Research Note

**Fate of Escherichia coli O157:H7, Listeria monocytogenes, and Salmonella typhimurium during Preparation and Storage of Beef Jerky**

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(MS# 96-12: Received 22 January 1996/Accepted 15 April 1996)

**ABSTRACT**

The fate of *Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Salmonella typhimurium* during preparation and storage of beef jerky was determined. Control strips and one-half of the inoculated beef loin strips were marinated at 4°C overnight and dried at 60°C (140°F) for 10 h. The remaining half of the inoculated samples were heated in marinade to 71.1°C (160°F). Strips were dried at 60°C (140°F) for 10 h. Microbial populations were determined at intervals during drying up to 10 h and also from samples stored at 25°C for 8 weeks at various moisture levels. In general, *L. monocytogenes* was more resistant to the treatments. After 3 h of drying, populations on the unheated, inoculated samples were reduced by 3.3, 1.8 and 3.1 log units, respectively, and all three were reduced by 5.5 to 6.0 log units after 10 h. Reduction of the three populations on strips that were cooked prior to drying was 4.5 to 5.5 log units immediately after cooking. The populations decreased to undetectable levels after 10 h of drying. None of the three pathogens were detected on the controls. After 8 weeks of storage none of the pathogens were detected, indicating that they were unable to recover under the moisture conditions during storage.

Key words: *E. coli* O157:H7, *S. typhimurium*, *L. monocytogenes*, beef jerky, pathogens, processed beef

A significant amount of beef jerky is consumed annually in the U.S. Its easy preparation, light weight, rich nutrient content, and stability without refrigeration make it a popular item for sports enthusiasts. To date, there have been only a few reported outbreaks of foodborne illness linked to jerky (1). However, a recent outbreak of salmonellosis from beef jerky (1), coupled with the fact that a variety of drying procedures abound, raises concern over safety. Holley (3, 4) examined the effectiveness of drying procedures in eliminating the risk of foodborne illness from *Salmonella* spp., *Staphylococcus aureus*, *Bacillus subtilis*, and *Clostridium perfringens*. Smith et al. (9) examined the effect of various drying methods on *Salmonella* and *Staphylococcus* species. The heat treatments used in these studies are less stringent than those currently recommended as adequate to eliminate pathogens in meat. Due to the outbreaks of foodborne illness in recent years linked to other pathogens such as *Escherichia coli* O157:H7 and *Listeria monocytogenes*, the United States Department of Agriculture (USDA) Meat and Poultry Hotline (10) has suggested cooking meat to 71.1°C (160°F) before drying. One suggested method is to marinate meat under refrigeration, cook in a 163°C (325°F) oven to 71.1°C (160°F) and cut into strips before drying. A second method is to simmer the meat in marinade until the temperature reaches 71.1°C (160°F). It is recommended that each of these methods be followed by drying at a temperature of 79.5°C (175°F) or above for several hours in an oven with the door ajar (10). Because jerky is simple to prepare, many consumers make jerky in home dehydrators. Some of these dehydrators have a factory-set temperature which cannot be altered. One manufacturer of such a dehydrator states that in a 75°F room, the dehydrator is set to maintain a range between 54.4°C (130°F) and 62.8°C (145°F). Such discrepancies indicate the need for investigation of the fate of *E. coli* O157:H7, *L. monocytogenes* Scott A, and *S. typhimurium* under various conditions. This study was undertaken to determine the effectiveness of a widely used method of jerky preparation (5) in eliminating the risk of foodborne illness from these pathogens.

**MATERIALS AND METHODS**

*E. coli* O157:H7, *L. monocytogenes* Scott A, and *S. typhimurium* were maintained on tryptic soy agar (TSA) (Difco Laboratories, Detroit, MI) slants at 4°C. Inocula were prepared by inoculating three separate tubes containing 9 ml of tryptic soy broth (TSB) (Difco) with a loopful of each strain of stock culture. These were incubated at 32°C for 18 h. Each culture was washed twice by centrifuging for 10 min at 3,000 rpm, decanting the spent TSB, resuspending the pellet in 10 ml of Butterfield's phosphate buffer

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solution (8) (0.1M, pH 7.0) and recentrifuging. After decanting the final wash of Butterfield’s buffer, cultures were suspended in separate sterile tubes containing 10 ml of Butterfield’s phosphate buffer. The cell suspension was then serially diluted using 9 ml of Butterfield’s phosphate buffer blanks to an approximate concentration of 10^6 CFU/ml.

Beef loin cut was obtained from a local grocery store and frozen at -10°C. Prior to inoculation, the beef was placed in a 4°C incubator for approximately 12 h to slightly thaw. The edges of the beef were trimmed of visible fat and then sliced under a laminar flow hood to approximately 15 x 1.5 x 1.5 cm pieces. Two-thirds of the strips were inoculated with 0.1 ml of each inoculum on one-third of each strip. Samples were then incubated at 4°C overnight to allow for microbial adhesion to the beef. One-third of the beef strips were left un inoculated to serve as controls. One of the inoculated jerky strips was then sampled to determine initial microbial load. Sampling was done by placing the jerky strip in a sterile stomacher bag with 100 ml of Butterfield’s phosphate buffer. It was then pummeled in a stomacher (TekMar model 400, Cincinnati, OH) for 30 s on regular speed. Serial dilutions of the rinse were prepared in Butterfield’s phosphate buffer. Portions were spread-plated on bismuth sulfite agar (Difco), MacConkey’s sorbitol agar (Difco) and modified Oxford formulation Listeria selective agar (Unipath) for enumeration of S. typhimurium, E. coli O157:H7, and L. monocytogenes, respectively. Samples were divided into three separate groups. The uninoculated samples and one-half of the inoculated samples were processed in a traditional way for beef jerky (5). This was done by placing the two sample groups (inoculated and control) in two separate shallow pans and covering them with a jerky marinade.

The marinade contained approximately 60 ml of soy sauce, approximately 15 ml of Worcestershire sauce, 0.6 g of pepper, 1.25 g of garlic powder, 1.5 g of onion powder, and 4.35 g of hickory smoke-flavored salt for approximately 900 g of meat. They were then incubated for approximately 1 h at 4°C.

The remaining half of the inoculated samples were placed in a shallow pan, covered with jerky marinade, and heated on a hot plate to 71.1°C (160°F). The pan was removed and allowed to cool 15 min under a laminar flow hood to prevent contamination.

Samples of the heated strips were analyzed for S. typhimurium, E. coli O157:H7, L. monocytogenes, and total psychrotrophic populations as described above. The strips were then dried at 60°C (140°F) in a food dehydrator (Model #7010, B&J Industries, Marysville, WA). Samples were taken during the drying at 1, 2, 3, 6, and 10 h. They were analyzed as described above.

Samples were then divided into four groups for each treatment. Three groups were stored in sterile desiccators with NaCl solutions below the support racks where the jerky was placed. NaCl solutions (26.4, 19.0, and 9.3%) were used to yield aw of 0.75, 0.84, and 0.94, respectively (6). The remaining samples were stored in Ziplock Freezer Bags (Dow Brands Inc., Indianapolis, IN). All samples were incubated at 25°C. After 8 weeks of storage, samples were analyzed for microbial growth as described above.

Three replications of the experiment were done. Data were analyzed by Statistical Analysis Systems (7) using general linear modeling and Duncan’s grouping.

RESULTS

The internal temperature of the unheated meat strips increased from refrigeration temperature to 60°C during the first 4 to 5 h of drying. The moisture content of the controls and the portions which were inoculated but not heated prior to drying decreased from 69.9% to 23.8%. For the portions which were heated prior to drying, the percent moisture decreased from 59.0% to 18.5%.

After 3 h of drying, E. coli O157:H7 and S. typhimurium populations on unheated, inoculated meat decreased by 3.3 and 3.1 log units, respectively (Fig. 1). After 10 h, populations of E. coli O157:H7 and S. typhimurium on the

![FIGURE 1. Survival of selected bacterial pathogens on beef jerky during drying at 60°C (140°F). A, B, and C represent jerky unheated prior to drying, inoculated with Escherichia coli O157:H7, Salmonella typhimurium and Listeria monocytogenes Scott A, respectively. D, E, and F represent jerky heated prior to drying, inoculated with Escherichia coli O157:H7, Salmonella typhimurium and Listeria monocytogenes Scott A, respectively.](image-url)
unheated, inoculated product decreased by 5.5 to 6.0 and 5.5 log units, respectively. Populations on heated, inoculated meat decreased by 5.0 and 5.6 log units, respectively, for E. coli O157:H7 and S. typhimurium during cooking prior to drying. The reduction in the population of either pathogen was the same (P = 0.05) for both the heated and unheated portions by the 6th h of drying and thereafter. Populations of both organisms decreased to undetectable levels after 10 h of drying.

L. monocytogenes Scott A populations on unheated, inoculated meat decreased by only 1.8 log units during the first 3 h of drying (Fig. 1). After 10 h, however, the Listeria population had decreased by almost 6.0 log units. On heated, inoculated meat, levels decreased by 4.5 log units during cooking prior to drying. The population of this microorganism decreased to undetectable levels after 10 h (Fig. 1), and the reductions in L. monocytogenes populations on the heated and unheated jerky were similar (P = 0.05).

No detectable levels of E. coli O157:H7, L. monocytogenes Scott A, and S. typhimurium were found on the control strips. Storage at varying aw yielded no survivors. After 8 weeks of storage, none of the pathogens were detected (data not shown) by direct plating or by enrichment.

DISCUSSION

As expected, an immediate reduction of detectable colony-forming units of all three pathogens was noted in samples heated in marinade to 71.1°C (160°F) prior to drying. The drastic reduction in colony-forming units after 10 h of drying, even in the unheated, inoculated samples suggests that drying alone would eliminate problems with these pathogens at normal levels of contamination on whole meat strips. Maintaining dry conditions during storage of jerky further eliminates potential problems from survivors of the drying process.

It should be noted that the preparation of this product traditionally relies primarily on the drying step to produce a product which is safe to eat. An additional preservative effect may be contributed by the presence of sodium chloride from the marination step. Holley (4) noted that levels of various pathogens decreased with heated drying at 52.9°C (127.2°F) for 4 h followed by 48.2°C (118.8°F) for 4 h, and were undetectable after 26 to 28 days of storage at 20°C and high relative humidity. The author concluded that jerky made from retail-quality beef posed little risk when dried rapidly at temperatures equal to or greater than those used in the study. Other studies involving fermented dry sausages have noted that the population of some foodborne bacterial pathogens on raw product can be reduced. Glass et al. (2) reported a 2-log unit reduction of E. coli O157:H7 populations in such products. Whiting and Masana (11) noted L. monocytogenes populations decreased by 4 log units during storage. In both cases, however, some of the reduction in viable cells was credited to the reduced pH of the product after the fermentation and drying procedures.

On the basis of the results obtained in this study, it appears that a traditional jerky preparation including drying at 60°C (140°F) is a sufficient process to reduce levels of E. coli O157:H7, L. monocytogenes Scott A, and S. typhimurium by at least 5 log units on whole beef strips.

REFERENCES