

Efficacy of Several Antimicrobial Processing Aids Sprayed on Meat and Pork Products Against E. coli O157:H7

Background

The contamination of food products by pathogenic organisms such as E. coli O157:H7 is an on-going problem that is addressed within the processing plant using antimicrobial products. The efficacy of these Food Contact Substances (FCS) is important to assure a safe and reliable food supply. Meat processing facilities are adopting new and improved chemical intervention steps of treating their meat carcasses with FDA approved sanitizers as part of their HACCP programs. E. coli is one of the primary pathogens of interest in most meat and pork processing plants. It can be seen in Table 1 that as little as 10 to 100 CFU/ml (Colony Forming Units/milliliter) E. coli O157:H7 bacteria cells can cause hemorrhagic colitis.

The primary method of applying the FCS in meat and pork processing plants on carcasses, parts, trim and organs, is using coarse spray technologies. Therefore, the purpose of this study was to determine the relative efficacy of a 30 second spray bar application of peroxyacetic acid (PAA) from Perasan MP-2®, DBDMH (from FCN No. 792), and HB2, which is FCN #944, based on liquid hypobromous acid as the active ingredient, against the bacteria, E. coli O157:H7. Several references are made in this report to HB2 and HB3, which are identical in chemistry and refer only to labeling differences.

Table 1: Estimated infectious dose of bacteria species

Bacteria Species	Estimated infectious dose (bacteria cell number)	Disease
E. coli O157:H7	10 to 100	Hemorrhagic colitis
E. coli	1,000,000 to 100,000,000	Traveler's diarrhea
Salmonella	100 to 1,000,000,000	Salmonellosis

Principal source: Foodborne Pathogens: Risks and Consequences, Report No. 122, CAST-Council for Agricultural Science and Technology, September 1994.

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Data Requirements

Efficacy Data of HB2 and HB3 for FSIS, USDA, FDA

Methods

Meat processing facilities commonly treat beef and pork with antimicrobial solutions for ~30 seconds by spraying the beef and pork carcasses and trim with the solution in a spray cabinet. To simulate this process, a small spray cabinet was created for this study. A one inch air pump was used to deliver the test solution into half inch PVC tubing, which in turn allowed the test solutions to be dispensed out of six nozzles placed four and a half inches apart in a 30 gallon drum. Each nozzle delivered 0.6 gpm of test solution. A regulator on the air pump was used to adjust the pressure of the spray as needed. The air pump used in this experiment can be seen in Image 1. The spray cabinet was calibrated using city water by adjusting the nozzles and pressure to ensure even distribution of the test solutions. Images 2 and 3 show the spray cabinet in operation at low pressure (10 psi) and high pressure (70 psi), respectively.

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IMAGE 1: One Inch Air Pump



IMAGE 2: Low Pressure Spray (10 psi)



IMAGE 3: High Pressure Spray (70 psi)



Due to variables such as temperature, spray pressures, meat types and sizes, operator techniques, and equipment that can alter the results of this study, two separate study days were set aside, the first day called Experiment 1 and the second repeat test, termed Experiment 2.

Experiment 1 was performed using duplicate cuts of meat and pork at 10 psi and 70 psi. After enumeration the experimenters found that there was no statistical difference between the low and high pressure results for the antimicrobial products (FCS). Therefore, it was determined to perform Experiment 2 using an average of 40 psi pressure on triplicate cuts of meat and pork. In all cases, the controls and challenges were plated on duplicate sets of 3M Petrifilm *E. coli* Plates.

The Food Contact Substances:

The MP-2 used to prepare the test solutions containing PAA was made from MP-2. Perasan MP-2 is a product that contains 15% peroxyacetic acid, 5.5% hydrogen peroxide, 35% acetic acid, and 0.7% HEDP and if used less than 220 ppm as peroxyacetic acid complies in all respects to 21 CFR 173.370 and specifically with Food Contact Notification #887, for use on meat and poultry carcasses, parts, trim and organs.

DBDMH is a dry material and comes in granular form at 99.5% activity. The product was obtained at a local store. Albemarle Corporation is the only US manufacturer of DBDMH and is the owner of Food Contact Notifications #334, #357, #453, #775, and #792 for use of DBDMH on meat, pork and poultry. The product was dissolved in water to obtain a concentrate which was subsequently filtered to remove any undissolved solids and added to potable water to obtain the appropriate concentration needed for these experiments.

The HB2 is the subject of a Food Contact Notification by the FDA (FCN #944). It is pure hypochlorous acid generated on-site by blending hydrogen bromide with a hypochlorite source. For this study, hypobromous acid was created on-site by combining hydrogen bromide and sodium hypochlorite.

Experiment 1:

A stock solution of a field strain of *E. coli* O157:H7 was incubated at 35 degrees C for four days in Sigma Nutrient Broth for microbial culture. Three daily, consecutive transfers of the inoculums were made to ensure a sufficient concentration of *E. coli* O157:H7 was available for the study. The broth and bacteria mixture was then centrifuged leaving the *E. coli* O157:H7 to be re-suspended in approximately 500 ml Butterfield's Buffer. The *E. coli* buffer solution was serially diluted and plated on 3M Petrifilm *E. coli* Plates, incubated at 35 degrees C for 48 hours where it was determined that the *E. coli* O157:H7 population was 6.76×10^7 CFU/ml or $\log_{10} 7.83$.

1. Twelve uncooked, boneless, London broil beef strips of equal size and twelve uncooked, boneless, pork chops of equal size were patted dry, weighed and marinated in the 500 ml *E. coli* Butterfield's Buffer solution overnight, turning occasionally. See Image 4. The beef weights ranged from 180.4g to 260.0g, the average being 209.5g. The average pork weight was 240.8g, the low being 182.8g and the high being 289.0g.

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IMAGE 4: Preparation of Beef and Pork



The sixteen beef pieces and sixteen pork pieces were removed from the *E. coli*. Butterfield's Buffer bath, shaken dry using sterile gloves, introduced into sterile poultry rinse bags and taken to an isolated area outside where the simulated spray bar portion of the study was taken place. This study was performed in duplicate, i.e., two pieces of each meat type was subjected to each test substance either at low or high pressure. During the 30 second spray, a piece of meat was held by a hook and moved up and down while rotating to ensure even distribution of the test spray at low pressure (10 psi) or high pressure (70 psi). The FCS concentration was measured prior to spraying the meat pieces by using a HACH DR/700 Colorimeter and HACH 10 ml Total Chlorine pillow packets (see Attachment 'A'). The value was multiplied by the molecular weight difference vs. chlorine and bromine (PAA = 1.07; DBDMH and HB2 = 2.25), respectively, and the dilution factor of each FCS.

In summary:

Beef-

- a) Control: Four beef pieces- low pressure- city water
- b) PAA: Four beef pieces- low pressure- 212 ppm PAA
- c) DBDMH: Four beef pieces- low pressure- 308 ppm total bromine
- d) HB2: Four beef pieces- high pressure- 276 ppm total bromine

Pork-

- a) Control: Four pork pieces- low pressure- city water
- b) PAA: Four pork pieces- low pressure- 212 ppm PAA
- c) DBDMH: Four beef pieces- low pressure- 308 ppm total bromine
- d) HB2: Four beef pieces- high pressure- 276 ppm total bromine

2. Immediately after each piece was sprayed a sample of the wash solution was taken from the bottom of the spray cabinet drum for microbial analysis. This test solution was plated on 3M Petrifilm *E. coli* Plates and incubated at 35 degrees C for 48 hours.
3. The drum was then rinsed clean with the test spray and made ready for use on the next piece of meat.
4. After challenge testing, the meat piece was gently shaken three times to remove excess liquid and returned to a new, sterile bag and taken to the lab where 200g of city water was introduced to the bag and subsequently tumbled gently for one minute to dislodge remaining *E. coli* bacteria. The water left at the bottom of the bag was plated using 3M Petrifilm *E. coli* Plates and incubated at 35 degrees C for 48 hours, upon which the plates were enumerated. All plating for *E. coli* was performed within 10 minutes after the challenge testing.

Experiment 2:

This test was performed subsequent to Experiment 1 in order to confirm that the results obtained the first time were not subjected to variables such as temperature, operator, equipment etc. Because there was no significant difference in the microbiological results between low pressure (10 psi) and high pressure (70 psi), the air inlet pressure was set at 40 psi throughout Experiment 2.

Another step omitted in Experiment 2 was the microbiological analysis of the solutions collected at the bottom of the drum (rinse water) immediately after the meat was sprayed. This step was omitted because there was such a dramatic decrease in *E. coli* present in Experiment 1 it seemed unnecessary to repeat this step. Also, it is known that what is left on the meat after treatment is more critical than what comes off of it during the wash.

The inoculums used in Experiment 2 were prepared in the same manner as Experiment 1 and yielded an *E. coli* O157:H7 population of 8.51×10^7 CFU/ml, or \log_{10} 7.93. This was then sprayed onto the beef and pork pieces and left to marinate for two hours, see Image 5. The type of beef used this time was chuck roast, which was cut into sixteen equal pieces. The average weight of beef piece used in this portion of the study was 257.1g and the average weight of pork was 142.9g.

All other steps performed in Experiment 2 were conducted in the same manner as Experiment 1, this time the study was performed in triplicate.

In summary:

Beef-

- a) Control: Four beef pieces- city water
- b) PAA: Four beef pieces- 215 ppm PAA
- c) DBDMH: Four beef pieces- 288 ppm available bromine
- d) HB2: Four beef pieces- 279 ppm available bromine

Pork-

- a) Control: Four beef pieces- city water
- b) PAA: Four beef pieces- 215 ppm PAA
- c) DBDMH: Four beef pieces- 288 ppm available bromine
- d) HB2: Four beef pieces- 279 ppm available bromine

IMAGE 5: *E. coli* 0157 H:7 Inoculum Sprayed on Pork



Results and Discussion

Note: This study was conducted on two separate days to rule out variables that can interfere with the outcome of the study. Because the two experiment days resulted in very little difference in inoculum concentrations, spray pressures, and microbiological results, it was decided that the data from the two experiment days, as well as the duplicate and triplicate testing of the meats be consolidated and the average results would be reported in this study. The average of all beef control results, the average of all pork control results, the average of all PAA, DBDMH and HB2-hypobromous acid-treated beef and pork results are reported below.

A nominal 212-215 ppm PAA from Perasan MP-2® was used as the test solution to be sprayed onto the meat by the spray bar apparatus created for this study. The actual concentrations were measured by DPD method (see Attachment 'A'). Experiment 1 used a PAA solution of 212 ppm and Experiment 2 used a 215 ppm PAA solution. The DBDMH concentrations were determined to be 308 ppm available bromine in Experiment 1 and 288 ppm available bromine in Experiment 2. The HB2 concentration was 276 ppm in Experiment 1, and 279 ppm in Experiment 2.

In Experiment 1, immediately after each piece of meat was treated in the spray cabinet for 30 seconds, a water sample from the bottom of the drum was subjected to microbiological analysis. The results can be seen in Table 2. The controls contained an average of 5.01 CFU/ml of *E. coli* O157:H7 in the beef wash water and a log₁₀ average 5.18 CFU/ml in the pork wash water. On the other hand, the PAA wash water, DBDMH wash water and HB2 wash water had very little *E. coli* O157:H7 present. There was an average log₁₀ reduction of 4.77 CFU/ml (99.998%) in *E. coli* O157:H7 in the PAA wash water that was used to spray the beef and an average log₁₀ reduction of >5.18 CFU/ml (>99.999%) in the pork wash water, meaning there were no bacteria colonies present. The DBDMH treated beef had an average log₁₀ reduction of 4.53 CFU/ml (99.997%) in *E. coli* O157:H7 in the wash water and an average log₁₀ reduction of 4.19 CFU/ml (99.994%) in the pork wash water. The HB2-treated beef wash water resulted in reductions of log₁₀ 4.86 CFU/ml (99.999%) and in the pork-treated wash water, an average reduction of log₁₀ 4.79 CFU/ml (99.998%) was seen. These are significant reductions in bacterial numbers but what is washed off the meat is not as significant as what is left on the meat.

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TABLE 2: Wash water microbiological results

Description	log10 (remaining)	log10 reduction	% reduction
Control Beef	5.01	N/A	N/A
PAA Beef	0.24	4.77	99.998
DBDMH Beef	0.48	4.53	99.997
HB2 Beef	0.15	4.86	99.999

Description	log10 (remaining)	log10 reduction	% reduction
Control Pork	5.18	N/A	N/A
PAA Pork	0.00	>5.18	>99.999
DBDMH Pork	0.99	4.19	99.994
HB2 Pork	0.39	4.79	99.998

After each piece of meat was sprayed with the test solution and taken back to the lab in sterile bags, 200g of city water was added to the bag and subsequently tumbled for one minute to dislodge any viable E. coli O157:H7 bacteria. Table 3 contains the average number of bacteria left on the meat after being sprayed for 30 seconds with either city water (control), PAA, DBDMH and HB2 solutions. It can be seen that the controls averaged a log10 of 6.15 for beef and log10 6.43 CFU/ml for pork. The log10 reduction in E. coli O157:H7 bacteria when PAA was sprayed onto beef, compared to the control, was 0.92 (87.98%). The log10 reduction when PAA was sprayed onto pork,

compared to the control, was 1.61 (97.55%). The log10 reduction in E. coli O157:H7 bacteria when the DBDMH solution was sprayed onto beef, compared to the control, was 0.59 (74.30%). The log10 reduction when the DBDMH solution was sprayed onto pork, compared to the control, was 0.72 (80.95%). The HB2 challenge resulted in reductions of 0.70 log10 CFU/ml for beef and 1.18 log10 CFU/ml for pork.

The average concentrations of E. coli O157:H7 bacteria present on both the beef and the pork after being sprayed is charted in Figure 1 on the next page.

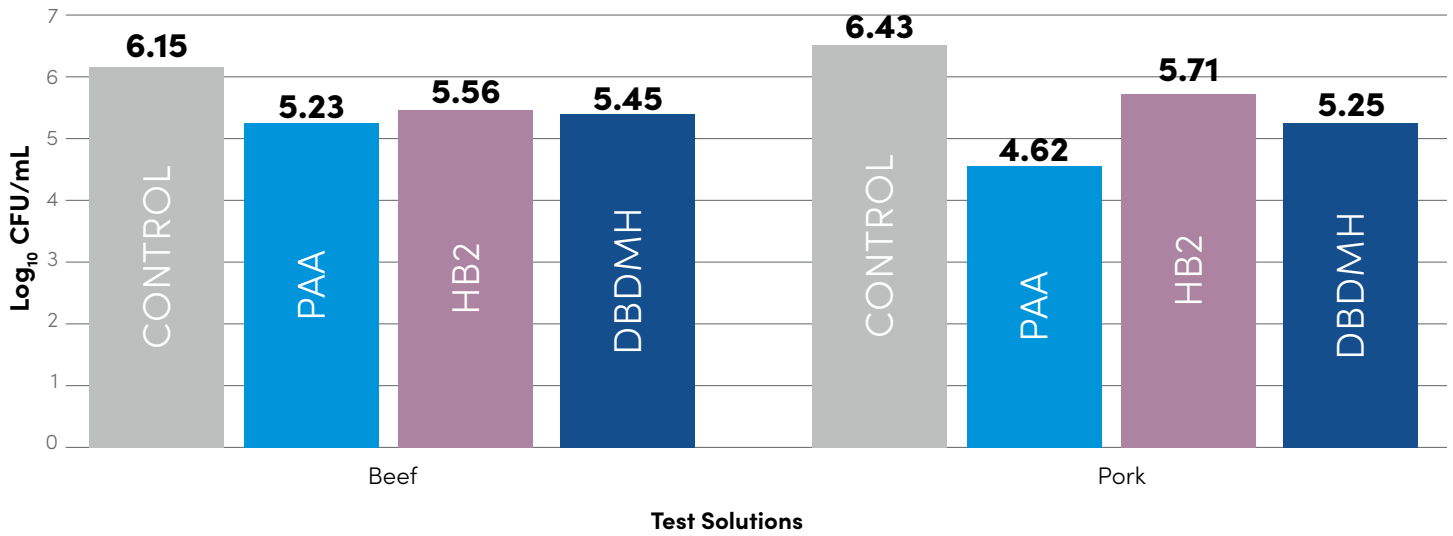
TABLE 3: Enumeration Results of Microbiological Analysis

Description	log10 (remaining)	log10 reduction	% reduction
Control Beef	6.15	N/A	N/A
PAA Beef	5.23	0.92	87.98
DBDMH	5.56	0.59	74.30
HB2 Beef	5.45	0.70	80.03

Description	log10 (remaining)	log10 reduction	% reduction
Control Pork	6.43	N/A	N/A
PAA Pork	4.82	1.61	97.55
DBDMH	5.71	0.72	80.95
HB2	5.25	1.18	93.39

FIGURE 1: Control vs. treatment, Log remaining

Log₁₀ CFU/mL of E. Coli 0157:h7 in Test Solutions



Conclusions:

- Due to variables such as temperature, spray pressures, meat types and sizes, operator techniques, and equipment that can alter the results of this study, two separate study days were set aside, the first day called Experiment 1 (which was conducted in duplicate) and the second a repeat test, called Experiment 2 (conducted in triplicate). The data from the two experiment days, as well as the duplicate and triplicate testing of meats were consolidated and the average results reported in this study because the two experiment days resulted in very little difference in inoculum concentrations, spray pressures, and microbiological results.
- Meat processing facilities commonly treat beef and pork with antimicrobial solutions for 30-60 seconds by spraying the beef and pork carcasses with the solution in a spray cabinet. To simulate this process, a small spray cabinet was created for this study.
- Immediately after each meat piece was sprayed a sample of the wash solution was taken from the bottom of the spray cabinet drum for microbial analysis. The results are very acceptable reductions in bacterial numbers for the PAA, DBDMH and HB2, but what is washed off the meat is not a significant factor in terms of food efficacy, but it is significant for the over-all health and safety of workers in and around the processing facility, as well as mitigating sanitation and wastewater issues. The PAA wash water had very little E. coli O157:H7 present. There was an average log₁₀ reduction of 4.77 CFU/ml (99.998%) in E. coli O157:H7 in the wash water that was used to spray the beef and an average log₁₀ reduction of >5.18 (>99.999%) in the pork wash water. The DBDMH-treated beef had an average log₁₀ reduction of 4.53 (99.997%) in E. coli O157:H7 in the wash water and an average log₁₀ reduction of 4.19 (99.994%) in the pork wash water. HB2 yielded log₁₀ reductions of 4.86 (beef) and 4.79 (pork) CFU/ml, respectively. All three test substances were effective in eradicating the planktonic (suspended) bacteria in the wash water retain challenge.
- 200 g of city water was added to the bag containing each piece of meat that was sprayed with the test solution and tumbled for one minute to dislodge any viable E. coli O157:H7 bacteria. Table 3 shows the average number of bacteria left on the meat after being sprayed for 30 seconds with either city water (control), the PAA solution or the DBDMH solution.
- The microbiological profile for the meat and pork challenges showed the controls averaged a log₁₀ CFU/ml of 6.15 for beef and 6.43 for pork. The log₁₀ reduction in E. coli O157:H7 bacteria when PAA was sprayed onto beef, compared to the control was 0.92 (87.98%). The log₁₀ reduction when PAA was sprayed onto pork, compared to the control was 1.61 (97.55%). The log₁₀ reduction in E. coli O157:H7 bacteria when the DBDMH solution was sprayed onto beef, compared to the control, was 0.59 (74.30%). The log₁₀ reduction when the DBDMH solution was sprayed onto pork, compared to the control, was 0.72 (80.95%). The HB2 solution yielded reductions of 0.7 log₁₀ CFU/ml and 1.18 log₁₀ CFU/ml for beef and pork, respectively. The average concentration of E. coli O157:H7 bacteria present on both the beef and the pork after being sprayed with each test solution is charted in Figure 1.
- This study was designed to give the reader a reasonably accurate idea of the relative qualitative efficacy of peroxyacetic acid (PAA), DBDMH and hypobromous acid (HB2) against E. coli O157:H7 beef and pork when applied as a spray for 30 seconds.
- The PAA and liquid hypobromous acid (HB2) solution, when sprayed on both beef and pork, outperforms DBDMH in short 30 second contact times when the products are employed at the upper limits of their tolerance ceiling. These shorter contact time scenarios represent those typically encountered when meat carcasses are sprayed at meat processing facilities during commercial processing. Both treatments exhibit demonstrable efficacy on meat and pork surfaces compared to the control group.

References:

Bell, Kristen Y, et al*; "Reductions of Foodborne Micro-Organisms on Beef Carcass Tissue Using Acetic Acid, Sodium Bicarbonate, and Hydrogen Peroxide Spray Washes"; Journal of Food Microbiology, 1997, 14, 439-448.

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