

Effect of cornstarch on rheological and functional properties of mince-starch gels prepared from the Indian major carp *Labeo rohita*

Sandeep Bhaskar Gore¹, K. A. Martin Xavier², Binay Bhushan Nayak², Ajay Trimbak Tandale² and Amjad Khansaheb Balange²

¹College of Fishery Science (MAFSU), Nagpur - 440 006, Maharashtra, India

²Department of Post-Harvest Technology, ICAR-Central Institute of Fisheries Education, Versova, Mumbai - 400 061, Maharashtra, India



Abstract

The aim of the present study was to find out suitability of mince of Indian major carps (*Labeo rohita*) and effect of corn starch on mince-starch gels for the development of sausage. Different concentrations (0, 2, 4, 8 and 10%) of commercial corn starch was used to study rheological, functional properties, colour, microstructure and sensory characteristics of mince-starch gels. Corn starch (8%) effectively increased the gel strength, significantly ($p < 0.05$) improved the hardness of gels and affected lightness (L^*) and whiteness index of gels. High densities of dispersion of starch were seen in gel. Based on the results of the study inclusion of 8% corn starch is recommended to develop mince-based products from *L. rohita*.

Introduction

Fish sausage is a heat processed fish meat product mixed with additives such as salt, starch and spices and stuffed into suitable food grade casings. Surimi (fish muscle protein concentrate) is the preferred intermediate material for the development of fish products such as kamaboko, imitated crab sticks, fish ball and sausages. Owing to its unique capability, fish muscle proteins form a translucent and highly deformable gel. Therefore, gelling ability of myofibrillar protein dictates functional and textural characteristics of fish products (Benjakul *et al.*, 2003). The gelation of myofibrillar protein is largely dependent on crosslinking reaction between adjacent myosin molecules. The gelation of myosin occurs in two step heating process at 30-40°C by unfolding α -helices in the tail portion (sol) and by interactions between hydrophobic regions in the head portions of myosin molecule above 50°C (gel) (Somjid *et al.*, 2021).

The conspicuous variation in thermal stability of myofibrillar protein of Indian major carps (IMCs) has been reported earlier by Sankar and Ramachandran

(2005). The thermal stability of natural actomyosin (NAM) of muscle proteins of IMCs varied from 20 to 45°C and NAM was unable to unfold at <40°C (usual setting temperature for marine fish muscle proteins) to the required extent for cross-linking. Formation of gelled network at lower temperature results in poor mechanical and textural properties of the final product (Sankar and Ramachandran, 2002).

Several food-grade additives such as cross-linking transglutaminase, beef plasma protein, egg whites and starches (Ramírez *et al.*, 2011) have been found to enhance gel strength of fish mince/surimi products. However, starch is the popular functional ingredient for improvement of textural properties of surimi products. Starch in foods is used for water holding, adhesion, binding, gelling, maintaining juiciness and tenderness in meat products.

Starch is composed of amylose and amylopectin and their ratio determines the physical properties of starch in the food system. The amylose and amylopectin fraction are responsible for firmness and elasticity of the starch gels (Zhang *et al.*, 2013). The different physical characteristics

*Correspondence e-mail:
sandipgore@mafsu.in

Keywords:

Corn starch, Gel strength, *Labeo rohita*, Microstructure, Mince, TPA

Received : 05.12.2022

Accepted : 20.03.2024

of starch granules vary with starches of different botanical origin (Wu *et al.*, 1985), which ultimately affects gelatinisation capacity of starch in fish protein gel. During protein gelation, protein physically and or chemically binds to water, which in the presence of starch limits accessibility of water for gelation of starch (Chung and Lee, 1991). The additional ingredients such as salt, sucrose and sorbitol in food system increases gelatinisation temperature of starch. Due to heat processing, the expanded starch granules interact with the proteins and impart gel strengthening effect on the gel matrix and affects gel texture (Yang and Park, 1998). Starch is by and large utilised to improve water holding capacity and to partially replace a portion of fish protein, while keeping optimum gel properties. The fish species, intrinsic quality of fish, salt concentration, available protein content and processing methods employed are responsible for rheological and textural properties of resultant fish-meat gel (Yoo, 2011).

Rohu (*Labeo rohita*), an Indian major carp species, is produced in large quantity through aquaculture in India. Therefore, to explore possibilities for utilising this Indian major carp as a fishery resource for international trade, methods for preparation of high-quality products from its mince are needed.

Most studies worldwide have recognised the importance of starch in fish food system to develop consumer oriented nutritionally healthy fishery products with great palatability (Prabpreet and Pongsawatmanit, 2011; Amiza and Ng, 2015). However, very few researchers have reported the interaction of mince-starch gels (Jamilah *et al.*, 2009) and use of minced muscle for the development of sausages from freshwater fish using corn starch. Therefore, the aim of this study was to evaluate the effect of corn starch on rheological, functional, microstructure and colour characteristics of the mince-starch gels.

Materials and methods

Rohu fish (*L. rohita*) having average total length and total weight of 51.30±0.06 cm and 1.86±0.05 kg respectively were procured from freshwater fish market at Dadar, Mumbai, Maharashtra, India and brought to the laboratory in thermocol boxes packed with ice (fish:ice @ 1:1) within 1 h of procurement. The fish were cleaned to cut head, remove fins and viscera and washed in ice cold water to make it free from adhering scales and slime, blood and viscera. The chemicals used in this study were of analytical grade. The corn starch was obtained from Urban Platter, India.

Preparation of mince

The mince of rohu was prepared using a deboning machine (Baader 694, Lubeck, Germany) with a counter-rotating belt and drum mechanism from cleaned and processed fillets. Fillets were fed into the drum sieve holes (5 mm diameter) to prepare mince. The prepared mince was sealed in polythene pouches (LDPE) and stored immediately in a refrigerator (4°C) and used within 1 h for preparation of mince-starch gels.

Gel preparation

The mince-starch mixture samples were prepared by grinding the mince with 2.5% NaCl for 3 min in a pre-cooled mixer grinder

(Lee, 1984). The chilled mince was again comminuted using a stainless steel bowl chopper (Stephan UMC 5 Electronic cutter, Germany) for 3 min followed by slow addition of corn starch and the mixing was continued for 3 more min. The samples with or without starch (0, 2, 4, 6, 8, and 10%) were prepared. The prepared mince-starch mixture samples were filled manually using hand stuffer into krehalon casing of 2.5 cm diameter, taking care to eliminate trapped air as much as possible. The ends of the tubes were tied tightly and pre-incubated at 40°C for 30 min in a temperature-controlled water bath followed by heating in a water bath at 90°C for 20 min. The gels obtained were immediately cooled in ice cold water (0°C) and stored in a refrigerator at 4°C overnight for further analysis.

Proximate composition

Proximate parameters such as moisture and ash content (%) of prepared gel samples were determined according to the AOAC methods (AOAC, 2005). Protein content (%) of samples was evaluated by determining total nitrogen content (micro-Kjeldahl method) using a distillation unit (Kjelplus Pelican, India) and multiplying by 6.25. Fat content (%) was determined using petroleum ether (60-80°C BP) as solvent according to the Soxhlet method. The carbohydrate content of samples was calculated by difference and expressed as percentage.

Measurement of gel strength

The gel strength was measured by using Rheo Tex DP SD-700II, Type Rheometer, Japan. The prepared gels were equilibrated to room temperature and cut into 2.5 cm dia and 3.0 cm length and placed on the platform. A 5 mm spherical probe was used for measurement. The gel strength was calculated by multiplying the peak load (g) and programmed distance (cm). The gel strength of the sample was expressed in g cm.

Gel strength (g cm) = Breaking force (g) x Deformation (cm)

Water holding capacity (WHC)

Approximately 10 g of gel sample from each treatment group was centrifuged at 12,000 g for 30 min at 4°C to determine WHC (Verbeke *et al.*, 2005). WHC was calculated as a percentage of retained water using the following equation:

$$\text{WHC (\%)} = (W_2 / W_1) \times 100$$

where, W₂ = Weight of sausage sample after centrifugation;
W₁ = Weight of sausage sample prior to centrifugation

Folding test (FT)

Folding test (Lanier, 1992) was performed to assess the quality of gel. Gel samples were cut into 3 mm thick slice. The slices were held between the thumb and the forefinger and folded to observe the way that they broke. The grades used were as follows: 5 - No cracks observed after folding, 4 - Cracks immediately when folded in half, 3 - Cracks gradually when folded in half, 2 - Cracks observed immediately after folding in half and 1 - Breaks by finger pressure.

Texture profile analysis (TPA)

TPA was performed using the Texture Analyzer TX-700 (Lamy Rheology, France). To perform TPA test, the gel samples were equilibrated to room temperature for 30 min and sectioned into a 2.5 cm diameter and 3 cm height. The samples were compressed twice in a cross speed of 1 mm per second to 40% of the original height. The mechanical properties *i.e.* hardness, cohesiveness, adhesiveness, elasticity and chewiness were evaluated from the resulting breaking force/deformation curves.

Instrumental colour parameters

The gel samples were equilibrated to room temperature for 30 min prior to the colour measurement using colourimeter. The sausage samples were cut in 2.5 cm diameter and 3 cm height to determine colour properties. L^* (lightness), a^* (redness/greenness) and b^* (yellowness/blueness) were measured and whiteness was calculated (Park, 1994) as follows:

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

Scanning electron microscopy (SEM)

The microstructure of the gel samples was analysed by SEM. The samples were prepared according to Maqsood *et al.* (2012) with slight modifications. The gel samples (2-3 mm thick) were fixed in a 3% glutaraldehyde solution overnight. The samples were then rinsed for 1 h in 0.2 molar phosphate buffer (pH 7.2) and then dehydrated in a gradient ethanol series of 50, 60, 70, 80, 90, and 100% (v/v). The samples were freeze-dried and stored in an air tight container. The dried samples were mounted on a bronze stub and sputter-coated with gold. The specimens were observed using SEM (JEOLJSM-5800 LV, Tokyo, Japan) at an acceleration voltage of 15 kV.

Sensory evaluation

Sensory quality of gel samples was evaluated by a panel of 10 trained panelists (staff and students of Department of Post-Harvest Technology, ICAR-Central Institute of Fisheries Education, Mumbai, India). Gel samples were cut into 1 cm slices, heated at 70°C and served to each panellist separately in a white plate for evaluating its appearance, colour, odour, taste, flavour, texture and overall acceptability based on a 9-point hedonic scale (Mailgaad *et al.*, 1999).

Statistical analysis

All experiments were performed in triplicate and data were subjected to one-way analysis of variance (ANOVA). The 95% confidence level (α) was used during the study. Duncan's multiple range tests from

Statistical Package for Social Science (SPSS 8.0 for windows, SPSS Inc., Chicago, IL, USA) was used for comparison of means.

Results and discussion

Effect of corn starch on proximate composition

Compositional analysis (moisture, protein, fat, ash and carbohydrate) of prepared mince-starch gel samples is given in Table 1. Traditionally, starch is added in sausage manufacturing to act as a binder or extender to increase water binding to improve textural quality and cooking yield of the product (Rahman *et al.*, 2007). The moisture content of the control gel (76.30%) was significantly ($p < 0.05$) higher than that of starch incorporated mince gel samples. The decrease in moisture content in the mince-starch gels can be attributed to the replacement of water in the sample by carbohydrates. An inverse relation was reported between water content and starch content (Rahman *et al.*, 2007). The addition of wheat or tapioca flour like starch ingredients caused decrease in moisture content (Elyasi *et al.*, 2010; Kilinceker, 2018). However, contradictory results of no interaction between mince and surimi with potato starch on moisture and protein content in fish sausage has also been reported (Amiza and Ng, 2015). Approximately 10-12% reduction in moisture content was reported in restructured tilapia product with the addition of 20% starch and the use of single washing cycle (Fogaca *et al.*, 2014) as starch filled the interstitial spaces previously occupied by water.

The addition of corn starch did not influence ($p > 0.05$) the protein content of the mince-starch gels made from rohu. This might be due to low protein in corn starch (0.4 % w/w) (Dhital *et al.*, 2011). Similar results were found by Amiza and Ng (2015), who reported no effect of potato starch addition in fish sausage due to presence of low protein residue in potato starch (Dongyu and Kaiyun, 2008).

The higher value (1.48%) of fat content was observed in control gel than that of mince-starch gel samples. Except control sample, significant difference ($p > 0.05$) was not noticed in fat content of mince-starch gel samples. The addition of starch affected the fat content of the product in the present study as reported earlier by Fogaca *et al.* (2014). This can be attributed to compensation of fat content in the samples by carbohydrate. The decrease in fat content was clearly seen with the addition of additives such as corn starch (Elyasi *et al.*, 2010).

Ash content is a measure of the approximate amount of minerals in a sample (Amiza and Ng, 2015). Somewhat similar values were obtained for ash contents in control and mince-starch gels. No contribution of starch in ash values were seen in the present

Table 1. Proximate composition of mince-starch gels

Parameter	Treatment					
	Control	2% S	4% S	6% S	8% S	10% S
Moisture (%)	76.30±0.09 ^d	75.80±0.38 ^d	73.86±0.73 ^c	72.06±0.09 ^b	71.03±0.12 ^a	70.85±0.13 ^a
Protein (%)	18.49±0.29 ^b	18.53±0.53 ^b	18.05±0.60 ^a	18.94±0.61 ^b	17.53±0.36 ^a	17.42±0.37 ^{ba}
Fat (%)	1.48±0.22 ^b	0.86±0.15 ^a	0.83±0.16 ^a	0.68±0.11 ^a	0.92±0.13 ^a	0.67±0.05 ^a
Ash (%)	3.35±0.03 ^d	3.21±0.05 ^b	3.42±0.05 ^e	3.39±0.02 ^d	3.28±0.03 ^c	3.13±0.02 ^a
Carbohydrates (%)	0.37±0.31 ^a	1.59±0.85 ^b	3.81±0.62 ^c	4.91±0.64 ^d	7.23±0.29 ^e	7.91±0.17 ^e

Data are expressed as the mean ±SD (n=3). Different superscripts in the same row signify statistical difference ($p < 0.05$)

study. Contrary to this, Amiza and Ng (2015) reported silver catfish mince and potato starch contributed to ash content of the sausage samples, which was due to phosphate groups in potato starch (Kaletunc and Breslauer, 2003).

In general, fish contains low amounts of carbohydrate in their muscle (Tokur *et al.*, 2006). In the present study, significant difference ($p < 0.05$) was observed in carbohydrate content and found increasing with the increase in level of corn starch incorporation in mince. The higher amount of carbohydrate in samples is certainly due to addition of carbohydrate rich corn starch. Similar results were also noted for fish finger produced from mirror carp (*Cyprinus carpio*) mince, where they used starch as coating material (Amiza and Ng, 2015). The coating materials like wheat flour and starch increased carbohydrate content of fish finger produced from mince and surimi of common carp (Elyasi *et al.*, 2010).

Effect of corn starch on rheological properties

Rheology is the science of flow and deformation of a material under controlled conditions and it helps to understand how food structure responds to the applied force and deformation. It measures mechanical behaviour of food. The structural information on gel network and interactions among the ingredients of food system can be understood in rheology and provide insight on sensorial and mechanical characteristics of the food (Burey *et al.*, 2009). The gel strength of control and mince-starch gels are depicted in Fig. 1.

Gel strength

The gel strength (Fig. 1) significantly ($p < 0.05$) increased in all starch incorporated mince gels compared with control and the greatest gel strength was observed in 8% starch incorporated sample (423.67 g cm). The increase in gel strength in starch incorporated gel samples could be due to swelling of starch granules filling void spaces in the food gel matrix.

The temperature of heat processing, water uptake by the starch granule and magnitude of swelling affects the gelatinisation of starch (Wu *et al.*, 1985) and gelation of fish proteins (Yang and Park, 1998). The chemical bonds and electrostatic interactions are responsible for protein gel in food system (Hunt *et al.*, 2009). The electrostatic interaction among anionic groups of the starch and the positively charged groups of the protein has a great influence on the stability properties of food dispersion (Jamilah *et al.*, 2009). The starch provides the base of gel structure (Burey *et al.*, 2009).

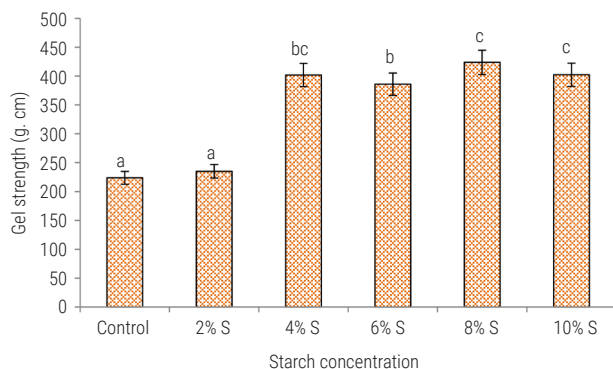


Fig. 1 Gel strength (g cm) of mince-starch gels

The amylose content defines firmness of starch gels, whereas amylopectin influences gel elasticity (Hunt *et al.*, 2009). The starch acts as filler in fish protein gels through absorption of water that exert a turgor pressure on the gel network (Lee *et al.*, 1992). Similar results of high breaking force, deformation, and gel strength was noticed in horse mackerel kamaboko prepared from surimi with the addition of starch (Chen and Huang, 2008). The direct relationship between shear-stress and potato starch concentrations was noticed in surimi gels up to a certain limit (Yang and Park, 1998). Owing to the ability of potato starch to bind large quantity of water and swelling, which led to better textural properties, Yoo (2011) suggested optimum concentration of 8% in fish meat paste products.

Water holding capacity (WHC) and folding test (FT)

The WHC and score of folding test of control and mince-starch gels are represented in Fig. 2a and b respectively.

Except control and 2% starch incorporated gel samples, WHC and folding score was not observed to be significantly different ($p > 0.05$) in other starch incorporated gel samples. Starch is basically utilised for its high WHC in food system (Hunt *et al.*, 2009). Corn starch showed water binding capacity (WBC) ranging from 82.1 to 97.7% depending on the varieties of corn (Sandhu and Singh, 2007).

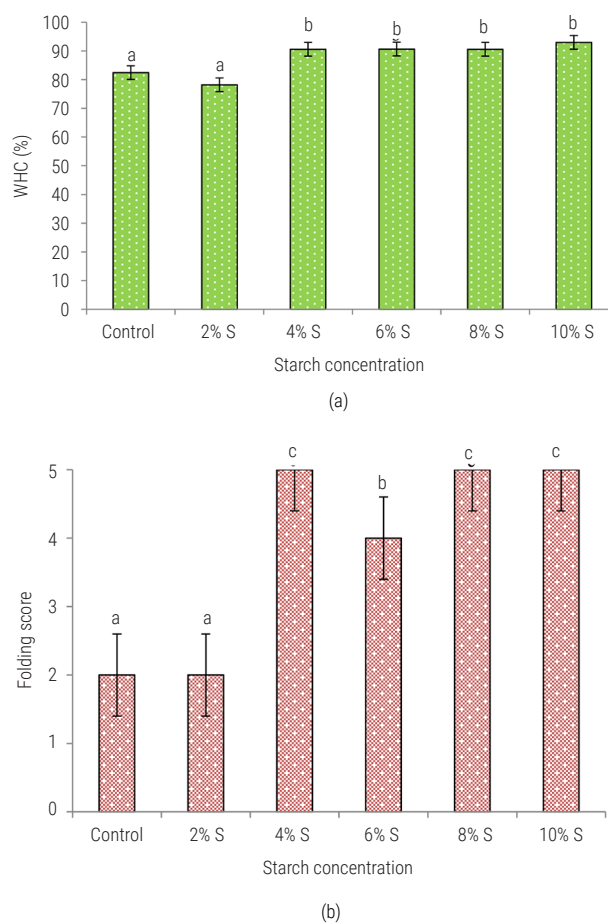


Fig. 2. (a) Water holding capacity (%) of mince-starch gels and (b) Folding score of mince-starch gels

The content of amylopectin and amylose in the starch defines swelling behaviour of starch granules and has a correlation with WHC (Sasaki and Matsuki, 1998). The higher WHC is related to high amylopectin content. Nevertheless, it decreases linearly with the increase in amylose content (Sasaki and Matsuki, 1998).

In the present study, higher FT score was for 8% starch incorporated gel samples indicating good gelling strength, which could be attributed to strengthening effect of both starch and gel matrix.

Similar results were noticed for folding score in sand lance meat paste product (SLMPP), when the concentration of potato starch was increased from 5 to 11% with good gel strength (Yoo, 2011). However, FT alone could not substantiate the quality of gel samples due to lack of precise evaluation.

Effect of corn starch on textural properties

Texture profile analysis (TPA) is an excellent instrumental method to evaluate and verify quality of food in product development. The mean texture scores for TPA parameters are indicated in Table 2. In the present study, the hardness of mince-starch gel samples (defined as the maximum force of the first compression to 40% deformation of the original sample height) increased significantly ($p < 0.05$) with an increase in concentration of corn starch compared with control. The present results are in agreement with Prabpree and Pongsawatmanit (2011), who found hardness increased from 7 to 12 N when the concentration of tapioca starch increased from 3.5 to 14% in small-scale mud carp sausages. The increased hardness attribute in fish mince sausages, due to addition of starch was found sensitive to the functionality of polysaccharide (Rahman *et al.*, 2007; Kasapis, 2009). Dincer and Cakli (2015) did not find any significant difference ($p > 0.05$) in hardness in emulsion-type fish sausages prepared from rainbow trout and saithe fillets prepared with modified potato starch (1.70%). The increase in hardness was also reported in silver carp mince added with potato starch (Yinghong *et al.*, 2003). The hardness of the product is generally inversely proportional to both fat and moisture levels. Contradictorily, harder sausages were reported in high fat and high starch sausages than the products with low-fat (Pietrasik, 1999). The important point to be noted is that the factors such as composition, ionic interaction, functionality of protein and fat content influences the protein concentration in the system, which may have effect on texture.

Cohesiveness measures the degree of difficulty to break down the well-integrated internal structure of the sausage gel. In the present study, the cohesiveness was not found to be influenced ($p > 0.05$) by the addition of starch in mince-starch gel samples. The results are

consistent with the research of Pietrasik (1999). Similarly, effect of addition of tapioca starch was not seen on the cohesiveness of the fish sausages (Prabpree and Pongsawatmanit, 2011). Dincer and Cakli (2015) also did not observe any significant difference ($p > 0.05$) in cohesiveness values between trout and saithe sausages.

Adhesiveness may be defined as the force required to remove the sample from the roof of the mouth after chewing (Kasapis, 2009). The adhesiveness increased with increasing corn starch content as with hardness. Similar results were reported by Prabpree and Pongsawatmanit (2011) in mince sausage containing tapioca starch. However, Rahman *et al.* (2007) did not observe change in adhesiveness with the rising level of starch in the products.

Springiness, otherwise referred to as “elasticity” dictates ability of a specimen to recover its original sausage height under applied forces. Significant differences ($p < 0.05$) in elasticity values were observed in starch-incorporated gel samples and found lower than that of control sample. This might be due to gel samples being manufactured without any additional ingredients in the mince. The results of the present study are in agreement with the work reported by Dincer and Cakli (2015) in the production of fish sausages. However, contradictory results were observed in the springiness values of the small-scale mud carp sausages, where tapioca starch did not influence the elasticity of the product (Prabpree and Pongsawatmanit, 2011). The texture of formulated gels depends on the composition and processing conditions employed during production.

Effect of starch on instrumental colour parameters

Colour measurement is one of the important parameters in cooked sausage products because of consumers' association with a bright and characteristic sausage colour. In the CIE Lab system, L^* denotes lightness on a 0 to 100 scale from black to white; a^* denotes (+) red or (-) green; and b^* denotes (+) yellow or (-) blue (Dincer and Cakli, 2010). Colour parameters such as L^* - lightness, $\pm a^*$ - redness/greenness, $\pm b^*$ - yellowness/blueness and whiteness of control and starch incorporated gel samples are shown in Table 3.

The addition of starch did not affect whiteness ($p > 0.05$) between control, 2 and 4% mince-starch gel samples. However, the decrease in whiteness was observed with the addition of starch from 6 to 10%. Similar trend as whiteness was observed for lightness in control and starch incorporated gel samples. This was expected since fish mince was somewhat darker in colour containing blood remains, slime and fat. The increased concentration of corn starch decreased whiteness/lightness values (Elyasi *et al.*, 2010). The results of the present study are in agreement with Amiza and Ng (2015) for different concentrations of silver catfish mince to

Table 2. Textural characteristic of mince-starch gels

Parameter	Treatment					
	Control (C)	2% S	4% S	6% S	8% S	10% S
Hardness (N)	5.48±0.18 ^a	6.26±0.18 ^a	7.43±0.18 ^b	7.37±0.18 ^b	8.60±0.18 ^c	8.81±0.18 ^c
Cohesiveness	0.83±0.07 ^a	0.86±0.07 ^a	0.77±0.10 ^a	0.65±0.16 ^a	0.65±0.01 ^a	0.71±0.15 ^a
Adhesiveness (J/m ³)	0.70±0.43 ^a	1.13±1.19 ^{ab}	3.10±0.39 ^a	3.90±2.19 ^{ab}	2.77±1.32 ^{ab}	5.10±4.28 ^b
Elasticity (mm)	1.06±0.04 ^b	1.05±0.03 ^{ab}	0.97±0.02 ^{ab}	0.92±0.11 ^a	0.95±0.00 ^{ab}	0.96±0.11 ^{ab}

Control (C)– Mince without starch; 2% S- Mince with 2% starch; 4% S- Mince with 4% starch; 8% S- Mince with 8% starch; 10% S- Mince with 10% starch
Data are expressed as the mean±SD (n=3). Different superscripts in the same row signify statistical difference ($p < 0.05$)

Table 3. Instrumental colour parameters of mince-starch gels

Parameters	Treatment					
	Control	2% S	4% S	6% S	8% S	10% S
Whiteness	62.67±0.95 ^c	63.16±0.76 ^c	62.23±0.24 ^c	61.20±0.33 ^b	60.16±0.82 ^a	59.41±0.92 ^a
L*	64.57±1.03 ^c	65.08±0.70 ^c	64.06±0.22 ^c	62.74±0.36 ^b	61.77±0.94 ^{ab}	61.11±0.92 ^a
a*	1.82±0.22 ^c	1.15±0.18 ^a	1.29±0.13 ^{ab}	1.91±0.19 ^c	1.41±0.19 ^{ab}	1.54±0.23 ^b
b*	11.57±0.73 ^b	11.67±0.39 ^b	11.53±0.49 ^b	10.64±0.50 ^a	11.09±0.57 ^{ab}	11.50±0.33 ^b
Chroma	11.71±0.74 ^b	11.74±0.40 ^b	11.60±0.49 ^b	10.81±0.5 ^a	11.19±0.58 ^{ab}	11.61±0.33 ^b

Control (C) - Mince without starch; 2% S - Mince with 2% starch; 4% S - Mince with 4% starch; 8% S-Mince with 8% starch; 10% S- Mince with 10% starch

Data are expressed as mean±SD (n=3). Different superscripts in the same row signify statistical difference (p<0.05)

surimi sausages containing 7% potato starch. Yang and Park (1998) observed that higher water content revealed lighter (higher L^* values) surimi gel. However, increased starch level of swollen granule showed lower L^* values demonstrating translucent gel and we observed that the properties and concentration of starch and its gelatinisation/swelling capacity affects the lightness of surimi-starch gels.

Except at 6% starch level, a^* value decreased with increasing concentration of starch than that of control sample. Since fish mince was used in the present investigation, it also retained sarcoplasmic proteins containing haeme proteins responsible for giving red colour. The probable reason for decrease in a^* could be attributed to low moisture content in the gel and masking effect of white coloured flour. The b^* (yellowness) values in gel samples with different starch concentrations were also decreased. Yellowness was reported to affect the level of inclusion of starch (p<0.05) (Amiza and Ng, 2015). The colour value of b^* with corn starch generally increased at 70°C, as the concentration of corn starch increased in surimi (Yang and Park, 1998). However, un-swollen corn starch granules affected b^* values of surimi corn starch gels cooked at 90°C due to different gelatinisation property of corn starch between 70 and 90°C.

SEM images of mince-starch gels

The form, shape, physico-chemical characteristics of a product has a substantial effect on consumer perception. Therefore, use of appropriate techniques to study particle properties of a product is very important (Burey *et al.*, 2009). The microstructure of surface layers of control and mince-starch gel samples at x25,000 magnification are presented in Fig. 3.

The control sample without starch displayed high density protein aggregation due to salt along with variable voids. The structure did not show any homogenous gel matrix. The starch incorporated mince gels showed numerous fragmented aggregates with visible crevices. The microstructure of 2, 4 and 6% corn starch added gel samples exhibited thin densities of dispersed phase, while higher densities of dispersion could be seen in 8% corn starch added samples. The excess incorporation of corn starch was observed in 10% samples as larger aggregates with crevices. The microstructure of all samples showed whitish precipitate of sarcoplasmic proteins. These structural changes might be associated with heat treatment, which at 40°C might be insufficient to denature the protein in the system and the gelatinisation temperature may also affect the interaction between proteins and starch. The aggregated material was observed in protein gel without starch heated at 90°C for 40 min than that

pre-incubated at 40°C for 30 min and heated at 90°C for 40 min (Kim *et al.*, 1987). At the cooking temperature, the amylopectin is assumed to remain in the gelatinised form. In starch-fish protein system, the gelatinisation of starch is limited due to availability of less amount of water since starch and protein compete for water during cooking. Whereas, starch granules in starch-water system cooked at 90°C for 40 min lost their shape completely, fused and adhered to one another (Kim *et al.*, 1987). The type of starch and its presence apparently affect the gel strength. No fat globules were recorded in the structure due to low amount of fat in gels. This is in consensus with the low-fat content in fish. Starch existed as dispersed liquid phase in protein gels and showed improvement in gel strength through formation of two interpenetrating network (Fan *et al.*, 2017).

Sensory quality of mince-starch gels

Fig. 4 shows sensory scores of appearance, colour, odour, taste, flavour, texture and overall acceptability for control and 2-10% starch containing sausage, on a 9-point hedonic scale. Higher sensory score was noted for control gel than mince-starch gels (Fig. 4). This may be attributed to sensitivity of palatability to fish mince. In the present study, significant differences (p<0.05) were noticed for appearance, colour, odour and overall acceptability which might be attributed to starch concentration. Among starch incorporated mince gels, higher overall acceptability, appearance, odour and texture was reported for 2% mince-starch gels, while higher colour, taste and flavour were noticed in the mince gels containing starch up to 4, 6 and 10% respectively. A significant difference was not reported for taste, flavour and texture of mince-starch gels under study. No definite pattern of overall liking towards various sensory characters was observed. Similar observations were also made by Yoo (2011) for restructured sand lance meat paste product (SLMPP) prepared using different concentrations of potato starch. In a study of Prabpree and Pongsawatmanit (2011), the higher starch containing fish sausages received lower overall acceptability. Based on the sensory and instrumental evaluation, 8% starch was the most commonly preferred material in fish sausage with desirable texture (Rahman *et al.*, 2007) and overall acceptability of the product could be enhanced with the addition of spices. In general, sensory evaluation of mince-starch gels gave overall acceptability score between 7.20 to 7.90, which denotes 'moderately like to like' rating on 9-point hedonic scale. This may be due to the fact that panelists were not very familiar with gels made from minced meat.

The present study demonstrated that mince of freshwater fish added with corn starch as an additive could be used for

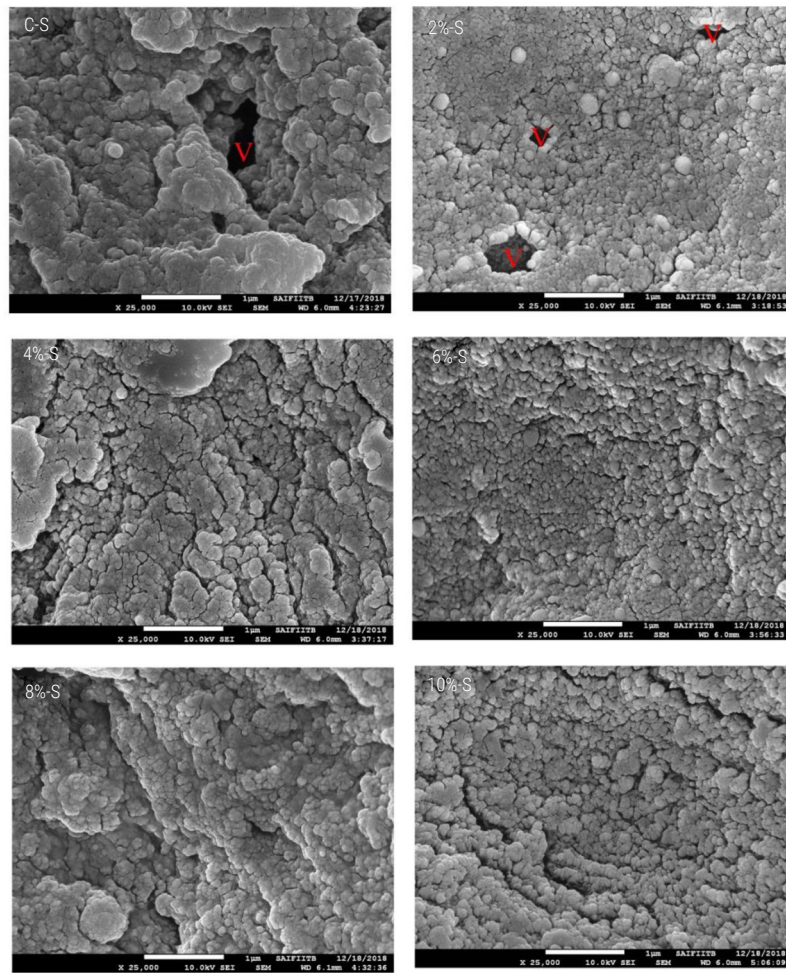


Fig. 3. SEM images of mince-starch gels. C-S – Control mince without starch; 2% S- Mince with 2% starch; 4% S- Mince with 4% starch; 6% S- Mince with 6% starch; 8% S- Mince with 8% starch; 10% S- Mince with 10% starch; V-voids

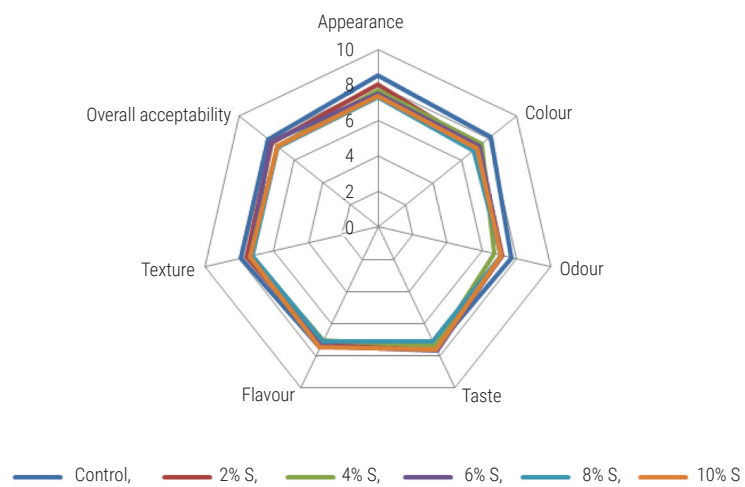


Fig. 4. Sensory score of starch treated sausage

manufacturing mince-based products such as sausage with good rheological properties. Overall, study indicated that incorporation of 8% corn starch in mince is sufficient to develop products like sausages from mince of freshwater fish at low cost of production. Further studies should include the addition of suitable spices to develop mince-based fish products such as sausages from freshwater fish to cater to specific consumer preferences. Research on the shelf-life stability of these products under refrigerated and frozen storage conditions also needs to be undertaken.

Acknowledgements

The authors wish to thank the Director, ICAR-CIFE, Mumbai for support to carry out this work. Analytical services provided by the SAIF, IIT, Bombay is also gratefully acknowledged.

References

- Amiza, M. A. and Ng, S. C. 2015. Effects of surimi-to-silver catfish ratio and potato starch concentration on the properties of fish sausage. *J. Aquat. Food Prod. Technol.*, 24(3): 213-226. <https://doi.org/10.1080/10498850.2013.766293>.
- AOAC 2005. *Official methods for analysis of the AOAC International*, 18th edn. Association of Official Analytical Chemists, Washington DC, USA.
- Benjakul, S., Visessanguan, W., Thongkaew, C. and Tanaka, M. 2003. Comparative study on physicochemical changes of muscle proteins from some tropical fish during frozen storage. *Food Res. Int.*, 36(8): 787-795. [https://doi.org/10.1016/S0963-9969\(03\)00073-5](https://doi.org/10.1016/S0963-9969(03)00073-5).
- Burey, P., Bhandari, B. R., Rutgers, R. P. G., Halley, P. J. and Torley, P. J. 2009. Confectionery gels: A review on formulation, rheological and structural aspects. *Int. J. Food Prop.*, 12(1): 176-210. <https://doi.org/10.1080/10942910802223404>.
- Chen, H. H. and Huang, Y. C. 2008. Rheological properties of HPMC enhanced surimi analyzed by small-and large-strain tests-II: Effect of water content and ingredients. *Food Hydrocoll.*, 22(2): 313-322. <https://doi.org/10.1016/j.foodhyd.2006.12.006>.
- Chung, K. H. and Lee, C. M. 1991. Water binding and ingredient dispersion pattern effects on surimi gel texture. *J. Food Sci.*, 56(5): 1263-1266. <https://doi.org/10.1111/j.1365-2621.1991.tb04748.x>.
- Dhital, S., Shrestha, A. K., Hasjim, J. and Gidley, M. J. 2011. Physicochemical and structural properties of maize and potato starches as a function of granule size. *J. Agri. Food Chem.*, 59(18): 10151-10161. <https://doi.org/10.1021/jf202293s>.
- Dincer, M. T. and Cakli, S. 2015. Textural acceptability of prepared fish sausages by controlling textural indicators. *Turkish J. Vet. Anim. Sci.*, 39(3): 364-368. <https://doi.org/10.3906/vet-1307-38>.
- Dincer, T. and Cakli, S. 2010. Textural and sensory properties of fish sausage from rainbow trout. *J. Aquat. Food Prod. Technol.*, 19(3-4): 238-248. <https://doi.org/10.1080/10498850.2010.509539>.
- Dongyu, Q. and Kaiyun, X. 2008. *How the Chinese eat potatoes*. World Scientific Publishing, Singapore, 432 p.
- Elyasi, A., Zakipour Rahim Abadi, E., Sahari, M. A. and Zare, P. 2010. Chemical and microbial changes of fish fingers made from mince and surimi of common carp (*Cyprinus carpio* L., 1758). *Int. Food Res. J.*, 17(4): 915-920.
- Fan, M., Hu, T., Zhao, S., Xiong, S., Xie, J. and Huang, Q. 2017. Gel characteristics and microstructure of fish myofibrillar protein/cassava starch composites. *Food Chem.*, 218: 221-230. <https://doi.org/10.1016/j.foodchem.2016.09.068>.
- Fogaça, F. H., Sant'Ana, L. S., Lara, J. A. F., Mai, A. C. G. and Carneiro, D. J. 2014. Restructured products from tilapia industry byproducts: The effects of tapioca starch and washing cycles. *Food Bioprod. Proc.*, 94: 482-488. <https://doi.org/10.1016/j.fbp.2014.07.003>.
- Hunt, A., Getty, K. J. K. and Park, J. W. 2009. Roles of starch in surimi seafood: A review. *Food Rev. Int.*, 25(4): 299-312. <https://doi.org/10.1080/87559120903155834>.
- Jamilah, B., Mohamed, A., Abbas, K. A., Rahman, R. A., Karim, R. and Hashim, D. M. 2009. Protein-starch interaction and their effect on thermal and rheological characteristics of a food system: A review. *J. Food Agric. Environ.*, 7: 169-174.
- Kaletunc, G. and Breslauer, K. J. 2003. *Characterization of cereals and flours: Properties, analysis and applications*. Marcel Dekker, New York, USA, 556 p.
- Kasapis, S. 2009. Developing minced fish products of improved eating quality: An interplay of instrumental and sensory texture. *Int. J. Food Prop.*, 12(1): 11-26. <https://doi.org/10.1080/10942910802252171>.
- Kilincceker, O. 2018. Effects of different starches on some of the frying and storage properties of meat patties. *Adv. Food Sci.*, 40(1): 35-41.
- Kim, J. M., Lee, C. M. and Hufnagel, L. A. 1987. Textural properties and structure of starch-reinforced surimi gels as affected by heat-setting. *Food Struct.*, 6(1): 81-89. <https://doi.org/10.1111/j.1365-2621.1987.tb06711.x>.
- Lanier, T. C. 1992. Measurement of surimi composition and functional properties. In: Lanier, T. C. and Lee, C. M. (Eds.), *Surimi technology*, Marcel Dekker Inc., New York, USA, pp. 123-163.
- Lee, C. M. 1984. Surimi process technology. *Food Technol.*, 38(11): 69-80.
- Lee, C. M., Wu, M. C. and Okada, M. 1992. Ingredient and formulation technology for surimi-based products. In: Lanier, T. C. and Lee, C. M. (Eds.), *Surimi technology*. Marcel Dekker Inc., New York, USA, pp. 273-302.
- Mailgaad, M., Cville, G. V. and Carr, B. T. 1999. *Sensory evaluation techniques*. CRS Press, Boca Raton, Florida, USA, 416 p.
- Maqsood, S., Benjakul, S. and Balange, A. K. 2012. Effect of tannic acid and kiam wood extract on lipid oxidation and textural properties of fish emulsion sausages during refrigerated storage. *Food Chem.*, 130(2): 408-416. <https://doi.org/10.1016/j.foodchem.2011.07.065>.
- Park, J. W. 1994. Functional protein additives in surimi gels. *J. Food Sci.*, 59(3): 525-527. <https://doi.org/10.1111/j.1365-2621.1994.tb05554.x>.
- Pietrasik, Z. 1999. Effect of content of protein, fat and modified starch on binding textural characteristics and colour of comminuted scalded sausages. *Meat Sci.*, 51(1): 17-25. [https://doi.org/10.1016/S0309-1740\(98\)00068-0](https://doi.org/10.1016/S0309-1740(98)00068-0).
- Prabpree, R. and Pongsawatmanit, R. 2011. Effect of tapioca starch concentration on quality and freeze-thaw stability of fish sausage. *Agric. Nat. Resour.*, 45(2): 314-324.
- Rahman, M. S., Al-Waili, H., Guizani, N. and Kasapis, S. 2007. Instrumental-sensory evaluation of texture for fish sausage and its storage stability. *Fish. Sci.*, 73(5): 1166-1176.
- Ramírez, J. A., Uresti, R. M., Velazquez, G. and Vazquez, M. 2011. Food hydrocolloids as additives to improve the mechanical and functional properties of fish products: A review. *Food Hydrocoll.*, 25(8): 1842-1852.
- Sandhu, K. S. and Singh, N. 2007. Some properties of corn starches II: Physicochemical, gelatinization, retrogradation, pasting and gel textural properties. *Food Chem.*, 101(4): 1499-1507. <https://doi.org/10.1016/j.foodchem.2006.01.060>.

- Sankar, T. V. and Ramachandran, A. 2002. Rheological characteristics of suwari and kamaboko gels made of surimi from Indian major carps. *J. Sci. Food Agric.*, 82(9): 1021-1027. <https://doi.org/10.1016/j.foodchem.2006.01.060>.
- Sankar, T. V. and Ramachandran, A. 2005. Thermal stability of myofibrillar protein from Indian major carps. *J. Sci. Food Agric.*, 85(4): 563-568.
- Sasaki, T. and Matsuki, J. 1998. Effect of wheat starch structure on swelling power. *Cereal Chem.*, (4): 525-529. <https://doi.org/10.1094/CCHEM.1998.75.4.525>.
- Somjid, P., Panpipat, W., Cheong, L. Z. and Chaijan, M. 2021. Reduced washing cycle for sustainable mackerel (*Rastrelliger kanagurta*) surimi production: Evaluation of bio-physico-chemical, rheological and gel-forming properties. *Foods*, 10(11): 2717. <https://doi.org/10.3390/foods10112717>.
- Tokur, B., Ozkütük, S., Atici, E., Ozyurt, G. and Ozyurt, C. E. 2006. Chemical and sensory quality changes of fish fingers, made from mirror carp (*Cyprinus carpio* L., 1758) during frozen storage (-18°C). *Food Chem.*, 99(2): 335-341. <https://doi.org/10.1016/j.foodchem.2005.07.044>.
- Verbeken, D., Neirinck, N., Van Der Meeren, P. and Dewettinck, K. 2005. Influence of κ -carrageenan on the thermal gelation of salt-soluble meat proteins. *Meat Sci.*, 70(1): 161-166. <https://doi.org/10.1016/j.meatsci.2004.12.007>.
- Wu, M. C., Hamann, D. D. and Lanier, T. C. 1985. Rheological and calorimetric investigations of starch-fish protein systems during thermal processing. *J. Texture Stud.*, 16(1): 53-74. <https://doi.org/10.1111/j.1745-4603.1985.tb00679.x>.
- Yang, H. and Park, J. W. 1998. Effects of starch properties and thermal-processing conditions on surimi-starch gels. *LWT-Food Sci. Technol.*, 31(4): 344-353. <https://doi.org/10.1006/fstl.1997.0366>.
- Yinghong, Q., Yokoyama, M., Hayakawa, F. and Saito, M. 2003. Effect of food additives on texture and smell of silver carp (*Hypophthalmichthys molitrix*) mince. *Food Sci. Tech. Res.*, 9(2): 176-179. <https://doi.org/10.3136/fstr.9.176>.
- Yoo, B. J. 2011. The effects of alkaline treatment and potato-starch content on the quality of fish meat paste products prepared from Pacific sand lance *Ammodytes personatus* Girard. *Fish. Aquat. Sci.*, 14(3): 161-167. <https://doi.org/10.5657/FAS.2011.0161>.
- Zhang, F., Fang, L., Wang, C., Shi, L., Chang, T., Yang, H. and Cui, M. 2013. Effects of starches on the textural, rheological, and colour properties of surimi-beef gels with microbial transglutaminase. *Meat Sci.*, 93(3): 533-537. <https://doi.org/10.1016/j.meatsci.2012.11.013>.