Research Note

Effects of smoking and marination on the sensory characteristics of cold-cut chicken breast filets: A pilot study

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Abstract This study aimed to determine individual and combined effects of smoking and marination on the sensory characteristics of boneless, skinless chicken breast meat. Four types of cooked, cold-cut chicken breast meat, i.e., marinated cooked, marinated smoked, and controls of non-marinated cooked and non-marinated smoked chicken, were evaluated for 28 sensory characteristics. Marination significantly increased saltiness, sweetness, roasted flavor, smoked flavor, and moistness of the cold-cut chicken breast meat. In addition, smoking significantly enhanced the saltiness, bitterness, roasted flavor, smoked flavor, and moistness of mass. Interestingly, a combination of smoking and marination processes resulted in a synergistic increase in the perceived moistness of mass compared to their individual treatments. In conclusion, this study demonstrates individual and combined influences of smoking and marination on the sensory characteristics of cold-cut chicken breast meat.

Keywords: chicken, cold cut, smoking, marination, sensory characteristics

Introduction

Poultry is by far the most popular meat in the United States (1). Poultry meat consumption in the U.S. doubled from 26.4 pounds/year in 1980 to 54.1 pounds/year in 2012 (2). A similar trend has also been observed in many other countries such as China, India, and South Korea. For example, the per capita chicken meat consumption in South Korea increased from 5.9 kg (1995) to 12.8 kg (2014) (3). Thus, meeting this high demand without compromising on the microbial food safety or quality of the product is a challenge for poultry processors today. To ensure optimum quality for poultry, the U.S. Department of Agriculture recently announced additional regulations for poultry processing (4). As a result, efficient preservation of poultry is becoming increasingly important to both academic and industry researchers. However, many of the preservation techniques, such as adding natural or chemical antimicrobials, have the potential to increase or decrease the sensory acceptability of poultry meat products with respect to their color, appearance, odor, flavor, and textural characteristics (5–7). In particular, poultry meat treated with natural or chemical antimicrobials retarded the off-odors/flavors associated with poultry meat over time (5). In contrast, the antimicrobials' own distinct odors/flavors may result in a decrease in the sensory acceptability of poultry meat products (6,7). In addition,

a systematic review found that the effect of antimicrobials on the sensory aspects of poultry meat depends on the concentration of antimicrobials (7). Van Loo *et al.* (8) reported that the consumers' perception of poultry meat quality depends on the meat's sensory acceptability. Therefore, ensuring good sensory appeal of the poultry products is essential for their overall market success, and additional care needs to be taken to ensure that preservation or other processing methods used in poultry do not adversely affect the sensory quality of the meat product.

Various techniques such as freezing, drying, and addition of chemicals, have been used for poultry preservation. Smoking is one of the oldest traditional techniques used for increasing the shelf life (9). Smoking involves burning wood to create smoke or its condensates (e.g., liquid smoke) in order to preserve poultry products by utilizing the antimicrobial and antioxidant properties of the smoke components on the exposed surfaces of the food (9,10). In addition to its preservative effect, smoking uniquely modifies the sensory characteristics of poultry meat products. In fact, smoking has been found to induce desirable color and flavor in various poultry products (9,11). However, prior research pertaining to the sensory impacts of smoking on poultry products has been somewhat ambiguous. For example, Modi *et al.* (12) demonstrated that fried nuggets prepared with smoked chicken meat of spent laying hens were superior to

those prepared with fresh meat with respect to color, texture, flavor, and overall quality. In contrast, incorporation of liquid smoke did not show any significant effect on the juiciness, chewiness, hardness, flavor, and overall quality of chicken/pork frankfurters (13).

Another traditional technique that has been used for preservation is marination. According to the poultry industry, marination can be characterized as the *“incorporation and retention of water by poultry to improve tenderness, juiciness, color, and flavor, by adding an alkaline solution of pH 7.5 and above, containing mainly sodium chloride and phosphates, although other additives are also used”* (14). Previous studies have demonstrated that marination increases water retention in muscle fibers, resulting in more tender and juicy chicken products (15–17).

As mentioned earlier, both smoking and marination have a definite impact on the sensory characteristics of poultry meat products. However, studies concentrating on the sensory impacts of smoking and marination as a “combined” process are still scarce. Moreover, most of the studies described above did not conduct descriptive sensory analysis with fully-trained panelists to evaluate the sensory characteristics of poultry meat (12,13). Such an analysis is valuable because it provides a precise estimate of a product’s sensory profile (18). Based on the abovementioned facts, this pilot study aimed to explore the individual and combined effects of smoking and marination on the sensory characteristics of cold-cut chicken breast meat using descriptive sensory analysis. Cold-cut chicken meat is popular for salad and sandwiches in many countries. For example, approximately 15% of U.S. adults reported that chicken was the most frequently consumed type of cold cuts; ham was the most popular (52.1%) cold cut in the U.S. (19). The results of this pilot study will show a direction for optimizing the combination of smoking and marination with respect to the sensory characteristics of cold-cut chicken meat when designing a large-scale study.

Materials and Methods

Chicken samples and preparation Four types of chicken breast were prepared for a descriptive sensory analysis: marinated cooked chicken, marinated smoked chicken, non-marinated cooked chicken, and non-marinated smoked chicken. Boneless, skinless chicken breast samples (680 g per breast) were purchased from a retail establishment (Sam’s Club, Fayetteville, AR, USA). Half of the chicken breasts were marinated in a 6% salt (NaCl, Amresco, Solon, OH, USA) and 3% sodium tripolyphosphate (Spectrum Chemical Manufacturing Corporation, Gardena, CA, USA) solution [added at 15% (w/w) of chicken breasts], followed by vacuum tumbling at 635 mm of Hg for 20 min. Half of the marinated and non-marinated samples were placed in pans, covered with aluminum foil, and cooked in a convection oven (Stein Lab Oven, Sandusky, OH, USA) at 190°C to an internal temperature of 74°C (marinated cooked chicken and non-marinated smoked chicken, respectively). The remaining half of the

marinated and non-marinated chicken breast samples were smoked in an Alkar smokehouse (Model 1000; Lodi, WI, USA) using sweetgum bark as the source of smoke (marinated smoked chicken and non-marinated smoked chicken, respectively). They were smoked for 1.5 h at a dry bulb and wet bulb temperature of 60 and 38°C, respectively, and then further cooked without smoke until the internal temperature reached 74°C. Both marination and smoking conditions were set up based on a preliminary study. After preparation, the chicken breast samples were cooled down and then sealed in a polyethylene bag. The samples were stored in a refrigerator (at approximately 4°C) until served; all samples were used for the sensory analysis within 24 h.

Descriptive sensory analysis Descriptive sensory analysis of chicken breast meat samples was conducted by eight panelists who have been trained according to the Spectrum® method with some modification with respect to reference intensity (Sensory Spectrum Inc., Chatham, NJ, USA) at the University of Arkansas Sensory Service Center (Fayetteville, AR, USA). All the panelists had extensive experience of more than 200 h with respect to descriptive analysis of meat products, including chicken breast filets.

During two orientation/training sessions (3 h per session), the panelists were asked to generate terms of the sensory characteristics to be tested in the descriptive sensory analysis. Table 1 summarizes the definition, reference, and/or evaluation technique for 24 flavor- and four texture-related characteristics. The texture-related characteristics of chicken breast meat samples were captured in two procedural stages: first bite/chew and then chewdown. During the training sessions, the panelists were trained to be familiar with the definitions and intensities of the sensory characteristics with their individual references.

The meat samples sealed in the polyethylene bag were taken out from the refrigerator and placed at room temperature (20–22°C) for approximately 45 min before serving. Each of the four cold chicken breast samples was cut into small cubes (1.2 cm×1.2 cm×1.2 cm), placed in a soufflé cup, and identified by a random 3-digit code. The panelists were given 5–6 cubes of each sample one after another in a random order. The time interval between sample presentations was approximately 10 min. During the break, spring water (Clear Mountain Spring Water, Taylor Distributing, Heber Springs, AR, USA) and unsalted crackers (Nabisco Premium Unsalted Tops Saltine Crackers, Mondelçz Global LLC, East Hanover, NJ, USA) were served for palate cleansing. All samples were evaluated for 28 sensory characteristics on 15-point universal scales (18) with references at four times on two different days.

Data analysis Data analysis was conducted using JMP 11.0 software (SAS Institute, Cary, NC, USA). To determine whether the four chicken breast samples differed with respect to each sensory characteristic, a two-way analysis of variance (ANOVA), treating the samples and panel as fixed effects, was used. If a significant difference was

Table 1A. Flavor-related characteristics and their definitions and references

Term	Definition	Reference (intensity)
Aroma characteristics		
Cooked chicken	Aroma associated with cooked white meats like chicken	Baked/broiled chicken breast (UAS)
Brothy	Aroma associated with boiled meat, soup, stock	Chicken stock or soup (UAS)
Smoked	Aroma related to smoke, whether it be hickory, apple, cherry, mesquite, or any artificial smoke flavoring	Liquid smoke (UAS)
Warmed-over	Aroma associated with re-warmed cooked meat after it has been refrigerated for 4–48 h	Re-warmed cooked chicken (UAS)
Roasted	Aroma associated with sweet characteristic of browned sugars and other carbohydrates	Roasted refrigerated beef, turkey, or pork (UAS)
Cardboard packaging	Aroma associated with slightly oxidized fats and oils, reminiscent of wet cardboard packing	Wet cardboard (UAS)
Oxidized	Aroma associated with various characteristics of oxidized foods, degrees include-cardboard, rancid, and painty	Old oil/old wheat germ (UAS)
Fishy	Aroma associated with cooked fish meat or other sea foods	Smoked fish/canned tuna (UAS)
Metallic	Aroma associated with metals, tinny, or iron	Tin foil (UAS)
Wet feather	Aroma reminiscent of wet poultry feather	Process poultry products/franks (UAS)
Basic tastes		
Salty	The basic taste, perceived on the tongue, stimulated by sodium salt, especially sodium chloride	0.2% and 0.5% sodium chloride solutions in spring water (2.0 and 8.5)
Sweet	The basic taste, perceived on the tongue, stimulated by sugars and high potency sweeteners	2% and 5% sucrose solutions in spring water (2.0 and 5.0)
Sour	The basic taste, perceived on the tongue, stimulated by acids, such as citric acid	0.05% and 0.08% citric acid solutions in spring water (2.0 and 5.0)
Bitter	The basic taste, perceived on the tongue, stimulated by substances such as quinine, caffeine, and certain other alkaloids	0.05% and 0.08% caffeine solutions in spring water (2.0 and 5.0)
Flavors (Aromatics) characteristics		
Cooked chicken	Aromatic associated with cooked white meats like chicken	Baked/broiled chicken breast (UAS)
Brothy	Aromatic associated with boiled meat, soup, stock	Chicken stock or soup (UAS)
Blood serum metallic	Aromatic associated with raw lean meat, cooked blood, serum	Drippings from raw beef (UAS)
Cardboard packaging	Aroma associated with slightly oxidized fats and oils, reminiscent of wet cardboard packing	Wet cardboard (UAS)
Warmed-over	Aroma associated with re-warmed cooked meat after it has been refrigerated for 4–48 h	Re-warmed cooked chicken (UAS)
Roasted	Aroma associated with sweet characteristic of browned sugars and other carbohydrates	Roasted refrigerated beef, turkey, or pork (UAS)
Oxidized	Aroma associated with various characteristics of oxidized foods, degrees include-cardboard, rancid, and painty.	Old oil/old wheat germ (UAS)
Smoked	Aroma related to smoke, whether it be hickory, apple, cherry, mesquite, or any artificial smoke flavoring	Liquid smoke (UAS)
Mouth-feeling characteristics		
Astringency	The feeling factor on the tongue or other skin surfaces of the mouth described as puckering or drying	0.01% Alum solution in spring water (6.0)
Metallic	Aromatic associated with metals, tinny, or iron	Tin foil (UAS)

UAS, Intensities were based on the universal aromatic scale (18) with some modification: saltine cracker=3.0; applesauce=7.0; orange juice=10.0; grape juice=14.0.

indicated by the ANOVA, post hoc comparisons between the chicken breast samples were conducted using Tukey's honestly significant difference (HSD) tests. In addition, in order to determine the effects of marination, smoking, and panel on the sensory characteristics of the chicken breast samples, a three-way ANOVA, treating marination, smoking, and panel as fixed effects, was used. A statistically significant difference was defined as $p < 0.05$.

Results and Discussion

Table 2 presents the mean ratings of the sensory characteristics with respect to the four chicken breast meat samples: marinated cooked chicken, marinated smoked chicken, non-marinated cooked chicken, and non-marinated smoked chicken. There were no significant two-way interactions (i.e., sample $\times$ panel) with respect to the sensory

Table 1B. Texture-related characteristics and their definitions, evaluation techniques and references

Term	Definition	Evaluation technique (Scale anchors)	Reference (Intensity)
First bite/Chew characteristics			
Hardness	The force required to compress the sample	Compress or bite through sample one time with molars or incisors (Soft–Hard)	Beef frank (5.5) Olive (7.0)
Cohesiveness	The amount of the sample deforms rather than splits apart, cracks or breaks	Place sample between the molar teeth and compress fully. May also be done with incisors (Crumbles–Deforms)	Soft pretzel (8.0) Caramel (13.0)
Chewdown characteristics			
Fibrousness	The amount of grinding of fibers required to chew through the sample.	Place sample between molars and chew 10–12 times. Evaluate during chewing (None–Much).	Apple (2.0) Salami (7.0) Toasted oats (5 pieces; 10.0)
Moistness of Mass	The amount of wetness/oiliness felt on the surface of the chewed sample	Chew sample with molar teeth up to 15 chews and evaluate (Dry–Wet).	Saltine (4.5) Jell-O (14.0) Water (15.0)

characteristics, except roasted aroma ($p=0.003$), wet feather aroma ($p<0.001$), saltiness ($p=0.001$), sweetness ($p=0.01$), cardboard packaging flavor ($p=0.02$), and metallic feeling ($p<0.001$). However, panel had significant effects on the sensory characteristics, except cardboard packaging aroma ($p=0.54$) and oxidized aroma ($p=0.23$), indicating that the panelists assessed the sensory characteristics of the chicken breast samples in a different manner (20–22), which has been observed in the results of the descriptive analysis (21,22). As shown in Table 2, the four chicken breast meat samples significantly differed with respect to 14 sensory characteristics, i.e., cooked chicken aroma ($p=0.04$), smoked aroma ($p<0.001$), wet feather aroma ($p=0.03$), saltiness ($p<0.001$), sweetness ($p=0.006$), cooked chicken flavor ($p=0.047$), blood serum metallic flavor ($p=0.02$), cardboard packaging flavor ($p=0.03$), warmed over flavor ($p<0.001$), roasted flavor ($p=0.02$), smoked flavor ($p<0.001$), astringency ($p=0.04$), metallic feeling ($p=0.03$), and moisture of the mass ($p<0.001$). However, post hoc comparisons using Tukey's HSD tests revealed no significant differences between the chicken breast samples for cooked chicken aroma and wet feather aroma ($p>0.05$).

Table 3 shows the results of the three-way ANOVA treating marination, smoking, and panel as fixed effects for the sensory characteristics of the chicken breast samples. There were no significant three-way interactions (i.e., marination $\times$ smoking $\times$ panel) with respect to the sensory characteristics, except wet feather ($p<0.01$). In addition, there were no significant interactions between marination and smoking with respect to the 28 sensory characteristics of cold-cut chicken breast (for all, $p>0.05$). However, panel had significant effects on the sensory characteristics, except cardboard packaging aroma ($p=0.54$) and oxidized aroma ($p=0.23$).

Marination significantly increased the perception of saltiness ($p<0.001$) of cold-cut chicken breast due to the presence of salt in the marinade (Table 2 and 3). Marination also significantly enhanced sweetness ($p=0.002$), despite no additional sugar. In particular, marinated smoked chicken showed significantly higher sweetness than non-marinated cooked or non-marinated smoked chicken

(Table 2). Furthermore, marination significantly increased the roasted flavor ($p=0.02$) and smoked flavor ($p=0.03$) of cold-cut chicken breast, while it significantly decreased the warmed-over flavor ($p=0.03$), characterized by the rancid flavor developed during storage under refrigeration (23). However, marination did not influence other flavor-related characteristics of cold-cut chicken breast (Table 3). It significantly decreased astringency of the cold-cut chicken breast ($p=0.03$). As shown in Table 2, marinated smoked chicken showed significantly lower astringency than non-marinated cooked chicken.

Marination significantly affected the textural characteristics of the cold-cut chicken breast; moreover, it increased moistness of mass ($p<0.001$), which is in agreement with previous findings that marination could increase water retention in muscle fibers, enhancing juiciness in chicken products (15–17). However, marination did not significantly affect the hardness, adhesiveness, cohesiveness, and fibrousness of cold-cut chicken breast ($p>0.05$), as shown in Table 2 and 3.

As expected, smoking significantly increased the smoked aroma ($p<0.001$) and smoked flavor ($p<0.001$) (Table 2 and 3). This indicates that the smoking treatment used in this study could produce detectable smoke aroma and flavor. Smoking significantly decreased the warmed-over flavor of cold-cut chicken breast ($p=0.001$), indicating that the cooking process might be more responsible for the warmed-over flavor of the chicken breast meat than the smoking process (24). Notably, the combination of smoking and marination resulted in the lowest mean intensity of the warmed-over flavor, which is in fact a sign of oxidation (undesirable characteristic) (24); marinated smoked chicken showed significantly lower intensity of the warmed-over flavor compared to marinated cooked and non-marinated cooked chicken (Table 2), i.e., smoking treatment for marinated cooked chicken could significantly reduce the warmed-over flavor of cold-cut chicken breast. In addition, there were significant enhancing effects of smoking on the saltiness ($p=0.003$) and bitterness ($p=0.02$) of the cold-cut chicken breast (Table 3). As excessive intake of dietary salt may increase the risk of chronic diseases, including cardiovascular or

Table 2. Mean ratings ($\pm$ standard deviation) of sensory characteristics in the four cold-cut chicken breast samples

	Marinated cooked chicken	Marinated smoked chicken	Non-marinated cooked chicken	Non-marinated smoked chicken	p-value
Aroma characteristics					
Cooked chicken	4.38 ($\pm$ 1.31) ^{a1)}	3.94 ($\pm$ 1.11) ^a	4.25 ($\pm$ 1.24) ^a	4.00 ($\pm$ 1.24) ^a	0.04 ²⁾
Brothy	1.19 ($\pm$ 1.57) ^a	1.09 ($\pm$ 1.55) ^a	1.03 ($\pm$ 1.58) ^a	0.97 ($\pm$ 1.47) ^a	0.59
Smoked	1.34 ($\pm$ 1.82) ^b	3.88 ($\pm$ 1.26) ^a	0.94 ($\pm$ 1.54) ^b	3.84 ($\pm$ 1.32) ^a	<0.001
Warmed-over	1.09 ($\pm$ 1.55) ^a	0.75 ($\pm$ 1.32) ^a	1.19 ($\pm$ 1.69) ^a	0.66 ($\pm$ 1.26) ^a	0.08
Roasted	2.66 ($\pm$ 1.31) ^a	2.56 ($\pm$ 1.44) ^a	2.50 ($\pm$ 1.48) ^a	2.69 ($\pm$ 1.33) ^a	0.66
Cardboard packing	0.00 ($\pm$ 0.00) ^a	0.00 ($\pm$ 0.00) ^a	0.09 ($\pm$ 0.53) ^a	0.09 ($\pm$ 0.53) ^a	0.58
Oxidized	0.09 ($\pm$ 0.53) ^a	0.13 ($\pm$ 0.71) ^a	0.31 ($\pm$ 1.00) ^a	0.00 ($\pm$ 0.00) ^a	0.32
Fishy	0.09 ($\pm$ 0.53) ^a	0.13 ($\pm$ 0.49) ^a	0.09 ($\pm$ 0.53) ^a	0.16 ($\pm$ 0.63) ^a	0.96
Metallic	0.00 ($\pm$ 0.00) ^a	0.19 ($\pm$ 0.74) ^a	0.00 ($\pm$ 0.00) ^a	0.09 ($\pm$ 0.53) ^a	0.20
Wet feather	0.00 ($\pm$ 0.00) ^a	0.00 ($\pm$ 0.00) ^a	0.19 ($\pm$ 0.74) ^a	0.00 ($\pm$ 0.00) ^a	0.03 ²⁾
Basic tastes					
Salty	7.03 ($\pm$ 1.49) ^a	7.53 ($\pm$ 1.46) ^a	5.81 ($\pm$ 1.79) ^b	6.34 ($\pm$ 1.88) ^b	<0.001
Sweet	0.47 ($\pm$ 0.51) ^{ab}	0.63 ($\pm$ 0.66) ^a	0.31 ($\pm$ 0.54) ^b	0.38 ($\pm$ 0.49) ^b	0.006
Sour	0.84 ($\pm$ 0.68) ^a	0.91 ($\pm$ 0.73) ^a	0.97 ($\pm$ 0.78) ^a	0.91 ($\pm$ 0.73) ^a	0.75
Bitter	0.53 ($\pm$ 0.67) ^a	0.72 ($\pm$ 0.77) ^a	0.53 ($\pm$ 0.62) ^a	0.75 ($\pm$ 0.72) ^a	0.15
Flavor characteristics					
Cooked chicken	5.31 ($\pm$ 1.23) ^a	5.06 ($\pm$ 1.39) ^{ab}	5.19 ($\pm$ 1.15) ^{ab}	4.88 ($\pm$ 1.26) ^b	0.047
Brothy	2.22 ($\pm$ 1.56) ^a	1.84 ($\pm$ 1.57) ^a	1.78 ($\pm$ 1.62) ^a	1.84 ($\pm$ 1.57) ^a	0.35
Blood serum metallic	1.53 ($\pm$ 1.70) ^{ab}	1.13 ($\pm$ 1.54) ^b	1.88 ($\pm$ 1.74) ^a	1.34 ($\pm$ 1.75) ^{ab}	0.02
Cardboard packaging	0.59 ($\pm$ 1.41) ^a	0.22 ($\pm$ 0.87) ^a	0.59 ($\pm$ 1.41) ^a	0.59 ($\pm$ 1.41) ^a	0.03 ²⁾
Warmed-over	1.84 ($\pm$ 1.80) ^{ab}	0.84 ($\pm$ 1.37) ^c	2.31 ($\pm$ 1.86) ^a	1.34 ($\pm$ 1.68) ^{bc}	<0.001
Roasted	2.81 ($\pm$ 1.33) ^{ab}	3.03 ($\pm$ 1.03) ^a	2.34 ($\pm$ 1.47) ^b	2.75 ($\pm$ 1.22) ^{ab}	0.02
Oxidized	0.28 ($\pm$ 0.89) ^a	0.19 ($\pm$ 0.74) ^a	0.38 ($\pm$ 1.01) ^a	0.25 ($\pm$ 0.88) ^a	0.83
Smoked	1.38 ($\pm$ 2.00) ^b	3.97 ($\pm$ 1.31) ^a	0.59 ($\pm$ 1.46) ^b	3.56 ($\pm$ 1.90) ^a	<0.001
Mouth-feeling characteristics					
Astringency	5.78 ($\pm$ 1.34) ^{ab}	5.47 ($\pm$ 1.54) ^b	5.88 ($\pm$ 1.21) ^a	5.84 ($\pm$ 1.32) ^{ab}	0.04
Metallic	0.81 ($\pm$ 1.77) ^{ab}	0.59 ($\pm$ 1.60) ^b	0.94 ($\pm$ 1.70) ^a	0.72 ($\pm$ 1.75) ^{ab}	0.02
Texture characteristics					
Hardness	5.63 ($\pm$ 0.79) ^a	5.66 ($\pm$ 0.83) ^a	6.03 ($\pm$ 0.90) ^a	5.75 ($\pm$ 0.67) ^a	0.12
Cohesiveness	5.63 ($\pm$ 0.83) ^a	5.56 ($\pm$ 0.88) ^a	5.50 ($\pm$ 0.72) ^a	5.66 ($\pm$ 0.83) ^a	0.84
Fibrousness	4.66 ($\pm$ 1.00) ^a	4.63 ($\pm$ 0.79) ^a	4.91 ($\pm$ 1.09) ^a	4.78 ($\pm$ 0.87) ^a	0.43
Moistness of mass	7.28 ($\pm$ 1.05) ^b	7.84 ($\pm$ 1.25) ^a	6.69 ($\pm$ 1.15) ^c	7.28 ($\pm$ 1.08) ^b	<0.001

All samples were evaluated for 28 sensory characteristics on 15-point universal scales (18) with references at four times on two different days.

¹⁾Mean ratings with different superscripts within each row represent a significant difference at $p < 0.05$.

²⁾Post hoc comparisons using Tukey's honestly significant difference (HSD) tests revealed no significant differences between chicken breast samples ($p > 0.05$).

renal diseases (25), further research is needed to maximize the smoking-enhanced saltiness perception of the cold-cut chicken breast. In other words, smoking treatment or liquid smoke might increase the saltiness perception without additional sodium, which may, in turn, help people reduce excessive sodium intake. Furthermore, smoking significantly decreased cooked chicken aroma ($p = 0.006$), cooked chicken flavor ($p = 0.01$), blood serum metallic flavor ($p = 0.007$), and metallic feeling ($p = 0.007$) (Table 3).

Moreover, smoking treatment significantly enhanced moistness of mass ($p < 0.001$). Interestingly, when a two-way ANOVA, treating sample and panel as fixed effects, was conducted, the moistness was rated significantly higher in the combination of marination and smoking treatments compared with individual marination ($p = 0.02$) or smoking ($p = 0.02$) treatment; moistness of mass was significantly lower in the

non-marinated cooked chicken meat ($p < 0.001$) (Table 2). In other words, moistness of mass seems to be a sensory characteristic specially associated with the combination of smoking and marination processes. Previous research showed that moistness of mass is correlated with the juiciness and tenderness of the meat (26). As most consumers like juicier and tenderer meat (27), the synergistic effect of smoking and marination on the moistness of mass may result in an increase in consumer acceptability of the cold-cut chicken breast meat; consumer testing is needed to determine the synergistic effect of smoking and marination on consumer acceptability. However, the two processes, i.e., smoking and marination, did not differ with respect to other textural characteristics such as hardness, cohesiveness, and fibrousness of the chicken breast meat. Morey *et al.* (13) reported similar results in their study, where smoking did not affect the textural properties of

Table 3. Three-way analysis of variance (*F*-values) of 28 sensory characteristics rated for cold-cut chicken breast samples

	Marination (M)	Smoking (S)	Panel (P)	M × S	M × P	S × P	M × S × P
Aroma characteristics							
Cooked chicken	0.07	7.81**	38.74***	0.58	0.54	1.80	0.47
Brothy	1.46	0.45	80.21***	0.02	0.72	1.44	1.00
Smoked	0.73	113.25***	3.45**	0.54	0.60	1.25	0.20
Warmed-over	0.00	6.72*	23.53***	0.31	1.67	1.18	1.74
Roasted	0.02	0.16	56.30***	1.42	2.18*	4.41***	0.38
Cardboard packing	2.00	0.00	0.86	0.00	0.86	1.14	1.14
Oxidized	0.15	1.37	1.37	2.05	0.19	0.95	0.85
Fishy	0.03	0.25	2.80*	0.03	0.41	1.38	0.41
Metallic	0.43	3.86	3.86**	0.43	0.43	3.86**	0.88
Wet feather	3.00	3.00	3.00**	3.00	3.00**	3.00**	3.00**
Basic tastes							
Salty	50.10***	9.20**	31.57***	0.01	4.73***	2.58*	0.41
Sweet	9.94**	2.88	21.03***	0.53	2.01	2.48*	1.47
Sour	0.62	0.00	31.12***	0.62	0.35	1.14	0.53
Bitter	0.03	5.34*	18.22***	0.03	0.47	1.30	1.19
Flavor characteristics							
Cooked chicken	1.92	6.23*	52.03***	0.08	1.13	2.19*	0.25
Brothy	1.31	0.67	22.18***	1.31	0.56	0.32	1.11
Blood serum metallic	2.72	7.54**	35.40***	0.13	1.85	2.62*	0.38
Cardboard packaging	3.27	3.27	67.38***	3.27	1.87	1.87	1.87
Warmed-over	5.09*	21.00***	15.88***	0.01	1.36	2.45*	0.71
Roasted	6.13*	4.26*	22.05***	0.38	0.37	2.04	0.94
Oxidized	0.29	0.56	5.54***	0.01	0.42	0.22	0.46
Smoked	5.18*	113.70***	5.13***	0.52	1.52	2.37*	0.51
Mouth-feeling characteristics							
Astringency	4.72*	2.54	71.23***	1.70	1.12	1.24	0.60
Metallic	2.46	7.54**	227.23***	0.00	3.25**	8.86***	0.79
Texture characteristics							
Hardness	3.69	0.92	5.14***	1.44	0.79	0.79	0.59
Cohesiveness	0.02	0.13	6.49***	0.71	0.31	0.89	0.48
Fibrousness	2.34	0.35	13.32***	0.12	0.28	0.25	0.47
Moistness of mass	18.25***	18.25***	22.06***	0.01	1.37	1.37	0.50

*, **, and *** indicate a significance at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively.

chicken/pork frankfurters.

To summarize, this study demonstrated that the effect of a combination of smoking and marination processes on the moistness of mass characteristics of cold-cut chicken breast was more pronounced than that of the two processes individually. Thus, a synergistic effect of marination and smoking on the moistness of mass characteristics of cold-cut chicken breast meat seems to be present. This implies that the combination of these two processes might help in producing juicer and tenderer chicken products. Based on the present findings, further studies should be conducted in a variety of treatment conditions to optimize the combination effect of marination and smoking on cold-cut chicken breast meat.

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References

1. Consumer Reports. Dangerous Contaminated Chicken. Available from: <http://www.consumerreports.org/cro/magazine/2014/02/the-high-cost-of-cheap-chicken/index.htm>. Accessed Sep. 11, 2015.
2. United States Department of Agriculture, Economic Research Service. Food Availability (Per Capita) Data System. Available from: [http://www.ers.usda.gov/data-products/food-availability-\(per-capita\)-data-system.aspx](http://www.ers.usda.gov/data-products/food-availability-(per-capita)-data-system.aspx). Accessed Sep. 30, 2015.
3. Ministry of Agriculture, Food and Rural Affairs. 2015 Agriculture, Forestry and Fishery Survey. Hanra Planning, Sejong, Korea pp. 344-345. (2015).
4. United States Department of Agriculture, Food Safety and Inspection Service. New regulations on *Salmonella* and *Campylobacter* on poultry. Available from: <http://www.fsis.usda.gov/wps/portal/%20fsis/topics/regulatory-compliance>. Accessed Sep. 30, 2015.
5. Vareltsis K, Soutos N, Koidis P, Ambroisiadis J, Genigeorgis C. Antimicrobial effects of sodium tripolyphosphate against bacteria attached to the surface of the carcasses. *LWT- Food Sci. Technol.* 30: 665-669 (1997)
6. Sallam KHI, Ishioroshi M, Samejima K. Antioxidant and antimicrobial effects of garlic in chicken sausage. *LWT-Food Sci. Technol.* 37: 849-855 (2004)

7. Samant SS, Crandall PG, O'Bryan C, Lingbeck JM, Martin EM, Seo HS. Sensory impact of chemical and natural antimicrobials on poultry products: A review. *Poult. Sci.* 94: 1699-1710 (2015)
8. Van Loo EJ, Caputo V, Nayga RM, Meullenet JF, Crandall PG, Ricke SC. Effect of organic poultry purchase frequency on consumer's attitude towards organic poultry meat. *J. Food Sci.* 75: S384-S397 (2010)
9. Rahman MS, Perera CO. Drying and Food Preservation. In: *Handbook of Food Preservation*. Rahman MS (ed). Marcel Dekker, Inc., New York, NY, USA. pp. 173-216 (1999)
10. Lingbeck JM, Cordero P, O'Bryan CA, Johnson MG, Ricke SC, Crandall PG. Functionality of liquid smoke as an all-natural antimicrobial in food preservation. *Meat Sci.* 97: 197-206 (2014)
11. Janky DM, Koburger JA, Oblinger JL, Riley PK. Effect of salt brining and cooking procedure on tenderness and microbiology of smoked cornish game hens. *Poult. Sci.* 55: 761-764 (1976)
12. Modi VK, Mahendrakar, NS, Sachindra NM, Narsimha Rao D. Quality of nuggets prepared from fresh and smoked spent layer chicken meat. *J. Muscle Foods* 15: 195-204 (2004)
13. Morey A, Bratcher CL, Singh M, McKee SR. Effect of liquid smoke as an ingredient in frankfurters on *Listeria monocytogens* and quality attributes. *Poult. Sci.* 91: 2341-2350 (2012)
14. Nuñez-González FA. Marination, cooking and curing: Principles. Vol. II, pp. 81-88. In: *Handbook of Poultry Science and Technology, Secondary Processing*. Guerrero-Legarreta I (ed). John Wiley and Sons Inc., Hoboken, NJ, USA. (2010)
15. Aberle ED, Forrest JC, Gerrard DE, Mills EW. *Principles of Meat Science*. 4th ed. Kendall/Hunt publishing Co., Dubuque, IA, USA pp. 173-253 (2001)
16. Alvarado C, McKee S. Marination to improve functional properties and safety of poultry meat. *J. Appl. Poultry Res.* 16: 113-120 (2007)
17. Pearson AM, Gillett TA. *Processed Meat*. 3rd ed. Chapman and Hall, New York, NY, USA. pp. 291-310 (1996)
18. Meilgaard M, Civille GV, Carr BT. *Sensory Evaluation Techniques*. 4th ed. CRC Press, Boca Raton, FL, USA. pp. 173-253 (2007)
19. Statista. U.S. households: Which kinds of cold cuts do you eat most often? Available from: <http://www.statista.com/statistics/279791/us-households-most-eaten-kinds-of-cold-cuts>. Accessed Apr. 11, 2016.
20. Lundahl DS, McDaniel MR. The panelist effect—fixed or random? *J. Sens. Stud.* 3: 113-121 (1988)
21. Luckett CR, Kuttappan VA, Johnson LG, Owens CM, Seo HS. Comparison of three instrumental methods for predicting sensory texture attributes of poultry deli meat. *J. Sens. Stud.* 29: 171-181 (2014)
22. Kwak HS, Ahn BH, Kim HR, Lee SY. Identification of sensory attributes that drive the likeability of Korean rice wines by American panelists. *J. Food Sci.* 80: S161-S170 (2015)
23. Mielche MM, Bertelsen G. Approaches to the prevention of warmed over flavor. *Trends Food Sci. Tech.* 5: 322-327 (1994)
24. Rhee KS. Chemistry of meat flavor. pp. 166-189. In: *Flavor Chemistry of Lipid Foods*. Min DB, Smouse TH (eds). American Oil Chemists' Society, Champaign, IL, USA. (1989)
25. He FJ, MacGregor GA. A comprehensive review on salt and health and current experience of worldwide salt reduction programs. *J. Hum. Hypertens.* 23: 363-384 (2009)
26. Otremba MM, Dikeman ME, Milliken GA, Stroda SL, Chambers IV E, Chambers D. Interrelationships between descriptive texture profile sensory panel and descriptive attribute sensory panel evaluations of beef Longissimus and Semitendinosus muscles. *Meat Sci.* 54: 325-332 (2000)
27. Saha A, Lee Y, Meullenet JF, Owens CM. Consumer acceptance of broiler breast filets marinated with varying levels of salt. *Poult. Sci.* 88: 415-423 (2009)