Received: 6 September 2021 | Revised: 25 November 2021 | Accepted: 12 December 2021

DOI: 10.1111/jfpp.16256

Journal of Food Processing and Preservation | Institute of Food Science + Technology ifst | WILEY

ORIGINAL ARTICLE

Effect of phosphates substitution with carboxymethyl cellulose and konjac glucomannan on quality characteristics of low-fat emulsion sausage

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Abstract

This research studied on replacement of phosphates by carboxymethyl cellulose (CMC) and konjac glucomannan (KGM) at 0%, 50%, and 100% of phosphates in low-fat chicken emulsion sausage. By substitution with KGM at 50% of phosphates or 0.15 PP/0.15 KGM, the sample showed the lowest expressible fluid and fat released, indicated better emulsion stability, and decreased cooking loss ($p < .05$). All treated sausages had a low level of fat (10.70%–11.76%) with no difference in moisture content, except 0.3 CMC sample that had the highest moisture content. Whereas the substitution reduced the hardness, cohesiveness, and chewiness of the sausages ($p < .05$). The 0.15 PP/0.15 CMC and 0.15 PP/0.15 KGM samples, containing high emulsion stability and less cooking loss, were evaluated for the sensory quality. It was found that their sensory attributes did not differ from 0.3 PP sample. The result suggested both CMC and KGM had the most effective when used up to 50% of phosphates or 0.15% by weight.

Practical applications

This study focused on the application of carboxymethyl cellulose (CMC) and konjac glucomannan (KGM) to substitute phosphates in low-fat chicken emulsion sausage. Results showed the sausages formulated with 50% of phosphate substitution by CMC and KGM had a positive effect on emulsion stability, cooking loss, and other physical properties as aspects of meat products. In addition, partially substituted phosphates with CMC and KGM in the sausage formulated in this research lead to healthier meat products because it is both low in fat and low in phosphates. Therefore, this study can provide effective phosphate substitutes in the low-fat emulsified product with partial replacement of 0.3% phosphates, and that the most effective application level is 50% substitution.

1 | INTRODUCTION

Phosphates are widely used as additives in meat and poultry processing (Petracci et al., 2013; Sebranek, 2015), they fulfill several functional properties in meat products such as a good buffering capacity (monophosphates) and the ability to dissociate the actomyosin complex of meat immediately (diphosphates) and activate meat proteins by partially chelating the protein-bound Mg^{2+} and Ca^{2+} (tri- and polyphosphates), which subsequently enhance solubilization of the meat proteins and depolymerization of the thick and thin filaments and inhibit off-flavor development (Balestra & Petracci, 2019; Puolanne & Halonen, 2010; Sebranek, 2015). This result in these proteins can maximally exert their emulsifying and gelling properties, which are very important with regard to fat and water stabilization (Goemaere et al., 2021). As such, the addition of phosphates was considered for improving quality characteristics such as emulsion stability, texture, and cooking loss investigated on emulsified meat products, emulsified meatball, and sausage (Glorieux et el., 2017; Kim et al., 2019; Yeung & Huang, 2018). However, phosphates are chemical synthetic analogs. Nowadays, an avoidable risk to health arises from the increased use of phosphates as a food additive. These inorganic phosphates are effectively absorbed in the gastrointestinal tract. An association was found between a high intake of phosphate additives and cardiovascular morbidity and mortality (Bai et al., 2016). According to the European legislation, food phosphates are not permitted in fresh meat and may be added in a maximum amount of 0.5% (expressed as P_2O_5) in meat products (European Food Safety Authority, 2013; Tabak et al., 2019). Therefore, several approaches have been purposed to find phosphates substitutes (Cho & Jeong, 2018; Schutte et al., 2021; Tabak et al., 2019). Schutte et al. (2021) suggested that iota-carrageenan can be substituted for sodium tripolyphosphate (STPP) at a level of up to 0.35% STPP and 0.2% iota-carrageenan to produce reduced STPP ham. They report that cooked yield, hardness, cohesiveness, and gumminess of restructured ostrich ham increased with increased replacement levels of iota-carrageenan and decreased levels of STPP but did not observe a significant trend in instrumental color measurements or springiness.

An interesting phosphates substituent is carboxymethyl cellulose (CMC), also known as cellulose gum. CMC is an anionic linear polymer, long chain, and water soluble, which obtained from cellulose after heating with alkali and posterior reaction with chloroacetic acid, leading to the etherification of the hydroxyl groups with methyl carboxyl groups (Jia et al., 2016; Mohkami & Talaeipour, 2011; Rodsamran & Sothornvit, 2020). CMC is a hydrocolloid with the surface activity that could act as emulsifiers in oil-in-water emulsions, thickener, as well as gelling and improving texture of a wide variety of food products (Arancibia et al., 2016; Gibis et al., 2015). Besides CMC is thoroughly used because it is odorless and tasteless and forms a clear solution without cloudiness or opacity and is commonly used in foods and beverages to prevent gravitational separation of suspended particles and to create desirable textural attributes and mouthfeel (Akkarachaneeyakorn & Tinrat, 2015; Arancibia et al., 2016; Panahirad et al., 2021).

Another one is konjac glucomannan (KGM), which is a neutral plant polysaccharide derived from the tubers of *Amorphophallus konjac*. It consists of sugar monomers, D-glucose and D-mannose, which are joined by β-(1–4) glycosidic linkages, having a mannose to glucose molar ratio of 1:1.5–1.6:1 with the polymer accounts for 5%–10%, has strong water retention as well as fat retention capacity, and possesses excellent hygroscopic property (Dos Santos & Grenha, 2015; Jian et al., 2016; Yang et al., 2017). KGM offers a great potential for applications in food technology because of its good water absorptivity, gel-forming ability, stability, emulsified ability, thickened ability, film-forming properties, ability to decrease cholesterol, and glucose in the blood, and it has been approved in Europe and the FDA as a kind of food additive (Devaraj et al., 2019; Kim et al., 2019; Wang et al., 2017; Yang et al., 2017).

Hydrocolloids, such as CMC and konjac, are already used in different low-fat type sausages with a reason for the reduction of fat in the end products. In previous studies, Atashkar et al. (2018) found fat substitution in low-fat sausage using konjac, kappa-carrageenan, and tragacanth. They were used at four different levels (0.0, 0.5, 1.0, and 1.5) as the fat substitutes in producing low-fat sausage with a 70% reduction based on formulated oil. Among the low-fat samples of which, the texture samples containing konjac were more favorable. Gibis et al. (2015) reported that CMC can be used as potential fat replacers to improve sensory characteristics such as texture, color, taste, flavor, and juiciness of fried beef patties at effective concentrations of 0.5%–3.0%. However, CMC is not suitable as a fat replacer in concentrations of more than 0.5% because that led to the destabilization of the microstructure, sensory quality, and texture of fried beef patties upon heating.

In view of our interest, the aim of this study is to investigate the effect of two hydrocolloids on phosphates substitution and quality characteristics of low-fat emulsion-type sausage to provide a healthier meat product. In this research, total phosphates at a level of 0.3% added in low-fat chicken emulsion sausage were substituted with CMC or KGM by 0%, 50%, and 100% of total phosphates used. As emulsion-type sausage was popular consumption in many countries, therefore, to provide healthy meat products with both low fat and low phosphate might be one of the choices to reduce health problems.

2 | MATERIALS AND METHODS

2.1 | Materials

The chicken breast was obtained from a local market in Bangkok (Thailand) and stored at 4°C prior to production. The content of chemical compositions of chicken breast meat is approximately 74% water, 23% protein, and 1.5% fat. All chemicals were food grade. Tetrasodium pyrophosphate was purchased from Thai Food and Chemical Co., Ltd., Bangkok, Thailand. STPP, CMC, KGM powder, and soy protein isolates were purchased from Krungthepchemi Co., Ltd., Bangkok, Thailand.

2.2 | Composition of samples

Six chicken emulsion sausages were produced with different emulsifiers as shown in the experimental design given in Table 1. In detail, the sample added with polyphosphates at 0.3% was prepared as the basic formula (0.3 PP) and a sample without polyphosphates was used as a control. The other four samples were studied, polyphosphate was replaced with CMC at 50% and 100% (0.15 PP/0.15 CMC and 0.3 CMC) and KGM at 50% and 100% (0.15

TABLE 1 Formulation of chicken emulsion sausages

Ingredients (% by weight)	Treatments					
	Control	0.3 PP	0.15 PP/0.15 CMC	0.3 CMC	0.15 PP/0.15 KGM	0.3 KGM
Chicken breast	66.8	66.8	66.8	66.8	66.8	66.8
Ice	9.5	9.5	9.5	9.5	9.5	9.5
Preemulsified oil	18	18	18	18	18	18
Salt	1.2	1.2	1.2	1.2	1.2	1.2
Sugar	1.1	1.1	1.1	1.1	1.1	1.1
Pepper	1	1	1	1	1	1
Garlic	1	1	1	1	1	1
Nutmeg	0.4	0.4	0.4	0.4	0.4	0.4
Paprika	0.7	0.7	0.7	0.7	0.7	0.7
PP	–	0.3	0.15	–	0.15	–
CMC	–	–	0.15	0.3	–	–
KGM	–	–	–	–	0.15	0.3

Note: PP = phosphates mixed of sodium tripolyphosphate and tetrasodium pyrophosphate (1:1), CMC = carboxymethyl cellulose, KGM = konjac glucomannan, Treatments; Control = without phosphate and hydrocolloids, 0.3 PP = with 0.3% phosphates, 0.15 PP/0.15 CMC = with 0.15% phosphates and 0.15% carboxymethyl cellulose, 0.3 CMC = with 0.3% carboxymethyl cellulose, 0.15 PP/0.15 KGM = with 0.15% phosphates and 0.15% konjac glucomannan and 0.3 KGM = with 0.3% konjac glucomannan.

PP/0.15 KGM and 0.3 KGM) by weight of the polyphosphate added in the sausages.

2.3 | Preparation of samples

All samples were prepared, separately, following the method of Juntachote et al. (2018) with slight modifications. Preemulsified oil was prepared as the fat source based on the procedure of Juntachote et al. (2018). Briefly, the ratio of soy protein isolates:soybean oil:water was 88.9:400:400 by weight respectively. Water was heated to ~45°C and homogenized with the soy protein isolate in a hand blender at turbo speed (MSM6S90B, Bosch, Slovenia). After blending for 1 min, the soybean oil was added slowly while homogenization continued for 5 min. The mixture was then poured into polyethylene bags and stored at 4°C overnight prior to the production of sausages. Chilled chicken breast fillet was chopped with all compositions except preemulsified oil and half of ice using a food processor (MCM3200W, Bosch, Slovenia) at high speed for 5 min. The remaining ice was added, followed by adding the preemulsified oil, and blended for 3 min until a homogenous mixture was obtained. A temperature probe was used to monitor the temperature of the meat batter and the temperature was kept below 15°C throughout batter preparation. The batter was then stuffed (BR058, Voice, Zolftech Innovation Co., Ltd., Bangkok, Thailand) in a collagen casing with a 21 mm diameter (PTK Solution and Supplies Co., Ltd. Bangkok, Thailand) and heated in a hot air oven at 55°C for 60 min, followed by cooked in a water bath at 75°C until the core temperature reached 72°C for 10 min, then cooled in cold water (10°C). The samples were finally placed in polyethylene bags and stored for a day at 4°C prior to measurement. Six batches (Table 1) were prepared for different treatments (1,000 g batch of each meat batter). All treatment preparations were repeated in triplicate.

2.4 | Determination of emulsion stability

Emulsion stability was measured as total expressible fluid (TEF) and expressible fat (EFAT) based on a method of Hughes et al. (1997) with slight modification. Exactly 25 g of the raw batter was placed in a centrifuge tube and centrifuged for 10 min at 3,704× *g* (4°C) using a Mikro 22R Hettich centrifuge (Hettich GmbH & Co., KG., Germany). The samples were carried in a water bath for 30 min at 80°C and then centrifuged for 10 min at 3,704× *g*. The supernatants were poured into preweight aluminum cans and dried for 6 hr at 105°C, while the centrifuge tubes and pellets were weighed. All treatments were performed in triplicate. The percentage of TEF and EFAT were calculated as follows (Equations 1 and 2):

$$\text{TEF}\ (\%) = \frac{\text{weight of centrifuge tube and sample} - \text{weight of centrifuge tube and pellet}}{\text{original sample weight}} \times 100, \quad (1)$$

$$\text{EFAT}\ (\%) = \frac{(\text{weight of can} + \text{dried supernatant}) - \text{weight of empty can}}{\text{original sample weight}} \times 100. \quad (2)$$

2.5 | Determination of cooking loss

Cooking loss of cooked samples from different batches was evaluated according to the method of Crehan et al. (2000). All treatments were performed in triplicate, where the total weight of each batch was measured before and after cooking. Cooking loss (%) was calculated using the following Equation (3):

$$\text{Cooking loss }(\%) = \frac{\text{raw weight} - \text{cooked weight}}{\text{raw weight}} \times 100 \quad (3)$$

2.6 | Determination of moisture and total fat contents

Moisture and total fat contents of the cooked sample were measured according to the method of AOAC (2016). All treatments were performed in duplicate.

2.7 | Determination of instrumental color

Cooked samples were brought to room temperature and cut into lengths of 1.5 cm. The color of the freshly cut cross-sectional area was determined on a colorimeter (Color Quest XE, Hunter Lab, Virginia, USA) using a D65 illuminant, 9.5 mm aperture, and 10° observer angle. The instrument was calibrated with a white tile and measured on the surface of all samples at three different locations for a total of five measurements of each treatment. The CIE L^* (lightness), a^* (redness/greenness), and b^* (yellowness/blueness) values were reported.

2.8 | Texture profile analysis

The texture profile analysis of the cooked sample was performed at room temperature using a texture analyzer (TA-XT plus, Stable Micro System, Surrey, UK) equipped with a 50-mm-diameter aluminum cylinder probe, according to the methodology proposed by Peña-Saldarriaga et al. (2020) with slight modification. The cooked sausages from each treatment were cut into the lengths of 2 cm. The conditions of the analysis were as follows: pretest speed, 2.0 mm/s; test speed, 2 mm/s; postspeed, 4 mm/s; and distance, 8 mm (40% compression). Each sample was performed. The textural parameters considered were hardness (maximum force of the first compression cycle, expressed in N), cohesiveness (ratio of positive force area during the second compression to that during the first compression area, dimensionless), springiness (ratio of the length of the second to the first compression peak, expressed in mm), and chewiness (product of hardness × cohesiveness × springiness, expressed in N mm). All treatments were performed in triplicate from three different sausages (five pieces per sausage) with a total of 15 measurements.

2.9 | Sensory analysis

Sensory evaluation was carried out by 25 trained panelists of habitual sausage consumers, consisting of 20 students with ages ranging from 20 to 34 years old (female = 15, male = 5) and five staff with ages ranging from 35 to 49 years old (female = 4, male = 1), who studied or worked in the Division of Food Safety Management and Technology of Rajamangala University of Technology Krungthep. Panelist training procedure comprises group discussion to define the sensory attributes, terms represented quality as well as establish scales by their own impression. Then all panelists were finally discussed to normalize the same scale. All samples were evaluated using a 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely) according to the method of Meilgaard et al. (2016). Cooked sample from each treatment were cut into 2 cm length pieces, placed in plastic containers with covers, and served warm at 35°C to each panelist in a three-digit code and the order of serving was determined randomly (Ali et al., 2011). Water was provided for cleansing the palate between treatments. The sensory characteristics were evaluated on appearance, color, flavor, taste, firmness, juiciness, and overall acceptance, where the products with good sensory scores must be tight surface and not wrinkled, golden yellow color, firm and soft juicy texture, and delicious flavor and taste.

2.10 | Statistical analysis

The treatments in the experiment were considered as fixed effects and the replicates as random effects. The data were presented as mean ± *SD*. Statistical analysis was performed by one-way analysis of variance using the IBM SPSS Statistics for Windows. Duncan's multiple range test was used to determine the statistical significance among the means at a 95% significance level.

3 | RESULTS AND DISCUSSION

3.1 | Emulsion stability and cooking loss

The effects of phosphates substitution with CMC or KGM on emulsion stability of different samples performed as batters after heating are shown in Figure 1. The partial replacement of phosphate with KGM at a level of 50% or 0.15 PP/0.15 KGM sample resulted in the lowest TEF value (5.78%) and EFAT value (0.49%) represented in percentages of liquids released from batters (%TEF and %EFAT) followed by 0.3 PP and 0.15 PP/0.15 CMC samples. On the other hand, samples without treatment (control) and totally replaced with hydrocolloids had a higher amount of liquid released from the samples by the range of 18.84%–20.75% of %TEF and the range of 3.43%–4.42% of %EFAT (Figure 1a,b).

According to the study by Balestra and Petracci (2019), TSPP or tetrasodium pyrophosphate is able to dissociate the actomyosin complex, detaching myosin which can act as a natural emulsifier. Additionally, TSPP can solubilize myofibrillar proteins, in which the protein matrix is stabilized and in which water and fat are entrapped.

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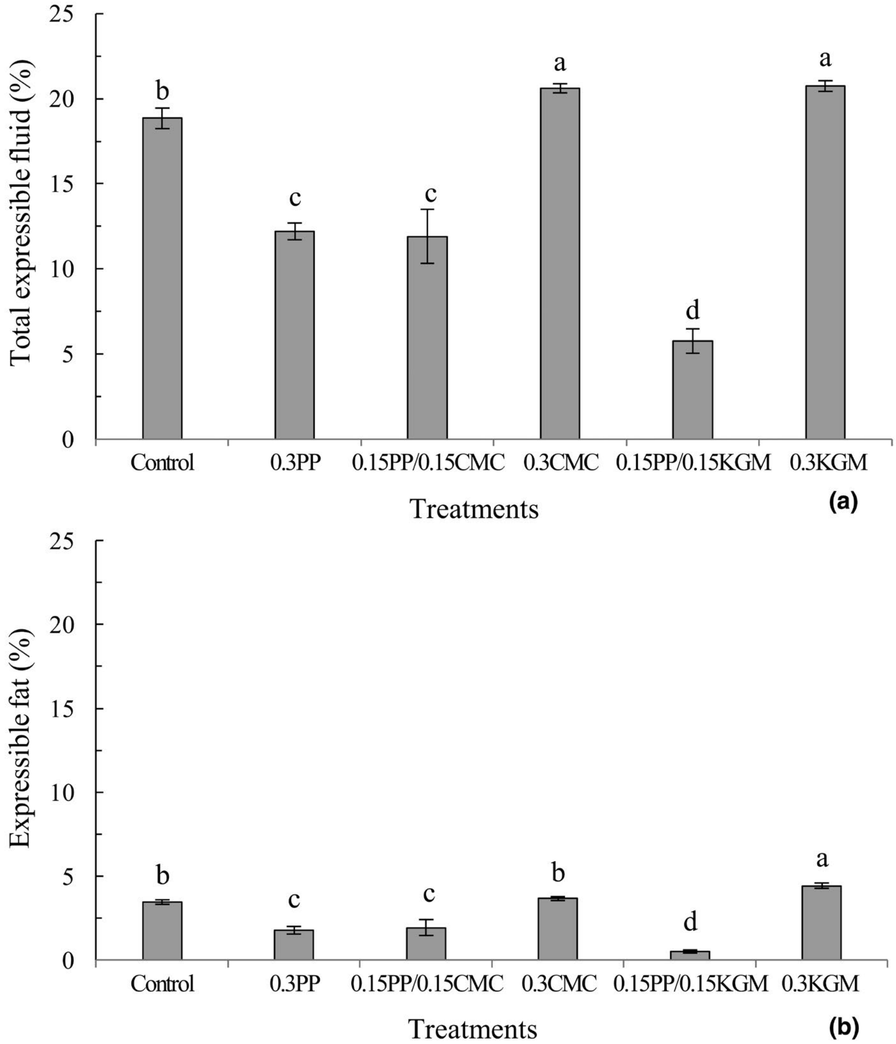

FIGURE 1 Total expressible fluid (a) and expressible fat (b) of raw meat batters from each sausage formulated with different substitution levels (%) of phosphates (PP) by carboxymethyl cellulose (CMC) and konjac glucomannan (KGM). Means with different letters were significantly different ($p < .05$)

For our result, the finding for 0.15 PP/0.15 CMC confirmed that CMC had an emulsifying ability similar to PP when used up to 50% of phosphates substitution. However, the result in lower liquid released for 0.15 PP/0.15 KGM sample indicated that KGM acts as a better emulsifier in the batter than CMC. It can be explained that the replacement of phosphates with these hydrocolloids increased the emulsion stability compared with phosphate samples and others, subsequently reducing the total liquid and fat released from batters. As noted, CMC and KGM alone have a limited effect on the absorption of water during emulsification of meat batter as shown in the treatments of all replacement. This agreed with the study by Jimenez-Colmenero et al. (2010) who suggested that konjac alone has a very limited effect on the absorption of additional water during emulsification in the presence of konjac for improvement of reduced-fat frankfurters. Whereas Gibis et al. (2015) suggested that CMC has a limited concentration in meat product and lead to destabilization of the microstructure, sensory quality, and texture of fried beef patties upon heating at the concentration of more than 0.5%.

The emulsion stability and cooking loss are indicative as binding property which represents the ability of meat emulsion to retain moisture and fat upon further processing (Glorieux et al., 2017; Kim et al., 2019). The results for cooking loss of sausages are shown in Figure 2. They indicated that the substitution of phosphates with CMC or KGM at level 50% (0.15 PP/0.15 CMC or 0.15 PP/0.15 KGM) influenced more decrease in cooking loss than the control and phosphate samples.

These results agreed with Atashkar et al. (2018) who found that the emulsion stability of the different meat batters was affected by composition. Their results noted that the effect of konjac in producing low-fat formula sausage was dependent on the level of konjac in the fat portion that increasing levels (0.0%, 0.5%, 1.0%, and 1.5%) as the fat substitutes. Moreover, Gibis et al. (2015) also noted that the addition of CMC (>1%) led to the destabilization of the microstructure of the fried beef patties upon heating. This was because CMC had a higher capability to counteract the impact of heat-induced protein denaturation on the water expulsion network (Han & Bertram, 2017).

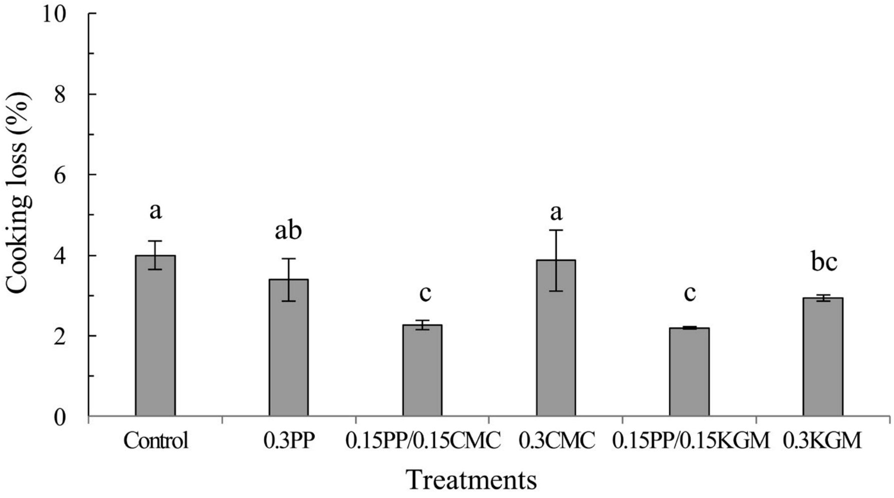

FIGURE 2 Cooking loss of cooked sausages formulated with different substitution levels (%) of phosphates (PP) by carboxymethyl cellulose (CMC) and konjac glucomannan (KGM). Means with different letters were significantly different ($p < .05$)

3.2 | Moisture and total fat content

The effect of substitution of phosphates with CMC or KGM on the moisture and total fat contents in sausages are shown in Figure 3. No significant difference in total fat content was found among the sausage samples ($p \geq .05$). The sausage added with 0.3% KGM (100% of total phosphates substitution) had the highest moisture content, followed by other samples ($p < .05$), and their moisture content was in the range of 63.69%–67.57% (Figure 3a). The total fat contents did not differ significantly among all samples. However, noticeably fat content as low as 10.70%–11.76% ($p \geq .05$) was shown in Figure 3b. The obtained result confirmed that the sausage formulated in this study was reduced by about 50% fat content compared with those of normal chicken sausages as reported in other studies by Lee et al. (2020) and Herlina et al. (2021) which contained 22.9%–23.69% of fat.

According to Xue et al. (2016), phosphates are employed in the processing of chicken breast sausages to increase the extraction and solubilization of proteins. As such, a stable gel matrix leads to a smaller release of water and fat and helps to improve the binding properties of emulsion systems, causing a better water holding capacity and softer texture. Another report, Choi and Chin et al. (2020) noted that sodium chloride at a low level (0.3%–1.8%) activated the proteins to increase the water holding capacity. Thus, the moisture retention in samples might have also been related to salt inclusion which has a function with solubilization of the functional myofibrillar proteins in processed meat.

The sausage with 0.3% KGM, containing no phosphate which may be implied for less-solubilized protein, nevertheless it contained more moisture. This may be due to enough protein aggregation to form a strong protein network to enhance water holding capacity. This result agreed with those reported by Zou et al. (2021) that the water that is already immobilized by konjac is likely difficult to remove from chicken plasma protein gelation.

3.3 | Instrumental CIE color

The instrumental CIE color (L^*, a^*, and b^*) values of a cross-section of each sausage are shown in Figure 4. The L^* value represents lightness (100) and blackness (0) and is an estimation of food whiteness. The a^* and b^* values represent red–green (positive–negative) and yellow–blue (positive–negative) hues of the food samples (Korley Kortei et al., 2015). The 0.15 PP/0.15 CMC sample had the highest L^* value, whereas the 0.3 PP sample showed no significant differences in the L^* values compared with the 0.15 PP/0.15 CMC sample, followed by the control in the range from 70.62 to 71.39. On the other hand, they had significantly lower a^* and b^* values compared with other treatments ($p < .05$), and their b^* values were similar trend to a^* values. These results implied that substitution of phosphate with CMC at a level of 50% did not negatively affect the colors of sausage compared with the phosphate sample. Conversely, the lowest color parameters (L^*, a^*, and b^*) were observed for the 0.3 KGM sample by 65.51, 15.27, and 1.63, respectively. This indicated the negative effect of replacement of phosphate with konjac alone, especially on L^* value causing darker in color. Akesowan and Choonhahirun (2017) mentioned konjac led to a more reddish-brown product by its susceptibility to Maillard browning. The present study was in agreement with Delgado-Pando et al. (2011) that the addition of konjac in low-fat pork liver pate caused a decrease in redness ($p < .05$) and yellowness.

3.4 | Textural properties

The effect of phosphates substitution with CMC or KGM on the textural properties of low-fat sausage is presented in Table 2. The control had the highest hardness, cohesiveness, and chewiness (40.17 N, 0.74, and 229.11 N mm, respectively) ($p < .05$), but no differences ($p \geq .05$) in springiness with the range of 6.83–7.54 mm was found among all samples. The phosphates at a level of 0.3% led to a significant decrease in hardness and chewiness compared with the control ($p < .05$) and slightly lower values of cohesiveness and springiness. It can be found that phosphate substituted with CMC or KGM at all levels significantly reduced the hardness, cohesiveness, and chewiness ($p < .05$) in the sausages.

On the other hand, previous studies had been reported that the addition of konjac gel could increase the hardness of meet emulsion (Yong et al., 2020). Whereas Gibis et al. (2015) found that the addition of up

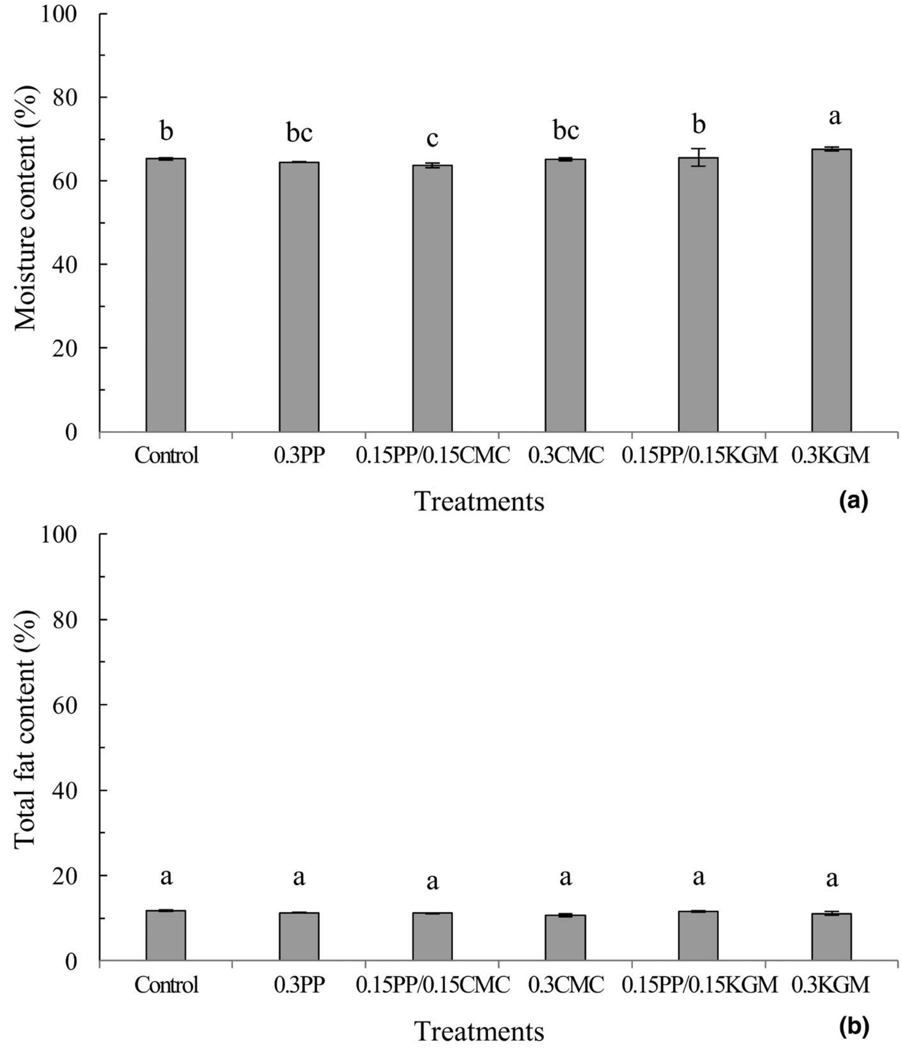

FIGURE 3 Moisture content (a) and total fat content (b) of cooked sausages formulated with different substitution levels (%) of phosphates (PP) by carboxymethyl cellulose (CMC) and konjac glucomannan (KGM). Means with different letters were significantly different ($p < .05$)

to 0.5% CMC did not affect the texture of fried beef patties, Santana et al. (2013) who reported that CMC and konjac at a level of 0.5% in sausages had quite similar cohesiveness values (0.31) compared with the sausage without hydrocolloids (0.29). Cohesiveness is one of the texture parameters related to meat products that play important role in handling sausages especially for the slicing of these products. However, if products are too cohesive, they become undesirably sticky and difficult to cut (Fahimeh et al., 2019). In this study, CMC and KGM showed a significant positive effect on the cohesiveness of low-fat sausage while also retaining a similar springiness. This study noted that when CMC or KGM was used as a phosphates substitute in the formulation of low-fat sausages, unwanted hardness, cohesiveness, and chewiness were decreased significantly compared with control.

3.5 | Sensory evaluation

The sausages formulated with 50% of phosphates substitution with CMC and KGM (0.15 PP/0.15 CMC and 0.15 PP/0.15 KGM samples), which were selected based on the positive results of high emulsion stability, less cooking loss, and other desirable physical properties, were evaluated on sensory qualities. Table 3 shows the sensory evaluation of the treated sausages compared with the 0.3 PP sample for appearance, color, flavor, taste, firmness, juiciness, and overall acceptability. As mentioned, the 9-point hedonic scale is used to measure the preferences. There were no significant differences ($p \geq .05$) among samples in terms of sensory qualities. Even though the results of physicochemical properties shown above had identified some differences among samples, such as the cooking loss, hardness, cohesiveness, and chewiness, were reduced ($p < .05$) in the samples substituted with CMC or KGM, but the panelist could not differentiate these differences. The 0.3 PP, 0.15 PP/0.15 CMC, and 0.15 PP/0.15 KGM samples receive scores in the moderate range of 7.00–7.36 for appearance and color and slightly for flavor, taste, firmness, juiciness, and overall acceptability about the range of 6–7. These results indicated no noticeable impacts on sensory qualities when used CMC or KGM as a phosphates substitute. Similar results were reported by Santana et al. (2013) that the addition of

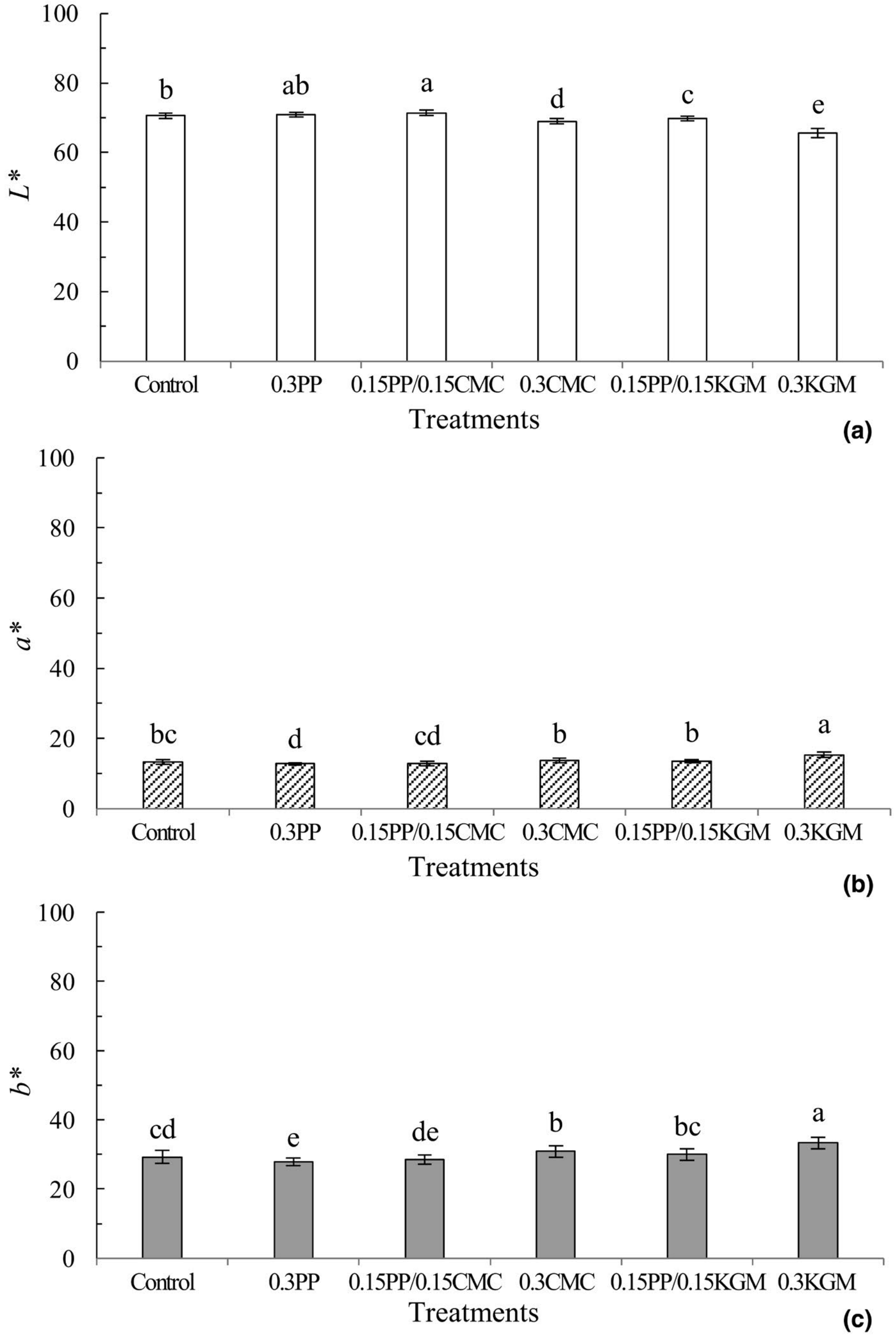

FIGURE 4 L^* (a), a^* (b), and b^* (c) values of cooked sausages formulated with different substitution levels (%) of phosphates (PP) by carboxymethyl cellulose (CMC) and konjac glucomannan (KGM). Means with different letters were significantly different ($p < .05$)

TABLE 2 Texture profile analysis of cooked sausages formulated with different substitution levels (%) of phosphates (PP) by carboxymethyl cellulose (CMC) and konjac glucomannan (KGM)

Treatments	Hardness (N)	Cohesiveness (ratio)	Springiness (mm)	Chewiness (N mm)
Control	40.17 ± 6.41a	0.74 ± 0.08a	7.54 ± 0.14a	229.11 ± 55.01a
0.3 PP	34.25 ± 5.51b	0.74 ± 0.11ab	7.10 ± 0.79a	182.00 ± 54.91b
0.15 PP/0.15 CMC	29.15 ± 4.86c	0.66 ± 0.12bc	6.95 ± 0.79a	127.72 ± 36.74c
0.3 CMC	28.72 ± 6.01c	0.60 ± 0.15c	6.83 ± 0.48a	125.15 ± 51.43c
0.15 PP/0.15 KGM	28.63 ± 5.47c	0.61 ± 0.12c	7.05 ± 0.65a	117.79 ± 18.10c
0.3 KGM	27.00 ± 3.95c	0.65 ± 0.08c	6.83 ± 0.74a	118.84 ± 19.09c

Note: Means with different letters were significantly different ($p < .05$).

TABLE 3 Sensory evaluation of cooked sausages formulated with different substitution levels (%) of phosphates (PP) by carboxymethyl cellulose (CMC) and konjac glucomannan (KGM)

Treatments	Appearance^{ns}	Color^{ns}	Flavor^{ns}	Taste^{ns}	Firmness^{ns}	Juiciness^{ns}	Overall acceptability^{ns}
0.3 PP	7.24 ± 1.23	7.00 ± 1.35	6.36 ± 1.29	6.80 ± 1.35	6.92 ± 1.08	6.16 ± 1.18	7.04 ± 1.02
0.15 PP/0.15 CMC	7.36 ± 0.91	7.20 ± 0.96	6.44 ± 1.04	6.88 ± 1.20	6.20 ± 1.55	6.16 ± 1.25	6.76 ± 1.13
0.15 PP/0.15 KGM	7.36 ± 0.95	7.20 ± 1.00	6.20 ± 1.22	6.52 ± 1.45	6.72 ± 1.49	6.76 ± 1.20	6.96 ± 0.98

Note: Means with ns represents not significantly different ($p \geq .05$).

hydrocolloids such as CMC and konjac at ~0.5% final concentration could improve the sensory qualities of sausages formulated with surimi, especially juiciness which might be due to water held in food structure assisted by hydrocolloids.

4 | CONCLUSIONS

This research demonstrated that the treated samples were enhanced emulsion stability representing low TEF and EFAT values as well as low cooking loss, which are desirable aspects of meat products. Moreover, the substitution of phosphate content with CMC or KGM at a level of 50% of total phosphate used had no negative effects on stability during heating and other properties of emulsion sausage. In conclusion, this research provided a promising approach for the trend of healthier meat products in which phosphate content is reduced by partial replacement with CMC or KGM in low-fat emulsion sausage. However, both CMC and KGM could effectively phosphate substitute in the product at a limited level of 0.15%, which is a 50% substitution to phosphate level. Further research may need to assess the combined effects of CMC or KGM with others to enhance the product's quality and offers a new possibility for phosphate replacement in the healthier sausage.

ACKNOWLEDGMENTS

This work was funded by the Rajamangala University of Technology Krungthep. Moreover, the authors would like to thank all staff of the faculty for their helpful maintenance and operation of the scientific laboratory and equipment.

CONFLICTS OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Naruemon Jommark: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing. **Savarak Chantarathepthimakul:** Conceptualization; Data curation; Methodology; Visualization; Writing – review & editing. **Pattama Ratana-arporn:** Conceptualization; Data curation; Resources; Validation; Visualization; Writing – review & editing.

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How to cite this article: Jommark, N., Chantarathepthimakul, S., & Ratana-arporn, P. (2022). Effect of phosphates substitution with carboxymethyl cellulose and konjac glucomannan on quality characteristics of low-fat emulsion sausage. *Journal of Food Processing and Preservation*, 46, e16256. https://doi.org/10.1111/jfpp.16256