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ORIGINAL ARTICLE

Quality of shrimp analogue product as affected by addition of modified potato starch

S. Remya · S. Basu · G. Venkateshwarlu · C. O. Mohan

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Abstract The present study was aimed to investigate the effects of addition of modified potato starch on the biochemical and textural properties of shrimp analogue/imitation shrimp, a popular value-added product prepared from surimi. Three batches of shrimp analogues were prepared with 0 % (NPS), 50 % (CPS) and 100 % (MPS) of modified starch incorporation and various quality attributes were monitored at regular intervals during frozen storage (−20 °C). Loss of myofibrillar protein was least for the shrimp analogue sample added with 100 % modified potato starch. The expressible moisture content of MPS (2.48 %) was less affected by long term storage compared to CPS (3.38 %) and NPS (3.99 %). During extended low temperature storage, the textural quality of sea food analogue was highly influenced by the type of starch added to it. The percentage of modified potato starch added to shrimp analogue significantly ($p \leq 0.05$) affected its hardness and fracturability. MPS samples did not show significant changes in hardness during storage as compared to other two samples. Springiness of shrimp analogue increased 2.57, 1.5 and 1.77 times with the storage period for samples with NPS, CPS and MPS, respectively. Addition of modified potato starch improved the sensory quality and textural properties of shrimp analogue and reduced the quality degradation during frozen storage as compared to NPS which contained only native potato starch.

Keywords Shrimp analogue · Modified starch · Texture · Myofibrillar protein · Expressible moisture

Introduction

Shellfishes like lobster, shrimp and crab are most sought after seafood products due to its unique taste and culinary properties. Recently, seafood analogues, which are commonly known as imitation products are gaining popularity, due to its low cost. Analogue products are produced from low-cost source of fish protein or surimi and are designed to imitate high-cost, luxury food items. Surimi is concentrated myofibrillar protein obtained after repeated washing of white meat from underutilized or low-valued fishes and then stabilized by cryoprotectants for extended storage life. Surimi is a potential raw material for a variety of products, which is becoming increasingly popular due to unique textural properties as well as high nutritional value (Park and Morrissey 2000). Shell fish analogues are popular surimi seafood products which mimic shell fishes such as crab, lobster, shrimp etc. in shape, color, appearance, flavor and textural properties. Shrimp analogue, a shellfish analogue resembling real shrimp, is made from surimi with other ingredients suitable for texture and taste modification.

To better suit the textural preferences of consumers, ingredients must be added to surimi that positively modify its textural and water mobility properties (Lee et al. 1992). The most widely used ingredient in shellfish analogues is starch, which is primarily used for its water-holding capacity and its ability to replace a portion of the fish protein while maintaining desired gel properties. Starch can improve the surimi gel strength, modify texture, reduce cost as well as improve freeze-thaw stability (Lee 1984). Addition of starch to surimi seafood at 4–12 % level is shown to improve gel strength and the textural properties (Okada 1963). Wheat, corn, maize,

S. Remya (✉) · C. O. Mohan
Fish Processing Division, Central Institute of Fisheries Technology,
Veraval Research Centre (Indian Council of Agricultural Research),
Veraval, Gujarat 362 269, India
e-mail: remya03cof@gmail.com

S. Basu · G. Venkateshwarlu
Central Institute of Fisheries Education (Indian Council of
Agricultural Research), Andheri (W), Mumbai, Maharashtra 400
061, India

tapioca and potato are the most widely used starches for making shell fish analogue products in the food industry. Among these, potato starch has the greatest gel-strengthening effect due to its ability to bind the largest amount of water and swell to a large diameter (Kim and Lee 1987).

In frozen food distribution chain, localized thawing is possible with each temperature change. The mini freeze/thaw cycles cause releasing of free water called syneresis or weeping and thus storage of fish products for long periods can lead to loss in water holding capacity and alteration of textural properties. Modified starches can be used, in place of native starches, to improve the textural qualities and frozen storage life of fish products. Modification makes the functional properties of starch different from those of the native starch. Stabilized modified starches are commercially prepared by hydroxypropylation or acetylation with or without cross-linking. Among the modified starches, hydroxypropyl starch is more popular for frozen products because of its stability. Kim and Lee (1986) have reported an extended shelf life of frozen fish paste products by incorporating modified starch. However, considering the cost and sticky nature of product prepared with modified starch, combination of modified starch and native starch is used commercially (Lee et al. 1992). Yoo and Lee (1993) suggest that native and modified starches can be blended and added to fish protein gels at a maximum concentration of 4 % to improve gel strength. Although modified starch has been used for fishery products, there is very limited information on the use of modified starch for improving the textural quality of shrimp analogue products prepared from surimi. Hence, the present study was undertaken to investigate the effects of addition of modified starch at different levels on the textural quality and frozen storage stability of shrimp analogue prepared from pink perch surimi.

Materials and methods

Materials

Surimi prepared from Pink perch (*Nemipterus japonicus*) was procured from a reputed processing industry located in Mumbai, Maharashtra, India. Surimi had 77.33 % of moisture, 17.19 % of protein, 0.344 % of lipid, and 0.501 % of ash content. Surimi was mixed with a 4 % commercial cryoprotectant blend (sucrose/sorbitol, 1:1). Upon arrival, surimi block of 1 kg each, was vacuum packaged and stored at −20 °C until use. Native and modified (Hydroxypropylated) potato starches were obtained from Jaisheel brothers (Vile Parle, Maharashtra, India). Paprika colorant (E160c), shrimp flavour (Ms Bio Co., Ltd., Busan, Korea), glycine (E640) and sodium tri-poly phosphate (E451) used, were of food grade quality. Cod liver oil was purchased from the Chemist in Mumbai, India. Other ingredients used for the shrimp analogue preparation such as salt, sugar, vinegar and shrimp were purchased from the local retail shops.

Preparation of shrimp analogue

Partially thawed (at 0 °C for 10 h) surimi block (1 kg) was chopped in a food processor (Philips, India) at low speed and mixed for 1 min. It was then mixed with salt (2.5 %) and sodium tri poly phosphate (0.2 %) for another 1 min. Subsequently sugar (1 %), acetic acid (0.5 %), glycine (0.4 %) and cod liver oil (2.5 %) were added. This base material was divided into three lots for preparing shrimp analogue by adding starch (4 %). For one lot, 100 % native potato starch was added (NPS) and the second lot was prepared with 100 % modified potato starch (MPS). For the third lot, both the starches were added at 50 % level (CPS). It was then mixed well for 2 min and the paste was stuffed into a plastic casing with a diameter of 2.5 cm and a length of 15 cm. The paste was kept in refrigerator (<5 °C) for 10 h for cold setting and transferred to water bath, for heat setting at 50 °C for 20 min. The heat set blocks were then transferred into 90 °C water bath and maintained for 3 min. The blocks were cooled and sliced into filaments using stainless steel knives. The filaments were further mixed with 25 % each of unheated surimi paste and cooked shrimp paste (shrimp cooked in boiling water for 10 min and ground) for 1 min and shrimp flavor (5 %) was added. The paste was moulded into shrimp shape using a mould made of plaster of paris and paprika colour (1 %) was applied manually with a brush before packing. The prepared shrimp analogue was exposed to 100 °C for 5 min in a water bath for heat setting and cooled before freezing. The packed shrimp analogue samples were frozen in an air blast freezer (Tecnomac, Italy) for 60 min to obtain an internal temperature of −18 °C and then stored at −20 °C and samples were drawn randomly at regular intervals for quality evaluation.

Quality evaluation of shrimp analogue product

Expressible moisture (EM) content

EM content was measured according to the method of Benjakul et al. (2001) with slight modification. A test piece of 10 mm was cut from the centre of a half-thawed sample (4 °C) and weighed exactly (W_1). The test piece was warmed up to 10–20 °C at room temperature and placed between two filter papers of Whatman No.41 with two boards at the bottom and top of the filter paper. A standard weight of 1 kg was placed on the board for 2 min. The test piece after pressing was weighed accurately (W_2). Expressible moisture was calculated from the following equation:

$$EM(\%) = (W_1 - W_2)/W_1 \times 100$$

Texture profile analysis (TPA)

Texture profile analysis (TPA) of sample was performed at ambient temperature with a Texture analyser (TA-XT2*i*, Stable Micro Systems, UK) equipped with a 50 kg load cell. Thawed samples with 25 mm thickness in the centre portion were placed on the platform of the testing machine. 5 mm diameter spherical stainless steel probe was used for the study. Analysis was done with a pre-test speed of 2 mm / s, test speed of 1 mm / s and a post- test speed of 5 mm / s. The penetration distance of the probe was kept at 10 mm and the time duration was adjusted to 5 s. From the resulting TPA curves, the following texture parameters were obtained: fracturability, hardness, cohesiveness and springiness.

Biochemical analysis

Salt soluble protein (SSP) content was extracted by the method of Dyer et al. (1950). About 2 g sample was taken and blended with 100 ml of chilled NaCl (5 %, w/v) in 0.02 M $NaHCO_3$ (pH 7.2) in a homogeniser. It was centrifuged at 3,000 rpm for 15 min at 4 °C and supernatant was collected. The nitrogen content in the extract was determined by Kjeldahl method and expressed as SSP (%).

Thiobarbituric acid reactive substances (TBARS) value (mg malonaldehyde per kg sample) was measured by the method described by Tarladgis et al. (1960).

Sensory analysis

Sensory quality of the shrimp analogue samples was assessed each month by 10 trained panelists. Sensory attributes like texture, juiciness, taste, flavor, odor, color and appearance were considered for assessing the sample. The overall acceptability of the sample was calculated by dividing the mean total of all the sensory attributes by number of attributes. Samples were heated in a microwave oven (700 W) for 5 min before serving to the panelists and a glass of water was provided to restore the taste sensitivity. Panelists were asked to score the samples from 1 to 10 viz.. 10, 9, 8, 7, 6, 5, 4, 3, 2, and 1 for excellent, like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely. The sensory score of 6 and above was considered as good and below 4 was considered poor.

Statistical analysis

The data were analysed by statistical package for social science (SPSS) software version 16 and results are expressed as mean±standard error. Two-way analysis of variance (ANOVA) was carried out to analyse the data and the significant difference between the treatments and storage period was determined by Duncan's Multiple Range Test (DMRT). The level of significance was set up at $p \leq 0.05$.

Results and discussion

Changes in the expressible moisture content

Expressible moisture (EM) content is an important quality attribute of frozen products which indicates the amount of liquid squeezed from a protein system when the force is applied (Jauregui et al. 1981). Addition of modified starch affected the EM content of shrimp analogue favourably (Table 1). The expressible moisture content of the shrimp analogue was reduced significantly ($p \leq 0.05$) when modified starch was used compared to NPS samples. In the present study, least EM content was observed for shrimp analogue with 100 % modified starch followed by CPS and NPS because the formation of free water decreased in the product with the addition of modified starch. The value of expressible moisture content of MPS shrimp analogue sample was significantly ($p \leq 0.05$) different from the CPS and NPS samples throughout the storage period. Minimum initial (2.48 %) and final values (6.30 %) of EM content were observed in MPS samples and maximum initial and final EM values (3.99 % and 10.5 %) were in the NPS sample. Initial (3.38 %) and final (7.52 %) values of EM of CPS samples containing both native and modified potato starch were in between the values of other two samples. Expressible moisture content of NPS increased significantly ($p \leq 0.05$) during frozen storage indicating loss of functionality and low water holding capacity of the product. Expressible moisture content is inversely related with water-holding capacity (WHC). The changes in the nature of actin and myosin molecules during frozen storage lead to reduced water holding capacity, which increases the free water in matrix (Rawdkuen et al. 2009). So, high amount of extracted water indicates poor WHC of the sample (Niwa 1992). During freezing and thawing, modified starches resist retrogradation (molecular association) unlike native starch which undergoes retrogradation and freeze syneresis (water separation). The chemical groups introduced during modification disrupt the linearity of the starch molecules, thus interfering with the tendency of the molecules to associate. Syneresis occurs when the amylose in the starch become tightly associated resulting in squeezing out of liquid. In the present study, water holding

Table 1 Changes in the Expressible moisture content (%) of shrimp analogue during storage period

Sample	Days					
	0	30	60	90	120	150
MPS	2.48 ± 0.06^{Aa}	3.17 ± 0.03^{Ab}	4.05 ± 0.19^{Ac}	5.30 ± 0.08^{Ad}	5.62 ± 0.12^{Ae}	6.30 ± 0.25^{Af}
CPS	3.38 ± 0.03^{Ba}	4.00 ± 0.06^{Bb}	4.95 ± 0.04^{Bc}	5.91 ± 0.03^{Ad}	6.39 ± 0.05^{Bd}	7.52 ± 0.05^{Be}
NPS	3.99 ± 0.06^{Ca}	4.38 ± 0.13^{Bb}	5.41 ± 0.09^{Bc}	6.82 ± 0.08^{Bd}	7.71 ± 0.10^{Be}	10.5 ± 0.13^{Cf}

$^{A-C}$ Means±SE in the column with different superscripts are significantly different between samples ($p\leq0.05$)

$^{a-f}$ Means±SE in the row with different superscripts are significantly different between storage period ($p\leq0.05$)

MPS Shrimp analogue product with Modified potato starch, *NPS* Native potato starch, *CPS* Combination of NPS& MPS

capacity of the samples containing modified starch was better than NPS throughout the frozen storage period, proving the ability of modified starch to resist retrogradation and freeze syneresis.

Changes in the textural characteristics of shrimp analogue

Undesirable change in texture as a consequence of long-term storage is a major consideration in grading the quality of frozen sea foods, especially analogue products. Several studies have been carried out on the potential use of modified starch as an ingredient, for improving the texture in the food industry. Fracturability (g), an important textural parameter, is the force at which there is the first significant break in the TPA curve (originally called the brittleness). Addition of modified starch increased fracturability of shrimp analogue product significantly ($p\leq0.05$) compared to native starch (Fig. 1). The highest fracturability was observed for MPS samples (185 g), while the lowest value was observed for NPS samples (110 g). Higher fracturability of MPS shrimp analogue could be due to the higher absorption of water by modified starch in the product. Fracturability of shrimp analogue samples increased during frozen storage and it varied in samples with different starches throughout the storage period. The values of fracturability after 150 days of storage were 267 g, 236 g and 222 g respectively for NPS, CPS and MPS samples. A significantly ($p\leq0.05$) lower changes in the fracturability of samples added with modified starch, even after 150 days of frozen storage, indicates the quality of modified starch to retain the textural properties to a great extent during extended frozen storage.

Hardness (g) is used to estimate the maximum force during the first cycle of compression which is also known as the firmness. Addition of modified potato starch significantly ($p\leq0.05$) increased the initial hardness of the surimi analogue product indicating the force required to deform the sample is very high and is a beneficial effect (Fig. 2). Initial value of hardness for NPS shrimp analogue was only 143 g which was positively increased by the addition of modified potato starch to 175 g in CPS and to 206 g in MPS. Hardness increased during storage in all the samples. The hardness of the MPS sample did not increase significantly ($p\leq0.05$) throughout the storage period whereas the CPS and NPS samples showed a significant ($p\leq0.05$) increase. On 150th day of storage, hardness values were 276, 256 and 244 g respectively for NPS, CPS and MPS samples. Ha et al. (2001) reported that moisture affects the hardness of fish paste and Kang et al. (2010) observed that lower moisture in surimi-like beef results in

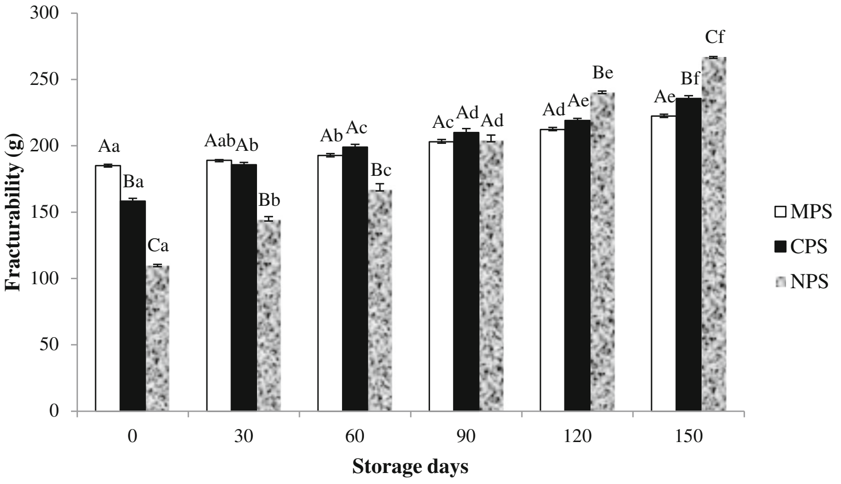

Fig. 1 Changes in the fracturability of shrimp analogues during frozen storage, $^{A-C}$ Means ±SE in the similar bars with different letters are significantly different between samples ($p\leq0.05$), $^{a-f}$ Means±SE in the similar bars with different letters are significantly different between different storage period ($p\leq0.05$), *MPS*=Shrimp analogue product with Modified potato starch, *NPS*=Native potato starch, *CPS*= Combination of NPS& MPS

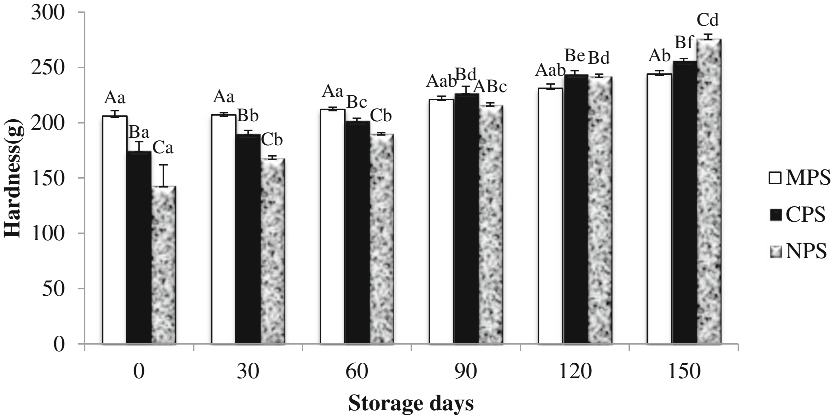

Fig. 2 Changes in the hardness of shrimp analogues during frozen storage, $^{A-C}$ Means±SE in the similar bars with different letters are significantly different between samples ($p \le 0.05$), $^{a-f}$ Means±SE in the similar bars with different letters are significantly different between different storage period ($p \le 0.05$), *MPS*=Shrimp analogue product with Modified potato starch, *NPS*=Native potato starch, *CPS*= Combination of NPS& MPS

stronger gel hardness. Martinez (1989) suggested that the protein content of surimi samples is known to have a great influence on the hardness of the gels made from surimi, while the protein quality influences their elasticity. It was presumed that the modified potato starch added sample was able to retain its softness even after five months of frozen storage due to its better water holding capacity and higher salt soluble protein compared to native starch added one. This result shows that hydroxypropyl groups inhibited the starch chain association and reduced the expressible moisture content. Thus, the hardening of shrimp analogue can be effectively retarded by using hydroxypropylated starches.

Cohesiveness is the ratio (dimensionless) of positive force during the second to that of the first compression cycle (downward strokes only). Cohesiveness indicates the ability of the sample to withstand the deformation. In the present study, the MPS shrimp analogue had the highest initial cohesiveness value (0.63) followed by CPS (0.61) and NPS (0.6) (Table 2). However, the changes in the cohesiveness between the different samples were not significantly different ($p \le 0.05$). Cohesiveness decreased significantly ($p \le 0.05$) during frozen storage in all the three samples. The MPS samples prepared with 100 % modified starch had the highest cohesiveness value (0.542) at the end of the frozen storage period of 150 days, whereas it was 0.53 and 0.51 for the CPS and NPS samples respectively. Myofibrillar protein plays the most critical role during meat processing as they are responsible for cohesiveness and the firm texture of meat products (Xiong 1997; Kang et al. 2007). Salt soluble protein content and cohesiveness values were highest in modified starch added samples indicating the ability of the added starch to modify the properties of the shrimp analogue positively. According to Lanier (1986), cohesiveness is the most sensitive parameter for evaluating the state of surimi proteins. Hsieh and Regenstein (1989) reported positive correlations between hardness and cohesiveness. However, other authors (Hamann and MacDonald 1992) have postulated mutually independent variation of these two parameters. In the present study, there was an increase in the hardness and a decline in the cohesiveness values during frozen storage in all samples.

Springiness is the height that the food recovers during the time that elapses between the end of the first cycle and the start of the second cycle. In other words, springiness is the rate at which a deformed sample recovers its initial condition. Tabilo-Munizaga and Barbosa-Cánovas (2004) reported that springiness is a typical characteristic of viscoelastic materials. The addition of modified starch increased the springiness of MPS & CPS, compared to NPS (Table 3). Springiness of the sample with different amount of modified starch were significantly

Table 2 Changes in the cohesiveness of shrimp analogues prepared with different starches

Sample	Days					
	0	30	60	90	120	150
MPS	0.63±0.01^{Ac}	0.58±0.01^{Aa}	0.57±0.02^{Aab}	0.55±0.00^{Ab}	0.55±0.00^{Aab}	0.54±0.01^{Aab}
CPS	0.61±0.00^{Ac}	0.59±0.00^{Ab}	0.54±0.01^{Aa}	0.53±0.00^{Aa}	0.53±0.00^{Aa}	0.53±0.01^{Aa}
NPS	0.60±0.03^{ABc}	0.56±0.01^{Abc}	0.53±0.00^{Aab}	0.53±0.00^{Aab}	0.52±0.00^{Aab}	0.51±0.00^{Aa}

$^{A-C}$ Means±SE in the column with different superscripts are significantly different between samples ($p \le 0.05$)

$^{a-f}$ Means±SE in the row with different superscripts are significantly different between storage period ($p \le 0.05$)

MPS Shrimp analogue product with Modified potato starch, *NPS* Native potato starch, *CPS* Combination of NPS& MPS

Table 3 Changes in the Springiness of shrimp analogues prepared with different starches

Sample	Days					
	0	30	60	90	120	150
MPS	0.80 ± 0.01^{Aa}	0.85 ± 0.01^{Aab}	0.90 ± 0.01^{Abc}	0.98 ± 0.01^{Ac}	1.20 ± 0.06^{Ad}	1.42 ± 0.01^{Ae}
CPS	0.73 ± 0.01^{Ba}	0.83 ± 0.0^{Ab}	0.88 ± 0.0^{Abc}	0.93 ± 0.01^{Acd}	0.98 ± 0.01^{Bd}	1.10 ± 0.06^{Be}
NPS	0.42 ± 0.01^{Ca}	0.66 ± 0.01^{Cb}	0.72 ± 0.01^{Cb}	0.82 ± 0.01^{Bc}	0.91 ± 0.01^{Cd}	1.08 ± 0.06^{Ce}

$^{A - C}$ Means±SE in the column with different superscripts are significantly different between samples ($p\leq0.05$)

$^{a - f}$ Means±SE in the row with different superscripts are significantly different between storage period ($p\leq0.05$)

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($p\leq0.05$) different. Springiness value of shrimp analogues showed an increasing trend during frozen storage in all the samples. Initially, springiness values of samples were 0.42, 0.73 and 0.80 which increased to 1.08, 1.10 and 1.42 for NPS, CPS and MPS samples respectively during 150 days frozen storage. However, the increase over 150 days of storage was 2.57 times that of initial value for NPS compared to only 1.5 and 1.77 times for CPS and MPS, respectively. Springiness of shrimp analogue sample prepared with 100 % modified starch was significantly ($p\leq0.05$) higher than the other samples throughout the storage period indicating better elastic quality as it returned more easily to its original shape after the deforming force was removed. Overall, modified potato starch added shrimp analogue samples (CPS and MPS) showed better textural properties throughout the storage period compared to the native starch added samples. Similar results were reported by Yang and Park (1998), who analysed the effects of different types of starches like native potato starch, native corn starch, modified potato starch and modified waxy maize starch on the texture of surimi gel.

Changes in the salt soluble protein content during storage

Salt soluble protein, which is the myofibrillar fraction of protein influences the texture as well as water holding capacity greatly along with other quality attributes during freezing and frozen storage. Myofibrillar protein denaturation, during frozen storage, is expressed by the loss of protein solubility. The addition of modified starch did not alter the salt soluble protein fraction initially (Fig. 3). The initial SSP content of samples with NPS, CPS and MPS were 10.13, 10.15 and 10.16 % respectively. Among the samples, MPS retained the SSP content significantly ($p\leq0.05$) with the increase in storage period compared to CPS and NPS samples. During frozen storage, salt soluble protein content decreased in all the three samples. There were 32, 29 and 25 % reduction in the salt soluble protein content of NPS, CPS and MPS samples after 150 days of frozen storage. Reddy and Srikar (1991) reported decrease in solubility of pink perch protein during frozen storage. The decrease in the myofibrillar protein content in the present study could be attributed to the aggregation of muscle into heavy polymers (Yoon and Lee 1990) and denaturation of protein fraction. During freezing and frozen storage, the denaturation and aggregation of protein initiates from the formation of disulfide bonds, followed by a rearrangement of hydrophobic and hydrogen-bonded regions on an intra- and inter-molecular basis (Buttkus 1974). Decrease in protein contents and its solubility in salts also affects the quality of fish and shell-fish meat (Bhobe and Pai 1986). The addition of modified potato starch to the shrimp analogue had beneficial effect as it retained higher percentage of SSP content compared to native

Fig. 3 Changes in the SSP content of shrimp analogues during frozen storage, $^{A - C}$ Means ±SE in the similar bars with different letters are significantly different between samples ($p\leq0.05$), $^{a - f}$ Means±SE in the similar bars with different letters are significantly different between different storage period ($p\leq0.05$), *MPS*=Shrimp analogue product with Modified potato starch, *NPS*=Native potato starch, *CPS*= Combination of NPS& MPS

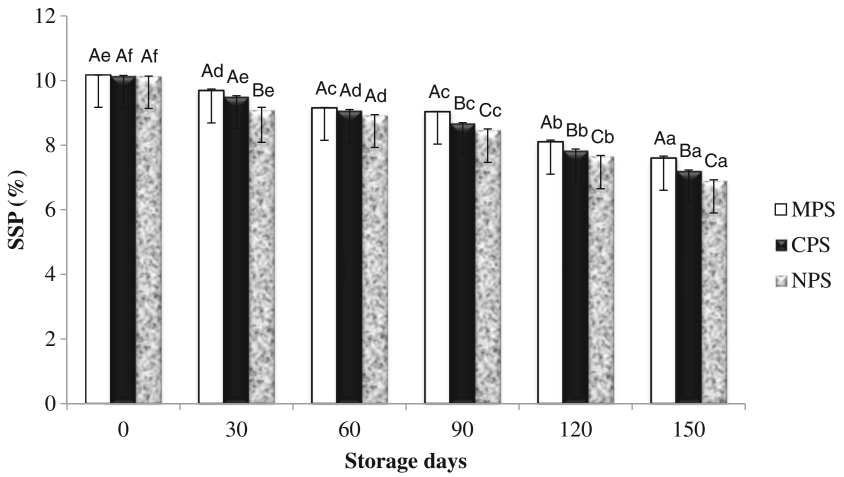

Table 4 Changes in the TBARS value (mg malonaldehyde/kg of sample) during storage

Sample	Days					
	0	30	60	90	120	150
MPS	0.39 ± 0.00^{Aa}	0.68 ± 0.01^{Ab}	1.06 ± 0.02^{Ac}	1.67 ± 0.02^{Ad}	2.20 ± 0.02^{Ae}	2.83 ± 0.01^{Af}
CPS	0.41 ± 0.01^{Aa}	0.82 ± 0.00^{Bb}	1.43 ± 0.02^{Bc}	1.82 ± 0.02^{Bd}	2.27 ± 0.03^{Be}	2.84 ± 0.03^{Af}
NPS	0.43 ± 0.01^{Aa}	0.94 ± 0.02^{Cb}	1.69 ± 0.03^{Cc}	2.05 ± 0.01^{Cd}	2.62 ± 0.02^{Ce}	2.89 ± 0.03^{Bf}

$^{A-C}$ Means±SE in the column with different superscripts are significantly different between samples ($p\leq0.05$)

$^{a-f}$ Means±SE in the row with different superscripts are significantly different between storage period ($p\leq0.05$)

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starch added sample indicating lesser aggregation as well as denaturation of proteins.

Changes in the TBARS value during storage

Lipid oxidation as TBARS was assessed in the samples as cod liver oil (2.5 %) was added to enhance the content of beneficial polyunsaturated fatty acid (PUFA) in the product. The formation of TBARS in the MPS samples was lower compared to other samples. Initial values of TBARS in MPS, CPS and NPS samples were 0.39, 0.41 and 0.43 mg malonaldehyde per kg of sample (Table 4) which indicated that addition of different sources of starch had no effect on the initial lipid oxidation. However, during storage, the formation of TBARS was significantly ($P\leq0.05$) less for MPS samples compared to CPS and NPS. On 150th day of frozen storage, TBARS values of 2.83, 2.84 and 2.89 mg malonaldehyde per kg of sample were observed, respectively. TBARS value is a measure of the secondary stage of oxidative rancidity. It has been widely used to indicate lipid oxidation in fish and fish products. TBARS value of 3–4 mg malonaldehyde/kg sample would lead to souring and quality loss in fish meat (Huss 1988). In the present study, none of the samples showed the above limit which causes quality loss. Perez-Villarreal and Howgate (1991) found increase in TBARS and peroxide value in European hake muscle during frozen storage. Rehbein and Orlick (1990) found that even severe lipid oxidation had only a slight effect on the texture of frozen minced fillets of Antarctic fish. But some other studies say that the TBARS value correlated well with extractability of salt-soluble protein and texture in fatty and lean herring (Kolakowska et al. 1992). Saeed and Howell (2002) also reported that lipid oxidation in fish muscle during frozen storage showed detrimental effect on protein structure and functionality. Oxidised products of lipids formed during storage of fishery products are known to influence the soluble proteins. Many lipid degradation products are also capable of cross-linking polypeptides and thus are responsible for the generation of insoluble protein aggregate (Buttkus 1970). In the present work, there was no significant difference ($p\leq0.05$) in the TBARS values of NPS, CPS and MPS samples, but TBARS value was highest in NPS samples, indicating higher lipid oxidation than in CPS and MPS samples. The high lipid oxidation in NPS sample also possibly contributed to the increased loss in solubility of protein and textural changes of NPS especially when the storage time increased. In the present study, although addition of modified starch inhibited the formation of TBARS compared to CPS and NPS, the exact mechanism is still not known. Further studies are needed to understand the inhibitory effect of lipid oxidation in the presence of modified starch.

Table 5 Changes in the sensory score of shrimp analogue during storage

Sample	Days					
	0	30	60	90	120	150
MPS	9.33 ± 0.17^{Ad}	9.17 ± 0.17^{Ad}	8.67 ± 0.17^{Ac}	8.33 ± 0.17^{Abc}	8.07 ± 0.07^{Aab}	7.73 ± 0.12^{Aa}
CPS	9.27 ± 0.15^{Ad}	8.67 ± 0.17^{Bc}	8.17 ± 0.17^{Bbc}	8.07 ± 0.07^{Bb}	7.67 ± 0.17^{Bb}	6.50 ± 0.29^{Ba}
NPS	9.23 ± 0.15^{Af}	8.03 ± 0.03^{Ce}	7.47 ± 0.03^{Cd}	6.93 ± 0.07^{Cc}	6.07 ± 0.07^{Cb}	5.07 ± 0.30^{Ca}

$^{A-C}$ Means±SE in the column with different superscripts are significantly different between samples ($p\leq0.05$)

$^{a-f}$ Means±SE in the row with different superscripts are significantly different between storage period ($p\leq0.05$)

MPS Shrimp analogue product with Modified potato starch, *NPS* Native potato starch, *CPS* Combination of NPS& MPS

Changes in the sensory quality of shrimp analogue

The addition of modified starch to the shrimp analogue product improved the initial texture and juiciness of the sample compared to CPS and NPS samples (Data not shown). However, there was no significant ($p \leq 0.05$) difference in the color, taste, flavor and odor of the different samples. Addition of 2.5 % cod liver oil didn't negatively affect the sensory properties of the shrimp analogue product. The retention of firm texture with juiciness was better in the MPS samples throughout the storage period. All the sensory attributes showed a decreasing trend with the increasing storage time. However, the NPS samples had lowest values followed by CPS and MPS. The shrimp analogue samples had an initial score of over 9 for overall acceptability which was assessed based on color, taste, flavor and odour of shrimp analogue and indicates very good quality of the product (Table 5). The sensory score for overall acceptability changed from an initial value of 9.33, 9.27 and 9.23 to 7.73, 6.50 and 5.07 in MPS, CPS and NPS samples respectively after 150 days of storage. The addition of modified starch did not affect the initial overall acceptability score. However, during the storage period, the MPS samples had significantly ($p \leq 0.05$) higher overall acceptability score compared to CPS and NPS. The modified starch improved the sensory texture and mouth feel of shrimp analogue sample. There was a greater decrease in the sensory score of NPS samples because of the substantial loss in the textural properties, color, taste and appearance. At the end of the storage time, the sensory score of MPS shrimp analogue was better than CPS and NPS respectively. However, none of the samples' score was below 5 indicating its sensory acceptability up to 150th day under frozen storage.

Conclusions

A wide variety of products with diverse textural properties are prepared from Surimi. Shell fish analogue products prepared from surimi represent a class of food products with distinct demand. At present, native potato starch, which has limited application in producing better textured products, is mainly used in surimi seafoods. Addition of modified potato starch is advantageous in analogue products as it improved the texture, reduced the expressible moisture content and retained higher SSP indicating better water holding capacity, compared to NPS added samples. Modified starch added samples also retained the improved quality better than native starch added samples in the frozen storage condition. The use of modified starches for producing analogue products from surimi based material will help in developing a variety of textured products with extended frozen storage life. This may open up new markets in many countries.

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