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ARTICLE

Effects of Partial Substitutions of NaCl with KCl, $CaSO_4$ and $MgSO_4$ on the Quality and Sensorial Properties of Pork Patties

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Abstract

This study investigated the effects of NaCl replacers (KCl, $CaSO_4$, and $MgSO_4$) on the quality and sensorial properties of pork patty. In the characteristics of spray-dried salt particles, KCl showed the largest particle size with low viscosity in solution. Meanwhile $CaSO_4$ treatment resulted in the smallest particle size and the highest viscosity ($p<0.05$). In comparison of the qualities of pork patties manufactured by varying level of Na replacers, $MgSO_4$ treatment exhibited low cooking loss comparing to control ($p<0.05$). Textural properties of KCl and $MgSO_4$ treatments showed similar pattern, i.e., low level of the replacers caused harder and less adhesive texture than those of control ($p<0.05$), whereas the hardness of these products was not different with control when the replacers were added more than 1.0%. The addition of $CaSO_4$ also manifested harder and less adhesive than control ($p<0.05$), but the textural properties of $CaSO_4$ treatment was not affected by level of Ca-salt. Eventually, sensorial properties indicated that KCl and $CaSO_4$ influenced negative effects on pork patties. In contrast, $MgSO_4$ showed better sensorial properties in juiciness intensity, tenderness intensity as well as overall acceptability than control, reflecting that MgSO4 was an effective Na-replacer in meat product formulation.

Keywords: sodium-replacements, potassium, calcium, magnesium, porcine-patty

Introduction

Sodium is an essential mineral to regulate physiological reaction in living bodies, thereby maintaining life (Durack *et al*., 2008; Kuwabara, 2010; SACN, 2003). Major dietary sources of sodium are from salt as a condiment or processed food containing salt as an additive (Alino *et al*., 2009; Engstrom *et al*., 1997; Stamler, 1997). Sodium is a viral constituent of the body and thus is an essential nutrient. However, high levels of salt intake have been associated with hypertension, also known as high blood pressure (HBP) which leads to cardiovascular disease (CVD) (Alino *et al*., 2010c; He and MacGregor, 2008). In meat processing, NaCl plays a key role in extending shelf-life and improving processing qualities such as extraction of salt-soluble proteins, thermal protein gelation and water-binding. In addition, salty flavor manifested by NaCl is an important sensorial property of meat products (Ruusunen and puolanne, 2005).

From the human health point of view, Na content has to be reduced in the formulation. Two kinds of approaches are possible to achieve low Na product manufacturing, i.e., the usage of Na replacer and flavor enhancer (Armenteros *et al*., 2012; Matthew and Strong, 2005). KCl is representatively used to provide salty taste for the purpose of the former. Meanwhile, the letter includes hydrolyzed proteins or yeast extract (Canto *et al*., 2014). Regardless of the mentioned approaches, both techniques are effective in reducing Na content in food formulation. On the other hand, reducing NaCl directly triggers deterioration of quality characteristics such as poor water-binding and texturization in the case of meat products (Desmond, 2006; Doyle and Glass, 2010; Ruusunen *et al*., 2005). For that reason, the usage of Na replacer would be appropriate technique to apply meat processing rather than flavor enhancer.

Theoretically, replaced salts, particularly KCl would maintain the quality and sensorial characteristics of meat products like the products manufactured with NaCl. Armenteros *et al*. (2009a) and Ripolles *et al*. (2011) reported that sensorial properties of meat products with

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substitution of NaCl up to 50% of KCl were not significantly different. One of disadvantage in the usage of KCl was that it affected sensorial properties of meat products, negatively (Gou *et al*., 1996). There were several studies reported that replacing 40% NaCl with KCl generated bitter flavor which attribute negative sensorial properties (Gelabert *et al*., 2003; Gou *et al*., 1996).

Sensory evaluation of dry-cured loin formulated with 15% NaCl substitution to $CaCl_2$ or $MgCl_2$ did not show significant difference (Armenteros *et al*., 2009b). According to Ruusunen *et al*. (2005), phosphate (P_2O_5) effectively reduced sodium content in ground meat patties. Toldra and Barat (2009) noted that salt mixture with low sodium chloride and high organic salts including magnesium and calcium orthophosphate were preferable for reduction of sodium content in food formulation. Ripolles *et al*. (2011) and Armenteros *et al*. (2012) indicated that replacement of NaCl content with other chloride salts could effectively control the final flavor of the dry-cured ham. In other case, it was still unclear if there was an optimum substitution level (Na-equivalent) for those Na-replacers (Alino *et al*., 2010a; Horita *et al*., 2011). Alino *et al*. (2010b) reported that 25% of potassium, 15% of calcium, and 5% of magnesium substitutes had no significant effect on the physicochemical characteristics and microbial counts of dry-cured loins. Despite of numerous in- vestigations, the results regarding the type and replacing level of non-Na salts are still contradictory. For that reason, this study investigated the effects of NaCl replacer (KCl, $CaSO_4$, and $MgSO_4$) on the quality and sensorial characteristics of pork patties.

Materials and Methods

Materials

All salt replacers (KCl, $CaSO_4$ and $MgSO_4$) were purchased from Sigma-Aldrich Co. (USA). Food grade NaCl and maltodextrin (MD) was obtained from a local market. Pork leg and backfat were purchased at 48 h post-mortem from three carcasses randomly. Meat and fat were separately ground through 3 mm plate and vacuum-packed with polyethylene pouch. Prior to pork patty preparation, the ground meat and fat were kept at 4°C within 3 h. For repeated experiments, the meat was purchased at the same market on three different days (n=3).

Preparation of low-Na salt particles

In order to reduce the sodium ion (Na^+) levels, K-salt (KCl), Ca-salt ($CaSO_4$), and Mg-salt ($MgSO_4$) were substituted with partial amount of Na-salt (NaCl). Control group was prepared by mixing 10% (w/v) of MD with 20% (w/v) of NaCl in water. Low-Na salts were also prepared by mixing 13% (w/v) NaCl and 10% (w/v) MD in water with 7% (w/v) KCl, $CaSO_4$, and $MgSO_4$, respectively. Each mixture was completely dissolved using a magnetic stirrer at 500 rpm for 30 min. After fully dissolution of all mixtures, solutions were spray-dried by the condition of 0.6 m^3/min blowing power, 500 mL/h flow rate, 150°C inlet temperature, and 180 kPa atomizing pressure.

Microstructure of low-Na salt particles

All powdered salts were kept in desiccator prior to analyses. For morphology observation, sample powders were gold-coated with platinum for 40 s using an ion sputter (E-1010, Hithachi, Japan) and microstructures were taken using a scanning electron microscope (FE-SEM, S-4700, Hitachi, Japan) at 15 mA current. The images contained above 100 particles were chosen for particle size determination. Particle diameters were automatically measured and analyzed with image analysis software (UTHSCSA, USA), whereby the average surface dimension and cumulative frequency graph were obtained.

Rheological property of low Na-salts

Salt powders (1%, w/w) were dissolved in water and aliquot 1 mL of the solution was loaded into sample cup. Rheology of the solution was determined using a Rheometer (MCR-302, Anton-Paar, USA) equipped with a concentric cylinder measuring geometry 303316 standard (DG26.7/T200/AL). The solution was sheared by linearly increasing shear rate (γ) from 1/s to 100/s for 500 s under the constant temperature of 25°C. Shear force (τ) was measured at 5 s interval. Samples viscosity (μ) was calculated by $\mu=\tau\cdot\gamma$ relationship.

Preparation of pork patty

Pork patties were formulated as followings; ground pork (78.8%, w/w), fat (19.7%, w/w), and various salts (total 1.5%, w/w) were mixed using a food mixer (5K5 SS, kitchen Aid, USA), and shaped with patty thickness of 3 cm. Pork patties were separately vacuum-packed in polyethylene pouch and cooked in 95°C water bath for 30 min. Cooked patties were cooled down at ambient prior to analyses.

Qualities of pork patties

Quality analysis of the pork patty was analyzed by cooking loss and compression test. The pork patties were weighed before and after cooking for the analysis of exudation value, and cooking loss were expressed as percentage of initial weight. For evaluation of textural properties, pork patties were cut into 2 cm^3 cubes and compressed using a texture analyzer (CT3 Texture Analyzer, BROOKFIFLD, USA) equipped with TA43 sphere 25.4 mm D probe (BROOKFIFLD, USA) under 10 mm target value, 20 g trigger load, 0.50 mm/s test speed. All samples were determined 6 times to eliminate technical errors.

Sensory test

For the sensory evaluation, porcine patties were cut into 2 cm cubes, and saltiness, juiciness, tenderness, and overall acceptability were evaluated. Sensory evaluation was carried out by using ranking method. For data analysis, samples were scored from 1 (least value) to 4 (highest value). The ratings were evaluated by relative ratio of total score of each group against control group. For salt release rate analysis, 2 cm cubes of pork patties were wrapped in cotton and submerged into 100 mL of water. Release rate graphs were obtained by determining salinity of each sample for 180 min using a SevenCompact S230 conductivity meter (Mettler Toledo AG, CH-8603, Switzerland).

Statistical analysis

The evaluation of the physicochemical and sensory properties of pork patty was done by the one-way analysis of variance (ANOVA) using a SAS statistical analysis program (ver. 9.1) and the means were compared by Duncan's multiple range test when the main effect was significant ($p<0.05$).

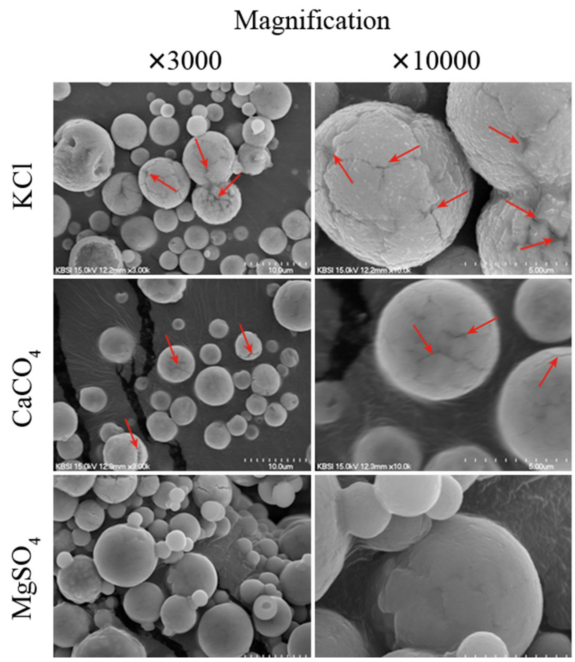

Fig. 1. SEM image of spray-dried salt micro-particles. Red arrows indicate cracks and holes on particle surface.

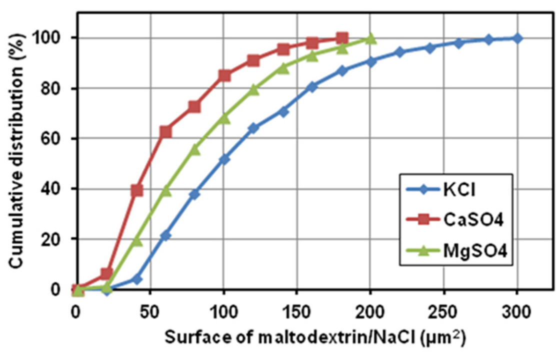

Fig. 2. Cumulative distributions of surface dimensions of spray-dried salt micro-particles.

Results and Discussion

Characteristics of low-Na salts

The morphology of salt crystals was different depending on type of salts (Fig. 1). For KCl particles, its boundaries were not clear. In particular, cracks or hollows on the particles were observed at ×10,000 magnification. The surface of KCl was not smooth, uneven rugged appearance and also empty micro-particles were observed. Both $CaSO_4$ and $MgSO_4$ salts were also showed a similar tendency but smoother surface appearance comparing to that of KCl. For particle size distribution (Fig. 2), KCl exhibited the largest particle size followed by $MgSO_4$ ($p<0.05$). $CaSO_4$ showed the smallest particle size ($p<0.05$). On the basis of 60% cumulative frequency, particle sizes of $CaSO_4$, $MgSO_4$, and KCl were 50 m^2, 80 m^2, and 110 m^2, respectively. No information regarding how salts attributed the morphology and particle size is available. Because the particle sizes of spray-dried samples were depending on the mass flow ratio (Costantino *et al*., 2000), it would also be closely related with rheological properties of the salt solution during spray-drying.

Flow behaviors of each salt solution are given in Fig. 3. All salts were highly soluble in water and the solution contained only 1% of salts, and the tested samples displayed a Newtonian fluid-like flowing behavior (Fig. 3A).

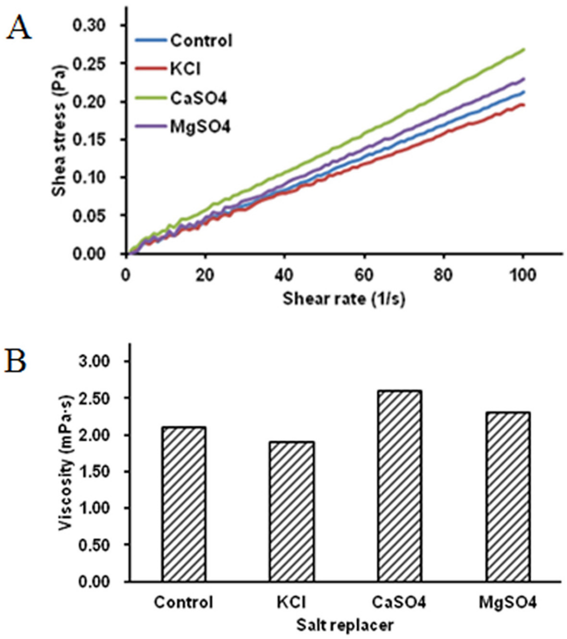

Fig. 3. Changes in (A) shear stress-strain relationship and (B) viscosity of salt solutions.

Meanwhile, shear stress of the samples indicated different responses with type of salts, reflecting Na-replacers had a different viscosity (Fig. 3B). KCl treatment (7% KCl + 13% NaCl) tended to decrease the viscosity of the solution comparing to control (20% NaCl), although the difference was not significant. Nevertheless, low viscosity of KCl would account for the largest particle size as mentioned above. Owing to low viscosity, the KCl solution would have high mass flow in the nozzle of spray-dryer, reflecting the large particle formation (Soottitantawat *et al*., 2003). The relationship between particle size and viscosity was also identified in $CaSO_4$ and $MgSO_4$ treatments. The former did not show a difference in viscosity comparing to control, while that of the latter was significantly higher than control (p<0.05). The higher the viscosity, the smaller the particle size of the salts. In addition, it was hypothesized that rheological properties of salts would influence on the saltiness. Depending on the flow behavior, sodium release rate will be different, that plays important role for recognition in the mouth.

Characteristics of pork patties

Since Na replacers exhibited different particle size and rheological properties, Na release rate would vary and it possibly resulted in different organoleptic properties. The release rate of Na as a function of time is presented in Fig. 4. Irrespective of type of salts, increasing level of Na

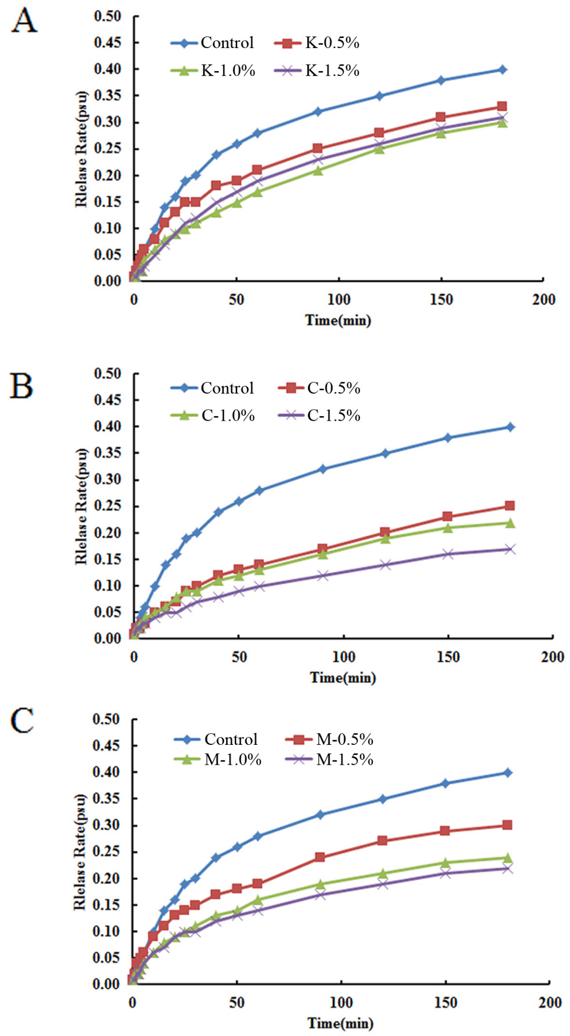

Fig. 4. Changes in salinity release rates of pork patties manufactured with NaCl substitution with (A) KCl, (B) $CaSO_4$ and (C) $MgSO_4$.

replacers delayed the Na release from pork patties. In comparison of Na replacers, release rate was fast in the order of KCl, $MgSO_4$ and $CaSO_4$. Probably, $CaSO_4$ would be adsorbed on the surface of NaCl more compact, causing small particle size and slow release of Na. In contrast, KCl formed a porous or cracked layer on the surface of NaCl, hence accelerating Na release. Eventually, the results reflected that rheological properties attributed the size of salt particles and rheology of the surface layer by which Na-release was affected.

For quality characteristics, Na replacers provided different characteristics comparing to control. Cooking loss of KCl or $CaSO_4$ treatments was significantly higher than control regardless of the replacer levels (p<0.05) with the exception of 1.0% KCl treatment (K-1.0%) (Table 1). Meanwhile, 0.5-1.0% $MgSO_4$ treatments showed signifi-

Table 1. Effect of salt substitutes on cooking loss of porcine patties

Replacer	Replacer concentration (%)			
	0	0.5	1.0	1.5
Cooking loss (%)				
KCl	27.7±0.94[a]	32.0±2.77[a]	25.5±2.13[b]	30.9±1.36[a]
$CaSO_4$	27.7±0.94[a]	31.6±0.90[a]	31.2±2.71[a]	31.1±0.48[a]
$MgSO_4$	27.7±0.94[a]	13.3±1.22[c]	19.4±0.44[b]	26.9±0.83[a]

Mean±S.D.
[a-c]Means with different superscript in each row are significantly different ($p<0.05$).

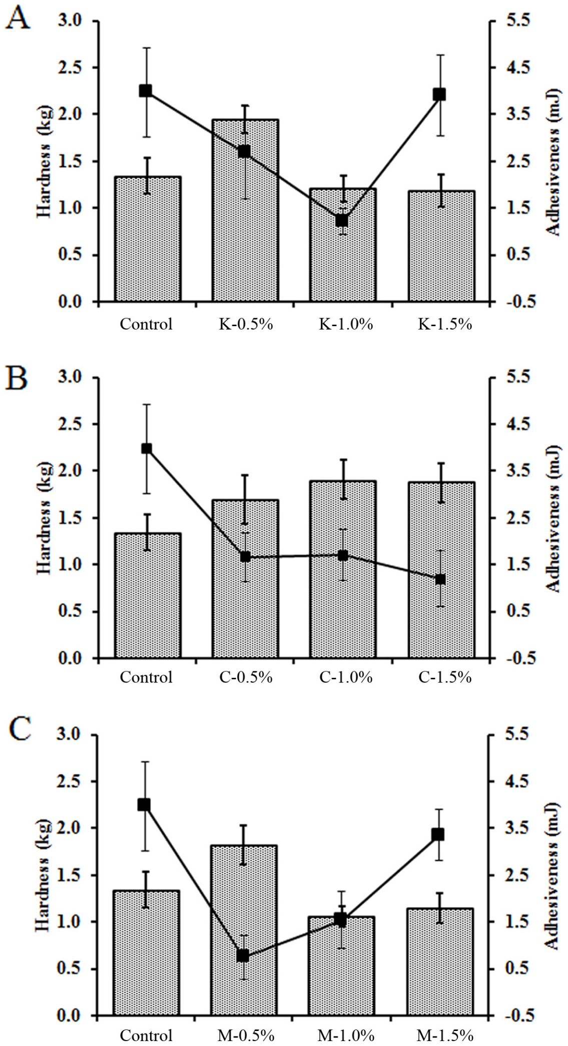

Fig. 5. Changes in hardness and adhesiveness of pork patties manufactured with NaCl substitution with (A) KCl, (B) $CaSO_4$ and (C) $MgSO_4$. Vertical bars indicate standard deviations. Means with different letters are significantly different ($p<0.05$).

cantly lower cooking loss than control ($p<0.05$). Although there was no report about the usage of $MgSO_4$ in meat product, it was thought that Mg^{2+} formed less rigid myofibrillar gel network comparing to those of K^+ or Ca^{2+}.

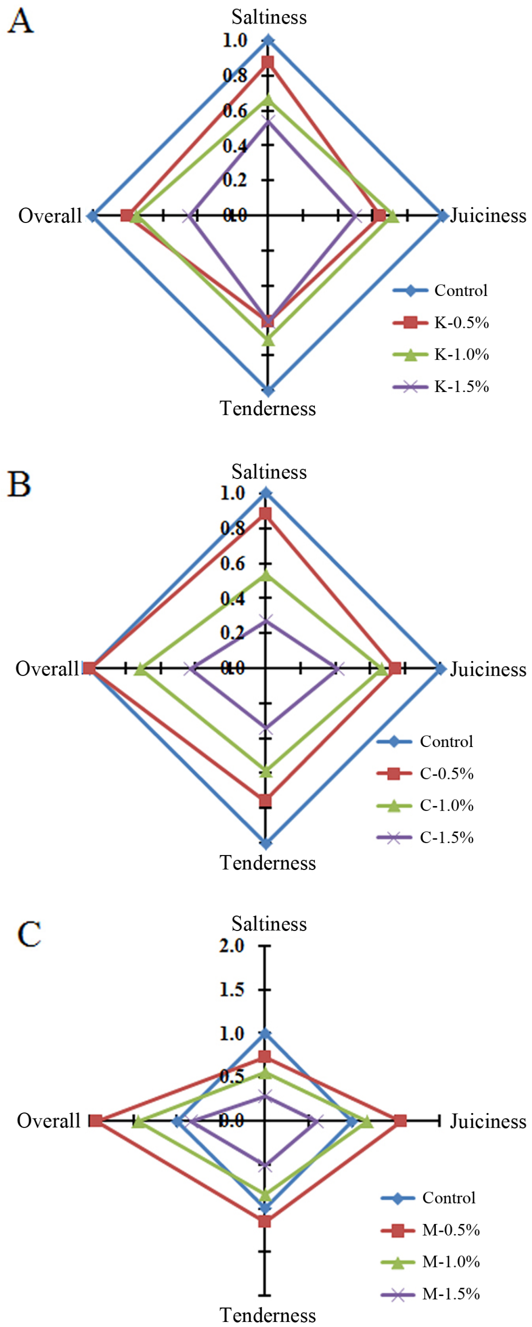

Fig. 6. Sensorial properties of pork patties manufactured with NaCl substitution with (A) KCl, (B) $CaSO_4$ and (C) $MgSO_4$.

The result was not in agreement with Panyathipong and Puechkamut (2008) who postulated that Mg-salts were more effective protein coagulants than Ca-salts in Tofu preparation. Type of protein sources might result in opposite results. For textural properties, all Na replacers modified the texture of pork patty including harder and less adhesive texture (Fig. 5). However, the textural modification was depending on the levels of Na replacers. For KCl and $MgSO_4$, 0.5% replacements produced harder and less adhesive than control ($p<0.05$), whereas their effect on hardness was disappeared when the level of replacer increased to > 1.0%. Texture of patties manufactured with $CaSO_4$ also attributed similar pattern to those of KCl and $MgSO_4$, while the patterns were still maintained with increasing $CaSO_4$ level.

Sensorial properties of pork patties were revealed that the addition of Na-replacers decreased the saltiness intensity significantly ($p<0.05$), and the saltiness was lower with increasing level of replacers (Fig. 6). The results were also identified in Na-release rate, while the decrease in saltiness was relatively low when $MgSO_4$ was used as a Na replacer. In addition, $MgSO_4$ treatment resulted in better juiciness, tenderness as well as overall acceptability than control. In contrast, KCl and $CaSO_4$ treatments showed negative sensorial attribute with increasing the level of them, as also supported by Gelabert *et al*. (2003) and Gou *et al*. (1996). Our data suggested that Mg-salt could possibly be the one of the potent candidate for beneficial salt replacement for reduction of Na in the formulation.

Conclusion

Based on the results of this study, $MgSO_4$ showed a potential application as NaCl replacer. Still, main mechanisms involved in rheological properties and Na-releasing rate in actual food matrix were not fully understood, $MgSO_4$ improved water-binding property and textural modification was also involved in better consumers' acceptability. Therefore, this study indicated that $MgSO_4$ could be applied as NaCl replacer with simultaneously improving quality characteristics of meat products.

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