Evaluation of phosphate replacement with natural alternatives in chicken patties as a novel approach

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Abstract. Polyphosphates are known to increase both the amount of bound water and the strength of the meat particle-particle binding in processed meat products. However, several health risks related to dietary phosphate intake are driving the meat industry to improve product formulations (less phosphate) and to search for alternative phosphate replacers. The aim of this research was to investigate the effects of using eggshell powder as a phosphate replacer on some quality characteristics of chicken patties. Chicken patties were subjected to four treatments, as follows: control contained 0.5% sodium tripolyphosphate; 0.5% eggshell powder; 0.5% eggshell powder+0.25% pectin, and; 0.5% eggshell powder+0.25% carrageenan. Chemical composition, technological parameters and sensory properties were evaluated in all patties. Total moisture, protein, fat and ash in uncooked/cooked patties were in the range of 72.20-75.24%, 13.84-15.39%, 8.14-10.87% and 2.71-3.14%, and 68.59-72.33%, 15.11-18.12% and 8.36-10.99%, respectively. The patties with 0.5% eggshell powder+0.25% carrageenan had the highest water holding capacity and cooking efficiency percentage in relation to pH among the patties studied. The results show the combination of eggshell powder with pectin or carrageenan could be an alternative additive for phosphate-free meat products.

1. Introduction

Phosphates are multi-functional, low-cost compounds that enhance product yield by increasing water holding capacity, improve color, flavor, and texture, and have antioxidant functions. Other beneficial effects of phosphates are; stabilization of emulsions and improved texture of meat products by increasing the extraction of salt-soluble proteins based on increasing ionic strength and charges, and reduction of lipid oxidation through their metal chelating activity, which subsequently inhibits off-flavor development\(^{[1]}\).

Phosphates are chemical synthetic analogues. Research shows that high dietary phosphate intake increases the risk of kidney and bone diseases, as well as triggering potential cardiovascular and pulmonary diseases. According to recent research, several health risks are caused by phosphate salts, and therefore, reducing the amount of phosphates in product formulations or replacing them with natural components that can provide the same technological effects have come to the fore. Although the negative effects of high salt consumption on health have been known for a long time, studies on the possible health risks caused by the use of phosphate above normal levels have been conducted, in general, since the beginning of the 2000s. Many previous studies have attempted to improve the functionalities of meat products by using various functional ingredients, such as inulin, pectin\(^{[2]}\), functional carbohydrates, including guar gum, carrageenan, alginic acid and chitosan\(^{[3]}\), 0.2% oyster shell calcium powder, 0.3% egg shell calcium powder, and 0.25% whey protein concentrate\(^{[4]}\).

Natural calcium powders, which are widely used in the meat industry, include oyster shell calcium (OSC), egg shell calcium (ESC), marine algae calcium (MAC), and whey calcium (milk calcium, MC).
Each of these natural calcium powders has their own unique physicochemical properties and sensory characteristics, as they differ in their basic sources from raw materials and manufacturing methods. Because of these differences, they provide different processing properties when added to meat products \cite{5}. The effects of different combinations of premixed natural calcium powders on the quality properties of cooked pork products were investigated, with the aim of developing high-quality phosphate-free meat products \cite{6}. Eggshell primarily contains calcium, magnesium carbonate (lime) and protein \cite{7}, so eggshell powder (ESP) can be an attractive source of calcium in human nutrition.

Another phosphate replacer, pectin, is used as coating, emulsifier, stabilizer and gelling agent in meat products. Studies show pectin should be used with other additives like calcium to form a good gel suitable for use as a natural phosphate replacer. As a result, pectin is useful in meat products but should not be used alone. Instead, different substances should be used together with pectin in order to provide the desired features of a phosphate replacer \cite{8}.

Carrageenan is composed of sulfated linear polysaccharides of D-galactose and 3,6-anhydro-D-galactose, and is extracted from red sea algae. It has no nutritional value, is used by the food industry due to its gelling, thickening and stabilizing properties, and recently, has been used in reduced fat meat products \cite{9}. When carrageenan is incorporated in low fat meat products, it improves the textural characteristics of the final product by decreasing toughness and increasing juiciness \cite{10}.

To the best of our knowledge, in previous studies, the suitability of eggshell powder in combination with pectin or carrageenan as natural phosphate replacers in chicken patties has not been studied. Consequently, the aim of this study was to evaluate the effect of the use of eggshell powder alone and with pectin or carrageenan as natural phosphate replacers on some quality characteristics of chicken patties.

2. Materials and Methods

2.1. Raw material
Chicken breast and thigh meat was obtained from a local market and stored at 4°C prior to production. All subcutaneous fat and intermuscular fat were removed. Food grade sodium tripolyphosphate (STPP) was kindly donated by Pacovis Food Co. (Izmir, Turkey), pectin was supplied by Sigma-Aldrich Co. (Istanbul, Turkey), carrageenan was purchased from Smart Chemical Co. (Izmir, Turkey) and chicken skin was purchased from a local market. Eggshell powder was prepared in laboratory.

2.2. Experimental design and preparation of chicken patties
Four different chicken patties were formulated; in control patties (C), 0.5 g/100 g food grade sodium tripolyphosphate was added. Other patties were formulated with: 0.5% eggshell powder (E); 0.5% E+0.25% pectin (EP), and; 0.5% E+0.25% carrageenan (EC) as phosphate replacers. Salt (1.5%) and ice (15%) was added to all formulations. Chicken skin was used (15%) as the fat source. Chicken meat (breast and thigh) and skin were ground through a 3 mm plate grinder (Arnica, Turkey), separately. Batches (approximately 700 grams) of each formulation were mixed with a thermomixer (Thermomix, Germany) until a homogenous mixture was obtained (3 min), then mixtures were processed into chicken patties by using a metal shaper. Patties were cooked in an electric oven (Teba, Turkey) at 180°C until the core temperature reached 73°C. Patties were cooled to room temperature and analyses were performed.

Table 1. Formulations of chicken patties

| Patty formulation | Meat (g) | Chicken skin (g) | Ice (g) | NaCl (g) | NaNO₂ (g) | STPP (g) | ESP (g) | Pectin (g) | Carrageenan (g) |
|-------------------|---------|-----------------|--------|----------|-----------|----------|--------|-----------|----------------|
| C                 | 68.35   | 15              | 15     | 1.5      | 0.05      | 0.5      | 0      | 0         | 0              |
Moisture and ash contents of the uncooked and cooked patties were determined according to the AOAC procedure (2012). Protein content of the patties was determined using an automatic nitrogen analyzer (FP 528 LECO, USA) based on the Dumas method. Fat content was evaluated according to Flynn and Bramblet (1975). pH of the patties was measured in triplicate using a pH-meter (WTW pH 3110 set 2, Germany), equipped with a penetration probe.

The percent cooking yield was determined by calculating weight differences for patties before and after cooking [11]. Water holding capacity was determined according to Hughes, Cofrades, and Troy (1997) with slight modifications [12]. The moisture retention was determined according El-Magoli et al. (1996) [13]. Fat retention was calculated according to Murphy et al. (1975) [11]. The Bradford method was used to measure protein solubility. Patties were imaged by scanning electron microscopy (SEM) (Thermo Scientific Apreo S, USA) after dried specimens of patties were sputter coated with gold (Leica EM ACE600, Germany). The Apreo SEM benefits from the unique in-lens backscatter detection, which provides excellent materials contrast, even at tilt, short working distance, or on sensitive samples.

Patties were randomly assigned for sensory evaluation. Patties were served warm to a ten-membered panel (graduate students and staff of Ege University Food Engineering Department). At each session, three patty samples were served immediately to panelists and were subjected to sensory evaluation for appearance, color, texture, flavor, juiciness, and overall acceptability.

The experiment was performed twice and the data was evaluated by two-way analysis of variance (ANOVA) using SPSS software version 21.0. Differences among the means were compared using Duncan’s Multiple Range Test.

### 3. Results and Discussion

Chemical composition and pH of uncooked and cooked patties are presented in Table 2. Total moisture, protein, fat and ash contents in uncooked patties were between 72.20-75.24%, 13.84-15.39%, 8.14-10.87% and 2.71-3.14%, respectively. The differences of formulation resulted significant changes in moisture, protein and fat contents of uncooked patties (P<0.05) while no effect was recorded on ash content (P>0.05). Uncooked EC patties had the highest moisture content among the patty groups (P<0.05). Uncooked EP patties had a similar protein content as C patties (P<0.05). The highest fat content was measured in EP patties, both uncooked and cooked. The pH of uncooked patties was between 6.16 and 6.22. Total moisture, protein and fat contents in cooked patties ranged between 68.59-72.33%, 15.11-18.12% and 8.36-10.99% respectively. The pH of cooked patties ranged from 6.18 to 6.27. Cooking resulted in increased pH, protein, fat and ash contents of patties, while moisture content decreased due to cooking loss. EC patties had the highest moisture content (P<0.05), so adding carrageenan led to an increase in total moisture content. This finding could be the result of the high WHC of carrageenan. The uncooked patty mixes of C and EC had higher pHs than other mixes (P<0.05), which could be the result of the greater effectiveness of EC in altering the pH. Adding eggshell powder with pectin and carrageenan increased the pH of cooked patties, and the highest pH was measured in cooked EP and EC patties (P<0.05). Among cooked patties, E patties had the lowest pH (P<0.05). These results showed that eggshell powder alone was not suitable phosphate replacer, so this product should be combined with other materials to produce more acceptable phosphate-free meat products.
Table 2. Chemical composition of uncooked and cooked patties

|                  | Moisture (%) | Protein (%) | Fat (%)  | Ash (%)  | pH          |
|------------------|--------------|-------------|----------|----------|-------------|
| **Uncooked patties** |              |             |          |          |             |
| C                | 72.20±0.15c  | 15.39±0.55a | 9.43±0.37b | 3.14±0.31a | 6.20±0.01a  |
| E                | 73.58±0.56b  | 13.84±0.35b | 8.14±0.64c | 2.71±0.09b | 6.17±0.00b  |
| EP               | 73.39±0.86b  | 15.16±0.53b | 10.87±0.33a | 2.71±0.16b | 6.16±0.00b  |
| EC               | 75.24±0.39a  | 14.21±0.35b | 10.08±0.85ab | 2.80±0.24ab | 6.22±0.01a  |
| **Cooked patties** |              |             |          |          |             |
| C                | 68.59±1.87b  | 18.12±0.66a | 9.99±0.73a | 3.75±0.16a | 6.23±0.01b  |
| E                | 70.72±0.61ab | 17.05±0.60a | 8.36±1.07b | 3.13±0.10b | 6.18±0.01c  |
| EP               | 72.33±1.06a  | 16.68±1.02ab | 10.99±0.13a | 2.98±0.00b | 6.27±0.01a  |
| EC               | 69.53±0.72b  | 15.11±0.87b | 9.96±0.15a | 3.15±0.01b | 6.27±0.01a  |

Mean±SD with different superscript letters indicate significant differences (p<0.05)

C: 0.5% sodium tripolyphosphate, E: 0.5% eggshell powder, EP: E+0.25% pectin and EC: E+0.25% carrageenan

Cooking characteristics and protein solubility values are shown in Table 3. Cooking yield was between 79.49%-85.91%, and the lowest cooking yield was recorded in EP patties. WHC was between 72.19-82.28, depending on pH. Moisture retention values were between 66.52-62.71%, and the highest moisture retention was observed in EP patties, while the lowest was observed in EC patties. Moisture retention in meat products is an important cooking parameter, since retained moisture in the product affects eating quality [14]. The fat retention percentages were between 85.29-96.06%. Fat retention was the greatest in C and EC patties, formulated with sodium tripolyphosphate and carrageenan, respectively. The protein solubility was significantly affected by patty formulation and was the highest (1118.01 µg protein/ml) in EC patties, using eggshell powder along with carrageenan.

Table 3. Cooking characteristics and protein solubility of chicken patties

|                  | Cooking Yield (%) | WHC       | Moisture Retention (%) | Fat Retention (%) | Protein Solubility (µg protein/ml) |
|------------------|--------------------|-----------|------------------------|-------------------|-----------------------------------|
| C                | 85.12±0.35b        | 75.82±0.96b | 63.95±1.64bc           | 96.06±1.82a       | 962.40±3.39c                      |
| E                | 83.86±0.57c        | 73.52±0.59c | 65.27±1.04ab           | 85.29±1.57c       | 805.57±7.60d                      |
| EP               | 79.49±0.19d        | 72.19±0.91c | 66.52±0.73a            | 90.44±1.88b       | 1026.83±3.07b                     |
| EC               | 85.91±0.27a        | 82.28±0.49a | 62.71±0.56c            | 94.61±1.49a       | 1118.01±2.42a                     |

WHC – water holding capacity; Mean±SD with different superscript letters indicate significant differences (p<0.05); C: 0.5% sodium tripolyphosphate, E: 0.5% eggshell powder, EP: E+0.25% pectin and EC: E+0.25% carrageenan

Typical SEM micrographs of chicken patties are presented in Figure 1. The distributions of particles and voids in the product structure were seen, enabling us to comment on the quality parameters such as
water holding capacity and texture [15]. Microstructural differences were observed between the patty formulations. In the C and EC patties particularly, fat globules were retained in the protein network.

![Scanning electron microscope images of chicken patties (500 ×)](image)

Figure 1. Scanning electron microscope images of chicken patties (500 ×)

The results of sensory analysis are presented in Figure 2. Appearance, color, texture, juiciness, flavor and general acceptability of the patties were scored between 6.10-7.30, 6.40-7.30, 6.80-7.50, 6.40-7.40, 5.90-7.20 and 5.90-7.20, respectively. The sensory quality of all patties was acceptable. There was no significant difference in terms of general acceptability between the different patties (P>0.05), and therefore, use of eggshell powder provided equivalent sensory characteristics to phosphate. The EP patties received the highest sensory analysis scores.

![Sensory scores of chicken patties](image)

Figure 2. Sensory scores of chicken patties
4. Conclusion

Our study showed that eggshell powder combined with carrageenan would be a suitable natural phosphate replacer in chicken patties. The pH of the patties with the combination of eggshell powder and carrageenan was significantly higher than the other patty types. In all patty groups, the water holding capacity was correlated with cooking yield. The results of our study showed the combinations of eggshell powder with pectin or carrageenan in chicken patties have good potential to enhance these products’ chemical, technological and sensory qualities and offers a novel possibility for phosphate replacement in formulation of healthier meat products.

References

[1] Sebranek J (2009) Basic curing ingredients Ingredients in Meat Products 1–23
[2] Méndez-Zamora G, García-Macas J A, Santellano-Estrada E, Chávez-Martínez A, Durán-Meléndez L A, Silva-Vázquez R and Quintero-Ramos A (2015) Fat reduction in the formulation of frankfurter sausages using inulin and pectin Food Science and Technology (Campinas) 35(1) 25–31
[3] Park K S, Choi Y I, Lee S H, Kim Ch H and Auh J H (2008) Application of functional carbohydrates as a substitute for inorganic polyphosphate in pork meat processing Korean J. Food Sci. Tech. 40(1) 118–21
[4] Jeong J Y (2018) Determining the optimal level of natural calcium powders and whey protein concentrate blends as phosphate replacers in cooked ground pork products Korean J. Food Sci. Anim. Res. 38(6) 1246–52
[5] Cho M G, Bae S M and Jeong J Y (2017) Egg shell and oyster shell powder as alternatives or synthetic phosphate: Effects on the quality of cooked ground pork products Korean J. Food Sci. Anim. Res. 37(4) 571
[6] Bae S M, Cho M G and Jeong J Y (2017) Effects of various calcium powders as replacers for synthetic phosphate on the quality properties of ground pork meat products Korean J. Food Sci. Anim. Res. 37 456–63
[7] Gowisika D, Sarankokila S and Sargunan K (2014) Experimental investigation of egg shell powder as partial replacement with cement in concrete Int. J. Engi. Trends and Tech. 14(2) 65–8
[8] Korkmaz F (2018) Edible films-coatings and they use in aquaculture Atatürk University Journal of the Agricultural Faculty. 49(1) 79–86
[9] Mangione M R, Giacomazza D, Bulone D, Martorana V and Biagio P L S (2003) Thermoreversible gelation of κ-Carrageenan: Relation between conformational transition and aggregation Biophy Chem. 104 95–105
[10] Zhang T, Xu X, Li Z, Wang Y, Xue Y and Xue C (2018) Interactions and phase behaviors in mixed solutions of κ-carrageenan and myofibrillar protein extracted from Alaska pollock surimi Food Res. Int. 105 82–127
[11] Murphy E W, Criner P E and Grey B C (1975) Comparison of methods for calculating retentions of nutrients in cooked foods J. Agri. Food Chem. 23 1153–7
[12] Hughes E, Cofrades S and Troy D J (1997) Effects of fat level, oat fibre and carrageenan on frankfurters formulated with 5, 12 and 30% fat Meat Sci. 45(3) 273–81
[13] El-Magoli S B, Laroia S and Hansen P T M (1996) Flavour and texture characteristics of low fat ground beef patties formulated with whey protein concentrate. Meat Sci. 42(2) 179–93
[14] Serdaroglu M and Öztürk B (2017) Effects of inulin and sodium carbonate in phosphate-free restructured poultry steaks IOP Conference Series Earth and Environmental Science 85(1) 012026
[15] Zhang M, Li F, Diao X, Kong B and Xia X (2017) Moisture migration, microstructure damage and protein structure changes in porcine longissimus muscle as influenced by multiple freeze-thaw cycles *Meat Sci.* **133** 10–8