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Decreased Dosage of Acidified Sodium Chlorite Reduces Microbial Contamination and Maintains Organoleptic Qualities of Ground Beef Products†

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ABSTRACT

Acidified sodium chlorite (ASC) spray was evaluated at decreased dosages and application rates to determine its efficacy for reducing bacterial contamination on boneless beef trimmings used for production of raw ground beef products while maintaining desirable consumer qualities in the finished ground beef products. Two different applications of ASC (600 ppm applied at a rate of 1.3 oz/lb and 300 ppm applied at a rate of 1 oz/lb) were used to treat boneless beef trimmings before grinding. The effect of ASC treatment on 50/50 lean beef trimmings was greater than on 90/10 trimmings. ASC at 600 ppm reduced both the aerobic plate counts (APC) and *Enterobacteriaceae* counts (EBC) by 2.3 log CFU/g on 50/50 trimmings, whereas treatment with 300 ppm ASC reduced APC and EBC of 50/50 trimmings by 1.1 and 0.7 log CFU/g, respectively. Ground beef formulations of 90/10 and 73/27 were produced from the treated boneless beef trim and packaged in chubs and in modified atmosphere packaging. The efficacy of ASC spray treatment to inhibit APC and EBC over the shelf life of each ground beef product was monitored. The APC and EBC in ground beef chubs were reduced by 1.0 to 1.5 log CFU/g until day 20. The APC and EBC for products in modified atmosphere packaging were reduced 1.5 to 3.0 log CFU/g throughout their shelf life. Both decreased dosages of ASC were equally effective on 90/10 lean ground beef, but the 300 ppm ASC treatment was slightly better at reducing the EBC of 73/27 ground beef. The organoleptic qualities (color, odor, and taste) of the ground beef products treated with 300 ppm ASC were found to be superior to those treated with 600 ppm ASC. Our results indicated that decreased dosages of ASC reduce contamination and lengthen the shelf life of ground beef. Furthermore, the 300 ppm ASC treatment reduced bacterial counts while maintaining desirable organoleptic ground beef qualities.

The degree of bacterial contamination occurring during production of ground beef is higher than that of whole-muscle cuts of beef *(7, 22).* Controlling this contamination is a high priority to the meat industry as well as consumers. A number of recent ground beef recalls were initiated because of contamination with *Escherichia coli* O157:H7 *(1, 16).* Effective interventions to reduce microbial load on beef trimmings used to produce ground beef have been described *(12, 17).* Kang et al. *(11, 12)* have described the merits of a multiple hurdle system to reduce contamination during ground beef production. However, many decontamination treatments of boneless beef trim used for production of ground beef result in ground beef that has undesirable organoleptic qualities, such as an off color and a bitter or sour taste *(18, 23).* Meat processors are exploring alternative interventions to reduce the risk of pathogen contamination of boneless beef trim and ground beef products while maintaining desirable consumer traits.

Acidified sodium chlorite (ASC) is an antimicrobial compound that has been used as a broad-spectrum disinfectant. Interventions that used ASC to effectively reduce contamination of poultry *(13, 14)* and beef products *(4, 20)* have been described. Beginning in 1996, the U.S. Food and Drug Administration (FDA) approved ASC as a secondary direct food additive permitted in food for human consumption to reduce pathogens and extend shelf life of poultry, red meats, seafood, and other raw agricultural commodities (21 CFR 173.325). The FDA-approved concentration for use in the processing of red meat, red meat parts, and organs was stated to be 500 to 1,200 ppm prepared at a final pH of 2.5 to 2.9. Concentrations of ASC used to reduce pathogens on beef trimmings before grinding have been reported at 1,000 to 1,200 ppm applied at rates of 1 to 3 oz/lb *(4, 20).* Although ASC has been shown to be effective at reducing pathogen contamination of beef trim when used at these dosages, the ground beef produced from this treated trim can be discolored and have a nontypical taste *(2).* Therefore, the goal of these experiments was to determine whether decreased dosages of ASC would still produce satisfactory microbial reductions in boneless beef trimmings

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† Names are necessary to report factually on available data; however, the U.S. Department of Agriculture neither guarantees nor warrants the standard of the product, and the use of the name by U.S. Department of Agriculture implies no approval of the product to the exclusion of others that may also be suitable.

and finished ground beef and extend shelf life of the ground beef products while maintaining desirable qualities of odor, color, and taste.

MATERIALS AND METHODS

Experimental design. A 3 (treatment group) × 2 (product type) × 2 (lean percentage) factorial arrangement of a completely randomized design was analyzed. The three treatment groups consisted of T1, a no-treatment control; T2, 600 ppm ASC as SANOVA (Alcide Corp., Redmond, Wash.) applied at a rate of 1.3 oz/lb of boneless beef trim; and T3, 300 ppm ASC applied at a rate of 1 oz/lb of boneless beef trim. The two finished product types were ground beef chubs and ground beef in modified atmosphere packaging (MAP). The lean percentages examined were 90/10 and 50/50 for treated boneless beef trim and 90/10 and 73/27 for the finished ground beef products. Aerobic plate counts (APC) and *Enterobacteriaceae* counts (EBC) were evaluated every 5 days for chub products (shelf life, 20 days) and every 4 days for MAP products (shelf life, 12 days). On day 0, samples of pre- and posttreated boneless beef trim were also examined for APC and EBC.

ASC treatment of boneless beef trim and production of ASC-treated ground beef products. ASC was prepared and applied according to the recommendations of the manufacturer. The described dosages of ASC were applied to boneless beef trim by the SANOVA Red Meat Parts and Trim Application System. This device is a continuous production treatment system screw conveyer auger designed to apply ASC spray to boneless beef parts and trim as they are conveyed through the screw conveyer auger. This system was used to treat 50/50 trim and 90/10 trim before grinding. Treated, boneless beef trim was blended in a standard American Food Equipment Co. (Hayward, Calif.) paddle blender, transferred to a mixer grinder (model-1109, Weiler & Co., Whitewater, Wis.), and then ground according to industry standards. Ground beef products of two specific fat percentages (90/10 and 73/27; 10% and 27%, respectively) were produced with the use of the treated boneless beef trim: 90/10 and 50/50. Treated and untreated 90/10 boneless beef trim was used without the addition of fat trim (50/50) to produce the 10% fat ground beef products. Twenty-seven percent ground beef (73/27) was produced by combining a percentage of 90/10 boneless beef trim with 50/50 boneless beef fat trim to achieve a blended 27% fat ground beef product. The treated and control ground beef were packaged in 5-lb chubs and 1-lb MAP products. The modified atmosphere was 80% $O_2$and 20% CO_2 and was packaged in Ecowrap G90 (Maptech Packaging, Hilton Head, S.C.) oxygen-impermeable film.

Trim sampling. Trim samples were taken sequentially before and after treatment (pre- and postauger, respectively) from the same lot of raw material. Ten pieces of trim were randomly chosen from the treatment conveyer. The surfaces of each piece were aseptically trimmed away for collection and composited into a sterile Whirl-Pak bag (Nasco, Fort Atkinson, Wis.) until a final composited sample weight of 375 g was obtained.

Ground product sampling. Twenty-five-gram ground beef samples were aseptically obtained from a standard ⅛-in. grind of the two treatment groups and control. A minimum of 125 g (five samples of 25 g) was collected for each standard grind sample. Ground products, either 5-lb chubs or 1-lb MAP products, were stored in the dark at a target temperature of 2°C. Chubs were sampled on days 1, 5, 10, 15, and 20 and MAP on days 1, 4, 8, and 12. On each sampling day, five packages of each product type from each treatment group were opened and aseptically sampled for a total of five samples per treatment group per lean percentage.

Microbiological sample processing. Day 0 trim samples were aseptically placed in a meat mincer (model MG-12, Davpol Enterprises, Inc., New York, N.Y.) fitted with a coarse (¼-in.) grinding blade. In order to avoid possible transfer of residual ASC between treatment types, separate grinding augers and blades were used for each treatment type. The grinding augers and blades were cleaned between uses by thorough washing with detergent in 60°C water and two rinses in distilled water. Each ground trim sample was aseptically collected from the grinder in a Whirl-Pak bag. Two 25-g portions of each ground trim sample were placed in a Whirl-Pak membrane stomacher bag with 50 ml of either bioMérieux (Hazelwood, Mo.) general-purpose medium (GPM)–Plus supplemented with 18 g/liter dextrose (for a final concentration of 2% dextrose) or bioMérieux entero medium (EM) and stomached for 1 min. Stomached samples were drawn from the filter side of the bag for use in APC and EBC determinations. Ground products from each sampling day were processed in a manner similar to the ground trim samples.

APC and EBC determinations. APC and EBC were performed by impedance measurements obtained with a bioMérieux Bactometer. One milliliter was removed from each stomached sample and placed undiluted into the Bactometer module wells for measurement. Samples processed in GPM-Plus were used for APC determination, and samples processed in EM were used in EBC determination. The Bactometer incubated samples for 16 h at 37°C while measuring the initial detection time (IDT) for each sample. Each IDT was converted to a log CFU per milliliter value with the use of a standard curve derived for each test. The standard curves were determined by performing quadratic regression analyses of IDTs and corresponding log CFU per milliliter values that had been determined with 3M Microbiology (St. Paul, Minn.) Petrifilm-AC for APC or Petrifilm-EB for EBC. The Petrifilms were incubated according to manufacturer recommendations, and bacteria were counted manually. Samples for the standard curve consisted of serial dilutions of ground trim from day 0. The APC standard curve comprised 87 independent sample points, and quadratic regression yielded APC = $(0.02517 \times IDT^2) - (0.85 \times IDT) + 7.80$ CFU (correlation = 0.97). EBC comprised 108 independent sample points and yielded EBC = $(0.04354 \times IDT^2) - (1.20 \times IDT) + 8.24$ CFU (correlation = 0.94).

Sensory odor, color, and taste. A sensory panel was used to evaluate sensory odor and color characteristics of raw MAP ground beef products and odor, color, and taste characteristics of cooked MAP ground beef products *(9)*. Sensory evaluation panelists consisted of experts with extensive experience in production of MAP ground beef. On the specified days, panelists rated overall odor and color of raw 90/10 and 73/27 products and rated the overall odor, color, and taste of the same products cooked. The responses of the panelists were divided into either ''typical'' or ''nontypical'' of ground beef. Responses assigned as nontypical were sour for odor; off-color for color; and bitter, sour, salty, and sweet for taste. Analysis showed no differences between time points or between 73/27 and 90/10 products; therefore, all data sets were combined for presentation in Table 1.

Statistical analysis. APC and EBC of trim were analyzed by analysis of variance with GLM procedures (SAS Institute Inc., Cary, N.C.) for a 3 (treatment) × 2 (product) × 2 (sampling location, pre- or postauger) factorial arrangement of a completely randomized design. The model included the main effects of treatment and sampling location. Data were analyzed by analysis of variance with GLM for 3 × 5 and 3 × 4 (treatment × day) factorial arrangements for chub and MAP ground beef, respec-

tively. The model included the main effects of treatment and day. Pairwise comparisons of frequencies of the organoleptic qualities of raw and cooked ground products were made by PROC FREQ and Mantel-Haenszel chi-square analysis (SAS).

RESULTS AND DISCUSSION

Effect of ASC treatments on APC and EBC of trim before grinding. Until recently, antimicrobial interventions have focused either on carcasses treated with lactic acid, hot water, or steam or on ground beef treated with irradiation. Because boneless beef trim undergoes considerable handling, contamination and transfer of bacteria are more likely to occur. Interventions that target boneless beef trim before grinding are now recognized as a practical point of treatment because this is the last stage of processing before grinding *(11, 17, 19).* We examined the effects of ASC treatments on 90/10 and 50/50 (lean-to-fat ratio) boneless beef trim before grinding (data not shown). Samples were taken from trim before entering and after exiting the treatment conveyer auger. After passage through the treatment conveyer auger without ASC (T1), the APC and EBC of boneless beef trim was unchanged ($P > 0.05$). Treatment with 300 ppm ASC (T3) reduced ($P < 0.05$) the APC and EBC of 50/50 trim by 1.1 and 0.7 log CFU/g, respectively. The subsequent treatment regime with the higher concentration of ASC at 600 ppm (T2) resulted in greater reductions ($P < 0.05$) of bacterial contamination. T2 reduced ($P < 0.05$) both APC and EBC of 50/50 trim by 2.3 log CFU/g. It has previously been noted that antimicrobial interventions appear more effective on adipose tissues compared with lean tissues *(5, 6, 11).* Our observations followed this pattern as well. When 90/10 trim was used, no significant reductions ($P > 0.05$) in APC or EBC following T3 or in EBC following T2 were observed. T2 reduced ($P < 0.05$) the APC of 90/10 trim by 1.0 log CFU/g. Variations in the initial levels of the bacterial content of the two types of boneless beef trim cannot account for the differences observed. The average initial bacterial levels on the 90/10 trim were slightly, although not significantly ($P > 0.05$), higher than the initial bacterial levels on the 50/50 trim. The APC was 0.4 log CFU/g higher (5.1 versus 4.7 log CFU/g), and the EBC was 0.3 log CFU/g higher (2.5 versus 2.2 log CFU/g) on the 90/10 trim compared with the 50/50 trim. Reports suggest a combination of surface chemistry and pH could account for the increased efficacy of interventions on adipose tissues. Less bacterial attachment is observed on adipose tissue surfaces compared with lean tissue surfaces *(5, 6),* suggesting lean tissues with greater numbers of bacteria initially attached and bacteria that might be attached more firmly, so as to be more resistant to antimicrobial removal *(11).* Additionally, adipose tissue maintains a lower pH than does lean muscle tissue following acidic treatments, thus providing potentially greater in situ inactivation of any bacteria present *(11).*

Other potential sources of the variation observed in the boneless beef trim measurements could be because the trim used in our experiments (i) had varying surface areas compared with its weight and (ii) had to be ground separately before microbiological testing. In an attempt to control for surface area variations, surfaces were trimmed away for sampling as consistently as possible, but unavoidable differences in the depth of cut to remove the surfaces occurred. These variations contributed to the overall weight of the samples, thus affecting the data generated. It was necessary to grind the boneless beef trim surface samples for APC and EBC determinations. Because of time constraints on sample processing, the augers and blades of the laboratory grinder were not sterilized by autoclave between samples; rather, each treatment group was assigned to a separate auger and blade that was thoroughly washed and rinsed between samples. This system might have allowed carryover of bacteria between samples of the same treatment type. However, the variation between samples of each type was small (APC, SEM = 0.2; EBC, SEM = 0.3), suggesting that any error introduced by sample weight or potential lack of sufficient sanitation of the grinding equipment also was small.

Treatment of beef trim with ASC has been described at levels of 1,000 ppm applied at rates of up to 3 oz/lb *(20).* Others have reported using ASC at levels of 1,200 ppm to treat carcass surfaces *(4).* The levels of reduction in these reports were described to be consistently greater than 2.0 log CFU/g for *E. coli* and greater than 1.0 log CFU/g for APC. Ransom et al. *(19)* observed reductions of 2 log CFU/g of *E. coli* O157 inoculated on trim pieces treated by dipping for 30 s in 0.02% (200 ppm) ASC. The lean percentages of trim used in the above-mentioned studies were not provided, so direct comparisons cannot be drawn. Our data show that treatment of trim with 600 ppm ASC applied at a rate of 1.3 oz/lb produced similar reductions of APC and EBC (2 log CFU/g) in the case of 50/50 boneless beef trim and a 1-log CFU/g reduction of APC on 90/10 boneless beef trim. For comparison, Pohlman et al. *(17)* showed that multiple-step interventions that used 5% acetic acid followed by 0.5% cetylpyridinium chloride (CPC) reduced APC on boneless beef trim by 1.8 log CFU/g. Chlorine dioxide (200 ppm) followed by 0.5% CPC reduced APC on boneless beef trim by 1.2 log CFU/g, and 0.5% CPC followed by 10% trisodium phosphate reduced APC on boneless beef trim by 0.9 log CFU/g.

Effect of ASC treatment of trim on APC and EBC during shelf life of ground beef products. Reducing bacteria in ground beef has proven to be challenging because boneless beef trimmings can be recontaminated by spoilage bacteria and/or pathogenic bacteria during carcass fabrication *(10).* As noted by Kang et al. *(11),* during the production of ground beef, the contaminated surfaces of the boneless beef trim are diluted by the overwhelming amounts of sterile meat from the interior. The opposite was also noted; that is, contaminated surface tissue becomes mixed with previously sterile tissue. Therefore, applying an antimicrobial process to trim offers a means of reducing the final source of surface contamination before grinding. The treated and control trim in our experiments were ground into two formulations: 90/10 and 73/27 lean ground beef. Each ground beef product was packaged and stored in 5-lb chubs and 1-lb MAP products, and their microbial status was eval-

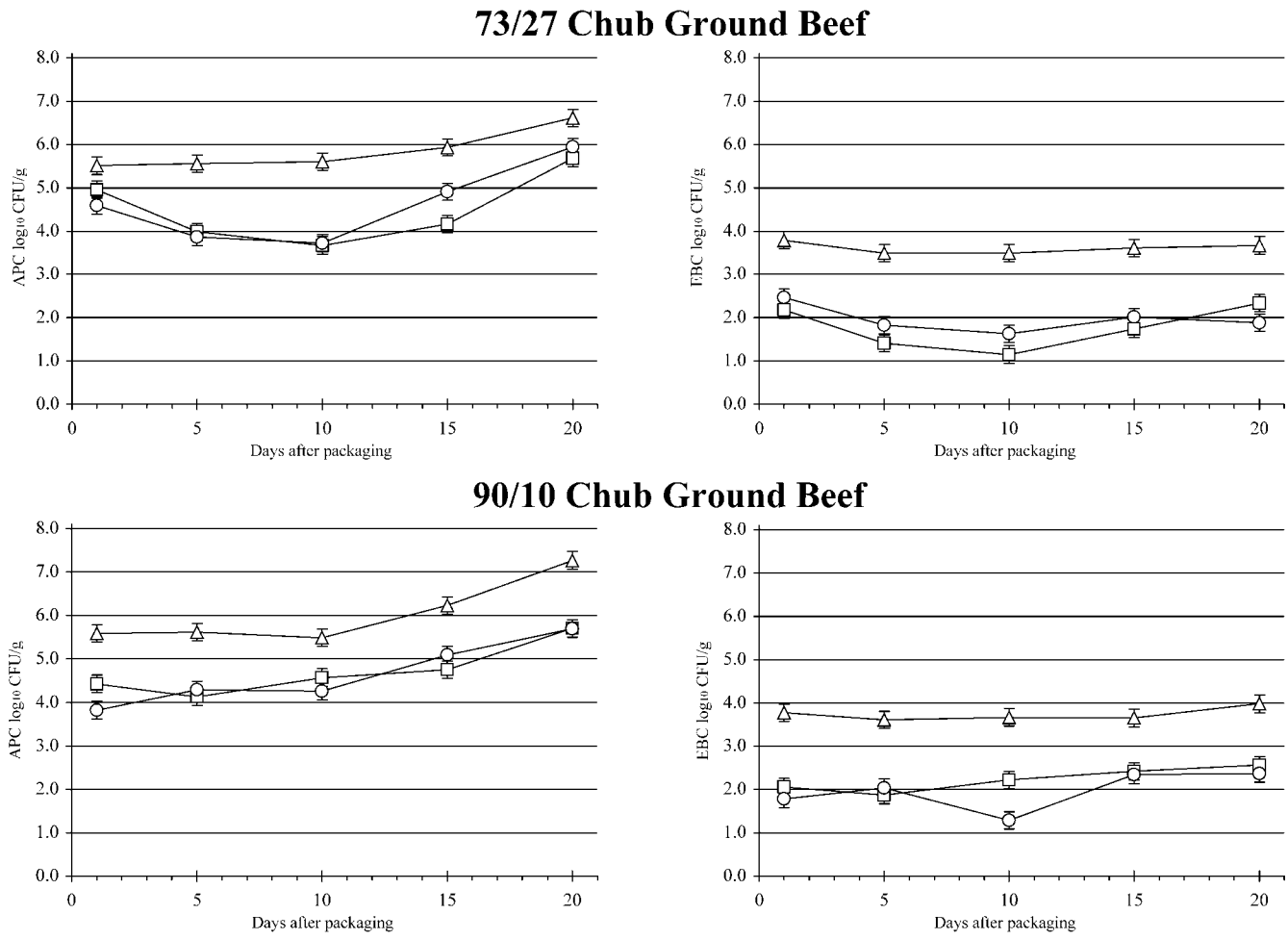

FIGURE 1. *Effects of acidified sodium chlorite (ASC) treatments on the aerobic plate counts (APC) and* Enterobacteriaceae *counts (EBC) of 90/10 and 73/27 ground beef stored as chubs at 2°C and sampled periodically over a shelf life of 20 days. Treatment 1 (△) was the nontreated control, treatment 2 (□) was application of 600 ppm ASC at a rate of 1.3 oz/lb beef trim, and treatment 3 (○) was application of 300 ppm ASC at a rate of 1 oz/lb beef trim. Each point represents the mean of samples taken from five individual packages at each day indicated. Error bars indicate SEM for each point.*

uated periodically over the shelf life of each. Whereas T2 demonstrated greater reductions in the trim compared with T3, the differences between the two treatments were only occasionally and slightly different when the microbial status of the ground beef products was examined.

After production, ground beef chubs stored at 2°C can have a shelf life of 17 to 20 days. In our experiments, the ground beef packaged in chubs was examined periodically for 20 days to assess the antimicrobial effects of ASC. The APC and EBC of ASC-treated 90/10 and 73/27 ground beef were significantly lower ($P < 0.05$) than the APC and EBC of the nontreated control ground beef (Fig. 1). Chubs of 73/27 control ground beef made from untreated boneless beef trim had APC that increased from 5.5 log CFU/g on day 1 to 6.6 log CFU/g on day 20, whereas EBC remained unchanged during the same time span (3.8 log CFU/g on day 1 and 3.7 log CFU/g on day 20). Compared with control ground beef, the bacterial counts of ground beef made from ASC-treated boneless beef trim were consistently lower ($P < 0.05$) throughout the time span examined. The APC of treated 73/27 chub ground beef was 0.5 to 1.5 log CFU/g lower, and the EBC was 1.0 to 2.0 log CFU/g lower. Similar results were observed in the 90/10 chub ground beef.

The shelf life of ground beef packaged in MAP stored at 2°C is 10 to 12 days. In all instances, both formulations of ground beef had APC and EBC that were significantly reduced ($P < 0.05$) by T2 and T3 (Fig. 2). The APC reductions in treated 73/27 MAP ground beef ranged from 1.8 to 3.8 log CFU/g, and the EBC reductions ranged from 2.0 to 3.0 log CFU/g. The reductions of APC and EBC measured in 90/10 MAP ground beef were not as great as those in the 73/27 MAP ground beef but were still greater than those observed in 90/10 ground beef chubs. APC reductions in the 90/10 MAP ground beef ranged from 1.6 to 3.9 log CFU/g, and EBC reductions ranged from 1.7 to 2.8 log CFU/g.

The ground beef stored in MAP showed reductions of APC and EBC that were greater than those observed in chubs. MAP with high CO_2 and high O_2 concentrations has been shown to produce initial reductions of bacterial numbers compared with chub packaging of the same product *(15)*. Modified atmospheres have been known to alter a

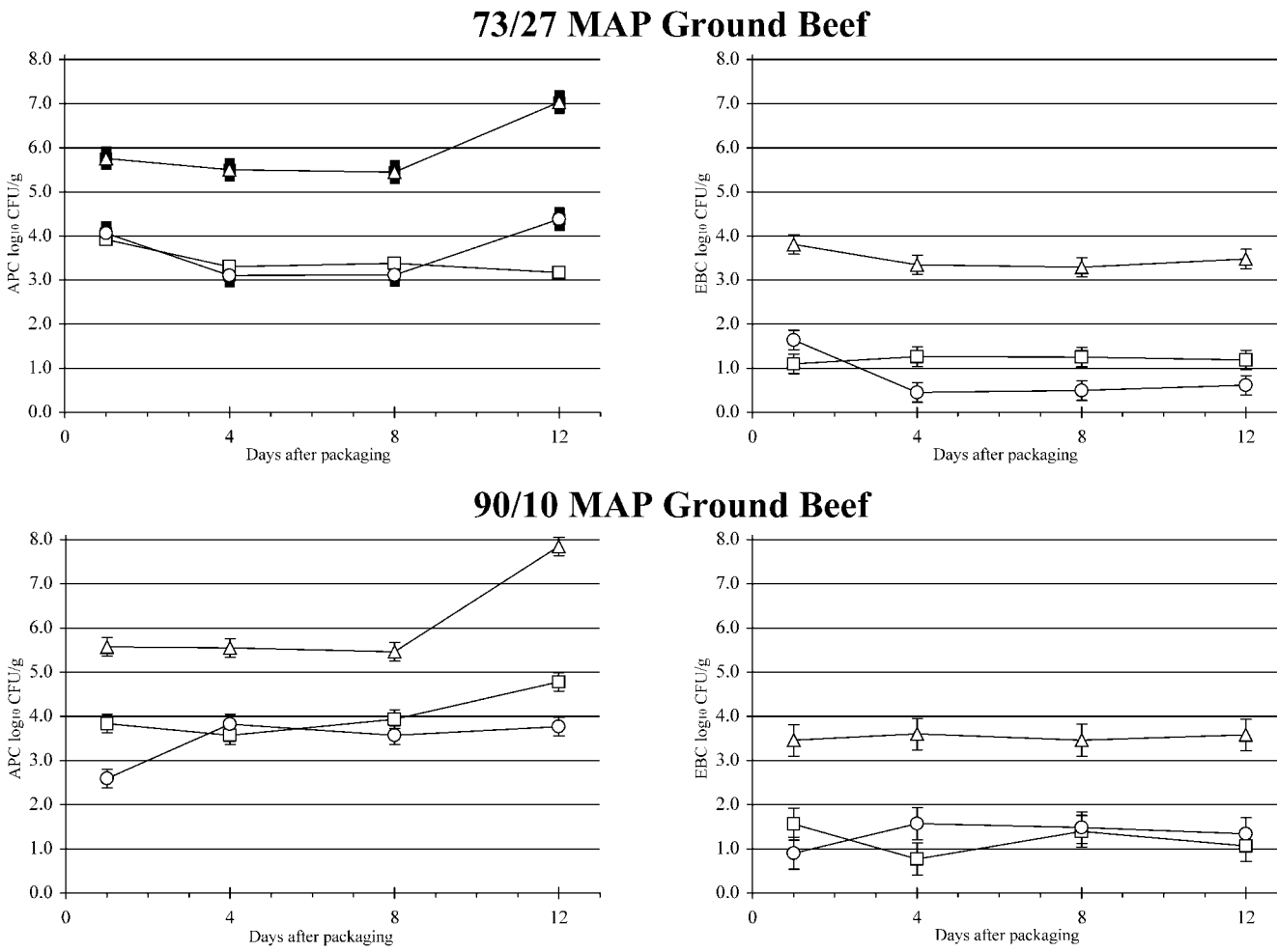

FIGURE 2. *Effects of acidified sodium chlorite (ASC) treatments on the aerobic plate counts (APC) and* Enterobacteriaceae *counts (EBC) of 90/10 and 73/27 ground beef stored at 2°C in modified atmosphere packaging (MAP) periodically sampled over shelf life of 12 days. Treatment 1 (△) was the nontreated control, treatment 2 (□) was application of 600 ppm ASC at a rate of 1.3 oz/lb beef trim, and treatment 3 (○) was application of 300 ppm ASC at a rate of 1 oz/lb beef trim. Each point represents the mean of samples taken from five individual packages at each day indicated. Error bars indicate SEM for each point.*

number of environmental factors that affect and repress bacterial growth; for example, replacing oxygen with CO_2 prevents the growth of strict aerobes and slows the growth of facultative anaerobes. Additionally, increased CO_2 has been shown to possess a specific antimicrobial action itself. *Pseudomonas* spp., for instance, are sensitive to concentrations of CO_2 as low as 5% *(8)*.

Comparing treatments T2 and T3 in 73/27 and 90/10 ground beef showed that treatment T3 was no better than treatment T2 in reducing APC and EBC ($P > 0.05$) in ground beef packaged in chubs. In the case of MAP ground beef products, neither treatment T2 nor treatment T3 yielded better results on APC than the other over the 12-day time span examined ($P > 0.05$). EBC of MAP ground beef products showed that neither treatment performed better than the other in 90/10 ground beef ($P > 0.05$), but in the 73/27 MAP ground beef, T3 produced a significantly greater, albeit small, effect on EBC than did T2 during days 4 to 12 of storage ($P < 0.05$).

APC levels increased over the shelf life of the ground beef, whereas EBC remained unchanged. Both control formulations of chub ground beef had an initial (day 1) APC of 5.6 log CFU/g. These levels remained unchanged until day 10, after which APC growth was noted. In the T2 and T3 ground beef chubs, growth was also noted after day 10. Increases between days 10 and 20 ranged from 1 to 2 log CFU/g. In the case of 90/10 ground beef, the APC levels increased 1.3 and 1.9 log CFU/g, whereas in the 73/27 chub ground beef, APC increased 2.0 and 2.1 log CFU/g. While stored in MAP, the APC of both formulations of untreated ground beef increased by 1.5 to 2.0 log CFU/g between days 8 and 12 of storage. The APC of T3 73/27 MAP ground beef and of the T2 90/10 ground beef increased by 1 log CFU/g, whereas the alternative treatments of those MAP products remained unchanged. The reason for this difference between formulations of ground beef and treatments in MAP ground beef is unclear but might have been related to sample collection and shipment before laboratory processing. Nevertheless, increases in APC at days 8 and 10 are not unusual and likely represent the outgrowth of aerobic spoilage bacteria *(3)*. The reduction in the initial levels of bacteria, though, suggests that the volatile compounds produced by spoilage bacteria would be delayed, so as to lengthen shelf life quality of ground beef made from

TABLE 1. *Overall effects of decreased dosages of acidified sodium chlorite (ASC) on organoleptic qualities of MAP ground beef*[a]

		Percent typical[d]				
		Raw		Cooked		
Product[b]	Treatment[c]	Odor	Color	Odor	Color	Flavor
90/10	T1	86 A	98 A	95 A	97 A	58 A
	T2	67 B	41 B	78 B	91 A	40 B
	T3	90 A	89 A	94 A	89 A	59 A
73/27	T1	73 A	83 A	97 A	92 A	58 AB
	T2	52 B	15 B	81 B	90 A	47 B
	T3	80 A	83 A	95 A	96 A	63 A

[a] A sensory panel was used to evaluate the characteristics of raw and cooked ground beef products.

[b] Products tested were 90/10 MAP ground beef and 73/27 MAP ground beef; products were tested on days 5, 8, and 12 after production. No significant ($P < 0.05$) differences were noted between products or days.

[c] Treatment T1 was nontreated control; treatment T2 was application of 600 ppm ASC at 1.3 oz/lb of beef trim before grinding; treatment T3 was application of 300 ppm ASC at 1 oz/lb of beef trim before grinding.

[d] Values represent average percentage of responses for typical. Nontypical responses included sour for odor; off-color for color; and bitter, sour, salty, and sweet for taste. Values of a given quality within a common product type with common letters are not significantly different ($P > 0.05$).

ASC-treated boneless beef trim. The observation of aerobic bacterial growth over *Enterobacteriaceae* growth in the controls and in treated ground beef is expected as well and has been described in modified atmospheres composed of 20% CO_2. Aerobes and facultative aerobes such as lactic acid bacteria, *Brochothrix thermosphacta*, and *Pseudomonas* spp. reached high levels in meat stored in MAP compared with *Enterobacteriaceae*, the growth of which lagged behind that of the aerobes *(15, 21)*.

There is little in the literature concerning the efficacy of ASC treatment of boneless beef trim and ground beef. Our results found ASC treatments typically caused reductions of APC and EBC that were twofold greater than those reported for other single-step interventions on trim before grinding. Trim interventions composed of 5% lactic acid, 10% trisodium phosphate, or 0.5% CPC reduced APC by 0.6 log CFU/g and coliforms and generic *E. coli* by 0.6 to 0.8 log CFU/g in finished ground beef *(18, 23)*. The reported reductions cannot be compared directly with ASC treatment results because of differences in the ground beef composition (85/15) and storage conditions (7 days simulated retail display). In their study of combination interventions, Pohlman et al. *(17)* described reductions of APC after 7 days of simulated retail storage of 90/10 ground beef made from beef trimmings treated with combinations of acetic acid followed by CPC and with chlorine dioxide followed by CPC (APC reductions of 1.8 and 1.2 log CFU/g, respectively) that were similar to those we observed with ASC. A single intervention of 300 ppm ASC is as effective as these combination treatments and superior to any of the described single-step treatments.

Effect of ASC treatment on odor, color, and taste of ground beef products. The ideal method to decrease bacterial counts on meat would, according to Jimenez-Villarreal et al. *(10)*, substantially reduce bacterial numbers while keeping discoloration and cooked off-flavors to a minimum. Trim interventions that use heat or denaturants can have adverse effects on color and protein qualities *(11)* because the exposed muscle tissues (of boneless beef trim) are more sensitive to these treatments than are the adipose and fascia tissues of intact carcasses. Various chemical interventions with artificially contaminated trim have been described with varying levels of success in maintaining desirable sensory qualities such as color and odor. Despite a number of reports on the antimicrobial effectiveness of ASC as a beef trim intervention, its effects on ground beef quality have not been reported. However, various segments of the beef industry have investigated its use and found that treatments that use ASC at a concentration of 1,000 ppm applied at the rate of 1.5 oz/lb boneless beef trim adversely affect the organoleptic qualities of ground beef made from that trim *(2)*.

In our experiments, samples of MAP ground beef were analyzed on days 5, 8, and 12 after the initial treatment day to determine the effects of ASC treatments on the organoleptic properties of fresh and cooked ground beef products. The samples were analyzed in a raw state for color and odor and, after being cooked, for color, odor, and flavor (Table 1). The data clearly show that treatment with ASC at 600 ppm had a significant effect ($P < 0.05$) on both color and odor when compared with the control group. When the control and treatment group ground beef was cooked and evaluated, the 600 ppm ASC–treated group was again significantly different ($P < 0.05$) from the control and the 300 ppm ASC–treated ground beef with regard to odor and flavor. No difference ($P > 0.05$) was observed in cooked color. The differences in odor were less pronounced in the cooked product than in the raw product, but the 600 ppm ASC–treated group was different ($P < 0.05$) from control, and the 300 ppm ASC–treated group was not ($P > 0.05$). The flavor of 300 ppm ASC–treated ground beef was scored as typical or better compared with the untreated control. This observation, made at days 8 and 12, suggests that ASC treatments controlled spoilage bacteria that adversely affected the untreated control ground beef. The effects of other single-treatment antimicrobial interventions on beef trim before grinding have been described. Those studies compared CPC, trisodium phosphate, chlorine dioxide, and lactic acid, but not ASC *(10)*. It was found that, like the 300 ppm ASC treatment, CPC and trisodium phosphate not only improved ground beef safety by reducing contamination but also enhanced ground beef quality without adverse effects.

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