

Safety and Quality Concerns – Ingredients

Dennis L. Seman

Introduction

The Problem

Listeria monocytogenes has been a menacing organism of concern in the food business. It has been difficult to control with the usual hurdles employed to prohibit bacterial growth and can be found nearly everywhere. Most food borne pathogens do not grow at temperatures as low as 4°C; however, not only can *L. monocytogenes* survive at 4°C, it can grow in vacuum packaged foods with a wide range of pH (5.2 to 9.6) and tolerate both high salt concentrations and freezing (Table 1). Outbreaks of listeriosis are the result of contamination occurring after cooking in ready-to-eat products from sources such as water splashing from floors, workers hands, and harborage points in the product handling equipment followed by growth of the organism to high numbers.

Options available for controlling *L. monocytogenes*

Traditional hurdles to bacterial growth in meat products have been the use of salt, adequate cooking, and adequate refrigeration. However, since *L. monocytogenes* is salt tolerant and can grow at refrigeration temperatures, other methods must be employed. These are listed in Table 2. In this paper, I would like to focus on the inhibition of *L. monocytogenes* growth using an antimicrobial system consisting of the incorporation of salts of lactate and diacetate.

Lactate and Diacetate

Sodium and potassium lactate (Table 3), have been incorporated into meat products as humectants, pH control agents, as flavor enhancers, and as ingredients to increase water-holding capacity and cook yield in meat and poultry products (Shelef, 1994). They have also been demonstrated to inhibit

D. L. Seman
Associate Principal Scientist
Oscar Mayer Foods Division
Kraft Foods North America, Inc.
910 Mayer Avenue
Madison, WI 53704
dseman@kraft.com

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TABLE 1. Selected characteristics of *Listeria monocytogenes* (Bahk and Marth (1990))

1.0 – 2.0 mm x 0.5 mm (small)
Gram positive
Three serotypes (1/a, 1/2b, 4b) cause 90% of the clinical infections)
pH 5.2 to 9.6
Salt tolerant (can survive for 4 months in 25.5% NaCl at 4°C)
Can survive freezing and has survived in ice cream
Can grow in an atmosphere of 5% O ₂ and 5-10% CO ₂
Growth observed at 3 to 4°C.

clostridia growth (Maas, 1989) and overall microbial growth (Papadopoulos, et al. 1991a; Bacus and Bontenbal, 1991). Several mechanisms by which the lactate ion acts as an antimicrobial agent have been postulated and include the ability of lactate to: 1) alter water activity (*a_w*), 2) pass through cell membranes and lower intracellular pH, and 3) affect cellular metabolism by inhibition of ATP generation (Bacus 1988; Maas et al. 1989). The amount of undissociated lactic acid seems to play a major role in its bacteriostatic activity (Houtsma, et al.

TABLE 2. Preservative methods to reduce growth of microorganisms in foods (adapted from Sofos, et al. 1998)

Prevention of inadvertent contamination
Removal of contamination
Thermal destruction by cooking
Inhibiting growth
Environmental control (refrigeration, freezing, dehydration, pH)
Adding antimicrobials (natural and synthetic)
Adding desirable microorganisms (fermentation)
Packaging (vacuum, modified atmosphere)
Post Package Pasteurization Treatments
Thermal
High pressure
Irradiation

TABLE 3. Properties of Selected Food Ingredients Having Bacteriostatic Properties

Compound	Chemical Formula	Molecular Weight	Comment
Sodium Acetate ¹	CH ₃ COONa	82.03	Sodium salt of acetic acid pKa = 4.76
Sodium Diacetate ¹	CH ₃ COONa·CH ₃ COOH	142	Bound compound of acetic acid and sodium acetate; soluble in water and liberates 42% available acetic acid
Sodium Lactate ²	CH ₃ CHOHCOONa	112.06	Sodium salt of lactic acid pKa = 3.86
Potassium Lactate ²	CH ₃ CHOHCOOK	128.16	Potassium salt of lactic acid pKa = 3.86
Calcium Lactate ²	Ca[CH ₃ CHOHCOO] ₂	218.22	Calcium salt of lactic acid pKa = 3.86

¹Anonymous (1996).

²Shelef, L. A. (1994).

1994). Although the exact mechanisms have not been specifically determined, lactates have been shown to be potent preservative agents in processed meat products (De Koos, 1992).

Sodium diacetate (Table 3) has been described in various ways including half-neutralized acetic acid, which when dissolved in water, liberates ca. 42% acetic acid (Anonymous, 1996). When sodium diacetate was added to brain-heart infusion broth inoculated with *L. monocytogenes* strain Scott A, Shelef and Addala (1994) noted that the MIC (minimum inhibitory concentration) decreased with decreasing temperatures. Sodium diacetate added to turkey slurries (4°C) was shown to be listericidal when added at 0.3 and 0.5% w/w (Schlyter et al. 1993); diacetate was less effective at higher temperatures (25°C). Mbandi and Shelef (2001) noted a slight drop in pH (0.2 to 0.3 pH units) when sodium diacetate was added to a sterile comminuted beef emulsion and it has been speculated that this may play a role in its antibacterial activity. Shelef and Addala (1994) made several other observations including: 1) sodium diacetate was more effective than acetic acid alone in inhibiting *L. monocytogenes* (pH range of 5 to 6) and 2) *B. cereus* along with *L. monocytogenes* species (Brie-1, DA 3, and LCDC) were suppressed by diacetate.

Implementation of the use of Lactate/Diacetate

Large and small meat establishments produce a wide range of meat products that vary in proximate composition, moisture content, and the use of other ingredients to fill customer expectations as well as to provide revenue for the manufacturer. It would be valuable to have a system whereby one could know how much lactate and diacetate would be required to provide additional insurance from *L. monocytogenes* growth if it ever was to find its way into a product. We developed such a system for formulating with lactate/diacetate mixtures by taking into account product salt content and product moisture. We developed separate models for cured and uncured meat products. Briefly, we chose a range of salt and product moisture contents and augmented the experiment by adding a range of sodium diacetate and potassium lactate

(Table 4). We designed the experiment as a central composite response surface methodology (RSM) design and cal-

culated the growth rate constants (wk⁻¹) for the test products inoculated with a cocktail of *L. monocytogenes* strains at log₁₀ 4 cfu/g using a simple kinetic model. The test products contained a minimum of ingredients including sodium erythrobate (317 ppm), modified starch (1%), sodium nitrite (97 ppm), carrageenan, 0.35%), sodium tripolyphosphate (0.276%), and varying amounts water. The growth rate constants were modeled in the RSM experimental design and reported (Seman et al.).

Figure 1 represents a surface plot of the interactions between potassium lactate syrup and product moisture on the growth rate constant of *L. monocytogenes* in cured meat holding salt and diacetate constant at 2.2% and 0.1%, respectively. Increasing amounts of potassium lactate decreased the growth rate of *L. monocytogenes* to nil at lower product moisture values. However, the moisture content of the products could not be ignored since the lowest growth rates observed at the higher moisture products were greater than zero. This indicated that under these conditions, one might not reach a zero growth rate in cured products containing 75% moisture (e.g., ham). Either one would have to manipulate the salt or diacetate content to attain a predicted zero growth rate, or one could accept the potential for some degree of growth. One must also be aware that addition of too much diacetate and lactate can change the flavor profile of a given product.

A similar model was developed for uncured meat products. Table 5 shows some of the major differences in the results between the cured and uncured models. Growth rates ranged from 0 to 0.05 wk⁻¹ for cured products and 0 to 0.24

TABLE 4. Experimental Ranges for Modeling *L. monocytogenes* Growth in Cured and Uncured Meat Products

Ingredient	Low value	High value
Salt (%)	1.5	2.9
Sodium diacetate (%)	0.05	0.15
Potassium lactate syrup (%) ¹	2.5	7
Product moisture (%)	55	74

¹ 60% potassium lactate

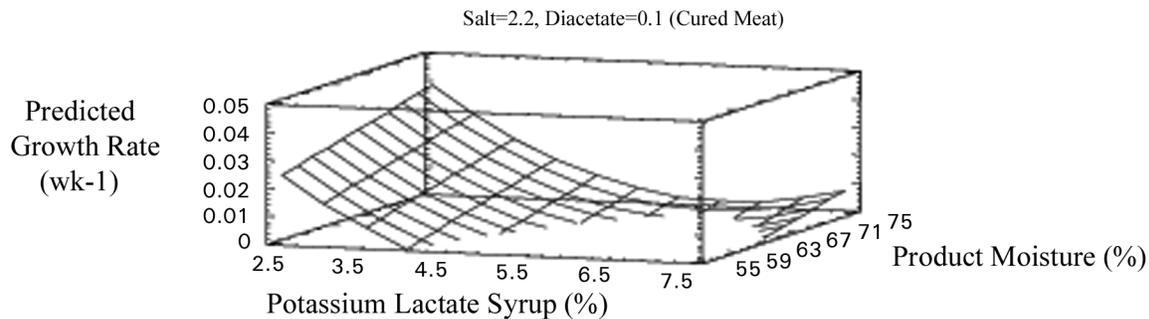


FIGURE 1. Influence of Lactate and Moisture on Predicted Growth Rate of *Listeria*

wk⁻¹ for uncured products. This indicates that nitrite was an important inhibitor of *Listeria* growth. The growth rate of *Listeria* was decreased with the increased addition of NaCl where it was a minor factor in the cured model. Lactate and diacetate decreased *Listeria* growth rates. However, it was more difficult to achieve zero *Listeria* growth in the uncured products in the absence of nitrite.

A response surface plot of potassium lactate syrup vs. product moisture (Fig. 2) illustrates that it was harder to get a zero growth rate in uncured products than in those that were cured. To do so requires relatively large amounts of potassium lactate at low product moisture. Most uncured processed meat products, however, fall into the higher moisture area of the response surface. This model is indicating that it was virtually impossible to attain zero growth rate constants in high moisture uncured meat products using these conditions. One can manipulate the ingredients to gain a minimal growth rate, but it may not be a zero growth rate.

Sodium diacetate can simply be added to the meat formulation during blending or dispensed into the brine. However, since the diacetate can dissociate into acetic acid almost immediately, the pH of the brine may be quickly reduced to a level at which some of the nitrite can be lost due to formation of nitrogen dioxide. This, however, may not be a great concern if phosphates have also been added to the brine; but "gassing off" of nitrogen dioxide has been observed with the addition of diacetate to some brines. One needs to be concerned if the pH of the brine is reduced to less than pH 6.0 upon the addition of sodium diacetate (Cahill, et al., 1974). Diacetate can also be mixed with dextrose, malto-dextrin, or

other suitable carrier and added to the product during blending or tumbling.

Impact of Lactate/Diacetate on Product Quality

Fresh Meat

Many studies have been conducted to determine the effects of using lactate on quality traits of fresh meat products, including fresh pork sausage, pork loins, and chicken breasts (Brewer, et al, 1991; Brewer et al., 1995; Lamkey et al., 1991; O'Connor et al., 1993; McKeith et al, 1994). The incorporation of lactate has been demonstrated to protect red meat color, delay the development of sour and off flavors, reduce surface discoloration, increase product juiciness, enhance meat flavor, and prevent flavor losses during storage. Few flavor problems have been observed as long as the lactate is used at no more than 4% of the product weight in red meats. Most researchers have indicated that the inclusion of lactates in the brine solutions used for enhanced pork products, primarily loins, resulted in positive product attributes and enhanced pork flavor. Sodium lactate seems to be a potent meat flavor enhancer with few detracting effects.

Precooked Meat

The flavor of precooked beef roasts containing sodium lactate exhibit enhanced fresh flavor notes, minimized warmed-over flavor notes, and a stronger beefy/meaty flavor (Papadopoulos et al., 1991b). Precooked beef roasts also appeared darker and redder than controls containing no lactate with less surface graying (Papadopoulos et al., 1991c). Maca et al. (1999) also observed increased cook yields, but also observed lower rancidity sensory scores, reduced lipid oxidation values, and decreased flavor deterioration. Again, sodium lactate appears to offer advantages when used in precooked beef products. Nnanna et al. (1994) reported that sodium lactate suppressed oxidation in pork when stored at 0 and 5°C nearly as well as BHT and was effective in controlling TBARS (thiobarbituric acid reacting substances) formation. They postulated a mechanism of Fe³⁺-lactate complexation or lactyl radical reduction of Fe³⁺ to Fe²⁺. Turner and Larik (1996) observed a significant loss of sulfur-containing compounds during storage at 4°C in sous vide processed chicken breasts containing sodium lactate. They speculated that a reduction of these compounds was an important contributor to meat aroma

TABLE 5. Differences between cured and uncured models

- Growth rates in uncured products are much higher
 - Nitrite is an inhibitor of *Listeria*
- NaCl effect was relatively more important for uncured products
- Lactate and diacetate were found to be effective inhibitors
- Overall, cannot easily achieve zero growth in uncured RTE meats with lactate and diacetate

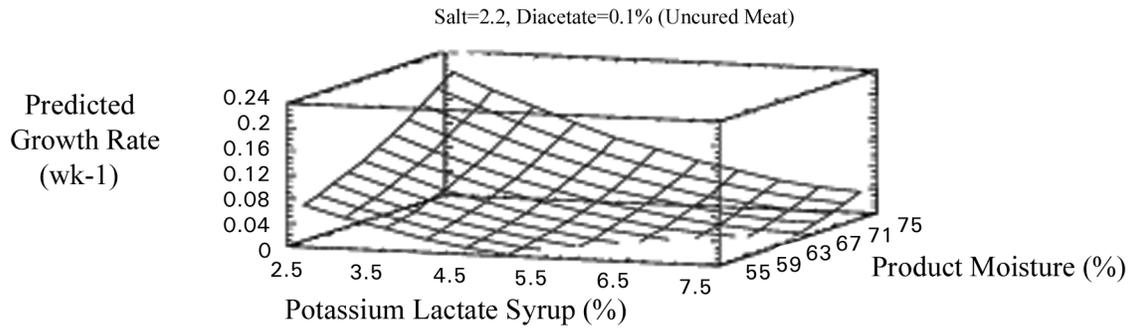


FIGURE 2. Influence of Lactate and Moisture on Predicted Growth Rate of *Listeria*

and their reduction during storage might result in a decrease in acceptable roasted meat flavor.

Processed Meat

Fewer studies have been reported for the use of lactate/diacetate in processed meats. Lactate has been shown to reduce the reddening in precooked bratwurst that was caused by high microbial counts during storage (Ghopade and Cornforth, 1991). Lactate was also shown to reduce fading in vacuum packaged beef bologna as well as increase salt flavor intensity and decrease off flavor development (Brewer et al., 1992). With ham, panelists preferred the control product in equal proportion to those which preferred the test product containing lactate and acetate (85 to 86, respectively) (Blom et al., 1997). When the milder-tasting servelat was tested, panelists preferred the control to the test product (111 to 60, respectively) (Blom et al., 1997).

Summary

Listeria monocytogenes is of serious concern to all people concerned in the food industry due to its ubiquitous nature. Each company can take steps to restrict the introduction of the organism into its plant(s) and to restrict its ability to contaminate ready-to-eat products. The precise methods used to control *L. monocytogenes* depend upon a given company's goals and other secondary methods used to prevent the growth of the organism or to kill it. The former can be accomplished with manipulation of some ingredients; the latter can be accomplished using post packaging pasteurization techniques. One useful method of reducing the growth rate of *L. monocytogenes* is to incorporate sufficient amounts of sodium diacetate and potassium/sodium lactate into meat products. One disadvantage of using lactate/diacetate combinations is that the product flavor profile may change depending upon the amount of the ingredients used. Too much diacetate can give a vinegar-type flavor and too much lactate can give a salty, metallic-type flavor particularly in uncured products. Some highly flavored products may be able to tolerate high amounts of diacetate and lactate, but others cannot. The addition of diacetate to curing brines may cause some curing problems since 42% of it dissociates into acetic acid; thus potentially lowering brine pH. These disadvantages, however, can be overcome and managed, thus making the use of lac-

tate/diacetate a useful secondary intervention to reduce the potential growth of *Listeria* in cured meat products.

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