Research Article

The Effect of NaCl, KCl, $CaCl_2$ and Coriander on the Characteristics of Salted Chicken Eggs

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Abstract | This study aims to determine the effect of partially substituting NaCl with KCl and $CaCl_2$ and the addition of coriander on the characteristics of salted eggs. The treatments used were soaking eggs in a 30% NaCl solution (T0), partial substitution of NaCl with KCl (T1), $CaCl_2$ (T2), KCl + coriander (T3) and $CaCl_2$ + coriander (T4). The parameters measured included salt content, moisture content, physical characteristic of albumen (pH, height, diameter, index, Haugh unit), physical characteristic of yolk (pH, height, diameter, index, colour) and organoleptic properties (saltiness, sandiness, oiliness and flavour). The results showed that T1 significantly ($P<0.05$) had lower salt content and saltiness compared to T0, but the other egg characteristic parameters were not significantly different ($P>0.05$). T2 significantly ($P<0.05$) had lower salt content, moisture content, yolk physical characteristics, saltiness, sandiness and oiliness compared to T0, but did not differ significantly ($P>0.05$) in albumen physical quality and flavour. T3 had significantly ($P<0.05$) higher flavour compared to T1, but other egg quality parameters were not significantly different ($P>0.05$). T4 significantly ($P<0.05$) had a higher shell percentage, smaller yolk diameter, higher yolk and larger yolk index compared to T2. The conclusion of this study is that partially substituting NaCl with KCl and $CaCl_2$ is beneficial for reducing the salt content of salted eggs. However, substitution with KCl is better, producing egg quality similar to the control and even better in terms of salt content and saltiness. Substitution with KCl and the addition of coriander are beneficial for developing low sodium salted chicken egg products with better flavour.

Keywords | Chicken egg, Coriander, $CaCl_2$, KCl, NaCl, Salt

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INTRODUCTION

Salted duck egg products are less favoured by the Indonesian public due to their off-flavour and relatively high price (Pundiswara *et al*., 2021). In contrast, chicken eggs are widely available, taste better and are cheaper. Therefore, salted chicken eggs can be a solution to increase public preference for salted eggs.

Salted eggs have a high salt content. Their sodium content can reach 529 mg per 100 g (Ilyas *et al*., 2023). High salt intake increases the risk of cardiovascular disease, kidney disease, hypertension and stomach cancer (Rysova and Smidova, 2021). One strategy to reduce salt content is to replace some of the sodium with other mineral salts such as potassium (K), calcium (Ca) and magnesium (Mg) (Liu *et al*., 2023; Liu *et al*., 2022b; Nurmilah *et al*., 2022). Substituting 3% of NaCl with KCl or $CaCl_2$ can inhibit infiltration and reduce the sodium content of eggs (Liu *et al*., 2022a). According to Rodrigues *et al*. (2016), NaCl can be substituted with KCl up to 30%.

Another issue is that salted eggs lack flavour variety. Therefore, some researchers have studied the effect of spices and herbs on the quality and taste of salted eggs (Lukman and Surmono, 2021; Pundiswara *et al*., 2021; Wasiyati *et al*., 2018). Adding spices is also an effective method in managing low-salt food products (Farapti *et al*., 2024). Coriander is one spice that has a distinctive taste and contains essential oils, antioxidants and ascorbic acid (Anita *et al*., 2014). Coriander can improve the quality and preference for salted eggs (Septinova *et al*., 2023; Pratama *et al*., 2022; Wasiyati *et al*., 2018).

In fact, salt reduction affects food characteristics such as consumer acceptance, shelf life, texture, pH, taste and aroma, water activity, water binding capacity, microbial activity and colour (Nurmilah *et al*., 2022). Moreover, the composition, type of replacement salt and spices also have different effects on food characteristics (Rysova and Smidova, 2021). Therefore, this study aims to determine the appropriate NaCl substitution, spices and reformulation to produce salted chicken eggs with the best quality.

MATERIALS AND METHODS

Salted Egg Production

The production of salted eggs followed the methode of Nursiwi *et al*. (2013). The eggs were soaked in a 30% (w/v) NaCl solution (T0), partial substitution of NaCl (30%) with KCl (T1), $CaCl_2$ (T2), KCl and coriander (T3) and $CaCl_2$ and coriander (T4). The ratio of NaCl to the replacement salt followed Kamleh *et al*. (2015). The addition of coriander followed Wasiyati *et al*. (2018), with slight modifications. The eggs were soaked for 12 days at room temperature (Nursiwi *et al*., 2013).

Parameters

Salt content was determined using a refractometer (Engelen *et al*., 2017). Moisture content was determined using the oven-drying method from AOAC (2016). The pH values of albumen and yolk were determined with a pH meter. The weight of the eggs and their components were measured using a digital scale. The percentage of egg components was determined by comparing the weight of each component to the whole egg weight. The height and diameter of the albumen were measured for the thick outer part using a digital caliper. The diameter of the albumen was the average of the longest and shortest diameters of the thick albumen. The albumen index was determined by comparing the height of the albumen to the average diameter of the thick albumen. The Haugh unit was determined by the formula $HU = 100 \log (H + 7.57 - 1.7W^{0.37})$, where H is the height of the albumen (mm) and W is the weight of the egg (g). The height and diameter of the yolk were measured using a digital caliper. The yolk index was determined by comparing the height of the yolk to the diameter of the yolk. The yolk colour was determined by comparing the yolk colour to the colour scale on a yolk colour fan (Kurtini *et al*., 2011). The organoleptic qualities of salted eggs assessed were saltiness, sandiness, oiliness and coriander flavour. The organoleptic quality was determined through a hedonic quality test (SNI, 2006) with a rating scale: (1) not salty/sandy/oily/ flavoured; (3) moderately salty/sandy/oily/flavoured; and (5) very salty/sandy/oily/ flavoured. The assessment was conducted by trained panelists.

Experimental Design and Statistical Analysis

This study is an experimental research with a completely randomized design consisting of five brine solution treatments. All data obtained were statistically analyzed using analysis of variance (ANOVA) and the Least Significant Difference (LSD) test at a 5% significance level. The data were analyzed using SPSS 23.

RESULTS AND DISCUSSION

Salt and Water Content

Table 1 shows that the salt content in T1, T2, T3 and T4 was significantly ($P<0.05$) lower compared to T0. This result is similar to the studies by Liu *et al*. (2023), Setyaji and Monica (2023) and Liu *et al*. (2022b), which found that KCl and $CaCl_2$ can reduce salt content. The salt content in T1, T2, T3 and T4 did not differ significantly ($P>0.05$). This result differs from the statement by Liu *et al*. (2023) that substitution with $CaCl_2$ results in much lower egg salt content compared to KCl. The difference in results could be due to differences in the type of eggs, salting method, substitution level, NaCl concentration and measurement methods used.

The addition of coriander (T3) did not significantly ($P>0.05$) affect the rate of water and sodium migration, so the salt content in T3 was not significantly different ($P>0.05$) from T1, nor was it different between T4 and T2. Rysova and Smidova (2021) stated that spices act as salt taste enhancers, which can reduce salt intake when preparing low-sodium foods.

The moisture content of the albumen and yolk in T1 and T3 did not differ significantly ($P>0.05$) from the control (Table 1). This result is similar to Liu *et al*. (2022b), indicating that KCl has properties similar to NaCl. Unlike T1 and T3, the moisture content in T2 and T4 was significantly ($P<0.05$) higher than in T0 as described by Liu *et al*. (2022b).

Table 1. Salt and moisture content of salted egg.

Variables	Treatment				
	T0	T1	T2	T3	T4
Albumen salt (%)	14±1.41[a]	10±0.50[b]	9±1.15[b]	10±0.96[b]	10±0.00[b]
Albumen moisture (%)	82.68±0.89[a]	82.04±0.60[a]	85.41±1.34[b]	82.46±0.34[a]	84.07±1.86[b]
Yolk moisture (%)	28.4±3.44[bc]	24.59±3.78[c]	37.77±8.38[a]	29.02±2.98[bc]	33.36±6.25[ab]

Different superscripts on the same row indicate significant differences (P < 0.05).
T0: NaCl solution; T1: substitution by KCl; T2: substitution by $CaCl_2$; T3: substitution by KCl + coriander; and T4: substitution by $CaCl_2$ + coriander.

Table 2. Weight proportions of salted eggs.

Variables	Treatment				
	T0	T1	T2	T3	T4
Albumen (g)	38.87±0.54[ab]	40.63±1.89[a]	37.34±1.55[b]	41.34±3.20[a]	35.92±1.01[b]
Yolk (g)	12.28±0.34[b]	12.30±0.08[b]	13.49±0.25[a]	12.42±0.61[ab]	12.40±0.42[ab]
Shell (g)	6.32±0.22	6.62±0.38	6.39±0.34	6.42±0.27	6.40±0.15
Albumen (%)	67.65±0.63[a]	67.98±0.64[a]	65.45±0.59[b]	68.58±0.92[a]	65.62±0.61[b]
Yolk (%)	21.38±0.63[b]	20.62±0.95[b]	23.65±0.60[a]	20.64±0.71[b]	22.65±0.57[a]
Shell (%)	10.84±0.35[b]	10.85±0.33[b]	10.86±0.31[b]	10.67±0.35[b]	11.56±0.21[a]

For statistical details and treatments, see Table 1.

Substitution with $CaCl_2$ causes a change in osmotic pressure, altering the diffusion rate of salt ions, salt content and water migration in the eggs. Salt reduces the moisture content of salted eggs (Wibawanti *et al.*, 2023). The relationship between salt content and moisture content is evident in T2 and T4, which have lower salt content, resulting in higher moisture content compared to T0, T1 and T3.

The moisture content in T1 did not differ significantly (P>0.05) from T3, meaning the addition of coriander did not affect the moisture content of salted eggs. Similarly, the moisture content in T2 did not differ significantly (P>0.05) from T4. This is because the hygroscopic coriander powder was separated from the soaking solution. This result is similar to Fadhlurrohman *et al.* (2021), which found that spices do not affect the moisture content of albumen and salted egg yolk.

Weight and Proportions of Egg

The weight and proportion of albumen, yolk and shell in T1 and T3 did not differ significantly (P>0.05) from the control. T2 and T4 had the lowest weight and proportion of albumen (P<0.05), but the weight and proportion of yolk in T2 were the highest (P<0.05). The shell weight in T1, T2, T3 and T4 did not differ significantly (P>0.05) from T0, but the shell proportion in T4 was significantly (P<0.05) higher compared to T0, T1, T2 and T3 (Table 2).

During salting, due to osmotic pressure, salt diffuses into the egg white, then water from the egg white slowly migrates into the yolk and water from the yolk flows into the egg white (Zheng *et al.*, 2023) and then exits through the shell pores via evaporation. The migration of water and CO_2 determines the egg weight, the weight of the egg contents and their proportions. The weight and proportion of egg components change during salting (Kaewmanee *et al.*, 2009). These changes vary depending on the rate of osmotic diffusion, the type of egg, salt concentration, salting time and salting method. In this study, the salt and water migration in T1 was similar to that in T0. The presence of Ca^{2+} inhibits sodium diffusion into the egg (Alino, 2010), resulting in T2 albumen being in a condition where more water migrates out of the albumen than enters. In T4, tannins from coriander and Ca^{2+} from $CaCl_2$ inhibit water migration in the shell, making the shell composition in T4 the highest among the treatments.

Physical Characteristics of Albumen

Table 3 shows that all treatments did not significantly differ (P>0.05) from the control in all physical characteristics' parameters of albumen. This means that KCl and $CaCl_2$ can partially replace NaCl and the addition of coriander does not affect the physical quality of the salted egg albumen. All treatments had high albumen pH values, which is due to the high concentration of NaCl in the brine solution. According to Xu *et al.* (2017), eggs salted in brine solutions with concentrations of 20% and 25% have higher albumen pH compared to eggs salted with low salt concentrations. The high concentration of brine causes a reduction in ovomucin levels, resulting in a high egg pH.

Table 3. Physical characteristics of salted egg albumen.

Variables	Treatments				
	T0	T1	T2	T3	T4
pH	8.98±0.21	7.95±0.27	7.85±0.26	7.78±0.13	7.66±0.26
Diameter (mm)	68.87±4.15	61.81±4.18	65.34±2.84	63.58±6.48	64.46±5.53
Height (mm)	5.91±0.76	7.02±1.20	6.98±0.78	6.51±1.45	5.96±0.53
Index	0.08±0.02	0.11±0.02	0.10±0.02	0.11±0.02	0.10±0.02
Haght unit	73.67±9.42	82.06±7.01	83.26±5.11	79.24±9.68	76.53±2.70

For statistical details and treatments, see Table 1.

Table 4. Physical characteristics of salted egg yolk.

Variables	Treatments				
	T0	T1	T2	T3	T4
Diameter (mm)	29.35±0.18[b]	29.19±0.83[b]	36.51±2.28[a]	28.96±1.65[b]	29.75±0.68[b]
Height (mm)	25.04±0.49[a]	23.43±0.85[ab]	15.87±2.79[c]	23.63±0.55[ab]	22.24±1.01[b]
Index	0.85±0.02[a]	0.80±0.03[a]	0.44±0.10[c]	0.82±0.04[a]	0.75±0.04[b]
Colour	13.83±0.19	14.08±0.57	13.75±0.32	14.17±0.19	13.58±0.5
pH	6.37±0.12[a]	6.49±0.12[a]	6.23±0.04[b]	6.39±0.05[a]	6.24±0.06[b]

Note: Different superscripts on the same row indicate significant differences (P<0.05).
T0: NaCl solution; T1: substitution by KCl; T2: substitution by $CaCl_2$; T3: substitution by KCl + coriander; and T4: substitution by $CaCl_2$ + coriander.

According to Li *et al.* (2022), during the salting process, the protein bonds and structure of albumen ovomucin weaken and at the same time, water slowly migrates from the yolk to the albumen, decreasing the viscosity of the albumen. This decrease in viscosity reduces the height, increases the diameter and lowers the index and haugh unit of the albumen. In this study, the partial substitution of NaCl with KCl, $CaCl_2$ and the addition of coriander did not alter the viscosity of the albumen, so the height, diameter, index and haugh unit of the albumen did not differ from the control.

Physical Characteristics of Yolk

Table 4 shows that the pH of the yolk in T1 and T3 did not significantly differ (P>0.05) from T0. The pH of the yolk in T2 and T4 was significantly (P<0.05) lower than in the other treatments. T2 and T4 were in a condition where water migration into the yolk was greater than the water migration out, resulting in high water and carbonic acid content in the yolk and thus a lower pH. This result is similar to the findings of Liu *et al.* (2022b). The pH of the yolk in T1 did not significantly differ (P>0.05) from T3 and the pH of the yolk in T2 did not significantly differ (P>0.05) from T4. Coriander did not hinder the rate of diffusion or water migration in the albumen and yolk.

The pattern of water and sodium migration in the yolk of T2 and T4 also affected the viscosity of the yolk. The yolks in T2 and T4 became more fluid compared to the other treatments, thus significantly (P<0.05) having a larger diameter, smaller height and lower index compared to the other treatments. Liu *et al.* (2022b) stated that the yolk index value approaches 1 as the dehydration of the yolk increases. The higher the yolk index, the higher the ripeness of the yolk.

The yolk colour in T1, T2, T3 and T4 did not significantly differ (P>0.05) from T0. KCl and $CaCl_2$ can be used as partial substitutes for NaCl based on yolk colour. The addition of coriander did not affect the yolk colour. This contrasts with the study by Bao *et al.* (2020), which found that partial substitution of NaCl with $CaCl_2$ resulted in a lighter yolk colour compared to the control. Based on the yolk index value, T0, T1 and T2 had nearly perfect yolk ripeness levels. At that stage, the changes in salt content and water dehydration had only a minor impact on yolk colour, so the yolk colour appeared not to differ significantly from T2 and T4.

Organoleptic Characteristics

Partial substitution of NaCl with KCl and $CaCl_2$ significantly (P<0.05) reduced the saltiness of the albumen and yolk. The reduction in saltiness in T2 and T4 was significantly (P<0.05) greater compared to T1 and T3. The saltiness of the albumen and yolk in T1 did not significantly differ (P>0.05) from T3, nor did T2 significantly differ from T4 (Table 5). The role of coriander as a salt taste enhancer (Rysova and Smidova, 2021) did not manifest because, to penetrate the egg, coriander must pass through the shell and shell membrane, resulting in a very small percentage that can enter.

Table 5. Organoleptic characteristics of salted egg.

Variables	Treatments				
	T0	T1	T2	T3	T4
Albumen saltiness	3.71±0.67[a]	2.92±0.45[b]	2.08±1.03[c]	2.98±0.74[b]	1.75±0.62[c]
Yolk saltiness	2.13±0.27[a]	1.8±0.55[b]	1.44±0.41[c]	1.86±0.44[b]	1.45±0.29[c]
Sandiness	4.52±1.58[a]	4.54±1.34[a]	2.42±0.82[c]	4.38±1.17[a]	2.43±0.60[c]
Oily	3.59±1.51[a]	3.49±1.26[a]	1.97±1.31[b]	2.95±1.04[a]	1.54±0.75[b]
Flavour	1.11±0.20[b]	1.13±0.15[b]	1.02±0.28[b]	1.4±0.72[a]	1.07±0.15[b]

For statistical details and treatments, see Table 1.

T1 exhibited sandiness and oiliness that did not significantly differ ($P<0.05$) from the control. T2 had significantly ($P<0.05$) lower sandiness and oiliness compared to T2. This aligns with the findings of Liu *et al*. (2022b). Partial substitution of KCl (T1) and $CaCl_2$ (T2, T4) did not affect the flavour of salted eggs. The salted eggs did not have the bitter taste of KCl or the chalky taste and smell of $CaCl_2$. This result differs from the findings of Ariviani *et al*. (2017), who found that salted egg products using KCl substitution had lower organoleptic quality compared to the control. The cause of this difference could be due to the concentration of NaCl in the soaking solution and the incubation time used. Coriander combined with KCl (T3) in the brine solution significantly ($P<0.05$) enhanced the flavour of the salted eggs. This supports the statement by Ariviani *et al*. (2017) that the addition of coriander can improve the quality of salted eggs.

CONCLUSION

KCl and $CaCl_2$ can partially substitute NaCl in the production of low-sodium salted chicken eggs. KCl is a better substitute for NaCl compared to $CaCl_2$. In the production of salted eggs with high salt concentration, substitution with KCl results in salted egg quality similar to the control, except for significantly better salt content and saltiness. Coriander affects the physical characteristics of the yolk and the flavour of salted eggs. Combination KCl with coriander is beneficial for developing low-sodium salted chicken egg products with improved flavour quality variation.

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NOVELTY STATEMENT

Research on the combination of NaCl, KCl, CaCl2 and coriander in chicken eggs has never been carried out. It is hoped that this research can produce innovations in salted egg products that are low in sodium and have additional functional and taste benefits.

AUTHOR'S CONTRIBUTION

All the authors contributed to the manuscript. Dian Septinova designed the experiment and drafted the manuscript. Isnaeni Nurfianti and Denita Eptiana collected and tabulated the data. Khaira Nova and Riyanti critically revised and approved the manuscript.

Conflict of Interest

The authors declared that there is no conflict of interest.

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