RESEARCH REPORT

PORK SAFETY

Title: Improving the Safety of Pork Products (Hams, Bacon and Frankfurters)Processed to Simulate Traditionally Cured Pork but Without Addition Of Nitrite or Nitrate. – **NPB #06-008**

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Industry Summary

Natural and organic processed pork products such as frankfurters, bacon and hams are required to use modified meat curing methods to qualify as natural or organic because traditional preservatives are not permitted in these products. One result of this is likely to be reduced antimicrobial protection in these products and a potential for greater risk of growth of food-borne pathogens because nitrite, used in conventional curing is a very effective antimicrobial agent. This project was initiated to first evaluate a representative sampling of commercially available natural and organic frankfurters, bacon and hams for cured meat properties important to microbial control with the objective of identifying the major differences in these products important to control of bacterial pathogens. The results of this phase of the project showed that residual nitrite concentration was the cured meat property that differed the most when comparing natural and organic cured meats with conventionally cured meats. Because nitrite is a powerful antimicrobial agent, this result supported the first hypothesis for this project (greater risk of pathogen growth on natural and organic cured meats). To test the hypothesis that there is greater potential for growth of pathogens on natural and organic products, the same brands of commercial products analyzed in phase one were again purchased and inoculated with *Listeria monocytogenes* and *Clostridium perfringens* to assess the potential for growth of the pathogens. This phase of the project confirmed that pathogenic bacteria are likely to grow faster and more quickly on natural and organic frankfurters, hams and bacon than on conventionally cured products of the same type. To meet the third objective of this project, the research investigated the addition of supplemental antimicrobial agents from natural sources that would be good candidates for addition to natural and organic processed meats. This phase of the projects demonstrated that addition of natural sources of acetic acid as vinegar, citric acid as lemon juice powder and natural lactate provided effective supplemental antimicrobial control for natural and organic processed pork products. The results of this research provide a means by which natural and organic cured pork products can be produced with a continued acheivement of safety for consumers that is similar to that of conventionally cured pork products.

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Scientific Abstract.
The rapid growth in consumer demand for natural and organic foods has resulted in a proliferation of processed pork products that are marketed as natural and organic. However, in the case of cured pork products like hams, bacon and frankfurters, the traditional curing agents, nitrite and nitrate, are not permitted in natural and organic products because the regulations for natural and organic products do not permit the use of "preservatives". Because these products cannot be produced with typical cured meat properties without nitrite or nitrate, the industry has developed a new approach that utilizes vegetable juice powder as a natural source of nitrate which is then used to provide the typical cure. However, this approach results in significantly less nitrite in the products. It has been suggested that these products represent a greater risk of bacterial pathogens and will require additional antimicrobial measures to provide consumers with the degree of safety that is expected of these products. Therefore this project was proposed to determine the relative risk of bacterial pathogens in natural and organic "cured" pork products and to suggest means of assuring safety of these products.

Our study first involved collection of commercially available natural and organic hams, bacons and frankfurters to compare the chemical properties of these products to conventionally cured commercial products of the same type. Traditionally cured commercial products were included as controls for the comparison. All of the products were first analyzed for nitrite, cured pigment content, salt concentration and available water. After chemical analyses were complete, another set of samples of each of the commercial products were collected and each was separately inoculated with bacterial pathogens (*Listeria monocytogenes* and *Clostridium perfringens*) to assess the potential risk of pathogen growth. Following the inoculations, additional antimicrobial treatments that might be used to provide for improved safety were investigated and evaluated for effectiveness. The results showed that the most significant chemical difference between the natural and organic products and the controls was for residual nitrite with the controls containing a higher concentration in most cases, as expected. The inoculation challenge resulted in faster growth by both pathogens on almost all of the natural and organic products, confirming our hypothesis that these products represent a greater safety risk. A screening of a variety of natural antimicrobial ingredients suggested two commercially available products with significant potential for safety improvement. One is a combination of acetic acid from naturally fermented vinegar combined with lactate, the other is natural vinegar with lemon powder (citric acid). For the final phase of this project, these ingredients were incorporated into naturally cured products manufactured in the ISU Meat Laboratory and challenged with inoculations of the two pathogens used earlier. Both antimicrobial treatments showed a level of inhibition of the pathogens that was comparable to that achieved by traditionally cured products for control of *L. monocytogenes* and improved control of *Cl. perfringens*. Therefore, use of natural blends of acetic acid (vinegar) and lactate or acetic acid (vinegar) and citric acid (lemon powder) offer the meat industry a means by which the safety of natural and organic processed pork products can be improved to a level that appears to be equivalent to that of conventionally cured products.

Introduction

Cured pork products have had an excellent history of food safety. Recent surveys by the Centers for Disease Control and Prevention have documented that there has been continued reduction of food-borne illnesses resulting from processed meats. However, there is a new category of processed pork products that represents a potentially significant new safety hazard. This category of products is the natural and organic processed meat products that are manufactured to simulate typical cured meats but without direct addition of nitrite or nitrate. These products have been growing very rapidly in retail market share and, consequently, the potential safety hazard is increasing as well.

It is important to note that nitrite is the definitive ingredient that achieves cured meat characteristics and that there is no substitute known for nitrite as a curing agent. Nitrite is a valuable and highly effective antimicrobial agent in cured meats and is best known for inhibitory effects on *Clostridium botulinum*. However, in addition to protection from botulism, nitrite has also been reported to reduce or delay growth of other pathogens including *Listeria monocytogenes*, *Clostridium perfringens* and *Salmonella* Typhimurium as well as spoilage bacteria. Consequently, meat products with little or no nitrite added are widely recognized as a significantly greater risk for bacterial food-borne illness than are traditionally cured products.

The United States Department of Agriculture (USDA) has permitted marketing of simulated cured meat products while recognizing the increased hazard. This category of products was first developed to accommodate those consumers who preferred processed meats without nitrite. The USDA has required labels for these products to include “not preserved”, “preservative-free” and “Keep below 40°F at all times”. These label notations have been included because of the recognized risk of clostridia and other pathogens associated with vacuum-packaged, cooked meat products that contain little or no nitrite. However, refrigeration is no assurance of control of all pathogens. *L. monocytogenes*, for example, is a cold-tolerant pathogen that has become a major food safety issue for cured, ready-to-eat (RTE) meat products. While *L. monocytogenes* can grow on nitrite-cured meats, it has been demonstrated that most anti-listerial ingredients and processes are significantly less effective in uncured than in cured meat products.

While the USDA has recommended good temperature control during distribution as a means of reducing pathogen risk in the “nitrite-free” products, it should be noted that retail display cases for food products often exceed the recommended temperatures, with meat cases among the worst offenders. For example, a study conducted for the American Meat Institute reported that almost 50% of all refrigerated foods in retail display exceeded 41°F. The average temperatures observed for all measurements were 44.3°F for prepackaged lunch meats and 47.1°F for deli counter meats. Consequently, products with reduced antimicrobial protection will be at considerably greater risk for growth of pathogens in such environmental temperatures.

The “no-nitrite” processed meats have not had a significant market share in the past but have experienced rapid growth recently because of greater consumer interest in “preservative-free” foods, and to the success of retailers who specialize in natural and organic foods. Whole Foods Market, as one example, has been growing by some 20%-25% per year. Sales of “nitrite-free” processed meats have been increasing by as much as 187% per year for some products. Currently, processed meats being marketed and sold as “no-nitrite-or-nitrate-added” include ham, bacon, frankfurters, bologna, salami, pepperoni, Kielbasa, braunschwieger and snack sticks. Many different manufacturers have entered the market with these products including major processors such as Hormel and Oscar Mayer. Clearly, these products have become a significant part of the market.

Research at Iowa State University has previously established that the no-nitrite-or-nitrate-added “cured” meat products are highly variable in color and appearance, as might be expected with little or no nitrite added. Some of these products are brown in color as is typical of uncured, cooked meat but most of the products currently on the market are a bright pink/red, as is typical of cured meats with nitrite. It has become clear that processors have adopted a new technology using vegetable juice concentrate or powder, most often from celery, that is very high in nitrate content. Because this is a natural form of nitrate, it qualifies for use in a product labeled as natural. This process requires bacterial reduction of the nitrate to form nitrite and accomplish the cure, so the process incorporates a starter culture to form nitrite from nitrate. However, the nitrate/nitrite content produced by this process is considerably less (about 20%-40%) than in a conventional cure. There has been no information available on the impact that this has on antimicrobial protection. Published research suggests that the amount of added nitrite is critical to the antimicrobial protection in cured meat which would mean that these products still represent greater food safety risk even though some “natural” nitrite is included in the product.

An additional concern for the products manufactured with indirect addition of nitrite is that, because the color and appearance can be identical to traditionally cured products, distributors and consumers will not realize that additional handling precautions are warranted. As a result, the relative risk associated with these products would be increased even more in the event of mild temperature abuse. Clearly, the research described in this proposal is needed to establish the level of risk associated with these products and to develop means to assure safety. This is important information for implementing safeguards before a major food-borne illness outbreak occurs.

At the time that this research was proposed and initiated, a major concern was the variability of the nitrate content in the vegetable/celery juice concentrates. This has since been resolved by suppliers who now standardize the nitrate concentration in these products. The commercial vegetable juice products available as ingredients to use in natural meat products now are typically either 20,000 ppm or 30,000 ppm nitrate. A second development that has occurred during the course of this study is that ingredient suppliers have started offering the vegetable juice products in "pre-converted" form which means that the supplier is incubating the vegetable product with the nitrate-reducing bacterial culture to form nitrite prior to use as an ingredient. This "preconverted nitrite" is much more convenient for meat processors to use because no holding time of the meat product for nitrate conversion is necessary. These preconverted vegetable products are now commercially available with a standardized nitrite concentration of 10,000 ppm, and qualify for use as a natural ingredient. Because of these developments, we did not pursue further evaluation of the variability of the nitrate and nitrite concentrations in vegetable powders and sea salts in this study. The efforts of this research were focused on the assessment of potential pathogen growth on natural and organic pork products and the means by which safety may be improved.

Objectives

The objectives of this research are: 1) evaluation of a representative sampling of currently available simulated cured pork products manufactured without direct addition of nitrite or nitrate to assess and document the variation of critical meat product properties that result in retail products, 2) determine the actual risk associated with commercial no-nitrite-or-nitrate-added "cured" pork products by pathogen inoculation studies, 3) utilize information from objectives1 and 2 to develop and validate processing treatments that will improve consistency and assure safety of these products.

Materials and Methods

While the original proposal described using 5 samples each of hams, bacon and frankfurters, we included 7-10 products from different manufacturers to improve the representation of products currently on the market. Traditionally cured products were included as controls. Products were purchased from retail outlets or from online sources that provided natural and organic processed meats for sale. Samples of each product were analyzed for nitrite, cured pigment, salt content and available water. Analytical measurements were done in duplicate and the sample collection replicated twice for each product and each manufacturer. Following the chemical analyses, packages of the selected products were again purchased, opened and inoculated with *L. monocytogenes* or *Cl. perfringens*. Inoculated packages were monitored over time for growth of the pathogens by sampling and counting the number of bacterial cells present. Again, traditionally cured products were included as controls to provide comparison of the rate of growth of each pathogen.

The inoculations of *L. monocytogenes* consisted of a 5-strain mixed culture as used in previous studies of this organism at Iowa State University. Samples were inoculated on the surface and repackaged for storage. Storage of the packages was at 7°C-10°C (45°F-50°F). Growth of the organism was monitored during the storage period until obvious differences in bacterial numbers developed. *Cl. perfringens* inoculations were done with a 4-strain mixture by injecting the spores into the interior of the product to simulate internal contamination. These samples were stored at room temperature after repackaging with the organism numbers enumerated until product differences were observed.

Following the inoculation studies, product ingredient statements for each of the tested products were compared to determine if additional ingredients in some products might explain some of the observed differences in growth response of the pathogens. This information was also used to suggest treatments that might be used to improve the safety of these products.

Because the results of the inoculations, product analyses and label comparisons suggested that addition of natural acetic acid (as natural vinegar), lactate and/or lemon powder (natural citric acid) would be effective supplements, these ingredients were used to manufacture “no-nitrite-or-nitrate-added” cured meat products in the Iowa State University Meat Laboratory that were then inoculated with the pathogens in the same manner as the commercial products described earlier. Again, these experiments were replicated and the sample measurements duplicated as previously described. This phase of the project was designed to assess potential means of improving the safety of the natural and organic processed meats manufactured with natural sources of nitrite and nitrate.

Results

Objective 1

The results of the chemical analyses of the commercial products are shown on the following pages in figure 1 (frankfurters), figure 2 (bacon) and figure 3 (hams). These figures show the relative difference in the properties measured that are most likely to impact inhibition of bacteria. For frankfurters (fig. 1), both of the traditionally cured controls contain greater concentrations of residual nitrite. Aw, pH and salt concentration did not differ between the naturally cured brands tested and were similar to the controls as well. A “truly uncured” sample which was manufactured without any attempt to provide a natural source of nitrate or nitrite was found in the marketplace and was included in this comparison. This product had the least amount of measurable nitrite, as might be expected, with the amount measured representing analytical background of about 1 ppm.

Similar results were observed for bacon (fig. 2) except that the residual nitrite of the control was intermediate to the naturally cured products and probably reflects the lower limit that the USDA permits for nitrite in injected bacon compared to other conventionally cured products. In the case of the hams (fig. 3), one of the controls contains significantly more residual nitrite than any other products. The second control has the second highest residual nitrite but is not significantly different than three of the naturally cured products. The control ham that had the greatest nitrite concentration also had a greater salt concentration as well, but the Aw and pH measurements showed no difference for any of the products.

Figure 1. Available water (Aw), pH, nitrite and salt measurements of commercial natural/organic frankfurter products relative to traditionally cured frankfurters.

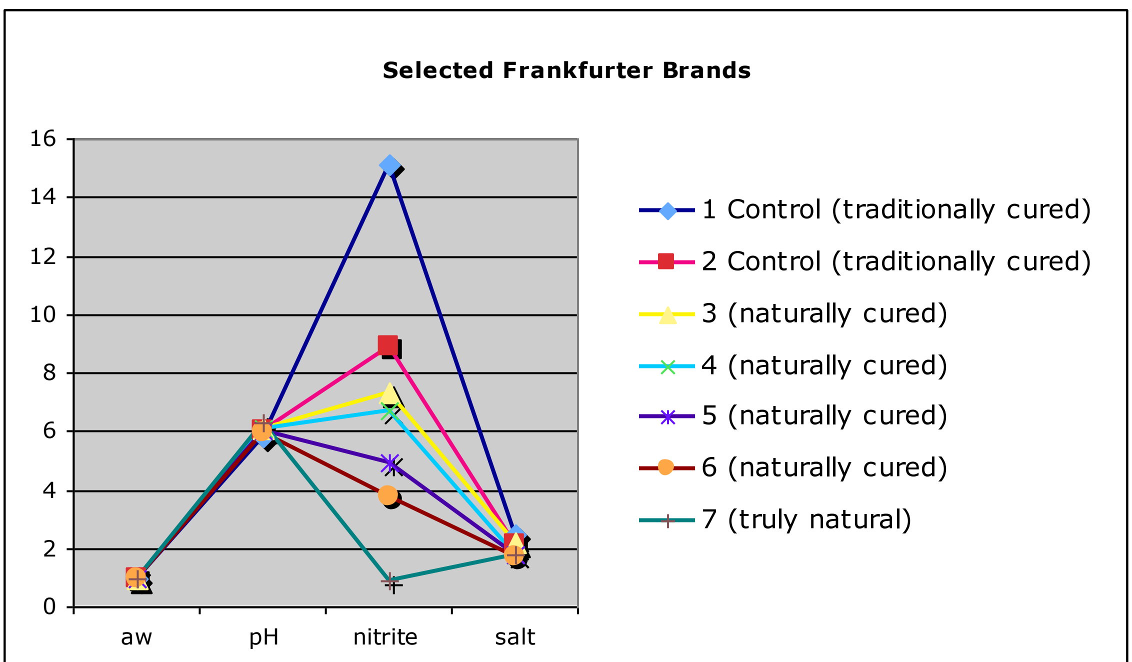


Figure 2. Available water (Aw), pH, nitrite and salt measurements of commercial natural/organic bacon products relative to traditionally cured bacon.

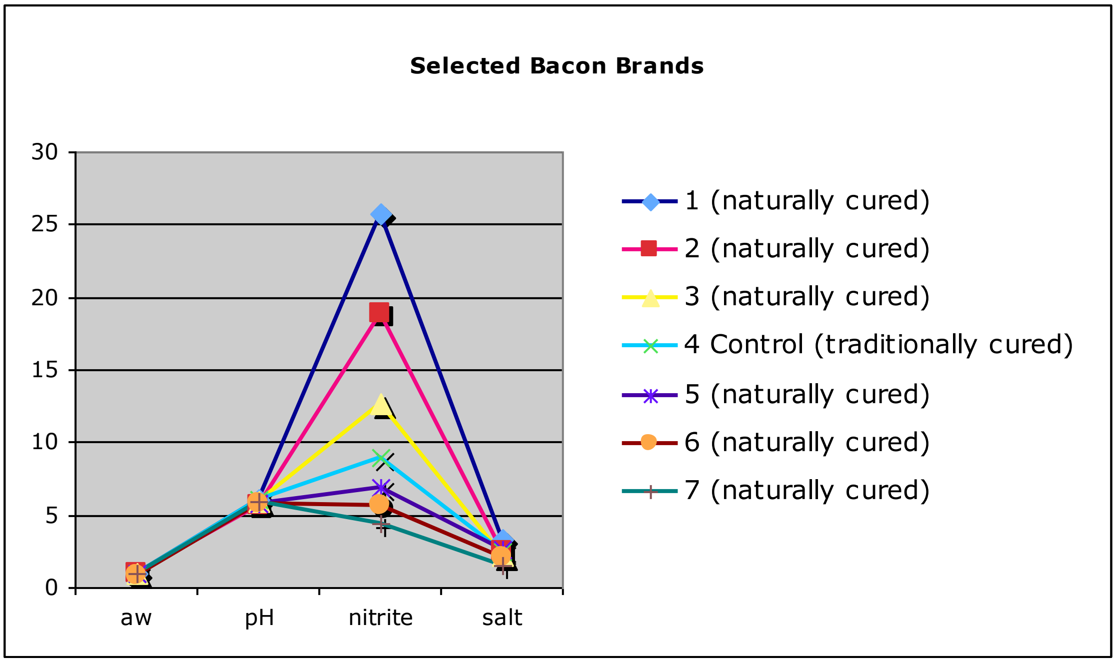
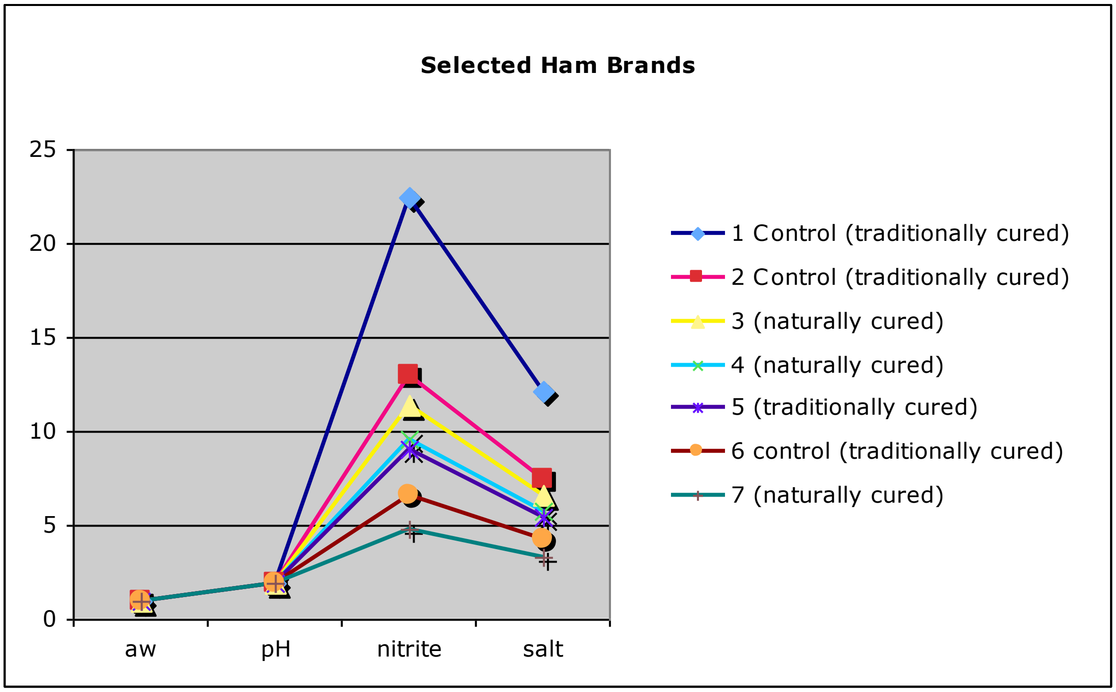


Figure 3. Available water (Aw), pH, nitrite and salt measurements of commercial natural/organic ham products relative to traditionally cured hams.



Objective 2

Figures 4, 5 and 6 show the results of the frankfurters, bacon and hams, respectively, inoculated with *Cl. perfringens*. Fig. 4 clearly shows rapid growth in the truly uncured product (no. 1, no form of nitrite added). The naturally cured products show slower growth than the two controls, though one (no. 5) demonstrated slower growth than any of the other

naturally cured products. The controls showed little or no growth over the same time period. In fig. 5, most of the naturally cured products showed faster growth than the control but one (no. 7) suppressed pathogen growth similar to the control for the first 6 days of storage and continued to suppress growth after 6 days at a level below the control. For hams (fig. 6), the growth of *Cl. perfringens* was again faster in the naturally cured products than the controls .

Figure 4. Survival and growth of *Cl. perfringens* on commercial natural/organic frankfurters relative to traditionally cured frankfurters.

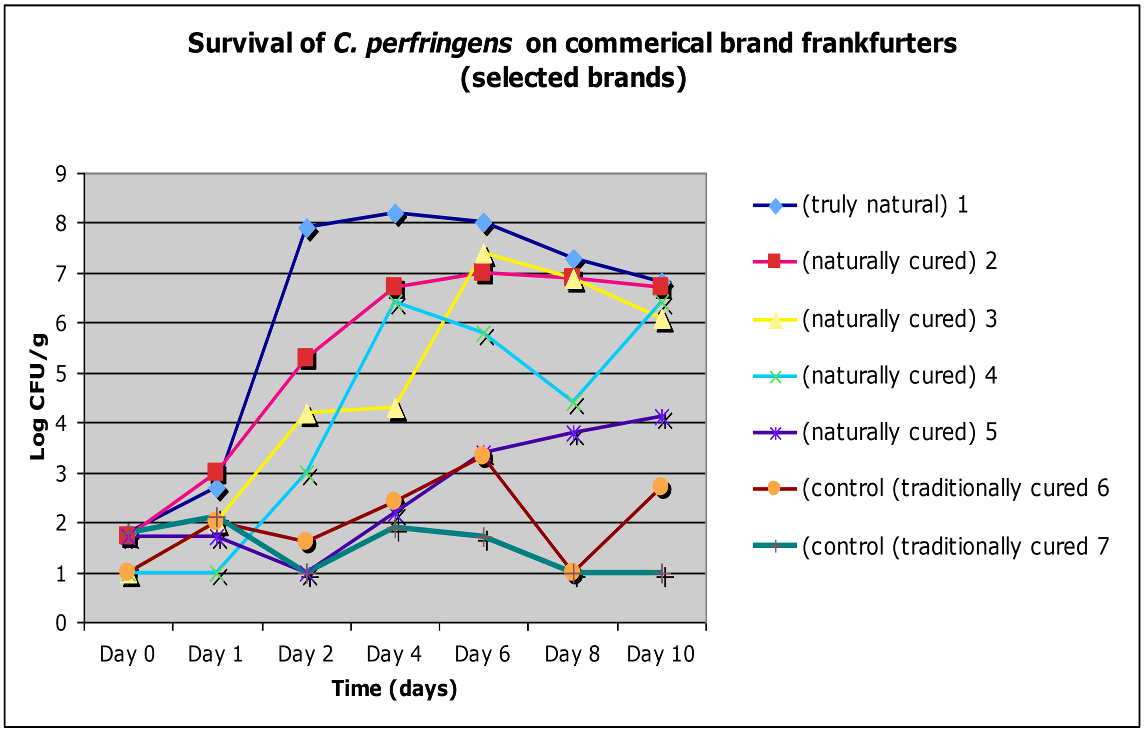


Figure 5. Survival and growth of *Cl. perfringens* on commercial natural/organic bacon relative to traditionally cured bacon.

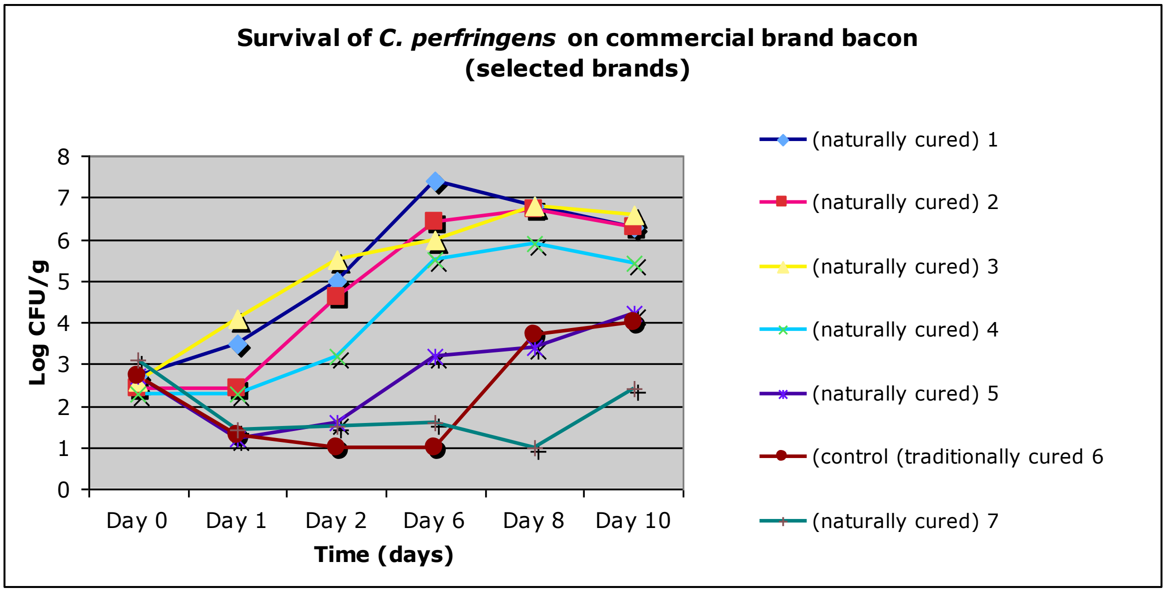


Figure 6. Survival and growth of *Cl. perfringens* on commercial natural/organic hams relative to traditionally cured hams.

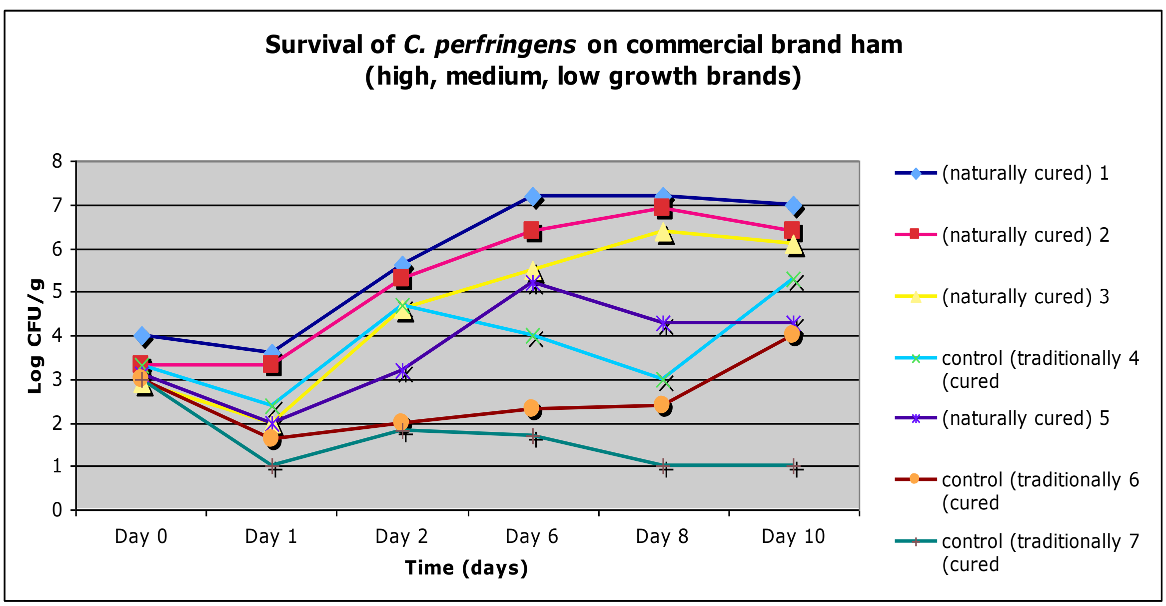
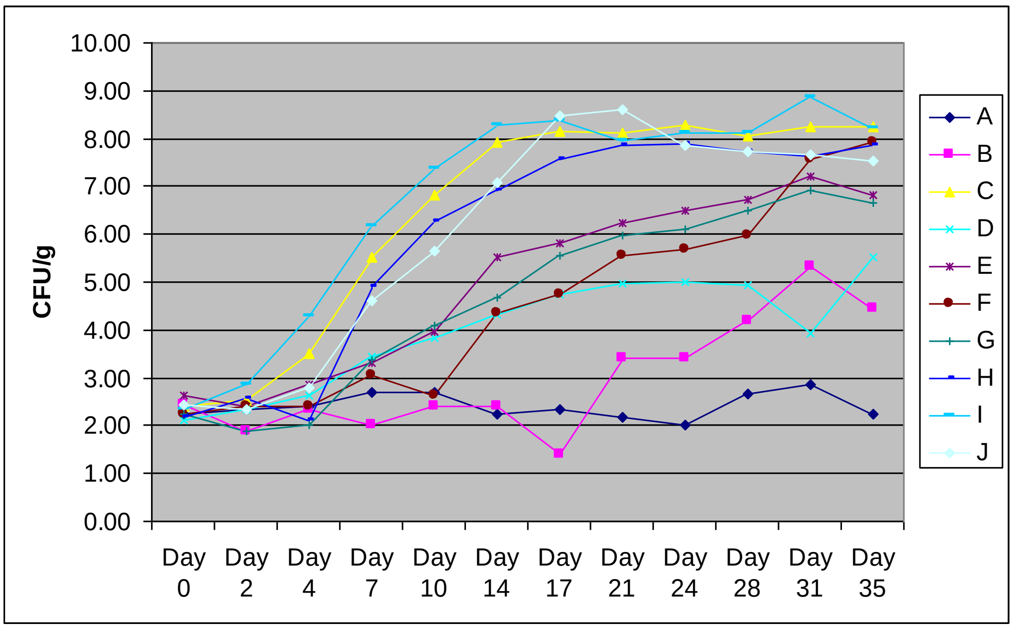


Figure 7 shows the the growth response of *L. monocytogenes* on the naturally cured products relative to the traditionally cured controls. Samples A (control) shows no growth while sample B (control) shows slow growth after day 17. The naturally cured products all show more rapid growth than the controls but can be separated into two groups. Samples D, E, F and G show a slower growth increase than C, H and I. The difference may be due to the addition of lactate to these products which was observed in the ingredients like of each of samples D, E, F and G.

Figure 7. Survival and growth of *L. monocytogenes* on commercial natural/organic frankfurters relative to traditionally cured frankfurters.

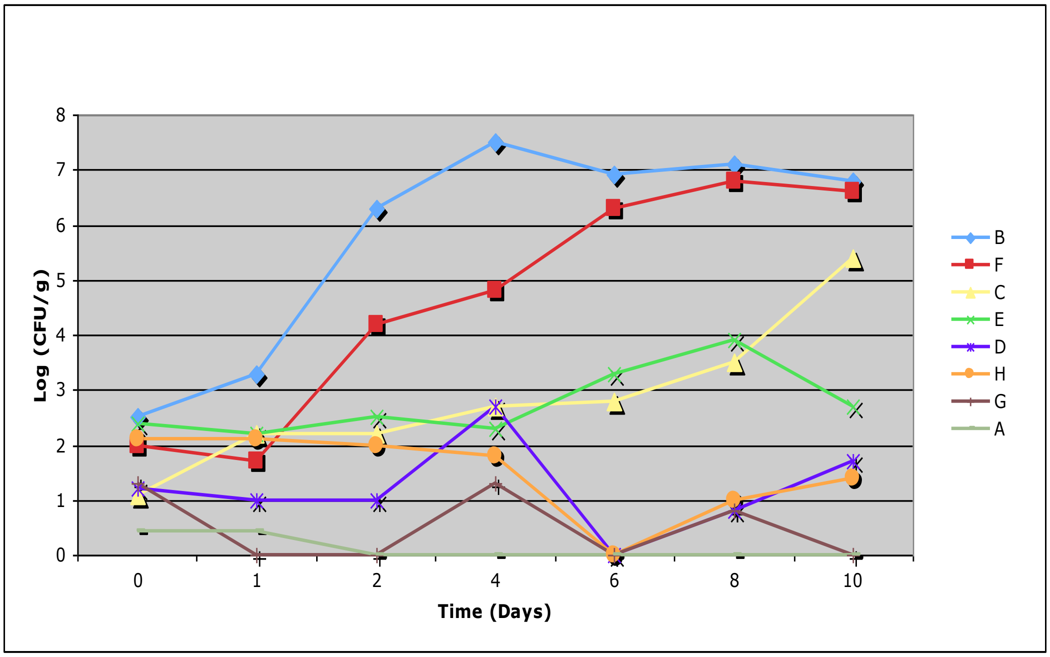


A,B are controls (traditional cure); C-J are naturally cured; D,E,F,G are naturally cured but also include lactate.

Objective 3
Following the inoculations and growth assessment of pathogens on the commercial products, potential antimicrobials were selected for evaluation of improved bacterial control when used in the naturally cured products.

Figure 8 shows the effects of added supplemental antimicrobials on *Cl. perfringens* in products manufactured in the Iowa State University Meat Laboratory. The antimicrobials were chosen based on the ingredient statements of the commercial products tested and in consultation with suppliers who have been developing ingredients to provide this function. Figure 8 shows that the truly uncured sample (treatment B) resulted in the fastest growth, as expected. The preconverted celery powder alone (nitrite formed by conversion prior to use (treatment F) slowed growth but the suppression of growth lasted only for one day. Treatments C and E were intermediate in their effect; C was the natural cure with unconverted celery powder and E was the natural cure with vinegar (acetic acid) and lactate. Growth of *Cl. perfringens* was effectively suppressed by treatments D, H and G (natural cure with vinegar (acetic acid and lemon powder (citric acid), preconverted natural cure with vinegar (acetic acid) and lactate, and preconverted natural cure with vinegar (acetic acid) and lemon powder (citric acid), respectively). The conventional cure with lactate and diacetate (treatment A) was most effective, resulting in no recovered *Cl. perfringens* after the second day.

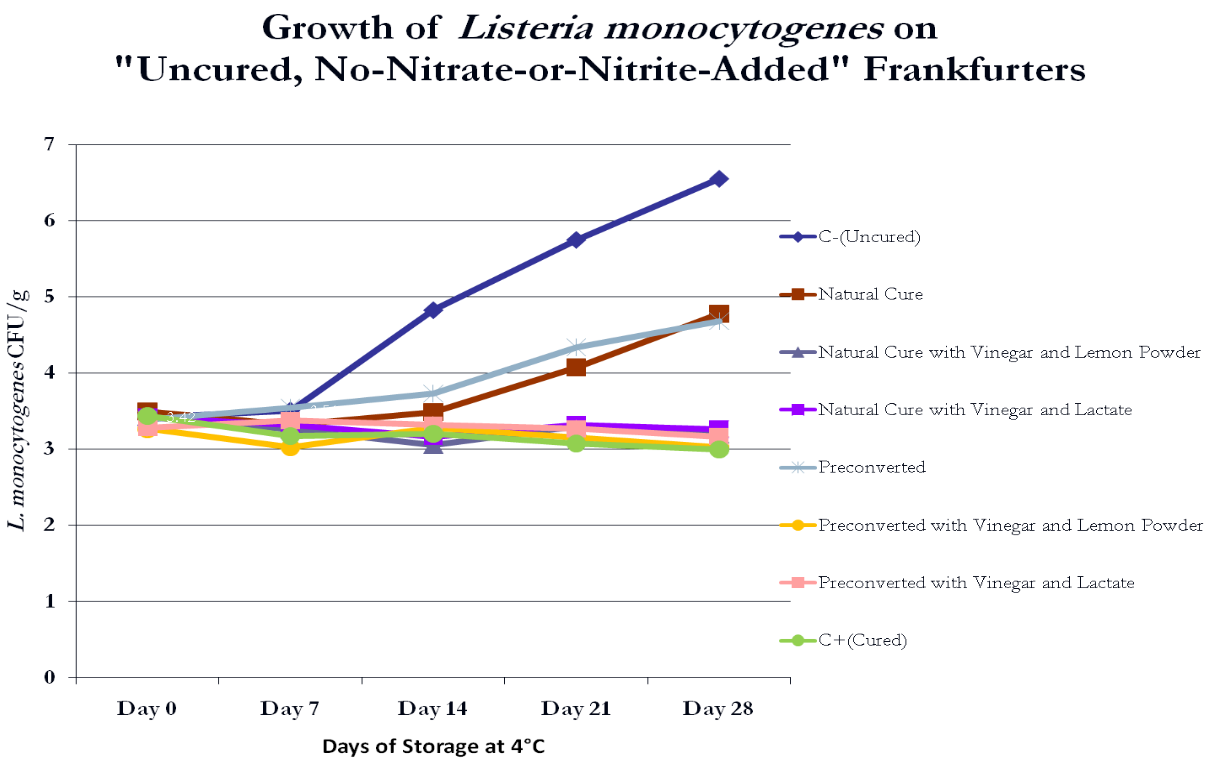
Figure 8. Growth of *Cl. perfringens* in naturally cured frankfurters manufactured with added antimicrobial ingredients to supplement the natural cure.



Sample A is conventionally cured control (with lactate and diacetate); B has no cure (spices only), C is natural cure with nitrate and starter culture, D is natural cure with added vinegar and lemon powder, E is natural cure with added vinegar and lactate, F is natural cure by precoverted celery powder, G is natural cure by preconverted celery powder plus vinegar and lemon powder and H is natural cure by preconverted celery powder plus vinegar and lactate.

Figure 9 shows the growth of *L. monocytogenes* on naturally cured products manufactured with the same added antimicrobial supplemental ingredients as used for *Cl. perfringens* shown in figure 8. The effect of the added antimicrobials is more dramatic and more complete for *L. monocytogenes* than in the case of *Cl. perfringens.* As shown in fig. 9, the pathogen grows in the uncured treatment, is slowed but still grows in both the natural cure and natural cure by preconverted nitrite, but did not grow in any of the natural cure treatements that included the vinegar and lemon powder or the vinegar and lactate treatments.

Figure 9. Growth of *L. monocytogenes* on naturally cured frankfurters manufactured with added antimicrobial ingredients to supplement the natural cure.



Sample C+ in figure 9 is conventionally cured control (with lactate and diacetate); C- has no cure (spices only), natural cure has nitrate and starter culture, preconverted is natural cure is by celery powder preconverted to nitrite.

Discussion

The results of objective 1 showed that the major difference between the commercial brands of natural and organic "cured" meats was for the amount of measurable residual nitrite. This was also the major difference between the natural and organic products and the conventionally cured, traditional cured meats. This is very suggestive that the nitrite concentration produced during the commercial production process of the natural and organic products results in considerably less nitrite and would be likely to reduce the antimicrobial protection inherent to these products. The remaining potential antimicrobial properties of these products (Aw, pH, salt content) that were analyzed, with few exceptions, did not differ. Cured color intensity and cured pigment concentration were also measured but did not show a consistent relationship to the type of curing system used.

Consequently, it appears that nitrite concentration is the primary candidate for any difference in microbial control that might exist in the natural and organic processed meats.

The results of objective 2 confirmed our hypothesis that the natural and organic "cured" meats are more susceptible to growth of pathogenic bacteria in the event of contamination, particularly in the case of storage temperature that is less than ideal. Both *Cl. perfringens* and *L. monocytogenes* grew more rapidly on the natural and organic products suggesting that the reduced amount of nitrite produced by the curing methods used for these products resulted in a reduced antimicrobial effect in these products. Because previous research has shown that there is a sensory limit to how much of the celery powder can be included in the natural curing process, it is not feasible to increase the celery powder in attempt to increase the amount of nitrite produced in the process. Consequently, supplemental microbial inhibitors are needed to provide improved control of bacteria. Several natural inhibitors have potential and several have been studied. Two of the most effective additional antimicrobials that are used in conventionally cured meats to provide extra protection are lactate and acetic acid (as diacetate). Conventional sources of these ingredients are not considered natural but suppliers have been developing natural forms of these compounds to provide for their use in natural-labeled products. Acetic acid, for example, is a major component of vinegar which, if produced by natural fermentation will qualify as a natural ingredient. Citric acid is also an effective preservative agent and is found in high concentration (up to 30%) in natural lemon juice powder. Thus, natural vinegar, lactate and lemon powder recently become commercially available for use as natural preservatives in foods and were selected for evaluation of safety improvement of the naturally cured pork products in objective 3 of this study.

The results of objective 3 demonstrated the effectiveness of the natural ingredients sources of acetic acid, lactate and citric acid. Both the acetic acid/lactate blend and the acetic acid/citric acid blend were highly effective for control of *L. monocytogenes*, completely suppressing recovery of this pathogen. The effect was equivalent to that in a conventionally cured product that included lactate and diacetate as is typical in commercial products. In the case of *Cl. perfringens*, both of the supplemental antimicrobials improved the control of the pathogen and suppressed growth during temperature-abuse storage, though not to the same extent as the conventionally cured product.

Therefore, use of the vinegar/lactate or vinegar/lemon powder ingredients provided natural antimicrobials that improved the safety of natural and organic cured pork products. This provides the meat industry with the means by which these products can be produced with a safety assurance that is comparable to conventionally cured products. This will benefit pork producers by preventing potential future food-borne illness outbreaks that could occur from the pathogen-susceptible processed meats that have reduced nitrite concentrations and reduced antimicrobial impact. The prevention of food-borne illness outbreaks prevents the loss of sales and market share that typically occurs for the food products that are the source of food-borne illness.