Lethality of Small-Scale Commercial Dehydrator and Smokehouse/Oven Drying Processes Against *Escherichia coli* O157:H7-, *Salmonella* spp.-, *Listeria monocytogenes*-, and *Staphylococcus aureus*-inoculated Turkey Jerky and the Ability of a Lactic Acid Bacterium to Serve as a Pathogen Surrogate

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Abstract:

Only one published study *(5)* has explored the lethality of commercial turkey jerky processes against *Salmonella* and other pathogens. Processors, therefore, are limited in their ability to comply with USDA guidance requiring use of jerky-making processes validated for lethality. Our laboratory strives to provide the industry with novel in-plant process validation methods using GRAS lactic acid bacteria (LAB) starter cultures as pathogen surrogates; here this concept is applied to whole-muscle turkey jerky.

Whole muscle turkey strips (5.08cm x 15.24cm x 0.6cm) were inoculated with *Listeria monocytogenes* (5 strains), *Staphylococcus aureus* (5 strains), Saga 200 (LAB –*Pediococcus acidilactici*), or a mixed inoculum of *Escherichia coli* O157:H7 and *Salmonella* (5 and 8 strains, respectively). After allowing for bacterial attachment, strips were marinated in Barbeque or Teriyaki spice mixes, hand tumbled, marinated 12 to 24 h (4 °C) and processed in a small commercial dehydrator or a large commercial smokehouse/oven. Initial inoculum concentration was ~10^7 CFU/cm^2.

Inoculum destruction was evaluated during three types of procesess: drying alone (dehydrator, smokehouse), drying (dehydrator) + post-dehydration storage, or drying (dehydrator) + post-dehydration oven heating. Samples were analyzed after marination, during the drying process, and, where appropriate, after post-dehydration oven heating at 133°C, or after 4-wk vacuum-storage at 21 °C. Trials were performed in triplicate.

Sufficient pathogen lethality was achieved using a commercial smokehouse process with high wet-bulb temperature, or when drying in a small commercial dehydrator (6 h) was followed by heating for 10 min in a 133° oven. Across all processes and spices, survival of Saga 200, *E. coli* O157:H7, and *Salmonella* spp. was not significantly different (p<0.05). Saga 200 could serve as an effective pathogen surrogate for in-plant validation of turkey jerky processing.

Materials and Methods:

Turkey Jerky Strip Preparation:

•Turkey breasts (whole de-boned) were purchased from a local butcher shop pre-sliced (0.6 cm thickness) and then cut into identical strips (5.08 cm by 15.24 cm by 0.60 cm).
•Average strip weight was 29 g.

Inoculum Preparation:

•Inocula consisted of ~10^8 CFU/ml of either *Listeria monocytogenes* (5 strains), *Staphylococcus aureus* (5 strains), Saga 200 (LAB – *Pediococcus acidilactici;* Kerry Bioscience, Rochester, MN), or a mixed inoculum of *E. coli* O157:H7 and *Salmonella* spp. (5 and 8 strains, respectively). Both the *E. coli* O157:H7 and *Salmonella* strains had been screened for thermotolerance and have been used in jerky process validation studies previously in our laboratory *(1,3)*.
•Pathogen inocula were prepared from stationary-phase cells that were re-suspended in Butterfield's phosphate diluent (BPD).
•LAB inoculum was prepared from 0.5g of Saga 200 re-suspended in 9ml BPD.

Inoculation of Turkey Strips:

•Either a pathogen- or LAB-inoculum (0.4 ml) was pipetted onto the surface of each meat strip at 21°C in a biosafety hood and evenly spread.
•After a 30 min attachment period, the strips were turned over and the inoculation repeated on the other side. Initial inoculum level was ~10^7 CFU/cm^2.
•Inoculated strips were transferred to 1-gal Ziploc ® bags for marination using one of two spice blends: Barbeque or Terikyaki (Excalibur Seasoning Company). Inoculated turkey strip/spice mix was hand-tumbled for 5 min and stored for 18-24 h at 4ºC.

Turkey Strip Processing Conditions:

•Marinated strips were dried in a small-scale commercial dehydrator (Pragotrade model TS160, Cabela's Inc.) in the laboratory, or in a commercial smokehouse/oven (Model 2000, Alkar-RapidPak) at the Alkar-RapidPak Research and Technology Center (ARPRTC, Lodi, WI) (Figures 1 and 2).
•Strips were laid out in groups of four, consisting of one strip inoculated with *E. coli* O157:H7 and *Salmonella* spp., and one strip each inoculated with *L. monocytogenes, S. aureus,* or LAB.
•Four thermal processes were evaluated: 1) a 6-h heating process in a small-scale commercial dehydrator set at maximum unit temperature (68.3°C); 2) the 6-h heating process in a dehydrator followed by heating 10 min in a pre-heated 133°C oven; 3) a smokehouse process with an initially high wet-bulb temperature; and 4) a step-wise smokehouse process with no humidity (wet-bulb temperature) control (Table 1).
•Additionally, the effect on process lethality of post-dehydration vacuum-storage for up to 4-wk was evaluated for samples dried 6-h in a small-scale commercial dehydrator.

Table 1. Processing conditions used to manufacture whole-muscle turkey jerky in a small-scale commercial dehydrator or a commercial smokehouse/oven.

Process Number	Step Time (min)	Cumulative Time (min)	Set Dry Bulb Temp. ºC (ºF)	Set Wet Bulb Temp. ºC (ºF)
1[a]	360	360	68.3 (155)	NC[b]
2	360	360	68.3 (155)	NC
	10	370	133 (275)	NC
3	90	90	57.2 (130)	51.7(125)
	150	240	85.0(185)	NC
4	90	90	54.5 (130)	NC
	60	150	60.0 (140)	NC
	60	210	65.5 (150)	NC
	60	270	71.1 (160)	NC

[a]Process 1 – small commercial dehydrator (Cabela's)
Process 2 – small commercial dehydrator + 10 min heating at 133°C
Processes 3,4 - commercial smokehouse/oven
[b]NC, not controlled

Figure 1.

Figure 2.

Enumeration of Surviving Cells:

•Samples were taken post-marination, at intervals throughout the drying process, and, where appropriate, after the post-dehydration oven heating, or during the 4-wk storage period.
•At designated sampling times, jerky strips (one per spice/ inoculum combination) were removed from the dehydrator/smokehouse, placed in separate Whirl-pak filter bags with 99 ml BPD and stomached for 2 min at medium speed. Further serial dilutions were made in BPD.
• *E. coli* O157:H7 and *Salmonella* were enumerated using modified eosin methylene blue (M-EMB) agar prepared from lactose-free EMB (Difco) with the addition of 10 g/l D-sorbitol and 5 g/l NaCl. This has been shown to be a superior method for enumeration of these pathogens from jerky *(1)*.
•For enumeration of *L. monocytogenes*, *S. aureus*, and Saga 200, samples were spread-plated on brain heart infusion agar (BHIA, Difco), incubated 1 h at 35ºC for injury-repair, and selective-medium overlays were performed : *Listeria* Selective agar (LSA, Difco) plus *Listeria* selective supplement (Difco), Baird-Parker (BP) agar (Difco) plus egg yolk-tellurite supplement (Difco), and lactobacilli deMan Rogosa Sharpe (MRS) agar (Difco), respectively.
•Plates were incubated at 35ºC for 24 h (M-EMB) or 48 h (LSA, BP, and MRS overlay plates). The count (log CFU/cm^2) for each organism was calculated, and mean counts were calculated for each organism-spice combination at each sampling time.

Statistical analyses:

•Mean log reduction for each process-spice-organism combination was calculated.
•Mean log reduction values were analyzed by three way Anova to determine significant differences between processes, spice marinades, and organisms, with interactions between these factors also evaluated for significance (version 9.1; SAS, Institute, Inc). A paired t-test was used to evaluate the significance of lethality achieved during post-dehydration vacuum storage.

Results and Discussion:

•Across all processes and spices, Saga 200, *E. coli* O157:H7, and *Salmonella* survived equally well (p > 0.05; see superscripts in column headings of Table 2). Therefore, Saga 200 appears to be a suitable pathogen-surrogate for use in evaluating the lethality of turkey jerky-making processes. By comparison, there were significantly greater reductions in levels of *L. monocytogenes* and *S. aureus.*
•The processes differed significantly in average lethality, across all organisms and spices. Significantly greater lethality was observed with the smokehouse process involving elevated wet-bulb temperature (Process 3), or when a post-dehydration oven heating step was added to a 6-h process in a small commercial dehydrator (Process 2; see superscripts in row headings of Table 2). Significantly less lethality was observed in samples processed using a small-scale commercial dehydrator operated at the maximum temperature setting and according to the manufacturer's instructions (Process 1), or when samples were dried in a commercial smokehouse using a step-wise temperature increase and no humidity control (Process 4).
•Spice mix did not significantly affect process lethality.
•Only samples processed according to Process 2 or 3 consistently met the USDA 5-log pathogen reduction standard.
•The addition of vacuum storage at 21°C for 4 wks significantly increased pathogen destruction by 0.49 log CFU/cm^2 (p<0.05) over standard processing in a small commercial dehydrator, but did not result in overall microbial reductions meeting the USDA 5-log standard (data not shown).

Table 2. Mean lethality (Δ log CFU/cm^2) against *Salmonella* spp., *E. coli* O157:H7, *L. monocytogenes*, *S. aureus*, and Saga 200 (LAB) on whole-muscle turkey jerky marinated in Teriyaki (Teri) or Barbeque (BBQ) spice mix and processed as described in Table 1. (n=3)

Process	*Salmonella*[1]		*E. coli* O157:H7[1,2]		*L. monocytogenes*[2]		*S. aureus*[2]		Saga 200[1]	
	Teri	BBQ	Teri	BBQ	Teri	BBQ	Teri	BBQ	Teri	BBQ
1[A]	2.6 (0.2)	3.8 (0.4)	2.3 (0.3)	3.0 (0.2)	3.1 (0.7)	3.0 (0.2)	2.6 (0.2)	4.1 (1.4)	2.6 (0.6)	2.6 (1.1)
2[B]	5.3 (0.3)	5.3 (0.3)	4.0 (0.7)	4.2 (0.9)	5.0 (1.9)	4.4 (2.1)	4.9 (1.2)	4.9 (1.0)	ND	ND*
3[B]	4.2 (0.1)	4.6 (0.5)	7.7 (0.2)	6.5 (1.2)	5.4 (0.9)	5.5 (0.7)	6.3 (0.3)	6.4 (0.8)	4.5 (0.6)	5.1 (0.2)
4[A]	2.2 (0.8)	2.4 (0.9)	1.8 (0.2)	2.3 (0.2)	3.8 (1.3)	4.4 (1.8)	3.4 (0.5)	3.5 (0.1)	3.1 (0.2)	3.2 (0.4)

*ND=Not determined.

Conclusions:

Lethality sufficient to meet USDA performance standards can not be achieved against *E. coli* O157:H7 or *Salmonella* spp. using a small-scale commercial dehydrator. A short (10 min) post-drying oven-heating step at 133°C (275°F), following a 6-h drying time at 68.3°C (155°F), will achieve the target lethality. Post-drying room temperature storage under vacuum will lead to a slight (0.49 log CFU/cm^2), but significant (p<0.05), increase in lethality. Saga 200 is a suitable pathogen-surrogate in the validation of whole muscle turkey jerky processes using a small scale commercial dehydrator or a smokehouse.

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Acknowledgments:

We thankfully acknowledge Alkar-RapidPak for allowing us access to their research facility. Expert advice was provided by Peter Crump (University of Wisconsin statistical consulting service) and Sarah Dierschke (M.S. University of Wisconsin-Madison, 2010). Funding has been provided for this research from the USDA Cooperative State Research, Education and Extension Service Hatch fund — Wisconsin Experiment Station project #WIS01329.