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INTERVENTIONS TO ACHIEVE PATHOGEN LETHALITY TARGETS AND IMPROVE THE SAFETY OF TRADITIONAL DRIED AND FERMENTED SALAMI

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I. INTRODUCTION

Traditional dried and fermented sausages, like salami, are made from ground pork and contain added ingredients, primarily salt, sodium nitrite/nitrate, fermenting starter cultures, and various spices. These products are marketed as ready-to-eat (RTE) and shelf-stable; however, they often do not undergo sufficient processing to eliminate foodborne pathogens such as *Salmonella* spp. and *Listeria monocytogenes*. These pathogens can be present in raw meat and in the environment where processing occurs after lethality controls have been applied. Although fermented sausages have traditionally been regarded as low-risk, outbreaks of *Salmonella* spp. have been associated with dried and fermented products globally [1,2]. Furthermore, *Listeria monocytogenes* continues to cause human foodborne illnesses and deaths linked to ready-to-eat meat and deli products [3]. Current USDA-FSIS guidance requires manufacturers to validate that their process can reduce *Salmonella* spp. by 5 logs and *L. monocytogenes* by 3 logs [4].

Objectives of this study were to evaluate effects of antimicrobial interventions on raw materials and post-packaging high-pressure pasteurization to enhance safety of dried and fermented ready-to-eat meat products.

II. MATERIALS AND METHODS

Four independent replicates of small-diameter (46mm) fermented and dried traditional salami were manufactured, with two replicates incorporating a raw material antimicrobial intervention (LA) and two replicates reflecting negative controls (CN). Pork raw materials (10kg) were inoculated (1% wt:vol) with an acid-adapted 5-strain cocktail of *Salmonella* (S. Senftenberg ATCC 43845, S. Typhimurium ATCC 14028, S. Anatum ATCC 9270, S. Newport ATCC 6962, and S. Enteritidis NFPA 7102) or *Listeria monocytogenes* (ATCC 19111, NFPA 7064, NFPA 6311, NFPA 6301, NFL 7092). After inoculation, inoculum was hand massaged for 30s and rested for 10m for attachment prior to a 3s hand application of 2.5% lactic acid (20°C) using a hand-pump sprayer (LA). Negative controls were inoculated in the same manner without applying the LA intervention. Inoculated raw materials were ground (4.5 mm), seasoned, mixed (2m), and stuffed into fibrous cellulose casings. Fermentation was achieved at 25 - 28°C and 90% RH, after which the product was dried and aged at 12 - 17°C and 70% RH until water activity (a_w) decreased to < 0.92. In addition, two independent replicates of 90mm and 105mm traditional salami were manufactured as previously described without raw material antimicrobial interventions. At the completion of the drying and aging period, these products were peeled, vacuum packaged, and subjected to high-pressure pasteurization (HPP) at 600 MPa for 180 seconds at 4°C.

Samples (25g; n=3/replicate) for pathogen recovery were aseptically collected before and after applying LA, from the batter, after fermentation, at the completion of drying, and before and after HPP. Samples were enumerated for *Salmonella* spp. counts (SAL) by plating serial dilutions on Bio-RAD Rapid *Salmonella* Agar (RSA) and incubating at 35 °°C for 24 h, *L. monocytogenes* counts (LM) were determined by plating serial dilutions on PALCAM and incubating at 35 °C for 48 hr. Results are reported as CFU/25 g of sample and log converted for analysis, with a lower detection limit of 10 CFU/25g.

Data were analyzed using JMP 18.1.1. Least squares means were computed and separated using Tukey's HDS with an alpha level of $P < 0.05$.

III. RESULTS AND DISCUSSION

Applying LA to inoculated pork trimmings reduced ($P< 0.05$) LM but not SAL; however, recoverable levels of both pathogens were lower at subsequent sampling points when LA was applied to the raw materials.

Table 1. Least Squares Means ± Standard Error (Reduction from inoculation) for *Listeria monocytogenes* and *Salmonella* spp. recovery (Log CFU/25g) taken throughout the duration of manufacturing, fermentation and drying of small diameter (46mm) salami (n = 6).

	Listeria monocytogenes		***Salmonella* spp.**	
Process Stage	**Intervention**	**No Intervention**	**Intervention**	**No Intervention**
Inoculated Pork	$6.00^{a,b} \pm 0.46$	$6.60^{a} \pm 0.32$	$7.32^{a} \pm 0.37$	$6.83^{a} \pm 0.26$
Post 2.5 % LA	$3.89^{c,d} \pm 0.46$ (2.11)	N/A	$6.45^{a} \pm 0.37$ (0.87)	N/A
Batter	$3.83^{c,d} \pm 0.46$ (2.17)	$6.55^{a} \pm 0.32$ (0.05)	$5.90^{a,b} \pm 0.37$ (1.42)	$7.04^{a} \pm 0.26$ (-0.21)
Post Fermentation	$3.67^{c,d} \pm 0.46$ (2.33)	$4.56^{b,c} \pm 0.31$ (2.04)	$4.17^{c} \pm 0.37$ (3.15)	$6.51^{a} \pm 0.26$ (0.32)
$a_w < 0.92$	$1.96^{d,e} \pm 0.46$ (4.04)	$3.48^{c,d} \pm 0.27$ (3.12)	$1.87^{d} \pm 0.37$ (5.45)	$4.73^{b,c} \pm 0.21$ (2.10)

^{a,b,c,d}Means, lacking common superscript letters, differ (P < .05).

Additionally, applying LA accelerated reduction of both LM *and* SAL throughout the process, resulting in lower (P<.05) recovery counts and a 4.04 and 5.45 log CFU/25g reduction when the product reached a shelf-stable a_w, compared to a 3.12 and 2.10 log CFU/25g reduction, respectively, when raw materials were not treated with an antimicrobial intervention before grinding (Table 1).

Small (46mm) and large (90 and 105mm) traditional salami products inoculated with SAL underwent HPP after drying. Recoverable levels varied among the different formats before HPP, likely due to the use of LA in producing the 46mm product. Treatment with HPP reduced recoverable levels of SAL in all formats to below detectable levels and demonstrated the ability to achieve a >4.5 log CFU/25g reduction in large diameter, fermented, and dry salami (Table 2).

Table 2. Least Squares Means ± Standard Error for *Salmonella spp.* counts (Log CFU/25g) taken before and after high pressure pasteurization (HPP) of 3 diameters of salami.

Process Stage	**46mm**	**90mm**	**105mm**
Before HPP	1.87 ± 0.36	4.58 ± 0.25	4.59 ± 0.24
After HPP	ND*	ND	ND

*ND = Not Detectable

IV. CONCLUSION

Fermented and dry, shelf-stable salami, ready to eat, are typically not subjected to a single process that achieves the necessary pathogen lethality to ensure product safety and must rely on multiple hurdles for this purpose. Application of antimicrobial interventions on raw materials before grinding, or use of HPP after the products have dried, serves as effective interventions that can be implemented. The impact of antimicrobial interventions on the sensory attributes of the finished product should be studied further to ensure there are no negative effects on the flavor and aroma of these traditional products.

V. REFERENCES

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