Evaluation of High Humidity and Wet Marinade Methods for Pasteurization of Jerky

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ABSTRACT: The USDA FSIS meat and poultry jerky compliance guidelines recommend a high humidity or liquid immersion pasteurization step before drying. The objective of this study was to evaluate the effects of high humidity (>90%) or wet marinade pasteurization on jerky characteristics (water activity, moisture/protein ratio, total aerobic plate count [TAC]) and sensory properties. Jerky pasteurized by nonmarinade method A (76.6 °C dry bulb, 54.4 °C oven wet bulb temperature for 1 h) had highest sensory scores for spice intensity and interior cured color (redness), and generally lower TACs than jerky from marinade pasteurization methods. Jerky pasteurized by method B (54 °C for 121 min in marinade) had higher TACs than other methods. Approximately 2-log reduction in TAC was observed using marinade pasteurization in the smokehouse to internal temperature of 60° for 12 min (method C), or in hot marinade to internal temperature of 70 °C before drying (method D), but jerky was less spicy and somewhat darker than jerky from method A. Extruded jerky (1.5-cm thickness) was similar to intact jerky for spice flavor intensity and interior redness, but required longer drying time to reach the target Aw of 0.85. Marinade pasteurization by methods C or D was feasible, and may be a preferred alternative for some processors, since monitoring of oven humidity during pasteurization is not necessary.

Keywords: humidity, jerky, microbial load, pasteurization, sensory

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Introduction

Jerky is a popular snack item in the United States. Because jerky has been heated and dried, it is widely regarded as microbiologically safe. However, gastroenteritis outbreaks have been attributed to consumption of both home-dried and commercially prepared jerky (Nummer and others 2004). Between 1966 and 1995, 8 outbreaks occurred in New Mexico, causing over 250 illnesses. Two outbreaks were associated with *Staphylococcus aureus*, and 6 were due to contamination with *Salmonella* (Eidson and others 2000). The cases were primarily traced to local commercially prepared jerky, where processing times and temperatures never reached a level to destroy pathogens. In 1995, an outbreak of *E. coli* O157:H7 occurred in Oregon, involving home-processed deer jerky (Keene and others 1997). Investigators concluded that this traditional home-drying jerky process was insufficient to kill *E. coli* O157:H7.

In 2003, at least 22 cases of salmonellosis were attributed to consumption of commercially produced beef jerky in New Mexico (ProMED-mail 2003). Twenty percent of the jerky lots tested positive for *Salmonella*. Although the jerky was dried to a crumbly state (Aw < 0.3), investigators concluded that the very slow drying process under low humidity conditions (82 °C oven, but only 30 °C wet bulb temperature) allowed *Salmonella* organisms to dehydrate during slow drying, and become very resistant to the dry heat.

A study by Levine and others (2001) also suggested that foodborne pathogens can survive the moderate drying conditions (approximately 60 °C) used by commercial jerky manufacturers. Their study reported a cumulative prevalence of *Salmonella* and *L. monocytogenes* of 0.31% and 0.52% in jerky produced in federally inspected plants from 1990 to 1999, even though good manufacturing practices were followed and Hazard Analysis Critical Control Point plans were in place.

In response to this issue, the USDA Food Safety and Inspection Service in March 2004 issued a compliance guideline for jerky processors, requiring manufacturers who use time–temperature guidelines for pathogen destruction to take into account the humidity of the oven, especially in high-altitude areas of the country where relative humidity is low (USDA-FSIS 2004). Both wet- and dry-bulb thermometer temperatures must be taken during heating/drying, and a difference of 1.67 °C between the two indicates that oven humidity is less than 90%, and thus insufficient for adequate pathogen kill (Nummer and others 2004). For home-dried jerky, USDA recommended cooking beef, pork, venison, and poultry to 71 °C followed by drying at 54 to 60 °C in a standard home-style dehydrator (USDA-FSIS 2000).

As an alternative to the high-humidity initial cook step, processors may heat (cook) jerky in water or marinade to various time–temperature combinations sufficient for either 6.5 or 7 log (base 10) reduction of *Salmonella*, as specified in the USDA lethality performance standards, Appendix A (USDA-FSIS 2004). After cooking following one of the approved time–temperature combinations, the jerky can be dried. To verify proper drying, the updated compliance guidelines for small and very small jerky processors recommend using a laboratory test for Aw (USDA-FSIS 2004). Acidification of jerky marinades has also been shown to increase the destruction of food pathogens on jerky (Calicioglu and others 2002; Albright and others 2003).

Jerky cooked in high humidity or liquid marinade may have altered sensory properties, compared to traditional oven-drying practices. Thus, the objective of this study was to compare sensory properties (flavor, texture, appearance), microbial load, and water activity of jerky prepared by high humidity or wet marinade methods, following USDA guidelines, including 1 oven heating method and 3 marinade heating methods (long time/low temperature,

intermediate time/temperature, short time/high temperature). After cooking, jerky was dried at 54 °C to a target Aw < 0.85. Preliminary tests also compared Aw measurement by 3 commercial instruments.

Materials and Methods

Jerky preparation and marination

For whole muscle jerky, vacuum packaged, select grade beef pectoral muscles were manually sliced perpendicular to the direction of the muscle fibers to 6- to 7-mm thickness. Slices (2.27 kg/batch) were then manually mixed with dry spice mix and Prague Powder, using a clean plastic spatula. Personnel wore sterile plastic gloves during processing, to minimize bacterial introduction into the product during slicing and mixing. For restructured jerky, lean beef trim (85:15 visible lean to fat) was used. The lean trim (2.27 kg/batch) was mixed with spice and cure mix, coarsely ground twice through a 9.5-mm grinder plate (Hobart Mfg. Co., Troy, Ohio, U.S.A.), and then extruded through a 1.5-cm-diameter stuffing horn, using a manual small volume sausage stuffer (F. Dick, Koch Supplies, Kansas City, Mo., U.S.A.).

The spice mix was Heller's Smoky Beef Jerky Seasoning (hydrolyzed corn protein, corn syrup solids, brown sugar, dextrose, natural smoke flavor [lipolyzed butter oil & soy lecithin], maltodextrin, spice, mustard, garlic powder, sodium erythorbate [0.64%], onion powder, not more than 2% calcium silicate and calcium stearate as anticaking agents). The spice mix was added according to manufacturer's instructions (3.91 kg spice mix/45.4 kg meat). Prague Powder (6.25% sodium nitrite + 93.75% salt) was also added (0.113 kg/45.4 kg meat) to obtain 156-ppm initial nitrite level. Whole muscle meat slices plus spice mix were held overnight at 2 °C in a covered tray, before heat pasteurization and drying. For restructured jerky, the extruded product was prepared immediately before pasteurization.

For nonmarinade pasteurization method A, spice-treated raw products were manually placed on stainless steel screens for heating and drying. For marinade pasteurization methods B, C, and D, spice-treated products were heated in a marinade consisting of 1.95 kg commercial spice mix/45.4 kg water. Because of the additional spice mix used to prepare the marinade solution, jerky prepared by marinade pasteurization methods B, C, and D resulted in 5.86 kg spice mix/45.4 kg meat.

Jerky pasteurization

Jerky was cooked (pasteurized) by 1 of 4 methods:

1. Nonmarinade method A was 76.6 °C (170 °F) dry bulb, 54.4 °C (130 °F) wet bulb oven temperature for 1 h.

2. B: Cook in marinade at 54.4 °C product temperature for 121 min (long time, low temperature).

3. C: Cook in marinade at 60 °C (140 °F) product temperature for 12 min (intermediate time and temperature).

4. D: Cook in marinade at 70 °C (158°F) product temperature for 1 s (short time, high temperature).

Two separate batches of jerky were produced by each method, for a total of 8 batches. Method A was recently validated at the Univ. of Wisconsin (Buege and others 2006). The marinade methods B to D were based on the time/temperature combinations from USDA lethality compliance guidelines, Appendix A (USDA-FSIS 2004). In preliminary tests, nonmarinade jerky pasteurization was also attempted by holding smokehouse humidity at 90% or greater during cooking, by placing a large pan of water in the smokehouse, or by regular injection of a water mist, via the smokehouse shower system. With dampers closed, smokehouse humidity was not attained

at cooking temperatures, probably because dampers were not sufficiently tight to retain humidity.

In nonmarinade method A, spice-treated samples were spread on stainless steel screens, placed in the smokehouse (Vortron Inc., Beloit, Wis., U.S.A.) with dampers closed, and heated at 76.6 °C (dry bulb oven temperature). The oven temperature was brought to 54.4 °C wet bulb temperature and held at that temperature for 60 min. The dry bulb oven temperature was then turned down to 54 °C for drying, to a target Aw < 0.85. Total cooking and drying time was about 5 h. Dry and wet bulb oven temperatures were recorded at 5-min intervals throughout cooking and drying, using a thermocouple thermometer (Datalogger RTM; Cole-Parmer Instrument Co., Vernon Hills, Ill., U.S.A.). Product temperature was recorded continuously, using a strip chart temperature recorder (Dickson, Addison, Ill., U.S.A.). For restructured jerky, the temperature probe was inserted longitudinally into the center of extruded product. For whole muscle jerky slices, a thick jerky strip (10 mm thick) was prepared for temperature measurement, as described by Ingham and others (2005). During heating, the thin strips would have the same or higher temperature as the strip used for temperature measurement.

For marinade methods B and C, spice-treated raw jerky was placed between 2 stainless steel screens, and then immersed in marinade in a stainless steel pan constructed for this purpose. The pan dimensions were 91.4 cm long, 77.5 cm wide, and 10.2 cm deep. A drain with manual on/off valve was placed in 1 corner. The screens fit snugly inside the pan. The screen dimensions were 86.4 cm long and 71.1 cm wide. The bottom screen had handles centered on each side. The purpose of the top screen was to hold product securely in place while submersed in the marinade. After heating for the designated time and temperature, the screens plus jerky were lifted out of the marinade and placed on the next higher level of the smokehouse truck. The marinade was drained from the pan, and the pan was removed from the smokehouse. The smokehouse was closed, and the pasteurized jerky was dried at 54 °C for an additional 3.5 to 4 h, to a target Aw < 0.85. Jerky product temperature was monitored by a thermocouple inserted into the center of a restructured jerky segment, or into a thick jerky slice, as previously described.

For marinade pasteurization method D, spice-treated jerky was heated to >70 °C by dipping into marinade solution heated to 82 °C on a portable gas grill (Gasone EZS-1000, Jooan Co. Ltd. Gyeonggido, Korea). Jerky product temperature was monitored by a thermocouple inserted into a jerky slice, as previously described. Marinade temperature was also monitored and recorded by a separate thermocouple lead. After jerky strips reached the desired temperature, they were removed from the solution and spread on the stainless steel screens using sterile disposable forceps (Busse Hospital Disposables, Hauppauge, N.Y., U.S.A.). Jerky was dried at 54 °C to a target Aw < 0.85.

Water activity

In preliminary experiments, water activity was determined using 3 different instruments: AquaLab Lite water activity meter (Decagon, Pullman, Wash., U.S.A.), Hygropalm Aw meter (Rotronic Instrument Corp., Huntington, N.Y., U.S.A.), and Aw value meter, (Abbeon Cal, Santa Barbara, Calif., U.S.A.). The Decagon and Rotronic units used electric humidity sensors, where water activity (Aw) = equilibrium relative humidity/100. Water activity values were completed within 5 min per sample (5 to 10 g) for the Decagon and Rotronic units. The Abbeon Cal Aw meter was a less expensive, nonelectronic unit that measured Aw based on the sensitivity of a synthetic fiber to changes in relative humidity. Water activity

measurements required about 2 h per sample (3 g), to allow humidity in the closed container to reach equilibrium. Water activity measurements were then made in triplicate in each instrument using calibration solutions of barium chloride at 0.90 (Abbeon Cal) and 6 M sodium chloride, with Aw = 0.76 (Decagon). There were no significant differences in Aw measurement among instruments. For subsequent Aw measurements on jerky in this study, the Decagon AquaLab Lite instrument was used.

For the Aw measurements on jerky products, means were calculated and compared by ANOVA for the main effects of jerky type (whole or ground), pasteurization method (A, B, C, or D) and their interaction, using Statistica™ (Statsoft Inc., Tulsa, Okla., U.S.A.). All analyses were performed in duplicate.

Moisture and protein

To calculate moisture protein ratio (MPR), jerky samples were analyzed in duplicate for percent moisture (AOAC 1990, method 950.46b) and protein by the Kjeldahl method (AOAC 928.08). MPR was calculated as the average percent moisture divided by the average percent protein for each jerky sample.

Preparation of samples for microbiological examination

Raw marinated meat was sampled after the marination step was complete. Samples (15 to 20 g) were placed directly into a preweighed stomacher bag. Dried samples were taken from the smoke house using sterilized tweezers, and were transferred immediately to preweighed stomacher bags. The bags were then weighed, and the weight of the marinated meat or jerky was recorded. Raw marinated sample weights ranged from 15 to 20 g, while cooked jerky weights were 10 to 15 g. To the stomacher bag, 99-mL sterile Butterfield's phosphate diluent was added. Samples were then processed for 60 s at medium speed on a Seward Stomacher 400 (Norfolk, U.K.). All subsequent dilutions were made using sterile Butterfield's phosphate diluent.

Microbiological examination of samples

Microbiological examination of samples was done to determine the relative efficacy of pasteurization methods A to D. Total aerobic counts (TACs) and total enterobacter counts (TECs) of raw marinated and cooked jerky samples were performed using Petrifilm plates (3M Corp., St. Paul, Minn., U.S.A.). One milliliter of the stomached/diluted sample was plated in duplicate on appropriate Petrifilm, according to manufacturer directions. Samples were incubated for 24 h at 35 °C for TEC (American Public Health Assn.), and 48 h at 35 °C for TAC (AOAC method 990.12). Colonies were enumerated according to manufacturer directions.

Sensory panel training

Ten panel judges (USU faculty, staff, and students, 21 to 60 y old) were recruited and trained in 2 training sessions. During training session 1, panelists were given samples representing anchor points for each attribute. For spice flavor intensity, a hot, flavorful, locally produced jerky was used as an example of "5, extremely intense", and a jerky produced in the USU meat lab using half the normal spice level was used as an example of "2, slightly intense". Cohesiveness was of interest primarily in the ground, extruded product. A commercially available extruded kippered product was used for "5, extremely cohesive", and a Vienna-type sausage was used for "1, not cohesive". Toughness anchor point "4, very tough" was represented by a commercial jerky product, and "1, not tough" by an extruded stick-type product. Anchor points for surface darkness were a dark brown commercial jerky product ("4,

very dark") and a light, kippered beef product which was more red than brown ("2, slightly brown"). Cured color intensity/redness examples were an intensely red, commercially available pepperoni-flavored sausage product ("5, extremely red"), and a brown jerky product with slight redness visible in the fibers when pulled apart ("2, slightly red"). Final anchor point ratings were decided upon by the entire training panel after initial evaluation and group discussion.

During training session 2, judges were provided with the same anchor points as given in session 1 to allow them to reorient themselves. After a brief discussion and an explanation of the typical ballot layout, judges were sent to panel booths for a trial sensory evaluation. Three coded jerky samples, consisting of duplicate samples of treatment A and a single sample of treatment D, were given to judges. Ballots were then evaluated for consistency, both within (individual ratings of the duplicate treatment A samples) and between judges (group ratings of treatment A and treatment D). Based on these results, no further training sessions were provided, and no judges were excluded from subsequent sensory evaluations.

Sensory evaluation

Due to microbial safety concerns, treatment B was excluded from sensory evaluation. Jerky samples were rated by a trained taste panel ($n = 10$) for spice flavor intensity, cohesiveness, toughness, surface darkness, and cured color intensity (redness). A rating scale of 1 to 5 was used for each attribute, with 1 = none/not observed, 2 = slight, 3 = moderate, 4 = very, 5 = extreme. Samples were cut no more than 30 min prior to the sensory evaluation and pieces were held in zippered plastic bags to prevent drying. Samples were presented to judges in individual booths under fluorescent light. Water and spit cups were provided to each judge, and anchor point examples were provided when requested. Two evaluations (on separate days) were conducted for whole muscle jerky, and 1 evaluation for ground jerky. Panel scores were evaluated statistically for main effects of treatment and judge using the proc glm function of SAS version 9.0 (SAS Inst. Inc., Cary, N.C., U.S.A.). Separation of means was performed using the Tukey adjustment for multiple means comparisons at a significance level of $P \leq 0.05$.

Results and Discussion

Water activity (Aw) was affected ($P = 0.006$) by jerky type (intact or extruded) and by pasteurization method (Table 1 and 2, respectively). Extruded jerky had higher Aw than intact jerky, even though extruded jerky was dried—1 to 2 h longer—after

Table 1 – Water activity of cooked and dried product as affected by meat type

Meat type	N	Aw
Intact slices (whole)	8	0.838 b
Extruded (ground)	8	0.857 a
P-value		0.006

Table 2 – Water activity of cooked and dried product as affected by pasteurization method

Pasteurization method[a]	N	Aw
A	4	0.854 ab
B	4	0.866 a
C	4	0.842 bc
D	4	0.830 c
P-value		0.006

[a]A = 76.6°C dry bulb and 54.4 °C wet bulb for 1 h; B = 54.4 °C for 121 min in marinade; C = 60 °C for 12 min in marinade; and D = 70 °C for 1 s in marinade.

pasteurization than intact jerky, in order to approach the target Aw of 0.85. This was probably due to the relatively large diameter (1.5 cm) of the extruded jerky. A smaller diameter extruded jerky would likely dry faster. The interaction of jerky type and pasteurization method did not significantly affect Aw (Table 3).
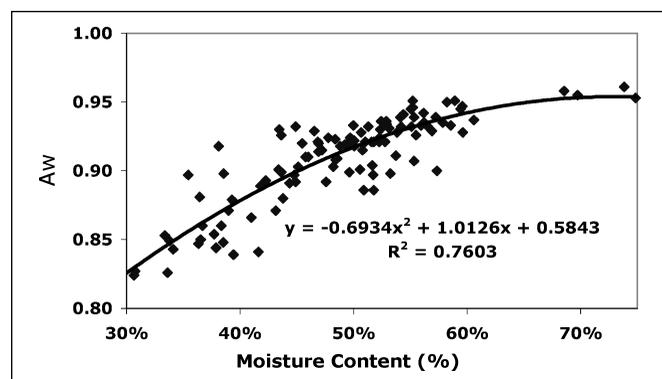
Jerky pasteurized by method D (rapid heating in hot marinade) had lower Aw ($P = 0.006$) than jerky from methods A or B (nonmarinade and long-time, low-temperature marinade pasteurization, respectively; Table 2). Extruded jerky pasteurized by long time, low temperature method B exhibited characteristics of "case hardening", including dry surface but a relatively moist interior, contributing to the higher Aw of jerky prepared by this method (Table 2). Values for MPR were also higher than 0.75 for extruded jerky pasteurized by methods A, B, and C, but intact jerky from these pasteurization treatments had MPR < 0.75 (Table 3). Dried meats with MPR > 0.75 cannot be labeled "jerky", according to the FSIS Food Standard and Labeling Policy Book (DeHoll 1981). However, dried meats with MPR ≤ 2.03:1 may be labeled "kippered" (DeHoll 1981). MPR < 0.75 and Aw < 0.85 were obtained in extruded jerky from pasteurization method D, where meat was immersed in hot marinade to rapidly attain an internal temperature >70 °C, then placed in the smokehouse for drying (Table 2 and 3).

After pasteurization, Aw and moisture content were monitored for all treatments at 30 min intervals initially, and 1-h intervals during the later stages of drying (Figure 1). Immediately after pasteurization, Aw values were as high as 0.95, with greater than 70% moisture content. At the end of the drying period, Aw values were as low as 0.82, with < 35% moisture content (Figure 1). There was a poly-

nomial relationship between Aw (*y*-axis) and moisture content (*x*-axis), with a correlation coefficient of 0.76. Thus, there was a strong positive relationship between Aw and moisture content. However, the relationship was not sufficiently high to be useful for predictive purposes. For 35% to 40% moisture samples, some samples had Aw as high as 0.93, while other samples had Aw < 0.85. Since rapid methods exist for both Aw and moisture, processors may obtain equipment for either or both measurements, as suits their needs.

TACs and total *Enterobacteriaceae* counts (TECs) were determined on spice-treated raw treatments A to D immediately before pasteurization and again after pasteurization and drying (Table 4), to compare effectiveness of the various heat treatments against the indigenous microflora. This is not a food pathogen lethality study, and the results presented here cannot be used in that context. In run 1, raw samples had lower TAC of 10^3 to 10^4, while raw samples in run 2 had TAC of 10^4 to 10^6. In run 1, a single sample from treatment B (low temperature, long time pasteurization) tested positive for *Enterobacteriaceae* after pasteurization and drying. In run 2 with high initial bacterial load, extruded jerky from marination

Table 3 – Water activity and moisture/protein ratio of cooked product as affected by the interaction of pasteurization method[a] and meat type

Pasteurization method	Meat type	N	Moisture/protein ratio	Aw
A	Intact	2	0.49	0.852
A	Extruded	2	0.769	0.857
B	Intact	2	0.58	0.849
B	Extruded	2	0.783	0.884
C	Intact	2	0.467	0.840
C	Extruded	2	0.780	0.844
D	Intact	2	0.581	0.825
D	Extruded	2	0.447	0.846
P-value				0.116

[a]A = 76.6°C dry bulb and 54.4 °C wet bulb for 1 h; B = 54.4 °C for 121 min in marinade; C = 60 °C for 12 min in marinade; and D = 70 °C for 1 s in marinade.

Figure 1 – Relationship between water activity (Aw) and moisture content of jerky during drying. Measurements were taken at intervals after pasteurization by methods A to D. Products were dried to a target Aw of 0.85.

Table 4 – Total aerobic count (TAC) and total Enterobacteriaceae (TEC) of cooked product as affected by pasteurization method (A to D) and initial microbial load

Treatment[a]	Run 1 Low raw marinated count (10^3 to 10^4)		Run 2 High raw marinated count (10^4 to 10^6)	
	TAC	TEC	TAC	TEC
A				
Intact	5.3×10^0	ND	2.7×10^0	ND
Extruded	1.5×10^2	ND	ND	ND
B				
Intact	5.3×10^2	4.5×10^0	5.6×10^3	ND
Extruded	8.9×10^1	ND	8.8×10^3	ND
C				
Intact	2.7×10^1	ND	4.7×10^2	ND
Extruded	2.8×10^1	ND	3.9×10^3	ND
D				
Intact	1.5×10^1	ND	2.9×10^2	ND
Extruded	1.4×10^1	ND	4.6×10^3	ND

[a]See Table 2 for treatment descriptions.
ND = No colonies detected (<10 CFU/g).

Table 5 – Mean sensory scores by meat type

Meat type	Spice intensity	Cohesiveness	Toughness	Surface darkness	Interior cured color
Intact	2.43 a	3.93 a	3.53 a	3.90 a	2.60 a
Extruded	2.33 a	3.07 b	2.77 b	3.23 b	2.90 a
P-value	0.655	0.001	0.001	0.002	0.133

Values in a column sharing letters are not different ($P > 0.05$).
Intensity scale 1 to 5; 1 = not intense; and 5 = extremely intense.

Table 6 – Mean sensory scores by treatment

Meat type	Spice intensity	Cohesiveness	Toughness	Surface darkness	Interior cured color
A	2.85 a	3.45 a	3.00 b	2.85 b	3.45 a
C	2.05 b	3.45 a	2.75 b	4.15 a	2.35 b
D	2.25 ab	3.60 a	3.70 a	3.70 a	2.45 b
P-value	0.014	0.848	0.002	<0.001	<0.001

[a]See Table 2 for treatment descriptions.
Values in a column sharing letters are not different ($P > 0.05$).
Intensity scale 1 to 5; 1 = not intense; and 5 = extremely intense.

methods B, C, and D all had TAC of 10^3 after heating and drying. In run 2 (high raw microbial load), jerky pasteurized by nonmarinade method A (76.6 °C dry bulb, 54.4 ° wet bulb oven temperature for 1 h) had generally lower total aerobic microbial counts than jerky from marinade pasteurization methods. When these conditions were achieved, the product temperature was high (70 to 74 °C), resulting in a substantial reduction in microbial load.

Pasteurization treatment B, where product internal temperature was held at 54.4 °C for 121 min (low temperature, long time) is one of the lowest temperature treatments approved for jerky processing, based on Appendix A of the USDA compliance guidelines (USDA-FSIS, 2004). The time–temperature guidelines for 6.5- to 7.0-log reduction of *Salmonella*, as listed in Appendix A, were based on a thermal death time study for *Salmonella* in beef emulsions in tubes (Goodfellow and Brown 1978). Perhaps the expected bacterial lethality was not observed in this study because TAC results included bacteria other than *Salmonella* that may be more heat resistant. Also, the jerky in this study contained substantial fat and added sugars that are known to increase bacterial heat resistance (Goepfert and others 1970), compared to the lean beef emulsions used by Goodfellow and Brown (1978). Whatever the explanation, results of this study indicate that a time–temperature combination of 54.4 °C for 121 min did not adequately reduce bacterial numbers in extruded or intact jerky.

Because of the high bacterial counts remaining after pasteurization, and the survival of an Enterobacter (the family than includes *Salmonella* and *E. coli* O157:H7), pasteurization method B was not served to sensory panelists. Jerky served to panelists was only from replication 1 for treatments A, C, and D (Table 4), where TAC of final dried product was 10^0 to 10^2. Samples were vacuum bagged and stored frozen (-10 °C for < 1 mo) prior to sensory panel evaluation.

Predictably, panel sensory scores of jerky were affected by meat type (intact or extruded). Intact jerky had higher ($P < 0.05$) cohesiveness, toughness, and surface darkness than extruded jerky (Table 5). In comparison of pasteurization methods, spice intensity was higher ($P < 0.05$) for jerky from nonmarinade treatment A, compared to marinade treatment C. Toughness was higher ($P < 0.05$) for method D jerky. Surface darkness was higher and red interior cured color was lower ($P < 0.05$) for marinade-pasteurized jerky (treatments C, D), compared to jerky from treatment A (Table 6). Thus, marinade pasteurization of jerky altered product appearance, and in some cases reduced spice flavor intensity, compared to nonmarinade pasteurized jerky (method A).

Conclusions

Recent USDA-FSIS guidelines for jerky manufacture recommend that processors use a validated pathogen lethality process or an approved time–temperature heat treatment in the presence of 90% or greater humidity to ensure product safety. In preliminary studies, 90% humidity could not be obtained in our smokehouse during heating. However, some marinade pasteurization methods were feasible, and may be a preferred alternative for small processors, since monitoring of humidity during heating is not necessary. Because marinade pasteurization of jerky altered sensory properties, it is recommended that processors using a marinade pasteurization method conduct sensory testing to optimize spice levels. Also, the long time/low temperature combinations listed in Appendix A of the USDA time–temperature tables for heat inactivation of pathogens may not adequately control spoilage organisms. It is recommended that processors confirm the efficacy of long time/low temperature marinade heating processes with their own products.

Acknowledgments

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