Antimicrobial Effect of Nisin against *Bacillus cereus* in Beef Jerky during Storage

Na-Kyoung Lee¹, Hyoun Wook Kim², Joo Yeon Lee³, Dong Uk Ahn⁴, Cheon-Jei Kim¹, and Hyun-Dong Paik¹,⁵*  
¹Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 143-701, Korea  
²National Institute of Animal Science, RDA, Suwon 441-706, Korea  
³Korea Livestock Products HACCP Accreditation Service, Anyang 430-731, Korea  
⁴Animal Science Department, Iowa State University, Ames, IA 50011, USA  
⁵Bio/Molecular Informatics Center, Konkuk University, Seoul 143-701, Korea

**Abstract**

The microbial distribution of raw materials and beef jerky, and the effect of nisin on the growth of *Bacillus cereus* inoculated in beef jerky during storage, were studied. Five strains of pathogenic *B. cereus* were detected in beef jerky, and identified with 99.8% agreement using API CHB 50 kit. To evaluate the effect of nisin, beef jerky was inoculated with approximately 3 Log CFU/g of *B. cereus* mixed culture and nisin (100 IU/g and 500 IU/g). During the storage of beef jerky without nisin, the number of mesophilic bacteria and *B. cereus* increased unlikely for beef jerky with nisin. *B. cereus* started to grow after 3 d in 100 IU nisin/g treatment, and after 21 d in 500 IU nisin/g treatment. The results suggest that nisin could be an effective approach to extend the shelf-life, and improve the microbial safety of beef jerky, during storage.

**Key words:** beef jerky, pathogenic bacteria, *Bacillus cereus*, nisin, microbial safety

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**Introduction**

From 2000 to 2008, the social cost of food-borne illness in the USA amounted to $9.4 million annually. *Bacillus cereus*, *Clostridium perfringens*, or *Staphylococcus aureus* was charged $1.3 million (Scallan et al., 2011). In these pathogens, *B. cereus* is a common food contaminant, and is an etiological agent of two distinct forms of illness, i.e., emetic and diarrheal. *B. cereus* is found in meats, milk, vegetables, and some *B. cereus* are able to grow at 5 or 7°C, acid condition, and heating by sporulation (Dufrenne et al., 1994; Simpson et al., 1994; van Netten et al., 1990). *B. cereus* is not dangerous in low level (< 10⁶ CFU/g), however *B. cereus* can multiply to dangerous levels in subsequent time and temperature. The counts of *B. cereus* were reported to be 2.9-4.59 Log CFU/g in meat products and *B. cereus* grow well after cooking (Tewari et al., 2015). Therefore, *B. cereus* in food must be controlled by heat treatment, radiation, and antimicrobials.

Jerky is processed almost everywhere in the world. It is microbiologically safe, easy to prepare, light-weight, has a rich nutrient content, and can be stored without refrigeration (Kim et al., 2008b). However, some stressed pathogens included spore-forming bacteria may exhibit lower infectious doses, foodborne disease outbreaks related to jerky products have actually increased (Edison et al., 2000; Keene et al., 1997). Jerky has been studied for food additives, heating, and irradiation against *Staphylococcus aureus*, *Listeria monocytogenes*, *Bacillus cereus*, *Salmonella Typhimurium*, Escherichia coli, etc. for microbial safety, without addressing the quality of jerky during storage (Kim et al., 2010).

Nisin is the most commercial bacteriocin produced by *Lactococcus lactis* subsp. *lactis*, which exhibits antimicrobial activity against a wide range of Gram-positive vegetative cells and spores. Nisin have been used for just processed cheese in Korea (Ministry of Food and Drug Safety). Bacteriocin has already been used in more than 50 countries in the food industry as an antagonistic additive (Ray, 1992). In addition, nisin has been permitted in processed meat include limits of 12.5 mg/kg in USA (Food
and Drug Association), and has mainly been applied to dairy and meat products as a target of Gram positive pathogen (mainly *Listeria monocytogenes*) (Balciunas et al., 2013). Meanwhile, *B. cereus* has been investigated in beef gravy, fruit beverage, and cooked chilled foods (Assous et al., 2012; Beuchat et al., 1997; Choma et al., 2000).

There are limited data in the literature describing microbial distribution, particularly pathogens in jerky. However, the hurdle of *L. monocytogenes*, *Salmonella Typhimurium*, and *Salmonella enterica* was studied in jerky for its safety (Boles et al., 2007; Calcicoglu et al., 2003; Yoon et al., 2009). Therefore, the purposes of this study were to determine microbial contamination status of the raw materials used for beef jerky, and beef jerky itself, and the antimicrobial effect of nisin on the growth of *B. cereus* inoculated in beef jerky during storage.

**Materials and Methods**

**Preparation of beef jerky**

Beef was purchased from a local market for the manufacture of beef jerky. The meat was tempered at 4°C for 24 h and sliced 6 mm thick. The composition of jerky spices was water (10%), soy sauce (9%), starch syrup (5%), sugar (2%), D-sorbitol (6%), pepper (0.5%), ginger powder (0.1%), garlic powder (0.2%), onion powder (0.2%), sodium nitrate (0.007%), sodium citrate (0.01%), and soup stock powder (0.1%), garlic powder (0.2%), onion powder (5%), sugar (2%), D-sorbitol (6%), pepper (0.5%), ginger powder (0.1%), garlic powder (0.2%), onion powder (0.2%), sodium nitrate (0.007%), sodium citrate (0.01%), potassium sorbate (0.1%), sodium erythorbate (0.036%), and soup stock powder (0.1%). Treated raw meats using jerky spices was water (10%), soy sauce (9%), starch syrup (5%), sugar (2%), D-sorbitol (6%), pepper (0.5%), ginger powder (0.1%), garlic powder (0.2%), onion powder (0.2%), sodium nitrate (0.007%), sodium citrate (0.01%), potassium sorbate (0.1%), sodium erythorbate (0.036%), and soup stock powder (0.1%). Treated raw meats using jerky spices were phase-dried in a dehydrator at 50°C for 24 h and sliced 6 mm thick. The composition of jerky spices was water (10%), soy sauce (9%), starch syrup (5%), sugar (2%), D-sorbitol (6%), pepper (0.5%), ginger powder (0.1%), garlic powder (0.2%), onion powder (0.2%), sodium nitrate (0.007%), sodium citrate (0.01%), potassium sorbate (0.1%), sodium erythorbate (0.036%), and soup stock powder (0.1%). Treated raw meats using jerky spices was water (10%), soy sauce (9%), starch syrup (5%), sugar (2%), D-sorbitol (6%), pepper (0.5%), ginger powder (0.1%), garlic powder (0.2%), onion powder (0.2%), sodium nitrate (0.007%), sodium citrate (0.01%), potassium sorbate (0.1%), sodium erythorbate (0.036%), and soup stock powder (0.1%). Treated raw meats using jerky spices was water (10%), soy sauce (9%), starch syrup (5%), sugar (2%), D-sorbitol (6%), pepper (0.5%), ginger powder (0.1%), garlic powder (0.2%), onion powder (0.2%), sodium nitrate (0.007%), sodium citrate (0.01%), potassium sorbate (0.1%), sodium erythorbate (0.036%), and soup stock powder (0.1%). Treated raw meats using jerky spices was water (10%), soy sauce (9%), starch syrup (5%), sugar (2%), D-sorbitol (6%), pepper (0.5%), ginger powder (0.1%), garlic powder (0.2%), onion powder (0.2%), sodium nitrate (0.007%), sodium citrate (0.01%), potassium sorbate (0.1%), sodium erythorbate (0.036%), and soup stock powder (0.1%).

**Microbiological analysis**

Each sample (25 g) was taken aseptically using a sterile stomacher bag containing 225 mL of 0.1% sterile peptone water, and macerated for 2 min. Decimal serial dilution in 0.1% peptone water was prepared. The number of mesophilic bacteria counts were determined using plate count agar (PCA, Difco Laboratories, USA), at 37°C for 48 h. *B. cereus* numbers were determined using cereus selective agar (Merck, Germany), at 30°C for 24 h. Microbial colonies were counted, and expressed as log colony forming units per gram (Log CFU/g). Pathogenic microorganisms of each sample were isolated, and identified as described in Table 1.

**Preparation of *B. cereus* strains and addition to beef jerky**

*B. cereus* strains isolated in raw meat, spices, and spiced meat were used for hurdle technology. *B. cereus* was grown on PCA (Difco) overnight at 30°C, and then left at ambient temperature for one week, to sporulate. When spores were detected microscopically, spore suspensions were created in sterile 0.1% peptone water, and heat treated (80°C for 10 min) to kill vegetative cells. Spores were enumerated by viable counts, and the suspensions were adjusted to 10⁶ spore/mL. Mixed inocula were prepared, by combining spore suspensions in equal concentrations. Spores were inoculated to the beef jerky, to give a predicted level of 10³ CFU/g.

**Preparation of nisin and addition to beef jerky**

Nisin (Sigma-Aldrich, USA) was used as a form of stock solution. A standard stock solution of nisin containing 1× 10⁵ IU/mL was prepared, by dissolving 100 mg of nisin in 0.02 M HCl (1 mL), and adding 9 mL of distilled water.

### Table 1. Conditions for the isolation, growth, and identification of pathogenic bacteria in raw meats

<table>
<thead>
<tr>
<th>Pathogenic bacteria</th>
<th>Isolation culture condition</th>
<th>Growth culture condition</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em> O157:H7</td>
<td>Sorbitol MacConkey agar, 35°C, 24 h</td>
<td>Modified EC medium, 35°C, 24 h</td>
<td>Gram stain, API 32E, serotypes</td>
</tr>
<tr>
<td><em>Bacillus cereus</em></td>
<td>Cereus selective agar, 30°C, 24 h</td>
<td>Tryptic soy agar, 30°C, 24 h</td>
<td>Gram stain, API CHB 50</td>
</tr>
<tr>
<td><em>Clostridium perfringens</em></td>
<td>Clostridium perfringens agar, 35°C, 24 h</td>
<td>Cook Meat medium, 35°C, 24 h</td>
<td>Gram stain, API 20A</td>
</tr>
<tr>
<td><em>Salmonella spp.</em></td>
<td>Hektoen enteric agar, 35°C, 24 h</td>
<td>Selentie F broth, 35°C, 24 h</td>
<td>Gram stain, Triple sugar iron agar (TSI), MIL, API 32E</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>Oxford agar, 30°C, 48 h</td>
<td>Listeria enrichment broth, 30°C, 24 h</td>
<td>CAMP test, hemolysis, API Listeria, serotypes</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>Mannitol salt agar with egg yolk, 35°C, 48 h</td>
<td>Tryptic soy broth with 10% sodium chloride, 35°C, 24 h</td>
<td>Gram stain, catalase, coagulase, API staph</td>
</tr>
<tr>
<td><em>Yersinia enterocolitica</em></td>
<td>Yersinia selective agar with cefsulodin, irgasan, novobiocin, 35°C, 24 h</td>
<td>Peptone sorbitol bile broth, 10°C, 10 days</td>
<td>Gram stain, urea, citrate, motility test, API 32E</td>
</tr>
</tbody>
</table>
Nisin was added at concentrations of 100 IU/g and 500 IU/g, respectively to the beef jerky.

**Package and storage of beef jerky**

A coextruded, multilayered film (C5045, nylon/PE/nylon/PE/nylon/LLDPE, Cryovac Division, Sealed Air Corporation, USA) was used for packaging and the pouches were heat-sealed under vacuum. Beef jerky samples were then stored at room temperature (25°C) for 60 d, and samples were taken at regular intervals throughout the storage period for quality measurements.

**Results and Discussion**

The pathogens most frequently associated with raw meats are *E. coli* O157:H7, *B. cereus*, *Salmonella* spp., *L. monocytogenes*, and *S. aureus* (Edison et al., 2000; Kim et al., 2008b). For the determination of microbial contamination, the incidences of pathogenic bacteria in raw meat, spices, spiced meats, and jerky products are summarized in Table 2. Five strains of *B. cereus* were isolated from raw meat, spices, and spiced meat, while no pathogens were detected in the final products. In addition, no other pathogens were detected. These results may be a drying process using dehydrator.

Five isolated strains using cereus selective agar were Gram positive, rod shaped, spore forming bacteria, and catalase-positive. These strains did not grow on Simon’s citrate, produced NO$_2$, and need to take arginine for growth. Therefore, these isolates were identified as *B. cereus* by ATB automated identification system, with 99.8% identity.

The antimicrobial effect of nisin against mesophilic bacteria in raw meat, spices, and spiced meat, while no pathogens were detected in the final products. In addition, no other pathogens were detected. These results may be a drying process using dehydrator.

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**Table 2. Isolation of pathogenic bacteria presented in raw meat, spices, spiced meat, and jerky**

<table>
<thead>
<tr>
<th>Pathogenic bacteria</th>
<th>Raw meat</th>
<th>Spices</th>
<th>Spiced meat</th>
<th>Jerky</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em> O157:H7</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Bacillus cereus</em></td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Clostridium botulinum</em></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Clostridium perfringens</em></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Salmonella</em> spp.</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Shigella</em> spp.</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Yersinia enterocolitica</em></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

−, negative; +, positive.
the growth of \textit{B. cereus} inoculated in beef jerky during storage was demonstrated. The addition of nisin can decrease the initial cell count of mesophilic bacteria and \textit{B. cereus} in beef jerky. The results suggest that nisin could be an effective approach to extend the shelf life, and improve the microbial safety of beef jerky, during storage.

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**References**


