Physicochemical properties analysis of bamboo salt on chicken emulsion sausage

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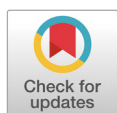https://orcid.org/0000-0001-5303-4595

Abstract

Quality characteristics of chicken emulsion sausage manufactured with various levels of NaCl and 9 times heated bamboo salt (0.3%, 0.6%, 0.9%, and 1.2% respectively) were examined. The pH value of chicken emulsion sausage was increase tendency with increasing amount of bamboo salt, on the contrary in case of NaCl sample were decrease tendency with increasing amount of NaCl. Both before and after heating, redness of chicken emulsion sausage with bamboo salt treatments were upward trend with increasing amount of bamboo salt. water holding capacity (WHC) of 1.2% NaCl sample was significantly higher than 0.3%–0.9% (p < 0.05), but 0.9%, 1.2% bamboo salt samples were significantly higher than 0.3, 0.6 % (p < 0.05). Water loss of 1.2% NaCl and 0.9% bamboo salt samples were significantly lower than other treatment (p < 0.05). Protein solubility values significantly increased amount of bamboo salt and NaCl (p < 0.05), and samples of 0.9% NaCl and 0.6% bamboo salt values show similar values. Cooking yield of samples were increased tendency with increasing amount of NaCl and bamboo salt. Also viscosity values of sample containing 1.2% bamboo salt sample showed higher viscosity than other treatments. These results show that containing 1.2% NaCl chicken emulsion sausage and 0.9% bamboo salt chicken emulsion sausage were similar physicochemical properties. Therefore, bamboo salt is suitable for manufacturing chicken emulsion sausage.

Keywords: Bamboo salt, Chicken, Low-salt, NaCl, Sausage

INTRODUCTION

According to the Korea National Health and Nutrition Examination Survey, the average daily consumption of sodium is showing a continuously decreasing trend with 4,027 mg in 2014, 3,890 mg in 2015, 3,890 mg in 2016, and 3,669 mg in 2017. However, the consumption level remains high, being almost two-fold higher than 2,000 mg, which is the recommended amount by the World Health Organization [1]. According to the survey by Nam [2], more than 50% of the respondents recognized the issue of over-consumption of sodium. Sodium over-consumption has been reported to induce disorders such as obesity, hypertension, strokes, diabetes, and cardiovascular diseases [3].

In the right amount, NaCl plays an important role in maintaining the homeostasis of our body, such as providing nutrients and removing waste from the cells, regulating blood salinity and pressure, and maintaining body moisture [4]. NaCl consumed through food significantly affects food taste, flavor, and

Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: Lee SH.
Data curation: Lee SH, Kim HY.
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Methodology: Kim HY, Kim GY.
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Ethics approval and consent to participate
This article does not require IRB/IACUC approval because there are no human and animal participants.

texture [5]. However, excessive intake of NaCl was brought up to harmful effect like hypertension, stroke, and kidney function decline [6]. Therefore, various studies are currently being conducted to decrease the salt concentration in paste, salted seafood, and kimchi industries [7]. These studies are mainly focusing on replacing NaCl with KCl, $MgCl_2$, $CaCl_2$, or natural substances [8].

In sausage production, it is difficult to extract optimum salt-soluble proteins below a certain level of salt concentration, leading to reduced emulsifying capacity, which negatively affects sausage taste and texture. Further, extraction of salt-soluble protein is greatly affected by pH change [9]. The lowest values of water holding capacity (WHC) in meat are observed around the isoelectric point at pH 5.2–5.4. Away from the isoelectric point, the cations and anions become more unbalanced, allowing water molecules to be incorporated [10] and increasing the WHC. Thus, the alkaline salts can be used to manufacture low-salt-processed meat products [11].

The alkaline salts include malt salt, yellow mud salt, baked natural sea salt, and bamboo salt. The bamboo salt is produced by placing natural sea salt in bamboo containers, covered and sealed with yellow mud, and baked at around 1,000℃ for 1–9 times [12]. In bamboo salt products baked for several times, the calcium and potassium contents increased, making the final salt alkaline [13]. The bamboo salt exhibits antioxidant activity in food and contributes to reducing the acidification in the body, which causes various diseases [14]. Kim et al. [15] reported bamboo salt to be effective in inhibiting dental plaque, reducing gum disease, and reducing bacteria in the oral cavity. Bamboo salt products have been developed and are being used as soybean paste, red pepper paste, soy sauce, soap, and cosmetics [16]. However, using bamboo salt for low-salt meat product was not been studied, and studies are required to bamboo salt on meat product. Therefore, this study aimed to compare and analyze chicken breast emulsion sausage with bamboo salt and NaCl.

MATERIALS AND METHODS

Preparation of NaCl and bamboo salt on chicken emulsion sausage
The chicken emulsion sausage used in this experiment were manufactured using chicken breast (ShinwooFS, Chungnam, Korea) 24 hours after butcher. The breast meat and pork lard ground using a grainder with 3 mm plates (PA-82, Mainca, Barcelona, Spain). The chicken breast meat, pork back fat, ice emulsified in a bowl cutter (K-30, Talsa, Valencia, Spain). 8 Samples made with 9 times heated bamboo salt (Kaeam food, Jeonbuk, Korea) and NaCl added 0.3%, 0.6%, 0.9%, and 1.2% respectively. The emulsion was filled with the stuffer (EM-12, Mainca, Barcellona, Spain) and heated for 40 min in the 80℃ chamber (10.10ESI/SK, Alto Shaam, WI, USA). After heating, it was cooled at 10℃ for 20 min. The sausages manufactured were kept at 4℃ and tested. The bamboo salt was contained 37.4% Na, 57.5% Cl, 0.55% K, 0.5% Ca, 0.52% Mg, 0.0093% Fe, 0.0026% Mn, 0.00085% Zn, 0.56% Si, and 0.86% S. The color of bamboo salt was CIE L*: 84.2, CIE a*: 2.5, CIE b*: 15.3.

pH
pH is measured mixing 4 g of sample and 16 ml of distilled water using anura turrax (HMZ-20DN, Pooglim Tech, Seongnam, Korea). Homogenizing for one min at 14,336 ×g and measuring a glass electrode pH meter (Model S220, Mettler-Twoldo, Schwitzer, Switzerland).

Instrumental color
Before and after heating the chicken emulsion sausage were measured and recorded. Color value were display the lightness (CIE L*), the redness (CIE a*) values and the yellowness value (CIE b*) using the colorimetric (CR-10, Minolta, Tokyo, Japan). The color calibrated with a white plate (CIE

L*: +97.83, CIE a*: −0.43, CIE b*: +1.98).

Protein solubility

Protein solubility of chicken emulsion sausage was determined following Farouk and Swan [17]. The total protein solubility was added 20 mL of buffer (1.1 M potassium iodide in 0.1 M potassium phosphate buffer) in a 2 g sample. The sarcoplasmic protein solubility measured mixture added to the 2 g raw sample with buffer (0.025 M potassium phosphate). Each sample were homogenized using homogenizer (AM-5, Nihonseiki, Kaissa, Tokyo, Japan) at 8,064 ×g for 2 min. After homogenized, keep for 16 hour at 4℃. Two sample filter using filter paper. The sample supernatant was measured by absorbance of 540 nm using multi-mode microplate reader (Spectra Max iD3, Molecular devices, CA, USA). Myofibrillar protein solubility were calculated by difference between total and sarcoplasmic protein solubility.

Water-holding capacity (WHC)

The experiment was conducted using centrifugation to measure the water-holding capacity of chicken emulsion sausage. Put in a cotton under the conical tube and seal the heated sample in a filter paper. Weighed before and after turning to the machine (temperature: 4℃, 224 ×g, time: 10 min). The moisture content was measured by the drying oven method at 105℃ [18].

$$WHC~(\%) = \frac{A - B}{A} \times 100$$

A = (Weight before centrifuge (g) × Water content (%)) / 100
B = (Weight before centrifuge − Weight after centrifuge)

Emulsion stability

A 15 mesh sieve (4 × 4 mm was placed in the under of a graduated glass tube and filled meat emulsion. Chicken emulsion sausage were cooked at 80℃ for 40 min using chamber (10.10ESI/SK, Alto Shaam, WI, USA). After cooling to approximately 4 ± 1℃ for 20 min. After cooling, The layer of water and fat were measured and calculated.

$$Water~exudation = \frac{The~water~layer~(mL)}{Raw~meat~better~weight~(g)} \times 100$$

$$Fat~exudation~(\%) = \frac{The~fat~layer~(mL)}{Raw~meat~better~weight~(g)} \times 100$$

Cooking yield

The weight before and after heating of the chicken emulsion sausage heated to 80℃ for 40 min was recorded. Cooking yield was calculated. The following formulation is to calculate the cooking yield.

$$Cooking~yield~(\%) = \frac{Weight~after~cooking~(g)}{Weight~before~cooking~(g)} \times 100$$

Texture profile analysis (TPA)

TPA of the chicken emulsion sausage were heated for 40 min in the 80℃ chamber (10.10ESI/SK, Alto Shaam Co., WI, USA) and cooled for 20 min at 10℃. Cooked sausage size of ⌀ 2.5 × 2.0 cm

(height) was measured using Texture Analyzer (TA 1, Lloyd Co., FL, USA). The analysis condition are set to pre-test speed 2.0 mm/s, post-test speed 5.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 8.0 mm, force 5 g equipped with 25 mm cylinder probe.

Apparent viscosity

The viscosity of the chicken emulsion sausage with NaCl and bamboo salt were investigated at $20 \pm 1^{\circ}C$ using a rotational viscometer (MerlinVR, Rheosys, USA) equipped with 30 mm parallel plate 2.0 mm gap at $25^{\circ}C$ under a shear rate of 4.48 ×g.

Statistical analysis

Conduct an experiment were evaluation at least 3 times under each condition. After experiment, results were expressed mean value and standard deviation using SAS (version 9.3 for window, SAS Institue Inc., NC, USA) and verified significant difference with ANOVA, Duncan's multiple range test.

RESULTS AND DISCUSSION

pH, color

Table 1 indicates the results for the pH and the color of chicken emulsion sausage as a function to the amount of added NaCl and bamboo salt, respectively. The treatment group with added bamboo salt before and after cooking showed significantly higher pH values compared to the control group with NaCl ($p < 0.05$). The pH showed an increasing trend with increasing the amount of bamboo salt. This could be the result of acidic pH of NaCl with pH 5.4 and alkaline pH of bamboo salt with pH 9.11. Research results of Choi et al. [19] also showed the highest pH after cooking meat with bamboo salt compared to other groups using various types of salt, which is in agreement with this study. Kim et al. [20] reported that the increased addition bamboo salt of 9 times heated led to an increase in pH, which is also in agreement with this study.

The color before cooking in food products showed an intensification trend of lightness with increased bamboo salt, which can be due to the high lightness of bamboo salt with 84.2. The explanation of the redness color intensification before and after cooking may be related to the formation of nitroso-myoglobin from bonding of nitrite and myoglobin in the bamboo salt [21]. There was no significant difference in lightness, redness color, and yellowness for NaCl addition before cooking, but the redness color intensified after cooking. In the study by Park et al. [22] on the redness of sausage with NaCl addition reported that increased NaCl leads to an intensification in the redness,

Table 1. pH, color of chicken-breast sausage formulated with various levels of NaCl and bamboo salt

Traits			NaCl (%)				Bamboo salt (%)			
			0.3	0.6	0.9	1.2	0.3	0.6	0.9	1.2
pH	Uncooked		5.73 ± 0.02[d]	5.68 ± 0.02[e]	5.68 ± 0.01[e]	5.65 ± 0.02[e]	5.77 ± 0.01[c]	5.90 ± 0.02[b]	5.93 ± 0.02[b]	5.94 ± 0.09[a]
	Cooked		6.10 ± 0.04[d]	5.87 ± 0.02[e]	5.87 ± 0.03[e]	5.85 ± 0.16[e]	5.95 ± 0.04[c]	6.05 ± 0.03[b]	6.08 ± 0.02[a]	6.09 ± 0.01[a]
Color	Uncooked	CIE L*	70.68 ± 1.02[a]	68.86 ± 0.84[bc]	68.86 ± 0.25[bc]	68.70 ± 0.47[bcd]	69.20 ± 0.25[b]	67.76 ± 0.53[d]	69.20 ± 0.81[bcd]	72.8 ± 0.57[d]
		CIE a*	3.77 ± 0.12[b]	3.73 ± 0.15[b]	3.67 ± 0.09[bc]	3.62 ± 0.28[bc]	3.45 ± 0.12[c]	3.55 ± 0.05[bc]	3.77 ± 0.09[b]	4.32 ± 0.12[a]
		CIE b*	15.4 ± 0.34[bc]	15.9 ± 0.40[c]	15.6 ± 0.12[bc]	15.5 ± 0.17[bc]	16.5 ± 0.45[a]	15.6 ± 0.37[bc]	15.9 ± 0.31[b]	15.2 ± 0.22[c]
	Cooked	CIE L*	78.9 ± 0.40[a]	78.5 ± 0.45[ab]	78.0 ± 0.09[ab]	77.6 ± 1.04[b]	79.0 ± 0.80[a]	77.8 ± 1.07[b]	78.0 ± 0.28[ab]	78.0 ± 0.53[ab]
		CIE a*	3.55 ± 0.1[c]	3.65 ± 0.19[bc]	3.72 ± 0.09[bc]	4.00 ± 0.21[ab]	3.67 ± 0.09[bc]	4.00 ± 0.21[ab]	4.20 ± 0.52[a]	4.17 ± 0.25[a]
		CIE b*	14.5 ± 0.17[b]	14.3 ± 0.18[bc]	14.9 ± 0.39[a]	14.0 ± 0.21[cd]	13.8 ± 0.17[d]	13.4 ± 0.34[e]	13.3 ± 0.35[e]	13.3 ± 0.19[e]

All values are mean ± SD.

[a–e] Mean in the all treatment with different letters are significantly different ($p < 0.05$).

which is in agreement with this study.

WHC, emulsion stability, protein solubility

WHC and emulsion stability of chicken emulsion sausage as a function to the amount of added NaCl and bamboo salt addition is shown Table 2. The WHC is important in emulsion since it determines the maintenance of the matrix structure of moisture, protein, and fat during salt addition [23]. The WHC showed an increasing trend with increasing NaCl and bamboo salt content, and the group with 1.2% bamboo salt showed a significantly higher WHC compared to all other treatment groups ($p < 0.05$). This is due to an increased WHC in pH further from the isoelectric point (pH 5.2–5.6) [20]. The 0.9% and 1.2% bamboo salt treatment groups had higher pH values compared to the other treatment groups. Similar to the results of this study, Debut [24] reported a decreased pH value leading to a decreased WHC value in chicken meat.

The results of chicken emulsion stability indicated that the 0.3% NaCl treatment group had significantly higher moisture contents compared to all the other treatment groups ($p < 0.05$), and the fat contents showed a decreasing trend with increased addition of both NaCl and bamboo salt. An explanation might be the reduced moisture contents with increased WHC due to strengthened cross-linked bonds between protein and water molecules. Kim et al. [20] studied sausages added with NaCl, alkaline salt, bamboo salt baked 2 and 9 times, and the results showed the treatment group with bamboo salt baked 9 times with high pH had the lowest moisture content, similar to the results of this study. This suggests that the use of bamboo salt with high pH can increase the WHC of meat products to produce food with excellent texture.

The protein solubility for NaCl and bamboo salt addition is shown in Table 3. The salt-soluble proteins affect the WHC, texture, and preference of sausage emulsion, and thus, have important effects on the final product [25]. The solubility of sarcoplasmic protein, myofiblilar protein, and total protein showed an increasing trend with increased NaCl and bamboo salt content, and the protein

Table 2. WHC and emulsion stability of chicken-breast sausage formulated with various levels of NaCl and bamboo salt

Traits		NaCl (%)				Bamboo salt (%)			
		0.3	0.6	0.9	1.2	0.3	0.6	0.9	1.2
WHC (%)		67.88 ± 0.74[b]	69.96 ± 1.35[b]	70.55 ± 1.90[b]	71.40 ± 0.43[a]	69.28 ± 1.28[b]	68.41 ± 0.25[b]	76.56 ± 0.41[a]	81.37 ± 1.30[a]
Emulsion stability (%)	Water loss (%)	12.45 ± 0.87[a]	7.24 ± 0.56[b]	6.22 ± 0.50[b]	5.30 ± 0.29[b]	8.35 ± 0.62[b]	6.92 ± 0.15[b]	5.46 ± 0.29[b]	4.64 ± 0.34[b]
	Fat loss (%)	0.47 ± 0.19[a]	0.26 ± 0.13[ab]	0.12 ± 0.12[bcd]	0.04 ± 0.03[d]	0.38 ± 0.10[ab]	0.20 ± 0.06[bcd]	0.11 ± 0.10[cd]	0.03 ± 0.02[cd]

All values are mean ± SD.

[a–d]Mean in the all treatment with different letters are significantly different ($p < 0.05$).

WHC, water holding capacity.

Table 3. Protein solubility of chicken-breast sausage formulated with various levels of NaCl and bamboo salt

Traits	NaCl (%)				Bamboo salt (%)			
	0.3	0.6	0.9	1.2	0.3	0.6	0.9	1.2
Total protein (μg/μL)	1,053.66 ± 0.49[f]	1,063.18 ± 0.49[e]	1,248.70 ± 0.49[c]	1,249.56 ± 0.49[c]	1,009.52 ± 0.99[g]	1,185.51 ± 0.49[d]	1,344.49 ± 0.49[b]	1,395.26 ± 0.86[a]
Myofibilla protein (μg/μL)	807.27 ± 0.49[g]	836.12 ± 0.86[f]	1,018.75 ± 0.86[d]	1,028.27 ± 0.86[c]	785.92 ± 1.32[h]	961.91 ± 0.99[e]	1,106.75 ± 0.86[b]	1,151.47 ± 0.99[a]
Sarcoplasmic protein (μg/ μL)	246.39 ± 0.50[a]	227.06 ± 0.50[e]	229.95 ± 0.49[d]	221.29 ± 0.49[g]	223.60 ± 0.39[f]	223.74 ± 0.45[f]	237.74 ± 0.45[c]	243.80 ± 0.49[b]

All values are mean ± SD.

[a–h]Mean in the all treatment with different letters are significantly different ($p < 0.05$).

solubility of the 0.6%–1.2% bamboo salt treatment groups, with the exception of the 0.3% bamboo salt treatment group, showed higher values compared to the NaCl group. According to the report by Kenney and Hunt [26], the emulsion in the 4% NaCl treatment group indicated the highest protein solubility among the 2 and 4% NaCl treatment, similar to the results of this study. This suggests that the bamboo salt has outstanding emulsion capacity and can be used to produce low salt meat products since its alkaline pH increases the WHC and the protein solubility.

Cooking yield, viscosity, and TPA

Fig. 1 shows the cooking yield of the chicken emulsion sausage according to the amount of added NaCl and bamboo salt, indicating an increased trend of cooking yield with increased NaCl and bamboo salt contents. Compared to the 0.3 and 0.6% NaCl treatment groups and the 0.3% bamboo salt treatment group, the 1.2% bamboo salt treatment group had a significantly higher cooking yield ($p < 0.05$). This could be due to an increased amount of extracted salt-soluble protein with increased salt addition, leading to stronger binding; the extracted salt-soluble protein increased the WHC, which in turn, increased the cooking yield. This is similar to the results of the study by Sikes et al. [27] that reported a decreased cooking yield at lower NaCl contents, where the binding capacity of emulsion increased with the bonding between moisture, fat, and protein, reducing the amount of water and oil separation [28].

The viscosity values of emulsion obtained with NaCl and bamboo salt respectively are shown in Fig. 2. The results indicated that the 0.3% NaCl has the lowest value and the 1.2% bamboo salt treatment group has the highest one. The emulsion treated with 0.9% NaCl and 0.3% bamboo salt exhibited similar viscosity values. Also, the values of the 1.2% NaCl and 0.6% bamboo salt groups were similar. Aktas and Genccelep [29] reported that the emulsion viscosity and stability are positively correlated, and the emulsion stability has an important role in the quality of meat products, thus viscosity being an important indicator for emulsion stability. Further, Zhao [30] reported that the increased emulsion viscosity lead to increase the score in sensory evaluation. Therefore, the emulsion with high viscosity can play an important role in the cooking yield, the WHC, and the physical properties of manufactured products.

The texture properties directly affect the customer's choice, therefore, it is important to analyze the optimum values [31]. The results of the TPA measurements of the chicken breast sausage with added NaCl and bamboo salt are presented in Table 4. Hardness was similar between the 0.9%
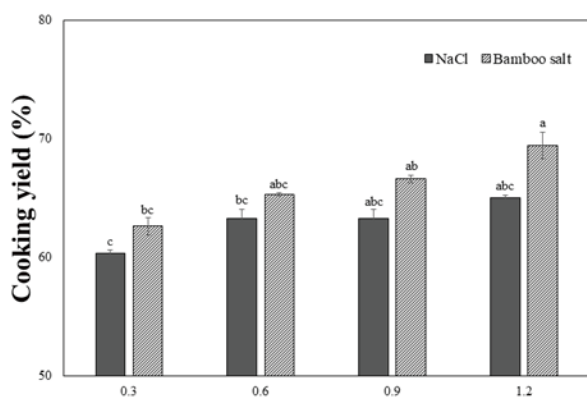

Fig. 1. Cooking yield of chicken-breast sausage formulated with various levels of NaCl and bamboo salt. [a,b]Mean in the all treatment bars with different letters are significantly different ($p < 0.05$).
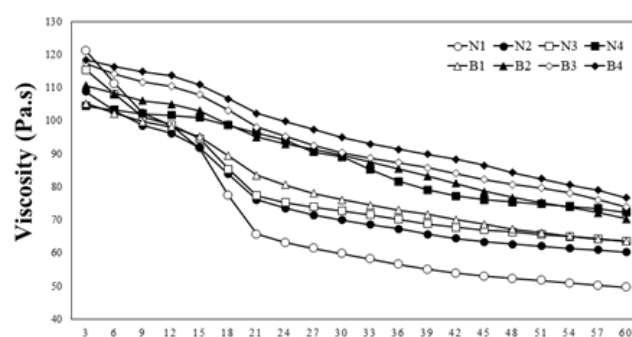

Fig. 2. Change of apparent viscosity on chicken-breast sausage formulated with various levels of NaCl and bamboo salt. N1, sausage with 0.3% NaCl; N2, sausage with 0.6% NaCl; N3, sausage with 0.9% NaCl; N4, sausage with 1.2% NaCl; B1, sausage with 0.3% bamboo salt; B2, sausage with 0.6% bamboo salt; B3, sausage with 0.9% bamboo salt; B4, sausage with 1.2% bamboo salt.

Table 4. Texture properties analysis of chicken-breast sausage formulated with various levels of NaCl and bamboo salt

Traits	NaCl (%)				Bamboo salt (%)			
	0.3	0.6	0.9	1.2	0.3	0.6	0.9	1.2
Hardness (kgf)	4.54 ± 0.34[d]	5.44 ± 0.35[c]	5.86 ± 0.30[bc]	6.32 ± 0.30[a]	5.44 ± 0.36[c]	5.84 ± 0.37[bc]	5.91 ± 0.61[ab]	6.34 ± 0.44[a]
Springness	0.83 ± 0.06[a]	0.79 ± 0.06[ab]	0.82 ± 0.08[a]	0.81 ± 0.01[ab]	0.75 ± 0.11[ab]	0.78 ± 0.06[ab]	0.82 ± 0.06[a]	0.73 ± 0.03[b]
Cohesiveness	0.47 ± 0.03[ab]	0.50 ± 0.08[ab]	0.49 ± 0.08[ab]	0.50 ± 0.04[ab]	0.45 ± 0.09[b]	0.51 ± 0.05[ab]	0.54 ± 0.08[a]	0.47 ± 0.05[ab]
Gumminess (kgf)	2.16 ± 0.18[c]	2.78 ± 0.58[ab]	2.91 ± 0.49[ab]	3.19 ± 0.37[a]	2.46 ± 0.54[bc]	3.01 ± 0.48[a]	3.18 ± 0.38[a]	3.00 ± 0.45[a]
Chewiness (kgf)	1.79 ± 0.17[c]	2.22 ± 0.58[abc]	2.44 ± 0.62[ab]	2.59 ± 0.33[a]	1.90 ± 0.62[bc]	2.36 ± 0.51[ab]	2.63 ± 0.46[a]	2.22 ± 0.41[abc]

All values are mean ± SD.

[a–c]Mean in the all treatment with different letters are significantly different ($p < 0.05$).

NaCl and 0.6% bamboo salt groups. This similarity could be due to the higher WHC in bamboo salt with alkaline pH. Further, increased NaCl and bamboo salt contents led to increasing values of hardness, which is in agreement with the report by Ruusunen et al. [32] showing increasing hardness with increased addition of NaCl in a frankfurter.

CONCLUSION

These results of this research suggest that bamboo salt can be used as a low salt in chicken emulsion sausage. Added at 0.9% bamboo salt were similar 1.2% NaCl, the addition of 0.9% bamboo salt can enhance the low salt chicken emulsion sausage. Furthermore, bamboo salt on meat would probably result in better than those that use NaCl.

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