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Functional Properties of Restructured Surimi Gel Product Prepared from Low Valued Short Nose White Tripod Fish (*Triacanthus brevirosterus*)

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Abstract

Low valued short nose white tripod fish (*Triacanthus brevirosterus*) was used for the preparation of minced meat, surimi and restructured surimi gel products. Eight different restructured surimi gel products (RS-1 to RS-8) were prepared using additives such as corn, egg white and casein in different proportions along with the control. Functional properties examined indicated that the control (RS-1) without additives had higher gel strength of 9.05 kgF than other products. RS-4 with egg white had more whiteness (74.75%) and got 'AA' class in folding test. Microstructure of surimi with egg white (RS-4) had less surface cracks and cavities contributing for good functional properties. Thus, RS-4 prepared with egg white could be best suited for surimi based products.

Keywords: Tripod; Restructured surimi gel; surimi; Minced meat; SEM

Introduction

Surimi is traditionally a Japanese product prepared from washed fish mince, in which myofibrillar proteins gets concentrated contributing for gel formation [1]. It is generally frozen at -20°C, with the addition of cryoprotectants, such as sucrose, sorbitol and polyphosphates to retain the functional properties [2]. It possesses some important functional properties such as gel forming ability, water holding capacity, foaming ability, emulsifying property and protein solubility [3].

Surimi based products mainly include restructured analogue or imitation products. Restructured products are prepared by the use of salt to solubilize and extract myofibrillar protein, to form sticky exudate that is responsible for the binding in these kinds of products to form desired shapes [4], but it however leads to salty product. It becomes therefore essential to form low salted restructured surimi gel products using some of the food additives, to improve the functional as well as mechanical properties of the resultant product. Egg white, casein, whey protein concentrate, beef plasma, thrombin and microbial transglutaminase are some of the additives that have been widely used to prepare restructured surimi gel products [5-7]. The textural characteristic of the restructured surimi gel products are based on the interaction between the myofibrillar proteins and different additives [8], Examination of the microstructures of these products becomes essential to understand the extent of cross linking and their possible effects on the functional properties. Additives at times cause discoloration in surimi gel products and thus, colour is another important property to be determined for these restructured surimi gel products.

Short nose white tripod fish (*Triacanthus brevirosterus*) belonging to the family Triacanthidae is one of the popular fish species available in surplus during certain season in South East coast of India and is found best suited for the surimi preparation due to their large availability, white flesh, low cost and less domestic consumption. It is an underutilized fish having silvery colour, dusky body on upper half, with or without darker blotches. So far, no work has been attempted in India on the preparation of restructures surimi gel products using surimi made out of trash fish and their functional as well as physical properties. Hence, in the present study, restructured surimi gel products are prepared from the white tripod fish and their functional properties in relation to microstructural changes were determined to examine their suitability in such products.

Materials and Methods

Materials

Short nose white tripod fish (*Triacanthus brevirosterus*) belonging to the family, Triacanthidae caught by the trawl net was procured fresh from the Fishing Harbour, Thoothukudi and brought to the laboratory in chilled condition with the ice to fish ratio (1:1) in insulated containers. The average length and weight of the fish were 28 cm and 330 g, respectively. The 3 ply laminated pouches of dimension 200 × 200 mm consisting of polyethylene, nylon and co-polyethylene were used for heat setting of the surimi gel product (Sealed Air India Ltd, Bangalore, India). Food additives (viz. Egg white, casein, corn starch and cryoprotectants (viz. Sucrose, sorbitol and polyphosphate used were food grade obtained from local merchants.

Preparation of restructured surimi gel product

Fish were washed with potable water to clean the dust, dirt, sand and other extraneous matter and dressed manually to remove the head, entrails and fins. The dressed fish were again washed thoroughly in chilled potable water. The temperature during all the processing steps was maintained between 5°C and 10°C by using sufficient flake ice made using flake ice maker (ZBE 150 Nr 940062, Orlando, Germany). The dressed fish were then fed into a mechanical deboner/mincer

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(Baader/601, Berlin, Germany) to obtain minced fish meat. The minced meat was washed with cold water (5°C) at a mince/water ratio of 1:3 (w/v), stirred gently for 4 min and then filtered with a nylon screen having a pore size of 0.2 mm. The washing process was repeated thrice. In the third washing step, cold 0.5% NaCl solution (5°C) was also used. To the washed minced fish, 4% sucrose, 0.25% NaCl, 4% sorbitol and 2.5% NaCl were added and mixed well to obtain surimi.

The moisture content of the surimi was adjusted to around 80% to prepare the restructured surimi gel product. Different food additives were added to the surimi at appropriate concentrations as shown in Table 1 and mixed thoroughly for 30 min using a blender (National Super Mixer Grinder, Matsushita Appliances Co, Japan, India). The mixture was then placed in 3 ply laminated pouches and flattened on the top with a wooden roller. The pouches were then evacuated in a vacuum sealer (Sevana's Quick Seal Vac, Kochi, India) and heat set at 40°C for 30 min in an incubator (Secor, NewDelhi) to form the gel. Then, the pouches were heated in steam at 90°C in an electric steam cooker (Salzer, Chennai, India), for 45 min, to form the restructured surimi gel products.

Functional properties

Gel strength: Gel strength of the restructured surimi gel products was determined using the Universal testing machine (Texture analyzer, Lloyd instruments, UK) following the procedure of Benjakul et al. [9]. Cylinder shaped sample with a length of 2.5 cm was prepared and gel strength was measured using the cylindrical plunger having a 5 mm diameter operated at a depression speed of 60 mm/min and expressed as kgF.

Folding test: Binding structure of restructured surimi gel product was determined by a folding test as described by National Fisheries Institute [10]. The test was conducted by folding a 3 mm slice of gel slowly in half, and then in half again to examine the structural failure of the surimi gel. The number of folding required to crack the surimi specimen was then scored from 1 to 5 and assigned to 5 classes: AA, A, B, C or D. Class AA (5) categorizes good quality and D (1) for poor quality of surimi gels related to the cracking of the gel.

Color: The color of the restructured surimi gel product was determined using the Hunter Lab MainiScan® XE Plus Spectrocolorimeter. The L* (lightness), a*(redness/greenness) and b* yellowness/blueness) were measured and whiteness was calculated as described by Park et al. [11] as follows:

$$\text{Whiteness} = 100 - [(100 - L^*)^2 + a^2 + b^2]^{1/2}$$

Scanning electron microscopy (SEM)

Surimi gels with a thickness of 2-3 mm were first fixed with 2.5% (v/v) glutaraldehyde in 0.2 M phosphate buffer (pH-7.2). They were then rinsed for 1 h in distilled water before being dehydrated in ethanol with serial concentrations of 50%, 70%, 80%, 90% and 100% (v/v). The dried samples were then mounted on a bronze stub and sputter-coated with gold (Sputter coater SPI-Module, West Chester, PA, USA). The specimens were observed with a scanning electron microscope (Field Emission Scanning Electron Microscope S – 3400 N (Hitachi, Japan) at an acceleration voltage of 1000 kV to determine the microstructures of the different restructured surimi gel products.

Types	Composition
RS 1	Surimi
RS 2	Surimi + Corn (4%)
RS 3	Surimi + Casein (2%)
RS 4	Surimi + Egg white (1%)
RS 5	Surimi + Corn (4%) + Casein (2%)
RS 6	Surimi + Corn (4%) + Egg white (1%)
RS 7	Surimi + Casein (2%) + Egg white (1%)
RS 8	Surimi + Corn (4%) + Casein (2%) + Egg white (1%)

Table 1: Additives and their proportions for the preparation of restructured surimi product.

Statistical analysis

Statistical analysis was performed for the various functional and physical properties of the different restructured surimi gel products to examine their significance based on SPSS software (SPSS 10.0, Chicago, IL, USA). All the analysis was carried out in triplicates and the average mean ± standard deviations were calculated. The whole experiments were repeated twice to obtain concurrent results.

Results and Discussion

Gel strength

Hardness of the surimi gel products is generally evaluated using compression and puncture tests. Compression force (kgF) is also known as gel strength. The average gel strength of control surimi gel RS-1 was 9.05 kgF ($p<0.05$). Surimi gels prepared with egg white (RS-4) had slightly lower gel strength of 6 kgF than control but higher than other gel products. The egg white had more gel strength due to the coagulating capacity of ovalbumin [12]. Kuhn et al. [13] had also indicated that the gel strength of king weakfish significantly increased with the presence of protein additives such as bovine serum albumin (BSA) and egg white. Gel strengths of the Alaska Pollack and Pacific Whiting surimi gels prepared with potato starch and egg white were also lower than those gels prepared without any additives or with egg white alone [14], in accordance with the present study.

Water holding capacity

Water holding capacity of food refers to its ability to hold its own and added water during the application of forces, pressing, centrifugation and heating. It is a physical property and as the ability of a food structure to prevent water from being released from the three dimensional structure of the protein [15]. Water holding capacity (WHC) of the restructured surimi gel products differed with the addition of the different proteins (Figures 1 and 2). WHC of the white tripod surimi gel RS-1 was 99%. Alvarez and Tejada [16] have observed

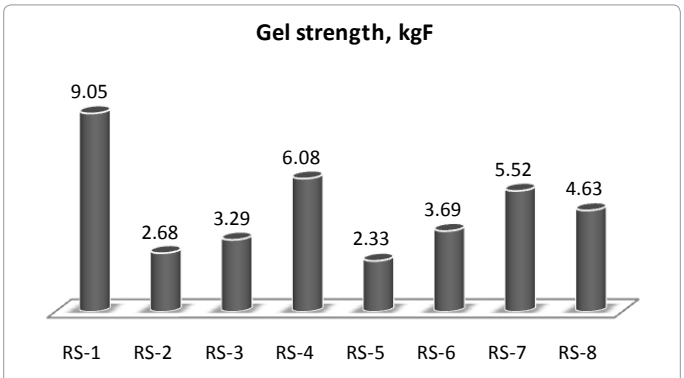

Figure 1: Gel strengths of the different restructured surimi gel products from short nosedwhite tripod fish (*Triacanthus brevirosterus*). (RS-1 Surimi, RS-2 Surimi with corn, RS-3 Surimi with casein, RS-4 Surimi with egg white, RS-5 Surimi with corn andcasein, RS-6 Surimi with corn and egg white, RS-7 Surimi with casein and egg white, RS-8 Surimi with corn, Casein and egg white).

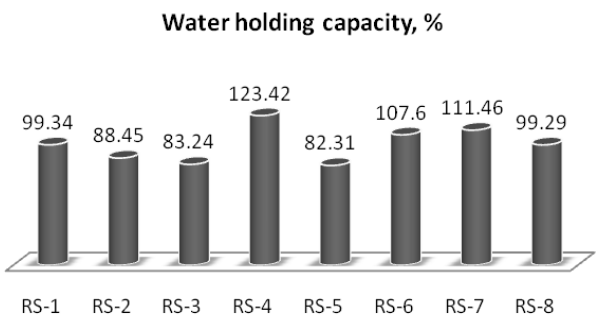

Figure 2: Water holding capacities of the restructured surimi gel products of short nosedwhite tripod fish (*Triacanthus brevirosterus*). (RS-1 Surimi, RS-2 Surimi with corn, RS-3 Surimi with casein, RS-4 Surimi with egg white, RS-5 Surimi with corn andcasein, RS-6 Surimi with corn and egg white, RS-7 Surimi with casein and egg white, RS-8 Surimi with corn, Casein and egg white).

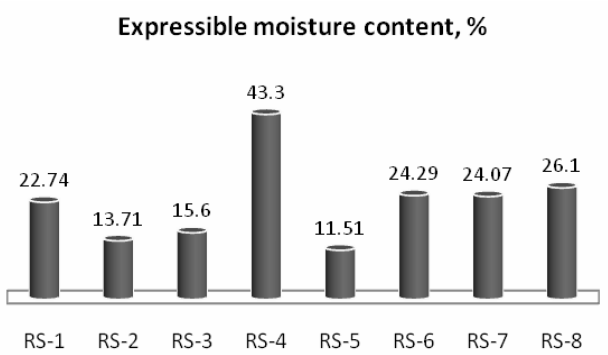

Figure 3: Expressible moisture contents of the restructured surimi gel products of short nosed white tripod fish (*Triacanthus brevirosterus*). (RS-1 Surimi, RS-2 Surimi with corn, RS-3 Surimi with casein, RS-4 Surimi with egg white, RS-5 Surimi with corn andcasein, RS-6 Surimi with corn and egg white, RS-7 Surimi with casein and egg white, RS-8 Surimi with corn, Casein and egg white).

that suwari gels have lower WHC than kamaboko gels. As the surimi gel products are processed at high temperature 90°C it is expected to contain more WHC, as heating induces the aggregation of protein after appropriate swelling and helps to imbibe the water in the gel matrix. But, the WHC's of the surimi gels prepared with corn (RS-2) and were lower than the control (RS-1). On the other hand, addition of egg white (RS-4) had increased WHC to 123% indicating that clefts and crevices in the coagulated egg protein having non–polar groups had helped in the retention of water as hydrodynamic water in the surimi gel matrix. Surimi gel products prepared with combination of different additives had intermediate WHC's.

Tabilo–Munizaga and Barbosa Canovas [14] have reported that Alaska polack surimi gels without additives Pacific Whiting surimi gel with egg white had the highest WHC stating that different fish surimi gels expressed different WHC based on the nature of fish proteins. The presence of sarcoplasmic proteins may also interfere with myosin cross linking during gel matrix formation because they do not form gels and have poor WHC [17]. It has also been reported that protein additives in surimi gels induce protein protein interaction which displace the water resulting in decreased WHC. Thus, it was clear, that WHC of surimi gels depends on gel setting temperature presence of sarcoplasmic proteins as well as additives.

Expressible moisture content (EMC)

Average expressible moisture contents of the control gel; RS-1 was 23% (Figure 3). With the addition of corn, RS-2 and casein, RS-3 there was a significant reduction in the EMC's ($p < 0.05$). Balange and Benjakul [18,19] reported lower EMC in mackerel surimi gels added with oxidized tannic acid due to increased breaking force and deformation of surimi gels. Similarly, in this study, surimi gels prepared with corn and casein (RS-2, RS-3 and RS-5) had much lower EMCs, as they failed to pass folding test due to lower gel strengths and lower WHCs. Surimi gels prepared with egg white, RS-4 had very high EMC of 43% ($p < 0.05$) than other gel products. Egg white forms protein stabilized foam at neutral PH that are more stable due to lack of repulsive interactions. This promotes fish protein - egg protein interaction and formation of viscofilm at the interface, which further adsorbs more protein. Subsequent heating coagulate the egg protein leaving aside several clefts and crevices in gel matrix, in which, bulk water condenses as hydrodynamic water that had increased WHC. This bulk water can easily be removed on compression and expressed as high EMC in these gels. It has been stated that gels prepared by direct heating showed higher EMC than kamaboko gels indicating that protein network of suwari gels has lower WHCs [20].

Folding test

Folding test is a simple and fast method to measure the binding property of the surimi gel. All the restructured surimi gel products of white tripod fish did not break when dipped with finger (Table 1). Generally high quality surimi does not show any fracture because of the presence of cryoprotectants that improve the stability of myofibrillar protein and gel forming capacity. In folding test, the control surimi gel (RS-1) showed breakage and was graded as 'B' class. Such breaks were also exhibited by the surimi gels, RS-2 and RS-7, as they were made of corn starch. Starch is known to inhibit the gelation of fish proteins by competing for the available water [21]. Slight breakages were noticed in the surimi gels, RS-3 and RS-5, which contained casein. There were no breaks in surimi gels prepared with egg white (RS-4) providing them good gelling ability. Earlier, the folding test performed for surimi gel products of Alaska Pollack and Pacific whiting with egg white and potato starch scored the maximum of 5.0 with grade 'AA' indicated good gelling ability [22].

Color

Color is an important factor determining the quality and acceptability of surimi gels. The lightness, L* was high in surimi gel, RS-4 with 74.55 ($p<0.05$), followed by RS -3 prepared with casein (Table 2). The demand for surimi gels with high lightness (L*), low yellowness, (b*) and high whiteness (W), is generally high. Addition

Samples	Folding test		
	Finger dip	Folding	Class/Grade
RS-1	No	Yes	Class B/3
RS-2	No	Yes	Class B/3
RS-3	No	Slightly break	Class A/4
RS-4	No	No	Class AA/5
RS-5	No	Slightly break	Class A/4
RS-6	No	No	Class AA/5
RS-7	No	Yes	Class A/4
RS-8	No	No	Class AA/5
RS-1 Surimi, RS-2 Surimi with corn, RS-3 Surimi with casein, RS-4 Surimi with egg white, RS-5 Surimi with corn and casein, RS-6 Surimi with corn and egg white, RS-7 Surimi with casein and egg white, RS-8 Surimi with corn, Casein and egg white.			

Table 2: Folding test grades and scores of the different restructured surimi gel products.

of egg white and casein had improved (L*) values, than corn starch. All protein additives have an impact on the colour of surimi gels with a slight reduction in (L*) values and a large increase of b* values [11]. Starch generally increases lightness as these granules absorb water and become fully swollen; and light can pass through them generating transparent gels [23], but this was not evidenced in case of corn starch due to improper gelatinization of starch in the protein gel. With the addition of corn, flaxseed, algae, menhaden, krill, and blend oils, the L*values reduced while with flaxseed and menhaden oils, the L* values increased due to minimal pigmentation in the oils [24]. Tabilo–Munizaga and Barbosa Canovas [14] reported that the L* values of heat induced Pacific Whiting surimi gels was 81.01, while it was 82.22 with potato starch, 81.36 with egg white and 80.86 with both egg white and potato starch. Corn starch added to white tripod surimi gels also did not increase the L*values, similar to potato starch. Tammatinna et al. [25] indicated that the L* values of shrimp surimi gels set at 24°C for 2 h were slightly higher than set at 40°C for 30 min. The processing time and temperature also affect the b* values of the Alaska Pollack surimi gels [26], similar to L* values.

The other two tri stimulus colour values, a* and b* are coordinates in which a* has positive or negative values for reddish or greenish hues, respectively and b* has positive or negative values for yellowish or bluish hues, respectively. White tripod surimi gels had greenish hue with negative a* values (Table 2), among which with RS-1 and RS-3 had higher negative values. Alaska Pollack surimi gels with no oil, corn, flaxseed, algae and menhaden oils also had slightly negative a* values [24]. However Park [27] indicated that there was no significant difference in the a* values at different heating and setting conditions of Alaska Pollack and Pacific Whiting surimi gels.

White tripod surimi gels had higher positive b* values indicating yellowness hues. The yellowness, b* was high in white tripod surimi gels with egg white than corn starch and casein (Table 3). But, in Pacific Whiting and Alaska Pollack surimi gels prepared with egg white, b* values were higher than potato starch [14].

The most important quality parameter in surimi seafood is the whiteness W, which was calculated as recommended by Park [24] due to its effectiveness to differentiate the behaviour of different additives. Whiteness of the surimi gels prepared with egg white (RS-4) was higher (74.75) than all other products ($p < 0.05$). Klesk et al. [28] had indicated that surimi gel prepared without additives exhibited higher whiteness values than those with additives. In Alaska Pollack and Pacific Whiting surimi gels with potato starch and egg white, whiteness was lower by 7% and 3% with respectively compared to control [14]. Addition of beef plasma protein (BPP) to the lizard fish surimi gel had resulted in the decrease of whiteness; while addition of egg white had no effect according to Benjakul et al. [22]. In our study, whiteness values were high in the surimi gels made of egg white. In general, heat induced surimi gels without additives exhibited better L* and b* values, but whiteness values were high in gel even with additives.

Samples	Lightness, L*	Redness, a*	Yellowness, b*	Whiteness, W
RS-1	71.76 ± 0.11	- 1.40 ± 0.17	7.80 ± 0.31	70.67 ± 0.59
RS-2	71.48 ± 0.70	- 1.32 ± 0.05	7.66 ± 0.15	70.39 ± 0.90
RS-3	72.43 ± 0.18	- 1.44 ± 0.08	9.58 ± 0.34	70.78 ± 0.60
RS-4	74.55 ± 1.01	- 1.02 ± 0.05	6.52 ± 0.66	74.75 ± 1.72
RS-5	71.55 ± 0.70	- 0.94 ± 0.26	8.19 ± 0.87	70.40 ± 1.83
RS-6	70.67 ± 0.50	- 1.35 ± 0.09	7.86 ± 0.54	70.52 ± 1.13
RS-7	72.01 ± 0.28	- 1.17 ± 0.49	9.04 ± 0.57	70.57 ± 1.34
RS-8	70.43 ± 0.40	- 0.86 ± 0.01	8.33 ± 0.08	69.26 ± 0.49
RS-1 Surimi, RS-2 Surimi with corn, RS-3 Surimi with casein, RS-4 Surimi with egg white, RS-5 Surimi with corn and casein, RS-6 Surimi with corn and egg white, RS-7 Surimi with casein and egg white, RS-8 Surimi with corn, Casein and egg white.				

Table 3: Colour values of the different restructured surimi gel products.

Microstructure (SEM)

Microstructure analysis is also another important phenomenon to identify the change in molecular structural arrangement after high temperature processing of surimi gels. SEM images at 1000 X magnifications of the surimi gel products are shown in Figure 4. In general, the appearances of the matrices were different with regular or irregular surfaces and formation of cracks and cavities. The control surimi gel (RS -1) showed an irregular pattern and looked very smooth with deep cavities. As all the surimi gel products are prepared with 2.5% NaCl, they are expected to have more extensive solubilisation of myofibrillar proteins [29-38] with regular mesh in the matrices. But, Gomez-Guillen et al. [30] had found in gels with 1.5% NaCl, that the mesh was rather more irregular with large pore size than in the gels with 2.5% NaCl [39-43]. Apart from the salt concentration, the heating temperature at 95°C was also the cause for the haphazard protein aggregation, giving rise to a less stable structure for the gels.

The matrix of surimi gel with corn (RS-2) was more uniform with regular cavities expressing a true 3-D network [44-50]. In this gel, the corn starch that gelatinizes at 67°C to 70°C in water did not gelatinize even at 90°C, indicating that gelatinization temperature is also influenced by the presence of fish myofibrillar proteins and the available hydrodynamic water for gelation. Also, the myofibrillar proteins were not been fully solubilised leading to aggregation upon heating, accompanied by more extensive protein syneresis. As a result, the water got expelled, the muscle protein got retracted and a number of holes or cavities had appeared in the gel [51-60]. The number and size of the cavities are determined by the amount of water expelled from the matrix [15]. Large white coloured spherical clusters on the surface of the RS-2 gel matrix indicated self-aggregation of corn molecules by means of hydrophobic interactions or hydrogen bonding. This

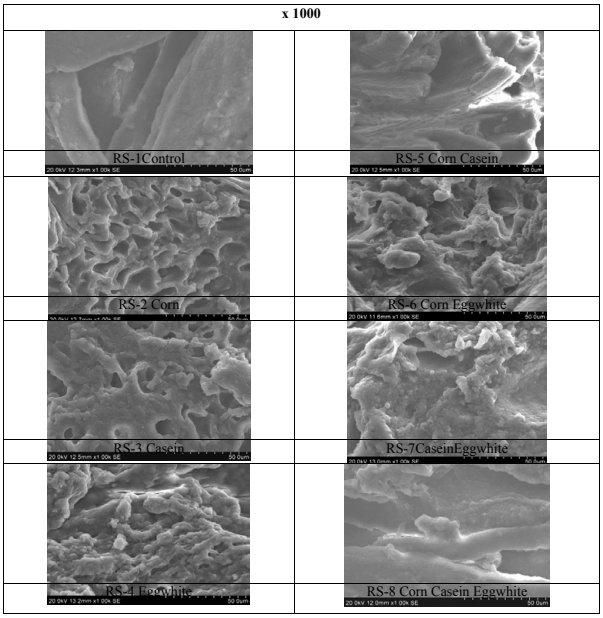

Figure 4: Electron microscopic images of the different restructured surimi gel products of short nosed white tripod fish at 1000 X magnification.

propensity of self-interaction of corn interferes with the cross-linking of myofibrillar proteins, to form an adequate gel network.

The surimi gel with casein, RS-3, more or less compact with less cavities. Casein acts as functional filler by increasing shear stress but not the shear strain values [27]. Casein and gluten were arranged in randomly distributed clusters in sardine surimi gels [30]. The aggregation of protein was such that there were deep cracks in the matrix; and there was lack of fibrillar orientation that had contributed for their very low gel strength.

The surimi gel with egg white (RS-4) had the matrix with more uniform, compact and fibrous appearance with clusters but no cavities. Egg white being a functional binder increases both the shear stress and shear strain values [27]. There was a negative relationship between the size of these cavities and gel strength. Thus, more visible cavities in the surimi gels with corn contributed for the lowest gel strength (2.68 kgF), less numbers of cavities in gels with casein had slightly lower gel strength (3.29 kgF), and no cavities in gels with egg white had the highest gel strength (6.08 kgF). Gomez-Guillen et al. [30] had reported that the sardine gels with egg white are better formed and more uniform with high gel strength and breaking force than with soy protein, casein or gluten, similar to our findings.

In other restructured gels containing egg white (RS-6, RS-7and RS-8), the matrix had a reticulate appearance with round, evenly sized pores. Egg white was visibly more aggregated in gel and appeared as small clusters throughout the matrix. According to Kuhn and Soares [31] coagulating capacity of the egg white occurred together with the starch gelation in gels leading to an increase in the viscosity of the batter, which prevents the coalescence of the air cells inside the structure thereby increasing the volume without contributing to the stability.

Conclusion

To protect network protein responsible for the gel formation, many compounds of protein nature are used to improve the gel physical properties and control proteolysis by avoiding myofibrillar cleavage. These compounds are the protease inhibitors and among them, egg white gave better effect than other proteins like potato extracts or whey proteins [31]. Use of protease inhibitors independently of fish species, but at different levels in Alaska Pollack and Pacific whiting had resulted in an increase in gel strength [32,33]. In the present study, the surimi gel with egg white, RS-4 had a uniform gel network with fewer cavities due to effective crosslinking and protein aggregation, provided good physical properties to the gel, mainly gel strength and WHC. Further, egg white is also an effective protease inhibitor that could avoid myofibrillar cleavage and provide high gel strength to the surimi gel products.

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