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Effects of natural antimicrobials on inhibition of *Listeria monocytogenes* and on chemical, physical and sensory attributes of naturally-cured frankfurters

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A B S T R A C T

Due to regulations for natural and organic processed meats, sodium nitrite and many antimicrobials cannot be used. Therefore, natural and organic processed meats are more susceptible to pathogenic bacterial growth, and natural alternatives to chemical preservatives are needed. Inhibition of *Listeria monocytogenes*, and quality characteristics of frankfurters manufactured with 3% cranberry powder, or with 1% or 2% cranberry powder each with either cherry powder (0.6%), lime powder (60 mg/kg), or a blend of cherry, lime and vinegar (1.4%) were investigated. Cranberry powder at 3% significantly reduced *L. monocytogenes* growth by 5.3 log CFU/g compared to the uncured co006Etrol ($P < 0.05$). However, cranberry addition over 1% also resulted in significant product pH decline and negatively impacted the color, texture and sensory attributes of the frankfurters.

1. Introduction

Nitrite is well known as the ingredient responsible for the distinctive color of cured meats, serves as a strong antioxidant to protect flavor, and functions as an effective antimicrobial agent to control pathogenic bacterial growth, most importantly *Clostridium botulinum* (Shahidi & Pegg, 1992). Nitrite also slows the growth of *Listeria monocytogenes* though it does not fully inhibit this pathogen (Glass, Preston, & Veesenmeyer, 2007; Xi, Sebranek, & Zhou, 2010; Xi, Sullivan, Jackson, Zhou, & Sebranek, 2011). No single ingredient has been found to replace all functions of nitrite (Gray, Macdonald, Pearson, & Morton, 1981). However, due to consumers' concerns about antibiotics, pesticides, synthetic hormones, genetic modifications in plants and animals, and chemical additives (Devcich, Pedersen, & Petire, 2007; Saher, Lindeman, & Hursti, 2006; Winter & Davis, 2006) that are associated with conventionally produced and processed foods, natural and organic foods have been experiencing a very rapid market growth (Sebranek & Bacus, 2007). For example, from 1997 to 2007, the market share of "natural" meats increased by 20%–22% per year (Food Product Design, 2010; Sebranek & Bacus, 2007).

The growing interests by consumers in natural and organic foods and concerns about nitrite in food have prompted consumer demands for uncured, no-nitrate/nitrite-added meat and poultry products. According to Sindelar, Cordray, Olson, Sebranek, and Love (2007), two types of uncured, no-nitrate/nitrite-added meat and poultry products currently exist in the North American marketplace: those that do not include nitrate or nitrite (truly uncured products), and those that replace conventional sodium nitrate and nitrite to simulate typical curing by using a natural source of nitrate, such as celery powder, and a bacterial starter culture to reduce nitrate to nitrite during the manufacturing process. Some processors are now using pre-converted celery powder/juice where nitrate has already been converted to nitrite by suppliers (Sebranek & Bacus, 2007). United States Department of Agriculture (USDA) regulations require that all of these products be labeled as "Uncured" because nitrite or nitrate is not added directly to the meat mixture (USDA, 2006; Sebranek & Bacus, 2007). However, for those products to which celery powder or other natural sources of nitrate and nitrite are added, a more technically correct term is "naturally-cured". Research by Sindelar et al. (2007) found that "Uncured", "No-Nitrate-or-Nitrite-Added" commercial meat products typically had lower residual nitrite concentration than conventionally versions, and relatively large variation in cured color and cured pigment was found, suggesting that different extents of curing may have taken place during product manufacture. Thus, the products may be more susceptible to growth of foodborne pathogens than the conventionally-cured meat versions. Because of this concern, a study of several commercial brands of meat products (frankfurters, hams, and bacon) labeled as "No-Nitrite-or-Nitrate-Added", "Natural", or "Uncured", was conducted by challenging these products with inoculations of *Clostridium perfringens* and *L. monocytogenes* to assess foodborne pathogen growth (Jackson, 2010; Schrader, 2010; Jackson,

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Sullivan, Kulchiayawat, Sebranek & Dickson, 2011). Reduced bacterial inhibition ($P<0.05$) was observed in the majority of the commercial naturally cured meat products with no nitrite or nitrate added when compared to controls that were conventionally manufactured with direct addition of sodium nitrite. Because of the USDA labeling requirements for natural products that do not allow formulation and direct addition of nitrite in products labeled "Natural", the most feasible options to improve the safety of these products are increasing the effectiveness of the natural source of nitrite and/or adding natural antimicrobials from spices, fruits, vegetables, or oilseeds that are considered as Generally Recognized As Safe (GRAS) and that qualify for use in natural and/or organic foods.

L. monocytogenes is a concern in ready-to-eat (RTE) processed food products. Since 1987, the USDA has established a "zero" tolerance policy for *L. monocytogenes* in refrigerated food products (USDA, 2003), because this organism can survive under relatively extreme physico-chemical conditions such as low temperature (as low as −0.4 °C), high temperature (as high as 45 °C), low pH (as low as 4.4), and high salt content (Barker & Park, 2001; Davis, Cotte, & O'Byrne, 1996; Jay, 2000; Rocourt & Cossart, 1997). Many phenolic and phytochemical-containing fruit and herbal products have been shown to possess antimicrobial properties that affect *L. monocytogenes.* For example, cranberry extracts and concentrates, a natural source of many phenolic compounds, has been reported to be an effective inhibitor of *L. monocytogenes in vitro* and in ground meat (Ahn, Grün, & Mustapha, 2004; Apostolidis, Kwon, & Shetty, 2008; Lin, Labbe, & Shetty, 2004; Qiu & Wu, 2007). Cherry powder and lime powder, high in ascorbic acid and citric acid, respectively, could serve as natural reducing compounds to increase the antimicrobial impact of nitrite reaction products (Del Rio, Gonzalez de Caso, Prieto, Alonso-Calleja, & Capita, 2008; Penniston, Nakada, Holmes, & Assimos, 2008). Most of the research on antilisterial effects of natural plant and fruit extracts has been conducted in either broth cultures or uncured ground meat systems. Few reports are available on cured and cooked RTE meat products. Therefore, the objectives of this study were to investigate: (1) the impact of cranberry powder on *L. monocytogenes* growth on inoculated naturally-cured frankfurters during refrigerated storage; (2) the effects of additional selected natural ingredients in conjunction with cranberry powder on the safety and quality characteristics of naturally-cured frankfurters during storage; (3) the sensory attributes of naturally-cured frankfurters with natural antimicrobials that may be affected by the ingredients selected for potential antilisterial effects.

2. Materials and methods

2.1. Ingredients

Ingredients used for manufacturing frankfurters in this study (Table 1) included celery powder (VegStable™ 504), cherry powder (VegStable™ 515), lime powder (VegStable™ 511), and a blend of cherry, lime and vinegar (VegStable™ 517) (Florida Food Products Inc., Eustis, FL, USA). The celery powder was a pre-converted celery concentrate where the naturally present nitrate had been converted to nitrite by the supplier. The nitrite concentration of the pre-converted celery powder was 12,000 mg/kg, which when used at 0.4% as in this study, would provide a calculated concentration of 48 mg/kg of nitrite in the frankfurter formulation. Cranberry powder (90 MX) was obtained from Ocean Spray International (Middleboro, MA, USA). Sodium nitrite, sodium erythorbate (food grade), and a frankfurter seasoning blend were purchased from A.C. Legg. Inc (Calera, AL, USA.). A potassium lactate and sodium di-acetate blend (Purasal OptiForm PD Plus) which is 74% potassium lactate and 5.5% sodium di-acetate (Purac America, Lincolnshire, IL, USA) and sodium tripolyphosphate (Curafos STPP®, Innophos, Chicago, IL, USA) were included for treatments 3 and 8, respectively that utilized these ingredients (Table 1). All concentrations of ingredients utilized in the experiment were based on recommendations from the suppliers or from results of our preliminary experiments. The natural ingredients chosen for this study were selected based on previous work (Xi et al., 2010, 2011) showing that each had an impact on growth of *L. monocytogenes* in a meat model system. Because cranberry powder at 3% was not only observed to be a very effective inhibitor but also impacted color and physical properties of the model system, combinations of other ingredients with cranberry powder were assessed in this study to determine if lower concentrations of the cranberry powder could be successfully utilized for improved control of *L. monocytogenes* without negatively impacting meat product quality characteristics.

Table 1
Ingredients and concentrations of each used for all frankfurter treatments in this study.

Treatments[a] (Trt.)	Code	Sodium nitrite	Pre-converted celery powder	Other ingredients
Trt. 1	(−) Control	–	–	–
Trt. 2	(+) Control	–	0.4% (w/w)	–
Trt. 3	Conventionally cured control (CC)	156 mg/kg	–	550 mg/kg Sodium erythorbate 2.5% Lactate and di-acetate blend
Trt. 4	Cb + CP	–	0.4% (w/w)	1% Cranberry powder and 0.6% cherry powder
Trt. 5	Cb + LP	–	0.4% (w/w)	2% Cranberry powder and 60 ppm lime powder
Trt. 6	Cb	–	0.4% (w/w)	3% Cranberry powder
Trt .7	Veg 517	–	0.4% (w/w)	1.4% VegStable™ 517
Trt. 8	Cb + P	–	0.4% (w/w)	3% Cranberry powder and 0.4% sodium tripolyphosphate

[a] All concentrations are expressed as weight/weight.

2.2. Manufacture of frankfurters

Meat trimmings, consisting of 90% lean boneless beef and 50% lean boneless pork were obtained from the Meat Laboratory at Iowa State University. The beef and pork were coarse-ground using a grinder plate with a 9.5 mm-diameter holes, analyzed for fat content with an Anyl-Ray (Kartridge-Pak, Davenport, IA, USA) and formulated to a final blend of 27% fat. Eight treatment batches of frankfurters were prepared containing the base ingredients of 6.54 kg of beef trimmings, 4.81 kg of pork trimmings, 2% natural frankfurter spice blend, 20% water/ice, 2.25% salt, and 2% dextrose. Other ingredients and concentrations of each for the eight treatments are listed in Table 1. An uncured negative control, a naturally-cured positive control and a conventionally-cured control with potassium lactate and sodium di-acetate were included in this study to provide baseline comparisons for experimental treatments. The experiment was replicated three times with separate preparation of meat batches for each replication.

The frankfurters were manufactured using a vacuum bowl cutter (Model VSM 65, Krämer & Grebe GmbH & Co. KG., Biendenkopf-Wallau, Germany). The beef trim, salt, pre-converted celery powder or sodium nitrite, dextrose, frankfurter seasoning blend and half of the water/ice were chopped under vacuum to 4 °C. The pork trim, remaining half of the water/ice and the other remaining left ingredients (except for the cranberry powder) were added and chopped until the meat emulsion reached 14 °C. For treatments 4, 5, 6 and 8, the cranberry powder was added when the meat emulsion reached 9 °C to limit protein denaturation due to the acidity of the cranberry powder. The emulsion was stuffed into 24 mm-diameter casings (WP-E Clear 35 Micron, WorldPac USA. Intl. Inc., Sturtevant, Wis., USA) using a rotary vane with a linking attachment (Risco, vacuum stuffer, Model RS 4003-165, Stoughton, Ma., USA). The uncured treatment (Trt. 1) was separated from the others (Trt. 2 to Trt. 8), and placed on a separate smoke house truck for thermal processing in a smokehouse (Maurer, AG, Reichenau,