Organic Acid Rinses

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Microbial contamination of animal carcasses occurs as a result of the necessary procedures required to process live animals into retail meat. The contamination can be minimized by good manufacturing processes, but the total elimination of foodborne pathogenic microorganisms is difficult, if not impossible. A variety of methods have been developed to reduce the levels of contaminating bacteria on carcasses, although most of the current methods focus on washing and sanitizing procedures. Organic acids, such as acetic or lactic acids, have been used to sanitize carcasses because they exhibit good bactericidal activity and are generally recognized as safe (GRAS) additives by the U.S. Food and Drug Administration. There is no single process that will assure that the product which reaches the consumer is absolutely free of bacteria. There are no "magic bullets", and any process which is approved must be approved as part of a comprehensive program to improve product quality.

Organic acids are natural, food grade additives that are found in a variety of food products. Although this group of acids includes citric, proprionic, formic and ascorbic acids, the two most commonly used acids for the decontamination of animal carcasses are acetic and lactic acids. Organic acid, as rinses or sprays, have been used as a method for decontaminating meat and meat products for several years. The effectiveness of these acids varies by the concentration, the application temperature and contact time, the sensitivity of the native microflora to the specific compound, and to a certain extent the design of the specific experiments. The consensus of the research is that carcass sanitizing with organic acid rinses can reduce the initial levels of bacteria on the surface of the carcass.

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Organic acids inactivate bacteria by reducing the pH within the bacterial cell. The acids overwhelm the natural buffering capacity of the cells and make the cytoplasm of the cell acidic. The internal pH of the cell is reduced to the point where proteins are denatured and enzymes vital to the cell's metabolism are inactivated. This stops bacterial metabolism, irreversibly in many cases, and the cell dies. The antimicrobial properties of the acids are related to the reduction in pH, the dissociation of the acid molecule and the specific toxicity of the acid. Organic acids are believed to have a greater antimicrobial effect than inorganic acids at equivalent concentrations and pH values, because bacterial cell membranes do not recognize organic acids as "foreign" materials.

Organic acids are applied as a "rinse" to the whole carcass. The rinse covers the entire carcass, and is not simply a spot treatment. This rinse affects not only the areas of the carcass which may be visibly contaminated, but also affects bacteria which have contaminated the carcass without visible contamination. The concentrations of the acids are limited by USDA-FSIS to levels which do not leave detectable residues. The acids are, in effect, self limiting due to discoloration of meat which occurs at or above the 3% concentration level.

Although the application of organic acid rinses and the overall reductions in microbial populations on meat surfaces have been well documented, the magnitude of these reductions varies because of the interaction of several factors. The nature and extent of bacterial contamination, the relative degree of bacterial attachment to the tissue surface and the type of tissue that the contaminating bacteria are attached to all influence the level of reduction. Organic acid rinses reduce total bacterial populations on the carcass surface. Although the level of the reductions vary by carcass conditions, acid concentration and temperature, typical reductions may be as much as 90% (1 $\log_{10}$ cycle). These reductions are seen in both indicator bacteria and bacteria of public health significance.

Khan and Katamay (16) determined the degree of inhibition of fatty acids against salmonellae in meat and bone meal. The researchers concluded that short chain fatty acids had an antagonistic effect on a mixture of salmonellae strains. Chung and Goepfert (10) evaluated 13 acids in inhibiting salmonellae in laboratory media, and found acetic and propionic acids to be most effective. Ockerman et al. (18) used acetic and lactic acid sprays in concentrations from 6% to 24% on lamb carcasses, and reported that 18% acetic acid was the most effective in reducing bacterial populations. However, the researchers also noted that concentrations in excess of 12% produced bleaching of the carcasses. The reductions in total aerobic populations did not exceed 1 $\log_{10}$ cycle.

Woolthuis et al. (26) immersed porcine livers in 0.2% lactic acid for 5 min and found significant reductions in total colony and *Enterobacteriaceae* counts after 1 and 5 days, when compared to untreated control samples. Woolthuis and Smulders (28) evaluated lactic acid in concentrations of 0.75% to 2.5% on calf carcasses and determined that 1.25% acid resulted in substantial reductions in total aerobic counts with minimal carcass discoloration. This concentration reduced total aerobic bacteria by approximately 1 $\log_{10}$ cycle, with similar reductions in Enterobacteriaceae. Smulders and Woolthuis (23) also reported calf carcasses sanitized with 1.25% lactic acid had significantly lower total aerobic populations than control carcasses after 14 days, and that there was some residual bactericidal effect of the lactic acid. Snijders et al. (24) concluded that the use of lactic acid sprays as a terminal process in carcass processing could provide significant microbiological advantages. Visser et al. (26) used 2% lactic acid to decontaminate veal tongues, and reported decreases in the total bacterial populations of almost three $\log_{10}$ cycles. Gill and Newton (13) reported that the inhibitory action of lactic acid was primarily attributable to low pH, and not to action of the undissociated acid. Smulders et al. (22) reviewed the literature on sanitizing meat with lactic acid and recommended that public health authorities allow the use of lactic acid as a decontaminating agent.

Reynolds and Carpenter (20) sprayed pork carcasses with a 60:40 mixture of acetic and propionic acids, and reported a two $\log_{10}$ reduction in total bacterial populations. Osthold et al. (19) developed an acid spray consisting of acetic, lactic, citric and ascorbic acids, and reported that it had a selective inhibitory effect on Enterobacteriaceae. Bell et al. (7) determined the effectiveness of 1.2% acetic acid and a mixture of 0.6% acetic and 0.046% formic acids. The researchers found that the acetic/formic acid mixture was as effective a bacteriocidal agent as the higher concentration of acetic acid, without adverse affects on the product. Rubin (21) reported that lactic and acetic acids were slightly synergistic in their inhibitory effects on *Salmonella typhimurium*. Adams and Hall (2) also noted an apparent synergistic interaction between acetic and lactic acids, which they concluded was a result of the potentiation of acetic acid in the lower pH environment created by the lactic acid. The interactions among acid type, concentration, and application temperature have been studied on lamb carcasses (3) and beef tissue (4,5). These researchers also evaluated a mixture of 2% acetic, 1% lactic, 0.25% citric, and 0.1% ascorbic acids and concluded that the acid mixture was no more effective than either acetic or lactic acids in similar concentrations (6). Typically, the bactericidal effectiveness increased with increases in concentration or temperature. Lactic acid solutions have also been applied to poultry (25), with immediate reductions of approximately 1 $\log_{10}$ cycle in bacterial populations. Zeitoun and Debevere (29) applied 10% lactic acid, buffered to pH 3.0, to extend the shelf life on chicken legs from 6 to 12 days. When the microflora on beef tissue was subjected to osmotic stress, either by physical or chemical dehydration, the effectiveness of acetic acid was dramatically enhanced (11).

Organic acids have been reported to have an immediate effect on the microflora of meat products, primarily when applied during the slaughtering and dressing applications. However, application of the acid after fabrication of individual cuts of meat has little impact on the ultimate microflora. Acuff et al. (1) and Dixon et al. (12) reported that steaks or loins decontaminated with acid sprays did not differ in total aerobic populations after storage and simulated retail display. In addition, Lillard et al. (17) reported that addition of acetic acid to poultry scald water did not reduce the populations of bacteria on the carcasses, although there were reductions in bacterial populations in the water itself.

There is an apparent consensus in the scientific literature that *Salmonellae* and *Listeria monocytogenes* are reduced by organic acid rinses. In regard to *Escherichia coli* O157:H7, the results in the literature are somewhat conflicting with some studies showing reductions while other studies show little or no reductions in populations. It is apparent from all of the studies that *E. coli* O157:H7 is more resistant to organic acids than salmonellae. (Brackett et al. 1994 (8), Cutter and Siragusa 1994 (9), Greer and Dilts,1992 (14), Hardin et al. 1995(15)).

Summary

In summary, organic acids are natural, food grade compounds which are applied as a whole carcass rinse to reduce populations of bacteria. No rinse treatment will guarantee elimination of all bacteria, but organic acids have been proven to show reductions in bacterial numbers.

References

Acuff, G.R.; Vanderzant, C.; Savell, J.W.; Jones, D.K.; Griffin, D.B.; Ehlers, J.G. 1987. Effect of acid decontamination of beef subprimal cuts on the microbiological and sensory characteristics of steaks. Meat Sci. 19:217-226.

Adams, M.R.; Hall, C.J. 1988. Growth inhibition of food-borne pathogens by lactic and acetic acids and their mixtures. Int. J. Food Sci. Technol. 23:287-292.

Anderson, M.E.; Huff, H.E.; Naumann, H.D.; Marshall, R.T. 1988. Counts of six types of bacteria on lamb carcasses dipped or sprayed with acetic acid at 25° or 55°C and stored vacuum packaged at 0°C. J. Food Prot. 51:874-877.

Anderson, M.E.; Marshall, R.T. 1989. Interaction of concentration and temperature of acetic acid solution on reduction of various species of microorganisms on beef surfaces. J. Food Prot. 52:312-315.

Anderson, M.E.; Marshall, R.T. 1990a. Reducing microbial populations on beef tissues: concentration and temperature of lactic acid. J. Food Safety. 10:181-190.

Anderson, M.E.; Marshall, R.T. 1990b. Reducing microbial populations on beef tissues: concentration and temperature of an acid mixture. J. Food Sci. 55:903-905.

Bell, M.F.; Marshall, R.T.; Anderson, M.E. 1986. Microbiological and sensory tests of beef treated with acetic and formic acids. J. Food Prot. 49:207-210.

Brackett, R.E.; Hao Y.-Y.; Doyle, M.P. 1994. Ineffectiveness of hot acid sprays to decontaminate *Escherichia coli* O157:H7 on beef. J. Food Prot.57:198-203.

Cutter, C.N.;Siragusa, G.R. 1994. Efficacy of organic acids against *Escherichia coli* O157:H7 attached to beef carcass tissue using a pilot scale model carcass washer. J.Food Prot. 57:97-103.

Chung, K.C.; Goepfert, J.M. 1970. Growth of Salmonella at low pH. J. Food Sci. 35:326-328.

Dickson, J.S. 1990. Surface moisture and osmotic stress as factors that affect the sanitizing of beef tissue surfaces. J. Food Prot. 53:674-679.

Dixon, Z.R.; Vanderzant, C.; Acuff, G.R.; Savell, J.W.; Jones, D.K. 1987. Effect of acid treatment of beef strip loin steaks on the microbiological and sensory characteristics. Int. J. Food Micro. 5:181-186.

Gill, C.O.; Newton, K.G. 1982. Effect of lactic acid concentration on growth on meat of Gram-negative psychrotrophs from a meatworks. Appl. Environ. Micro. 43:284-288.

Greer, G.G.; Dilts, B. 1992. Factors affecting the susceptibility of meatborne pathogens and spoilage bacteria to organic acids. Fd. Res. Int. 25:355-364.

Hardin, M.D.; Acuff, G.R.; Lucia, L.M.; Oman, J.M.; Savell, J.W. 1995. Comparison of methods for contamintion removal from beef carcass surfaces. J. Food Prot. 58.

Khan, M.; Katamay, M. 1969. Antagonistic effect of fatty acids against Salmonella in meat and bone meal. Appl. Microbiol. 17:402-404.

Lillard, H.S.; Blankenship, L.C.; Dickens, J.A.; Craven, S.E.; Shackelford, A.D. 1987. Effect of acetic acid on the microbiological quality of scalded picked and unpicked broiler carcasses. J. Food Prot. 50:112-114.

Ockerman, H.W.; Borton, R.J.; Cahill, V.R.; Parrett, N.A.; Hoffman, H.D. 1974. Use of acetic and lactic acid to control the quantity of microorganisms on lamb carcasses. J. Milk Food Tech. 37:203-204.

Osthold, W.; Shin, H.-K.; Dresel, J.; Leistner, L. 1984. Improving the storage life of carcasses by treating their surfaces with an acid spray. Fleischwirtsch 64:828-830.

Reynolds, A.E.; Carpenter, J.A. 1974. Bactericidal properties of acetic and propionic acids on pork carcasses. J. Anim. Sci. 38:515-519.

Rubin, H.E. 1978. Toxicological model for a two-acid system. Appl. Environ. Micro. 36:623-624.

Smulders, F.J.M.; Barendsen, P.; van Logtestijn, J.G.; Mossel, D.A.A.; van der Marel, G.M. 1986. Review: Lactic acid: considerations in favor of its acceptance as a meat decontamininant. J. Food Technol. 21:419-436.

Smulders, F.J.M.; Woolthuis, C.H.J. 1985. Immediate and delayed microbiological effects of lactic acid decontamination of calf carcasses - Influence of conventionally boned versus hot-boned and vacuum-packaged cuts. J. Food Prot. 48:838-847.

Snijders, J.M.A.; van Logtestijn, J.G.; Mossel, D.A.A.; Smulders, F.J.M. 1985. Lactic acid as a decontaminant in slaughter and processing procedures. Vet. Quart. 7:277-282.

van der Marel, G.M.; van Logtestijn, J.G.; Mossel, D.A.A. 1988. Bacteriological quality of broiler carcasses as affected by in-plant lactic acid decontamination. Int. J. Food Micro. 6:31-42.

Visser, I.J.R.; Koolmees, P.A.; Bijker, P.J.H. 1988. Microbiological conditions and keeping quality of veal tongues as affected by lactic acid decontamination and vacuum packaging. J. Food Prot. 51:208-213.

Woolthuis, C.H.J.; Mossel, D.A.A.; van Logtestijn, J.G.; de Kruijf, J.M.; Smulders, F.J.M. 1984. Microbial decontamination of porcine liver with lactic acid and hot water. J. Food Prot. 47:220-226.

Woolthuis, C.H.J.; Smulders, F.J.M. 1985. Microbial decontamination of calf carcasses by lactic acid sprays. J. Food Prot. 48:832-837.

Zeitoun, A.A.M.; Debrevere, J.M. 1990. The effect of treatment with buffered lactic acid on microbial decontamination and on shelf life of poultry. Int. J. Food Micro. 11:305-312.