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The Influence of Chitosan on Textural Properties of Common Carp (*Cyprinus Carpio*) Surimi

Habib Allah Hajidoun[1] and Ali Jafarpour[2]*

[1]Department of Fisheries, Faculty of Marine Science and Natural Resources of Nour, Tarbiat-Modares University (TMU), Iran
[2]Department of Fisheries, Faculty of Animal Science and Fisheries, Sari University of Agricultural Science and Natural Resources, Sari, Iran

Abstract

The influence of different concentrations of chitosan (0.5%, 1.0% and 1.5%) on texture, color, Water Holding Capacity (WHC), viscosity and sensory properties of common carp surimi was investigated. Chitosan was added at 0.5%, 1% and 1.5% to the common carp surimi paste, stuffed in polyamide casing and heated in a hot water bath at 90 ± 2°C for 30 min. Chitosan treatments showed significant ($p<0.05$) effect on functional properties of resultant surimi gels as enhanced its viscosity, WHC, color, gel strength, TPA parameters and sensory characteristics. According to the results, there was an association between texture quality parameters and different concentrations of added chitosan. For instance, 1.5% chitosan treatment singnificantly ($p<0.05$) improved the viscosity, WHC, gel strength, hardness and whiteness of surimi gel by 35.4%, 19%, 50.6%, 40% and 11%, respectively, compared to the control sample with no added chitosan. Ultimately, the best score ($p<0.05$) of sensory evaluation was allocated to the surimi gel with 1.5% chitosan by the panelists, all indicating the positive effect of added chitosan on functional properties of resultant surimi gel.

Keywords: Chitosan; Surimi; Common carp; Textural properties; Color; Viscosity

Introduction

Surimi is a Japanese loan word referring to the fish flesh that is deboned, minced and washed with water in order to imitate various high-priced products such as crab legs, oyster and lobster. Surimi is recognized as a major source of nutrients and have grown substantially in use in response to the increasing demand for low-cholesterol, low-fat foods [1]. High-priced fishery products are becoming increasingly scant or even nearly unavailable in developing countries by effect of massive overexploitation of some fish species [2]. The FAO has estimated that "19% of the world's major fishing grounds have either reached or exceeded their natural limits and that at least nine fishing areas, about 69% of the world's fisheries, are either fully exploited, overexploited, depleted, or slowly recovering from the effects of overfishing". In order to meet the protein requirements of the world population, which is likely to increase to 8.5 billion in the next 25 years, fish production has to be doubled during this period. While efforts are needed to maintain sustainable fish production to satisfy the demand, growth in capture fisheries has not been promising [3]. By increasing of world population and rapid reduction in marine resources, aquaculture section has been grown to address the gap between global seafood supply and demand, thereafter, fresh water fish species can be considered as an alternative resource for surimi industry mainly due to their reliable resources and fairly low prices.

Common carp is raised in polyculture fish production systems in the world. In Iran, the total production of this species was reported more than 20,000 tons in 2011 [4]. Due to feeding behavior and because of muddy smell of its flesh, the price of common carp is lower than its counterparts [5]. According to FAO statistics, the per capita seafood consumption in Iran (7.8 kg) is far beyond the world average (18.4 kg) [6], hence, it would be promising to convert warm water fish species as a valuable source of protein into an intermediate product such as surimi paste that could be easily formulated into various types of secondary seafood products based on local taste.

Gelation of fish proteins is the most important step in formation of desired texture in many seafood products [7]. In terms of surimi gel, it is crucial to enhance its textural properties such as color, water holding capacity (WHC), expressible moisture and gel strength in order to increase the acceptance of surimi-based products by consumers. Since, derived surimi paste from freshwater fish show only moderate gel forming ability and the frozen storage negatively affects its protein properties [8], hence, it is needed to modify its textural and water mobility properties [9] mainly by addition of various components. Chitosan is a biopolymer obtained from the deacetylation of chitin, which has been used as an active material with extended activity in various industries. Chitosan is an additive used in surimi preparation steps to improve its textural properties and applied in surimi research studies on many different fish species such as Thai catfish (*Pangasius sutchi*) [10], barred garfish *(Hemiramphus far)* [11] horse mackerel *(Trachurus spp.)* [12], and grass carp (*Ctenopharyngodon idellus*) [13, 14].

However, there is no report on the influence of added chitosan on textural characteristics of common carp surimi. Thus, the objective of this study was to investigate the effects of chitosan addition at different concentrations on functional properties of common carp surimi.

Materials and Methods

Fish and surimi

Commercial chitosan *powder* (95% deacetylation) was obtained from Dingguo Biotechnology Company (Shanghai, China). Fresh

***Corresponding author:** Ali Jafarpour, Department of Fisheries, Faculty of Animal Science and Fisheries, Sari University of Agricultural Science and Natural Resources, Sari- Iran, E-mail: a.jafarpour@sanru.ac.ir

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whole common carp fish (body length: 380 ± 25 cm; body weight: 800 ± 30 g) were purchased from a fish sale market in Nour city-Iran, and transported in ice in ratio of 1:1 to the laboratory. Afterward, fish were gutted, headed, washed with water and then filleted manually. The white portion of common carp muscle was separated and used to prepare surimi. Fillets were minced by a meat mincer (Braun, Triumph G3000, Czech Republic), equipped with a disc by mesh size of 3 mm. The mince was washed three times in ratio of 1:4 (mince:water) with distilled cold (below 10°C) water. During last washing cycle, 0.3% NaCl was added to the mixture to remove water more effectively by manual pressing in a double folded cheese cloth. Prepared surimi was mixed with cryoprotectant agents (sugar 4%, sorbitol 4%, and sodium tripolyphosphate 0.3%) and homogenized for a further 2 min in a food processing chopper. Surimi was packed in blocks of 250 g in zip-lock plastic bags, froze at -18°C and kept frozen for 1 month.

Preparation of surimi gel

To prepare the gel, frozen surimi was left at room temperature for 1.5 h. The thawed pieces were homogenized in a food processor for 60 s to create a homogeneous surimi paste. In continuous, ice water (to adjust the moisture content of the paste to 80 ml/100 g), 2.5% (w/w) NaCl and chitosan [0.5%, 1% and 1.5% (w/w)] were added to the common carp surimi and homogenization was continued for further 2 min. The gels were put into polyvinylidene chloride casing with diameter of 2.5 cm and length of 20 cm. The stuffed casings were sealed and refrigerated (4-6°C) overnight (18h) in order to elapse low temperature setting. Afterward, the stuffed surimi casings were heated in a hot water bath at 90 ± 2°C for 30 min. After heating, the casings were immediately cooled in ice water (about 4°C) to stop further effect of heat on the surimi gel texture. The gels were put in plastic bags and stored in refrigerator at 4-6°C for 24 h until carrying out further experiments.

Evaluation of viscosity

To evaluate the viscosity of surimi paste, 143g of surimi from each treatment (without and with chitosan at different concentrations) was mixed with 857 ml of 3.5% NaCl solution and homogenized in a warring blender for 8 min and then left at room temperature for 40 min. Finally, the viscosity was measured with Brookfield Tokyo Instruments (Model C), at 4 rpm at 10°C [15].

Water Holding Capacity (WHC)

WHC test was carried out following the method of Himonides et al. [16] with slight modification. For each treatment, 5 g sample was separated and wrapped in individual Whatman filter papers (No. 41) and centrifuged at 1700×g for 30 min at 8°C. The rate of water drained from surimi was estimated from the weight difference of the filter paper before and after centrifugation. The WHC of the common carp surimi affected by chitosan in various concentrations was calculated by the following equation:

$$WHC\ g/kg = \left[\left(1 - Mw/Ms \right) 1000 \right]$$

That Mw is the mass (g) of expelled water and Ms is the initial mass (g) of the sample.

Texture properties

Puncture test: Puncture test was carried out based on the method was described by Jafarpour and Gorczyca [17,18]. For this purpose, the surimi gel samples were sliced transversely into 25 mm pieces and equilibrated to room temperature before puncture tests. Puncture tests were performed using a texture analyzer (Stable Micro Systems Ltd., Surrey, United Kingdom) equipped with a spherical head stainless steel probe (Ø =5 mm). The load cell and crosshead speed were set at 25 kg and 1 mm/s, respectively. Gel strength was calculated base on breaking force (g) and breaking distance (mm). All evaluations were carried out based on the mean of three replicates for each treatment.

Texture profile analysis (TPA): TPA was performed as described by Jafarpour and Gorczyca [17]. The surimi gel samples with height of 25 mm and 25 mm diameter were placed on the flat plate of a texture analyzer and axially compressed by a cylindrical plunger (Ø = 50 mm) set to load cell of 25 kg at a deformation rate of 1 mm/s. Preliminary trials established a compression limit of 50% of the original height for surimi gel (any greater compression resulted in cracking of most samples). Each sample was compressed twice and the average was recorded. The measured parameters were as hardness (N), cohesiveness, adhesiveness (N/s) and elasticity. All determinations were based on a mean of three replicates in treatments.

Determination of whiteness

Colorimetery of chitosan treatments was evaluated by hunter colorimeter, model RT 450. Color parameters such as L^* (lightness), a^* (redness/greenness) and b^* (yellowness/blueness) were investigated and whiteness calculated by Equation of Park, [19] as follow:

$$\text{Whiteness} = (L^* - 3b^*)$$

Sensory evaluation

Hedonic method based on method of Runglerdkeriangkrai, Banlue, & Raksakulthai [20] with slightly modifications was performed for sensory evaluation test. In this regards, 15 untrained panels using a Nine-point Hedonic scale evaluated color, odor, flavor, texture and overall liking of surimi gel treated without and with different concentrations of chitosan.

Statistical analysis

To evaluate the mean data from different treatments, one-way ANOVA test was used by application of SPSS software version 15.0. Sensory evaluation data were analyzed by Mann-Whitney U test. In order to determine the significance difference between means, LSD test was used at confidence level of 95%.

Results and Discussion

Influence of chitosan on viscosity

The viscosity of surimi paste after addition of different levels of chitosan increased significantly ($p < 0.05$) compared to the control sample (Table 1). Accordingly, the viscosity of no added chitosan treatment (control) stood at 2654.42 Pa.s whereas by increasing of chitosan concentration from 0.5%, to 1% and 1.5%, viscosity of common carp surimi was improved by 26.6%, 30.8% and 35.4%, respectively.

treatment	viscosity (Pa.s)
CON.	2654.42 ± 11.84^a
CHI 0.5%	3618.74 ± 11.21^b
CHI 1%	3840.56 ± 14.87^c
CHI 1.5%	4109.74 ± 19.25^d

Different letters in the same column indicated significant difference (P<0.05) according to a 1-way ANOVA and LSD test

Table 1: Viscosity of common carp surimi including various concentrations of chitosan (mean ± standard deviation).

WHC affected by chitosan

The influence of various concentrations of chitosan on WHC is shown in table 2. With elevation of chitosan concentrations in surimi gel formula, WHC was significantly (p <0.05) increased in comparison with the control treatment.

The WHC of control sample was recorded at 76.47% but after addition of 0.5%, 1% and 1.5% chitosan to the common carp surimi, it was increased to 86.51%, 90.12% and 94.34%, respectively. Surimi of common carp with 1.5% added chitosan had the highest WHC among the treatments as it caused 19% improvement of WHC compared to the control sample. Mao and Wu [13] reported that addition of 1% chitosan to grass carp surimi gel improved the WHC of restructured products, mainly due to increasing of chitosan-water interactions during the gelling of fish surimi containing chitosan.

The influence of chitosan on texture properties

Puncture test: Influence of various concentrations of chitosan on breaking force and breaking distance of surimi gel is shown in table 3. The values indicated that with increasing of chitosan concentration in common carp surimi, both breaking force and distance were increased significantly (p<0.05) and consequently elevated the gel strength of resultant surimi gels. Breaking force and breaking distance of control treatment were recorded at 224.29 g and 6.59 mm, respectively and gel strength was determined as 1478.40 g×mm. Surimi gel containing 1.5% chitosan showed the highest textural indices as its breaking force and breaking distance were recorded at 314.52 g and 9.62 mm, respectively which caused almost double improvement in gel strength of resultant surimi gel compared to the control sample.

Kataoka et al. [21] stated that breaking force of walleye pollock surimi after setting was increased with increasing the amount of chitosan incorporated in the gels up to about 1.5% and then declined. The same authors reported that deformation of gels increased slightly with the presence of 1.5% chitosan, indicating that the elasticity of setting gels was less influenced by chitosan concentration than breaking force. Kataoka et al. [21] also reported that a similar relation was observed after heating of setting gels at 80°C for 30 min as the gel strength of surimi increased about two-fold by addition of 1.5% chitosan in combination with setting at 25°C. Benjakul et al. [22] also found that addition of 7β chitosan with 65.6% degree of deacetylation (% DD) at the level of 15 mg g^{-1} into surimi from barred garfish (*Hemiramphus far*) increased the gel strength of resultant surimi gel mainly because that amino group of chitosan molecules partially cross-linked with myofibrils and also work as filler in the gel matrix. The same authors also stated that "Kamaboko gel containing chitosan had an increased breaking force as the calcium chloride concentration increased (*P*<0.05), indicating the role of endogenous transglutaminase in cross-linking of protein-protein and protein–chitosan conjugates". The same effect of chitosan was reported by Kungsuwan et al. [10] on catfish (*Pangasius sutchi*) surimi gel. In 2003, Benjakul and his colleagues reported an increase in breaking force of surimi gels (approximately 24%) after addition of 1% prawn shell chitosan. These authors also reported that "in general, addition of MTGase remarkably increased both breaking force and deformation of surimi gel (P<0.05). However, enhancing effect of MTGase was retarded in the presence of chitosan, resulting in lower magnitude of breaking force and deformation (P<0.05)."

Texture profile analysis (TPA): The effect of various concentrations of chitosan on hardness, cohesiveness, adhesiveness and elasticity of surimi gel samples is shown in table 4. According to the data, there was an association between different levels of added chitosan in surimi paste and hardness of resultant surimi gel samples. Hardness of surimi gel sample with no added chitosan (control) recorded at 28.18 N, whereas the addition of different levels of chitosan significantly (P<0.05) improved the hardness and it reached to 47.32 N at 1.5% added chitosan, which is equal to about 40% improvement in the hardness of surimi gel.

treatment	WHC (%)
CON.	76.47 ± 0.24[a]
CHI 0.5%	86.51 ± 0.21[b]
CHI 1%	90.12 ± 0.37[c]
CHI 1.5%	94.34 ± 0.88[d]

Different letters in the same column indicated significant difference (P<0.05) according to a 1-way ANOVA and LSD test

Table 2: Water holding capacity property of common carp surimi with various concentrations of chitosan (mean ± standard deviation).

treatment	Breaking Force (g)	breaking distance (mm)	Gel strength (g×mm)
CON	224.29 ± 16.36[a]	6.59 ± 0.74[a]	1478.40 ± 19.57[a]
CHI 0.5 %	251.14 ± 19.81[b]	7.64 ± 0.36[b]	1930.84 ± 11.35[b]
CHI 1%	285.64 ± 13.39[c]	8.76 ± 0.25[c]	2469.08 ± 14.76[c]
CHI 1.5%	314.52 ± 17.15[d]	9.62 ± 0.58[d]	2995.30 ± 15.43[d]

Different letters in the same column indicated significant difference (P<0.05) according to a 1-way ANOVA and LSD test

Table 3: Puncture test characteristics of common carp surimi with various concentrations of chitosan (mean ± standard deviation).

treatment	Hardness	Co-hesiveness	Adhesiveness	elasticity
CON	28.18 ± 0.19[a]	0.65 ± 0.01[a]	-0.59 ± 0.03[a]	0.96 ± 0.01[a]
CHI %0.5	39.19 ± 0.16[b]	0.73 ± 0.01[b]	-0.92 ± 0.02[b]	0.99 ± 0.01[b]
CHI %1	43.52 ± 0.32[c]	0.76 ± 0.00[c]	-1.01 ± 0.10[c]	0.99 ± 0.01[b]
CHI %1.5	47.32 ± 0.75[d]	0.80 ± 0.00[d]	-1.20 ± 0.04[d]	0.99 ± 0.01[b]

Different letters in the same column indicated significant difference (P<0.05) according to a 1-way ANOVA and LSD test

Table 4: TPA test characteristics of common carp surimi with various concentrations of chitosan (mean ± standard deviation).

This result was in agreement with Kataoka et al. [21] who indicated that the hardness of setting surimi gels was nearly doubled by the addition of 1.5% chitosan. The same trend was observed in terms of cohesiveness and adhesiveness as the treatment with 1.5% chitosan caused approximately 23% and 50% increase in cohesiveness and adhesiveness of resultant surimi gel compared to the control. By addition of different levels of chitosan in common carp surimi paste, the elasticity of surimi gels was significantly (p<0.05) increased compared to the control sample whereas there was no significant (p>0.05) difference in elasticity of surimi gels of treatments containing different levels of chitosan. The possible explanation regarding the improvement of TPA parameters of common carp surimi gels after addition of different levels of chitosan is that the presence of chitosan slightly reduce the myosin heavy chain content via its polymerization, hence, enhance the formation of cross-linked myosin heavy chain components, simultaneously.

Wu and Mao [14] indicated that addition of 1% chitosan in grass carp (*Ctenopharyngodon idellus*) surimi improved the hardness, springiness, cohesiveness, chewiness, and adhesiveness of surimi texture and prevented the lipid oxidation. Martin-Sanchez et al. [23] reported that additives such as calcium compounds, chitosan and oxidizing agents seem to act by forming stronger protein gel networks [23].

The effect of chitosan on whiteness of common carp surimi

The influence of various concentrations of chitosan on tristimulus color parameters is shown in table 5. The results indicated that addition of 0.5% chitosan in surimi had no significant (p>0.05) effect on lightness (L^*) of sample compared to the one from the control but by increasing the concentration of chitosan to 1% and 1.5% the difference became significant (p<0.05) as the *L^*-value* of treated samples elevated from 73.89 to 75.15 and 75.62, respectively. Mao and Wu [13] reported that grass carp surimi gels with chitosan exhibited higher *L^*-value* than that of control, but yellowness (b^*) of gels decreased by the addition of chitosan, and as a result, whiteness of gel was improved from 63.81 to 72.26.

In our study, in terms of *b^*-value*, the control treatment showed the highest (p<0.05) yellowness (5.72) compared to the rest, however, after addition of different levels of chitosan into the common carp surimi, the *b^*-value* was significantly (p<0.05) reduced and the highest improvement (32.8%) was belong to the 1.5% treatment.

According to the results, the improvement in Lightness was coincided with the decrease in the *b^*-value*, hence it was expected to achieve the whiter surimi gel by addition of chitosan into common carp surimi. Data showed that the control treatment had the lowest whiteness (56.81) whereas by addition of different levels of chitosan (0.5%, 1.0% and 1.5%), the whiteness of resultant surimi gel significantly (p<0.05) improved by 8.3%, 8.8% and 11%, respectively. Hsu and Chiang [24] also reported that gels with higher lightness and lower yellowness could result in higher whiteness surimi gel in which are highly demanded by consumers. It can be explained that interaction of chitosan-chitosan and cross linking of protein-chitosan covalent apparently could modify the gel network, exhibiting a more gleaming and transparent appearance, and thus modifying the lightness of resultant surimi gels [13]. This research confirmed that addition of chitosan into surimi is able to improve the whiteness of common carp surimi.

Sensory evaluation affected by chitosan

The effect of various concentrations of chitosan on sensory characteristics of common carp surimi gel is shown in table 6. The analysis of data indicated that addition of 1% and 1.5% chitosan significantly (P<0.05) improved the color (whiteness) of surimi gel samples but at 0.5% level had no significant difference (P>0.05) with the control. In items of odor, three treatments containing chitosan showed significant (p<0.05) difference compared to the control, meant that addition of chitosan improved the odor of resultant surimi gel and the highest score was given to the 1.5% chitosan treatment, by the panelists. Apart from 0.5% chitosan treatment, the flavor of common carp surimi gel treated with 1.0% and 1.5% chitosan were significantly (p<0.05) different compared to the control and again the highest score was obtained by 1.5% chitosan treatment.

In a study conducted by Wu and Mao [14], the authors reported that application of chitosan at a level of 1% (w/w) on grass carp surimi gel during storage at 4°C suppressed the lipid oxidation and bacterial growth in the gels. The preservative function of chitosan was attributed to the molecular weight of chitosan as relative low molecular weight chitosan showed a higher antioxidant capacity than high molecular weight chitosan [14]. The texture of common carp surimi gel containing different levels of chitosan was significantly (p<0.05) different compared to the one from the control and the score of texture was increased by increasing the concentrations of added chitosan and the best texture score was allocated to 1.5% chitosan treatment. Three levels of added chitosan into common carp surimi significantly (P<0.05) influenced the overall liking of resultant surimi gels.

treatment	L^*	b^*	L^*-3b^*
CON	72.15 ± 0.48[a]	5.72 ± 0.30[a]	56.81 ± 0.11[a]
CHI 0.5%	73.89 ± 0.25[a]	4.15 ± 0.19[b]	61.94 ± 0.38[b]
CHI 1%	75.15 ± 0.72[b]	4.02 ± 0.71[b]	62.28 ± 0.44[b]
CHI 1.5%	75.62 ± 0.14[b]	3.84 ± 0.61[c]	63.94 ± 0.82[c]

Different letters in the same column indicated significant difference (P<0.05) according to a 1-way ANOVA and LSD test

Table 5: Color characteristics of common carp surimi with various concentrations of chitosan (mean ± standard deviation).

treatment	Color (whiteness)	odor	flavor	Texture	Overall liking
CON	7.5 ± 0.2[a]	6.4 ± 0.4[a]	6.7 ± 0.5[a]	6.9 ± 0.3[a]	6.7 ± 0.5[a]
CHI 0.5%	7.6 ± 0.7[a]	6.8 ± 0.4[b]	6.9 ± 1.2[a]	7.2 ± 0.8[b]	7.3 ± 0.7[b]
CHI 1%	7.9 ± 0.8[b]	6.9 ± 0.7[c]	7.5 ± 0.7[b]	7.6 ± 0.6[c]	7.8 ± 0.9[c]
CHI 1.5%	8.1 ± 1.0[b]	7.4 ± 0.6[d]	8.0 ± 0.8[c]	8.3 ± 0.4[d]	8.2 ± 0.8[d]

Different letters in the same column indicated significant difference (P<0.05) according to a Mann-Whitney U test

Table 6: Sensory evaluation characteristics of common carp surimi with various concentrations of chitosan (mean ± standard deviation).

Conclusions

By reviewing the texture results of common carp surimi without and with added chitosan, it was observed that there is an association between different levels of added chitosan and different texture quality parameters such as viscosity, WHC, puncture test and TPA. The results showed that addition of chitosan at 0.5%, 1% and 1.5% concentrations improved the textural and organoleptic properties of common carp surimi in comparison with the control with no added chitosan. The best results came from surimi gel with 1.5% chitosan as caused the highest viscosity, WHC, gel strength, and whiteness among the treatments. Panelists also gave the highest score to this treatment (1.5% chitosan treatment). The results of this study indicated the positive effect of added chitosan on textural properties and sensory characteristics of common carp surimi, however, it is needed to evaluate the efficiency of some other additives and compare the results with the chitosan treatment.

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