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Influence of Temperature on the Gel-forming Ability of Some Under-utilized Marine Fish Species in Bangladesh

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Abstract: Seven species of marine fish such as Queenfish (*Chorinemus lysan*), Jew fish (*Otolithus argenteus*), Silver belly (*Leiognethus* spp.), hard tail (*Megalespis cordyla*), lizard fish (*Saurida tumbil*), Bombay duck (*Harpadon nehereus*) and catfish (*Tachyssurus thalassinnus*) having limited use in fresh market were used in present study for evaluation of gel forming ability under a wide range of incubation temperature. The resulting suwari gels were subjected to the puncture test, expressible moisture test, teeth cutting test and folding test. The gel strength of *Chorinemus lysan* suwari-gel in one-step heating showed the maximum breaking force at 45°C (1196 ± 32g) after incubation for 120 minutes. In case of two-step heating, the product heated at 40°C for 120 min had the highest gel strength (1485 ± 79g). The gel strength of *Otolithus argenteus* in one-step heating showed the higher breaking force (BF) at 50°C (926 ± 34g) for 180 min, while in two steps heating, the highest gel-strength of 1451 ± 49g was obtained at 45°C after an incubation of 120 minute. In *Megalespis cordyla* both in one-step and two-step heating, maximum breaking force was obtained at incubation temperature of 45-50°C. The gel-strength of *Leiognethus* sp. in one step heating had highest breaking force at 50 °C for 120 minutes (1010 ± 51g) and in two-step process the highest breaking force was obtained after pre-heating at 40 °C for 180 min (1323 ± 58g). The results of gel strength *Saurida tumbil* suwari-gel both in one step and two-step heating showed poor ability irrespective of incubation temperature used. *H. nehereus* showed poor gel strength with maximum range of 207–213g at the temperature range of 40 -50°C both in one and two steps heating at various incubation temperatures. In *T. thalassinus*, the highest gel strength of 420 ± 87 g was obtained at 35°C in 180 minutes during one step heating while in two step heating, the resulting suwari-gel of *T. thalassinus* was the highest after pre-heating at 35°C for 120 min (313 ± 12 g).

Key words: Temperature, gel-forming ability, surimi

Introduction

Bangladesh possess a typical tropical multi-species fisheries ecosystem. In the coast of Bangladesh, particularly in the shallow artisanal and off-shore demersal fisheries, different sizes and varieties of species are caught. A total of 490 species of fish belonging to 133 families were recorded and out of these 65 species are commercially important (Hussain, 1971).

In most shrimp fisheries, the by-catch compromises 80-95 percent of catch. The post-harvest losses from 50 Bangladeshi trawlers were reported to over 40000-45000 MT annually (BOBP, 1991) and the catch composition of 40 trawlers consists of shrimp (4%), commercial fish (12.3%), juveniles of economic demersal by-catch (47.3%), trash fish (25.9%) and discarded (9.7%) (Khan and Mustafa, 1992). Surimi, a deboned and washed fish paste stored frozen in the presence of cryoprotective agent is a Japanese specialty and used primarily for preparation of traditional gel like products called "kamaboko" and more recently for the production of seafood analogues. The surimi process results in a frozen intermediary product with a durability of more than one year without loss of water binding capacity and get-forming ability. Surimi is a phenomenon in which myosin after being dissolved in NaCl becomes jelly like structure having elasticity and it is an important criterion of quality product. The gel-softening phenomenon, called "modori" or "hi-modori" in Japanese, is very unique to fish meat and is now considered to be caused by an alkaline proteinase having an optimum temperatures at 60°C for 15 min. The addition of starch to kamaboko is reported to reinforce its elasticity through a filler reinforcement effect of the starch granules thus "modori" is inhibited. Dried egg white albumin (Niwa *et al.*, 1975), alcohol's, such as n-butyl-, n-amyl-, and n-hexyl- alcohol's (Taguchi *et al.*, 1983) and in some cases, protease inhibitors (Yaguchi *et al.*, 193; Lanier *et al.*, 1981) are also noted.

All the species are not equally suitable for processing of various value-added products. Fish muscle types such as ordinary and dark muscle, total yield, their properties, chemical composition and protein composition vary among the fish species. Different flesh characteristics in a product may influence the quality and make the product unattractive to the consumers in terms of appearance, flavour and odor. The organoleptic characteristics of fish species are the important criteria to assess the quality of raw material for use in any value added activity.

The ideal characteristics of fish to be used for mince or surimi-based products would be abundantly available low value white fleshed meso-pelagic or demersal species. Smaller economic size fish species such as catfish, lizardfish, croakers etc. are abundantly available and might provide an attractive source of raw materials for production of surimi. However, to make the sea fishing more profitable and give the under-utilized fish species an acceptable food grade structure, and mostly, to protect our sea against serious pollution due to bulk discard, it is therefore very important to investigate the suitability of under-utilized fish species for use in value added products especially surimi production.

Materials and Methods

Species selection: Bangladesh Fisheries Development Corporation (BFDC, 1986) has identified a number of under-utilized fish species with their composition as raw material for the production of value added fish products (Table 1). Among those under-utilized fish species, seven species such as Queenfish (*Chorinemus lysan*), Jewfish (*Otolithus argenteus*), Silver belly (*Leiognethus spp.*), Hard tail (*Megalespis cordyla*), Lizard fish (*Saurida tumbil*), Bombay duck (*Harpadon nehereus*) and catfish (*Tachyssurus thalassinnus*) were used for the present study due to their abundance round the year (plate 1-7).

Several lots of samples were obtained from day fishing boats of BFDC fish harbour, Cox,s Bazar in between April 1999 to October 2000. The biological information about these species are shown in Table 2.

Procedure and analytical methods:

Preparation of meat paste: The fish were thoroughly washed to remove slime and blood. The dorsal and lateral muscle of fish were excised as fillet form. Skin and belly fats were carefully removed. The muscles were deboned by a mechanical mincer cum bone separator. The minced were washed using chilled freshwater twice. The mince in a flat cotton cloth bag was pressed initials 5 kg /cm^2 for 10 min. and finally at 10 kg/cm^2 for 15 min. All the operations were done under cold condition. Detailed procedure for preparation of meat paste is shown in Flow chart 1.

Preparation of gel: Immediately after pressing the washed minced was ground with 3% NaCl by a mortar for 20 min. in cooled condition. The salt ground meat paste was then carefully stuffed in heat stable polyethylene tube and

Fish (Iced)
↓
Washing with chilled water
↓
Deheading and gutting
↓
Filleting
↓
Deboning by mincer
↓
Deboned minced
↓
Washing with chilled water (two times)
↓
Dewatering (Pressing by 5 Kg/cm^2 for 10 min)
↓
Final dewatreing (Pressing by 10 Kg/cm^2 for 15 min)
↓
Ground with 3% NaCl for 20 min
↓
Meat paste

Flow chart 1: Procedure for manufacture of meat paste

Plate 1: Queen fish *Chorinemus lysan*

Plate 2: Hard tail *Megalespis cordyla*

Plate 3: Jewfish *Otolithus argenteus*

Plate 4: Silver belly *Leiognethus* spp.

Plate 5: Bombay duck *Harpadon nehereus*

Plate 6: Lizard fish *Saurida tumbil*

Plate 7: Catfish *Tachyssurus thalassinnus*

both ends of the tubes were tightened. The paste in the polyethylene tube was heated at a wide range of temperature to produce gel. In the one-step heating, samples were heated for 60, 120 and 180 min in water bath at temperatures 35, 40, 45, 50, 60, 70 and 80 ^{o}C. In two-step heating, the first heating was for 60, 120 and 180 min. in water bath at 30, 35, 40, 45, 60, 70 and 80 ^{o}C. After this pre- heating treatment, they were immediately heated for another 30 min. in water at 85 ^{o}C. After heat treatments the samples were taken out of the water bath and kept in iced water for 1 hour for following tests.

Measurement of gel strength: The gel strength of the

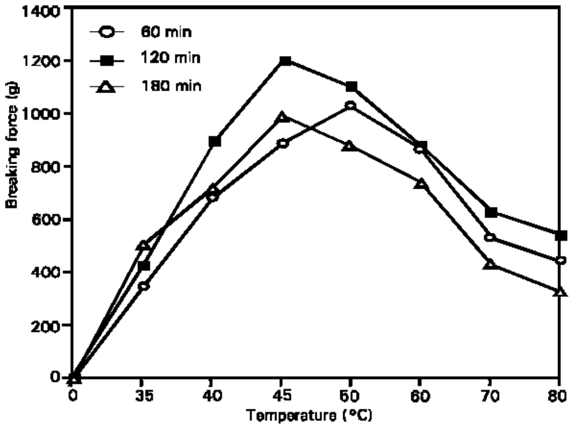

Fig. 1: Temperature gelation curve of *Chorinemus lysan* meat paste in one-step heating.

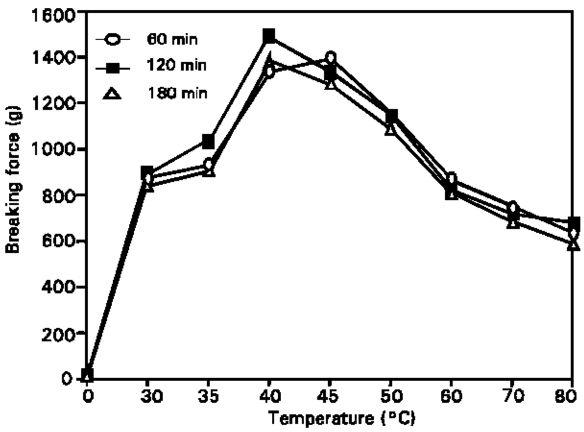

Fig. 2: Temperature gelation curve of *Chorinemus lysan* meat paste in two-step heating.

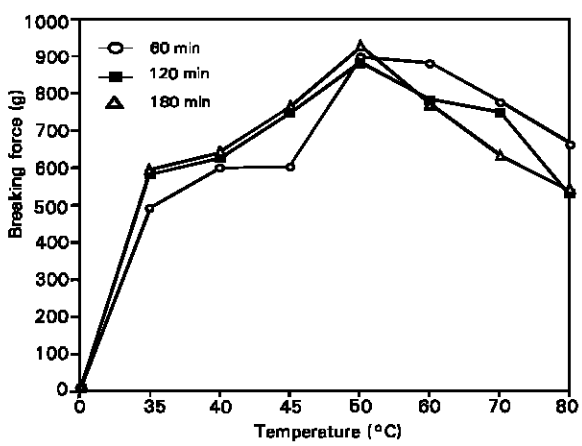

Fig. 3: Temperature gelation curve of *Otolithus argenteus* meat paste in one step heating

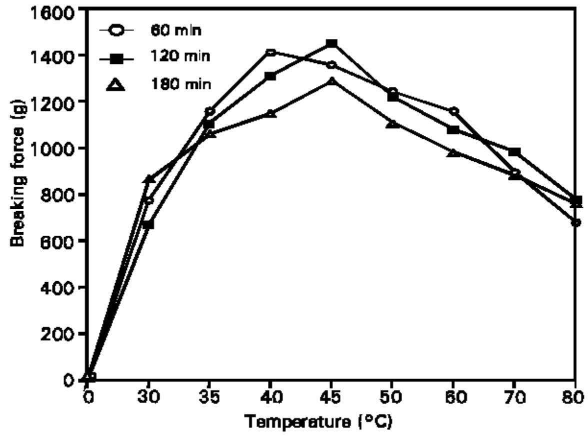

Fig. 4: Temperature gelation curve of *Otolithus argenteus* meat paste in two step heating

Table 1: Species composition of under-utilized marine fish species of Bangladesh

Species	Family name	Composition (%)
Catfish	Aridae	25.0
Lizard fish	Synodontidae	23.2
Silver belly (pony fish)	Leognathidae	18.3
Jewfish (croaker)	Sciaenidae	8.9
Hard tail scad	Carangidae	5.1
Solefish	Cynoglossidae	3.8
Threadfin bream	Nemipteridae	3.0
Goatfish	Mullidae	2.3
Squid & cuttlefish	Sepiidea/Ommastrephidae	2.2
Shad		2.2
Miscellaneous	Clupidae	5.9
Total		100

Source: INFO fish marketing digest no 5/86

products was assessed by objective and organoleptic methods. A five person panel as described by Poon *et al.* (1981) was constituted for the organoleptic assessment. The gel was removed from the tube and subjected to puncture test, folding test, expressible moisture test and teeth cutting test for physical measurement of the gel punctured test that measured the breaking strength of the gel against insertion of a ball type plunger (6 mm diameter). The folding test measured the resistance against breaking along the folds when the sample discs of 1 mm stickiness were folded into halves and then quarters and the teeth cutting test was a measure of the resistance of the disc cut by the incisors of members of the panel.

Puncture test (PT): The test was done by removing the gels from the tube and cut into equal pieces of 2 cm. The breaking force of the gel was measured against the penetration of a ball type spherical plunger (6mm diameter) on the pan of an electronic balance. The force in g required to break the gel by the plunger was recorded from the balance display window.

Expressible moisture test (EMT): The amount of expressible water was measured by compressing a hemispherical slice of gel (about 0.1 g) between two double layers of filter paper (Watt man No. 1) at a pressure of 1 kg/cm^2 for 3 min.

Table 2: Biological data on the experimented marine fishes

Scientific names	Bangali names	English names	Storage duration (h)	Date of capture	Average size	
					Length (cm)	Weight (g)
Chorinemus lysan	Chapa	Queenfish	24	14/04/99	37.5	331.0
Otolithus argenteus	Poa	Jewfish	24	16/05/99	19.0	82.0
Megalespis cordyla	Kaoa	Hard tail	24	16/09/99	29.5	225.0
Leiognethus spp.	Tak chanda	Silver belly	24	9/02/2000	22.5	166.1
Saurida tumbil	Achila	Lizard fish	24	9/02/2000	32.1	118.6
Harpadon nehereus	Loitta	Bombay duck	24	1/10/2000	27.3	97.86
Tachyssurus thalassinnus	Goigga	Catfish	24	1/10/2000	401.5	533.0

Expressible moisture in percent was calculated from the following formula:

$$\% \text{ Expressible moisture} = \frac{W_1 - W_2}{W_1} \times 100$$

where, W_1 = Weight of the gel slice before compression W_2 = Weight of the gel after compression

Folding test (FT): For folding test a spherical disc of 1 mm thick gel was cut off and placed on the index and middle finger of the right hand, the disc was folded first into halves and then quarter with the help of thumb and index finger (plate 12). The gel was graded using scores presented in the following, as suggested by Poon *et al.* (1981).

Teeth cutting test (TCT): The disc gel of same size used in folding test was supplied to the panelists to recognize the test by cutting it through incisor for teeth cutting test. Gel strength was evaluated by the following numerical scores as suggested by Shimizu *et al.* (1981), which are presented below in Table 4.

Results

Characteristics of raw materials:

The results of the chemical composition of the fish are shown in Table 5. Chemical composition differed from species to species. The moisture content of these fish species were in the range of 70.62 to 84. 30 in which Bombay duck had higher moisture content. The lipid contents were in the range of 2.24 to 7.66% in which Bombay duck contained low and catfish high lipid content. Protein contents were in the range of 12.30 to 23.56% in which Bombay duck had low and had tail had high protein content. Except Bombay duck all other species fall in the classification of high protein contents.

Assessment of gel-forming ability

***Chorinemus lysan* (Queen fish):** The results of gel strength of *Chorinemus lysan* Suwari-gel in one-step heating are shown in Fig. 1 The pH of the salt ground meat paste was 6.23 . The setting of gel started at 35 ^{0}C and the average breaking force (BF) gradually increased with the rise in temperature. The highest average breaking force (1196±32g) was obtained at 45 ^{0}C for 120 min and then again declined with further increase in temperature. The gel-strength began to decrease with further rise in incubation temperature is due to "modori" phenomenon. At the temperature of 45^{0}C for 120 min. incubation period, the resulting product had the highest fold test (FT) score of "AA" grade and the expressible moisture (EM) and teeth cutting test (TCT) scores were 43.36% and 7, respectively. Some products showed "A" and some showed "B" FT score. The salt ground meat paste of *Chorinemus lysan* did not set at 30 ^{0}C in one-step heating treatment.

The results of the gel-strength of *Chorinemus lysan* suwari-gel during two-step heating are shown in Fig. 2. In two-step heating all the samples were heated at 85^{0}C for 30 min. after pre-heating. As shown in Table 4 the product heated at 40^{0}C for 120 min. had the highest gel strength (1485±79g). The

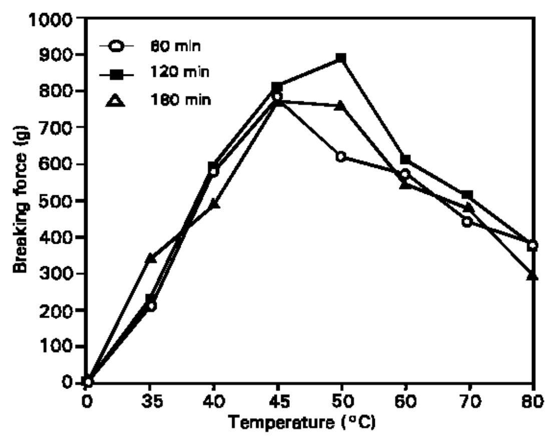

Fig. 5: Temperature gelation curve of *Megalespis cordyla* meat paste in one-step heating.

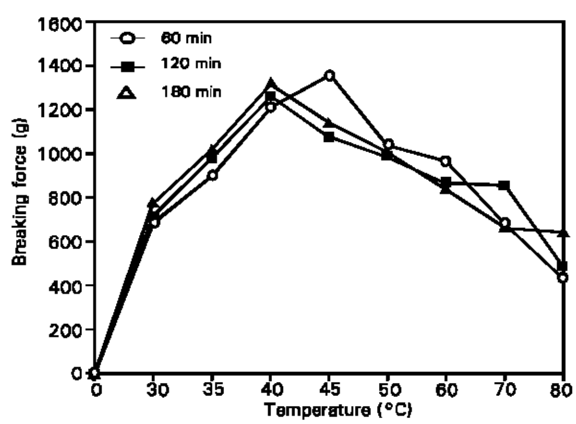

Fig. 6: Temperature gelation curve of *Megalespis cordyla* meat paste in two-step heating.

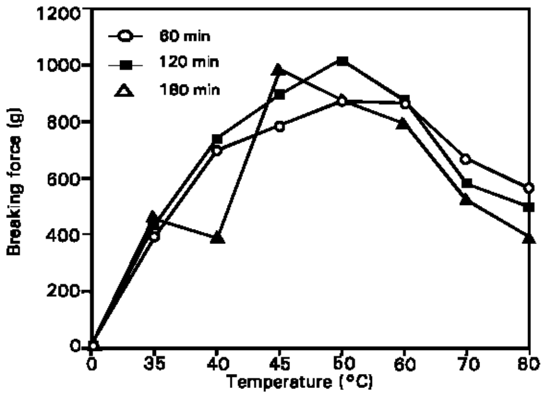

Fig. 7: Temperature gelation curve of *Leiognethus* spp. meat paste in one step heating.

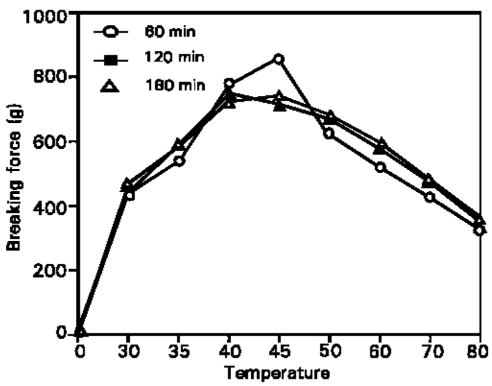

Fig. 8: Temperature gelation curve of *Leiognethus* spp. meat paste in one step heating.

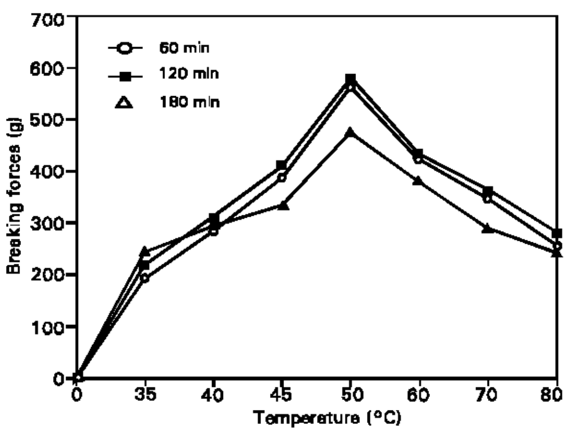

Fig. 9: Temperature gelation curve of *Saurida tumbil* meat paste in one step heating

resulting product had a fold test score of "AA" grade and expressible moisture and TCT scores were 38.90% and 8, respectively at the same temperature and heating duration's. All the suwari-gel had the FT score of " AA" grade. In two-step heating, the gel-strength of this fish increased at

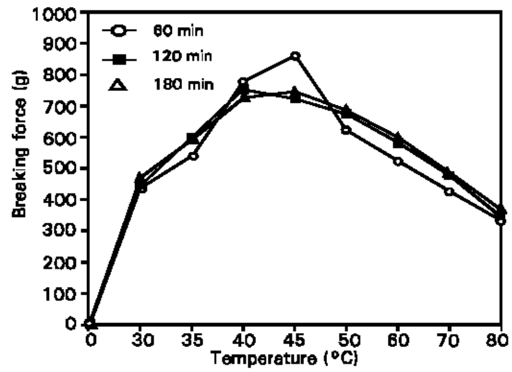

Fig. 10: Temperature gelation curve of *Saurida tumbil* meat paste in two-step heating.

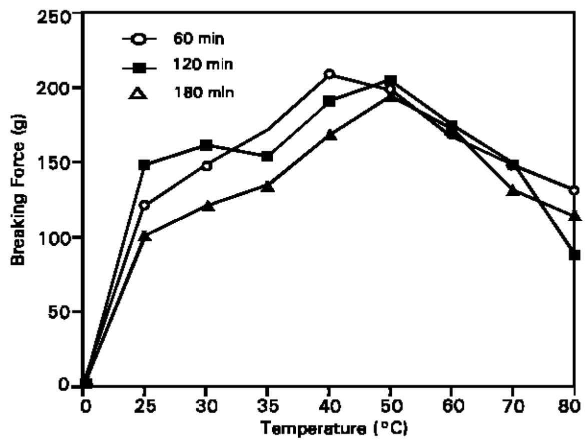

Fig. 11: Temperature gelation curve o *H. nehereus* meat paste in one-step heating.

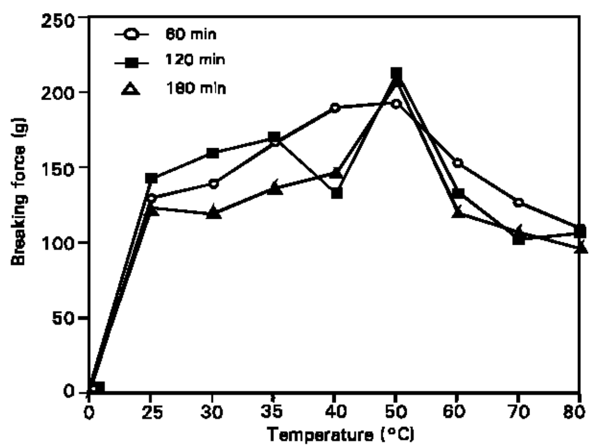

Fig. 12: Temperature gelation curve of *H. nehereus* meat paste in two-step heating

temperatures from 40-45°C but the gel forming ability declined gradually at temperature above 40°C.

Table 3: Grades used in the folding test of the gel

Grade	Results on folding
AA	No crack visible when disc is folded into quarter.
A	No crack when disc is folded into half, but one or more cracks or breaks are visible when folded into quarter.
B	One or more cracks are visible when disc is folded into half.
C	Breaks, but does not split into halves.
D	Splits into halves when folded into half.
0	Sample too soft to evaluate.

Table 4: Score used in the teeth cutting test of the gel

Scores	Characteristics of the gel
0-1	Paste or mud like gel
2-3	Very frail gel
4-5	Frail gel
6	Medium gel strength
7-8	Strong gel
9-10	Very strong gel

Table 5: Proximate composition of experimented marine fish

Species	Proximate composition (%) wt. matter basis			
	Protein	Lipid	Moisture	Ash
Chorinemus lysan	23.56	3.56	70.62	0.91
Otolithus argenteus	20.80	3.60	73.6	0.93
Megalespis cordyla	23.56	4.20	70.80	0.92
Leiognethus spp.	22.73	3.88	71.81	0.81
Saurida tumbil	19.84	6.22	72.10	1.14
Harpadon nehereus	12.30	2.24	84.30	1.10
Tachyssurus thalassinnus	18.25	7.66	72.38	1.32

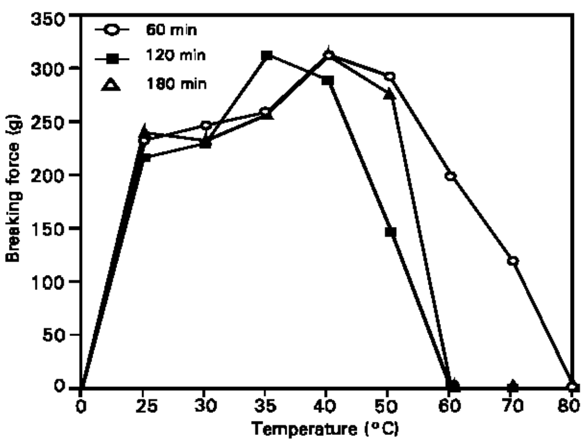

Fig. 13: Temperature gelation curve in *T. thalassinus* meat paste in one step heating

***Otolithus argenteus* (Jew fish):** The results of gel-strength of *Otolithus argenteus* in one-step heating are shown in Fig. 3. The pH of *Otolithus argenteus* fish meat paste was 6.24. The highest BF was obtained at 50°C at all incubation periods. The BF began to increase gradually at incubation temperature of 35 °C and the higher BF was observed at 50 °C but the gelling ability gradually declined with the further increase in temperature. The gel incubated for 180 min at 50°C had the highest average gel strength (926±34 g) for 180 min of incubation period. The decreases in gel forming ability over 50 °C indicates slight "modori" phenomenon. The gel strength expressed by BF, EM, FT and TCT were not measurable at 30 °C for any heating duration. The highest TCT was 8 and lowest was 4. Some gel products had "AA" grade FT scores and some had "A" and "B" grade.

The results of gel strength of *Otolithus argenteus* in two steps heating are shown in Fig. 4. The BF of the suwari-gel of *Otolithus argenteus* was the highest at 45°C (1451±49g) after an incubation of 120 min. The BF increased at two-step process under different temperature conditions compared with one-step processes. The gel strength declined at temperature above and below 45°C. The resulting product received a fold test score of "AA" grade and at the same time the EM and TCT scores were 41.10% and 8, respectively.

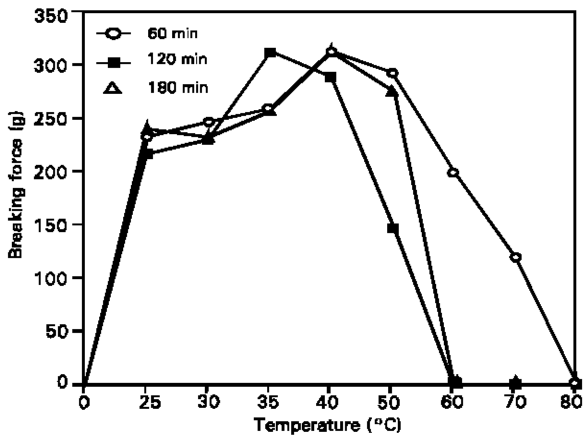

Fig. 14: Temperature gelation curve in *T. thalassinus* meat paste in one step heating

***Megalespis cordyla* (Hard tail):** The results of gel strength of *Megalespis cordyla* in one-step heating treatment are shown in Fig. 5. The pH of salt ground paste was 6.38. The results show that the BF of the resulting suwari-gel *Megalespis cordyla* had the highest average gel strength (891±25g) at 50 °C after incubation of 120 min. The resulting product received a fold test (FT) score of "AA" and at the same time the EM and TCT scores were 46.20% and 8 respectively. The BF began to increase with the increase in incubation temperature up to 50°C and then decreased. The salt ground paste of *Megalespis cordyla* did not set at 30 °C in one-step heating.

The results of gel strength of *Megalespis cordyla* suwari gel in two-step heating are shown in Fig. 6. All samples were cooked at 85°C for 35 min. after pre-setting along with various heating durations and temperatures. The resulting product heated for 60 min at 45°C had the highest gel-strength (1361±52g). All the products had a FT score of "AA" grade except at 80°C for all incubation periods. The gel-strength in terms of BF increases gradually with the increment of heating temperature and time and showed a highest gel strength at 45°C for 60 min. The gel-forming ability soon dropped for further rise in temperature till 80 °C.

***Leiognethus* spp. (Silver belly):** The results of gel strength of *Leiognethus* spp. in one-step heating are shown Fig. 7. The pH of the gel was 6.21. The BF was the highest (1010±51g) at 50 °C for an incubation of 120 min. At that temperature resulting product received FT score of "AA" grade. The EM and TCT scores were 47.36 and 8 respectively. The maximum gel strength of the product was found between 45 and 50 °C and then declined with further rise in temperature.

The results of gel strength of *Leiognethus* spp. suwari-gel, in two-step process are shown in Fig. 8. The figure shows that the BF of the resulting suwari-gel of *Leiognethus* spp. was the highest after pre-heating at 40 °C (1323±58 g) for 180 min.

The resulting product received a fold test FT score of "AA" grade at the same time The Em and TCT scores were 42.58 and 8 respectively. Figure shows that BF increased with raising of initial incubation temperature and decreased gradually with further increase in incubation temperature.

***Saurida tumbil* (Lizard fish):** The gel-strengths of *Saurida tumbil* suwari-gel in one-step-heating are presented in Fig. 9. The pH of *Saurida tumbil* fish meat paste was 6.03. The gel did not set until the temperature raised up to 35 °C. however, the braking force suddenly increased considerably with the raising of temperature and the peak was recorded (580 ± 50 g) at incubation temperature of 50 °C for 120 min. The gel-strength expressed by BF, EM, TCT and FT were not measurable at 30 °C for any heating duration.
The results of gel-strength of *Saurida tumbil* suwari-gel in two-step heating process at 85°C for 30 min after the pre-setting are shown in Fig. 10. The average breaking force of the resulting suwari-gel of *Saurida tumbil* was the highest when pre-heated for 60 min (860 ± 34 g) at 45°C. The BF then gradually decreased continuously with raising of temperature till 80° C. The BF of gel produced at 45° C was much higher than that of the gel produced at one-step heating. Some products showed "AA" grade FT score and some products showed "A" and "B" grade FT score.

***H. nehereus* (Bombay duck):** The results for one-step heating are shown in Fig. 11. The pH of the meat gel was 6.08. The BF of 207 g was highest for *H. nehereus* suwari-gel at 40°C after 60 minute incubation. This is significantly ($P < 0.05$) different than those obtained in other heating duration's and temperature treatments. However, the gel-forming ability of this fish was very poor irrespective of temperature and duration of incubation used. The measurements for EM, TCT and FT could not be taken at any given temperature.
The results of the gel strength of *H. nehereus* suwari-gel in two-step heating are shown in Fig.12. The pH of the meat paste was 6.07. The gel strength in terms of BF was very low. A maximum of only 213 g was recorded in the gel at 50°C for 120 minutes. The EM and other tests, however, could not be determined for the gel incubated at all the temperatures because of strong adherence of gel to the filter paper due to its stickiness.

***T. thalassinus* (Catfish):** The gel-strength of *T. thalassinus* in one-step heating are shown in Fig. 13. The pH of the gel was 6.21. The highest breaking force was found at 35°C at an incubation of 180 minutes (420 ± 87 g) and significantly differed ($P < 0.05$) from the remaining temperature and heating duration's. At that temperature and time the resulting product received FT score of "A" grade. The EM and TCT scores were 50.75% & 4 respectively. The gel strength of the products in terms of BF increased gradually for 30°C. The peak gel strength was at 35-40 °C and then declined with further increase in temperature. The paste did not set at the temperatures of 25, 60, 70 and 80 °C for any duration due to the softness of the gel. The BF, EM, TCT and FT of the products, produced after incubation of 180 minutes at 50°C could not be determined for its softness. Similarly, measurement of these parameters was not possible at 30°C for lacking of gel strength.
The results of gel strength of *T. thalassinus* suwari-gel, in two step process are shown in Fig. 14. The pH of the meat paste was 6.18. Table 13 shows that the BF of the resulting suwari-gel of *T. thalassinus* was the highest after pre-heating at 35°C for 120 min (313 ± 12 g), which was significantly different from the remaining temperatures. Similar results were also obtained after pre-heating at 40°C for 60 and 180 minutes. The figure shows that BF increased with increase in initial incubation temperature. The gel strength decreased gradually over 50°C of incubation temperature. The gel becomes very soft at 60°C for 60 min. The paste did not set at 80°C irrespective incubation period. The BF for 120 min. and 180 min at 60° and 70°C could not be measured due to softness of the gel. Similarly, EM, TCT and FT of products could not be measured at 25°, 50°, 60°, 70° and 80°C irrespective duration. The resulting products showed a FT scores of "C". The BF of the gel was lower compared to that of one-step heated gel.

Discussion

Present study indicated that the gel forming ability varied greatly among the species depending upon the incubation period and temperature as described by Shimizu *et al.* (1981). There are a number of factors that influence the Kamaboko gel forming ability; including high fat content, large amount of sarcoplasmic proteins and high proportions of dark to ordinary muscle. High fat content in the muscle weaken the gel forming ability and consequently, gel forming ability is lowered with decrease in freshness of fish (Suzuki and Watabe, 1987). More over on the basis of the species of fish "suwari" occurs rapidly of slowly or some times does not occur at all (Okada, 1959). The elasticity or gel forming ability of Kamaboko is an important criteria of quality products. Myosin is the only component of protein concerned with the elasticity of Kamaboko (Kitabayashi, 1954; Miyake and Hayashi, 1957; Nowsad *et al.*, 1993). Gelation characteristics of salt added myosin sol have been reported by Shimizu *et al.* (1983); Setting phenomenon in teleosts and rabbit occurred at 30-40°C and "modori", gel disintegration phenomenon, occurred at around 60°C.
However, in the present study the "suwari" started at 35°C in one-step heating irrespective of incubation temperature and duration. Good gel forming ability was obtained in the range of temperature of 40-60°C with peak at 50°C. While "modori" effect resulted at temperature after 60°C in all cases.
On the other hand , the Suwari started at 30°C in two-step heating irrespective of incubation temperature and duration. Good gel forming ability was obtained in the range of 35-60°C with peak at 45°C; while "modori" effect began after 60°C.
For estimating the gel forming ability of fish, it is important to know how firmly the meat paste sets the gel within the setting temperature range and to what extent the set gel degrades within modori temperature range. This is because the mode of setting and modori of meat paste varies widely from species to species. In that case, it is useful to draw temperature-gelation curves for the meat paste. It became clear by analyzing the patterns of the curves that two reactions are contained in the gel forming process of fish meat paste; one is a structure-setting reaction proceeding at temperatures below 50°C, promoted especially at 30-40°C, and other is a structure-disintegration reaction occurring at temperatures between 50 and 70°C, optimum at 60°C. The former reaction was considered to be responsible for the so called "suwari" phenomenon and the latter reaction to the phenomenon known by the name of "modori". Because of wide variation in the rate of both reactions with species, patterns of the gelation curve were highly characteristics with species.
Out of seven marine water species, *Chorinemus lysan* showed the highest gelling performance both in one and two- step heating treatments. *Chorinemus lysan* is a white, fleshed lean fish with minimum and red muscle content. Red muscle

reduces the gel forming ability (Shimizu *et al.*, 1981). Generally speaking, red meat fish are susceptible to "modori". High proportion dark to ordinary muscle, high fat content, instability of muscle proteins and a high "modori" susceptibility of myofibrils might be responsible for the poor gel formation. The dark muscle myosin exhibits quite different properties from ordinary muscle counterpart. One of the most distinguished features of the dark muscle myosin is that its structure is quite unstable in the alkaline region.

In the present study Bombay duck and lizard fish showed low gel forming ability for all incubation periods; the low gel forming ability of this was probably related to denaturation of muscle protein caused by low muscle pH. The pH of this fish was around 6.0 during study period.

Many workers agree that pH is the most important factor associated with change in meat texture (Kramer and Peters, 1981). Ishikawa *et al.* (1977, 1979) have reported that rapid pH decline in sardine muscle during post-mortem ice storage markedly influenced the kamaboko gel forming ability. Among other factors low pH of these muscle might be responsible for their poor gel formation. On setting and gel disintegration, these two different but very common phenomena were observed in the paste of the main species under present investigation. There was, however, the "recovery" of the gel strength at higher temperatures also observed in some species like queen fish and jew fish. The "recovery' was comparatively slight. However, the "recovery in gel strength was not sustained under prolonged heating at high temperatures. This was probably due to the disintegration of the gel structure under excessive heating; this has also been observed by Yamazawa *et al.* (1979), when they heated fish jelly products above 100 °C.

However from the present investigation it was observed that in spite of variation to the gel strength of the products, the meat paste from *Chorinemus lysan, Otolithus argenteus, Leiognethus* spp. *Tachyssurus thalassinnus and Megalespis cordyla* showed the high satisfactory gelling performance except *Saurida tumbil* and *Harpadon nehereus* . Therefore *Chorinemus lysan, Otolithus argenteus, Leiognethus* spp. and *Megalespis cordyla* could successfully be used as raw material for surimi based value added products.

The experiment was conducted to evaluate the washing effect on gel forming ability of *Chorinemus lysan*. The present study indicated that the gel forming ability varied between unwashed and washed meat paste and depend on incubation temperature as described by Nakagawa *et al.* (1989), who reported that gel strength of washed mince had about three times higher than unwashed mince.

The highest gel forming ability was obtained from second washed meat paste followed by first and third washed meat paste. The poor gelling ability was obtained from unwashed meat paste. The result is in agreement with Suwansakornkul *et al.* (1993) and Lee (1966), who stated that washed fish mince is always superior to unwashed mince in gel quality. However peak setting was observed at 45 ^{0}C with distinct but little gel disintegration at 60^{0}C for 120 minutes in two-step heating. The available report suggest that if the product is heated at 60-70^{0}C for about 30 minutes the proteolytic enzymes in many of fish species cause a weakening of final gel structure. The improvements in textural characteristics is possible to make when salt ground surimi is heated in two-steps process at 30-40 °C for short time (1-2h) and then cooked at 80-90 °C for 30 minutes to prepare final kamaboko products (Niwa *et al.*, 1991a.).

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