Effects of different phosphate content on the quality of wheat bran chicken sausage

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Abstract

Introduction. The addition of phosphates improves the emulsifying and gelling properties of meat proteins as well as overall product quality. The effect of phosphate addition on the properties of low-fat chicken sausages containing wheat bran was studied in this article.

Materials and methods. Cooking loss, emulsification stability, water distribution, texture and sensory characteristics of wheat bran chicken sausage added with different amounts of complex phosphate were determined.

Results and discussion. The positive influence of phosphate addition on technological and textual properties of meat products is known, however taking into account consumer's acceptability, determination of phosphate content in sausages ensuring their high quality but not but not exceeding this value is needed. Low–fat chicken sausages with increased dietary fiber content due to inclusion in the sausage formulation of wheat bran were used as the object of the study. Comparative characteristics of wheat bran chicken sausage added with different amounts of complex phosphate, namely, 1.0, 1.5 or 2.0 g to 400 g of ground chicken meat were determined. It was shown that the minimum cooking water and fat losses were observed when addition of 1.5 g of complex phosphate was used. Thus, addition of 1.5 g of complex phosphate to 400 g of ground chicken meat ensured better retaining of water and fat, lowest cooking loss and highest emulsifying stability than in cases when 1.0 or 2.0 g of complex phosphate were added. At the same time, the results showed that the sausage containing 1.5 g phosphate per 400 g of ground chicken had the highest hardness, elasticity and chewiness, and the highest overall acceptability score of sensory evaluation, but the difference was not significant ($P>0.05$). Addition of 1.5 g phosphate per 400 g of ground chicken reduced the fluidity of free water in the sausage, and thus enhanced the water-retaining ability of chicken sausage. In addition, the results of the pseudo-color map showed that the semi-bound water of the S2 and S3 treatment groups increased significantly.

Conclusions. Addition of complex phosphate, 0.2 %, in formulation of low-fat wheat bran chicken sausages decreases cooking, moisture and fat losses, and improves the texture and sensory properties of the final product.

Introduction

The world produces a huge variety of different types of sausages, such as ham, smoked, Chinese, fermented, mixed and others, in the preparation of which various types of meat are used (Marcos et al., 2016; Wang et al., 2021; Wang et al., 2022). Due to its high protein content and balanced nutritional composition, the use of chicken meat as a raw material for the production of sausages is extremely popular (Delgado-Pando et al., 2010; Shan et al., 2017).

Traditional sausages are prepared using a mixture of grounded meat, animal fat, salt, water, spices, and other additives and have high enough fat content up to 30% allowing to produce emulsion needed for gelling of meat product. Despite those meat products having high popularity among consumers, the high fat content containing mainly saturated fatty acids is an issue of significant health concerns (Stabnikova et al., 2021). Thus, a lot of studies to reduce the animal fat content in the meat product by partial replacement with different fat substitutes are conducting at recent time (Antonini et al., 2020; Choi et al., 2012; Pintado et al., 2016).

Another way to reduce animal fat content in the meat products is its partial replacement with different plant materials such as grape seed oil (Kim et al., 2020), pineapple dietary fibres (Henning et al., 2016), dietary fiber extracted from makgeolli lees (Choi et al., 2014), chia seeds (Ding et al., 2017), oatmeal (Yang et al., 2010) and many others. Partial replacement of fat, 10 %, with hydrated oatmeal resulted in improvement of technological parameters and sensory properties of low-fat sausages (Kim et al., 2020), pineapple dietary fibres （Henning et al., 2016), dietary fiber extracted from makgeolli lees （Choi et al., 2014), chia seeds (Ding et al., 2017), and oatmeal (Yang et al., 2010). Partial replacement of fat, 10 %, with hydrated oatmeal resulted in improvement of technological parameters and sensory properties of low-fat sausages (Yang et al., 2010). Addition of wheat bran together with dried carrot pomace to chicken sausage in quantity 6% each was recommended to increase dietary fiber content under keeping good level of acceptability (Yadav et al., 2018).

Application of emulsion gels as animal fat replacement is one of the main trends for manufacturing products with high sensory quality while reducing its fat content (Ren et al., 2022). Application of fat emulsions prevents moisture loss during heat treatment and results in the manufacturing of meat products with high structural and mechanical properties. There are a lot of different emulsifying agents. There is known addition of polysaccharide-based emulsion gels for partial replacement (20 and 40%) of pork back-fat in production of dried fermented sausages (Chen et al., 2021). Altogether with improvement of nutritional value there are a lot of studies aimed to enhance the acceptability of low fat sausages. Thus, addition of powder of *Lamina japonica*, 1%, to the breakfast sausage allows to maintain their high overall sensory quality (Kim et al., 2010). Addition of gelatin hydrolysates significantly improved the process performance of cooked sausage (Ham et al., 2020). The addition of 1.0% curdlan improved the functional and textural properties of low-fat sausages (Lee and Chin, 2019).

Phosphates are very different from other emulsifiers traditionally added to meat products. The use of phosphorus-containing food additives in the processing of poultry and red meat products, including the direct addition of phosphates during the preparation of sausages, was allowed by a 1982 ruling of the Food Safety and Inspection Service of the United States Department of Agriculture (Sherman and Mehta, 2009). The addition of phosphates improves the emulsifying and gelling properties of meat proteins as well as overall meat product quality. Addition of phosphates stabilizes the pH value, increases water-holding capacity, reduces moisture loss during cooking, improves texture and sensory properties (tenderness, juiciness, color and taste), and extends shelf life of the finished product (Wang et al., 2009).

The aim of the present study was to evaluate the effect of phosphate addition on the quality of low-fat chicken sausage containing wheat bran to make recommendations for their production.

Materials and Methods

Materials

Chicken breast, fatty pork, wheat bran, tapioca starch, modified tapioca starch, potato starch, ice water, salt, five-spice powder, pepper, rice wine, red yeast rice powder, beet red, casings (commercially salt-cured fresh pig small intestine) were used as raw materials for low-fat sausage preparation. Wheat bran (Henan Jinyuan Grain & Oil Company, Zhengzhou, China, 18% protein, 0.6% fat, and 31.4% dietary fiber) (Shang et al., 2022) was crushed and sifted (part below 80 mesh). Complex phosphate (Harsen Foods (Hongkong) Co., LTD, Shantou, China including sodium pyrophosphate, 60%; sodium tripolyphosphate, 39%, and sodium hexametaphosphate, 1%) was used to study effect of phosphate addition on sausage quality. All these phosphate components are allowed to be used as phosphate additives in the sausage preparation (Knipe, 1983).

Instruments and equipment

Colorimeter (color difference meter CR-400, Shoufeng Instrument Technology Co., Ltd, Changzhou, China) was used to check colour difference of meat products; texture profile analysis was done at a room temperature with a texture analyzer (TA.XT PLUS, Stable Micro System, UK). Water distribution analyses were performed with a low field nuclear magnetic resonance instrument, nuclear magnetic resonance imaging analyzer (NMI20, Shanghai Newmai Electronic Technology Co., Ltd, Shanghai, China).

Processing of wheat bran chicken sausage

Stuffing for sausages was prepared by the following steps. Defrosting chicken breast was cleaned, cut and grounded. Pig skin was soaked in water added with a small amount of rice wine for 30 min. Grounded chicken breasts were added with other ingredients according to the recipes, mixed together, stirred evenly, and put into the sausage casing. The base formulation of the chicken sausages included the following ingredients, g: chicken breast, 400; pig skin, 80; pork fat, 50; wheat bran (part below 80 mesh), 6; cassava starch, 35; cassava denaturant starch, 20; potato starch, 20; ice water, 100; salt, 7; spices, 4.5; pepper, 0.5; rice wine, 25; red rice powder, 1.5, and beet red 2.0. To study the phosphate influence on the quality of low-fat chicken sausage containing wheat bran three samples were prepared with addition of complex phosphate, g: 1.0 (S1), 1.5 (S2), and 2.0 (S3). The sausage ingredients were chopped and put into the pig's small intestine. The chicken sausages were placed in a water bath at a temperature of 80 for 30 min, cooled to room temperature (about 20) and stored in the refrigerator.

Determination of cooking, moisture, and fat losses

To determine the cook loss, 35 g of sausage raw materials were chopped, placed in a 50 ml centrifuge tube, and centrifuged (3000 rpm, 5 min) to remove air bubbles. Then it was heated in a water bath (75 °C, 30 min), cooled at room temperature for 1 h, and weight after cooling was recorded (Choi et al., 2015). The cooking loss was calculated by formula (1):

$$\text{Cooking loss, \%} = (W_0 - W_1)/W_0 \times 100, \quad (1)$$

where W_0 denotes the weight of raw meat sample before cooking, g; W_1 denotes the weight of cooked meat sample, g.

To calculate moisture loss and fat loss the liquid lost during heating was poured into a glass dish and dried at 105 °C for 16 h. The weight lost by evaporation was water loss and the remaining mass on the plate after drying was fat loss. The calculation formulas for water loss and fat loss were (2) and (3):

$$\text{Moisture loss, \%} = (W_2 - W_3)/W_0 \times 100, \quad (2)$$

$$\text{Fat loss, \%} = W_3/W_0 \times 100, \quad (3)$$

where W_0 denotes the weight of raw meat sample before cooking, g; W_1 denotes the weight of cooked meat samples, g; W_2 denotes the weight of cooking liquid, g; W_3 denotes the remaining weight of cooking liquid after drying.

Determination of color difference

The chicken sausages stored at 4°C were kept before measurement at room temperature for 1 h. O/D test was used to determine the brightness value, redness value, and yellowness value.

Determination of pH

5 g of crushed sausage samples were placed into a 50 mL beaker and 20 mL of distilled water were added. Magnetically stirring was provided for 5 min, and the mixture was allowed to stand at room temperature for 30 min. pH of the upper liquid was measured with a pH meter.

Determination of moisture content

Standard drying method (AOAC, 2006) was used to determine moisture content in meat sample dried at 100-102 □ to a constant weight.

Performance of texture planer analysis

The chicken sausages stored at 4 °C were kept before measurement at room temperature for 1 hour, the samples were cut into cylinders of 40×20 mm (height × diameter), and the texture was determined using texture planer analysis (TPA). The probe model was P/5. Set the measured parameters, 5 mm/s before the test rate, 1 mm/s test rate, 1 mm/s after the test rate, 50%, and the compression ratio, 5 g trigger force, was used. The measurement indicators include six parameters such as hardness, elasticity, cohesiveness, chewiness, adhesiveness, and recovery.

Determination of moisture distribution

To determine the dynamic distribution of moisture inside sausages low-field nuclear magnetic resonance (LF-NMR) technology was used (Aursand et al., 2008; Chen et al., 2019).

The sausage was cut into pieces with size of 1 cm × 1 cm × 4 cm and placed in a nuclear magnetic test tube (the diameter of the test tube was 1.8 cm, the height was 18 cm). The Carr-PurcellMeiboom-Gill (CPMG) program was used to determine the sample relaxation time (T2). Lateral relaxation (T2) and corresponding relaxation time (T2B, T21 and T22) and amplitude (A2B, A21 and A22) were determined using the CONTIN imaging software that comes with the system to scan the sample into a magnetic resonance imaging (MRI) image using the IPT.2014 pseudocolor software to process the MRI pseudocolor image (Luo et al., 2020).

Sensory evaluation

10 food specialists with sensory evaluation experience were invited to form the evaluation team. The color, hardness, flavor, viscosity and overall acceptability of bran chicken sausage were evaluated according to the Sensory evaluation standard (Chen et al., 2019; Shang et al., 2019) (Table 1).

Table 1

Sensory evaluation standard

Evaluation index	Evaluation points		
	1~3 points	**4~6 points**	**7~9 points**
Color	No appetite, poor color	Average appetite, normal color,	Appetite, attractive color
Texture	The taste is rough and hard	The taste is slightly rough and hard	The taste is fine and elastic
Flavor	No sausage taste	Average sausage taste	Suitable sausage taste
Viscosity	Sticky teeth	Slightly sticky teeth	Non-sticky teeth
Overall acceptability	Not accept	Accept	Like

Statistical analysis

All measurements were performed at least in triplicates, and the data are expressed as mean ± standard deviation ($\overline{X} \pm S$). All data used the one-way analysis of variance (ANOVA) post-multiple comparison method in the IBM SPSS Statistics 22 data editor, set the significance level to P=0.05, and used the LSD program to analyze the significant differences ($P<0.05$ is significant). Use Microsoft Excel 2017 software to draw charts.

Results and discussion

Low–fat chicken sausages with increased dietary fiber content due to including in the sausage formulation of wheat bran were used as an object of study (Shang, 2019). To evaluate incorporation of complex phosphate to chicken- sausage on their technological and sensory properties, three samples of sausages with the complex phosphate added in quantity of 1.0 g (S1), 1.5 g (S2), and 2.0 g (S3) to 400 g of ground chicken meat were prepared and studied.

Effects of different phosphate content on cooking loss and emulsification stability of ground chicken meat

Results of the study of the effects of different phosphate amounts on cooking loss and emulsification stability, which was indirectly evaluated by water loss and fat loss, of ground chicken meat are shown in Table 2.

Table 2
Effects of different phosphate content on cooking loss and emulsification stability of ground chicken meat

Samples with phosphate content	Cooking loss, %	Moisture loss, %	Fat loss,%
1.0 g/400 g of ground chicken meat (S1)	9.26±0.29^{a}	9.07±0.30^{a}	0.19±0.05^{a}
1.5 g/400 g of ground chicken meat (S2)	7.18±0.20^{c}	7.10±0.18^{c}	0.08±0.03^{b}
2.0 g/400 g of ground chicken meat (S3)	8.24±0.22^{b}	8.14±0.25^{b}	0.10±0.03^{b}

Note: Means within a column with different letters are significantly different ($p<0.05$).

The stabilizing and emulsifying action of phosphate used in manufacturing of emulsified meat products is well known (Xu et al., 2021). The decrease of the phosphate content led to lowering of the cooking yield, emulsion stability and texture properties of meat products (Pinton et al., 2019), meanwhile, the high amounts of phosphate is not welcomed by consumers（Goemaere et al., 2021). So, it is necessary to determine the optimum content of phosphate in the meat product ensured its high quality but not to exceed this value. In our research it was shown that the minimum cooking loss, water loss and fat loss was observed for sample 2 (S2) of low-fat chicken sausages, followed by sample 3 (S3), meanwhile the highest losses were found for sample 1 (S1). Thus, addition of 1.5 g of complex phosphate to 400 g of ground chicken meat ensured better retaining of water and fat, lowest cooking loss and highest emulsifying stability than in cases when 1 or 2 g of complex phosphate were used.

Effects of different phosphate content on chicken sausage color

Color is an important characteristic of sausages. The effect of different phosphate content in low-fat chicken sausages is shown in Table 3.

According to the results, the brightness values of the sausages S2 and S3 were higher than that of the ground meat, meanwhile the redness values of sausages S2 and S3 decreased compared with the ground meat. The yellowness value of sausage S2 increased, indicating that the red color of processed sausages was less and more yellow. Increasing sodium tripolyphosphate and salt contents did not affect lightness ($p > 0.05$), but did increase redness and yellowness ($p < 0.05$) of low-fat chicken sausages (Choi et al., 2020).

Table 3

Effects of different phosphate content on the color of ground chicken meat and chicken sausages

Sample	Brightness value		Redness value		Yellowness value	
	Ground meat	Sausage	Ground meat	Sausage	Ground meat	Sausage
S1	64.83 ±0.29[a]	62.86 ±0.69[b]	21.34 ±0.20[c]	20.23 ±0.47[a]	10.48 ±0.49[b]	12.51 ±0.10[a]
S2	61.24 ±1.28[c]	61.64 ±0.81[b]	24.11 ±0.36[a]	17.89 ±0.22[b]	11.92 ±0.22[a]	12.04 ±0.34[a]
S3	62.98 ±0.22[b]	69.14 ±0.44[a]	22.88 ±0.66[b]	17.15 ±1.71[b]	11.10 ±0.47[ab]	10.99 ±0.24[b]

Note: Means within a column with different letters are significantly different ($p<0.05$).

Effects of different phosphate content on moisture content and pH value

According to the results present in Table 4, the moisture content of ground chicken meat increased with the increase of the amount of phosphate, and there was a significant difference among the studied samples.

Table 4

Effects of different phosphate content on moisture and pH of ground chicken meat and chicken sausage

Sample	Moisture, %		pH, units	
	Ground meat	Sausage	Ground meat	Sausage
S1	48.73±0.59[c]	59.85±0.45[b]	6.29±0.01[ab]	6.33±0.03[b]
S2	54.70±0.38[b]	63.43±0.44[a]	6.22±0.05[b]	6.31±0.04[b]
S3	59.21±0.29[a]	63.44±0.87[a]	6.33±0.05[a]	6.48±0.03[a]

Note: Means within a column with different letters are significantly different ($p<0.05$).

The moisture contents in S2 and S3 sausages were significantly higher than in S1, but there was no difference in the moisture content in sausages S2 and S3. There was no significant difference in pH between samples S1 and S2, but values of pH of the ground meat and sausages of sample S3 were a little bit higher than those for S1 and S2.

Effects of different phosphate content on texture properties of sausages

The texture is one of the most important sensory characteristics of emulsified sausages. Texture properties of low-fat chicken sausages with different amounts of complex phosphate were estimated (Table 5).

It was shown that addition of phosphates in emulsion-type sausage could change their texture characteristics and the amount of phosphate added positively correlated with the hardness of the sausages made from frozen meat (Wang et al., 2009). According to our results, the hardness of low-fat chicken sausages with the addition of 1.5 g of complex phosphate per 400 g of ground chicken meat (sample S2) was significantly higher than that of the sausage prepared with 1.0 g of complex phosphate per 400 g of ground chicken meat (sample S1) ($p<0.05$). Meanwhile, all other texture parameters did not differ significantly for all tested sausages (Table 5). However, springiness and chewiness were better in sample S2 ($p<0.05$).

On the whole, the sample S2 with the content of complex phosphate around 0.2% had the best quality and taste. In another study, the best textual properties of low-fat chicken sausage were observed when sodium tripolyphosphate, 0.3%, was added ($p < 0.05$) (Choi et al., 2009).

Table 5

Effect of different phosphate content on texture of chicken sausage

Sample	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
S1	91.90 ±10.88[b]	0.39 ±0.17[a]	0.39 ±0.22[a]	36.54 ±20.70[a]	16.44 ±13.36[a]	0.05 ±0.01[a]
S2	156.44 ±22.52[a]	0.58 ±0.05[a]	0.27 ±0.04[a]	34.25 ±4.17[a]	25.15 ±2.76[a]	0.05 ±0.01[a]
S3	113.83 ±28.31[ab]	0.17 ±0.04[a]	0.17 ±0.05[a]	18.41 ±3.72[a]	13.13 ±1.18[a]	0.03 ±0.00[a]

Note: Means within a column with different letters are significantly different ($p<0.05$).

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Effects of different phosphate content on distribution of water in chicken sausages

Low-field nuclear magnetic resonance technology was used to study the distribution of water in sausages. Effects of different phosphate content on distribution of water in chicken sausages is represented in Figure 1.

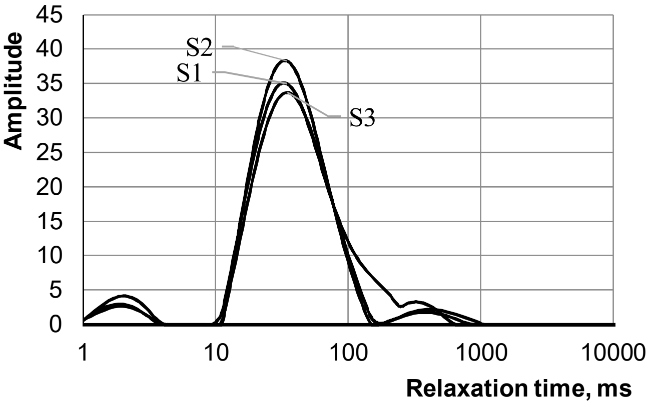

Figure 1. Effects of different phosphate content on distribution of moisture in chicken sausage

The amount of free water is in the range of 0-10 milliseconds (ms) and moves towards a short relaxation time. The bound water (namely, by phosphates and protein complex) and immobilized water don't move and are in the range from 100-1000 ms. This is the interval for water strongly bound to the meat proteins. The interval of 10 to100 ms represents weakly bound water. The highest peak in this interval was observed for sample S2. Analysis of curves presented in Fig. 2 indicates that the increase of the phosphate amount in sausage S2 increases the amplitude of weakly bound water and contributes to better binding of free water improving the water-holding capacity of chicken sausages and obtaining a dense texture of the meat product. This is in a study by Shao et al. (2016) also noted that the addition of phosphate to ground pork meat shortens the water relaxation time, and the addition of phosphate and NaCl to sausage increases their water-holding capacity.

Nuclear magnetic imaging analysis

Distribution of water in low-fat wheat bran chicken sausages prepared with different content of phosphate was studied by low-field nuclear magnetic resonance (Figure 2).

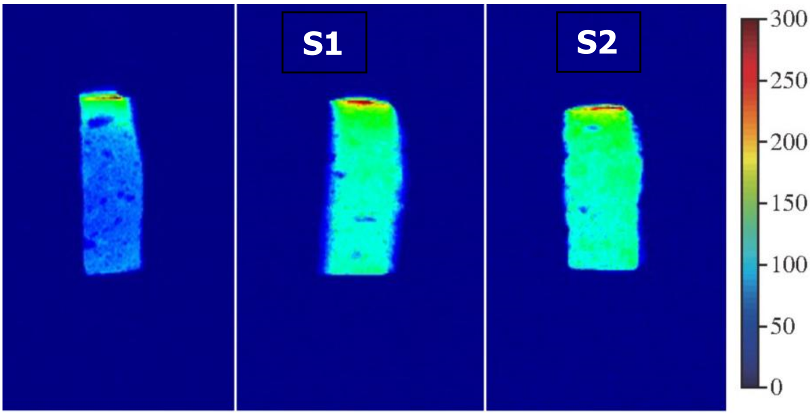

Figure 2. Pseudo-color map of chicken sausage with different phosphate content per 400 g of ground chicken meat:
1.0 g (S1); 1.5 g (S2), and 2.0 g (S3).

Green color corresponds to strongly bound water molecules in sausages, and blue color reflects the amount of free water. According to the nuclear magnetic imagines, increase of phosphate amounts resulted in an increase of water bound molecules content in sausages S2 and S3 that indicates a better binding of water by phosphates and a network of proteins that ensures improving of the water holding capacity of low-fat chicken sausages.

Effects of different phosphate content on sensory evaluation of wheat bran chicken sausages

Sensory properties of low-fat wheat bran sausages added with different amounts of phosphate were evaluated to assess the consumer's acceptance of the product (Table 6).

Table 6
Effect of different phosphate content on sensory evaluation of wheat bran chicken sausages

Sausages	Color	Texture	Flavor	Viscosity	Acceptability
S1	3.80±0.79[a]	4.10±0.99[a]	4.10±1.85[a]	4.00±1.76[a]	5.30±1.06[a]
S2	4.30±1.42[a]	4.50±1.08[a]	5.10±1.29[a]	5.00±1.56[a]	5.40±1.43[a]
S3	4.50±1.08[a]	4.00±1.05[a]	4.80±1.55[a]	3.90±1.52[a]	5.30±1.20[a]

It was found that phosphate addition in studied amounts had no significant effect on the sensory scores of wheat bran chicken sausage ($P < 0.05$). The sausages S2 with addition of 0.2% of phosphate (1.5 g per 400 g of ground chicken meat) received the highest scores by the sensory evaluation team members in terms of color, texture, flavor, viscosity, and overall acceptability. This evaluation result was consistent with the physicochemical property analysis.

Conclusion

Addition of 1.5 g of complex phosphate in formulation of low-fat chicken sausages (400 g chicken breast, 50 g pork back fat, 80 g pig skin and 6 g wheat bran as raw materials) decreases cooking loss,moisture loss andfat loss; improved the texture properties, mainly the hardness ($P>0.05$), meanwhile other characteristics varied but were not significantly different, and increases water holding capacity and sensory evaluation value of the sausages. So, it can be recommended to add 0.2% of complex phosphate in formulation of low-fat wheat bran chicken sausages to enhance their technological and sensory properties.

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