Pathogen Reduction in Smokehouse versus Dehydrator-Prepared Beef Jerky

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Abstract

Beef jerky is a heat-treated, shelf stable ready-to-eat meat product. Commercial jerky processors need to show their processes can reduce *Salmonella*, *Escherichia coli* O157:H7, and *Listeria monocytogenes* populations by >5 logs. Many small processors use dehydrators rather than smokehouses to process their product, and while humidity control during drying and its effect on pathogen survival has been questioned, controlling humidity in a dehydrator is more difficult compared to a smokehouse. Beef jerky strips were made using a horizontal-flow dehydrator at 62oC (143.6oF) and a commercial-type smokehouse with a dry-bulb/wet-bulb setting of 63oC/43oC (145oF/110oF) (33% relative humidity) with or without pretreatments of acidic calcium sulfate (1:2 and 1:3 water:calcium sulfate ratios), and chlorine dioxide (500 and 1200 ppm) to determine effectiveness of treatments in inactivation of *Salmonella*, *E. coli* O157:H7, and *L. monocytogenes*. *E. coli* O157:H7 populations were reduced by >5 logs cfu/strip ($p<0.05$) for all treatments except for jerky pretreated with 500 ppm chlorine dioxide and dried in the dehydrator. For *L. monocytogenes*, 5 log reductions ($p<0.05$) were noted for all treatments regardless of the drying method.

Abstract, continued

Salmonella populations were reduced by >6.5 logs ($p<0.05$) on jerky strips that were pretreated with the higher concentration of calcium sulfate and dried in the dehydrator and jerky pretreated with 1200 ppm chlorine dioxide and dried in the smokehouse. Populations were reduced almost as well on calcium sulfate jerky when dried in the smokehouse. While effective treatments may be attained using a dehydrator coupled with an antimicrobial pretreatment, processing jerky in the smokehouse with similar temperature conditions was more effective. Generally, acidic calcium sulfate was a more effective pretreatment than chlorine dioxide. Small processors using dehydrators with limited humidity control within the drying chamber may find using these antimicrobial treatments beneficial in achieving the desired level of pathogen reduction.

Introduction

- Jerky is one of the oldest meat products
- High demand snack food, high in protein and iron content, low fat
- USDA Classification – Heat treated, shelf stable, ready-to-eat, moisture protein ratio (MPR) of 0.75–1.0, water activity (a_w) <0.8
- Variety of recipes and marination techniques
- Meat type: beef, poultry, wild animals
- Preparation procedure: ground and formed or sliced – thick or thin
- Drying: dehydrator and smokehouse
- In 2004, FSIS issued the *Compliance Guidelines for Meat and Poultry Jerky Produced by Small and Very Small Plants*.
- Small and very small jerky processing establishments can develop customized lethality processes that achieve an appropriate reduction of pathogens throughout the product. Process must be validated.
- Pathogen population reduction is influenced by marination, drying temperature and additional treatments.
- Antimicrobial intervention allows options to increase pathogen reduction greater than that achieved by heating and drying alone. A variety of antimicrobial intervention methods to reduce numbers of pathogens on jerky products have been studied and developed.

Introduction, cont.

- **Acidic Calcium Sulfate** (ACS)
  - A highly acidic calcium sulfate (ACS) with pH ≤ 2.0 has been used as a food additive to eliminate microbial contaminants.
  - When mixed with organic acids, ACS reduces the pH sufficiently to maintain more organic acid in its undissociated form.
  - ACS ingredients affirmed GRAS by the U.S. FDA (21CFR 184.1230).

- **Acidified Sodium Chlorite** (ASC)
  - Antimicrobial intervention treatment for poultry, red meat, seafood, and raw agricultural commodities
  - ASC used at the concentration of sodium chlorite ($NaClO_2$) between 500 and 1,200 ppm in combination with any GRAS acid (citric acid, phosphoric acid or hydrochloric acid) at levels sufficient to achieve pH 2.5 to 2.9 (FDA, 2001).
  - ASC approved by the FDA (21CFR 173.325) as a secondary direct food additive permitted in food for human consumption.

Objectives of the Study

- To compare the effectiveness of various beef jerky processing methods
  - Comparing chemical pretreatments (acidic calcium sulfate, acidified sodium chlorite) to no pretreatment
  - Comparing drying methods (use of a dehydrator or smokehouse)
  - Pathogens of interest: *Salmonella, Escherichia coli* O157:H7, and *Listeria monocytogenes*

Materials and Methods

- Bacterial strains
  - *Salmonella*: California, Enteritidis, Typhimurium DT 104 H3380, Typhimurium DT 104 H3402, Typhimurium 654
  - *E. coli* O157:H7: 932, E009, 204 P, E0019, 380-94
  - *L. monocytogenes*: Brie, Scott A, V7, LCDC#81-861, 301
- Beef strip preparation - Sliced into 0.5 x 2.5 x 30 cm size strips
- Antimicrobial solutions preparation
  - Acidic calcium sulfate with lactic acid solution
    - (ACS) ($Safe_2O$™ RTE-01; Mionix ™) diluted with tap water for 1:2 and 1:3 water ratios
    - Final pH value of solution was 1.4-1.7
  - Acidified sodium chlorite solution (ASC)
    - Sodium chlorite (Keeper™) mixed with citric acid anhydrous and diluted with tap water for 1,200 and 500 ppm conc.
    - Final pH value of solution was 2.7-2.9
- Marinade - water, salt, sugar, vinegar, Worchestershire sauce, sodium erythrobate, monosodium glutamate, garlic powder, thyme, sodium nitrite

Materials and Methods, Cont.

- Drying methods
  - Horizontal air flow food dehydrator model # 3936T, Excalibur® Products, 62 ± 2°C; no R.H. control
  - Commercial style smokehouse model # 450, Alkar-Rapidpak, Inc., 33% R.H., dry-bulb temperature 63°C and wet-bulb temperature 43°C
- Meat inoculation and pretreatments
  - Strips were inoculated separately with 500 µl of bacterial cocktail *Salmonella, E. coli* O157:H7, *Listeria monocytogenes*
  - Stored at 4 ± 2°C for 22 ± 2 h
  - Chemical solutions and marination
    - Strips immersed into the solutions for 30 s
    - 1 strip from each pan was sampled – after pretreatment (AP)
    - 1 L of marinade was added to each pan
    - Strips were stored at 4 ± 2°C for 21 ± 3 h
    - 1 strip from each pan was sampled – after marination (AM)

Materials and Methods, Cont.

- Drying treatments and storage
  - Marinated strips dried in a dehydrator or a smokehouse for 8-9 h
  - 1 strip from each pan was sampled – after drying (AD)
  - Each strip placed into a Cryovac® bag, vacuum packed, and stored in an incubator at 25 ± 2°C
- Sampling
  - Strips were also sampled after 1, 2, and 3 months of storage
  - Samples placed into sterile Stomacher™ bags
  - Added 225 ± 5 ml of pre-enrichment media - nutrient broth for *Salmonella,* mEC broth for *E. coli* O157:H7, UVM broth for *L. monocytogenes*
  - Stomached for 2 min
  - Spiral plated on plate count agar (PCA), bismuth sulfite agar (BSA), sorbitol MacConkey agar (SMAC), modified Oxford agar (MOX)
  - Incubated at 37 ± 2°C for 20-24 h
  - Incubated pre-enrichment media at 37°C for 20-24 h
  - Transfer into enrichment broth and isolation
    - For *Salmonella* - 10 ml TT broth and RV(R10) broth incubated at 42°C for 24 h, then streaked onto BSA
    - For *L. monocytogenes* - 10 ml Fraser broth incubate at 35°C for 26 h

Materials and Methods, Cont.

- For *E. coli* O157:H7 - Streak from mEC broth onto SMAC and plates incubated at 35°C for 20-24 h
- Representative colonies enumerated and isolates were identified
- Physical properties analysis
- Water activity (a_w) measured with a water activity meter
- pH measured using a surface electrode
- Statistical analysis
- Average bacterial counts of three replications analyzed
- Data was evaluated using a 2x4x3x3x7x2 factorial design (drying methods x chemical treatments x different pathogens x replications x sampling times x agar media).
- ANOVA of main effects (organism, pretreatment, marination, drying methods and agar media) and interactions were conducted using the PROC GLM procedure in SAS.
- To compare pretreatments with each other for a fixed time difference, one-way ANOVA was performed for testing the null hypothesis that the mean of $\log_{10}$ of the response variable for pretreatments was the same versus the alternative that there was some difference.

Pathogen survival (log cfu/strip) on whole strip beef jerky pretreated with acidic calcium sulfate or not pretreated and dried in a dehydrator at 62°C

Organisms	1 : 2 water					1 : 3 water					Control				
	I[a]	AP[b]	AM[c]	AD[d]	LR[e]	I[a]	AP[b]	AM[c]	AD[d]	LR[e]	I[a]	AP[b]	AM[c]	AD[d]	LR[e]
Salmonella	8.78	6.56	6.15	1.60	7.18	8.78	7.09	6.85	2.06	6.72	8.78	8.43	7.62	3.87	4.91
E. coli O157:H7	8.28	7.05	7.02	<1.60[f]	>6.68	8.28	7.31	7.22	<1.60	>6.68	8.28	8.16	7.50	<1.60	>6.68
L. monocytogenes	8.48	7.66	7.27	<1.60	>6.88	8.48	7.85	7.74	<1.60	>6.88	8.48	8.25	7.77	2.12	6.36

Comparing initial populations and after pretreatment populations –

2.22 log reduction for 1:2, 1.69 log reduction for 1:3, 0.35 log reduction for control

1.23 log reduction for 1:2, 0.97 log reduction for 1:3, <0.2 log reduction for control

0.82 log reduction for 1:2, 0.63 log reduction for 1:3, 0.23 log reduction for control

[a] I: Initial population

[b] AP: After pretreatment - Dipped in 1 part Mionix + 2 water, 1 part Mionix + 3 water, and water control for 30 sec

[c] AM: After marination - Marinade composed of: water, salt, sugar, vinegar, Woecestershire sauce, sodium erythrobate, MSG, thyme, garlic powder, and sodium nitrite

[d] AD: After drying - ~ 8-9 h and drying temperature at 62°C (143.6°F); no humidity control

[e] LR: Log reduction = After drying – Initial population

[f] Enumeration below detection level (4.0×10^1 cfu/strip); positive ID after enrichment

Pathogen survival (log cfu/strip) on whole strip beef jerky pretreated with acidic calcium sulfate or not pretreated and dried in a smokehouse

Organisms	1 : 2 water					1 : 3 water					Control				
	I[a]	AP[b]	AM[c]	AD[d]	LR[e]	I[a]	AP[b]	AM[c]	AD[d]	LR[e]	I[a]	AP[b]	AM[c]	AD[d]	LR[e]
Salmonella	8.43	6.67	6.32	1.60	6.83	8.43	6.79	6.51	<1.60	>6.83	8.43	8.48	7.10	<1.60	>6.83
***E. coli* O157:H7**	8.31	6.62	6.14	<1.60[f]	>6.71	8.31	6.75	6.61	<1.60	>6.71	8.31	8.20	7.11	<1.60	>6.71
L. monocytogenes	8.52	7.16	6.52	<1.60	>6.92	8.52	7.19	6.98	<1.60	>6.92	8.52	8.44	7.18	<1.60	>6.92

Comparing initial populations and after pretreatment populations –

1.76 log reduction for 1:2, 1.64 log reduction for 1:3, no log reduction for control

1.69 log reduction for 1:2,1.56 log reduction for 1:3, <0.2 log reduction for control

1.36 log reduction for 1:2, 1.33 log reduction for 1:3, <0.2 log reduction for control

[a] I: Initial population

[b] AP: After pretreatment - Dipped in 1 part Mionix + 2 water, 1 part Mionix + 3 water, and water control for 30 sec

[c] AM: After marination - Marinade composed of: water, salt, sugar, vinegar, Woecestershire sauce, sodium erythrobate, MSG, thyme, garlic powder, and sodium nitrite

[d] AD: After drying - ~ 8-9 h; conditions of smokehouse: 33% relative humidity, dry-bulb temperature 63°C (145°F) and wet-bulb temperature 43°C (110°F)

[e] LR: Log reduction = After drying – Initial population

[f] Enumeration below detection level (4.0×10^1 cfu/strip); positive ID after enrichment

Pathogen survival (log cfu/strip) on whole strip beef jerky pretreated with acidified sodium chlorite or not pretreated and dried in a dehydrator at 62°C

Organisms	1,200 ppm					500 ppm					Control				
	I[a]	AP[b]	AM[c]	AD[d]	LR[e]	I[a]	AP[b]	AM[c]	AD[d]	LR[e]	I[a]	AP[b]	AM[c]	AD[d]	LR[e]
Salmonella	8.29	7.68	7.28	2.95	5.34	8.29	8.17	7.33	3.35	4.94	8.29	8.27	7.37	3.54	4.75
E. coli O157:H7	8.49	7.86	7.17	1.76	6.73	8.49	8.36	7.65	2.81	5.68	8.49	8.26	7.33	1.86	6.63
L. monocytogenes	8.15	8.03	7.40	<1.60[f]	>6.55	8.15	8.11	7.57	<1.60	>6.55	8.15	8.31	7.69	<1.60	>6.55

Comparing initial populations and after pretreatment populations –

0.61 log reduction for 1:2, <0.2 log reduction for 1:3, no log reduction for control

0.63 log reduction for 1:2, <0.2 log reduction for 1:3, 0.23 log reduction for control

<0.2 log reduction for 1:2, <0.2 log reduction for 1:3, no log reduction for control

[a] I: Initial population

[b] AP: After pretreatment - Dipped in 1,200 ppm, 500 ppm of $NaClO_2$ and water control for 30 sec

[c] AM: After marination - Marinade composed of: water, salt, sugar, vinegar, Woecestershire sauce, sodium erythrobate, MSG, thyme, garlic powder, and sodium nitrite

[d] AD: After drying - ~ 8-9 h and drying temperature at 62°C (143.6°F); no humidity control

[e] LR: Log reduction = After drying – Initial population

[f] Enumeration below detection level (4.0×10^1 cfu/strip); positive ID after enrichment

Pathogen survival (log cfu/strip) on whole strip beef jerky pretreated with acidified sodium chlorite or not pretreated and dried in a smokehouse

Organisms	1,200 ppm					500 ppm					Control				
	I[a]	AP[b]	AM[c]	AD[d]	LR[e]	I[a]	AP[b]	AM[c]	AD[d]	LR[e]	I[a]	AP[b]	AM[c]	AD[d]	LR[e]
Salmonella	8.57	7.09	6.94	<1.60	>6.97	8.57	8.24	7.13	1.86	6.71	8.57	8.38	7.24	2.79	5.78
E. coli O157:H7	8.49	7.59	6.87	<1.60	>6.89	8.49	8.02	7.01	<1.60	>6.89	8.49	8.23	6.95	<1.60	>6.89
L. monocytogenes	8.49	7.79	6.83	<1.60	>6.89	8.49	8.27	7.19	<1.60	>6.89	8.49	8.40	7.31	<1.60	>6.89

Comparing initial populations and after pretreatment populations –

0.48 log reduction for 1:2, 0.33 log reduction for 1:3, <0.2 log reduction for control

0.90 log reduction for 1:2, 0.47 log reduction for 1:3, 0.26 log reduction for control

0.70 log reduction for 1:2, 0.22 log reduction for 1:3, <0.2 log reduction for control

[a] I: Initial population

[b] AP: After pretreatment - Dipped in 1,200 ppm, 500 ppm of $NaClO_2$ and water control for 30 sec

[c] AM: After marination - Marinade composed of: water, salt, sugar, vinegar, Woecestershire sauce, sodium erythrobate, MSG, thyme, garlic powder, and sodium nitrite

[d] AD: After drying - ~ 8-9 h; conditions of smokehouse: 33% relative humidity, dry-bulb temperature 63°C (145°F) and wet-bulb temperature 43°C (110°F)

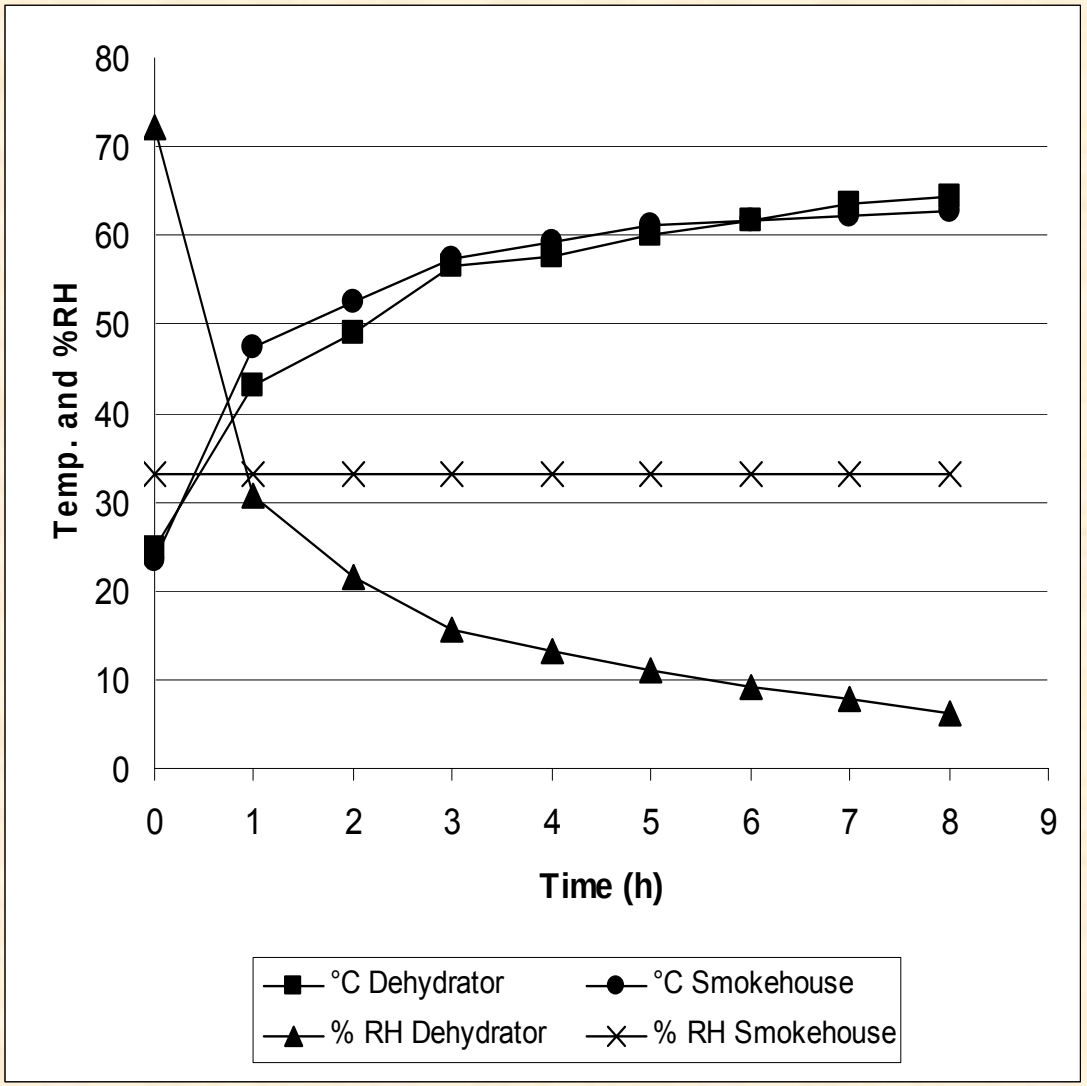
[e] LR: Log reduction = After drying – Initial population

[f] Enumeration below detection level (4.0×10^1 cfu/strip); positive ID after enrichment

Average a_w and pH values of whole strip beef jerky pretreated with acidic calcium sulfate (ACS) and acidified sodium chlorite (ASC) or not pretreated and dried in a dehydrator at 62°C

Processing step		1:2 ACS		1:3 ACS		Water Control (ACS)		1,200 ppm ASC		500 ppm ASC		Water Control (ASC)	
		a_w	pH	a_w	pH	a_w	pH	a_w	pH	a_w	pH	a_w	pH
Before pretreatment	*Sal*	0.992	5.68	0.992	5.68	0.992	5.68	0.997	5.92	0.997	5.92	0.997	5.92
	Ec	0.995	5.85	0.995	5.85	0.995	5.85	0.993	5.89	0.993	5.89	0.993	5.89
	Lm	0.994	5.90	0.994	5.90	0.994	5.90	0.994	5.84	0.994	5.84	0.994	5.84
After pretreatment	*Sal*	0.994	4.55	0.995	4.74	0.994	5.72	0.995	5.83	0.995	5.81	0.994	5.90
	Ec	0.992	4.56	0.993	4.73	0.993	5.85	0.993	5.53	0.995	5.57	0.995	5.85
	Lm	0.994	4.63	0.994	4.76	0.995	5.94	0.996	5.60	0.994	5.74	0.995	5.78

Average internal temperature of beef jerky strips and percent relative humidity in a horizontal dehydrator at 62°C and in a commercial smokehouse with dry bulb/wet bulb temperatures of 63°C and 43°C



Conclusions

- *Salmonella* inactivation was greater than *E. coli* O157:H7 and *L. monocytogenes* when whole-muscle strips were pretreated with acidic calcium sulfate.
- Both concentrations of the acidic calcium sulfate used were effective in reducing the populations of *Salmonella* with the greater concentration being more effective.
- There was no statistical difference in the effectiveness of the acidic calcium sulfate in contributing to the reduction of *E. coli* O157:H7 and *L. monocytogenes* although it is possible to rank the effectiveness with the greater concentration being more effective.
- Acidified sodium chlorite had little antimicrobial effect on the pathogens even at the highest concentration (1,200 ppm) approved by the FDA (21 CFR 173.325).
- *Salmonella* populations were significantly reduced by 6.5 logs cfu/strip for these treatments:
  - acidic calcium sulfate 1:2 water with dehydrator
  - for acidic calcium sulfate treatments with smokehouse
  - 1,200 ppm acidified sodium chlorite with smokehouse
- *E. coli* O157:H7 populations were significantly reduced by 5 logs cfu/strip for all the treatments except for 500 ppm acidified sodium chlorite with dehydrator
- *L. monocytogenes* populations were significantly reduced by 5 logs cfu/strip for all the treatments regardless of the drying method
- Heating and drying strips in the commercial smokehouse was more effective in reducing the pathogen populations than with the horizontal dehydrator.
- While processing jerky in a smokehouse was more effective, effective treatments may be attained using a dehydrator coupled with an antimicrobial pretreatment.
- **In general, the acidic calcium sulfate was a more effective antimicrobial pretreatment than acidified sodium chlorite.**

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