Effects of Inulin and Sodium Carbonate in Phosphate-Free Restructured Poultry Steaks

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Abstract. Recently inorganic phosphates used in meat product formulations have caused negative impact on consumers due to their potential health risks. Therefore, utilization of natural ingredients as phosphate replacers has come into prominence as a novel research topic to meet consumer demands for clean-label trends. In this study, we objected to investigate the effects of inulin utilization either in the powder or gelled form, alone or in combination with sodium carbonate on quality of phosphate-free restructured chicken steaks. Total moisture, protein, lipid and ash values of the trial groups were in the range of 71.54-75.46%, 22.60-24.31%, 0.94-1.70% and 1.45-2.13%, respectively. pH of the samples was between 6.18-6.39, significant increments were recorded in samples containing inulin with sodium carbonate. L*, a* and b* values were recorded as 78.92-81.05, 1.76-3.05 and 10.80-11.94, respectively, where use of gelled inulin resulted in changes of L* and a* values. Utilization of inulin in combination with sodium carbonate decreased cook loss and enhanced product yield. Sensory scores in control group with phosphate showed a similar pattern to sensory scores in groups with inulin and sodium carbonate. During storage, purge loss and lipid oxidation rate were similar in control and inulin + sodium carbonate samples. The results showed that use of inulin in combination with sodium carbonate provided equivalent physical, chemical and sensory quality to phosphates in restructured chicken steaks.

1. Introduction
In the last years, there has been a considerable increase in consumption of ready-to-eat poultry products in line with technological improvements, modernization of everyday life and consumer habits. However, some of the food additives used in formulation of further processed products cause negative impact on consumers due to potential health concerns. Hence, recently consumption of clean-label products in which synthetic additives are minimized has been a growing trend. Accordingly, a novel reformulation strategy is the reduction of widely used additives in poultry product formulations such as salt, nitrite and phosphate or replacement of them with alternative natural ingredients [1, 2].

Utilization of phosphates lead to change pH value that is highly related to water-holding capacity, breakdown the calcium bridges of actomyosin complex and improve the functionality of meat proteins, such as water-holding, solubility, emulsification and gelling. Thus, in various meat products phosphates could enhance product yield, texture, flavor and colour, decrease cook loss, thaw loss and purge loss, as well as they act as antioxidants extending shelf life [3, 4]. However, recently inorganic phosphates used in meat product formulations have caused negative impact on consumers due to their potential health risks [4, 5]. Therefore, utilization of natural ingredients as phosphate replacers has come into prominence as a novel research topic to meet consumer demands for clean-label trends.
Inulin is a soluble and health-promoting prebiotic dietary fiber industrially extracted by a washing process mainly from chicory (Cichorium intybus) roots and consisted of oligo and polysaccharides [6, 7]. Inulin was reported to enhance various quality parameters like water-holding capacity, emulsion stability, textural and sensory attributes in different types of meat products [6, 8-10]. In this study, we aimed to research the effects of inulin (powder/gelled) utilization with or without sodium carbonate on quality characteristics of restructured chicken steaks.

2. Material and Methods

Fresh boneless post-rigor chicken breast cubes (2x3x3 cm) were supplied from the production line of Lezita Integrated Meat Processing Plant (Abahoğlu Co., Izmir) and stored at 4°C prior to production. Food-grade sodium tripolyphosphate (STPP) and sodium caseinate was donated by Pacovis Food Co. (Izmir, Turkey), Orafti-HP inulin was purchased from Artisan Food Co. (Istanbul, Turkey), rosemary extract was supplied from Frutarom-Etol Co. (Kocaeli, Turkey) and microbial transglutaminase was purchased from Stern Ingredients (Izmir, Turkey). Sodium carbonate (SC) and other ingredients were purchased from local market. For production of control treatment (P), breast cubes were tumbled with NaCl (1%), STPP (0.5%), rosemary extract (0.015%) and ice (added to have 72% initial moisture) using a tumbler (Vakona GmbH, Germany) operated at 50 rpm under vacuum for 45 min. Other treatments were formulated with: 0.2% SC (C), 4.5% powder inulin (I), 4.5% powder inulin and 0.2% SC (IC), 4.5% gelled inulin (GI), 4.5% gelled inulin and 0.2% SC (GIC) as phosphate replacers. Gelled inulin was prepared as 30% (w/v) aqueous solution. All treatments were also contained sodium caseinate (1.5%) and microbial transglutaminase (0.7%) to enhance meat binding. The tumbled mixture was stuffed into synthetic ham casings, cold-setting was applied for 18 h at 4°C and then the products were steam-cooked for 4-6 h at 85°C. After that, the samples were cooled to 4°C, casings were removed and samples were sliced into 1 cm thickness. The steaks were finally packaged under modified atmosphere consisted of 70% N₂ and 30% CO₂ (Multivac 240, Germany) and stored for 15 days at 2±2°C.

In restructured poultry steaks, total moisture, lipid and ash analysis were carried out according to AOAC [11] and protein content was determined according to AOCS [12]. pH was measured by using a pH-meter (WTW, Germany) equipped with a penetration probe. Hunter colour (L*, a*, b*) parameters of the emulsions was measured with a portable colorimeter (Konica Minolta, Japan). Cook yield was determined as a percentage from the weight loss between un-cooked and dry-cooked samples. A 9-point hedonic scale was used to evaluate sensory characteristics of the samples. Thiobarbituric Acid Reactive Substances (TBARS) was measured according to Witte et al. [13] to determine lipid oxidation secondary products during storage. Data was statistically analysed by Analysis of Variance (ANOVA) and Duncan Post-Hoc tests using the SPSS software.

3. Results and Discussion

Chemical composition of the treatments is presented in Table 1. Total moisture, protein, fat and ash values ranged between 71.54-75.46%, 22.60-24.31%, 0.94-1.70% and 1.45-2.13%, respectively. Samples containing STPP (P group) and sodium carbonate (C group) had higher moisture content compared to others (P<0.05). Protein content of the samples generally did not differ, except GI samples having higher protein content compared to P (P<0.05). The highest fat content was obtained in I, IC and GI samples, while the lowest fat content was in P and GIC samples (P<0.05). However, it was found that fat content of the samples was generally pretty low since no added fat was included in the formulations. P samples had the highest ash content among treatments (P<0.05, probably due to higher inorganic content.
### Table 1. Chemical composition of restructured poultry steaks.

| Treatments | Moisture (%) | Protein (%) | Fat (%) | Ash (%) |
|------------|--------------|-------------|---------|---------|
| P          | 75.46±0.33^a | 22.60±0.37^b | 0.94±0.06^c | 2.13±0.09^a |
| C          | 72.99±0.81^b | 23.25±1.26^ab | 1.48±0.09^b | 1.71±0.04^b |
| I          | 70.52±0.29^d | 23.68±1.17^ab | 1.63±0.09^a | 1.45±0.05^d |
| IC         | 72.23±0.74^bc | 22.64±0.69^b | 1.70±0.06^a | 1.51±0.03^cd |
| GI         | 71.55±0.37^cd | 24.31±0.28^a | 1.68±0.11^a | 1.59±0.03^c |
| GIC        | 71.54±1.00^d | 23.36±0.47^ab | 1.04±0.05^c | 1.70±0.02^b |

a, b, c: Different letters indicate significant difference (P<0.05). Data is presented as mean values ± standard deviation.

pH values of restructured steaks are presented in Figure 1. The values were between 6.18-6.39 and significant differences were obtained depending on formulations (P<0.05). The lowest pH values were belonged to I and GI samples (P<0.05). However, pH of the treatments formulated with inulin and SC (IC and GIC samples) were significantly increased (P<0.05). Control samples with STPP (P group) had significantly lower pH compared to C, IC and GIC (P<0.05). Therefore, it was found that utilization of inulin and SC combination in restructured poultry could meet the effect of phosphates on pH value, regardless of the form of inulin (powder/gelled).

![Figure 1. pH value of restructured chicken steaks.](image)

The surface colour parameters of restructured steaks are shown in Table 2. L*, a* and b* values were between 78.92-81.05, 1.76-3.05 and 10.80-11.94, respectively. GI samples with gelled inulin had higher L* values compared to P samples with STPP (P<0.05), while the other treatments had similar values. This result showed that utilization of gelled inulin alone could favour lighter colour probably due to the opaque gel colour. a* values of GIC samples were higher than P, C and GI samples (P<0.05). No significant differences were obtained in b* values of the samples. A study reported that inulin utilization in fermented chicken sausages had an increment effect on L* and a* values [14].
Table 2. Surface colour of restructured poultry steaks.

| Treatments | L*       | a*       | b*       |
|------------|----------|----------|----------|
| P          | 78.92±0.61<sup>b</sup> | 1.92±0.72<sup>b</sup> | 10.80±0.49 |
| C          | 80.98±0.87<sup>ab</sup> | 1.76±0.61<sup>b</sup> | 11.92±0.85 |
| I          | 80.07±1.00<sup>ab</sup> | 2.49±0.58<sup>ab</sup> | 11.94±0.27 |
| IC         | 80.95±0.93<sup>ab</sup> | 2.34±0.81<sup>ab</sup> | 11.76±0.65 |
| GI         | 81.05±1.75<sup>a</sup> | 2.03±0.23<sup>b</sup> | 11.79±1.07 |
| GIC        | 79.28±1.94<sup>ab</sup> | 3.05±0.64<sup>a</sup> | 11.64±0.73 |

a, b, c: Different letters indicate significant difference (P<0.05). Data is presented as mean values ± standard deviation.

Figure 2 presents the results of cook yield of restructured steaks, which were between 71.72-85.83%. Compared to P groups; C, IC, GI and GIC samples had higher cook yields (P<0.05). Therefore, the combined addition of inulin and SC presented an advantage to increase cook yields, which is probably due to the synergistic effect of pH increment by SC and binding ability of inulin. The form of inulin was also effective on cook loss, when used solely and in powder form, cook yield was significantly decreased (P<0.05). Thus, when used in gelled form, since inulin was homogenously mixed with meat it could favour meat binding and thus product yield. On the other hand, powder form of inulin likely was not able to provide homogenous distribution and thereby decreased the yield.

![Figure 2](image_url)  
**Figure 2.** Cook yield (%) of restructured chicken steaks. a, b: Different letters indicate significant difference (P<0.05).

The results of sensory analysis are presented in Figure 3. Appearance, colour, texture, juiciness, saltiness, sweetness, flavour and general acceptability of the samples were scored between 6.44-7.33, 6.56-6.89, 6.22-7.33, 5.44-7.67, 6.22-7.44, 6.78-7.56, 5.89-7.67 and 5.89-7.67, respectively. The scores were generally found to be in acceptable ranges. The highest acceptability was obtained in samples formulated with STPP (P groups) and formulated with inulin and SC (IC and GIC groups) (P<0.05). Therefore, use of inulin and SC together should provide equivalent sensory characteristics to phosphates. In samples containing inulin alone (I and GI), juiciness, flavour and general acceptability was significantly lower than other samples (P<0.05). Previously, inulin was reported to enhance sensory quality in different kind of meat product formulations [9, 14]. However, in phosphate-free formulations it could be suggested to use inulin in combination with SC to obtain similar sensory quality to phosphate containing products.
TBARS values of the samples analysed during storage are presented in Figure 4. The initial TBARS values were measured between 0.24-0.56 mg malonaldehyde/kg, while the values were between 0.73-0.90 mg malonaldehyde/kg in the end of the storage period. In final products, it was found that P and C samples had higher TBARS values compared to IC, GI and GIC ($P<0.05$). During the storage period, significant increments were detected in samples depending on the propagation of oxidation ($P<0.05$). Final values were generally similar in treatments. Therefore, it was indicated that inulin could compensate for the antioxidant effect of phosphates and have the potential to meet oxidative quality.

4. Conclusion
Our study indicated that inulin and SC as clean-label ingredients presented favourable results as phosphate replacers in restructured chicken steaks. Although proximate composition of the products generally did not seem to change intensely, pH of the products was significantly increased with combination of inulin and SC. Colour values were similar to control samples in most of the phosphate-free formulations. The combined usage of inulin and SC had an increment effect in cook yield. It was also observed that inulin should favour product yield when used in gelled form and presented advantages over powder form. Sensory analysis and lipid oxidation rate showed that usage of inulin and SC could enhance sensory parameters and oxidative quality and showed similar acceptability to phosphate
containing products. The results indicated that utilization of inulin and SC in restructured chicken steaks have good potential to enhance physical, chemical, technological and sensory quality and offers a novel possibility for phosphate replacement in formulation of healthier poultry products.

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