Effect of different marinade treatments on survival of pathogens in ground beef jerky

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Abstract

In the early fall of 2003, the Food Safety and Inspection Service found that producers of meat and poultry jerky were not adequately processing to achieve the lethality required to kill or reduce the number of microorganisms. In this project, ground beef jerky was prepared with four different treatments i.e. traditional marinade (TM), modified marinade (MM), acetic acid-traditional marinade (AATM), Tween 20-traditional marinade (TWTM) along with a control. The jerky strips were individually inoculated with four different bacterial strains i.e. *E. coli* O157:H7, *Salmonella typhimurium*, *Listeria monocytogenes* and *Staphylococcus aureus* and 30 minutes were allowed for bacterial attachment. The strips were then individually vacuum packaged and stored at ambient temperature for analysis at 7 days interval up to 28 days. The parameters studied were pH, water activity and enumeration of microbial count. The pH ranged from 5.2 for control to 4.45 for MM. The water activity ranged from 0.886 for control to 0.531 for MM. For microbial count a decline from 10^8 to 10^5 CFU was observed within 14 days and after that a further decline to 10^3 CFU for MM and a decline of 10^4 CFU for AATM and TWTM within 21 days. Therefore, the results confirmed efficacy of all the treatments in controlling post-processing contamination of ground beef jerky which was evident by low microbial count in treated jerky samples compared to control. However, modified marinade (MM) was the most effective of all the four treatments used as seen by the lowest pH and lowest water activity values.

Introduction

Beef jerky is a product that is easy to prepare, lightweight, has a rich nutrient content, and is shelf stable without refrigeration. However, in the early fall of 2003, the U.S. Food Safety and Inspection Service (FSIS) found that some producers of meat and poultry jerky were not adequately processing jerky to achieve the lethality required to kill or reduce the numbers of microorganisms. The association of jerky products with foodborne disease outbreaks (CDC, 1995; Keene *et al*., 1997; Eidson *et al*., 2000) has raised questions about the microbial safety of such products. A recent report (Levine et al., 2001) indicated that from 1990 to 1999, cumulative prevalence of *Salmonella* and *Listeria monocytogenes* in jerky produced in federally inspected plants was 0.31 and 0.52 %, respectively. This suggests that the safety of beef jerky for human consumption may be impaired.

It is evident in the outbreak reports that some of the pathogen contamination occurred post-processing through cross-contamination of dried product with raw product via knives, work surfaces or through worker handling. As a result, control of post-processing contaminating pathogens is particularly important in foods that are consumed without further cooking. However, the survival of pathogens, including *Salmonella*, on jerky products inoculated after drying has not been well studied and the use of chemical intervention strategies has not been studied adequately (Albright, 2000). Such interventions can be a viable option to avoid severe heat treatments and may provide residual antimicrobial effects during product storage.

Previous studies have also determined that jerky made from ground beef may pose a greater risk of fooborne illness than that from whole meat strips (Harrison and Harrison, 1996; Harrison *et al*., 1997). The reason for this is that whole muscle jerky involves mostly the interior of large muscles such as the top round, which should be free of bacteria (any bacteria present would only be on the surface). Therefore, it is suitable to use ground and formed jerky as a model as it is commercially produced by small and large processing companies and provides a representative model with better laboratory control than whole muscle jerky. In this project, we prepared ground beef jerky as it dries faster and that no marinade is wasted; it's all absorbed during the marinating process. So, the main aim of this project was to study the efficacy of four treatments in controlling the post-processing contamination by key pathogens in ground beef jerky.

Materials and methods

Four different marinade treatments were prepared with the indicated ingredients added to each kg of beef: Traditional marinade (TM) 60 mL soy sauce, 15 mL worcestershire sauce, 0.6 gm black pepper, 1.25 gm garlic powder, 1.5 gm onion powder and 4.35 gm salt; Modified marinade (MM) 120 mL soy sauce, 30 mL worcestershire sauce, 0.6 gm black pepper, 1.25 gm garlic powder, 1.5 gm onion powder, 4.35 gm salt, 3.6 mL sodium-L-lactate, 16 mL glacial acetic acid; Acetic acid-traditional marinade (AATM): 50 mL acetic acid + traditional marinade; Tween 20-traditional marinade (TWTM): 10 mL Tween 20 + 50 mL acetic acid + traditional marinade.

Inocula for the four bacterial strains were prepared by inoculating four separate tubes containing 9 mL of tryptic soy broth (TSB) with a loopful of each strain of stock culture. These were incubated at 37^0 C for 18 hours. Each culture was then used to inoculate four separate flasks containing 50 mL of tryptic soy broth (TSB); the flasks were again incubated at 37^0 C for 8 hours. Each culture was washed twice by centrifuging at 10 minutes at 8000 rpm, decanting the spent TSB and resuspending the pellet in 40 mL of 0.1% peptone. The cell suspension was then adjusted to an approximate concentration of 10^8 CFU/mL.

Beef sirloin was ground in a bowl chopper and mixed with the different treatments. A jerky gun resembling a caulking gun with an extruder nozzle was used to give shape to jerky strips. Jerky strips were then dried in a convection oven for about 1 hour and 40 minutes at a set temperature of 140^0 C. The jerky strips were then individually inoculated with four different bacterial strains i.e. *E. coli* 0157:H7, *Salmonella typhimurium*, *Listeria monocytogenes* and *Staphylococcus aureus* and 30 minutes were allowed for bacterial attachment. Approximately 8 log CFU of challenge dose was applied for all the four bacterial strains. The slices were then individually vacuum packaged and stored at ambient temperature.

All pH measurements were done according to the AOAC method for which 5 gm of jerky was mixed with 45 mL of distilled water and blended, the slurry was filtered and the clear solution was used to measure pH with a calibrated pH meter. Water activity was measured by placing a piece of jerky in a sample cup and then observing the reading on an Aqualab^{TM} water activity meter.

Each vacuum bag was opened on a particular day (day 1, day 7, day 14, day 21 and day 28) for enumerating the microbial count. The selective media used for the four different pathogens were: MacConkey Sorbitol Agar for *E coli* 0157:H7; XLD Agar for *Salmonella typhimurium*; Modified Oxford Agar for *Listeria monocytogenes*; and Baird Parker Agar for *Staphylococus aureus*. About 1 gm of jerky piece was mixed with 99 mL of peptone water and stomached at 250 rpm for 2 minutes in the stomacher; further serial dilutions were made to 10^{-7} and 1 mL plated onto the already prepared petri plates of respective media. The plates were incubated at 37^0 C for 24 hours and colonies were enumerated visually the next day.

SAS (version 9.1, SAS Institute, Cary, NC) was used to perform the statistical analysis. Fisher's least square means were used to determine significant differences ($P<0.05$) among treatments.

Results and discussion

Both pH and water activity were low for all the treated samples as compared to the control for all the four bacterial strains used. The pH ranged from 5.2 to 5.53 for control, 5.31 to 5.81 for TM, 4.45 to 4.71 for MM, 4.78 to 5.23 for AATM and 4.93 to 5.35 for TWTM. The water activity ranged from 0.886 to 0.926 for control, 0.802 to 0.886 for TM, 0.531 to 0.701 for MM, 0.635 to 0.821 for AATM and 0.77 to 0.868 for TWTM. The pH and water activity were lower for all the treatments in comparison to control. A decline in microbial count from 10^8 to 10^5 CFU was observed within 14 days for all microorganisms and after that there was a further decline to 10^3 CFU for modified marinade (MM) and 10^4 CFU for acetic acid-traditional marinade (AATM) within 21 days for *E. coli* culture. In case of *Staphylococcus*, a decline from 10^8 to 10^5 CFU was observed within 28 days for MM, AATM and TWTM and after that a further decline to 10^4 CFU. Therefore, the decline in microbial numbers confirmed the efficacy of all the four treatments in controlling the post-processing contamination, which was manifested as a result of low pH and water activity which exerted a metabolic stress on bacterial cells leading to their death. The modified marinade (MM) was selected as the most effective of all the four treatments used as seen by the lowest pH and lowest water activity values.

FSIS identified points in commercial jerky processing where producers need to modify current practices. First, use of moist cooking is an option, which means a relative humidity above 90% should be maintained throughout the cooking or thermal heating process by using a sealed oven or steam injection (FSIS, 2004). Secondly, FSIS suggested cooking of meat to 71.1^0 C before drying (FSIS, 2004) but preheating meat and /or drying jerky at high temperatures for extended periods may result in a product that differs from traditional jerky. Populations of *Salmonella* present on jerky after drying may be reduced from approximately 5.7 log CFU/cm^2 to below detection limit (-0.4 log CFU/cm^2) in 14 to 60 days of storage if

jerky products are marinated with a combination of glacial acetic acid and sodium-L-lactate along with traditional marinade, or subjected to a three-step process involving sequential dipping into 1% Tween 20 solution and 5% acetic acid followed by marination with a traditional marinade (Calicioglu *et al*., 2003). The effectiveness of an acid dip as a predrying treatment can also be explained by the results of a recent report (Shadbolt *et al*., 2001) that demonstrated that an initial low pH shock (in tryptic soy broth, pH-3.5 with HCl for 24 hours) followed by exposure to low water activity (0.90) was significantly more effective in reducing numbers of bacteria compared with an initial exposure to low water activity followed by exposure to low pH. It is also speculated that Tween 20 may loosen or prevent cellular attachment on the meat surface through its surfactant and hydrophobic effects, thus making cells more vulnerable to the effect of subsequent acid exposure (Calicioglu *et al*., 2002).

Conclusions

Every marinade used in this study was effective in reducing pathogen survival on inoculated beef jerky when compared to the control. In order to reduce the survival of pathogens that are introduced to the surface of beef jerky post-processing, the modified marinade was the most effective of all the four treatments used. A combination of marinade reformulation, effective thermal processing, and avoidance of cross-contamination is considered ideal for ensuring the safety of beef jerky for consumers.

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