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Effect of ethanolic extract of potato (*Solanum tuberosum*) peel on textural and functional qualities of surimi gel from striped catfish (*Pangasianodon hypophthalmus*) (Sauvage, 1878) during refrigerated storage

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Abstract
The present research work was undertaken to examine the utilisation of potato peel, a waste material, as a source of natural antioxidants and phenolic compound for retarding lipid oxidation and protein degradation in striped catfish/pangas (*Pangasianodon hypophthalmus*) surimi gel during refrigerated storage. Potato peel ethanolic extract (PpEE) with four different concentrations (PpEE-0.5%, PpEE-1.0%, PpEE-1.5% and PpEE-2.0 %) of ethanolic extracts of potato peel and a control with no added extracts were prepared. The samples were stored at 4^0C for 20 days and the sampling was done at 4 days interval. The ethanol extracts, which contained high amounts of phenolic compounds, was found to be effective in retarding lipid oxidation, protein degradation and increase gel strength as it resulted in improving the shelf-life of pangas surimi gel. On the basis of sensory evaluation the control was acceptable only up to 12 days and PpEE-0.5% was acceptable only up to 16 days, remaining treated samples, they were acceptable up to day-20.

Keywords: Antioxidants, Lipid oxidation, Phenolic compounds, Surimi gel, Gel strength.

Introduction
Fish proteins are having high biological value as they contain all essential amino acids in the right proportion and about 85% to 95% of the protein is assimilable. Fish protein behaves as a hypocholesterolemic agent, probably because of the characteristic amino acid composition. Fish is regarded a healthier meat option due to the high content of Long Chain Polyunsaturated Fatty Acids (LCPUFAs), which are associated with improving health and preventing diseases of old age including reducing the risk of heart disease. Among the polyunsaturated fatty acids (PUFAs), arachidonic acid (AA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are the major components. However, due to the high levels of LCPUFAs, fish products are susceptible to oxidation especially during storage. Besides rancid taste and off flavour, lipid oxidation in fish-products leads to development of different substances which have adverse effects to human health. Oxidation limits storage time and thereby also affects marketing and distribution of both fish and meat products. Furthermore, peroxidative products, particularly aldehydes, can react with specific amino acids to form carbonyls (Uchida and Stadtman, 1993) [1] and protein aggregates (Buttkus, 1966) [2], causing additional nutritional losses.

The addition of antioxidants is therefore necessary to increase storage stability, sensory quality and nutritional value of fish products. At present different synthetic antimicrobials and antioxidants are used to prevent growth of pathogens and inhibit lipid autoxidation. But, present day consumers are very much health conscious and hardly accept any food preserved with chemical preservatives. Therefore, many food research scientists had recently concentrated in the area of natural antimicrobials and antioxidants. A wide variety of herbs, spices and fruits are used more and more as additives with antioxidative capacity (Brannan and Mah, 2007; Haak *et al.*, 2009) [3, 4].

The recent trend at consumer level world over is the demand of fresh food without any chemical preservative. In the recent years, a lot of research has been carried out evaluating the potential of herbs, spices as antioxidative additives in food products leading to novel combinations of antioxidants and the development of novel food products (Perumalla and Hettiarachchy, 2011) [5]. Common spices like ginger, garlic, clove, turmeric, black pepper, cinnamon etc. have been reported to have antimicrobial and antioxidant properties. Polyphenolics are one of the compounds that are found in both edible and inedible plants and herbs/spices and it could be the source of a good antioxidant agent. These can act as reducing agents, free radical scavengers and Fe^{2+}chelators or quenchers in the formation of singlet oxygen (Pizzale *et al.*, 2002; Juntachote *et al.,* 2006) [6, 7]. Thus phenolics are of increasing interest in the food industry because they retard the oxidative degradation of lipids and thereby improve the quality and nutritional value of food (Wojdylo *et al.,* 2007) [8]. The high antioxidant capacity of these plant parts is particularly due to their content of different phenols, anthocyanins and ascorbic acid, which can act as radical scavengers (Pantelidis *et al*., 2007) [9].

Potatoes (*Solanum tuberosum*) are one of the most commonly consumed vegetables throughout the world. The global consumption of potatoes as food is shifting from fresh potatoes to value added processed products such as French fries, chips and puree. Peels are the major by-product of potato processing industries, which represent a major waste disposal problem for the industry concerned. Up-grading of this by-product to value added products is therefore of interest to the potato industry. Extracts of potato peel have been shown to be a good source of dietary fibre (Toma *et al.,* 1979) [10] and rich in phenolic acids especially of chlorogenic, gallic, protocatechuic and caffeic acids (Habeebullah *et al.,* 2010) [11]. The antioxidant property of potato peel extract from some Asian varieties (*Kufri Chandramuki*) has been reported in muscle foods and in soybean oil (Zia-ur-Rehman *et al.,* 2004; Kanatt *et al.,* 2005) [12, 13]. Extracts of peels from Sava variety of potatoes were highly efficient in reducing lipid peroxidation both in fish oil and in oil-in-water emulsions (Habeebullah *et al.,* 2010) [11].

Safeguarding fats against oxidation is normally done by restricting the access of oxygen or adding antioxidants. Many synthetic preservatives, such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA) and propyl gallate (PG), are typically used to protect foods from spoilage, although their use is restricted due to possible carcinogenic effects. Their safety, however, is doubtful (Imadia *et al*., 1983) [14]. Therefore, attention is focused on natural antioxidants and there has been increasing interest in alternative additives from natural sources, which has gradually provided impetus to eliminating synthetic preservatives in food (Parke and Lewis, 1992; Shan *et al*., 2009) [15, 16]. These antioxidants are polyphenol compounds (Helle and Grete, 1995; Yen *et al*., 2003) [17, 18], which are found in all plants and in all parts of the plants (tree bark, stalks, leaves, fruits, roots, flowers, pods and seeds) (Aruoma *et al*., 1994; Kim *et al*., 1997) [19, 20].

Materials and methods

Raw material

Thai pangas was procured from the Battala fish market located at Agartala, West Tripura (Distt.), brought to the laboratory in iced condition in plastic polystyrene insulated containers within 1h and used for this study. The average length and weight of fish were 45.5±5.27 cm and 2500.3±17.60 gm respectively.

Preparation of surimi

Immediately after reaching Fish processing laboratory (Department of Fish Processing Technology and Engg, College of Fisheries, Lembucherra) the raw material fish, i.e., Pangasius was washed with ice cold potable water to remove dirt, sand and unwanted material. Immediately the fishes were gutted, dressed, filleted by hand and minced by employing a mechanical meat mincer with a perforated plate having 3 mm-dia hole. Washing of the minced meat was performed in wash tanks maintaining a water temperature of 8-10°C using a fish mince to water ratio of 1:4 (w/v) for three times with ten min duration of each wash (twice with potable water and last wash with 0.1% NaCl solution to facilitate dewatering). The slurry was stirred for 4 min and allowed to settle for 6 min before water was decanted. Final dewatering was carried out using a screw press. Sorbitol (4 g), sucrose (4 g) and polyphosphate (0.3 g) were added to 100 g of dewatered mince as cryprotective agents and then mixed for 5 min in a silent cutter. The washed mince (surimi) was packed in low density polyethylene (LDPE) pouches (500 g per pouch) and immediately frozen at -35°C for 2 h in air blast freezer and stored at -20°C in a deep freezer for preparation of surimi gel within a week.

Preparation of surimi gel

Frozen surimi was tempered for about 2h 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 using ice water. Salt (NaCl) was added @ 2.5% and mixed in silent cutter for five min. Potato peel extract were added at different concentration (0.5, 1.0, 1.5 and 2.0%, w/w) to each 500 g part and the control (CON) was made without addition of plant extract (only 2.5% NaCl).

Throughout the mixing operation temperature of surimi sol was kept below 10°C. The surimi paste was stuffed into poly vinylidene chloride (PVC) casing (10 cm length, 2.0 cm diameter). Thermal setting was done according to the two-step heating method suggested by Luo *et al.* (2008) [21]. The casings were immersed in water at 40°C for 30 min followed by immersion in water at 85°C for 30 min. After cooking, the casings were immediately removed, placed in iced water, and cooled at 4–5°C for 30 min. The gels were stored overnight at 4-5°C in a refrigerator. For storage study, the gels were stored at 4-5°C in a refrigerator for 20 days and storage changes were analysed at 4 days interval.

Preparation of ethanolic extract (EE) of potato peel

To prepare extract, potato peel were collected, washed and dried in hot air oven at temperature 40±2°C. Dried materials were ground using an electric blender. Twenty grams of the ground material was soaked in 100 ml of 90% ethanol and allowed to stand for 48 h. The crude extracts were obtained by filtration. The process was repeated twice and all the filtrates were collected and subjected to evaporation at 40°C in rotary vacuum evaporator. The extract was stored at -20°C for future use.

Analyses of moisture, ash, protein, fat content and pH

Moisture, ash, protein and fat content of Thai pangas, surimi and were determined according to AOAC (2000) [22]. For determination of the pH, 10 g of sample was homogenized

With 50 ml distilled water and pH value was measured by a digital pH-meter (Sartorius, PB-20).

Determination of total volatile base nitrogen (TVBN)
Total volatile basic nitrogen was estimated by Conway (1947) [23] method. The volatile nitrogenous substances present in the sample was distilled over and trapped by the standard H_2SO4 solution. The remaining acid can be back titrated with the standard NaOH.

Determination of thiobarbituric acid reactive substances (TBARS)
The 2-thiobarbituric acid (TBA) assay was carried out according to the procedure of Schmedes and Holmer [24] (1989). Surimi gel sample (10 g) was mixed with 25 ml of trichloroacetic acid solution (200 g/l of TCA in 135 ml/l phosphoric acid solution) and homogenized in a blender for 30 s. After filtration, 2 ml of the filtrate were added to 2 ml TBA solution (3 g/l) in a test tube. The test tubes were incubated at room temperature in the dark for 20 h; then the absorbance was measured at 532 nm by using UV–VIS spectrophotometer (Shimadzu, Japan). A standard curve was constructed using malondialdehyde (MDA), and results were expressed as mg malondialdehyde per kg of surimi gel.

Determination of protein solubility (PS) and water holding capacity (WHC)
Gel (0.5 g) were homogenised in 10 ml of 0.6 M KCl in 50 mM pH 7.4 tris–HCl buffer for 1 min in a tissue homogenizer (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 performed by Biuret method (Gornall *et al.* 1949) [25]. Analyses were performed in triplicate and the solubility was expressed in mg of soluble protein/100 mg of gel.
WHC was evaluated by the technique outlined by Barrera *et al.* (2002) [26]. A portion of 5 g of each gel was weighed and placed on 8 layers of filter paper (Whatman No. 1). Samples were placed in 50 ml centrifuge tubes and centrifuged at 5000×g at 4 °C for 15 min. immediately after centrifugation; the gels were 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 the gel after centrifugation.

Determination of whiteness
Colour of gel was determined in triplicate using spectrocolourimeter (Colourflex EZ, Hunter Associates Laboratory, Inc, Reston, VA) with illuminant of D 65/10°. This instrument was calibrated with black and white reference tile before analysis. A horizontal section of gel measuring approx. 5mm was placed above the light sources and post processing 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 Lanier *et al.* (1991) [27] as follows:

Whiteness = 100 - (100-L*) + a*2+b*2 ½

Analysis of gel strength (GS)
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 profile analysis (TPA)
Texture profiles of gel 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 30min 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 50mm diameter. Samples were compressed to 60% of the initial height using a compression speed of 60mm min^{-1}. Hardness, springiness, cohesiveness 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 triplicate, and the evaluation was performed with the samples at room temperature. The panel judges were trained on the attributes of the restructure fish products such as appearance, flavour, taste and texture. Based on those attributes they were instructed to evaluate overall acceptability using 9-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). A score below 5 was considered as rejected.

Statistical Analysis
All statistical analyses were performed using Statistical Package for Social Sciences (SPSS, version 16.0 for windows). Analysis of variance (one way - ANOVA) was performed to determine the differences between experimental periods of maturation. The tests for differences were done by using Duncan's Multiple Comparison Test. Significance of differences was defined at $p < 0.05$.

Result and discussion
Proximate analyses of fish muscle and surimi
The moisture, crude protein, total lipid and ash contents of Thai pangas was determined as 74.4±0.25, 16.9±0.34, 7.7±0.14 and 1.09±0.02 respectively. Hossain *et al.* [28] (2004) reported almost similar proximate composition of pangas as moisture- 78.6±2.14, ash- 0.78±0.06, protein- 16.5±0.88, lipid- 6.8±0.39 and NPN- 0.35±0.04. However, the composition of fish muscle depends upon various factors such as sex, size, stages of maturity and season (Sankar & Ramachandran, 2001) [29].
After washing the moisture content of mince increased from 74.4 to 79.57%. This could be explained as increased hydration of protein because of increase of water holding capacity due to removal of sarcoplasmic proteins during washing. Lin & Park (1997) [30] reported that removal of fat and water-soluble constituents, such as blood, pigments, proteins, and salts, by washing resulted in increased hydration

Of the mincemeat. Protein decreased from 16.9% in raw fish meat to 14.68% in surimi. This content decrease produced during the washing process can be easily explained by means of partial solubilization of the sarcoplasmic protein into the washing solution (Sikorski & Kolakowska, 1994) [31]. Lipid is very important, as far as surimi is concerned, because of its interference with the gel formation. The lipids in surimi products may bring about an adverse effect on the surimi quality, because the oxidized lipids interact with proteins, causing denaturation, polymerization and changes in functional properties (Smith, 1987) [32]. Pangas is considered as fatty fish (> 5% lipid) and the total lipid of the muscle was found to be 7.7% which reduced to 1.33% in surimi due to washing of mince.

Table 1: Proximate composition of raw fish and surimi*

	Raw fish	Surimi
Moisture	74.4±0.25	79.57±0.18
Protein	16.9±0.34	14.68±0.27
Lipid	7.7±0.14	1.33±0.04
Ash	1.09±0.02	3.36±0.14

* The result is mean ± SD of three determinations

Changes in functional and biochemical properties

The pH of the surimi gel in day-1 was found 7.67 in control which slightly reduced ($p<0.05$) in treated samples (7.65 to 7.66). pH showed gradual increase ($p<0.05$) in all the samples during the period of storage. On 20th day, the pH was recorded as 7.86, 7.82, 7.79 and 7.79 in treatments PpEE-0.5%, PpEE-1.0%, PpEE-1.5% and PpEE-2.0 % respectively. Whereas almost similar increase in pH was observed in treated surimi gels. Decomposition products such as volatile bases could lead to a pH rise during storage of surimi gel (Rodger *et al*., 1980) [33].

Water holding capacity (WHC) is often used to assess the textural quality of the surimi gels and it also indicates the deterioration of protein quality during low temperature storage. In control, the initial WHC recorded on day-1 as 80.18% was decreased to 71.81% on day-20. In this study, all the treatments experienced increase ($p<0.05$) of WHC in day-1compared to control. The result suggested that as the storage progressed, the WHC decreased ($p<0.05$) in all the treatments. The increase in WHC on day-1 observed in treated surimi gels may be explained on the basis of the formation of stronger three dimensional network induced by polyphenols, which might facilitate better entrapment of water in the three dimensional matrix. However, the variation in WHC between the treatments may be due to differences in the concentration of phenolics in different treatments. This may be explained as the result of protein denaturation induced by refrigerated storage leading to low affinity for water and it was accompanied by gradual loss of protein solubility. Moreover, modification of protein-phenolics interaction with the gradual denaturation and/or degradation of protein during storage may also be responsible for changes in WHC of protein as observed in this study. The texture of gel is also dependent on WHC which affect or influence sensory acceptability. So WHC is important to maintain at higher level during the storage period for better sensory quality.

The 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 & Howell, 2002) [34]. Protein solubility (PS) was estimated to be 82.37% in control on day1, which gradually reduced ($p<0.05$) to 69.22% on day-20. There was no significant difference ($p>0.05$) in day-1 between treatments and control. In the present study, protein solubility (%) was found to be decreased significantly ($p<0.05$) in all the groups as the storage progressed indicating the formation of protein aggregates. The decrease in solubility suggests the formation of protein aggregates during storage as a result of protein denaturation. The formation of disulphide bond which results in the aggregation of proteins (Lim & Haard, 1984) [35] 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. From the result, the decreased solubility indicated the aggregation as well as denaturation of proteins caused by low temperature storage (Viji *et al*., 2015) [36]. Protein denaturation, water holding capacity and protein solubility (PS) are factors which are interdependent and changes during low temperature storage.

The rate of increase of TBA values was found to be less in treated gels compared to control. Also, the rate of increase was reduced with the higher concentration of extracts. The auto-oxidation of fat poses a major problem leading to deterioration in the quality of the foods in which they are contained which finally reduce their nutritional value (Esterbauer, 1993; Kubow, 1992) [37, 38]. Safeguarding fats against oxidation is normally done by restricting the access of oxygen or adding antioxidants. Antioxidant potential of plant extracts has long been documented. Antioxidant compounds in herbs are mainly comprised of phenolic acids (Cao & Cao, 1999) [39] and presence of -OH groups in phenolic compounds are largely responsible for their antioxidative activity. Phenolic acids especially of chlorogenic, gallic, protocatechuic and caffeic acids considered to be the main antioxidant compounds present in potato peel extracts (Habeebullah *et al.,* 2010) [11]. The phenolic derivatives present in rosemary extracts have shown strong antioxidant effects on cooked meat. Extracts of peels from Sava variety of potatoes were highly efficient in reducing lipid peroxidation both in fish oil and in oil-in-water emulsions (Habeebullah *et al.,* 2010) [11].

Total volatile basic nitrogen (TVBN) which are breakdown products of endogenous nitrogenous compounds, increased ($p<0.05$) in control as well as in the treated samples during storage, but the rate of increase in treated samples were lower than the control. In control, the TVBN (mg %) increased from initial value of 5.17 to 8.67 mg% on day-20 (Fig. 3), whereas, in the treated samples the TVBN did not exceed 7.26% during this period. The protective action of spice extracts on protein degradation may be the probable explanation of the slow increase of TVBN value in treated gels compared to control.

In control, the whiteness value was recorded as 76.65 on day-1 which was reduced ($p<0.05$) to 66.53 on day-20. The result indicated that the interaction of phenolic compounds with protein influenced the whiteness of gel. The whiteness values showed a reduction on day-1 compared to control. Control samples tended to have the largest decreasing rate of whiteness during the period of storage, compared to the treated groups. Such observation may be related with the interaction between the free amino groups and lipid oxidized products, the formation of which was more in control and lower in treated groups, as both the denaturation of protein and lipid oxidation were more in control. There possibility of interaction of different phenolic compound with the muscle pigments during thermal setting and low temperature storage might be responsible for different degree of whiteness of gels is treatments.

Whiteness of the gels was found to be reduced ($P<0.05$) upon addition of extracts. That may be due to grayish colour of extracts. This may be due to interaction of phenolic compounds with the muscle pigments leading to increase of the whiteness of the gel. But there were no significant changes ($P > 0.05$) in whiteness during refrigerated storage of all the treatments as well as control. The differences in colour alteration between treatments were possibly caused due to the differences in pigment content in muscle. The result also indicates that the surimi treated with extracts prevented the oxidation of heme proteins present in the gel which are red in their reduced form and brown in their oxidized ferric form leading to maintain the whiteness during storage. Since, whiteness of surimi gel tends to be an important sensory attributes, therefore, optimization of extract concentration in surimi gel on the basis of their total phenolics is essential.

Table 2: Changes in functional and biochemical properties of potato peel ethanolic extract incorporated surimi gel from pangas during storage

	Treatments	Day 1	Day 4	Day 8	Day 12	Day 16	Day 20
pH	CON	7.67 ± 0.01^{Ba}	7.72 ± 0.04^{Bab}	7.76 ± 0.02^{Bb}	7.86 ± 0.04^{Cc}	7.93 ± 0.02^{Bd}	7.96 ± 0.05^{Cd}
	PpEE0.5	7.65 ± 0.01^{ABa}	7.68 ± 0.01^{Cab}	7.70 ± 0.02^{Bb}	7.77 ± 0.03^{Cc}	7.76 ± 0.04^{Ac}	7.86 ± 0.02^{Bd}
	PpEE1.0	7.65 ± 0.02^{ABa}	7.66 ± 0.03^{Ba}	7.65 ± 0.0^{Aa}	7.74 ± 0.02^{BCb}	7.76 ± 0.03^{Ab}	7.82 ± 0.03^{ABc}
	PpEE1.5	7.64 ± 0.01^{Aa}	7.65 ± 0.02^{Ba}	7.66 ± 0.03^{Aa}	7.72 ± 0.02^{ABb}	7.76 ± 0.03^{Ac}	7.79 ± 0.01^{Ac}
	PpEE2.0	7.66 ± 0.01^{ABa}	7.66 ± 0.02^{Aa}	7.68 ± 0.01^{ABa}	7.68 ± 0.02^{Aa}	7.74 ± 0.04^{Ab}	7.79 ± 0.04^{Ab}
WHC (%)	CON	80.18 ± 1.55^{Ae}	78.38 ± 1.00^{Ade}	77.39 ± 0.58^{Acd}	75.87 ± 1.04^{Ac}	73.90 ± 1.00^{Ab}	71.81 ± 0.76^{Aa}
	PpEE0.5	81.47 ± 0.31^{ABc}	81.10 ± 0.13^{Bc}	80.32 ± 0.03^{Bcb}	79.07 ± 0.16^{B}	76.29 ± 1.53^{Ba}	75.60 ± 0.28^{Ba}
	PpEE1.0	82.80 ± 0.72^{BCd}	82.87 ± 0.96^{Bd}	81.43 ± 0.10^{Cc}	79.38 ± 1.09^{Bb}	78.15 ± 0.60^{BCb}	76.07 ± 0.57^{BCa}
	PpEE1.5	83.44 ± 0.38^{Cc}	83.33 ± 0.54^{Bc}	82.23 ± 0.21^{Dbc}	81.96 ± 1.32^{Cbc}	80.82 ± 1.12^{Db}	77.41 ± 0.81^{Ca}
	PpEE2.0	84.07 ± 0.58^{Ce}	82.14 ± 0.88^{Bd}	80.86 ± 0.56^{BCc}	79.53 ± 0.06^{Bb}	78.95 ± 0.56^{CDb}	77.39 ± 1.13^{Ca}
TVBN (mg %)	CON	5.17 ± 0.06^{Aa}	5.73 ± 0.67^{Aa}	6.53 ± 0.55^{Bb}	7.60 ± 0.52^{Bc}	8.37 ± 0.38^{Dcd}	8.67 ± 0.21^{De}
	PpEE0.5	5.31 ± 0.03^{Ba}	5.46 ± 0.01^{Bb}	5.57 ± 0.01^{Ac}	5.68 ± 0.02^{Ad}	6.83 ± 0.02^{Ce}	7.26 ± 0.04^{Cf}
	PpEE1.0	5.30 ± 0.02^{Ba}	5.40 ± 0.01^{Bb}	5.51 ± 0.03^{Ac}	5.56 ± 0.01^{Ac}	6.69 ± 0.06^{BCd}	6.83 ± 0.02^{Be}
	PpEE1.5	5.29 ± 0.02^{Ba}	5.39 ± 0.03^{Ba}	5.45 ± 0.03^{Aa}	5.53 ± 0.04^{Aa}	6.21 ± 0.56^{Bb}	6.72 ± 0.01^{ABcc}
	PpEE2.0	5.29 ± 0.02^{Ba}	5.37 ± 0.02^{Bb}	5.41 ± 0.01^{Ac}	5.51 ± 0.02^{Ad}	5.56 ± 0.01^{Ae}	6.62 ± 0.01^{f}
PS (%)	CON	82.37 ± 1.17^{Af}	79.79 ± 0.72^{Ae}	77.25 ± 0.23^{Ad}	74.73 ± 0.80^{Ac}	71.28 ± 0.35^{Ab}	69.22 ± 0.34^{Aa}
	PpEE0.5	82.79 ± 0.56^{Ad}	82.11 ± 0.57^{Ad}	80.55 ± 0.56^{BCc}	75.89 ± 0.72^{ABb}	73.29 ± 0.07^{Ba}	72.45 ± 0.08^{Ba}
	PpEE1.0	83.14 ± 0.52^{Ae}	82.24 ± 0.12^{Ae}	80.92 ± 0.11^{Cd}	76.15 ± 0.55^{Bc}	74.44 ± 0.04^{Cb}	73.27 ± 1.16^{Ba}
	PpEE1.5	83.11 ± 1.11^{Ae}	82.15 ± 0.03^{Ade}	81.32 ± 0.53^{Ccd}	80.63 ± 0.31^{Cc}	79.07 ± 0.49^{Db}	75.76 ± 0.14^{Ca}
	PpEE2.0	83.41 ± 0.91^{Ad}	81.29 ± 1.03^{Ac}	80.05 ± 0.52^{Bc}	75.87 ± 0.55^{ABb}	73.91 ± 0.54^{BCa}	73.15 ± 0.99^{Ba}
TBA (mg malonaldehyde /kg)	CON	0.75 ± 0.02^{Ba}	0.82 ± 0.06^{Ba}	0.92 ± 0.04^{Bb}	1.08 ± 0.04^{Dc}	1.16 ± 0.06^{Cd}	1.27 ± 0.04^{De}
	PpEE0.5	0.75 ± 0.02^{Ca}	0.81 ± 0.01^{Bb}	0.90 ± 0.02^{Cc}	0.97 ± 0.01^{Bd}	1.02 ± 0.01^{Be}	1.11 ± 0.02^{Df}
	PpEE1.0	0.74 ± 0.01^{BCa}	0.79 ± 0.03^{ABb}	0.84 ± 0.02^{Bc}	0.93 ± 0.01^{Bd}	1.01 ± 0.01^{Be}	1.06 ± 0.01^{Cf}
	PpEE1.5	0.72 ± 0.02^{ABa}	0.75 ± 0.01^{Ab}	0.78 ± 0.01^{Ac}	0.83 ± 0.01^{Ad}	0.91 ± 0.01^{Ae}	0.97 ± 0.01^{Bf}
	PpEE2.0	0.70 ± 0.01^{Aa}	0.75 ± 0.01^{Ab}	0.77 ± 0.01^{Ac}	0.83 ± 0.01^{Ad}	0.88 ± 0.02^{Ae}	0.92 ± 0.01^{Af}
Whiteness	CON	76.65 ± 1.13^{Ac}	67.88 ± 0.48^{BCb}	77.32 ± 0.49^{Ac}	66.65 ± 0.50^{Aa}	66.88 ± 0.57^{Bab}	66.53 ± 0.28^{Ba}
	PpEE0.5	70.15 ± 1.08^{BCd}	70.22 ± 0.94^{Bd}	68.50 ± 0.48^{Cc}	66.37 ± 0.48^{Bb}	64.44 ± 0.79^{Aa}	63.86 ± 0.29^{Aa}
	PpEE1.0	71.22 ± 1.24^{Cab}	70.20 ± 1.09^{Ba}	71.06 ± 0.36^{Dab}	71.79 ± 0.26^{Cc}	72.41 ± 0.15^{Dcd}	73.15 ± 0.23^{Cd}
	PpEE1.5	66.41 ± 1.63^{Aa}	66.52 ± 1.83^{Aa}	64.96 ± 0.55^{Ba}	65.22 ± 0.24^{Aa}	65.42 ± 0.06^{Ba}	66.16 ± 0.59^{Ba}
	PpEE2.0	68.15 ± 0.99^{ABd}	68.49 ± 0.82^{ABd}	63.62 ± 0.23^{Aa}	65.01 ± 0.58^{Ab}	66.57 ± 0.35^{Cc}	66.84 ± 0.38^{Bc}

The overall acceptability scores of the samples were assigned based on the attributes such as appearance, flavour, taste and texture. In case of control, there was a steady decrease ($p<0.05$) of all the sensory attributes and on this basis, since the gel scored below 5 in all the attributes including overall acceptability in day-16, the product was considered to be of acceptable up to 12 days. In case of treated samples PpEE-0.5 was found acceptable only up to Day-16 as per overall acceptability was concerned, however, in respect of all remaining treated samples, they were acceptable upto day-20. The control was found acceptable only up to Day-12. Textural properties of sausage type of products are regarded as an important criterion for the consumer's acceptability is concerned.

TPA based on the recognition of texture as a multiparameter attribute, is an objective method of sensory analysis pioneered by Szczesniak (1963) [40]. Texture profile of sausage from surimi is usually influenced by the gelling properties and it changes during low temperature mostly due to protein denaturation. But addition of cross linking agents like phenolic compound also influence the texture profile of surimi gel due to enhanced protein-protein interaction (Buamard *et al*., 2017) [41]. Texture parameters like hardness, springiness, cohesiveness and gumminess were determined. Among textural attributes, hardness is the most important textural attribute to the consumers, as it decides the commercial value of the meat [42] (Chambers & Bowers, 1993). The hardness (the resistance at maximum compression during the 1st compression) was found higher in control than the treated samples. This may be related with the higher breaking deformation as observed in the treated samples compared to the control. In control, the day-1 value of hardness (752.7 g) reduced ($p<0.05$) 21% and reached to 592.0 in day-20. The differences in hardness between the treatments may be due to different phenolic compounds, their concentration and mode of interaction with protein.

Thermal setting results from the activity of a calcium-dependent endogenous transglutaminase (TGase). However, addition of any cross linking agent interferes in protein-protein interaction and influences gelling properties in particular and overall textural properties in general. The result showed that the gel strength (GS) of treated samples increased significantly ($p<0.05$) compared to that of control sample (CON) (Fig.). In control, the GS of Day-1 (179.72) reduced to 134.55 on Day-20. In all the treated samples, the GS reduced during the period of storage. The results revealed that phenolic compounds at the optimum concentration were effective in increasing gel strength of striped catfish surimi.

The phenolic compounds present in potato peel extract have been reported to enhance protein-protein interaction which results in the enhancement of GS. Naturally derived plant phenolic compounds have been shown to be the potential protein cross-linker (Rawel *et al*., 2002; Wang *et al*., 2017) [43, 44]. Phenolic phytochemicals present in natural spices contain sufficient hydroxyls and other suitable groups (such as carboxyls) to form strong complexes with the proteins and other macromolecules. The GS of the gel was significantly increased by the addition of extract with the maximum value for the PpEE-1.5%. The decreased gel strength at higher concentrations in the present study might be associated with self-aggregation of phenolic compounds, leading to the loss in capability of protein cross-linking. The lower solubility of large phenolic compounds at high concentration causes the difficulty to interact with proteins (De Freitas and Mateus, 2001) [45]. It is also possible that the size of the phenolic compound can decrease its conformational flexibility in protein–phenolic compound interactions, which is observed to be an important parameter in protein–phenolic compound interactions (Frazier *et al*., 2003) [46].

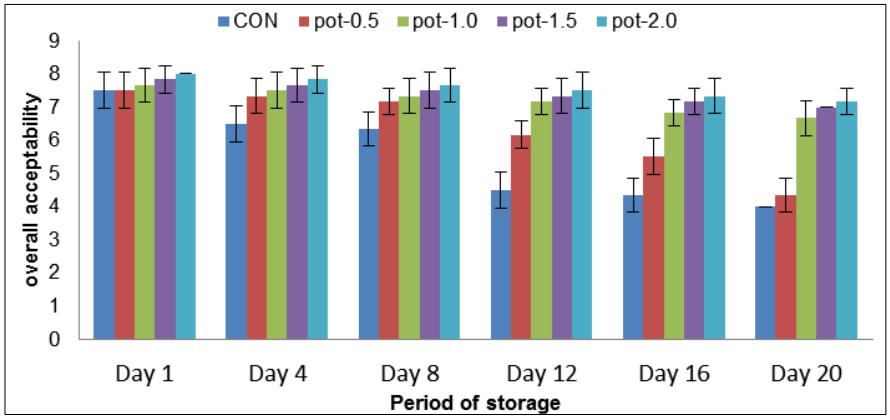

Fig 1: Changes in overall acceptability

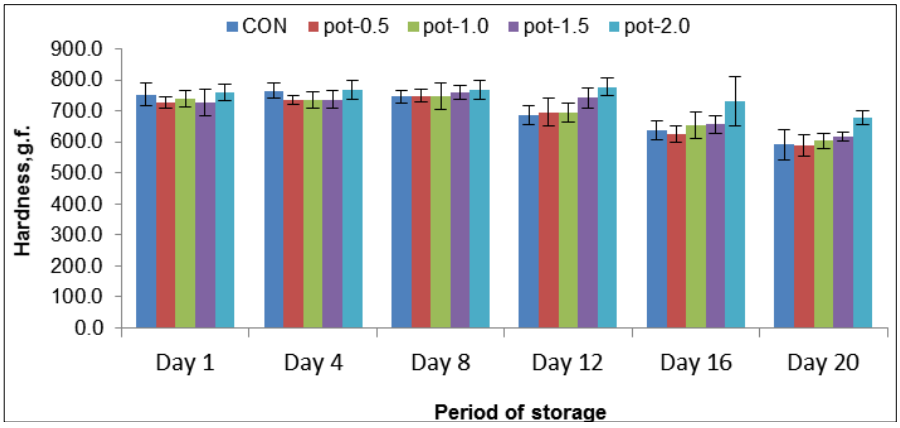

Fig 2: Changes in hardness

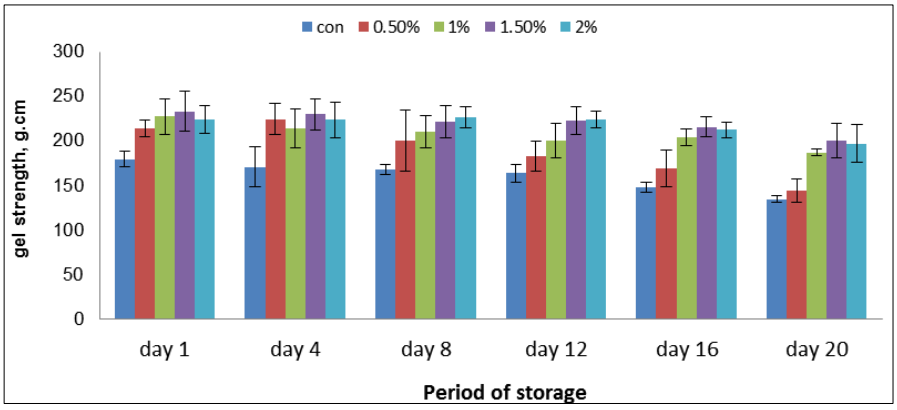

Fig 3: Changes in gel strength

Conclusion

Antioxidants are therefore necessary to incorporated in order to increase storage stability, sensory quality and nutritional value of fish products. Beneficial effect of suitable agents possessing antioxidant activity for maintaining meat quality, extending shelf-life and prevent economic loss. Since, addition of synthetic antioxidants has been restricted because of their health risks and toxicity. In case of potato peel extract treated samples PpEE-0.5% was found acceptable only up to Day-16 as per overall acceptability was concerned, however, in respect of all remaining treated samples, they were acceptable up to day-20. Therefore, for development of

sausages from freshwater fish like pangas with inherent low gelling capacity, potato peel extract may be used for safety of the product as well as for making the product as health food due to its enrichment with antioxidants and dietary fibre.

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