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Sensory, Physicochemical and Microbiological Characteristics of Venison Jerky Cured with NaCl and KCl

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Abstract

Traditionally, jerky is produced from sliced whole muscle marinated in a high sodium chloride (NaCl) concentration and dried. Because a high salt diet has been linked to hypertension, salt substitutes are often recommended as a healthier alternative. However, potassium chloride (KCl), a popular salt substitute may impart an undesired bitterness and metallic aftertaste. The objective of this study was to evaluate specific attributes of venison jerky prepared in three different (NaCl/KCl) salt solutions. Through sensory testing, each preparation was evaluated for consumer product acceptance and purchase intent. Additionally, the venison jerky was assayed for physicochemical characteristics and microbial counts. Using a 9-point hedonic scale, sixty-eight consumers evaluated the jerky for acceptability of flavor, texture, taste, saltiness, bitterness and overall liking. Physicochemical characteristics were evaluated for moisture content, pH, color and TBAR. Jerky was assayed for microbial counts via aerobic plate count, *Escherichia coli*, *Staphylococcus aureus* and *Campylobacter* spp. Results show that jerky prepared with 100% KCl received the most desirable score (8.75), compared to jerky prepared with 100% NaCl (6.28), and jerky prepared with 50% NaCl + 50% KCl (6.13). Acceptability and purchase intent questionnaires indicate jerky prepared with 100% KCl ranked the highest at 86.8% and 70.6%, respectively. Jerky prepared with 100% KCl had the lowest moisture content, TBAR, and a* values ($P<0.05$). No *E. coli*, *S. aureus* and *Campylobacter* spp. were detected over the 28 day period. Our study suggests that jerky prepared with KCl represents a low sodium alternative to traditional jerky.

Keywords: venison, jerky, sensory testing, salt substitute, microbial counts

1. Introduction

Jerky is a popular snack item and is classified by the U.S. Department of Agriculture (USDA) as a heat-treated and shelf-stable ready-to-eat meat product (USDA-FSIS, 2004). Whole or molded from chopped or ground meat, jerky may be cut into strips or stuffed into narrow casings. Jerky is made from a diversity of meat types and additives including sodium nitrite, table salt (sodium chloride) and spices (Ingram, 1973; Quintion et al., 1997; Gailani & Fung, 1986; Konieczny et al., 2007; Lim et al., 2014). Salt enhances the flavor of jerky (Gillette, 1985), acts as a preservative and provides sensations termed mouthfeel (Pszczola, 2006). However, overconsumption of table salt might increase blood pressure which has been linked to other health concerns, such as hypertension and stroke. Strokes result in 130,000 deaths in the United States (CDC, 2015) and 6 million deaths worldwide (WHF, 2015) annually. In the United States, strokes cost $34 billion annually in health care services, medications and lost productivity (CDC, 2015). Additionally, high blood pressure might be associated with in heart and kidney disease and congestive heart failure. Faced with these health issues, many consumers are concerned with limiting their salt intake. Their concerns have likewise influenced food processing manufacturers.

It has been reported (IOM, 2015) that the tolerable upper intake level for table salt is 5.8 g (or 2.3 g of sodium) per day. Healthy 19 to 50 year old adults can safely consume 3.8 g of salt or 1.5 g of sodium per day (Palar & Sturm, 2009). It is estimated that reducing table salt by 3 g per day will annually reduce the number of Americans with high blood pressure by 11 million, coronary heart disease by 120,000 and stroke by 66,000. Additionally, this amount of salt reduction would save up to 392,000 quality-adjusted life-years and $10 to $24 billion in health care costs (Palar & Sturm, 2009).

Using alternatives, such as potassium chloride (KCl), is one of the most common ways to reduce the sodium content in processed foods. According to the US Dietary Guideline (US-HHS, 2005), a potassium-rich diet reduces the effects of table salt on blood pressure and an intake of 4.7 g potassium/day is recommended. KCl has physicochemical properties closely resembling NaCl, but some consumers might experience an unpleasant aftertaste. However, it was reported (Mickelsen et al., 1977) that a mixture containing equal amounts of NaCl and KCl tasted similar to that of pure NaCl.

Eating quality has long been recognized as a factor for repeat customer purchasing (Grunert, 2004). Venison meat has become more popular in recent years partly due to its low intramuscular fat content (Hoffman & Wiklund, 2006) and higher n-3 polyunsaturated fatty acids (Bures et al., 2015) which is considered healthier than other red meats (Cordain et al., 2002; Giordano et al., 2010). In addition, venison meat is highly desirable for sensory properties such as aroma, taste, juiceness, and tenderness (Daszkiewicz et al., 2009).

To date, no studies have addressed the sensory, physicochemical and microbiological characteristics of venison jerky cured with a mixture of NaCl and KCl. The objective of this study is to evaluate specific attributes of venison jerky prepared in three different (NaCl/KCl) salt solutions.

2. Method

2.1 Preparation of Venison Jerky Samples

Venison semimembranosus muscles were obtained locally in Lake Charles, Louisiana. Muscles were cut into 5.0×10.0×0.5 cm slices. All subcutaneous and intermuscular fat and visible connective tissue were removed from the muscles. The muscle samples were refrigerated at 3ºC. Samples were subjected to three treatments and cured using the following salt solutions: 100% KCl, 50% KCl + 50% NaCl and 100% NaCl. Other ingredients included: 5.91% Worcestershire sauce (Lea & Perrins Inc., Pittsburgh, PA), 4.22% soy sauce (Kikkoman Foods, Inc., Walworth, WI), 2.53% liquid smoke (The Colgin companies, Mint Way, Dallas, TX), 0.46% garlic powder (Bolner's Flesta Products Inc., San Antonio, Texas), 0.46% onion powder (Kroger Co Cincinnati, Ohio) and 0.23% black pepper (Kroger Co Cincinnati, Ohio). The samples were allowed to cure for 12 hours at 3°C.

The cured jerky samples were then dried in a dehydrator (Model 778SS LEM^{TM}) at 70°C for 6 h. After drying, the samples were cooled to ambient temperature. Each sample was evaluated for consumer product acceptance and purchase intent. Additionally, each sample was analyzed for pH, moisture content, color (L*, a*, and b* values), lipid stability (TBARS), aerobic plate count, *Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*) and *Campylobacter* spp. at 7 d intervals for 28 d.

2.2 Sensory Evaluation

Each preparation was evaluated for consumer product acceptance and purchase intent. Using a 9-point hedonic scale, sixty-eight consumers evaluated the jerky for acceptability of flavor, texture, taste, saltiness, bitterness and overall liking. Consumers also completed an acceptability and purchase intent questionnaire.

2.3 pH Test

Samples were evaluated for pH with a probe electrode portable meter (Model 2000 VWR Scientific). Calibration of the pH meter was accomplished using pH 7 and pH 4 standardization buffers before use.

2.4 Moisture Content

Moisture content was determined according to the method of the Association of Official Analytical Chemists (AOAC 2000). Each 3 g sample was dried in an air oven (Model 26 Precision Thelco) at 102°C for 24 h.

2.5 Color Test

Color was measured at three different locations on each sample with a Minolta colorimeter (Model CR-10 portable) using an 8 mm aperture, 10° observer angle, D65 illuminant source in terms of L* (white = 100, black = 0), a* (+40 = red, -40 = green, b* (+40 = yellow, -40 = blue).

2.6 TBARS Test

The thiobarbituric acid-reactive substances (TBARS) method (Tarladgis, 1964) was used to measure lipid oxidation. Thiobarbituric acid reacts with the oxidation products of fat in solution to form malonaldehyde, which was measured on a spectrophotometer (Beckman Du-640) at 530 nm. The TBA value was expressed as mg malonaldehyde (MDA)/kg tissue.

2.7 Microbial counts

The microorganisms were determined following the standards of AOAC (2000). For this study, jerky was assayed for four undesirable microorganisms: aerobic plate count (APC), *E.coli*, *S. aureus* and *Campylobacter* spp.

The following protocol was used for APC, *E. coli* and *S. aureus*. Buffered peptone water (BPW) was added as a diluent option for serial dilutions. Following 3M™ Petri film plating instructions, plates were incubated in a horizontal position, clear side up, in stacks of no more than twenty at 37°C for 24-48 h.

The following protocol (Corry et al., 2003) was used for *Campylobacter* spp. BPW was added as a diluent option for serial dilutions. All samples were mixed with a vortexer for 2 min to release the bacteria. Each 0.1 ml of sample was aseptically transferred and spread onto modified charcoal cefoperazone deoxycholate agar. The inoculated plates were then incubated at 42°C for 48 h under a microaerophilic environment (5%O_2, 10%CO_2, and 85%N_2). Data were collected from countable plates (30-300 colonies per plate). The counted colonies were reported as CFU/g.

2.8 Statistical Analysis

The Proc GLM procedures of SAS windows (SAS, 2003) were used to evaluate the significance of differences of the obtained data. The PDIFF option of LSMEANS was employed to determine significance among treatments. All data are presented as means with standard deviation (SD) and a significance level of P<0.05 was used for statistical analysis of means from treatments.

3. Results and Discussion

3.1 Demographic Information

Demographic information of the 68 consumers in this study are presented. All consumers were volunteers solicited through advertisements posted in the Agricultural Sciences building on the McNeese State University Campus. The two largest age groups (18-24 and 45-54 years old) accounted for 63.2% of the total. Female participants (63.2%) exceeded males (36.8%).

3.2 Rank Response and Bitterness Evaluation

To confirm that consumers can distinguish relative saltiness and bitterness, discriminative tests by ranking were performed. Consumers were asked to rank the three preparations in order of most to least salty. The 100% NaCl samples received a plurality of 42.6% as the most salty (Table 1). By a slight margin, the 50% KCl + 50% NaCl samples were selected as the least salty (P<0.05) at 36.8% (Table 1). The 100% NaCl and 100% KCl samples received 33.8% and 29.4% of the vote respectively (Table 1).

Samples prepared with 100% KCl were rated the most bitter by 39.7% of consumers (Table 1). The 100% NaCl samples were rated the least bitter at 41.1% (Table 1). These results suggest that the prepared samples were distinguishable for saltiness and bitterness by the consumers.

Table 1. Least squares means for rank responses for saltiness and bitterness

Jerky Treatments	Consumers (N = 68)		
	Number/Percentage		
Saltiness	1st Most salty	2nd Most salty	3rd Most salty
100% KCl	25/36.8^a	22/32.4^a	20/29.4^a
50% KCl + 50% NaCl	14/20.6^b	30/44.1^b	25/36.8^a
100%NaCl	29/42.6^a	16/23.5^a	23/33.8^a
Bitterness	1st Most bitter	2nd Most bitter	3rd Most bitter
100% KCl	27/39.7^a	17/25.0^a	25/36.8^a
50% KCl + 50% NaCl	19/27.9^a	34/50.0^b	15/22.1^b
100%NaCl	22/32.4^a	17/25.0^a	28/41.1^a

[a,b] LSMeans with different superscripts within a column is significantly different (P<0.05).

3.3 Consumer Acceptability

Using the hedonic scale, participants evaluated the jerky for flavor, texture, taste, saltiness, bitterness and overall liking (Table 2). With reference to flavor, texture, taste and saltiness, scores among all three treatments statistically were not significantly different (Table 2). However, bitterness and overall liking scores were different between treatments. Specifically, jerky prepared with 100% KCl increased bitterness and had favorable scores for overall liking (Table 2). These results suggest that jerky prepared with KCl is a viable alternative to jerky prepared exclusively with NaCl.

Table 2. Least squares means for consumer acceptance scores for sensory attributes and overall liking of three salt solutions

Properties	100% KCl	50% KCl + 50% NaCl	100% NaCl
Flavor	6.65^{a}	6.38^{a}	6.30^{a}
Texture	6.65^{a}	6.41^{a}	6.53^{a}
Taste	6.59^{a}	6.32^{a}	6.42^{a}
Saltiness	5.98^{a}	6.1^{a}	5.92^{a}
Bitterness	5.39^{a}	3.75^{b}	4.79^{a}
Overall liking	8.75^{a}	6.13^{b}	6.28^{ac}

[a,b,c] LSMeans with different superscripts within a row is significantly different ($P<0.05$).

3.4 Acceptability and Purchase Intent

Using the acceptability and purchase intent questionnaire, consumers evaluated the jerky for acceptability, whether or not they would purchase the product and whether or not they would purchase the product if it claimed to contain reduced sodium, which might impact blood pressure (Table 3).

All three jerky treatments received similar scores with respect to acceptability and purchase intent ($P>0.05$). However, the 100% KCl jerky samples received the highest scores of 86.8% and 70.6% for acceptability and purchase intent respectively (Table 3). Finally, with respect to whether or not the consumers would purchase the product if it claimed to contain reduced sodium, both reduced sodium jerky treatments received similar scores ($P>0.05$). However, the jerky samples prepared with 50% NaCl + 50% KCl scored the highest at 64.7% (Table 3). Once again, these results suggest that jerky prepared with KCl is a viable alternative to jerky treated exclusively with NaCl.

Table 3. Least squares means for acceptability and purchase intent questionnaire (N = 68)

	100% KCl Number/Percentage	50% KCl + 50% NaCl Number/Percentage	100% NaCl Number/Percentage
Acceptable			
Yes	$59/86.8^{a}$	$55/80.9^{a}$	$55/80.9^{a}$
No	$9/13.2^{a}$	$13/19.1^{a}$	$13/19.1^{a}$
Purchase			
Yes	$48/70.6^{a}$	$47/69.1^{a}$	$45/66.2^{a}$
No	$20/29.4^{a}$	$21/30.9^{a}$	$23/33.8^{a}$
Purchase + health claim[1]			
Yes	$40/58.8^{a}$	$44/64.7^{a}$	N/A
No	$28/41.2^{a}$	$24/35.3^{a}$	N/A

[a]LSMeans with the same superscripts within a row is not significantly different ($P>0.05$).

[1]Reduced sodium jerky.

3.5 pH

The initial pH values of each individual jerky treatment ranged from 5.54 to 5.79 (Figure 1). Over the 28 day experimental period, changes in pH over each treatment profile exhibited significant differences ($P<0.05$). However, the pH values in each treatment followed a general decrease over the experimental period (Figure 1).

USDA defines intermediate pH, of which jerky is an example, possess a pH between 4.72 and 6.73 (Jose et al., 1994). The pH value has important implications with respect to safety. Specifically, the pH of properly processed jerky will inhibit or delay the spoilage of various dried meat products from mold and microorganism growth (Leistner, 1987). Initial and final pH values for each of the three treatments fell within or below the defined pH range (Figure1). More specifically, the pH value of the 100% KCl treated jerky was 4.48 at day 28 sampling time.

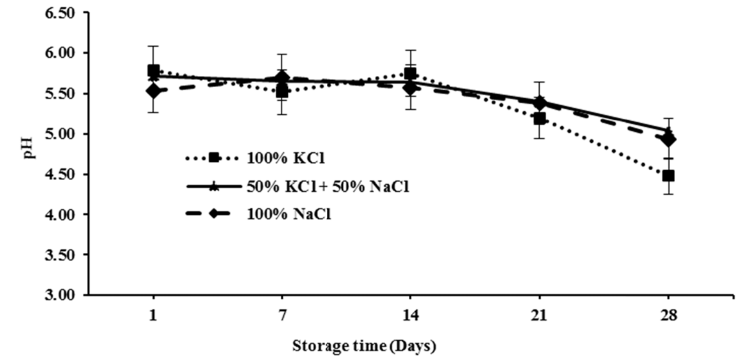

Figure 1. Least squares means for pH values of venison jerky during ambient storage for 28 days. SEM = 0.06

3.6 Moisture Content

Commercial intermediate foods have moisture contents of 20% to 40% (Jose et al., 1994). Moisture content affects sensory properties, stability and safety. Moisture contents of the three salt treatments are shown in Figure 2. The initial water content of each of the three treatments declined during the course of the experiment. Specifically, a respective decline of 17.7%, 14.8%, and 4.6% for 100% KCl, 50% KCl + 50% NaCl and 100% NaCl was detected over 28 days. These values were statistically significant ($P<0.05$).

These results clearly show that jerky treated with KCl experiences materially more moisture loss than that treated with NaCl. Therefore, packaging might become a critical factor in the commercial market for venison jerky.

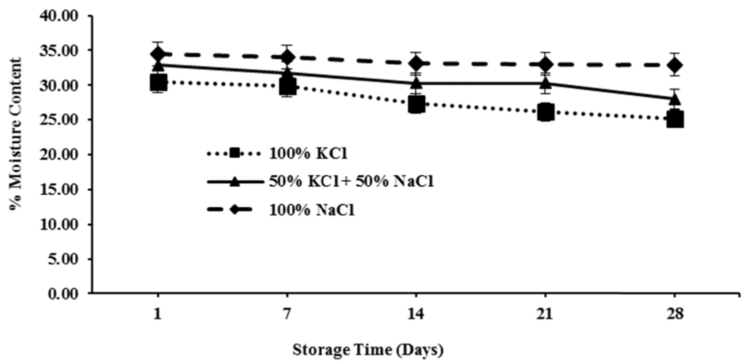

Figure 2. Least squares means for moisture content (%) of venison jerky during ambient storage for 28 days. SEM = 2.62

3.7 Color Test

Increasing changes in lightness (L*) values represent greater light dispersion and increased lightness and is correlated with changes in meat structure, especially protein destruction (MacDougall, 1982). This is likely due to protein denaturation (Insausti et al., 2001). Results from the present study indicated that no significant differences occurred in the L* values among the three treatments during each week of the storage period (P>0.05) (Table 4). These results suggest that the treatment concentrations of NaCl and KCl used in this study did not significantly affect the meat structure of the venison jerky. These results are similar to those found by Soldatou, Nerantzaki, Kontominas, & Savvaidis (2009).

Redness (a*) values help gauge consumers acceptability of meat product color (Brewer et al., 2002). Typically, the red color of meat transitions to brownish red due to the formation of metmyoglobin. There was a significant difference (P<0.05) observed in a* values between treatments at days 1 and 21. However, no interactions were observed between the treatments and storage periods (P>0.05). The nominal values between the three treatments were small (Table 4). Therefore, color transition among the three different treatments was similar. This suggests that KCl has little impact on initial color or color as it changes through time.

Yellowness is measured in terms of positive b* values. In general, no clear trend in yellowness per treatment was evident during the experimental period. For example, from its initial value, yellowness exhibited alternate declines and increases during the course of experiment (Table 4). However, all three treatments fell within yellowness values between 5.80 and 17.57. Therefore, KCl had no appreciable impact on the yellowness.

Table 4. Least squares means for HunterLab L*, a*, and b* values of venison jerky during ambient storage for 28 days

Parameter	Treatment	Storage time (d)				
		1	7	14	21	28
L*	100% KCl	25.70^{a}	30.90^{a}	31.40^{a}	26.40^{a}	28.30^{a}
	50% KCl + 50% NaCl	33.20^{b}	29.43^{a}	32.97^{ab}	33.37^{b}	30.87^{a}
	100% NaCl	32.20^{ab}	24.60^{a}	24.47^{ac}	29.10^{ab}	32.90^{a}
a*	100% KCl	4.90^{a}	6.03^{a}	3.33^{a}	2.23^{a}	2.83^{a}
	50% KCl + 50% NaCl	8.85^{b}	5.00^{a}	3.73^{a}	4.87^{b}	4.63^{a}
	100% NaCl	6.90^{a}	4.20^{a}	3.17^{a}	3.10^{ab}	4.67^{a}
b*	100% KCl	9.25^{a}	14.6^{a}	7.07^{a}	5.80^{a}	7.77^{a}
	50% KCl + 50% NaCl	16.50^{b}	10.83^{a}	17.57^{b}	12.67^{b}	12.30^{ab}
	100% NaCl	14.35^{ab}	10.20^{a}	7.80^{ac}	10.27^{ab}	13.37^{bc}

^{a,b,}cLSMeans with different superscripts within a row is significantly different (P<0.05).

3.7 Lipid stability (TBARS)

Lipid composition constitutes the major determinant for susceptibility to oxidative changes and rancidity development leading to flavor deterioration or what has been termed a *warmed-over* flavor (Sato & Hegarty, 1971). Additionally, oxidation causes off-odors (Lillard, 1987). There was a statistically significant difference (P<0.05) in terms of TBARS values between treatments at days 1, 14, 21, and 28 (Figure 3). However, the data exhibited similar trajectories over the experimental period. That is, TBARS values steadily increased over time which similarly to the study of Melton (1983) and Hamid et al (2010). Additionally, the two treatments containing KCl consistently exhibited TBARS values less the NaCl treatment. This may be due to the presence of NaCl acting as a prooxidant and an increase of lipid oxidation during meat processing (King & Bosch, 1990; Rhee 1999; Rhee & Ziprin, 2001). King and Bosch (1990) found that 2% sodium chloride was more prooxidant compared with 2% potassium chloride in turkey patties. Therefore, the KCl treated jerky represents a viable alternative to jerky treated with NaCl with respect to flavor and odor associated with lipid oxidation.

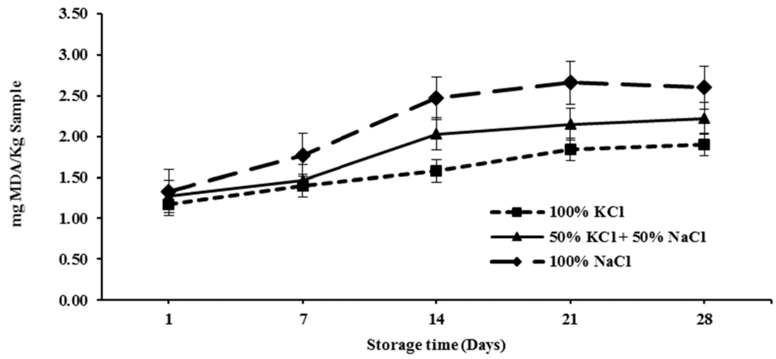

Figure 3. Least squares means for TBARS (thiobarbituric acid-reactive substances) values of venison jerky during ambient storage for 28 days. SEM = 0.90

3.8 Microbial Counts

Jerky is widely regarded as microbial safe. However, gastroenteritis outbreaks have been attributed to consumption of both home-dried and commercially prepared jerky (Nummer et al., 2004). Similar findings by Levine et al. (2001) also reported that food borne pathogens can survive the moderate drying conditions (60-70°C) used by commercial jerky manufacturers. Holley (1985) identified that *S. aureus* can grow in the jerky production process in the initial drying period. However, from our analyses, the presence of *E. coli*, *S. aureus* and *Campylobacter* spp. was not detected over ambient storage for 28 days.

Aerobic plate count is a common method used to indicate the microbiological quality of a food (Stannard, 1997). Aerobic plate counts above 10^7 cfu/cm^2 is commonly used as an indicator of spoilage (Korkeala et al., 1987; Borch et al., 1996). Our study found that aerobic plate counts were detected at levels considered safe for human consumption at 3.21-3.45 log CFU/g for all three jerky treatments over ambient storage for 28 days (Stannard, 1997; Patricia & Azanza, 2005). In general, all three treatments exhibited modest increases in the enumeration of aerobic plate counts over the experimental period (Figure 4). Aerobic plate counts among the three treatments were not statistically significant (P>0.05) which is similar to the study of Blesa et al., (2008). These results suggest that KCl provides similar bacterial protection to venison jerky treated with NaCl.

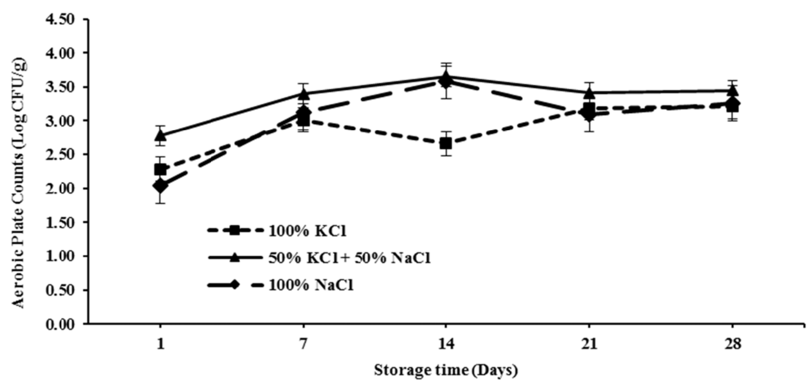

Figure 4. Least squares means for aerobic plate counts of venison jerky during ambient storage for 28 days. SEM = 0.45

4. Conclusions

The results of this study suggest that venison jerky prepared with KCl is a viable alternative to jerky treated exclusively with NaCl. Specifically, participants rated all three treatments similarly with respect to flavor, texture, taste and saltiness. With respect to overall liking, participants rated jerky prepared with 100% KCl as the highest. Additionally, all three treatments received positive participant ratings with respect to acceptability and purchase intent with and without health claims. Therefore, jerky prepared with KCl, is a marketable alternative to traditional jerky.

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