Effect of Non-Meat Ingredients as an Aid to Shelf-Life

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Introduction

Throughout history, the meat industry has utilized non-meat ingredients to extend or aid in the shelf-life of products. The classic use of salt and/or nitrites to control and limit microbiological growth and to provide flavor stability during storage has provided needed "insurance" for meat product shelf-life. Currently, consumers' concern for food safety continues to make methods of extending meat product shelf-life a high priority throughout the meat industry. As a result, the examination of new ingredients to aid in extending meat product shelf-life is an on-going, evolving area of research. The objective of this paper is to present new information on non-meat ingredients that are being examined to extend shelf-life in meat products.

Color Stability of Fresh Meat

Optimization of color in fresh meat and meat products is a strong indicator of shelf-life. Non-meat ingredients that stabilize color or decrease the time prior to meat color fading are viable aids in improving shelf-life of meat products. Wilson Foods sprayed pork chops with a water solution containing ascorbic acid and citric acid to extend the length of time a bright, grayish-pink color could be maintained in pork chops at the retail meat case. Wilson produced a line of products which were introduced in October, 1986 under the brand-name of TenderCuts. These products were cut at a central location, sprayed with a water, ascorbic acid and citric acid solution, placed in over-wrapped polystyrene trays with a soaker pad, and master packaged in a modified-atmosphere package. The TenderCuts were marketed with 17 days of shelf-life (14 days in distribution and 3 days for retail display; Anonymous, 1988). Ascorbic and citric acids have been shown to act as heavy metal chelators and ascorbic acid acts as an oxygen absorber. It is through these mechanisms that ascorbic and citric acids have been shown to stabilize the heme-portion of muscle pigments.

The addition of whole seasonings, either individually or in combination, into meat products has been shown to limit the time desirable color can be maintained in meat products. Oleoresins or the oil fraction of spices that contain the spice flavoring agents are being used to replace whole spices. These compounds have been shown to assist in maintaining a desirable color and to limit color fading in meat products (Bacus, 1991). Bacus (1991) indicated that compounds associated with color deterioration are removed during the spice extraction process when the spice oil or oleoresin is obtained.

Papadopoulos et al. (1991b) found that the addition of 2% to 4% sodium lactate in cooked beef top rounds resulted in a redder-colored lean surface. As sodium lactate increased the pH of the final product, the color enhancement in cooked beef roasts was attributed to the subsequent increase in pH. Sodium lactate was added to 10% fat ground beef patties to reduce dehydration and to maintain a bright, cherry-red color in the product during frozen storage (Mendez et al., 1992). Preliminary results indicate that the addition of 3% sodium lactate reduced visible dehydration. Additionally, the sodium lactate-treated low-fat beef patties were brighter red immediately post-freezing and during frozen storage for up to 42 days. The addition of non-meat ingredients that limit or affect microbiological growth can affect product color stability by limiting the color deterioration associated with microbial spoilage.

Microbiological Shelf-Life

Non-meat ingredients have been used throughout history as a method of limiting or controlling the growth of microorganisms in meat systems. This discussion will concentrate on ingredients that are recently being evaluated or used in meat products to aid in shelf-life.

Organic Acids

Food grade organic acids, such as malic, acetic, lactic, benzoic, sorbic and propionic acids, have been used to limit microbiological growth.

Recently, the interest in lactic, citric and acetic acids for the decontamination of carcasses by the meat industry has escalated. Numerous research studies have shown that organic acid reduces bacterial counts on carcasses if the organic acid is applied prior to microbial attachment to the carcass or meat surface (Acuff, 1991). Table 1 summarizes some of the major research studies which have examined the use of organic acids to reduce microbiological contamination of meat. Acuff (1991) stated that the antimicrobial effects of organic acids are mainly dependent on: 1) the sole effect of pH; 2) the extent of dissociation of the acid, which is related to the pH; and 3) the specific effect of the acid molecule. He further clarified that at a given pH the antimicrobial activity of an acid is related to the ability of the acid to penetrate the cell, the part of the cell which is attacked and the chemical nature of the attack. Acuff (1991) concluded that hot organic acid used as a decontaminate is effective for beef carcasses on the slaughter floor in combination with good manufacturing practices. Currently, a

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Table 1. Summary of Research Examining the Effect of Organic Acids in Carcass Wash Systems to Reduce the Microbiological Levels.

Study	*Meat Species /Product*	*Organic Acid/Level*	*Summary of Results*
Snijders et al. (1985)	Beef/ carcass	Lactic acid/1.25%	a bactericidal and bacteriostatic when used as a final processing aid.
	Veal/ carcass	Lactic acid/1.25%	
	Pork/ carcass	Lactic acid/1.5%	
Dickson (1991)	Beef/ cubes	Acetic acid/2%	up to 3 log cycle reduction in *Salmonella typhimurium, Listeria monocytogenes and Escherichia coli* 0157:H7.
Dickson and Anderson (1992)	Beef/ tissue	Acetic acid/2%	2 $\log_{10}$ reduction in *Salmonella california.*
Hamby et al. (1987)	Beef/ carcasses	Acetic acid/1%	0.8 and 2.4 $\log_{10}/cm^2$ reduction in total aerobic numbers.
Bell et al. (1986)	Beef/cubes	Acetic acid/1.2%	65% reduction in bacterial levels.
Eustace et al. (1979)	Lamb/ carcasses	Acetic acid/1.5% and 3.0%	96 and 99% reduction in bacterial levels, respectively.
Acuff et al. (1987)	Beef/ subprimals	Lactic, acetic, citric, ascorbic acids/varied	No effect in aerobic plate counts with treatment.
Dixon et al. (1987)	Beef/ steaks	Lactic, acetic, citric, ascorbic acids/varied	No effect on extending shelf-life of beef steaks.
Woolthuis and Smulder (1985)	Beef/ calf carcass	Lactic acid/1.25%	Decrease surface pH by 3 unites at 2.5 h postmortem.

major research project to examine the industrial application of lactic, citric and acetic acids as carcass decontaminates is being conducted by the National Live Stock and Meat Board.

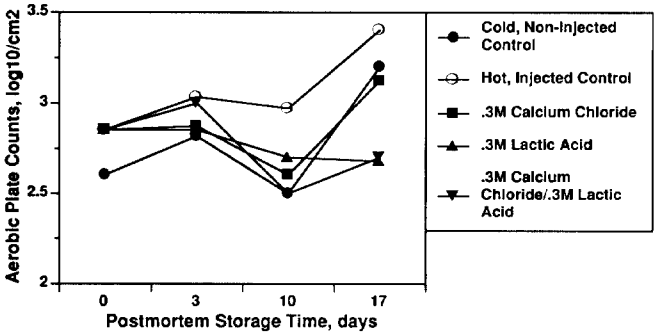
Organic acids also can be added directly to meat systems as antimicrobial agents. However, the addition of organic acids, which usually will alter pH, can have detrimental effects on color stability if concentrations are too high within the system. For example, Eilers et al. (1992) injected a 10% water solution to mature beef, hot-boned, cow top round so that the top rounds contained either .3M lactic acid, .3M lactic acid and .3 M calcium chloride, .3M calcium chloride, or water only. A cold, non-injected control also was used in the study. After 17 days of refrigerated storage, the top rounds containing .3M lactic acid or .3M lactic acid and .3M calcium chloride had lower aerobic plate counts ($P<.05$) than other treatments used in the study (Figure 1). However, discoloration of the lean occurred in the top rounds containing lactic acid. It was concluded that lactic acid aided in reducing aerobic plate counts in a hot-injected meat system, but that the level of lactic acid was detrimental to the color characteristics of the lean. Research is ongoing to adjust the level of lactic acid used in this system.

Micro-encapsulated organic acids could provide new meat applications for organic acids. Micro-encapsulation provides the opportunity to control or delay the effects of the acid, whereas the acid would be activated upon degradation, disruption or melting of the encapsulation material.

Sodium and/or Potassium Lactate

Sodium and potassium lactate currently are approved at levels of 2% for use as flavor enhancers and flavoring agents in cooked meat, poultry products, cured cooked meat and raw poultry products (Federal Register, 1990). Research documenting the antimicrobial activity of sodium lactate in the meat industry has been reported (Table 2). It can be concluded that sodium lactate is an aid in extending the shelf-life of meat products. It is not clear as to the exact mechanisms or mode of action for this effect. The role of sodium lactate to reduce water activity has been exam-

Figure 1



Aerobic plate counts for *Semimembranosus* muscle.

Adapted from Eilers et al. (1992)

Table 2. Summary of Research Examining the Effect of Sodium Lactate to Aid In Extending the Shelf-Life of Meat Products.

Study	*Meat Species/Product*	*Summary of Results*
Grau (1980)	Meat aqueous extracts	Growth inhibition of *Brochothrix thermosphacta* during 7 days of incubation in the presence of 100 mM sodium lactate; concentration of undissociated lactic acid was the governing factor.
Krol (1972)	Pork/Country-style hams	Decreased growth of *Lactobacilli spp.* and *Micrococci spp.*
Maas et al. (1989)	Turkey/cook-in-bag products	Demonstrated antimicrobial effect of sodium lactate at various levels.
Anders et al. (1989)	Fish and poultry	Patent application for using lactate salts to delay *Clostridium botulinum* growth at 1 to 7% levels.
Debevere (1989)	Pork/liver paté	Increasing sodium lactate from 0% to 2%, decreased microbiological levels.
deWitt and Rombout (1990)	Medium broth	*Streptococcus faecalis, Staphylococcus aureus* and *Salmonella typhimurium* were inhibited when grown in a medium containing sodium lactate at a constant water activity (.958).
Papadopoulos et al. (1991a)	Beef/cooked top round	Roasts containing 3% to 4% sodium lactate had a 2 log reduction in aerobic plate count.
Papadopoulos et al. (1991c)	Beef/	3% and 4% sodium lactate decreased growth of *Salmonella typhimurium, Listeria monocytogenes, Escherichia coli* 0157:H7, and *Clostridium perfringens* up to 28 days at 10°C.
Lamkey et al. (1991)	Pork/ fresh sausage	3% sodium lactate reduced the lag phase of microbial growth and reduced off-odor development.
Brewer et al. (1991)	Pork/ fresh sausage	Addition of 2% or 3% delayed microbial deterioration by 7 to 10 days at 4°C.

ined as a mode of action and the scientific literature supports the water activity lowering effect of sodium lactate. However, evidence also exists that supports an alternate mode of action of the lactate ion (the lactate ion effect is discussed under organic acids). The inability to clearly define the mode of action of sodium lactate stimulated additional research in my laboratory which incorporated the use of potassium lactate in addition to sodium lactate to aid in extending the shelf-life of meat products.

Pagach et al. (1992) utilized a standard level of lactate concentration and varied the concentration of either sodium or potassium in precooked beef roasts to examine if sodium lactate or potassium lactate and combination of these ingredients affected microbiological growth during refrigerated storage (Table 3). Control roasts (those roasts not containing sodium or potassium lactate) had higher aerobic plate counts than roasts containing 4% sodium lactate (a 2 $\log_{10}$ difference). When sodium lactate was replaced with potassium lactate in increasing amounts until the final product contained 4% potassium lactate, aerobic plate counts did not differ from the control; however, aerobic plate counts tended to concomitantly increase with decreasing levels of sodium lactate. It should be noted that commercially available sodium lactate and potassium lactate contain slightly different concentrations of lactate due to the differences in molecular weight of sodium and potassium. Therefore, an additional study was conducted which examined varying levels of sodium and/or potassium lactate where the lactate level was standardized (Harris et al., 1992). In this study, the lactate ion concentration was formulated so that the final cooked beef product contained either 0% (control) or 2% or 4% sodium and/or potassium lactate combination and the lactate concentration was standardized within treatment. Water activity and aerobic plate counts were determined (Figure 2a,b). Aerobic plate count increased with storage for the control non-injected and the water-injected control. The addition of either sodium and/or potassium lactate reduced aerobic plate count during storage. However, the addition of 4% sodium lactate resulted in lowering the water activity to .90 or less, from .98 in the control roasts. These data support the water activity lowering effect of sodium lactate. At the 4% sodium and/or potassium lactate level, the replacement of the sodium ion by potassium resulted in sequential increases in water activity. These data suggest that the sodium ion is responsible for the water activity lowering effect of sodium lactate and when sodium lactate is replaced with potassium lactate, the tendency for a decrease in the bacteriostatic effect is due to the limited ability of potassium lactate to lower water activity. These data indicate that potassium lactate reduces microbial growth through the effect of the lactate ion and that sodium lactate limits microbial growth through a combined effect of lowering water activity and the effect of the lactate ion.

The use of sodium lactate, potassium lactate or combinations of these ingredients can continue to provide an aid

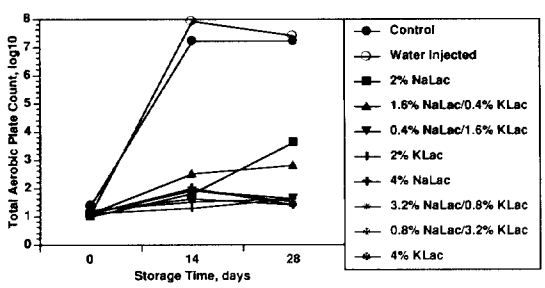
Table 3. Means and Residual Standard Deviations for Laboratory Analyses, Microbiological Data and Cook Yields by Treatments of Sodium and/or Potassium Lactate and Storage Periods.

Treatment	*Microbial values (CFU log_{10}/cm^2)*	*TBA (mg/100g)*	*pH*
Lactate Level[a]	*	**	**
Control (0% Na and/or K lactate)	6.3^{d}	3.02^{h}	5.77^{c}
4.0% sodium lactate	4.0^{c}	$.54^{c}$	6.07^{i}
3.2% sodium lactate/.8% potassium	5.9^{d}	1.23^{e}	6.00^{h}
2.4% sodium lactate/1.6% potassium lactate	5.6^{d}	1.51^{f}	5.95^{g}
1.6% sodium lactate/2.4% potassium lactate	5.5^{cd}	1.62^{g}	5.93^{f}
.8% sodium lactate/3.2% potassium lactate	5.4^{cd}	1.06^{d}	5.91^{e}
4.0% potassium lactate	5.2^{cd}	1.21^{e}	5.89^{d}
Storage Period (days)	**	**	**
0	1.3^{c}	1.85^{e}	5.97^{e}
28	6.5^{d}	2.32^{f}	5.87^{c}
56	6.7^{d}	$.98^{d}$	5.98^{e}
84	7.2^{d}	$.67^{c}$	5.90^{d}
RSD[b]	1.2	.03	.02

[a]Identifies the concentration of sodium and/or potassium lactate in the final product.
[b]RSD - residual standard deviation.
[cdefghi]Means within a column, main effect (lactate level or storage period) and blocking variable having different superscripts are significantly different ($p<.05$).
* Significance level reported in analysis of variance ($p<.05$).
**Significance level reported in analysis of variance ($p<.01$).

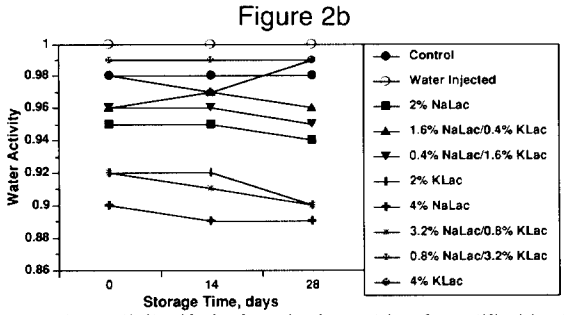
Adapted from Pagach et al. (1992).

Figure 2a



Mean aerobic plate count (log_{10}/cm^2) of cooked roast beef stratified by treatment and storage time.

Figure 2b



Mean water activity (A_w) of cooked roast beef stratified by treatment and storage time.

Adapted from Harris et al. (1992).

to meat product shelf-life. Varying applications within new products should be explored.

Sodium Citrate, Sodium Acetate, Sorbic Acid and Potassium Sorbate

The ability of the organic salt of citrate and acetate, sodium citrate and sodium acetate, sorbic acid and potassium sorbate to extend the shelf-life of meat and poultry products has been examined (Robach and Sofos, 1982; Sofos and Busta, 1981). Additionally, combinations of these ingredients have shown positive benefits for limiting the bacterial growth in meat. For example, a solution containing 10% potassium sorbate, 10% sodium acetate, 10% sodium citrate, and 5% sodium chloride was shown to reduce the growth of *Escherichia coli, Staphylococcus aureus, Streptococcus faecalis* and *Clostridium perfringens* on inoculated, unchilled beef held at 20°C and 30°C (Kondaiah et al., 1985). Mendonca et al. (1989) dipped pork chops in solutions containing potassium sorbate, sodium acetate, phosphates and sodium chloride alone or in combination prior to vacuum-packaging. They showed that potassium sorbate alone reduced microbial counts more than it did when combined with phosphates, but pork chops dipped in the potassium sorbate mixture were darker in color and contained higher amount of exudate in the package. Unda et al. (1990) treated beef steaks with combinations of potassium sor-

bate, phosphate, sodium chloride and sodium acetate. They concluded that surface treatment with a potassium sorbate/phosphate/sodium chloride/sodium acetate solution was effective in reducing the microbiological levels of vacuum-packaged beef steaks. Use of these ingredients, alone, in combination, and with phosphates could provide opportunities for the extension of shelf-life of meat products.

Bacteriocins

The term "bacteriocin" has been broadly used as a method of identifying protein substances with antagonistic effects on specific or a range of bacteria. The production of substances by bacteria that either have bacteriostatic or bactericidal effects on competing organisms has been documented. For example, the production of lactic acid by *Lactobacillus spp.* has been shown to have a bactericidal effect on many competing organisms commonly found in meat systems. Other ingredients which have been shown to be produced by bacteria which have growth-limiting or lethal effects on other strains of bacteria include hydrogen peroxide, organic acids and ammonia. A bacteriocin was characterized as having: 1) a narrow spectrum of activity against other bacterial strains; 2) an essential, biological moiety for activity; 3) bactericidal activity; 4) adsorption to specific receptors on cells; 5) the genes for production and immunity to the bacteriocins are found on plasmids; and 6) lethal biosynthesis (Eckner, 1992).

While bacteriocins provide the meat industry with an excellent opportunity for controlling microbial growth using new technology, some disadvantages exist. A single bacteriocin has a narrow range of bacterium that it will affect and bacteriocins interact with gram-positive bacterium only. A major concern in whole-muscle and particle-reduced meat products is that bacteriocins would be limited to the area where the bacteriocin-producing bacteria are located (Eckner, 1992). Bacteriocins have been shown to be effective in fluid products such as milk and soup, but in larger-sized particle and solid products, the form of most meat products, pockets of bacteriocin-producing microorganisms could be formed. The effectiveness of the bacteriocin would be limited to these locations.

A number of bacteriocins have been presented in the literature, such as listeriocins and moncins which are inhibitory against *Listeria monocytogenes.*; colicins which are produced by coliforms; or lactostrepcins which are produced by lactic streptococci. Nielsen et al. (1990) examined a bacteriocin that was produced by *Pediococcus acidilactici* and demonstrated that *Listeria monocytogenes* could be reduced in fresh meat by 0.5 to 2.2 log cycles.

Eckner (1992) stated that bacteriocin-producing starter cultures or adjunct cultures in dry and semi-dry, fermented sausages, where pediococci, lactobacilli, and other lactic acid bacteria are used as starter cultures, had potential for use in meat products. Bacus (personal communication) indicated that bacteriocin-producing bacteria are being examined in starter culture for use in fermented sausages. At a constant pH which removed the pH effect, bacteriocins were effective in limiting bacterial growth at a constant pH. In Europe, starter cultures are used in non-fermented meat products as an aid in shelf-life. Bacus (personal communication) has suggested that the isolation of extracts from bacteriocin-producing cultures containing more than one single bacteriocin is needed. This would expand the functionality of the bacteriocin and increase the range of the bacteriocidal effect. It is clear that bacteriocins could have efficacy in controlling the microbial populations in meat. However, combinations of different bacteriocins, levels, handling techniques and long-term benefits and concerns should be examined.

Nisin

Nisin is a naturally occurring bacteriocin which has been shown to be effective against *Clostridium botulium* spores, but it is only approved for use in processed cheese in the United States. In 1988, nisin was approved as Generally Recognized as Safe (GRAS) by the FDA (Federal Register, 1988) and to date is the only bacteriocin to receive GRAS status. Whereas nisin is not approved for use in meat

Table 4. Advantages and Disadvantages for the Use of Nisin in Meat Products.

Advantages	*Disadvantages*
1. GRAS approved.	1. Limited antimicrobial scope.
2. Product thermal processing could be reduced which saves energy costs and improves product sensory properties and nutritional content.	2. Effective on low levels of sensitive bacterial species.
3. Added level of microbial safety (insurance) from both spoilage and pathogenic microbes which would not hide spoilage and poor manufacturing practices.	3. Chemical or enzymatic activity, processing treatments, or physical characteristics like high viscosity or particulates may affect the effectiveness.
4. Not effective against high levels of contamination so it does not hide poor quality.	4. Concern on product stability in relation to pathogens and spoilage microbes, maintaining the competitive environment and the effect on suppression or alteration of typical spoilage properties which could lead to consumer abuse.

Adapted from Eckner (1992).

products in the United States, it has been used internationally for about 40 years (Suresh, 1991).

The advantages and disadvantages for the use of nisin in meat products are summarized in Table 4. It is clear that nisin is an exciting and potentially positive aid in extending shelf-life of meat products; however, examination of the negative and unknown aspects of its use must be examined and carefully considered.

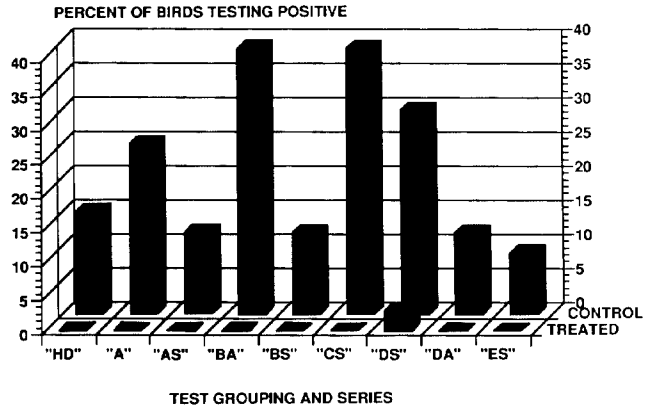
Eckner (1992) stated that bacteriocins contain active protein, lipid and carbohydrate groups. The bacteriocin proteins are essential for function and it is thought that it is the proteins which interact with the bacterial cell of inhibition. Research has documented that nisin affects the phospholipid component in the cytoplasmic membrane (Hennings et al., 1986; Ramseier, 1960; Ruhr and Sahl, 1985; Sahl and Brandis, 1983) which results in an alteration of the membrane potential causing a rapid efflux of amino acids and cations into the cell, and cell viability decreases (Kordel and Sahl, 1986; Ruhr and Sahl, 1985). Nisin has been shown to be very effective against gram-positive microorganisms, but has limited or no effect on gram-negative organisms (Eckner, 1992). However, Suresh (1991) indicated that on-going research examining the use of chelating agents in combination with nisin increased the bactericidal effect on gram-negative bacteria such as *E. coli.* Additionally, Suresh (1991) stated that the spectrum of activity of nisin can be enhanced by the use of emulsifiers and surfactants.

Rayman et al. (1981) and Eckner (1992) proposed the use of nisin in cured meat products as an alternative for reducing the nitrite levels in meat products. Rayman et al. (1981) did find a synergistic effect between nisin and nitrite, and suggested the use of 75 ppm of nisin and 40 ppm nitrite as a method for controlling *C. botulinum* spore outgrowth and that this combination of nisin and nitrite was more effective in controlling *C. botulinum* than 150 ppm nitrite used in these same products.

Trisodium Phosphate

The use of trisodium phosphate as a processing aid for poultry carcasses is currently under consideration by USDA, FSIS (a petition has been submitted and is under consideration by USDA, FSIS). Trisodium phosphate is a GRAS approved compound and is commonly used in cheese at a level of 2%. The Rhone-Poulenc process, which is patented, uses a solution of water containing 10% trisodium phosphate at 10°C or less. Poultry carcasses then are immersed in the solution for no more than 15 seconds. The result is a reduced incidence of Salmonella on poultry at a cost of less than $.01 per bird (Figure 3). Trisodium phosphate did not significantly reduce aerobic plate counts and poultry carcasses spoiled in the same period of time as untreated carcasses (Anonymous, 1992). Low residues of trisodium phosphate are found on poultry carcasses after immersion. It has been concluded that trisodium phosphate only operates during the immersion process and that it has no lingering effects during subsequent storage. Additionally, trisodium phosphate did not bind water and should not be confused with sodium tripolyphosphates.

Figure 3



Salmonella results summary for poultry carcasses treated with a prechilled, 15 second treatment by immersion in a solution of trisodium phosphate or a control (not containing trisodium phosphate).

Adapted from Anonymous (1992).

Where the pH and the ionic strength of solutions are increased by the addition of trisodium phosphate, the mode of action was purposed by trisodium phosphate's effect on the cell wall of the bacteria. Trisodium phosphate affected mainly fecal pathogens or gram-negative pathogens (Anonymous, 1992). Alternate uses of trisodium phosphate in other meat products must be explored. The ability to add trisodium phosphate to other meat products provides an opportunity to assist in controlling *Salmonella spp.* and other gram-negative bacteria. The synergistic effect of trisodium phosphate with other antimicrobial agents could be a method of extending meat shelf-life.

Blood Fractions

Research on the use of animal blood fractions as antimicrobial agents in meat products has been examined (van Roon and Olsman, 1977; Tompkin et al., 1978a,b, 1979). However, new interest in the use of blood fractions in combination with nitrite as antibotulinal agents in beef sausage has emerged (Miller and Menichillo, 1991). Miller and Menichillo (1991) examined six strain spore mixture of *Clostridium botulinum* type A (33, 62A, 69) and proteolytic type B (999, 169, ATCC 7949) in a model beef sausage product. They utilized plasma, red blood cells and whole blood fractions within the system at levels of 0% to 5%. In control beef sausage mixtures not containing nitrites, toxin production occurred in 1 wk, but when blood fractions were added to the product, toxin production was delayed to 1 to 3 wk. They found that the use of blood fractions that increased the iron levels in beef above 30 μg/g interfered with the antibotulinal efficacy of sodium nitrite. They concluded that iron in the blood fractions extracellulary bound to nitrite which prevented nitrites entry into the cell. They suggested that additional microbial growth barriers should be added to meat products when iron-containing compounds are added to cured meats.

Water Activity Lowering Ingredients

Consumer awareness of the relationship between consumption of dietary fat and disease, especially coronary heart disease and colon cancer, has resulted in a low-fat product development revolution. As new products are developed as fat replacements (for a review of currently available fat replacements, see Keeton, 1991), these ingredients could have positive or negative effects on product shelf-life. Many fat replacements bind water (i.e., gums or hydrocolloids, starches, protein-based fat replacements), and therefore act to replace the juiciness associated with fat with juiciness derived with the release of water from the fat replacement. Altering the amount of water added in combination with the fat replacement used in meat products could influence water activity and ultimately shelf-life. It has been well documented that lowering of water activity assists in limiting microbiological growth and increasing water activity generally enhances microbiological growth. Consideration of the amount of water needed to provide positive sensory properties and balancing the amount of water (by lowering water activity) to possibly enhance shelf-life should be examined as new products are developed. Additionally, some fat replacements contain carbohydrates which can stimulate microbiological growth and provide new challenges in maintaining product shelf-life.

Soy proteins have traditionally been added to meat products as a method of extending the meat component and reducing the overall cost of the final product. As soy proteins absorb water and are hydrated prior to addition to meat systems, the addition of soy protein most likely either does not alter water activity or increases water activity in the final product. As new products are developed, lowering of water activity through the use of soy proteins, which are not fully hydrated, could offer shelf-life extending opportunities.

Flavor Stability During Shelf-Life

The use of ingredients to stabilize flavor components of meat products during storage has been extensively investigated. The major issues in meat product flavor stability are the development of off-flavors which result from the oxidation of lipids and the deterioration of characteristic species flavors during storage. The traditional oxidized or "warmed-over" flavor (WOF) that results during flavor deterioration has been shown to be the result of lipid oxidation. Compounds that retard lipid oxidation are classified as either chelators (compounds that bind up heavy metals, especially divalent metals such as iron and copper), free-radical scavengers (compounds which react with free radicals that are formed during propagation), retarders (compounds which reduce hydroperoxides, but do not form additional free radicals), and singlet oxygen quenchers (compounds which bind singlet oxygen, therefore limiting initiation) (Pokorny, 1991).

Identification of naturally-occurring ingredients in food products has been investigated by numerous researchers. Extracts from different food ingredients including green peppers, onions, potato peelings (Watts, 1962), extracts from different plants (Pratt and Watts, 1964), glandless cotton seed (Ziprin et al., 1981), defatted, glandless cotton seed flour (Rhee and Smith, 1983), soy protein flour, soy protein concentrates and soy protein isolates (Hayes et al., 1977; Pratt and Birac, 1979; Pratt et al., 1981; Arganosa et al., 1991; Romijn et al., 1991), and spices (Bishov et al., 1977; Chang et al., 1977; Houlihan et al., 1984,1985; Barbut et al., 1985) have been proposed.

Tocopherols and Spice Extractives

Natural tocopherols and spice extracts, oils and oleoresins are currently in use as antioxidants in the meat and poultry industry. Tocopherols are commercially available and are used in rendered animal fats and poultry products (Bacus, 1991). When tocopherols are included in a product, the label must include the name "tocopherols" or "natural tocopherols." These products aid in shelf-life extension by stabilizing flavor. The antioxidant properties of rosemary and sage whole spices have been well documented (Chang et al., 1977), but clove, cinnamon, mace, oregano, allspice and nutmeg also have shown antioxidant properties. Bacus (1991) discussed the use of oleoresins and their functionality as antioxidants. The addition of oils and oleoresins provide multifunctions in extending shelf-life of meat products. These ingredients have been shown to reduce color fading, provide flavor stability through antioxidant properties and as these ingredients are sterile and "cleaner," the negative effect of spices on increasing microbiological growth is eliminated. The replacement of whole spices in meat products by spice extractive continues to escalate (Bacus; personal communication) and continued understanding of the functional properties of spice extractives is on-going.

Soy Proteins

As numerous research studies have documented the antioxidant properties of soy proteins, extensive discussion will be limited. However, it should be noted that recent research continues to provide additional information that soy proteins provide antioxidant properties. Arganosa et al. (1991) showed that when soy protein isolates were used singly or in combination with sodium tripolyphosphate in restructured beef roasts, soy protein isolates were more effective in reducing lipid oxidation at lower degrees of doneness, but at higher degrees of doneness, sodium tripolyphosphate had stronger antioxidant properties. The low cost of soy proteins and the inherent antioxidant properties of these compounds should stimulate new applications for these products.

Skidmore Flavor Stabilizer-O™

A new ingredient called Skidmore Flavor Stabilizer-O™, developed by Robert Terrell, is currently being merchandised to the meat industry. This ingredient can be added to raw meat or poultry products at a level of .1875% (85.125 gms or 3 oz. per 100 pounds of meat) and can be identified as a "natural flavoring" or "spice extractive" on the label declaration. The product is a dry ingredient, contains no preservatives, and can be used to replace chemical antioxidants in meat and poultry products. It is a pH-stabilized flavoring which contains extractive of spice on a malto-

dextrin carrier. The product ingredient statement defines the following ingredients in the product in order of predominance: malto-dextrin, extractive of spice, vegetable oil, citric acid, and mono and diglycerides, with not more than 2% tetrasodium pyrophosphate as an anticaking agent. It has been shown to be effective for use in preblends or in mechanically deboned or desinewed meat materials. This product has been on the market since 1991 and has application as an aid in limiting lipid oxidation in meat and poultry products. The unique characteristic of this ingredient is that it utilizes a combination of antioxidants to control lipid oxidation. This trend is to combine antioxidants (metal chelator, free-radical scavenger) to increase control of and the functionality of the flavor within meat systems.

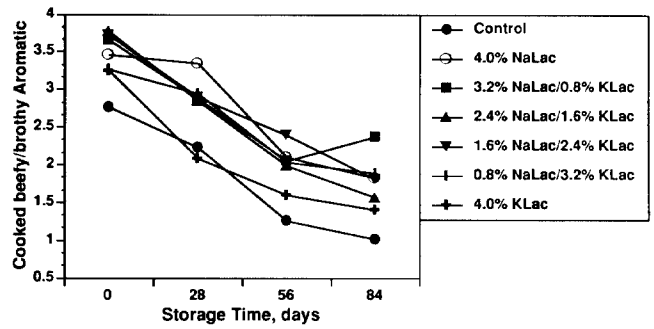
Carnosine

Interest in carnosine, which is a naturally occurring skeletal muscle dipeptide consisting of ß-alanine and histidine (Crush, 1970), as a "natural" antioxidant has increased (Decker and Crum, 1991). Decker and Crum (1991) examined 0.5% and 1.5% carnosine added to frozen salted ground pork during 6 months of frozen storage. They found that carnosine was more effective than α-tocopherol, butylated hydroxyltoluene and sodium tripolyphosphate in retarding lipid oxidation, as evaluated by trained sensory panels and TBA values. These results suggest that carnosine has application as an antioxidant in meat systems and examination of alternate uses should be initiated.

Sodium and/or Potassium Lactate

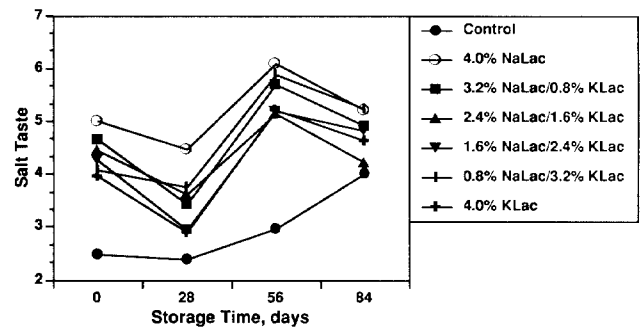
Sodium lactate has been shown to enhance the cooked beefy/brothy aromatic and to limit the subsequent decline in this aromatic during refrigerated storage in cooked beef roasts (Papadopoulos et al., 1991 b,c; Evans et al., 1991). As cooked beefy/brothy aromatic declined during refrigerated storage, increased intensity of aromatics associated with WOF have been reported (Papadopoulos et al., 1991b,c; Evans et al., 1991; Pagach et al., 1992). Pagach et al. (1992) examined the effect of sodium lactate and/or potassium lactate on flavor attributes and TBA values of cooked beef during refrigerated storage from 0 to 84 days (Figures 4a,b and 5a,b; Table 3). The addition of sodium lactate, potassium lactate, or combinations of sodium and potassium lactate so that the final product contained 4% of the ingredients enhanced cooked beef/brothy aromatic at 0 days of storage. During storage, cooked beefy/brothy declined; however, the products containing combinations of .8% sodium lactate/3.2% potassium lactate to 4% sodium lactate tended to maintain higher levels of cooked beefy/brothy aromatic, whereas the addition of 4% potassium lactate had similar levels of cooked beefy/brothy aromatic from 28 to 84 days of refrigerated storage when compared to control roasts. Cardboardy and painty aromatics were evaluated in these cooked beef top rounds as an indication of WOF development (Johnsen and Civille, 1987). Cardboardy and painty aromatics increased with refrigerated storage (Figure 5a,b), whereas control roasts and those containing 4% potassium lactate had the highest intensity of cardboardy and painty aromatics after 56 and 84 days of refrigerated storage.

Figure 4a



Effect of sodium and/or potassium lactate concentration and storage time on cooked beefy/brothy aromatic.

Figure 4b



Effect of sodium and/or potassium lactate concentration and storage time on salt taste.

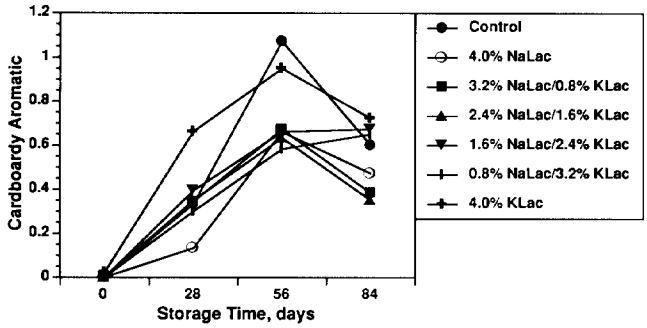
Adapted from Pagach et al. (1992).

These data indicate that the addition of sodium lactate enhances cooked beefy/brothy aromatics, and limits the development of aromatics associated with WOF; however, when 4% potassium lactate was incorporated into cooked beef top rounds, the aforementioned flavor aromatics were similar in intensity to control roasts. These data suggest that potassium lactate does not function in stabilizing flavor in cooked beef products. Additionally, these data suggest that the sodium ion, not the lactate ion, is influencing the flavor stabilizing effect of sodium lactate.

Cooked beef top rounds containing sodium and/or potassium lactate tended to have lower TBA values throughout storage when compared to control roasts. The overall TBA values for cooked beef top rounds throughout storage (Table 3) showed that roasts containing 4% sodium lactate had the lowest TBA values when compared to the control roasts or roasts containing combinations of sodium and/or potassium lactate. Whereas variability for TBA values traditionally is high, trends indicated that the addition of sodium and/or potassium lactate assisted in reducing malanaldehyde levels in cooked beef top rounds during storage and therefore, would assist in limiting WOF development in cooked beef.

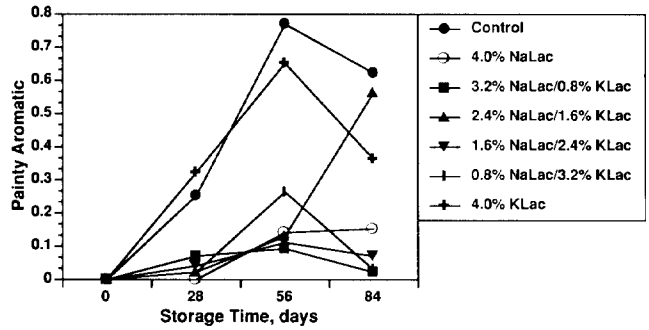
The addition of sodium lactate has been shown to affect other flavor attributes in addition to the aforementioned aromatics. For additional information on the effect of sodium lactate and/or potassium lactate on flavor attributes

Figure 5a



Effect of sodium and/or potassium lactate concentration and storage time on cardboardy aromatic.

Figure 5b



Effect of sodium and/or potassium lactate concentration and storage time on painty aromatic.

Adapted from Pagach et al. (1992).

of cooked beef, see Papadopoulos et al. (1991b,c), Evans et al. (1991), and Pagach et al. (1992). However, incorporation of sodium lactate into cooked beef top rounds did increase the intensity of salty taste (Figure 5b), but as sodium lactate was replaced with potassium lactate, salty taste was slightly reduced. Adjustments in the sodium chloride levels in the final product are needed when sodium lactate is added to meat products if the desired salty taste in the final product should not be altered.

Summary

As product development personnel, ingredient suppliers and meat scientists examine or search for new non-meat ingredients, greater emphasis is being placed on identifying non-meat ingredients with the following characteristics: 1) an ingredient that is a component of another substance, or carrier substance, that would be identified as "natural" or a "common" food ingredient; 2) the carrier substance would have positive consumer appeal on the product ingredient label; 3) the carrier substance is already on the Food and Drug Administration's (FDA) Generally Recognized As Safe (GRAS) list and is an approved meat ingredient as defined by the United States Department of Agriculture's (USDA), Food Safety and Inspection Service (FSIS) Standards and Labeling Division; and 4) the incorporation of the carrier substance would not be used at levels that would impart flavor, texture or visual changes in the original product. For example, the addition of lemon juice to a product could function as a "natural" source of ascorbic acid (used to stabilize or enhance color stability in the product). With the addition of lemon juice, the list of ingredients on the label would include "lemon juice" and not "ascorbic acid" which could be perceived by the consumer as more acceptable. Therefore, the ascorbic acid is the functioning ingredient needed to stabilize color, but the carrier substance of lemon juice, which is GRAS, would be added to the product and listed on the label.

Short-term trends for non-meat ingredients to aid in shelf-life of meat products are toward ingredients that are readily available, off-the-shelf ingredients that are currently used in some form within the food industry. The use of organic acids and the sodium salts of these acids are prime examples. Ingredients that are GRAS, are approved for use in meat products by USDA, FSIS or approved for use by FDA will continue to be examined for functionality as aids in extending meat product shelf-life.

The long-term trends emphasize natural sources of antimicrobials, antioxidants and color-stabilizing ingredients. These natural-occurring compounds have to have a positive image on the label, be easy to use and have functionality. The trend toward isolating ingredients from commonly used food ingredients that have shelf-life extending properties, then controlling the addition of these compounds in a pure or "cleaner" form has been indicated. The ability to use ingredients in combinations to enhance the functionality of each ingredient and control all aspects of shelf-life, color, flavor and microbiological levels and growth.

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Discussion

C. Nettles: Dr. Miller, you were talking about bacteriocins, and you showed that slide about them being lactic acids and peroxides. Because they are proteins, they are not lactic acids or peroxides.

R. Miller: I appreciate that, and in the lack of time I didn't get to explain that slide, so I appreciate the clarification.

Nettles: The other thing is, is when you mention a lot of these are produced on plasmids, I've worked with one that is on a chromosome, and believe me, they are not all on plasmids.

R. Miller: Thank you very much.

B. Terrell: Jerry, I just want to make one comment that hasn't been covered on the organic acid sprays of carcasses. The concern that a lot of the processors are going to have is not the fact that the technology does not work on the carcass, but EPA is coming out with new levels of chlorine and these kinds of things in the effluent. We learned a long time ago in the hot dog business that acids we used to spray with, the various acids to help peelability, and we destroyed a lot of stainless steel equipment; so I think at some point we need to look at this thing as a systems thing so that you don't get your heart broken, that nobody adopts the technology next week because a lot of these plants still have some cast iron plumbing in the drains. I remember getting into listeria where we wanted to use an acid vs. an alkaline material; and the engineering staff said "man, we can't handle the acid load through the drain system and through the sewage disposal plant." I just wanted to point that out, that the environment aspect of organic acids needs to be looked at.

Unidentified speaker: Maybe another brief comment on that—just a speculation. I have been working on stabilizing offal for rendering. When you use some of these organic acids in too high of levels and cook those things, the fumes come off in your rendering plant, and they really cause a choking fume in your rendering plant and can cause you some air quality problems. If too much of this organic acid goes to rendering, it could cause a rendering problem.

Unidentified speaker: I guess to talk on your rendering problems, some of the salts of the acids have worked. We have used sodium lactate in, for instance, pig's feet held at room temperature and have found some pretty good success using that.