Fate of *Listeria monocytogenes* in Ready-to-Eat Turkey Breast Rolls Formulated with Antimicrobials Following E-Beam Irradiation

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Summary and Implications

The objective of this study was to determine the effect of antimicrobials on the survival and proliferation of *L. monocytogenes* in turkey breast rolls following electron-beam irradiation. Six antimicrobial additive treatments that include no preservatives (control), 0.1% potassium benzoate (PB), 2% sodium lactate (SL), 0.1% potassium benzoate plus 2% sodium lactate (PB+SL), 2% sodium lactate plus 0.1% sodium diacetate (SL+SDA), and 0.1% potassum benzoate, 2% sodium lactate and 0.1% sodium diacetate (PB+SL+SDA) were used. Sliced turkey breast rolls were artificially inoculated with ~10^6 CFU/cm^2 five-strain-*L. monocytogenes* cocktails, then vacuum-packaged and irradiated at 0, 1.0, 1.5, 2.0 or 2.5 kGy. D_{10} values for breast rolls with various additive treatments ranged from 0.56 to 0.58 kGy. Adding PB (0.1%) or SL (2%) in turkey rolls failed to prevent *L. monocytogenes* from growing during refrigerated storage. In turkey rolls added with two (PB+SL or SL+SDA) or three (PB+SL+SDA) antimicrobial combinations had 2 or 3 weeks of lag phases before *L. monocytogenes* growth, respectively. Irradiating turkey rolls, which were added with PB+SL or SL+SDA, at 1.0 kGy was effective in suppressing the growth of *L. monocytogenes* for about six weeks when stored at 4 °C. No growth of *L. monocytogenes* after irradiation occurred during 42 d storage for 2.0 kGy irradiated breast rolls formulated with 0.1%PB+2%SL, 2%SL+0.1%SDA or 0.1%PB+2%SL+ 0.1%SDA, and 1.0 kGy irradiated turkey breast with 0.1% PB + 2% SL + 0.1% SDA. Sensory panelists found that low-dose irradiation (1.0 kGy) had no effect on the sensory characteristics of RTE turkey breast rolls. Including SL+SDA had slightly negative effect for nonirradiated turkey breast rolls, but the sensory characteristics of 1.0 kGy irradiated turkey roll containing SL+SDA was not significantly different from the others receiving 1.0kGy irradiation. For microbial safety, PB+SL and SL+ SDA antimicrobial treatments combined with 1.0 kGy or 2.0 kGy irradiation are a promising technology.

Introduction

Due to its high mortality rate (~ 25%) and economic losses caused by expensive product, *Listeria monocytogenes* is a big food safety issue for the processed meat industry. For RTE meat products, the most frequently applied hurdles such as thermal processing, vacuum packaging, refrigerated storage and nitrite seem insufficient when it comes to *L. monocytogenes* due to its ubiquitous nature, ability to grow at refrigerated temperature and anaerobic condition, and resistance to salt and nitrite. Although *L. monocytogenes* can be killed during the thermal processing of RTE meats, post-processing contamination of RTE meat with *L. monocytogenes* during slicing and packaging is difficult to avoid. To ensure microbiological safety of RTE meat, it is essential to have additional intervention to control the growth of pathogen during refrigerated storage.

Formulating meat products with antimicrobial additives is one approach to suppress the growth of contaminated *L. monocytogenes* during storage, but they can not destroy the pathogenic organisms that existed in RTE-meat. Furthermore, including high concentration of antimicrobials such as SDA has a negative effect on the flavor of meat products. Food irradiation is an effective post-packaging intervention technology to eliminate those contaminated *L. monocytogenes* in RTE meat products. Due to its negative effects on meat quality, only low dosages of irradiation are recommended in RTE meats. However, pathogens that survive low-dose irradiation can repair themselves, proliferate and cause a health hazard during refrigerated storage, suggesting that an intervention in addition to low-dose irradiation would be necessary.

Antimicrobials were used in combination with irradiation to suppress the growth of *L. monocytogenes* following irradiation. Gamma irradiation of *L. monocytogenes* suspended in SDA resulted in synergistic reductions of the microorganism, and supplementing SDA in beef bologna inhibited the proliferation of *L. monocytogenes*, which survived the irradiation process. Gamma irradiation at 3.0 kGy prevented the proliferation of *L. monocytogenes* and background microflora in bologna containing 0.07% SDA and 1% potassium lactate, and in bologna containing 0.15% SDA and 2% potassium lactate over 8 weeks of storage at 9 ºC. We found that turkey hams formulated with 2% SL+0.1% SDA and 0.1% potassium benzoate (PB) +2% SL in combination with 1.0 kGy e-beam irradiation was effective in suppressing the growth of *L. monocytogenes* for about six weeks at 4 °C, and 2.0 kGy irradiation was listeriostatic. No studies were conducted to

assess the effect of irradiation in combination with antimicrobials on the growth of *L. monocytogenes* in uncured turkey breast rolls, where *L. monocytogenes* may behave differently.

In the current study, potassium benzoate, sodium lactate and sodium diacetate alone or in combination were tested for their ability in inhibiting the growth of *L. monocytogenes* in RTE turkey breast rolls following 1.0-kGy or 2.0-kGy e-beam irradiation during 4°C storage.

Materials and Methods

Five different *L. monocytogenes* strains (Scott A, H7969, H7596, H7762 and H7962) were used to inoculate sliced turkey breast rolls. Six antimicrobial additive treatments include: 1) basic formula without any preservatives (control); 2) 0.1% potassium benzoate (PB); 3) 2% sodium lactate (SL); 4) 0.1% potassium benzoate and 2% sodium lactate (PB+SL); 5) 2% sodium lactate and 0.1% sodium diacetate (SL+SDA); and 6) 0.1% potassium benzoate, 2% sodium lactate and 0.1% sodium diacetate (PB+SL+SDA). Antimicrobial additives were mixed with meat and other ingredients then stuffed into large fibrous casings (ϕ=11.5cm). The rolls were heat processed to 74°C internal temperature in an 84°C smoke house, chilled (4°C), sliced to 2-mm-thick pieces and used for microbiological study. Each sample slice was inoculated with 0.1 ml *L. monocytogenes* cocktail to achieve a level at approximately 10^6 CFU/cm^2 surface area. Inoculated turkey roll samples were manually mixed for 30 s to evenly distribute the inoculum, then vacuum sealed, and kept refrigerated overnight prior to irradiation.

All samples were irradiated using a Linear Accelerator Facility. The vacuum-packaged inoculated samples of each additive treatment were divided randomly into five groups and irradiated at 0 (control), 1.0, 1.5, 2.0 or 2.5 kGy. Samples irradiated at 0, 1.0 and 2.0 kGy were stored at 4° C for up to 42 d. The number of *L. monocytogenes* survivors in inoculated samples receiving 0, 1.0, 1.5, 2.0 and 2.5 kGy irradiation were analyzed at a 7-d interval. The D_{10} value, radiation dose (kGy) that results in 90% reduction of viable cells, was determined by plotting the log number of survivors per cm^2 (Log_{10} CFU/cm^2) versus irradiation dose (kGy). Linear regression curves were generated with SAS software. The D_{10}-value was calculated as the reciprocal of the absolute value of the slope of the regression line.

Ten trained panelists participated in the evaluation of the sensory attributes of RTE turkey rolls. Samples were evaluated for turkey-roll-like aroma, off-aroma, turkey-roll-like flavor, off-flavor and saltiness. Data were analyzed by the General Linear Model (GLM) of the Statistical Analysis System (SAS, 2000).

Results and Discussion

The D_{10} value for breast rolls with various additive treatments ranged from 0.56 to 0.58 kGy. Our results showed that including single antimicrobial additive (2% SL or 0.1% PB) in turkey roll formulation was not sufficient to inhibit the proliferation of *L. monocytogenes* surviving irradiation. Turkey rolls without irradiation, however, 2% SL plus 0.1% SDA or 2% SL plus 0.1% PB antimicrobials combination delayed the growth of *L. monocytogenes* for about two weeks and then pathogen organisms start to grow again at a lower growth rate than that in the control turkey rolls or turkey rolls formulated with single antimicrobial. Including three antimicrobials in turkey roll formulation suppressed *L. monocytogenes* from growth for about 21 d. Including two or three combinations of antimicrobials were very effective in control of the growth of *L. monocytogenes* in turkey rolls receiving 1.0 or 2.0 kGy irradiation.

Sensory analysis indicated that turkey rolls formulated with SL+SDA had less turkey-roll-like aroma and flavor than others, but no difference in turkey-ham-like aroma and flavor was observed when they were added to turkey ham. This could be related to the masking effect of intensive ham flavor and aroma. This lower aroma and flavor could be associated with a lower pH in the SL+SDA adding turkey rolls. From the microbiological safety point of view, both PB+SL and SL+ SDA antimicrobial treatments in combination with 1.0 kGy or 2.0 kGy irradiation were effective in controlling post-packaging contamination and proliferation of *L. monocytogenes*, with SL+SDA more effective than PB + SL. Regarding sensory characteristics, PB + SL is better than SL + SDA in non irradiated turkey rolls, but no significant difference was detected between turkey rolls with PB+SL and with SL+SDA received 1.0 kGy irradiation. However, the volatile analysis indicated that the turkey rolls added with PB in formulation produced a significant amount of benzene during 1.0-kGy or 2.0-kGy irradiation (Zhu et al., 2004b). Due to negative health effects of benzene (Mehlman, 2002), PB is not a proper antimicrobial for products receiving irradiation, thus SL+SDS combination is a better choice to control *L. monocytogenes* contamination in turkey rolls receiving low-dose irradiation.

Acknowledgement

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Figure 1. Growth of *L. monocytogenes* at 4°C in non-irradiated vacuum-packaged RTE turkey breast rolls with or without antimicrobial additives (Control= basic formula, PB= including 0.1% potassium benzoate, SL= including 2% sodium lactate, PB+SL= including 0.1% potassium benzoate and 2% sodium lactate, SL+SDA= including 2% sodium lactate and 0.1% sodium diacetate, PSS= including 0.1% potassium benzoate, 2% sodium lactate and 0.1% sodium diacetate), n = 3.

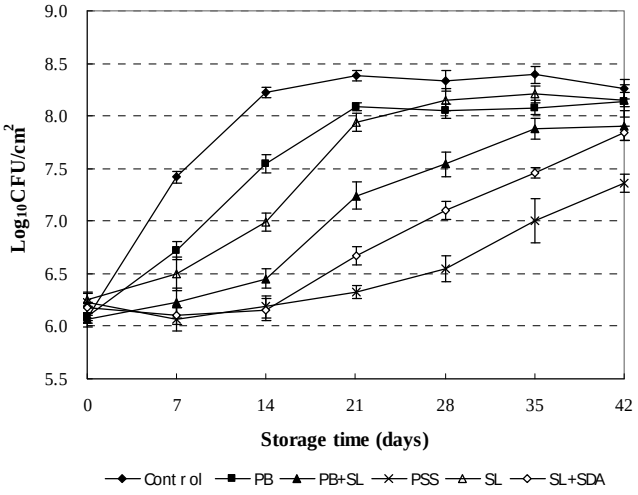

Figure 2. Viability of *L. monocytogenes* at 4°C in 1.0 or 2.0 kGy irradiated vacuum-packaged RTE turkey breast rolls with or without antimicrobial additives (Control= basic formula, PB= including 0.1% potassium benzoate, SL= including 2% sodium lactate, PB+SL= including 0.1% potassium benzoate and 2% sodium lactate, SL+SDA= including 2% sodium lactate and 0.1% sodium diacetate, PSS= including 0.1% potassium benzoate, 2% sodium lactate and 0.1% sodium diacetate), n = 3.