

Destruction of *Salmonella* and *Staphylococcus* During Processing of a Nonfermented Snack Sausage

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(Received for publication December 6, 1976)

ABSTRACT

Survival of *Salmonella dublin*, *Salmonella senftenberg* 775W, *Staphylococcus aureus* 196E, and *S. aureus* 184 was studied during processing of an inoculated beef, nonfermented snack sausage. No viable staphylococci or salmonellae were detected in sausages that had been heated at an internal temperature of 53.9-55.0 C or 57.8-58.9 C for 3.5 h followed by drying at 21 C and 50-55% relative humidity for 4 days. Heating at an internal temperature of 51.1-52.2 C for 3.5 h followed by drying did not produce a salmonellae- or staphylococci-free sausage.

In the 10-year period from 1965 to 1975, snack food sales in the United States increased from 2.6 to 6.4 billion dollars. Snack meat products commanded about 2% of the 1975 snack food market with a value of 143 million dollars (2). Among snack meats, snack sausages (both fermented and unfermented), beef jerky, and pork skins were the biggest sellers (2).

Information concerning formulation and preparation of meat snacks is not readily available. A procedure for production of a hot bar sausage (6) and a nontechnical description of the preparation of beef jerky (5) have been published. Meat chips, a potential meat snack, have been described by Fox and Ackerman (4).

We found no published data on the microbiology of snack sausages. Further, the fate of food-borne pathogens, such as *Salmonella* and *Staphylococcus*, during processing of snack sausages has not been considered. Therefore, survival of *Salmonella* and *Staphylococcus* species during processing of a nonfermented all-beef snack sausage was investigated.

MATERIALS AND METHODS

Preparation of snack sausages

Either fresh or frozen whole beef chuck was used. Frozen beef (previously ground through a 3/4-inch plate, packed in 5-10-kg amounts into Cry-O-Vac² bags and frozen at -27 C) was thawed

overnight at 10 C. The thawed or fresh beef was ground through a 3/16-inch plate and mixed with spices, sugars, salt, nitrate, and nitrite according to the formulation shown in Table 1. The mixture was

TABLE 1. *Ingredients for experimental sausage^a*

Ingredient	g/kg Beef
NaCl	20.0
NaNO ₃	1.9
NaNO ₂	0.123
Sucrose	5.0
Glucose	5.0
White pepper	4.0
Allspice	1.0

^aThe sausages used for data in Tables 2-5 had a pH range of 5.7 ± 0.1 at zero time (immediately after stuffing) and a pH range of 5.6 ± 0.2 at the end of the heating period.

stuffed into 13-mm diameter collagen casings (#130-712-0, Devro, Somerville, New Jersey). Sausages were placed in an air-conditioned smokehouse with the dry bulb and wet bulb set at temperatures needed to maintain the desired internal temperature of the product for 3.5 h. The time necessary to reach the desired internal temperature for sausages was 25 ± 5 min. The internal temperature was monitored by a thermocouple probe inserted into the center of the sausage. Heavy smoke was maintained during the heating step. After heating, the smoked product was placed in a drying room maintained at 21 C and 50-55% relative humidity (RH) for 4 days.

Experiments with salmonellae and staphylococci

Difco Tryptic Soy Broth (TSB) cultures of *Salmonella dublin*, *Salmonella senftenberg* 775 W (the most heat resistant strain of salmonella known), *Staphylococcus aureus* 196E, and *S. aureus* 184 were grown for 24 h at 37 C. The cultures were diluted with sterile 0.1% Difco Peptone water to give the appropriate concentration of cells. Suspensions of the pathogens were added to the meat during the formulation step. The viable count of the *Salmonella* strains were determined by the method of Smith et al. (7).

The following 3-tube MPN procedure was used to isolate, quantitate, and identify coagulase positive staphylococci: 50 g of sausage were weighed aseptically into sterile blender jars, and 200 ml of sterile 0.1% peptone water was added. The material was blended at high speed for 1 min. Appropriate dilutions of the blended material were placed into tubes of Difco Brain Heart broth (BHI). The tubes were incubated at 37 C for 48 h. Growth from each BHI tube was streaked onto Vogel-Johnson agar plates (950 ml of Difco Vogel-Johnson agar plus 50 ml Difco EY Tellurite Enrichment) and then incubated 48 h at 37 C. Representative typical black colonies were selected for catalase, gram stain, and coagulase tests. For the coagulase reaction, 0.2 ml of TSB, in 12 × 100 mm tubes, was inoculated and incubated at 37 C for 24 h.

¹Agricultural Research Service, U.S. Department of Agriculture.

²Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

TABLE 2. Effect of heating at an internal temperature of 57.8-58.9 C on the survival of salmonellae and staphylococci during processing of a snack sausage^a

Organism	Sample number	MPN ^b of cells/g sausage at zero time	MPN cells/g after heating	MPN cells/g after drying
<i>Salmonella dublin</i>	1	6.9×10^4	<0.03	<0.03
<i>Salmonella dublin</i>	2	6.4×10^3	<0.03	<0.03
<i>Salmonella senftenberg</i> 775W	3	6.9×10^4	<0.03	<0.03
<i>Salmonella senftenberg</i> 775W	4	3.6×10^3	<0.03	<0.03
<i>Staphylococcus aureus</i> 196E	5	9.3×10^2	<0.3	<0.3
<i>Staphylococcus aureus</i> 196E	6	2.4×10^6	0.3	<0.3
<i>Staphylococcus aureus</i> 184	7	2.1×10^2	<0.3	<0.3
<i>Staphylococcus aureus</i> 184	8	2.4×10^6	<0.3	<0.3

^aThe smokehouse was initially set at a dry bulb of 65.5 C, wet bulb set at 57.2 C; the settings were adjusted as needed to maintain the internal temperature of the sausages at 57.8-58.9 C for 3.5 h, the sausages were dried at 21 C and 50-55% RH for 4 days.

^bThe three tube MPN method was used.

Then 0.2 ml of Difco Coagulase Plasma was added, tubes were incubated at 37 C for 4-5 h, and the coagulase reaction was observed. Micrococci that were positive for catalase, gram stain, and coagulase tests were considered to be *S. aureus*. The MPN/g was calculated by the use of a table (9).

RESULTS

Preliminary experiments indicated that a satisfactory snack sausage could be prepared by heating and smoking the product at an internal temperature of approximately 58 C for a least 3.5 h followed by drying for 4 days. Viable cells of *S. senftenberg* 775W or *S. dublin* were not detected (<0.03 cells/g) after heating snack sausages at an internal temperature of 57.8-58.9 C for 3.5 h nor after 4 days of drying (Table 2). When *S. aureus* 196E was present initially in the snack sausages at more than 10^6 /g, an estimated MPN of 0.3 viable cell/g was found at the end of the heating period but none after drying. With low numbers of *S. aureus* 196E and both high and low numbers of *S. aureus* 184, no viable cells (<0.3/g) were found at the end of the heating or drying periods (Table 2).

Efforts were then directed towards determining the minimum internal temperature necessary to heat snack sausages to destroy salmonellae or staphylococci. When the internal processing temperature of the sausages was lowered to 53.9-55.0 C and maintained for 3.5 h, viable cells of *S. senftenberg* were not detected (<0.03/g); however, *S. aureus* 196E was still present in low numbers after the heating step but not after drying (Table 3). When the internal processing temperature was reduced to 51.5-52.5 C, neither salmonellae nor staphylococci

TABLE 3. Effect of heating at an internal temperature of 53.9-55.0 C on the survival of salmonellae and staphylococci during processing of snack sausage^a

Time	MPN ^b cells/g sausage	
	<i>Salmonella senftenberg</i> 775W	<i>Staphylococcus aureus</i> 196E
Zero time	5.6×10^3	1.1×10^4
Heated 3.5 h	<0.03	0.3
After drying	<0.03	<0.3

^aThe smokehouse was initially set at a dry bulb of 61.1 C, wet bulb at 51.7 C, and the settings adjusted as needed to maintain the internal temperature of the sausages at 53.9-55.0 C for 3.5 h; the sausages were dried at 21 C and 50-55% RH for 4 days.

^bThe three tube MPN method was used.

were eliminated from the snack sausages during the heating step and viable cells of both pathogens were detected at the end of the drying step (Table 4).

TABLE 4. Effect of heating at an internal temperature of 51.1-52.2 C on the survival of salmonellae and staphylococci during processing of a snack sausage^a

Time	MPN ^b cells/g sausage	
	<i>Salmonella senftenberg</i> 775W	<i>Staphylococcus aureus</i> 196E
Zero time	1.9×10^3	4.3×10^4
Heated 2 h	1.1×10^2	1.1×10^4
Heated 3.5 h	1.1×10^4	4.3×10^4
After drying	0.073	2.1

^aThe smokehouse was initially set at a dry bulb of 60 C, wet bulb at 46.1 C, and the settings were adjusted as needed to maintain the internal temperature of the sausages at 51.1-52.2 C for 3.5 h; the sausages were dried at 21 C and 50-55% RH for 4 days.

^bThe three tube MPN method was used.

Use of the lower temperature resulted in sausages that did not have a cooked appearance and that did not dry to form the typical snack sausage.

A commercial snack sausage meat mixture containing 39.4% fat and an experimental mix containing 7.3% fat were contaminated with either salmonellae or staphylococci and then processed into snack sausages. The data in Table 5 indicate that the amount of fat in sausages did not influence thermal destruction of either *S. senftenberg* 775W or *S. aureus* 196E.

DISCUSSION

The survivor data obtained and presented in this study are the result of end point determinations, i.e., the number of pathogens (salmonellae or staphylococci) which were detectable at the end of the selected heating conditions given the snack sausage. The data indicate that heating snack sausages at an internal temperature of >54 C for 3.5 h followed by 4 days of drying at 21 C and 50-55% RH led to the complete destruction of salmonellae and staphylococci. In custard and chicken á la king, Angelotti et al. (1) showed that temperatures which killed *S. senftenberg* 775W, the most heat resistant strain of *Salmonella* known, were satisfactory for thermal destruction of other salmonellae as well as strains of *S. aureus*. In general, data obtained with *S. senftenberg* 775W in this study support the conclusions of

TABLE 5. Effect of fat content on the destruction of *Salmonella senftenberg* and *Staphylococcus aureus* during processing of snack sausages^a

Formula	% Fat ^c	MPN ^b cells/g sausage					
		<i>Salmonella senftenberg</i> 775W			<i>Staphylococcus aureus</i> 196E		
		Zero time	After heating	After drying	Zero time	After heating	After drying
Commercial formula	39.4	9.0×10^4	<0.03	<0.03	4.6×10^3	<0.3	<0.3
Experimental formula	7.3	9.0×10^4	<0.03	<0.03	2.4×10^3	<0.3	<0.3

^aSausages were heated at an internal temperature of 57.8-58.9 C for 3.5 h, then dried at 21 C and 50-55% RH for 4 days.

^bThe three tube MPN method was used.

^cFat content was determined on the unprocessed sausages by the standard AOAC method (3).

Angelotti et al.

Many food technologists believe that microorganisms are more resistant to thermal inactivation in the presence of large amounts of fat even though real proof is lacking. Data in Table 5 indicate that snack sausages contaminated with salmonellae or staphylococci heated at 57.8-58.9 C for 3.5 h contained no survivors of either bacterial type regardless of the fat level of the sausage. Recently Smith et al. (8) utilizing frankfurters and coarsely comminuted sausages, have shown that there was little difference in the thermal destruction of pseudomonads or micrococci when the fat level of sausages varied from approximately 10-40%.

In conclusion, heating snack sausages at an internal temperature of 53.9-55.0 C or 57.8-58.9 C for 3.5 h followed by drying for 4 days gave salmonellae- or staphylococci-free products. However, heating at an internal temperature of 51.1-52.5 C for 3.5 h did not eliminate the food-poisoning bacteria; drying reduced the bacterial population but did not completely eliminate it.

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