.00	4.33
12	5.7	6.5	>180	—	0	0/2	6.36	5.06
13	6.0	6.4	>180	—	0	0/2	5.77	6.42
14	5.9	6.0	93	54-138	5	2/2	6.05	6.53
15	5.9	6.2	>180	—	0	2/2	6.50	d

[a] Calculated from process brine concentration and moisture content of bacon (original brine was 17.7% NaCl (w/w)).
[b] For statistical purposes, 180 days was used as the presumed swell time for cans not swelling during this period.
[c] Hedonic, 9-point scale (9 being the most acceptable score). Student t test of flavor scores showed no significant difference ($p < 0.05$) due to storage. Average flavor score, all fresh = 6.35; all stored = 6.08.
[d] Sample was spoiled and was not tested.

Table 4—Analytical data on bellies processed with 120 ppm nitrite[a]

Belly no.	pH	NaCl in water phase(%)	Can swell time (days) Mean	Range	No/5	No. cans toxic/ no. tested	Flavor score[b] Fresh	Stored	NaNO ppm2
1	5.8	5.3	>180	—	0	0/2	6.88	6.42	12
2	6.3	4.3	48	48	1	0/2	6.29	5.95	78
3	6.0	5.8	>180	—	0	0/2	5.88	5.74	34
4	6.1	6.1	>180	—	0	0/2	6.65	5.89	50
5	6.0	3.6	79	58-109	5	2/2	7.30	6.45	17
6	5.9	4.3	>180	—	0	0/2	5.80	5.70	17
7	6.2	5.0	>180	—	0	0/2	6.50	6.05	38
8	5.8	3.9	>180	—	0	0/2	7.33	6.05	14
9	6.0	6.6	>180	—	0	0/2	7.14	6.22	24
10	6.0	4.6	107	107	1	2/2	6.67	7.04	16
11	6.0	4.2	>180	—	0	1/2	6.67	6.65	13

[a] See Table 3 for explanation of data.
[b] Student t test of flavor scores showed a significant ($P < 0.05$) decrease after shortage. Average flavor score, all fresh = 6.54, all stored = 6.20.

Table 5—Analytical data on bellies processed with sorbic acid: Plant B

Belly no.	Sorbic[b] acid %	NaCl in water phase(%)	pH	Can swell time (days) Mean	Range	No/5	No. cans toxic/ no. tested	Flavor score[a] Fresh	Stored
1	0.16	6.5	5.6	47	47	1	0/2	7.00	6.37
2	0.11	3.0	5.8	8	8	5	0/2	6.25	5.53
3	0.12	3.3	5.5	42	42	1	0/2	5.58	5.74
4	0.07	3.7	5.6	5	5	5	2/2	6.36	4.53
5	0.10	3.8	5.7	26	26	3	2/2	6.18	6.67
6	0.10	2.2	5.7	7	7	5	2/2	5.77	6.39
7	0.12	5.6	5.4	97	97	1	0/3	6.90	5.72
8	0.12	5.2	5.5	14	14	1	1/3	6.45	6.33
9	0.11	3.5	5.7	28	28	5	2/2	6.00	6.55
10	0.11	2.8	5.5	9	9	5	2/2	6.22	ND[c]
11	0.16	4.2	5.4	>180	—	0	0/2	6.00	5.65
12	0.14	4.3	5.5	>180	—	0	0/2	6.61	6.50

[a] Student t test of flavor scores showed no significant difference ($p < 0.05$) due to storage. Average flavor score—all fresh = 6.28; Average flavor score—all stored = 6.00.
[b] Sorbic acid was finely ground ("sorbic acid fines" - Monsanto). It was pre-mixed with water to form a thick paste before adding to the brine.
[c] Sample was spoiled (off odor) and was not tested.

Table 6—Analysis of variance, plant B data

Source	d.f.	Sum of squares	Mean square	F	Significance
Treatments	2	20.10	10.05	1.27	n.s.
Bellies (within treatments)	33	261.73	7.93	4.36	$p < 0.005$
Storage	1	36.12	36.12	1.07	n.s.
Storage x Treatment	2	2.86	1.43	1.00	n.s.
Storage x Bellies	33	1112.20	33.70	18.52	$p < 0.005$
Error	1412	2566.38	1.82		

0.20% sorbic acid or 0.26% potassium sorbate were effective in controlling *C. botulinum* spore outgrowth in meat.

The average flavor scores of the nitrite-free bacon from plant B (Table 3) decreased from 6.35 for the fresh bacon to 6.08 after 6 wk storage at 0–2°C. This difference was not statistically significant ($p > 0.05$). There were large variations in flavor scores among the bellies ranging from 5.59–7.45 for the fresh samples and 4.33–7.05 for the stored. Five of the 14 bellies analyzed before and after storage showed apparent increases in flavor scores. This was probably a result of variation inherent in the sensory methodology.

The flavor scores of the nitrite-cured bacon (Table 4) also showed large variations between bellies. Ten of the 11 bellies analyzed before and after storage showed decreased flavor scores after storage. The difference in average flavor scores of the fresh bacon (6.54) and the stored (6.20) was significant ($p < 0.05$).

The flavor scores of the sorbic acid treated bacon (Table 5) were also quite variable and were about the same as those of the control, nitrite-free, bacon. These were slightly lower than the scores for the regular nitrite-cured bacon but the differences were not statistically significant at the 95% confidence level. Storage of the sorbic acid-cured bacon for 6 wk resulted in a lower mean flavor score; the difference, however, was not statistically significant. Similar results were reported by Paquette et al. (1980), who indicated that bacon formulated with 0.26% potassium sorbate and 40 or 80 ppm nitrite was not significantly different in sensory qualities from conventional nitrite cured bacon. In contrast to our results, however, these workers reported no change in flavor scores after storage for 63 days at 4°C.

An analysis of variance of the flavor scores of the plant B bacon, Table 6, showed no significant differences between treatments, nor was there a difference between fresh and stored bacon when all treatments were combined. There were significant differences between bellies. There was also a significant belly-storage interaction; this was a reflection of the lower flavor score of the nitrite-cured bacon after storage.

The judges in these tests were not asked for any comments on the bacon other than their assessment of flavor score; nevertheless, a number of comments were made relating to saltiness. Significantly, there were no comments on rancidity in any of the fresh or stored bacons, nor were there any complaints of irritation or allergic reactions from any of the samples.

These experiments have demonstrated the great variability among bellies used for bacon manufacture. This is due not only to their inherently different fat, moisture, and protein compositions, but also to variations in pumping rate. In plant B, for example, the pumping rate for the control bellies ranged from 106–122% of the green weight with an average of 109%. The pumping rate within each plant is based on the average weights of large numbers of bellies; this results in some bellies being inadequately pumped while others may be overpumped. Such large variations could cause some bacon to contain inadequate amounts of salt or nitrite for protection against *C. botulinum* spore outgrowth. For maximum protection against the possibility of botulism from bacon consumption, the target amount of antibotulinal agent (whether salt, nitrite, sorbic acid, or other chemical) should be based on the lowest pump rate rather than on average rates for several bellies. This, unfortunately, would result in some bellies being overpumped with resultant deleterious flavor changes due to excess salt or other additive.

The experiments reported here showed that insoluble sorbic acid could be pumped into bellies. The resulting bacon was of acceptable sensory quality even though nitrite was omitted; it was also satisfactory for preventing *C. botulinum* spore outgrowth providing that the final concentration of sorbic acid was around 0.13%. Larger scale tests are required to determine its suitability for commercial bacon production. Such a test should take into account the variation to be expected within bellies.

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