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Microbial and Quality Attributes of Ground Pork Prepared from Commercial Pork Trim Treated with Combination Intervention Processes†

MAURICIO M. CASTELO,‡ MOHAMMAD KOOHMARAIE, AND ELAINE D. BERRY*

United States Department of Agriculture, Agricultural Research Service, Roman L. Hruska U.S. Meat Animal Research Center, P.O. Box 166, Clay Center, Nebraska 68933 USA

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ABSTRACT

The effects of combination intervention treatments of commercial pork trim on microbial and quality attributes of the subsequent ground pork were examined. Fresh commercial pork trim was inoculated with swine feces and subjected to five different intervention treatments: (i) control (untreated), (ii) water (15°C, 120 s), (iii) water followed by 2% lactic acid wash (15°C, 75 s), (iv) Combination 1 (water plus lactic acid plus hot air [510°C, 90 s]), and (v) Combination 2 (hot air plus water plus hot air). Following treatment, the pork trim was stored at 4°C for 24 h, then ground, stuffed, vacuum packaged, and stored at 4°C for 21 days. Populations of aerobic bacteria, coliforms, *Escherichia coli,* and lactic acid bacteria in the ground pork were monitored before treatment, after treatment (day 0), and at 2, 7, 14 and 21 days. In addition, uninoculated pork trim was treated as described above, and the color and emulsion stability of the ground product was evaluated. Ground pork prepared from trim treated with any of the treatment processes had lower initial microbial populations compared to the untreated samples. The applications of water plus lactic acid or Combination 1, which included a lactic acid wash, were more effective than water or Combination 2 at both reducing initial populations and suppressing the growth of aerobic bacteria, coliforms, and *E. coli* in ground pork during refrigerated storage. By day 21, populations of aerobic bacteria in ground pork prepared from control, water-treated, and Combination 2–treated trim were 8.22 to 8.32 log CFU/g, but in water plus lactic acid and Combination 1 ground pork, populations were 6.32 and 4.90 log CFU/g, respectively. Among the trim interventions examined, Combination 1 was most detrimental to the color and emulsion stability of the ground pork. The water plus lactic acid treatment provided the greatest microbial reduction and inhibition without large negative effects on quality attributes of the ground pork.

The occurrence of foodborne illness associated with meat products and the recent U.S. implementation of pathogen reduction legislation has resulted in increased efforts to reduce the extent to which raw meat becomes contaminated with pathogenic bacteria during the slaughtering process *(32).* Procedures investigated for use in the removal and reduction of fecal and microbial contamination on meat include steam vacuuming, steam pasteurization, dry heat desiccation, and spray washing at various pressures using water, hot water, or numerous sanitizing solutions, such as organic acids, trisodium phosphate, chlorine compounds, hydrogen peroxide, sodium bicarbonate, and cetylpyridinium chloride *(2, 3, 6–12, 14, 18, 20, 24, 25, 27, 30).* Many of these antimicrobial intervention procedures are currently used by the meat processing industry, and are primarily used on the freshly slaughtered animal carcass. However, in the normal process of fabricating the carcass, there are opportunities to not only spread any remaining bacterial contamination but to introduce contamination from equipment, tools, and personnel *(26).* In the process of fabrication and trimming, the surface area of cut muscle is increased and microorganisms become distributed throughout the product *(1, 16).* Bacteria on beef trim can disperse into purge in combos and be distributed to previously uncontaminated trim *(15).* Bacterial contamination is distributed further in the grinding process *(1, 16).* These occurrences are reflected in the higher numbers of microorganisms and shorter shelf life typically observed with fresh ground meat products compared to whole-muscle meat cuts.

Applying antimicrobial processes to meat trim would provide additional means of reducing bacterial contamination prior to grinding, thus increasing the product shelf life and reducing the probability of pathogen presence in the ground product. Trim production is an appropriate location for such interventions because it typically is the last step in fabrication involving physical handling prior to packing the trim into combos or grinding. Recent works have indicated that antimicrobial treatments applied to meat trim could be useful for reducing bacteria, including pathogens, in both ground beef and pork *(4, 5, 17, 19, 22, 23).* To preserve such quality attributes as color and quality of the ground meat, a trim intervention approach that combines shorter, sequential exposures of antimicrobial treatments might be more appropriate *(4, 22, 23).* In our previous study, the application of combination treatment processes for the microbial decontamination of both lean and fat pork

* Author for correspondence. Tel: 402-762-4204; Fax: 402-762-4109; E-mail: berry@email.marc.usda.gov.

† Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

‡ Present address: Lopez Foods Incorporated, 9500 N.W. 4th Street, Oklahoma City, OK 73127, USA.

trim surfaces was evaluated *(4)*. This previous study showed that although combination intervention treatments, including water washes, hot water washes, 2% lactic acid washes, and hot air, were effective in reducing microbial contamination, the use of hot water in any of the treatments generally resulted in a decrease in emulsion stability and affected the color of the ground pork. The objective of the current work was to expand our previous observations to include the application of interventions to commercially fabricated pork trim and to evaluate alternative combination intervention processes that could reduce microbial contamination without compromising quality attributes such as color and emulsion stability of the resultant ground pork.

MATERIALS AND METHODS

Pork trim collection and inoculation. Fresh trim fabricated from chilled pork carcasses was obtained from the abattoir at the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, NE. The pork trim was of 80% lean and 20% fat content, and individual trim pieces were not larger than ca. 15 by 20 by 2.5 cm.

On each day of an experimental replicate, inocula were prepared from fresh feces collected from three pigs. A three-pig composite fecal slurry was prepared by pooling 50 g of each fecal sample and mixing with 300 ml of sterile distilled water (1:2). The fecal slurry was mixed using a sterile tongue depressor for 2 min and filtered using a sterile filtered stomacher bag (Spiral Biotech, Bethesda, Md.). Ten milliliters of the filtered slurry was used to inoculate separate ca. 800-g portions of pork trim and was kneaded into the trim for 3 min using gloved hands to distribute the slurry over the trim surfaces. The inoculated trim was incubated overnight at 4°C prior to experiments to approximate the short period of refrigerated storage of the trim that typically occurs prior to grinding in-house or during transport of the trim to a grinding facility *(23)*. The inoculated pork trim was then subjected to intervention strategies as described below.

Evaluation of combination intervention treatments. The trim intervention table and chamber used to apply the treatments have been described by Kang et al. *(23)*. The table is identical in scale to an industrial fabrication table and was designed for testing the application of antimicrobial interventions to meat trim, including pressurized applications of cold and hot water and antimicrobial solutions and application of hot air. The spray-washing treatments were applied with a spray bar oscillation rate of 60 passes/min. The chain speed was 1 cm/s. Hot air was applied in an in-line hot air cabinet fitted with three heat guns (Varitemp, Master Appliance Corp., Racine, Wis.).

The inoculated commercial pork trim was treated using a split-plot in time design with intervention treatments as the main plot and storage time as the split-plot in time factor. Five different intervention treatments were evaluated as follows: (i) control (untreated); (ii) water wash (15°C, 65 lb/in^2, 120 s); (iii) water followed by 2% (vol/vol) lactic acid (15°C, 35 lb/in^2, 75 s); (iv) Combination 1 (water plus lactic acid plus hot air [510°C, 90 s]); and (v) Combination 2 (hot air plus water plus hot air). Following treatment, the pork trim was placed in separate plastic bags and stored at 4°C for 18 to 20 h. Following this overnight refrigerated storage, the trim was ground, first through a 1-cm grinder plate followed by a 0.5-cm grinder plate (model MG12, Davpol Enterprises, Inc., New York, N.Y.). The ground pork was manually stuffed into nylon-polyolefin casing with an oxygen transmission rate at 23°C of 31 cm^3/m^2/24 h/atm (454 g/package; Visflex casing, Viskase, Chicago, Ill.), vacuum-sealed (model LV10G; Hollymatic, Inc., Countryside, Ill.), and stored at 4°C. This experiment was replicated six times on six separate days.

Sampling and microbial analysis. Microbial populations in the ground pork were determined before treatment, after treatment (day 0), and at 2, 7, 14, and 21 days after storage at 4°C. At each sampling time and from each treatment, a 50-g sample of ground pork was taken aseptically and placed into a sterile, filtered stomacher bag containing 50 ml of sterile buffered peptone water (BPW; Difco, Becton Dickinson Microbiology Systems, Sparks, Md.) with 0.1% Tween 20 (Sigma, St. Louis, Mo.). The sample in the bag was pummeled in a Model 400 stomacher (Tekmar, Inc., Cincinnati, Ohio) for 2 min. Appropriate sample dilutions were made in BPW. For the determination of aerobic bacteria populations, samples were plated onto Petrifilm aerobic count plates (3M Microbiology Products, St. Paul, Minn.) that were incubated at 37°C for 48 h prior to enumeration. Coliforms and *Escherichia coli* were enumerated by plating onto Petrifilm *E. coli*/coliform count plates (3M) that were incubated at 35°C for 24 h. Presumptive lactic acid bacteria (PLAB) were determined by spread plating on prepoured Lactobacilli MRS agar plates (Difco) containing 0.02% sodium azide. The MRS plates were anaerobically incubated in a BBL GasPak jar (Becton Dickinson) with AnaeroGen (Oxoid Ltd., Basingstoke, Hampshire, UK) for 48 h at 30°C.

pH determination. The pH of the lean and fat tissue surfaces of the fresh pork trim was determined both before and immediately after intervention treatments using a flat surface combination probe (Corning model 440, Corning Inc., Corning, N.Y.). The pH of the ground pork prepared from the treated pork trim was measured with the same probe, following grinding (day 0) and at 2, 7, 14, and 21 days after storage at 4°C.

Color evaluation. Fresh pork trim as described above was obtained from the Roman L. Hruska U.S. Meat Animal Research Center abattoir. The pork trim was subjected to the five intervention treatments described above, stored at 4°C for 24 h, and ground. Following grinding through a 1-cm grinder plate, one-half of the ground pork (ca. 500 g) from each treatment group was removed and subjected to emulsion stability testing as described below. The remaining half of the ground pork was ground again through a 0.5-cm grinder plate and used to make patties (150 g each) for color measurement. A Hunter Miniscan XE Plus model 45/O-L (Hunter Associates Laboratory, Inc., Reston, Va.) was used to evaluate L* (lightness), a* (redness), and b* (yellowness) values. Readings were taken randomly from each of three patties from each treatment group, and the three measurements were averaged. This experiment was replicated six times on separate days, resulting in at least 18 readings per treatment group.

Emulsion stability test. Emulsions were prepared by mixing ground pork with 2% sodium chloride, 0.4% phosphate blend (Vitaphos, First Spice Mixing Company, Inc., San Francisco, Calif.), and 20% flaked ice in a food processor (Quick N' Easy FP1200, Black and Decker, Towson, Mass.). The ground pork, sodium chloride, phosphate blend and half of the flaked ice were chopped for 30 s, then the remainder of the ice was added and all was chopped for another 30 s. Emulsion stability of these ground pork mixtures was determined in triplicate following the procedure of Townsend et al. *(31)*. This experiment was replicated six times.

Statistical analysis. Six replications of each experiment were done, with each replicate being done on each of six separate days. Bacterial counts for each treatment were converted to log CFU/g

values and analyzed statistically for analysis of variance using the SAS GLM procedure for repeated measurements *(28)*. Means were separated using the least significant difference test (PROC MIXED) at a 0.05 probability level. Data from the Hunter color values and emulsion stability test were analyzed by analysis of variance using the GLM procedure. Differences among treatments were examined for level of significance ($P < 0.05$) by Tukey–Kramer multiple comparisons test.

RESULTS

The pH values of the pork trim surfaces and the resulting ground pork following intervention treatments and over the 21-day storage period are shown in Table 1. Surface pH on both lean and fat tissue after treatment with water plus lactic acid and Combination 1 was significantly lower than the pH of control, water, and Combination 2 tissue ($P < 0.05$). Following grinding, the pH of the ground pork prepared from water plus lactic acid and Combination 1 trim (pH 5.40 and 5.32, respectively) was significantly lower than control, water-treated, and Combination 2–treated samples ($P < 0.05$; pH 5.92, 5.88, and 5.91, respectively) and differed through day 7 of storage at 4°C. The pH values of the ground pork samples within the different intervention treatments decreased slightly during the 21 days, dropping only by increments of 0.10 to 0.35.

The effects of the combination intervention treatments on the microbial populations in ground pork prepared from the treated pork trim are shown in Figure 1A through 1D. For all microbial populations examined, all intervention treatments significantly reduced microbial populations in the ground pork compared to the untreated control samples ($P < 0.05$). The mean aerobic bacteria population in ground pork samples prior to treatment was 4.97 log CFU/g. Following treatments, aerobic bacteria were reduced to significantly lower levels in ground pork treated with water plus lactic acid (2.80 log CFU/g) and Combination 1 (2.54 log CFU/g) compared to water (4.10 log CFU/g) and Combination 2 (4.25 log CFU/g). By day 2, aerobic bacteria in water-treated and Combination 2–treated samples had attained populations of 4.48 and 5.07 log CFU/g, respectively, which were not significantly different from populations in the control ground pork (5.35 log CFU/g). Aerobic bacteria populations increased in all ground pork samples during the 21 days of storage, but levels remained lower in water plus lactic acid– and Combination 1–treated samples than levels in the control, water-treated, and Combination 2–treated samples (Fig. 1).

Initial levels of PLAB in ground pork prepared from untreated trim averaged 6.64 log CFU/g. As a result of the trim intervention treatments, populations of PLAB were significantly lower in water (5.86 log CFU/g), water plus lactic acid (5.48 log CFU/g), Combination 1 (5.45 log CFU/g), and Combination 2 (5.87 log CFU/g) ground pork samples than in the control pork. Regardless of treatment, populations of PLAB increased significantly during storage at 4°C ($P > 0.05$) and were similar in all treatments at 21 days.

Coliforms and *E. coli* behaved similarly in terms of reduction, growth, and survival in ground pork made from

TABLE 1. *Surface pH values of treated pork trim and resulting ground pork stored for 21 days at 4°C (n = 6)*

Treatment	pH values[a]								
	Before treatment		After treatment[b]		Ground pork trim (stored at 4°C)				
	Fat[c]	Lean[c]	Fat	Lean	Day 0	Day 2	Day 7	Day 14	Day 21
Control	6.42 (0.15) A	6.00 (0.05) A	6.42 (0.15) A	6.00 (0.05) A	5.92 (0.06) A	5.87 (0.08) A	5.81 (0.04) A	5.69 (0.10) A	5.69 (0.15) A
Water	6.37 (0.14) A	5.98 (0.05) A	6.82 (0.09) B	6.29 (0.08) B	5.88 (0.09) A	5.87 (0.07) A	5.77 (0.11) A	5.54 (0.18) AB	5.78 (0.58) A
Water plus lactic acid[d]	6.43 (0.18) A	6.02 (0.06) A	2.77 (0.09) C	3.33 (0.15) C	5.40 (0.17) B	5.37 (0.09) B	5.44 (0.11) B	5.42 (0.12) B	5.25 (0.03) B
Combination 1[e]	6.42 (0.11) A	5.97 (0.03) A	2.71 (0.08) C	3.41 (0.09) C	5.32 (0.09) B	5.33 (0.09) B	5.35 (0.12) B	5.40 (0.10) B	5.20 (0.07) B
Combination 2[f]	6.44 (0.13) A	5.96 (0.05) A	6.76 (0.14) B	6.27 (0.12) B	5.91 (0.09) A	5.87 (0.10) A	5.72 (0.13) A	5.57 (0.14) AB	5.56 (0.21) AB

[a] Values in parentheses are standard deviations. Means with the same letter in a column are not significantly different ($P < 0.05$).
[b] Surface pH was taken immediately after treatment.
[c] Fat, fat pork trim tissue; lean, lean pork trim tissue.
[d] Water plus lactic acid, water wash (15°C, 65 lb/in^2, 120 s) followed by 2% lactic acid wash (15°C, 35 lb/in^2, 75 s).
[e] Combination 1, water plus lactic acid plus hot air (510°C, 90 s).
[f] Combination 2, hot air plus water plus hot air.

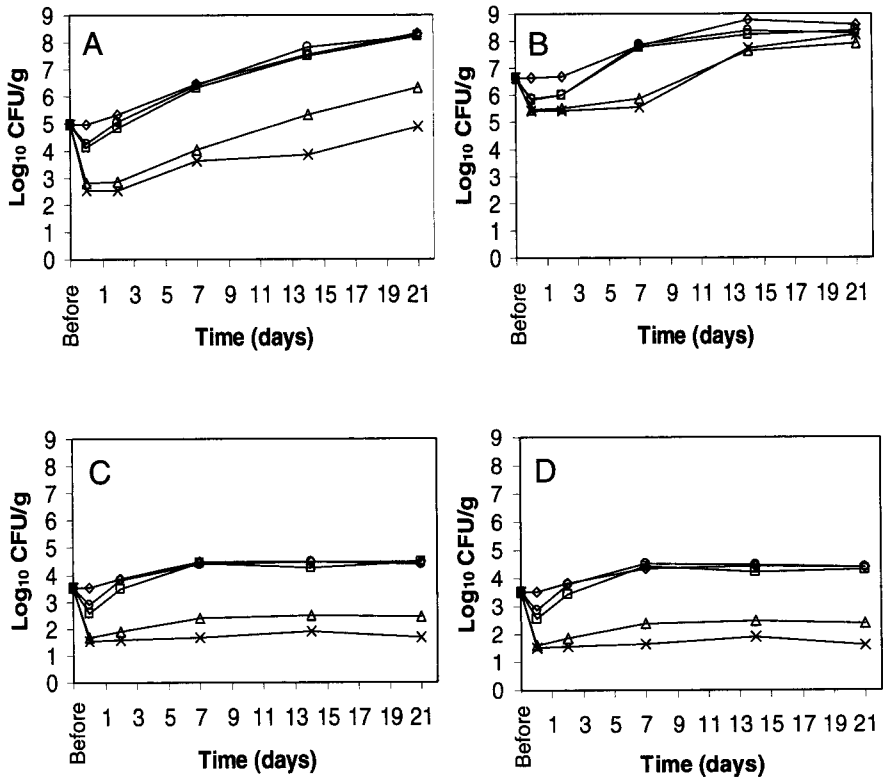

FIGURE 1. *Effects of the combination intervention processes on microbial populations on ground pork prepared from treated pork trim before treatment, after treatment (day 0), and on days 2, 7, 14, and 21 after storage at 4°C* (n = 6). *(A) Mesophilic aerobic bacteria; standard error of the least squares means was 0.34, (B) presumptive lactic acid bacteria; standard error of the least squares means was 0.30, (C) total coliforms; standard error of the least squares means was 0.35, and (D)* Escherichia coli*; standard error of the least squares means was 0.34. Control (—◇—), water spray (—□—), water followed by lactic acid spray (—△—), Combination 1 (water plus lactic acid plus hot air [510°C, 90 s]; —×—), and Combination 2 (hot air plus water plus hot air; —○—).*

pork trim treated with the combination intervention treatments. Total coliform populations in ground product made from untreated pork were 3.54 log CFU/g but were reduced to 1.67 and 1.54 log CFU/g by water plus lactic acid and Combination 1 treatments of trim, respectively. These reduced populations remained unchanged throughout the 21-day storage period, whereas the numbers of total coliforms increased on control samples (from 3.54 to 4.46 log CFU/g), water-treated (from 2.56 to 4.48 log CFU/g) and Combination 2–treated (from 2.88 to 4.40 log CFU/g) ground pork samples ($P < 0.05$). *E. coli* population results were similar. Of the various combination treatments, water plus lactic acid and Combination 1 reduced *E. coli* to the greatest extent, and only 2.40 and 1.59 log CFU/g remained in water plus lactic acid and Combination 1 pork samples, respectively, at the end of the 21-day storage period.

TABLE 2. *Effects of the intervention treatments on Hunter lab color of ground pork prepared from treated pork trim* (n = 6)

Treatment	Hunter color values[a]		
	L*	a*	b*
Control	59.81 A	14.95 A	16.05 A
Water	61.22 AB	14.75 A	15.89 A
Water plus lactic acid[b]	61.97 B	11.97 B	15.71 A
Combination 1[c]	63.72 C	10.38 C	15.51 A
Combination 2[d]	60.22 AB	14.49 A	15.63 A

[a] L*, lightness; a*, redness; b*, yellowness. Means with the same letter within a column are not significantly different ($P < 0.05$).
[b] Water plus lactic acid, water wash (15°C, 65 lb/in^2, 120 s) followed by 2% lactic acid wash (15°C, 35 lb/in^2, 75 s).
[c] Combination 1, water plus lactic acid plus hot air (510°C, 90 s).
[d] Combination 2, hot air plus water plus hot air.

Mean instrumental color values as affected by the different intervention treatments are shown in Table 2. No significant differences were found between the L*, a*, and b* values of water-treated or Combination 2–treated samples compared to control samples. Treatment of commercial pork trim with Combination 1 did not affect b* values of the ground pork but decreased a* values and increased L* values compared to the control samples. The water plus lactic acid–treated samples had lower a* values than control, water, and Combination 2 samples but similar L* and b* values to water and Combination 2 samples. Visual observation of the ground pork patties showed negligible effects on the color and appearance in water-treated and Combination 2–treated samples when compared to the untreated control samples. Pork trim treated with water plus lactic acid resulted in ground pork of a darker red color. Small, brown, cooked, open spots were observed in ground pork patties treated by Combination 1 and were likely due to the combination of lactic acid and heat (hot air) used in this treatment.

No significant differences were found between emulsion stabilities of ground pork prepared from control trim or trim treated with water or Combination 2 interventions (Table 3; $P > 0.05$). Of the intervention treatments evaluated, Combination 1 most substantially increased the volumes of liquid and fat released from the ground pork emulsions. Emulsion stability was also reduced by water plus lactic acid treatment of pork trim, though not to the extent seen with Combination 1 treatment.

For each of the six experimental replicates, pork trim samples were weighed both before and immediately after the application of the combination intervention treatments to determine the fluid gained by the pork trim as a result

TABLE 3. *Effects of the intervention treatments on emulsion stability of ground pork prepared from treated pork trim* (n = 6)

Treatment	Emulsion stability[a]		
	Fat	Liquid	Total[b]
Control	0.29 A	2.71 A	3.0 A
Water	0.35 AB	2.88 A	3.23 A
Water plus lactic acid[c]	0.40 B	3.96 B	4.36 B
Combination 1[d]	0.71 C	8.38 C	9.09 C
Combination 2[e]	0.32 AB	2.79 A	3.11 A

[a] Volume of emulsion components released (ml per 100 g emulsion). Means with the same letter within a column are not significantly different ($P < 0.05$).
[b] Total volume of fat and liquid released.
[c] Water plus lactic acid, water wash (15°C, 65 lb/in^2, 120 s) followed by 2% lactic acid wash (15°C, 35 lb/in^2, 75 s).
[d] Combination 1, water plus lactic acid plus hot air (510°C, 90 s).
[e] Combination 2, hot air plus water plus hot air.

of spray washing. Pork trim treated with Combination 2 gained significantly less fluid, resulting in an average gain of 0.48% compared to trim treated with water (3.15%), water plus lactic acid (4.60%), and Combination 1 (3.78%).

DISCUSSION

The red meat slaughter and processing industry currently directs antimicrobial interventions at the carcass to minimize the risk of introducing fecal contamination and bacterial pathogens from the carcass into the final products. As a normal result of the process of producing cuts and trim from these sanitized carcasses, however, meat tends to be recontaminated or existing contamination can be spread. As reasoned previously, intervention processes targeted at meat trim, prior to grinding, could improve both the microbial safety and shelf life of ground products. In addition, such trim interventions may assist processors in meeting the *Salmonella* performance standards for ground beef, as well as the proposed *Salmonella* standards for fresh pork sausage *(32, 33)*. Results of this work demonstrate that interventions applied to pork trim can be used to reduce aerobic bacteria, *E. coli,* and coliform levels in the resultant ground pork.

To date, research examining the microbial decontamination of meat trim and its effects on the microbial quality of subsequently ground meat is limited. Conner et al. *(5)* reported that spray treatments of 2 and 4% acetic and lactic acid mixtures applied to inoculated beef trim were of limited effectiveness in reducing *E. coli* O157:H7 or *Listeria monocytogenes* in ground beef. Gill and Badoni *(19)* immersed commercial beef trim in 85°C water for 15 s or 1 min and found that this hot water treatment was useful for reducing bacteria, including *E. coli* and coliforms, in the ground beef prepared from the treated trim. Ellebracht et al. *(17)* inoculated commercial beef trim with *E. coli* O157:H7 and *Salmonella* Typhimurium and dipped trim pieces either in 95°C water for 3 s alone or in a combination of 95°C water for 3 s and 55°C 2% lactic acid for 11 s prior to grinding the trim and examining the microbial populations in the ground beef. Hot water alone reduced the pathogen populations but had no effect on aerobic plate counts of the ground beef, whereas the combination of hot water and lactic acid improved the immediate reductions of *E. coli* O157:H7 and *Salmonella* Typhimurium (log reductions of 1.1 and 1.8, respectively), and reduced the aerobic bacteria populations by a 1.5 log reduction *(17)*. Kang et al. *(22)* applied a combination treatment comprised of a water spray wash, a hot water spray wash (82°C), hot air (510°C), and a 2% lactic acid spray wash to commercial beef trim. The combination treatment initially reduced all examined microbial populations in the ground beef to nearly undetectable levels, and although some of these populations increased during the 4°C storage, they remained lower at the end of 20 days than those in ground beef prepared from untreated trim *(22)*. The results of the current study are in agreement with those previous studies examining combinations of treatments for microbial decontamination of trim *(17, 22)*. Although the use of water alone or in a combination of hot air plus water plus hot air (Combination 2) resulted in initial reductions of aerobic bacteria, PLAB, coliforms, and *E. coli,* populations of these microorganisms increased during refrigerated storage to match those levels in ground pork made with untreated trim (Fig. 1). In contrast, and with the exception of lactic acid bacteria, those combination treatments incorporating a lactic acid wash (water plus lactic acid and Combination 1) resulted in greater reductions of the microbial populations and greater suppression of microbial growth during the 20 days of storage at 4°C (Fig. 1). Lactic acid treatments have previously been shown to afford residual antimicrobial activity on meat tissue *(12, 13, 29)*.

Previous works have demonstrated that combinations of antimicrobial treatments can more effectively reduce bacterial contamination from carcasses than separate single treatments *(14, 21, 25)*. The application of combinations of short, sequential antimicrobial treatments to meat trim might not only be more effective *(4, 17, 22, 23)* but, as reasoned by Kang et al. *(22, 23)*, might be more appropriate for use in trim decontamination than would applications of single treatments for more prolonged exposure times. The exposed cut surfaces of the trim can be denatured by heat or acid, which can negatively affect the color, appearance, or functionality of the ground meat. Such changes in quality could affect consumer acceptance of the ground product or affect the suitability of the ground product for use in sausages or other comminuted meat products. Kang et al. *(22)* found that beef trim surfaces were discolored following the application of a multiple-step intervention process that included hot water, hot air, and lactic acid but noted the dilution of the discolored surface tissue by the interior tissue following grinding of the trim. In a study examining hot water immersion treatments of beef trim, a triangle taste test found no difference in the flavor of cooked ground beef patties prepared from untreated trim and from trim treated 1 min at 85°C *(19)*. Although immersion of the trim in hot water resulted in ground beef that was both lighter and duller in color than the control ground beef, Gill and Badoni *(19)* concluded that the pasteurization treatment would not cause the appearance of the ground beef to be unac-

ceptable to consumers. In previous work investigating the use of combination trim interventions to decontaminate pork trim *(4)*, we found that the inclusion of hot water washes of 65.5 or 82.2°C for 15 to 45 s as steps in combination processes that included water, hot air, and 2% lactic acid negatively affected both ground pork color and emulsion stability. Emulsion stability is an important functional property of ground meat destined for use in processed meats and sausages, and decreases in emulsion stability can result in lower product yield and unacceptable texture and appearance. Because of these previous results *(4)*, the current work with commercial pork trim decontamination examined alternative combination intervention processes that did not include the use of hot water washes. Among the combination trim processes examined in the current study, Combination 1, which included the use of both hot air and lactic acid, produced the most extreme negative changes in both pork trim color and emulsion stability. However, the Combination 1 effects on these quality attributes were less than those of combination processes using hot water washes *(4)*. Emulsion stability was also reduced by water plus lactic acid treatment of pork trim, although not to the extent seen by Combination 1 treatment, and the difference was not deemed of practical importance. However, the changes or effects on color or emulsion stability that are of practical importance will depend on the intended use of the ground pork.

An additional consideration in the application of interventions to decontaminate meat trim is the uptake of water or fluid by the trim, which might not be desirable, depending on the use intended for the subsequent ground product. The results of this work indicate that the use of hot air in the combination processes could provide not only another microbial inactivation step but also could serve to remove the excess fluid from the surface of the trim, thus minimizing fluid uptake.

The combination intervention processes were effective in reducing microbial populations in ground pork prepared from commercial pork trim. In particular, those combination treatments incorporating a lactic acid wash were especially effective at both reducing and controlling these populations during refrigerated storage of the ground pork. The use of a hot air treatment as the final step in combination treatments significantly removed the excess fluid gained by the pork trim as a result of the spray wash treatments. However, this study also showed that although using hot air in combination with a water wash and a lactic acid wash (Combination 1) was effective in reducing microbial contamination, it also resulted in a decrease of emulsion stability and affected the color of the ground pork. Water plus lactic acid was the most favorable intervention treatment in reducing microbial populations without negatively affecting the quality attributes of the ground pork.

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