

Destruction of Acid-Adapted and Non-Adapted *Salmonella* During Drying and Storage of Beef Jerky Treated with Marinades

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SUMMARY

Salmonella may survive the jerky manufacturing process and may cause foodborne disease outbreaks. This study evaluated influence of various pre-drying treatments on inactivation of acid-adapted or nonadapted *Salmonella* on beef jerky during preparation, drying and storage. Dipping meat slices into 1% Tween 20, and 5% acetic acid prior to traditional marinade (TM), or using double amount of modified TM (1.2% sodium lactate, soy sauce with 5% ethanol, and 9% acetic acid) resulted in significantly ($P < 0.05$) higher reductions of bacterial populations during drying and storage compared to TM alone or control, regardless of acid adaptation.

Key Words: *Salmonella*, Jerky, Drying, Storage.

INTRODUCTION

The *Salmonella* and *Escherichia coli* O157:H7 outbreaks linked to jerky consumption (CDC, 1995; Eidson et al., 2000; Keene et al., 1997) have increased concerns for the safety of jerky products. A recent report (Levine et al., 2001) by the Food Safety and Inspection Service of the United States Department of Agriculture (FSIS/USDA) indicated that for the period of 1990 to 1999, cumulative prevalence of *Salmonella* in jerky produced in federally inspected plants was 0.31%. Therefore, interest in evaluating the efficacy of jerky processing,

especially when prepared in home-type dehydrators, in inactivating foodborne pathogens including *Salmonella* (Harrison and Harrison, 1996, 2001; Holley, 1985) has increased. As a response to the problem, FSIS has suggested cooking meat to 160°F (71.1°C) before drying to eliminate risk of pathogens. However, pre-heating of meat and/or drying of jerky at high temperatures for extended periods of time may result in a product that differs from traditional jerky, thus reducing consumer acceptability. Use of chemical intervention strategies as pre-drying treatments, however, has not been studied adequately. Such interventions can be a viable option to avoid severe heat treatments as well as may provide residual antimicrobial effects during product storage. These chemicals may include organic acids (e.g., acetic acid), ethanol, lactates, and food grade surfactants (e.g., polysorbates). Therefore, the objective of the present study was to evaluate the effectiveness of various chemical-based pre-drying treatments (modified marinades) on acid-adapted or nonadapted *Salmonella* during preparation, drying, and storage of whole muscle beef jerky.

MATERIALS AND METHODS

Preparation of inoculum

A five-strain composite of *Salmonella* Typhimurium (ST) was used for inoculating beef slices. These strains were SF530 (ST UK1), ATCC700408 (ST DT104), R-4 (ST Copenhagen DT104), and R-5 (ST Copenhagen DT104), and ATCC14028 (ST). Each strain was grown in glucose-free trypticase soy broth for nonacid adapted cells or in glucose-free TSB with 1% added glucose for acid-adapted cells for 24 h at 95°F (35°C) prior to combining, centrifuging and diluting to a final level of 7.0 log CFU/ml.

Inoculation of meat slices

Vacuum packaged and frozen/thawed beef slices (0.2 x 3.4 x 1.6 inch (0.6 x 8.7 x 4.0 cm)) were placed on plastic trays and inoculated with

0.5 ml of the *L. monocytogenes* inoculum on the surface of each side at 15 min interval for bacterial attachment. The resulting level of inoculum was approximately 6.0 log CFU/cm².

Pre-drying marinade treatments and drying

Inoculated meat slices were subjected to the following pre-drying marinade treatments for 24 h at 40°F (4°C): 1) no treatment (C), 2) traditional marinade (for 1.0 kg of meat: 60 ml soy sauce, 15 ml Worcestershire sauce, 0.6 g black, 1.25 g garlic powder, 1.5 g onion powder, and 4.35 g old hickory smoked salt (Andress and Harrison (1999)) (TM), 3) modified marinade (for 1.0 kg of meat: 120 ml of soy sauce containing approximately 4.7-5.0 % ethanol as preservative, 30 ml of Worcestershire sauce, 0.6 g black pepper, 1.25 g garlic powder, 1.5 g onion powder, 4.35 g smoke-flavored salt, 3.6 ml of a 60% preparation food grade sodium-L-lactate, and 16 ml of glacial acetic acid to adjust the pH to 3.0) (MM), 4) dipped in 5% acetic acid for 10 min, and then exposed to TM (AATM), and 5) dipped in 1% Tween 20 for 15 min, then in 5% acetic acid for 10 min, followed by TM (TWTM). Marinated meat slices were dried at 140°F (60°C) for 10 h in home-type dehydrators. The temperature of the dehydrators and surface temperature of meat slices were monitored using thermocouples and recorded with real-time data recording software. After drying, the jerky strips were held in the dehydrators overnight as recommended (Andress and Harrison, 1999), and then placed into 24-oz sterile plastic bags for storage at ambient temperature 77°F (25°C).

Analysis

Two samples (1 slice per sample) per treatment in each of two replicates were taken after inoculation, and 0 (after 24 h marination at 40°F (4°C)), 4, 7 and 10 h during drying, and on days 15, 30 and 60 of storage at 77°F (25°C). Each sample was pummeled

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for 2 min with a 25 ml portion of 0.1% sterile buffered peptone water (BPW) in a sterile sample bag. Serial decimal dilutions were made using 9-ml BPW tubes and 0.1 ml portions were surface plated on tryptic soy agar with 0.1% sodium pyruvate (TSAP), and XLT-4 agar. All plates were incubated at 95°F (35°C) for 48 h. The enumeration detection limit was $-0.4 \log \text{CFU}/\text{cm}^2$. Enrichment of samples was done when countable colonies were not detected.

RESULTS

Figure 1 shows populations of *Salmonella* during drying and storage of beef slices.

Effect of agar media

Bacterial populations recovered were higher on TSAP compared to XLT-4 agar. These results indicate a level of bacterial injury as estimated by the differences in counts between nonselective (TSAP) and selective (XLT-4) agar media, which may have been affected by acid adaptation, pre-drying treatment, and drying time. Although not expected in dried foods, injured cells may repair their damage and become a safety concern with product storage.

Effect of pre-drying treatments

Initial numbers of bacteria were significantly ($P \leq 0.05$) reduced after 24 h-refrigerated marination as determined on XLT-4 agar in TWTM (0.9-2.1 log), MM (0.9-1.9 log), regardless of acid adaptation and in AATM when the product was inoculated with an acid-adapted culture (1.9 log) compared to C (-0.1-0.3 log) and TM (-0.2-0.2 log). However, there was no significant difference in the numbers of bacteria between treatments as determined on

TSAP, indicating occurrence of bacteria injury caused by modified marinades.

Effect of drying and storage

Regardless of acid-adaptation or the recovery media used, initial bacterial counts were significantly ($P \leq 0.05$) reduced in all treatments after 4 h of drying. Bacterial populations further declined between 4, 7 and 10 h of drying, but these declines were not significant in all treatments. Results indicated that pre-drying treatments reduced bacterial populations during drying in the order TWTM (5.8-6.0 $\log \text{CFU}/\text{cm}^2$) \geq AATM \geq MM $>$ C \geq TM (2.6-5.0 $\log \text{CFU}/\text{cm}^2$). Nonadapted *Salmonella* were significantly ($P < 0.05$) more resistant to drying than acid-adapted in all treatments.

Bacterial populations continued to decline during storage in all treatments. Counts from all treatments were still detectable by direct plating after 60 d on TSAP in products inoculated with nonadapted culture. However, counts in products inoculated with acid-adapted culture dropped below the detection limit ($-0.4 \log \text{CFU}/\text{cm}^2$) in TWTM, AATM, and MM earlier than C and TM. Complete elimination of the pathogen (enrichment negative) by 60 d occurred in MM, AATM, and TWTM when the products were inoculated with acid-adapted culture (Figure 1).

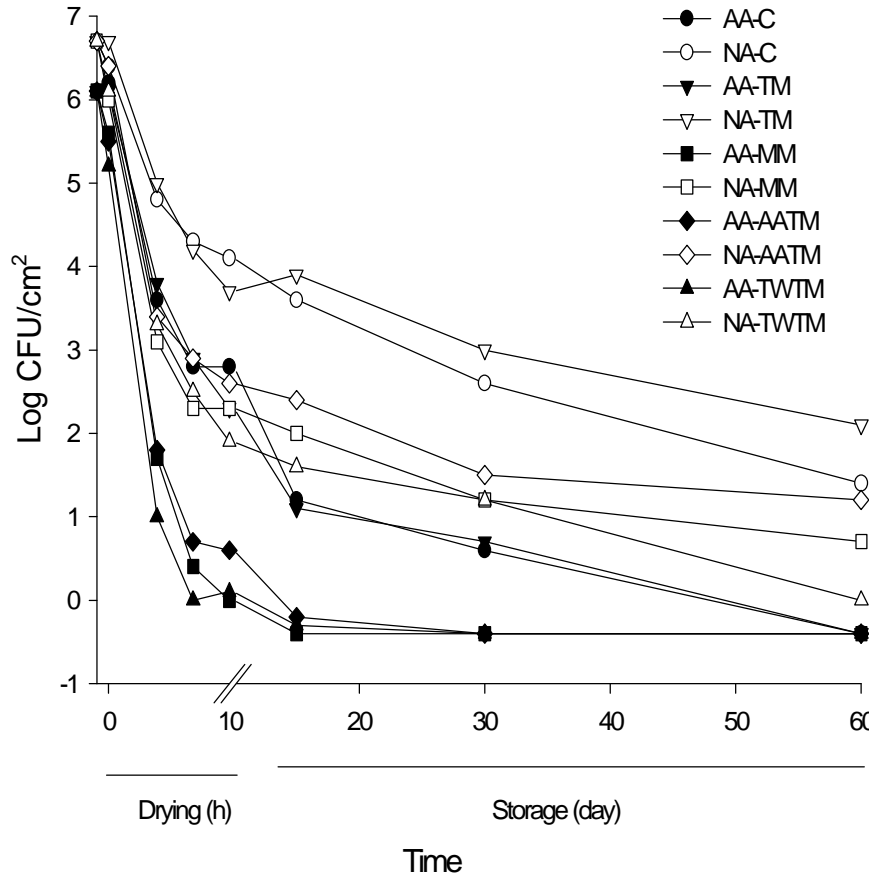
IMPLICATIONS

These results indicated that previous acid-adaptation may not cause increased resistance of *Salmonella* to the microbial hurdles involved in jerky processing. In addition, use of modified marinades in jerky may improve the effectiveness of drying in inactivating *Salmonella*.

LITERATURE CITED

- Andress, E.L., and J.A. Harrison. 1999. So easy to preserve. 4th Edition. Cooperative Extension Service. University of Georgia. Athens, GA.
- Centers for Disease Control and Prevention (CDC). 1995. Outbreak of Salmonellosis associated with beef jerky – New Mexico. 1995. Morbid. Mortal. Weekly Rep. 44: 785-788.
- Eidson, M., C.M. Sewell, G. Graves, and R. Olson. 2000. Beef jerky gastroenteritis outbreaks. J. Environ. Health 62 (6): 9-13.
- Harrison, J.A., and M.A. Harrison. 1996. Fate of *Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Salmonella typhimurium* during preparation and storage of beef jerky. J. Food Prot. 59:1336-1338.
- Harrison, J.A., M.A. Harrison, R. A. Rose, and R.A. Shewfelt. 2001. Home-style beef jerky: Effect of four preparation methods on consumer acceptability and pathogen inactivation. J. Food Prot. 64: 1194-1198.
- Holley, R.A. 1985. Beef jerky: Viability of food-poisoning microorganisms on jerky during its manufacture and storage. J. Food Prot. 48:100-106.
- Levine, P., B. Rose, S. Green, G. Ransom, and W. Hill. 2001. Pathogen testing of ready-to-eat meat and poultry products collected at federally inspected establishments in the United States, 1990 to 1999. J. Food Prot. 64: 1188-1193.

A. *Salmonella* during processing of beef jerky (TSAP)



B. *Salmonella* during processing of beef jerky (XLT-4)

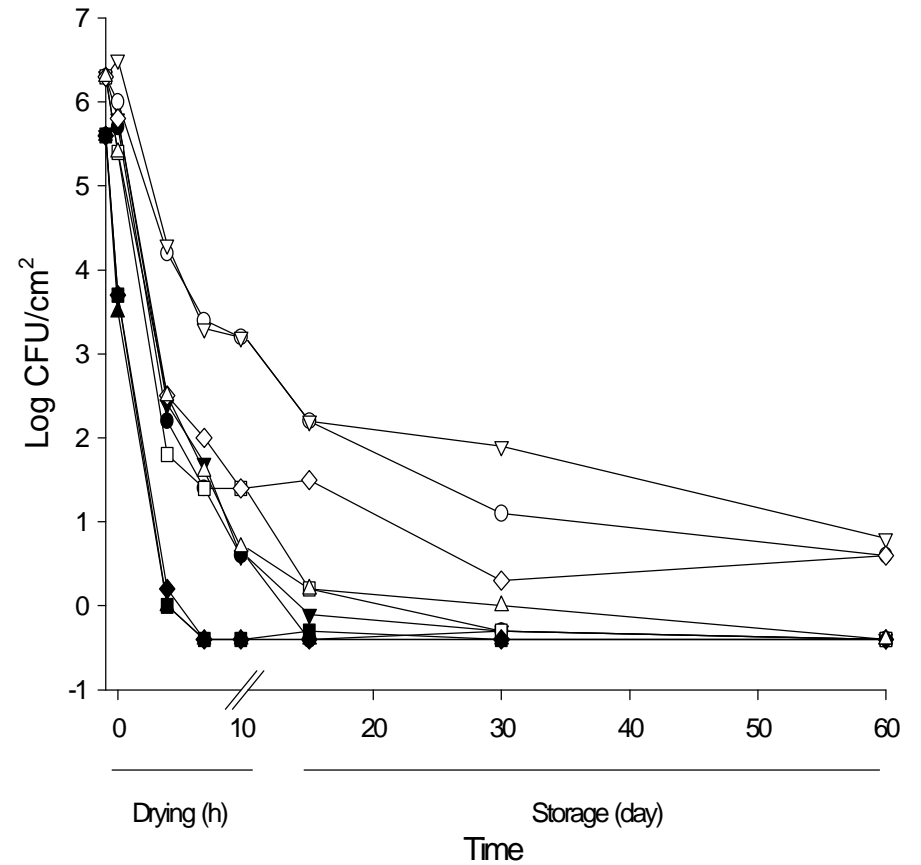


Figure 1. Survival of acid-adapted (AA) and nonadapted (NA) *Salmonella* during drying (60°C, 10 h) and storage (25°C, 60 d) of beef jerky treated with control (C); traditional marinade (TM); modified TM [double amount, 1.2% sodium lactate, 5% EtOH, and 9% acetic acid (MM)]; acetic acid dip (5%) then TM (AATM); and Tween 20 dip (1%), then acetic acid dip (5%) followed by TM (TWTM). A, tryptic soy agar with 0.1% pyruvate (TSAP), B, XLT-4 agar.

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