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Research Article

Effect of Gelatin/Chitosan Coating on Chicken Patty Quality During Frozen Storage: A Response Surface Methodology Application [1]

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Abstract

Quality loss of food products is an important problem for food producers and consumers. Edible coating application is an alternative method to preserve food quality and to extend shelf life. In this study, a coating solution composed of chicken gelatin (0-6%), chitosan (0-2%) and sorbitol (0-1.5%), was practiced to preserve chicken patty during frozen storage. Gelatin was extracted from chicken MSM (Mechanically Separated Meat) residue and chicken patties were prepared from spent hen. The physicochemical properties (moisture, pH, thiobarbituric acid value, shrinkage value, texture and color) of chicken patties were evaluated using response surface methodology (RSM) by 15 different coating combinations. The increase in gelatin and chitosan concentrations reduced significantly lipid oxidation. The application of chitosan decreased hardness of chicken patties and improved texture properties. Shrinkage decreased by increasing sorbitol concentration. Overall, an optimal coating blend formed by chicken gelatin (6%), chitosan (1.5-2.0%) and sorbitol (1.0-1.5%) showed the best effect on preserving quality of chicken patties during frozen storage.

Keywords: *Chicken gelatin, Chicken patty, Chitosan, Edible coating, Lipid oxidation*

Jelatin/Kitosan Kaplamanın Dondurarak Muhafaza Edilen Tavuk Köftesi Üzerindeki Etkisi: Bir Yanıt Yüzey Metodu Uygulaması

Öz

Gıda ürünlerindeki kalite kayıpları, gıda üreticileri ve tüketiciler açısından önemli bir sorundur. Yenilebilen kaplama işlemi, gıda kalitesini muhafaza ve raf ömrünü uzatmak amacıyla uygulanan bir metoddur. Bu çalışmada tavuk köftelerine (%0-6) tavuk jelatini, (%0-2) kitosan ve sorbitoldan (%0-1.5) oluşan kaplama işlemi uygulanmış ve dondurarak muhafaza edilmiştir. Jelatin, mekanik ayrılmış kanatlı eti posasından; tavuk köfteleri ise anaç tavuklardan üretilmiştir. Tavuk köftelerinin fizikokimyasal özellikleri (nem, pH, tiyobarbütirik asit değeri, büzüşme oranı, tekstür ve renk) yanıt yüzey metoduna göre 15 farklı kombinasyonda değerlendirilmiştir. Kaplama solüsyonunda jelatin ve kitosan oranlarının artışı, lipid oksidasyonunu belirgin şekilde azaltmıştır. Kitosan uygulaması tavuk köftelerinin sertliğini düşürmüş ve tekstürel özelliklerini geliştirmiştir. Büzüşme oranı, solüsyondaki sorbitol oranı arttıkça azalmıştır. Sonuçta tavuk köftelerinin dondurarak depolama sürecinde kalite özelliklerinin korunmasında optimum etkiyi gösteren kaplama formülasyonunun %6 tavuk jelatini, %1.5-2.0 kitozan ve %1.0-1.5 sorbitol olduğu tespit edilmiştir.

Anahtar sözcükler: *Kitosan, Lipit oksidasyonu, Tavuk jelatini, Tavuk köftesi, Yenilebilir kaplama*

Introduction

Recently, there is a big awareness of healthy diet according to the consumers for their lifestyle and new natural techniques need to be developed instead of some conventional methods that used for extending shelf life of foods. For this reason, using some edible coating and film materials became important alternatives. Edible film or coating material is a primary packaging material prepared from some edible materials. This material can cover the food

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without having any effect to its content or process. This method is used for many types of foods in order to make a gas/water vapor barrier, to enhance some sensory and mechanical properties and to prolong the shelf life preventing form some oxidative and microbiological factors [1]. Edible coating or film materials can be prepared by some proteins, polysaccharides, lipids or their composites because of their potential advantage of being biodegradable. Most prevalent proteins used for this purpose are collagen, gelatin, casein, whey protein, corn zein, wheat gluten, soy protein, egg white protein, myofibrillar proteins and keratin. Most prevalent polysaccharides are starch, cellulose and its derivatives, pectin, chitosan, alginate, carrageenan, pullulan and gellan gum [2]. At the other hand, glycerol, sorbitol, monoglyceride, polyethylene glycol and glucose can be used as a plasticizer to make more flexible the material. Some lipid compounds can also be used to make an emulsion based edible films such as waxes, vegetative oils and fatty acids [1].

Gelatin is a food additive having a characteristic of protein derived from collagen which is one of the major proteins in animal tissues. Gelatin is an effective hydrocolloid used prevalently in food industry through its gelling and thickening properties. The surface properties of gelatin comes from the charged groups in protein chain and the hydrophobic/hydrophilic amino acids repeating at collagen molecule [3]. For this reason, gelatin may be used for the manufacture of edible films or coating materials because of its some properties such as being cheaper, being biodegradable and being capable to interact with many types of materials [4-8].

Chitosan, an animal origin fiber, is one of important materials used as a coating or film forming material. It is derived from chitin which is a polysaccharide material consisted of *N*-acetylglucosamine and glucosamine units. The anti-microbial activity and film forming property [9], texturizing property [10,11] and antioxidant property [11,12] of chitosan have been reported. The use of chitosan for preserving different types of meat, fish and poultry products are reported [9,11-14].

Some studies were performed by formulating chitosan and gelatin [7-9,12,13]; however there is no available information on optimization of an edible coating material prepared by a combination of chicken gelatin, chitosan and sorbitol. Therefore, the aim of this study was to investigate the effects of three factors (chicken gelatin, chitosan and sorbitol in a coating solution) on some physicochemical, textural and industrial quality properties of chicken patties and to propose an optimal coating blend.

Material and Methods

Materials

Mechanically separated chicken meat residues and spent hens were collected from a chicken slaughterhouse (Beypiliç, Turkey) and kept at -18°C till use. All chemicals and reagents used were analytical grade. Cleaning the material and preparation of the samples was carried out as described by Erge and Zorba [15].

Gelatin Extraction

Washed material was subjected to 1 g/100 mL NaCl for 30 min at ambient temperature and the material was washed and filtered. After that, the pretreatment process was performed in 6.73 g/100 mL HCl solution for 24 h and extraction process was performed at 86.8°C for 2 h in water bath (Memmert WNB-45, MEMMERT, Germany). After the extraction, the slurry was filtered using double folded of cheese-cloth to get gelatinous extract. Lastly, gelatin solution was dried at 42°C and stored at at 4°C described as Erge and Zorba [15].

Preparation of Coating Solutions

The different combinations of coating solutions composed of three independent factors (gelatin, chitosan and sorbitol concentrations) prepared according to the central composite design *(Table 1)*. Gelatin was put in water at 25°C for 1 h and heated to 55°C for 30 min. Chitosan was solubilized in 1g/100 mL acetic acid solution. At the end, gelatin solution, chitosan solution and sorbitol were mixed in order to make a final ratio according to the experimental design *(Table 1)*.

Preparation of Chicken Patties and Coating Process

Deboned and defatted spent hen meat prepared from breast fillets and legs was ground with a chopper to 3 mm. 1.5 g/100 g Salt, 5 g/100 g onion powder, 5 g/100 g bread crumbs, 0.3 g/100 g sodium tripolyphospate and 0.7 g/100 g spices were added homogeneously to the grounded chicken meat and standard chicken patties (70 mm diameter and 15 mm thickness) were prepared before the coating process [16]. Chicken patties were kept at refrigerator overnight and were coated by dipping in different coating solutions for 5 min. Coated patties were kept in ventilated oven for 2 min at room temperature in order to lose over solution. The patties were put at refrigerator at 4°C for 4 h in order to make dry partially their surface. Lastly, chicken patties were put in plastic trays closed and kept in freezer for 4 months at -18°C. After this period, frozen patties were thawed at refrigerator overnight and were cooked at 185°C for 25 min.

Biochemical Analysis

The pH analysis was performed by homogenizing a mixture of 10 g sample in 100 mL of distilled water using a digital pH meter (Schott Instruments, Lab 860, Germany). The pH analysis of coating solutions were measured directly dipping in the solution [17]. Moisture content was determined by drying 10 g of chicken patty sample to a stable weight in an air oven at 105°C for 16 h [18]. Crude fat content

Table 1. Central composite design of three independent variables			
Run Order	**Gelatin Concentration (g/100 mL) X_1**	**Chitosan Concentration (g/100 mL) X_2**	**Sorbitol Concentration (g/100 mL) X_3**
1	0.00	0.00	0.75
2	0.00	1.00	0.00
3	0.00	1.00	1.50
4	0.00	2.00	0.75
5	3.00	0.00	0.00
6	3.00	0.00	1.50
7	3.00	1.00	0.75
8	3.00	1.00	0.75
9	3.00	1.00	0.75
10	3.00	2.00	0.00
11	3.00	2.00	1.50
12	6.00	0.00	0.75
13	6.00	1.00	0.00
14	6.00	1.00	1.50
15	6.00	2.00	0.75

was determined by the extraction with hexane [18]. After the storage period, lipid oxidation of the samples was evaluated spectrophotometrically as thiobarbituric acid (TBA) value in duplicate as described by Raharjo et al.[19].

Physical Analysis

- Technological quality evaluation

The shrinkage analysis was performed according to Serdaroğlu and Değirmencioğlu [20].

Shrinkage (%) ={[uncooked (g) - cooked (g)] + [diameter of uncooked - diameter of cooked sample]}/[thickness of uncooked sample + diameter of uncooked sample] x100 (1)

- Textural analysis

In this context, texture profile analysis (TPA) and Warner Bratzler Shear Force (WBSF) analysis were performed using a texture analyzer (TA-XT2 Stable Micro Systems, Surrey, England) equipped with a load cell of 5 kg. Patty samples were prepared cutting into standard cubes with (5x2 cm) length and width. For TPA analysis, a cylindrical plunger (58 mm in diameter) was used. The samples were compressed to 50% of height. The parameter values determined were hardness (g), springiness (g/100 g), cohesiveness (adimensional), chewiness (g.cm), gumminess (g), and adhesiveness (g/cm) [21]. For Warner Bratzler Shear Force (WBSF) analysis, cutting measurements were performed on coated surface of chicken patties using Warner-Bratzler shear blade (crosshead speed of 1 mm s^{-1}). The units of WBSF and the cutting work values were defined with *g* and *g.second,* respectively. Each sample was tested two times, and the average of the two measurement was used [16].

- Color evaluation

The colorimetric evaluations were performed according to Du et al.[22] on the surface of chicken patties using a Chroma Meter (Konica Minolta CR-400, Japan) in duplicate. The color values were evaluated by using L*, a*, and b* values showing lightness, red (+)/green (-) and yellow (+)/blue (-) color respectively.

Statistical Analysis

The analysis was performed using Response Surface Methodology (RSM) with 15 combinations. Box - Behnken design was used including three replicates of the centre point. The effect of three factor [gelatin concentration (X1), chitosan concentration (X2) and sorbitol concentration (X3)] were analyzed *(Table 1)*. This study was expressed by using a second order polynomial equation. The equation is:

$$Y = \beta_o + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{\substack{i=1 \\ i<j}}^{3} \sum_{j=1}^{3} \beta_{ij} X_i X_j \qquad (2)$$

where Y is the dependent variables (moisture and lipid contents, pH and TBA values, color properties, technological and texture properties of chicken patties), β0, βi, βii, and βij are regression coefficients, k (3) is the number of factor variables, and Xi, Xii, and Xij are levels of independent variables. The (SAS 6.12) was used to carry out the statistical analysis [15].

Results

The results of variance analyses were indicated at the *Table 2*.

Table 2. *Variance analyses results of the effects of independent variables on the physicochemical properties of chicken patties*													
Sources of Variation	**DF**	**Moisture (g/100 g) F-value**	**TBA (mg/kg) F-value**	**Peroxide (meq/kg) F-value**	**L* F-value**	**WBSF (g) F-value**	**WB Cutting Work (g.sec) F-value**	**Hardness (g) F-value**	**Cohesiveness F-value**	**Chewiness (g*cm) F-value**	**Gumminess (g) F-value**	**Adhesiveness (g/cm) F-value**
Model	9	1.6541	2.7732	1.4304	2.6271	2.2027	2.2895	1.8928	2.737	2.2027	2.2316	1.7573
X_1 (Gelatin g/100 mL)	1	0.0453	13.0634**	1.0792	1.1331	2.7457	7.9359*	0.2310	1.0182	2.7457	0.3349	3.3442
X_2 (Chitosan g/100 mL)	1	0.2044	7.6494**	3.8891	15.8829**	8.6354**	8.8244**	8.2598**	14.0732**	8.6354**	11.1544**	9.3222**
X_3 (Sorbitol g/100 mL)	1	0.0861	0.0800	0.4862	1.1989	1.6843	0.1130	0.4166	2.3459	1.6843	0.6704	0.0679
X_1*X_1	1	3.6023	0.2554	5.2510*	0.3666	0.4364	0.8719	0.1517	0.0871	0.4364	0.1540	0.0062
X_1*X_2	1	9.3923**	0.1976	0.9988	2.7211	0.3065	0.4137	7.0296*	0.6573	0.3065*	6.8520*	0.7538
X_2*X_2	1	0.0174	2.0060	0.6783	0.1524	2.5521	1.6268	0.0008	0.0148	2.5521	0.0020	1.7074
X_1*X_3	1	0.2597	0.8712	0.0675	1.9698	2.8584	0.5665	0.0415	0.0550	2.8584	0.0661	0.0137
X_2*X_3	1	1.1865	0.0711	0.0350	0.2360	0.2865	0.0402	0.7064	3.5550	0.2865	0.4555	0.4835
X_3*X_3	1	0.0340	0.7416	0.1235	0.0035	0.0911	0.0201	0.1712	2.9053	0.0911	0.3540	0.1501
Lack of fit	5	0.2466	1.3717	1.1028	2.8108	1.8992	0.8142	0.1927	0.1600	1.8992	0.2418	0.3642
General	31	1.6541	2.7732	1.4304	2.6271	2.2027	2.2895	1.8928	2.737	2.2027	2.2316	1.7573
*** P<0.01; * P<0.05*												

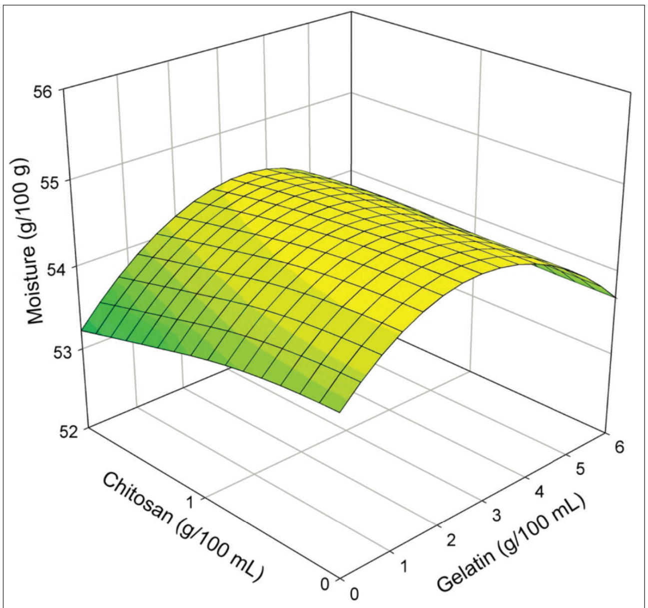

Fig 1. The effect of gelatin and chitosan concentration on the moisture of chicken patties

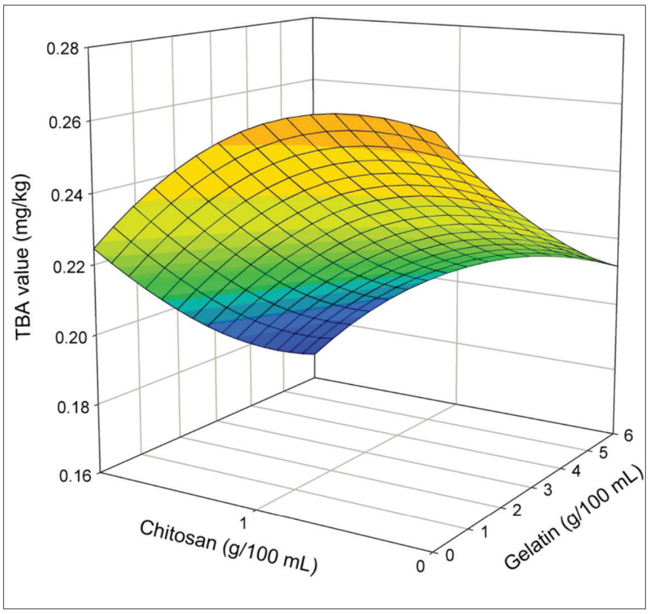

Fig 2. The effect of gelatin and chitosan concentration on the TBA value of chicken patties

Physicochemical Properties of Chicken Patties

The interaction between gelatin concentration and chitosan concentration had significant (P<0.01; *Table 2*) effects on the moisture of chicken patties. The maximum moisture content was determined at 3.5 g/100 mL gelatin concentration approximately *(Fig. 1)*. The effects of independent variables on the lipid content and pH values were insignificant (P>0.05; *Table 2*).

A significant linear effect of gelatin (P<0.01) and chitosan (P<0.05) concentrations on TBA values were viewed *(Table 2)*. Results showed that gelatin concentration was effective in decreasing TBA values *(Fig. 2)*. Minimum TBA value was observed at 6 g/100 mL gelatin concentration.

The color is another quality characteristic of meat products because of its direct effect on consumer choice. A significant (P<0.01) quadratic effect of chitosan concentration on L* value of cooked chicken patties was viewed *(Table 2)*. L* value increased by increasing of chitosan concentration at cooked patties *(Fig. 3)*. Coating with chitosan decreased the redness and increased the lightness of chicken patties after a freezing storage.

Technological Properties of Chicken Patties

A significant (P<0.05) interaction effect between chitosan and sorbitol concentration on the shrinkage of chicken patties was viewed *(Table 2)*. The shrinkage value decreased by increasing of sorbitol concentration *(Fig. 4)*.

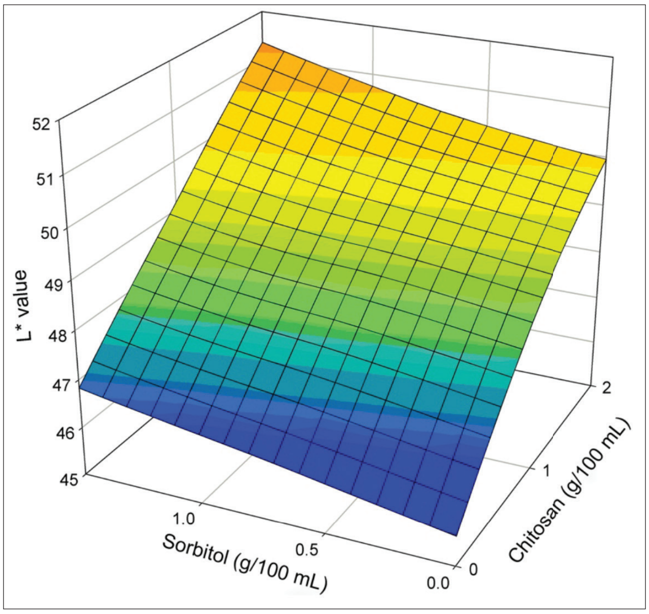

Fig 3. The effect of chitosan and sorbitol concentration on the L* value of chicken patties

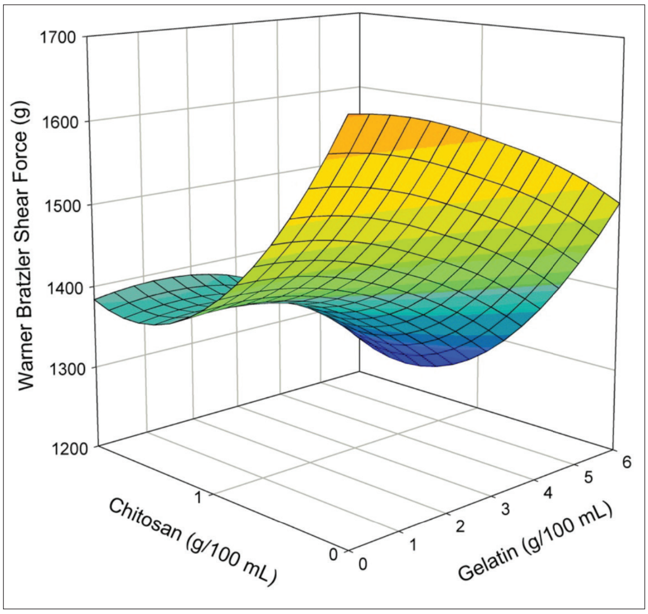

Fig 5. The effect of gelatin and chitosan concentration on the Warner Bratzler Shear Force value of chicken patties

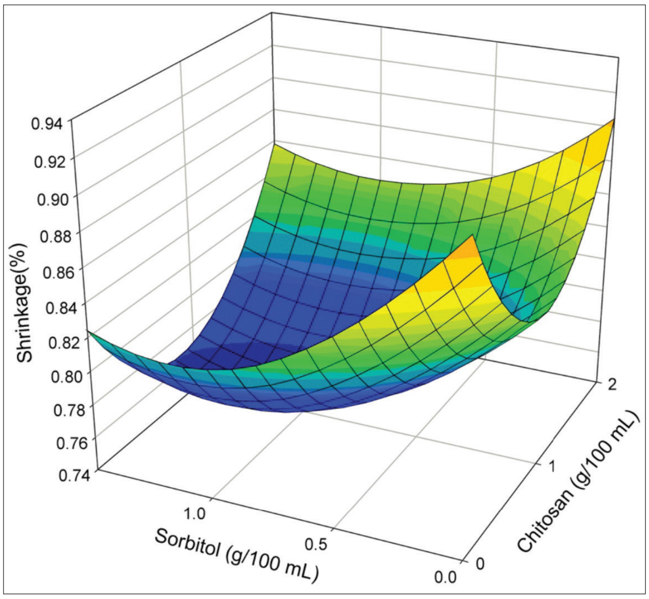

Fig 4. The effect of chitosan and sorbitol concentration on the shrinkage of chicken patties

Texture Properties of Chicken Patties

A significant (P<0.01) linear effect of chitosan concentration on the Warner Bratzler Shear Force (WBSF) of chicken patties was viewed *(Table 2)*. As observed *(Fig. 5)*, the increase of chitosan concentration reduced the WBSF of patties. This reduction was clearer until 1 g/100 mL chitosan concentration. The linear effects of gelatin (P<0.05) and chitosan concentration (P<0.01) on the Warner Bratzler cutting work of patties were found to be significant *(Table 2)*. Warner Bratzler cutting work decreased with increasing of chitosan.

In point of TPA parameters, a significant (P<0.01) linear effect of chitosan concentration on the hardness value of chicken patties was viewed *(Table 2)*. As observed *(Fig. 6)*, the increase of chitosan concentration reduced the hardness of chicken patties. The linear effects of chitosan on the adhesiveness, cohesiveness and chewiness values of patties were found to be significant (P<0.01; *Table 2*). The effects of independent variables are stated mathematically in *Table 3*. These predicted model equations are useful for understanding the effects of studied factors.

Discussion

The increase in the moisture of chicken patties can be referred to the positive effect of gelatin preventing the water loss from chicken patties. Cardoso et al.[12] also observed a reduction in weight loss in chitosan-gelatin coated beef steaks. Similar results have been stated also by Yu et al.[11] who reported that chitosan coating reduced the water loss of grass carp fillets.

The biggest effect on TBA values was found to be gelatin concentration. The decrease in TBA values could be explained by the positive effect of gelatin preventing the lipid oxidation by covering chicken patties. The minimum TBA value (0.18 mg/kg) was observed at the 15th treatment (6 g/100 mL gelatin, 2 g/100 mL chitosan, 0.75 g/100 mL sorbitol). The results showed us that the lipid oxidation reduced when the gelatin ratio is over 3 g/100 mL. During the frozen storage, lipid oxidation is one the most important factor resulting to the quality loss in meat products [23]. Similarly to our study, Morachis-Valdez et al.[23] reported a decrease of TBA value in chitosan coated carb. Farajzadeh et al.[24] stated also a decrease of TBA value in

***Table 3.** Predicted model equations for the effects of independent variables on the physicochemical, technological and textural properties of chicken patties*

Parameters	Equations	P-Values
Moisture (g/100 g)	$Y = 54.54 + 0.07X_1 - 0.15X_2 - 0.09X^3 - 0.90X_1^2 + 1.39X_2X_1 - 0.06X_2^2 - 0.23X_3X_1 - 0.50X_3X_2 + 0.087X_3^2$	0.1668
TBA value (mg/kg)	$Y = 0.23 - 0.03X_1 - 0.02X_2 + 0.002X_3 + 0.006X_1^2 - 0.005X_2X_1 - 0.02X_2^2 + 0.01X_3X_1 - 0.003X_3X_2 - 0.01X_3^2$	0.0275
Peroxide value (mEq/kg)	$Y = 4.41 - 0.24X_1 + 0.46X_2 + 0.16X_3 - 0.79X_1^2 - 0.33X_2X_1 + 0.29X_2^2 + 0.09X_3X_1 + 0.06X_3X_2 - 0.12X_3^2$	0.2406
L* Value	$Y = 48.94 + 0.59X_1 + 2.19X_2 + 0.60X_3 - 0.49X_1^2 + 1.28X_2X_1 - 0.32X_2^2 - 1.09X_3X_1 + 0.38X_3X_2 + 0.05X_3^2$	0.0345
Shrinkage	$Y = 0.77 + 0.03X_1 + 0.007X_2 - 0.03X_3 - 0.01X_1^2 + 0.01X_2X_1 + 0.08X_2^2 - 0.01X_3X_1 + 0.09X_3X_2 + 0.04X_3^2$	0.3782
Warner Bratzler Shear Force (g)	$Y = 1397.08 - 72.42X_1 - 128.43X_2 + 56.72X_3 - 42.50X_1^2 + 34.22X_2X_1 + 102.77X_2^2 - 104.49X_3X_1 - 33.08X_3X_2 - 19.42X_3^2$	0.0679
WB Cutting Work (g.sec)	$Y = 15875.78 - 1315.96X_1 - 1387.68X_2 + 156.10X_3 - 642.08X_1^2 + 424.9X_2X_1 + 877.02X_2^2 - 497.25X_3X_1 - 132.49X_3X_2 + 97.54X_3^2$	0.0590
Hardness (g)	$Y = 2892.95 - 45.05X_1 - 269.35X_2 - 60.49X_3 + 53.73X_1^2 - 351.40X_2X_1 + 3.91X_2^2 + 27.008X_3X_1 + 111.39X_3X_2 - 57.07X_3^2$	0.1126

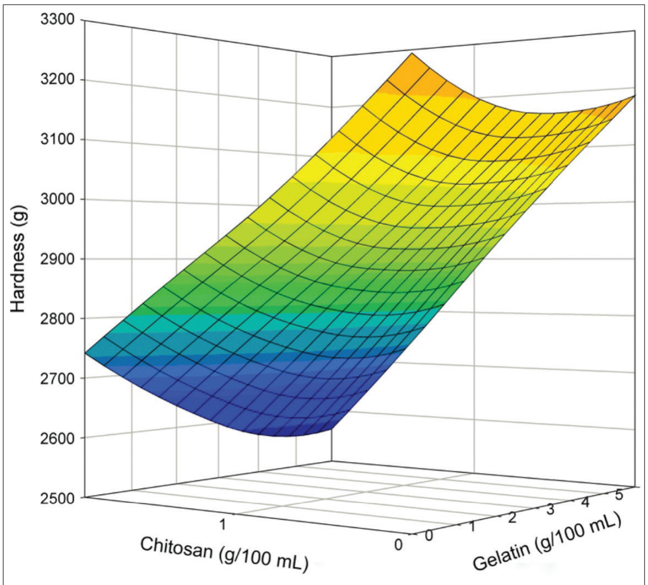

Fig 6. The effect of gelatin and chitosan concentration on the hardness of chicken patties

chitosan-gelatin coated shrimp. The function of gelatin coating as a barrier to oxygen could be explained by the hydrogen bonds in gelatin gel preventing against lipid oxidation [25]. Cardoso et al.[12] observed minimum TBARS values in beef steaks coated with a combination of gelatin and chitosan at higher gelatin concentration (>2%). Jeon et al.[26] reported also a decrease in TBA value of herring as a result of chitosan coating. Another work performed by Ojagh et al.[27], who observed that chitosan coated rainbow trout exhibited lower TBA value than untreated samples.

The positive effect of chitosan coating on the lightness of products was reported in some previous studies [13,24,26,28]. The color protection effect of chitosan on beef and pork meat was reported by Antoniewski et al.[29] and Herring et al.[25], respectively. The reduction in a* value with the increase of chitosan concentration could be related to the thickness of the film less translucent composed by higher polymer concentration [30].

The decreasing influence of sorbitol on the shrinkage value might be related to the plasticizer effect of sorbitol and to the high-moisture characteristic of chitosan coating. So, the loss of moisture from patties could be prevented, as well.

The decrease in hardness value of chicken patties might be due to the higher water retention of chicken patty with the increase of chitosan. The minimum hardness value (2095.68 g) was observed at the 15th treatment (6 g/100 mL gelatin, 2 g/100 mL chitosan, 0.75 g/100 mL sorbitol). Results about the texture properties showed that coating with chitosan can improve the texture properties such as hardness, adhesiveness, cohesiveness and chewiness in chicken patties during frozen storage. Similar findings were stated in the literature. Fang et al.[31] reported that chitosan coating of pork loins was capable to preserve the meat tenderness decreasing the shear force values during MAP storage. Chamanara et al.[32] showed that the hardness and springiness values of rainbow trout were decreased by chitosan coating. Benjakul et al.[33] reported also the decreasing effect of chitosan on the gel strength of surimi.

Overall, edible coating prepared by chicken gelatin, chitosan and sorbitol decreased effectively lipid oxidation, improved textural and technological properties for chicken patties during 4 months of frozen storage. RSM was used in order to optimize the coating solution formulation, and based on the predicted models, the best concentrations were determined as (6 g/100 mL) chicken gelatin, (1.5-2 g/100 mL) chitosan and (1-1.5 g/100 mL) sorbitol. On the other hand, with this study, two important poultry industry by-product such as chicken MDM residue and spent hen have been evaluated to some added value products.

Conflicts of Interest

There is no conflict of interest between authors.

Statement of Authors' Contributions

AE and ÖE designed the project. AE provided samples, performed gelatin extraction, prepared coating solution, prepared chicken patties and performed the analysis. ÖE performed statistical analysis of data and AE wrote the article. All authors read and approved the final manuscript.

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