

Textural and functional properties of surimi from striped catfish Pangasianodon hypophthalmus (Sauvage, 1878) as affected by natural spice extracts

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ABSTRACT

Effects of aqueous extract of natural spices such as garlic, clove and cinnamon on the textural and functional properties of surimi gel from Striped Catfish, *Pangasianodon hypophthalmus* (Sauvage, 1878) was studied and a positive effect was observed. Different levels of extract (0.5, 1.0, 1.5 and 2.0%, w/w) were used. Protein solubility significantly (p<0.05) changed in treated gels and major change was found in clove and cinnamon incorporated gels. Water holding capacity of the treated gels were found to be higher compared to control and higher values were observed in respect of treatments with cinnamon and clove than that of garlic. Gel strength of treated samples increased significantly (p<0.05) from the control and maximum was found with clove extract at 0.5% level. Whiteness of gel slightly reduced in treated samples. All the texture profiles differed from the control with maximum hardness in clove extract incorporated gels followed by garlic and cinnamon treated ones.

Keywords: Cinnamon, Clove, Functional properties, Garlic, Pangasius, Surimi, Texture profile analysis

Introduction

Surimi, a wet concentrate of high quality myofibrillar proteins, is obtained by washing minced fish meat with cold water several times to remove water soluble and odour bearing compounds comprising enzymes, sarcoplasmic proteins, blood, inorganic salt and certain lipids and other undesirable materials like pigments that enhances the gel forming ability of the washed proteins (Venugopal, 2006) which otherwise would interfere with the storage and rheological characteristics of the product (Lee and Park, 1998). For surimi products, the technique mostly used for obtaining a good gel depends on solubilising and extracting myofibrillar proteins with 2 to 3 g of salt per 100 g meat. The solubilised expanding proteins form a continuous matrix and then undergo thermal aggregation, cross linking and develop into fine three dimensional solid like networks resulting in an elastic gel. The cross linking of myosin is promoted by a calcium dependent endogenous transglutaminase (TGase) contained in fish muscle, which catalyses an acyl transfer reaction between γ-carboxyamide groups of glutaminyl residues in proteins (Nio et al., 1986). To enhance the gel strength of surimi or fish mince, various food grade ingredients and cross linking enzymes such as microbial transglutaminase have been used (Benjakul et al., 2004). Due to adverse effects of some ingredients on the surimi gel, particularly on its flavour or colour, the need of natural additives having ability of protein cross linking has been given increasing attention by the surimi industry.

Polyphenols are natural compounds which are abundant in plants. The interactions between phenolic compounds and proteins play a very important role in the processing of certain food products. In an alkaline solution, phenols may be oxidised easily to their corresponding quinones which can readily undergo attack by nucleophiles such as lysine, methionine, cysteine and tryptophan residues in a protein chain (Hurrell and Finot, 1984). The formation of rigid molecular structures by reactions of ortho quinones with proteins has been demonstrated by Strauss and Gibson (2004). Interactions of different phenolic acids and flavonoids with soy proteins were reported by Rawel *et al.* (2002). Significant increase in the gel strength of bigeye snapper surimi was observed when oxidised phenolic compounds were added (Balange and Benjakul, 2009).

Surimi making ability of many freshwater fish species is relatively lower than that of their marine counterparts, but could be upgraded by manipulating the processing techniques. Striped Catfish *Pangasianodon hypophthalmus* (Sauvage, 1878) is extensively cultured in India and Bangladesh. This fish has good aquaculture potential due to its very high growth rate compared to popular major carps. The abundant catch of Striped Catfish in peak season could be utilised as an

alternative source of surimi raw material for development of restructured products. Important bioactive phenolics present in spices used in this study include allicin in garlic, eugenol in clove and cinnamaldehyde in cinnamon. This study aims to determine the effects of aqueous extract of natural spices such as garlic (*Allium sativum*), clove (*Syzygium aromaticum*) and cinnamon (*Cinnamomum aromaticum*) on textural and functional properties of gel from Striped Catfish surimi.

Materials and methods

Preparation of aqueous extract of spices

To prepare aqueous extract of garlic, they were peeled, cut into pieces and dried in hot air oven at 40±2°C. Clove and cinnamon were also dried overnight in hot air oven at 40±2°C. Dried garlic, clove and cinnamon were ground using an electric blender. Twenty grams of the ground material was soaked in 100 ml of hot sterile water and allowed to stand for 48 h. The crude extracts were separated by filtration. The process was repeated twice and all the concentrated filtrates were collected and subjected to evaporation at 50°C in rotary vacuum evaporator (OSAKA J.P. Selecta, Spain). The concentrated aqueous extract was collected from the flash evaporator, dried at 40±2°C in a mechanical dryer. The particulate aqueous extract was ground in an electric mixer followed by sieving with a fine meshed sieve and the powdered aqueous extract of spices were kept in aluminium pouch and stored at -20°C for future use.

Preparation of surimi

Fresh Striped Catfish for the study was collected from local fish farm at Lembucherra, Tripura. Length and weight of fish ranged from 37 - 49 cm and 636 - 809 g respectively. Fishes were washed in chilled water, gutted, dressed, filleted by hand and minced using a mechanical meat mincer with a 3 mm-hole plate. Washing of the minced meat was performed in wash tanks maintaining a water temperature of 10°C, using a fish mince to water ratio of 1:4 (w/v), for three times with 10 min duration for each wash (twice with potable water and last one with 0.1% NaCl solution to facilitate dewatering). The slurry was stirred for 3 mins and allowed to settle for 2 min before water was decanted. Final dewatering was carried out using a screw press (Deb Enterprise, India). Sorbitol (4 g), sucrose (4 g) and polyphosphate (0.3 g) were added to 100 g of dewatered mince as cryoprotective agents and then mixed for 5 mins in a silent cutter (Sunlabz, India) at temperature below 10°C. The washed mince (surimi) was packed in low density polyethylene (LDPE) pouches (150 g per pouch) and quickly frozen at -35°C for 2 h in air blast freezer (Sanyo, Japan) and stored at -20°C in a deep freezer (Vest Frost, Denmark) for development of surimi gel within a week.

Preparation of surimi gel

Frozen surimi was tempered for about 2 h at 20±2°C until it reached 5 ± 1 °C, followed by chopping for 1 min at high speed in a silent cutter. Moisture of surimi was adjusted to 80% by adding ice water. Salt (NaCl) was added @ 2.5% and mixed in silent cutter for 5 mins. Aqueous extract of natural spices were added to each 150 g part @ 0.5, 1.0, 1.5 and 2.0%, w/w. Throughout the mixing operation, temperature of surimi was kept below 10°C. The control (CON) was made without addition of spice extract. Surimi paste was then stuffed into vinylidene chloride casing (10 cm length, 2.0 cm dia). Thermal setting was done according to the two step heating method suggested by Luo et al. (2008). The casings were immersed in water at 40°C for 30 min followed by immersion in water at 85°C for 30 mins. After cooking, the casings were immediately removed, placed in iced water and cooled at 4 - 5°C for 30 mins. The gels were then stored overnight at 4°C in a refrigerator.

Proximate composition and pH

Moisture, ash, protein and fat content of *Pangasius* surimi were determined according to AOAC (2000). For determination of pH, 10 g of sample was homogenised with 50 ml distilled water and pH value was measured by a digital pH meter (Sartorius, USA).

Determination of protein solubility

Gel (0.5 g) was homogenised in 10 ml of 0.6 M KCl in 50 mM tris-HCl buffer (pH 7.4) for 1 min in a tissue homogeniser (IKA, Germany). The homogenate was centrifuged at 10,000 rpm for 10 min at 4°C (Remi, India). The supernatant was diluted ten-fold with 0.6 M KCl and protein determination was carried out following Biuret method (Gornall *et al.*, 1949). Analyses were performed in triplicate and the solubility was expressed in mg of soluble protein per 100 mg of gel.

Water holding capacity (WHC) was evaluated as per Barrera *et al.* (2002). A portion of 5 g of each gel was weighed and placed on 5 layers of filter paper (Whatman No. 1). Samples in filter papers were placed in 50 ml centrifuge tubes and centrifuged at 5000 g at 4°C for 15 min (REMI, India). After centrifugation, the gels were immediately removed and re-weighed. WHC was expressed as the weight of the centrifuged gels relative to the original weight of samples.

WHC (%) =
$$(W2 / W1) \times 100$$

where, W1 represents the weight of the gel before centrifugation and W2 represents the weight of gel after centrifugation.

Determination of whiteness

Colour of gels was determined in triplicate using spectrocolourimeter (Colourflex EZ, Hunter Associates

Laboratory, Inc, Reston, VA). This instrument was calibrated with black and white reference tiles before analysis. A horizontal section of gel measuring approx. 5 mm was placed above the light sources and post processing, the L* (lightness), a* (redness/greenness) and b* (yellowness/blueness) values were recorded. The CIELAB (L*, a*, b*) colour scale was used for the study. Whiteness was calculated as described by Yin *et al.* (2002) as follows:

Whiteness = $100 - \{(100 - L^*) + a^{*2} + b^{*2}\}^{\frac{1}{2}}$

Analysis of gel strength (GS) and texture profile (TPA)

Heat induced gels were cut into 3 cm high cylindrical slices. Puncture tests were carried out using a 5.0 mm dia spherical head stainless steel plunger attached to a 50 N cell connected to the crosshead of a TA-XT2 Stable Micro Systems Texturometer (Surrey, England, UK). Breaking force (g), breaking deformation (cm) and work of penetration, *i.e.*, gel strength (g.cm) were determined from force deformation curves obtained at a crosshead speed of 0.2 mm sec⁻¹. Each measurement was replicated 3 times.

Texture profiles of gels were determined using a TA-XT2 Stable Micro Systems Texturometer (Surrey, England, UK). Restructured fish products (surimi gel) were removed from the casings and equilibrated to room temperature for 30 mins in a plastic bag to avoid dehydration before the mechanical properties were measured. Textural profile analysis (TPA) was performed using an aluminium cylindrical probe (P/50) with 50 mm dia. Samples were compressed to 60% of the initial height using a compression speed of 60 mm min⁻¹. Hardness, cohesiveness, adhesiveness, springiness and gumminess were reported for each treatment. Six samples were analysed for each treatment at room temperature (25 - 27°C).

Sensory evaluation

Sensory evaluation was performed by a panel of 6 judges. The panel evaluated each treatment within each replication in triplicates. For sensory evaluation, the gels were conditioned to room temperature and served to the judges in white melamine dishes as 2 - 2.5 cm thickness slices. The panel judges were trained on the attributes of the restructured fish products such as aroma, flavour, meat colour, juiciness, tenderness and taste. Based on those attributes they were instructed to evaluate overall acceptability using ten point Hedonic Scale (like extremely - 9, like very much - 8, like moderately - 7, like slightly - 6, neither like nor dislike - 5, dislike slightly - 4, dislike very much - 3, dislike moderately - 2, dislike slightly - 1) as per Majumdar *et al.* (2015). A score below 6 was considered as rejected.

Statistical analysis

The data obtained were analysed using analysis of variance (ANOVA) and when significant differences

were found, comparisons among means were carried out by Duncan's multiple comparison test (p<0.05) using SPSS (version 11.0 for windows).

Results and discussion

Proximate analyses of fish muscle and surimi

Important biochemical constituents of the raw material (P. hypophthalmus meat) were: moisture ($74.04 \pm 0.25\%$), protein ($16.39\pm0.34\%$), fat ($7.57\pm0.14\%$) and ash ($1.09\pm0.02\%$). The proximate analysis indicated that the fish has low moisture, high protein and moderate fat content. Lower moisture and slightly higher lipid content in pangas muscle was also reported by Hossain *et al.* (2004). Proximate composition of fish species is influenced by various factors such as nutrition, fish size, sex, habitat, season and other environmental conditions. Surimi prepared from P. hypophthalmus meat had moisture content of $79.57\pm0.18\%$, protein $14.68\pm0.27\%$, fat $1.33\pm0.04\%$ and ash $3.36\pm0.14\%$.

Functional properties of surimi gel

pH: pH reduced significantly (p<0.05) in all the spice extract treated surimi gels, except in the gel treated with cinnamon extract (Table 1). In case of garlic and clove extracts treated gels, pH was found to decrease with increase in concentration of aqueous extract. Maximum reduction in pH compared to control was found in case of garlic followed by clove extract treated gels. Such decrease in pH following addition of garlic and clove extracts may be attributed to their richness in organo-sulphur compounds.

Protein solubility: Native myofibrillar proteins are normally soluble in high ionic strength buffer. While heating, proteins undergo denaturation and aggregation to form a three dimensional structure (Stone and Stanley, 1992). Alteration of protein extractability is a useful factor which may be used to determine the textural quality of fish muscle, as protein aggregation is accompanied by a significant decrease in their solubility (Badii and Howell, 2002). Protein solubility of control was found to be $82.59 \pm 0.65\%$ (Table 1). But protein solubility changed significantly (p<0.05) in treated gels, in which major change was found in clove and cinnamon extract incorporated gels. Protein solubility was found to decrease with the increase in concentration of spice extracts. The decrease in solubility suggests the formation of protein aggregates during gelation process. Formation of disulphide bond which results in the aggregation of proteins (Lim and Haard, 1984) might have contributed to low solubility of proteins. Hydrogen bonds might involve in the interactions between hydroxyl groups of phenolic compounds and the nitrogen or oxygen of amino acids. Decreased solubility of protiens indicates aggregation as well as denaturation of proteins caused by thermal setting.

Table 1. Functional properties and acceptability of natural spice extract incorporated surimi gel from Striped Catfish**

	Control	Garlic				Clove				Cinnamon			
		0.5%	1.0%	1.5%	2.0%	0.5%	1.0%	1.5%	2.0%	0.5%	1.0%	1.5%	2.0%
рН	7.81a	7.63 ^b	7.59b	7.51°	7.33 ^d	7.64 ^b	7.62 ^b	7.51°	7.39 ^d	7.82ª	7.82ª	7.81a	7.79a
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.02)	0.03)	(0.01)
PS (%)	82.59a	82.7a	81.5a	80.8^{ab}	80.1ab	81.1ab	79.07^{b}	79.78^{b}	78.56 ^c	80.36^{ab}	80.08^{ab}	80.92a	78.47°
	(0.65)	(0.66)	(0.43)	(0.88)	(0.29)	(0.32)	(0.62)	(0.42)	(0.19)	(0.37)	(0.53)	(0.18)	(0.24)
WHC (%)	71.8 ^d	73.8°	85.4bc	87.6^{ab}	89.2a	90. 8a	89.9^{a}	88.4^{ab}	87.7 ^b	87.5 ^b	90.1a	88.9^{ab}	89.2ª
	(0.49)	(1.66)	(0.79)	(0.43)	(1.61)	(0.27)	(0.67)	(0.47)	(0.44)	(0.23)	(0.52)	(0.28)	(0.66)
Whiteness	86.50a	85.34a	85.18a	84.58ab	84.49ab	85.41a	83.33ab	81.21 ^b	79.87°	86.25a	85.43ab	83.81 ^b	81.94 ^b
	(1.03)	(0.16)	(0.14)	(0.26)	(0.23)	(0.27)	(0.35)	(0.48)	(0.43)	(0.41)	(0.75)	(0.48)	(1.02)
Acceptability	8.40 ^a (0.32)	8.8 ^b (0.42)	9.6 ^d (0.52)	9.0 ^{bc} (0.32)	9.2 ^{bc} (0.48)	8.6 ^{ab} (0.22)	8.6 ^{ab} (0.32)	9.0 ^{bc} (0.22)	8.4 ^a (0.18)	8.4 ^{ab} (0.44)	8.6 ^b (0.32)	8.8 ^b (0.42)	9.0 ^{bc} (0.18)

[#] Values bearing different superscripts in the same row denote significant differences (p<0.05)

Water holding capacity: Indices such as water holding capacity, is often used to assess the textural quality of surimi gel. Water holding capacity (WHC) increased significantly (p<0.05) in garlic treated surimi gel and was also found to increase with increasing concentration of the extract (Table 1). In clove aqueous extract treated gel, higher WHC (90.8%) was found when concentration was 0.5% and decreased significantly (p<0.05) with increase of clove extract. This may be attributed to the self-aggregation of phenolic compounds of clove, leading to loss in protein cross linking capacity (De Freitas and Mateus, 2001) which further lead to reduced water binding capacity of protein. Whereas, in cinnamon treated gels, WHC increased significantly (p<0.05) than the control, and maximum value was found when concentration of extract was 1.0% (90.1%). The results suggest that formation of stronger protein-protein network induced by phenolic compounds of the spices might imbibe more water.

Whiteness: Whiteness of gel slightly reduced in treated samples and maximum reduction was observed in clove

treated samples (Table 1). These results are in agreement with O'Connell and Fox (2001) who reported that phenolic compounds were responsible for darkening in cheese products. Moreover, rate of decrease of whiteness in each treatment was in the order of increase of concentration of aqueous extract in gel. Tesoriere *et al.* (2007) reported that the phenolic extracts from capers effectively prevented the activation of myoglobin to its hypervalent state, ferryl myoglobin indicating a potential interaction between some phenolic compounds and heme protein redox reactions. In addition, the natural pigments of extracts may also be responsible for reduction in whiteness.

Textural characteristics

Gel strength: Gel strength (GS) of treated samples increased significantly (p<0.05) as compared to control CON (Table 2). In garlic extract treated gels, maximum GS was found at 1% concentration, whereas, in clove treated gels same was obtained at 0.5 % level and the GS was found to decrease with increase in concentration of extract. The rate of increase of gel strength in cinnamon treated gels were

Table 2. Textural properties of natural spice extract incorporated surimi gel from Striped Catfish*#

	Control	Garlic				Clove				Cinnamon			
		0.5%	1.0%	1.5%	2.0%	0.5%	1.0%	1.5%	2.0%	0.5%	1.0%	1.5%	2.0%
GS	188.8 ^f (21.02)	238.5 ^{ed} 51.6)	265.7° (11.9)	253.4° (42.1)	222.7 ^d (13.5)	311.9 ^a (41.0)	291.1 ^b (32.1)	245.9° (3.7)	221.2 ^d (5.4)	203.89° (25.9)	246.8 ^{cd} (34.3)	224.2 ^d (24.8)	234.1 ^{cd} (14.3)
HRD	1211.5 ^{ab} (48.17)	834.5 ^d (42.5)	920.0° (17.02)	775.8 ^{de} (13.1)	955.1° (26.5)	1146.4 ^{ab} (26.48)	1166.8ab (34.08)	1292.3 ^b (35.94)	1454.5 ^a (46.66)	773.81 ^{de} (53.7)	962.68° (28.7)	933.78° (28.73)	977.72° (7.72)
СОН	0.768 ^a (0.01)	0.867 ^b (0.02)	0.881 ^{bc} (0.03)	0.874 ^{bc} (0.04)	0.886 ^{bc} (0.02)	0.858 ^b (0.01)	0.858 ^b (0.01)	0.836 ^b (0.01)	0.813 ^b (0.01)	0.838 ^b (0.04)	0.852 ^b (0.01)	0.841 ^b (0.01)	0.837 ^b (0.04)
ADH	-3.53° (0.41)	-5.2 ^a (0.1)	-5.3 ^a (0.3)	-4.5 ^b (0.6)	-4.1 ^b (0.5)	-4.35 ^b (0.07)	-2.96 ^{cd} (0.26)	-1.07° (0.56)	-1.53 ^e (1.00)	-2.75 ^{cd} (0.79)	-3.05 ^{cd} (1.43)	-3.06 ^{cd} (2.34)	-2.41 ^d (1.82)
SPR	0.918 ^a (0.03)	0.983 ^{bc} (0.01)	0.986 ^{bc} (0.02)	0.979 ^{bc} (0.01)	0.957 ^b (0.02)	0.977 ^b (0.02)	0.973 ^b (0.02)	0.966 ^b (0.01)	0.950 ^b (0.01)	0.990° (0.01)	1.28 ^d (0.56)	0.986 ^{bc} (0.04)	0.958 ^b (0.01)
GUM	955.7 ^{bc} (72.74)	735.5 ^a (61.1)	711.5 ^a (84.2)	696.7 ^a (38.3)	842.2 ^b (62.7)	982.76° (4.79)	967.57 ^{bc} (47.56)	1014.09 ^d (35.23)	1147.74 ^d (48.25)	648.51 ^a (43.92)	820.59 ^{ab} (9.78)	784.78 ^a (34.69)	818.79 ^{ab} (63.32)

^{*}GS=Gel strength (g.cm), HRD=hardness (gf), COH=cohesiveness, ADH=adhesiveness (gf), SPR=springiness (mm) and GUM = gumminess (mm)

^{*}GS = gel strength, PS= protein solubility, WHC= water holding capacity

 $^{{\}it \# Values bearing different superscripts in the same row denote significant differences (p \!\!<\!\! 0.05)}$

relatively lower than the other two treatments and maximum GS was found at 1%. Natural spices are sources of various biologically active phytomolecules, including organosulfur compounds, phenolic acids, allyl thiosulfinates, flavonoids and vitamins. Phenolic phytochemicals present in natural spices contain sufficient hydroxyls and other suitable groups (such as carboxyls) to form strong complexes with proteins and other macromolecules. Catechin, ferulic acid, syringic acid, (-) epigallocatechin gallate, gallic acid, vanillic acid, p-coumaric acid, and caffeic acid were detected in cinnamon (Lv et al., 2012). The lower gel strength at higher concentrations of spice extracts in respect of garlic and clove treated gels might be associated with self aggregation of phenolic compounds, leading to the loss in protein cross linking capacity. Lower solubility of large phenolic compounds at high concentration makes it difficult to interact with proteins (De Freitas and Mateus, 2001) and decrease its conformational flexibility, which is observed to be an important parameter in proteinphenolic compound interactions (Frazier et al., 2003).

It is also possible that the size of phenolic compounds can decrease its conformational flexibility in protein-phenolic compound interactions. Additionally, the cross links mainly contributed to the increase in gel strength of surimi added with extracts at optimal level. In this study, the optimal level of extracts for enhanced gel strength was found to be 1% in case of garlic and cinnamon and 0.5% in case of clove. Cao *et al.* (2007) reported polymerisation of protein molecules as a possible subsequent reaction of different proteins with phenolic substances.

Textural profile analysis

Textural attributes like hardness, cohesiveness, adhesiveness, springiness and gumminess are presented in Table 2. Hardness, peak force required for the first compression, decreased significantly (p<0.05) in all the treated samples. Amongst all the treated gels, clove extract incorporated gels showed maximum hardness followed by garlic and cinnamon treated ones. In clove aqueous extract treated gels, the hardness (gf) ranged from 1146.2 to 1454.5 and increased with increase in concentration of extract. In case of garlic and cinnamon treated gels, maximum hardness was found when the concentration of extract was 2%. Different levels of cross linking following the addition of spice extracts may be responsible for induction of different amount of protein aggregates and flexibility. The observed hardness of treated gels was found to increase with increase of gel strength. This also supports the observation by Ngapo et al. (1996), who reported that more interactions or cross links restrict flexibility of the protein aggregates, and the gel thus become less springy and more rigid. Adhesiveness,

the negative force area of the first compression bite, increased significantly (p<0.05) only in garlic treated groups. Cohesiveness, the extent to which the sample could be deformed before rupture which is also indicative of inter-molecular cohesion, increased in the treated gels. Gumminess was found to be higher in clove treated gels but lower in two others in comparison to control. Springiness also increased in treated gels. Such changes of texture profiles in treated gels may be explained as a result of difference in nature of protein-protein interactions induced by phenolic compounds present in the spice extracts. Moreover, the lower solubility of large phenolic compounds at high concentration causes difficulty in interaction with proteins (De Freitas and Mateus, 2001). It is also possible that the size of the phenolic compounds can decrease its conformational flexibility in protein-phenolic interactions.

Acceptability

Overall acceptability of the surimi gel as affected by different concentration of spice aqueous extract is presented in Table 1. The overall acceptability of treated samples was found to be superior compared to the control. In garlic treated gels, the overall acceptability was found to be in the order of 1.0% > 1.5% > 2.0% > 0.5%. Whereas, in clove and cinnamon treated gels it was 1.5% > 1.0% and 0.5% > 2.0% and 2.0% > 1.5% > 1.0% > 0.5% respectively. The consumers' acceptability was based on the cumulative effect of tenderness, juiciness, flavour, taste as well as colour and appearance of the product. However, the overall acceptability of garlic treated samples showed superiority over others including control.

The study revealed that addition of aqueous extract of garlic, clove and cinnamon showed a positive effect on the gelling as well as textural properties when incorporated in surimi made from *P. hypophthalmus*. Water holding capacity of treated gels increased with increase in concentration of extracts, whereas, attributes like whiteness of the gels showed a reverse trend. As observed from the results of textural parameters, increasing concentrations of aqueous extracts had negative influence on the parameters studied. Hence, as per the present study, only lower concentrations were found suitable for incorporation in surimi. Therefore, for development of sausage type of products from low-cost freshwater fish like pangasius with inherent low gelling capacity, aqueous extract of spices such as garlic, clove and cinnamon may be incorporated in surimi for enhanced consumers' acceptability. Moreover, safety of the product from lipid peroxidation as well as enrichment with phenolic antioxidants of spice extracts would also render the product as health food.

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