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Functional properties of fish protein concentrate extracted from ribbon fish, *Lepturacanthus savala* by different methods

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SUMMARY :

Fish protein concentrate (FPC) is a healthy and highly nutritive product produced hygienically from fishes in which, protein and other nutrients are more concentrated than fresh fishes. In the present study an attempt was made to study the functional properties of FPC derived from ribbon fish, *Lepturacanthus savala* so as to know the quality of the FPC. The important findings are summarized as: The chemical analysis of ribbon fish meat was observed to be moisture 76.82 per cent, crude protein 17.75 per cent, fat 2.08 per cent and ash 3.35 per cent. The percentage yield of separated ribbon fish meat was found to be 38 per cent, based on the total weight of fish. The chemical analysis and yield of FPC extracted from ribbon fish by using five different methods *i.e.* British process, Lever brother process, Canadian process, Viobin process and Indian process were observed moisture content as 13.88, 11.77, 10.78, 12.52 and 12.36 per cent, respectively; crude protein content as 81.61, 84.63, 86.80, 84.39 and 84.54 per cent, respectively; fat content as 0.97, 0.87, 0.55, 0.65 and 0.64 per cent, respectively, ash content as 3.54, 2.73, 1.87, 2.44 and 2.46 per cent, respectively and also, the percentage yield of FPC were observed to be 17.54, 17.56, 19.94, 18.19 and 19.61 per cent, respectively. The functional properties of FPC extracted from ribbon fish by using five different methods *i.e.* British process, Lever brother process, Canadian process, Viobin process and Indian process were observed viscosity as 91.67, 92.33, 114.00, 104.00 and 97.00 cP, respectively; solubility as 81.40, 80.09, 88.92, 83.41 and 83.79 per cent, respectively, emulsification capacity as 53.86, 54.67, 67.66, 53.60 and 59.77 per cent, respectively; emulsification stability as 45.03, 46.55, 58.84, 47.76 and 49.75 per cent, respectively, foaming capacity as 28.93, 31.75, 42.50, 32.40 and 35.10 per cent, respectively, foaming stability as 18.37, 20.47, 26.50, 18.87 and 21.42 per cent, respectively and water holding capacity as 2.78, 2.79, 4.27, 3.11 and 3.13 ml/g, respectively.

KEY WORDS : Fish protein concentrate, Chemical analysis, Functional properties, Yield, Ribbon fish

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The adequacy in nutrient intake in terms of quantity and quality are major determinants of health of a nation. India is undergoing nutrition transition and is facing the dual burden of malnutrition *i.e.* problem of under-nutrition and micronutrient deficiencies. Fish is one food that can address this problem unswervingly.

Fish is one of the most important sources of animal protein available worldwide and has been widely accepted as a good source of protein and other elements for the maintenance of healthy body. In recent years the importance of finfish in the diet has extended from its image as a cornerstone of a healthy diet to more specialized roles in the disease prevention. Fish is one of the most nutritious foods available for human consumption. Fish flesh on an average contains 18–20 per cent protein (Balachandran, 2012).

FPC can play an effective role in decreasing protein deficiency in some crowded parts of the world that suffers from malnutrition. Studies have shown that adding FPC to human diets has positive effects especially for growing babies and pregnant women (FAO, 2006). FPC is a low cost animal protein with high quality, so it can be used as a protein supplement to increase nutritive value of foods (Cordova-Murueta *et al.*, 2007). Considerable works were done to develop FPC production methods and use it in different foods, but unfortunately there is little information about sustainability of FPC during storage at different environmental conditions (Rasekh *et al.*, 2001).

The methods practiced elsewhere based on solvent extraction e. g. French process, Viobin process, Canadian process, British process, Lever-Brother process, Indian process etc. are riot free from drawbacks. In extraction by acetone, difficulty is experienced to remove traces of acetone even under reduced pressure. Moreover acetone is less efficient in lipid liberation and will extract substances other than lipids (Moorjani *et al.*, 1962). In Viobin process, which employs the principle of azeotropic extraction with ethylene dichloride, (Moorison and Munro, 1965) showed that ethylene dichloride destroys cysteine, histidine and interfere with the release of cysteine, histidine and methionine by pancreatic digestion. Another important process employed for the preparation of edible fish flour is the Canadian process which employs isopropyl alcohol for the extraction; but the flour retains a solvent taint even after prolonged steam stripping under vacuum (Moorjani *et al.*, 1962). The process was later modified and extended to the preparation of edible FPC from whole fish by the Bureau of Commercial Fisheries U.S.A. (1966). MIT-UNICEF process described by Allen (1963) employs hexane and alcohol for the extraction of fat.

Functional properties of food macromolecules including proteins are defined as a set of physico-chemical characteristics that contribute to the structural, mechanical and other physico-chemical properties and determine the behaviour of food systems during processing, storage, preparation and consumption. The commonly used functional properties of proteins in foods include solubility, viscosity, water holding capacity, gelation, emulsification and foaming (Hamann, 1994).

The annual marine fish landing of India was 37, 81, 868 tonnes out of total ribbon fish landing of India was 2, 52, 179 tones (CMFRI, 2013). The total marine fish landing of Maharashtra state was 26, 749 tonnes out of total ribbon fish landing was 27, 329 tonnes and the total ribbon fish landing of Ratnagiri district was 7, 840 tonnes (Maharashtra state fisheries, Dept. 2012-2013).

The aims of present study were to extract FPC from minced meat of the ribbon fish (*Lepturacanthus savala*) as a raw material for the production of FPC. The ribbon fish (*Lepturacanthus savala*) was available throughout the fishing seasons, cheapest and white flesh meat over other marine fishes. Therefore, ribbon fish was used in the present study.

EXPERIMENTAL METHODS

Fresh ribbon fish, *Lepturacanthus savala* locally known as 'Bala' was used for the preparation of FPC. The fresh ribbon fishes were purchased from Mirkarwada landing center and transported in iced condition and then cleaned, minced and frozen in deep freezer at -18°C until further process. All the media and chemicals were used in this study were purchased from Hi-media and MERCK Chemical Company Pvt. Ltd., Mumbai, India, respectively.

Separation of meat:

The fishes were washed thoroughly and dressed (descaled, beheaded and evisarated) then put into the meat separator to separate meat and passed through the strainer.

Preparation of FPC:

Five different methods were tried for extraction of FPC *viz.*,

Method for preparation of fish protein concentrate by the British process (Govindan, 1985) :

– Cooked meat is minced with equal weight of acetone for 45 min., filtered, pressed and the residue dried under vacuum

– Then it is mixed with an equal weight of 90 per cent ethyl alcohol (refluxed for 45 min., cooled, filtered, pressed and the residue dried under vacuum)

– Dried mass is once again extracted with alcohol, filtered, heated under vacuum to drive away the last traces of solvent

– Pulverized

– Stored at ambient temperature (25 ± 2°C)

Method for preparation of fish protein concentrate by the Lever-brothers process (Govindan, 1985) :

– Minced meat is mixed with 1 per cent by weight of sodium sulphite and sufficient sodium hydroxide solution to raise the pH to 10.

– Mixture is dried, extracted with 95 per cent ethanol containing a small amount of Sulphuric acid and solvent filtered off

– Residue is suspended in water, pH adjusted to 7, stirred well

– Filtered

– Pressed and dried at 50°C

– Stored at ambient temperature (25 ± 2°C)

Method for preparation of fish protein concentrate by the Canadian process (Govindan, 1985) :

– Fish is comminuted in a grinder

– Acidified with phosphoric acid to pH 5.5

– Cooking for 30 minutes at 70–80°C with stirring

– Filtered residue washed with hot water

– Residue suspended in double volume of isopropyl alcohol and refluxed for 15 min

– Solvent removed by filtration/ centrifugation

– Again treated with solvent until water and oil are reduced to desired level

– Residue after final treatment is pressed dried and pulverized

Method for preparation of fish protein concentrate by the Viobin process (Govindan, 1985) :

– Fish muscle is ground well

– suspended in ethylene dichloride (B.P. 181°C) and heated externally with steam

– The solvent forms an Azeotropic mixture (B.P. 160°C) with the water (B.P. 160°C) in the muscle and distils over

– When all the water is removed, the mixture of residual solvent, which holds all the fat present in the fish meat in solution, and the dehydrated meat are separated by filtration

– Meat portion washed repeatedly with the solvent to remove all adhering fat, freed from all the solvent by heating

– Pulverized

– Packaging

– Stored at ambient temperature (25 ± 2°C)

Method for preparation of fish protein concentrate by the Indian process (Govindan, 1985) :

– Minced meat is cooked with an equal volume of 0.5 per cent acetic acid, allowed to settle and the oil that floats on the surface laded off

– The slurry is filtered through canvas bags and pressed

– The press–cake is extracted first with ethanol which removes both odour and moisture

– Then ethanol which removes both odour and moisture and then with an Azeotropic mixture of hexane and ethanol (33.2 mole % of ethanol; B.P. 58.69°C)

– Filtered, pressed, and dried under vacuum

– It is then steam–stripped to remove the last traces of solvent, dried under vacuum,

– Pulverized

– Packed

– Stored at ambient temperature (25 ± 2°C)

Chemical analysis:

Chemical analysis of raw materials and extracted FPC powder were analyzed by measuring moisture, ash, protein and fat contents according to AOAC official methods (AOAC, 2005).

Functional properties of FPC:

Determination of viscosity :

FPC sample was determined according to the method of Cho *et al.* (2006). FPC solutions at the concentration of 6.67 per cent (w/v) were prepared by dissolving the dry powder in distilled water and heating at 60°C for the determination of viscosity. The viscosity (cP) of 10 ml of the solution was determined using Brookfield digital

viscometer (Model DV – E Brookfield Engineering, USA) equipped with a number 1 spindle at 40°C ± 1°C.

Determination of solubility :

The solubility of FPC was determined according to Hoyle and Merritt (1994). About 500 mg of FPC sample was accurately weighed and dispersed in 50 ml of 0.1M NaCl at pH 7. The solution was stirred for 1 hr. and centrifuged for 30 min at 10,000 rpm. The supernatant was analyzed for nitrogen by the micro–Kjeldhal method (AOAC, 2005). The Nitrogen Solubility Index (NSI) was calculated as,

$$\text{NSI \%} = \frac{\text{Supernatant nitrogen concentration (mg)}}{\text{Sample nitrogen concentration (mg)}} \times 100$$

Emulsifying capacity and stability :

The method of Butt and Batool (2010) was used to determine emulsifying capacity and stability. FPC sample (1.8 g) was added to 25 ml of distilled water (pH 7) and dispersed at maximum speed in a homogenizer/ blender. Corn oil (12.5 ml) was added and homogenized/ blended at high speed for 1 min.; the emulsion formed was equally divided into two 12 ml centrifuge tubes and centrifuged for 5 min. at 5200 rpm. Emulsion capacity was calculated as follows:

$$\text{Emulsifying capacity (\%)} = \frac{\text{Height of emulsified layer}}{\text{Height of total contents of tube}} \times 100$$

Emulsion stability was determined in a similar way to that of emulsion capacity except that the emulsion was initially heated in a water bath at 85°C for 30 minutes and subsequently cooled to 25°C prior to centrifugation.

$$\text{Emulsifying stability (\%)} = \frac{\text{Height of emulsified layer after heating}}{\text{Height of total contents of tube}} \times 100$$

Foaming capacity and stability :

The method of Miller and Goninger (1976) was used to determine foaming properties. The FPC powder (1 g) was added to 100 ml of distilled water and homogenized for 1 min. at high speed. The mixture was carefully transferred into a 250 ml calibrated beaker for volume measurement. The foam was calculated as the volume of mixture after blending compared to the original volume. The foaming stability was the ratio of the foam capacity after 30 min. divided by the original foam capacity.

Estimation of water holding capacity :

Water holding capacity (WHC) was determined using the centrifugation method (Diniz and Martin, 1997). Duplicate samples (0.5 g) of FPC were dissolved in 20 ml of water in centrifuge tubes and dispersed with a vortex mixer for 30 sec. The dispersion was allowed to stand at room temperature for 6 hr, and then centrifuged at 2800 ×g for 30 min. The supernatant was filtered with Whatman No. 1 filter paper and the volume recovered was measured. The difference between the initial volume of distilled water added to the protein sample and the volume of the supernatant was determined, and the results were reported as ml of water absorbed per gram of FPC sample.

Statistical analysis :

The data were analysed to test significant difference by applying analysis of variances (ANOVA) tool available in MS-Excel 2010. The significant differences were tested by 5 per cent level of significances and are mentioned as $p < 0.05$ for significances difference (Zar, 1999).

EXPERIMENTAL FINDINGS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Chemical analysis of ribbon fish (*Lepturacanthus savala*) meat :

Chemical analysis of ribbon fish meat is shown in Table 1. Chemical analysis of ribbon fish meat was observed to be moisture 76.82 per cent, crude protein 17.75 per cent, fat 2.08 per cent and ash 3.35 per cent. On similar line the biochemical quality of fresh ribbon fish showed that 75.66 per cent moisture content, 17.66 per cent crude protein content, 2.08 per cent fat content and 0.76 per cent ash content (Relekar *et al*., 2014). The variation noted in proximate composition may be due to seasonal and size variation of the fish selected.

Table 1 : Chemical analysis of Ribbon fish (*Lepturacanthus savala*) meat

Ribbon fish meat	Proximate composition (%)
Moisture	76.82
Crude protein	17.75
Fat	2.08
Ash	3.35

Yield (%) :

In the present study Ribbon fish (*Lepturacanthus savala*) was used for preparation of FPC. The non-edible portion of fish such as head, gut, fin and intramuscular bones were removed and meat was separated. The yield of ribbon fish separated meat was 38 per cent that was showed in Table 2. According to Joseph and Perigreen (1989) yield percentage of picked meat from horse mackerel *(Megalespsiscordyla)*, Ribbon fish *(Trichiurus savala)*, pola (*Chorinemus tala*), vatta *(Selaroides leptolepis)* and tuna *(Euthynnus affinis)* were 34, 35, 51.2, 40.2 and 46.2 per cent, respectively. This may be dueto wash mince-meat used. The yield percentage of separate mince for whole tilapia was 33.2 per cent as reported by Ninan *et al.* (2008).

Table 2 : Yield (%) meat separated from Ribbon fish (*Lepturacanthus savala*)

Particulars	Yield (%)
Whole raw fish	100
Whole dressed fish	62
Separated meat	38

Chemical analysis of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods :

Moisture content :

In present study, moisture content of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 13.88, 11.77, 10.78, 12.52 and 12.36, per cent, respectively (Table 3). The moisture content was significantly ($p<0.05$) lower in Canadian process as compared to British process, Lever-brother process, Viobin process and Indian process. In Canadian process acidified treatment was given, due to acidified treatment the protein content in meat were denatured because of that reason the moisture content of FPC were lowest. Asfar *et al.* (2014) has been reported the similar value of water content of albumin extraction from Snakehead fish, *Channa striatus* in producing the FPC by using different treatment such as A_1B_1 = water solvent without heating; A_1B_2 = water solvent with heating at temperature 50–60°C for 10 min.; A_2B_1 = HCl 0.1M solvent without heating; A_2B_2 = HCl 0.1M solvent with heating at temperature 50-60°C for 10 min.; A_3B_1 = ethanol 50 per cent solvent without heating and A_3B_2 = ethanol 50 per cent solvent with heating at temperature 50–60°C for 10 min. were 10.93, 21.53, 8.49, 13.92, 13.31 and 16.25 per cent, respectively.

Protein content :

Proteins are highly complex nitrogenous organic substances of very high molecular weight. They are colourless, amorphous and colloidal in nature. Proteins are polymers of amino acids that contain the elements carbon, hydrogen, oxygen, nitrogen and, in some cases, sulphur. The amino acids are united by a peptide linkage –CO-NH- (Balachandran, 2012). In present study, protein content of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 81.61, 84.63, 86.80, 84.39 and 84.54 per cent, respectively (Table 3). The protein content was significantly ($p<0.05$) higher at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process. In Canadian process acidified treatment was given, due to acidified treatment the protein content in meat were denatured because of that reason the protein content was highest.Ooshiro *et al.* (1981) has been reported similar result of total protein content of FPC extracted from Sardine (*Sardinopsme lanosticta*) was prepared using ethanol and n-hexane by low temperature treatment were found to be 85 per cent. Spencer *et al.* (1971) has been used FPC as supplementation that contained 89.4 per cent protein. Muraleedharan and Gopakumar (1998) reported the similar results of protein content of functional protein concentrate from Tuna, *Euthynnus affinis* were 89.5

Table 3 : Chemical analysis of FPC extracted from Ribbon fish (*Lepturacanthus savala*) by using five different methods

FPC Extraction process	Moisture%	Protein%	Fat%	Ash%
British process	13.88±0.80	81.61±0.84	0.97±0.14	3.54±0.21
Lever-brother process	11.77±0.34	84.63±0.26	0.87±0.09	2.73±0.26
Canadian process	10.78±0.47	86.80±0.54	0.55±0.02	1.87±0.14
Viobin process	12.52±0.23	84.39±0.28	0.65±0.09	2.44±0.05
Indian process	12.36±0.25	84.54±0.45	0.64±0.04	2.46±0.31

per cent.

Fat content :

In present study, fat content of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 0.97, 0.87, 0.55, 0.65 and 0.64 per cent, respectively (Table 3). The fat content was significantly ($p<0.05$) lower at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process. In Canadian process acidified treatment was given, due to acidified treatment the protein content in meat were denatured because of that reason the fat content of FPC were lowest. Napugan *et al.* (1961) has reported the similar values of fat content of FPC prepared from Lizard fish, *Sauridatumbil* were found to be 0.5 per cent. Gopakumar and Shenoy (1977) have been observed the similar values of fat content of FPC and FFPC from Catfish, *Tachysurusjella* were found to be 0.2 and 0.35 per cent, respectively.

Ash content :

Ash was the portion left after complete combustion of the organisms (Balachandran, 2012). In present study, ash content of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 3.54, 2.73, 1.87, 2.44 and 2.46 per cent, respectively (Table 3). The ash content was significantly ($p<0.05$) lower at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process. In Canadian process acidified treatment was given, due to acidified treatment the protein content in meat were denatured because of that reason the ash content of FPC were lowest.Mahesh *et al.* (1993) has been reported the similar values of ash content of FFPC extracted by using various treatments enzymes and different drying methods were namely, Enzyme treated and vacuum dried FFPC, Enzyme treated (0.25 %) and spray dried FFPC, and Enzyme treated (0.5 %) and spray dried FFPC as 1.8, 2.2 and 2.4 per cent, respectively. Gopakumar (1997) has given in the book of tropical fishery products the FPC extracted from ribbon fish, *Trichiurus savala* (mince-meat) ash content was found to be similar value 1.4 per cent. Shenoy *et al.* (1977) has been reported similar results of ash content of FPC extracted from eviscerated meat of ribbon fish were found to be 1.4 per cent.

Percentage yield of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods :

In present study, Percentage yield of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 17.54, 17.56, 19.94, 18.19 and 19.61 per cent respectively (Table 4). The Percentage yield was significantly ($p<0.05$) higher at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process.Solanki *et al.* (1977) has been showed the similar value of yield percentage of Dhoma powder samples prepared by different methods were whole fish paste dried and powdered as such; steam cooked whole fish, pressed, dried and powdered; fillets minced, dried and powdered as such; minced fillets cooked in water containing acetic acid, pressed, dried and powdered; defatted whole fish press cake dried and powdered; and defatted fillets press cake dried and powdered as 17.5, 17, 9.9, 7.3, 12 and 7 per cent, respectively. Napugan *et al.* (1961) has reported the similar values of yield percentage of FPC prepared from Lizard fish, *Saurida tumbil* were found to be 18.56 per cent.

Table 4 : Yield of FPC extracted from Ribbon fish (*Lepturacanthus savala*) by using five different methods

FPC Extraction methods	Yield (%)
British process	17.54 ± 0.14
Lever brother process	17.56 ± 0.11
Canadian process	19.94 ± 0.27
Viobin process	18.19 ± 0.07
Indian process	19.61 ± 0.20

Functional properties of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods :

Viscosity :

Viscosity of proteins provides information on physico-chemical interaction among proteins indicating structural changes that may occur in the protein molecules (Kinsella, 1976). The measurement of viscosity provides useful information on shape and state of protein molecules

(Prakash, 1982). The viscosity of protein solution was directly related to protein concentration (Sarma *et al.*, 2000). In present study viscosity of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 91.67, 92.33, 114.00, 104.00 and 97.00 cP, respectively (Table 5). The viscosity was significantly ($p<0.05$) higher at Canadian process as compared to British process, Lever-brother process, Viobin process and Indian process. Viscosity was partially controlled by molecular weight and molecular size distribution (Sperling, 1985).Mahesh *et al*. (1993) has been reported the viscosity of FFPC extracted by using various treatments enzymes and different drying methods were Enzyme treated and vacuum dried FFPC at different concentration 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 per cent as 114, 116, 118, 120, 123, 125 cP; Enzyme treated (0.25%) and spray dried FFPC at different concentration 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 per cent as 116, 118, 121, 123, 125,127 cP; and Enzyme treated (0.5%) and spray dried FFPC at different concentration 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 per cent as 116, 118, 121, 123, 125,127 cP, respectively.

Solubility :

Solubility was considered important for a protein to exhibit its functional properties (Kinsella, 1984). It was the quantity of protein that goes in to solution under specified conditions (Xiong, 1997) and was influenced by amino acid composition and sequence, conformation and the content of polar and non-polar groups of amino acids in the protein (Zayas, 1997). Protein solubility was a delicate balance between repulsive and attractive intermolecular forces, which are dependent on native structure of protein, extraction medium and extraction conditions (Ramachandran *et al.*, 2010). In present study solubility of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 81.40, 80.09, 88.92, 83.41 and 83.79 per cent, respectively (Table 5). The solubility was significantly ($p<0.05$) higher at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process. Sathivel *et al.* (2009) has reported the nitrogen solubility of catfish roe protein powder was found to be 64.0 per cent.

Emulsification capacity :

Emulsifiers are surface active materials that adsorb to interfaces and facilitate the production of small droplets by lowering the interfacial tension during homogenization (Walstra, 2003). In present study emulsification capacity of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 53.86, 54.67, 67.66, 53.60 and 59.77 per cent, respectively (Table 5). The emulsification capacity was significantly ($p<0.05$) higher at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process. FPC from whole fish prepared by isopropyl alcohol extraction has been described, which exhibited a decreased emulsifying capacity (Sikorski *et al.*, 1981). Shaviklo (2015) has reported emulsification capacity of fish protein powder by using different types of drying methods were freeze dried saithe protein isolate without additives; freeze dried fish protein isolate (5% sucrose and 0.2% phosphate); spray dried saithe with additives (2.5% sucrose and 0.2% phosphate); freeze dried saithe without additives and freeze dried saithe with additives (2.5% sucrose and 0.2% phosphate) as 78.51, 82.45, 61.35, 50.24 and 83.40 per cent, respectively.

Emulsification stability :

In present study emulsification stability of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 45.03, 46.55, 58.84, 47.76 and 49.75 per cent, respectively (Table 5). The emulsification stability was significantly ($p<0.05$) higher at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process. Shaviklo (2015) has reported emulsification stability of fish protein powder by using different types of drying methods were freeze dried saithe protein isolate without additives; freeze dried fish protein isolate (5% sucrose and 0.2% phosphate); spray dried saithe with additives (2.5% sucrose and 0.2% phosphate); freeze dried saithe without additives and freeze dried saithe with additives (2.5% sucrose and 0.2% phosphate) as 76.50, 76.55, 47.51, 39.23 and 60.45 per cent, respectively.

Table 5 : Functional properties of FPC extracted from Ribbon fish (*Lepturacanthus savala*) by using five different methods

Functional properties	FPC Extraction process				
	British process	Lever-brother process	Canadian process	Viobin process	Indian process
Viscosity (cP)	91.67 ± 2.33	92.33 ± 2.60	114.00 ± 3.06	104.00 ± 1.15	97.00 ± 2.08
Solubility (%)	81.40 ± 1.36	80.09 ± 1.16	88.92 ± 1.24	83.41 ± 1.61	83.79 ± 0.54
Emulsification capacity (%)	53.86 ± 0.85	54.67 ± 1.27	67.66 ± 2.84	53.60 ± 1.21	59.77 ± 1.23
Emulsification stability (%)	45.03 ± 1.58	46.55 ± 1.11	58.84 ± 1.85	47.76 ± 0.54	49.75 ± 1.54
Foaming capacity (%)	28.93 ± 2.06	31.75 ± 0.70	42.50 ± 2.29	32.40 ± 0.83	35.10 ± 1.84
Foaming stability (%)	18.37 ± 1.23	20.47 ± 1.26	26.50 ± 2.12	18.87 ± 1.45	21.42 ± 1.50
Gelation (g.cm)	15.50 ± 1.73	12.50 ± 1.15	26.50 ± 1.13	14.50 ± 0.58	18.50 ± 1.15
Water holding capacity (ml/g)	2.78 ± 0.27	2.79 ± 0.12	4.27 ± 0.16	3.11 ± 0.13	3.13 ± 0.22

Foaming capacity :

Foaming capacity depends on molecular flexibility and physico-chemical properties of proteins. In present study foaming capacity of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 28.93, 31.75, 42.50, 32.40 and 35.10 per cent, respectively (Table 5). The foaming capacity was significantly ($p<0.05$) higher at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process. Shaviklo (2015) has reported foaming capacity of fish protein powder by using different types of drying methods were freeze dried saithe protein isolate without additives; freeze dried fish protein isolate (5% sucrose and 0.2% phosphate); spray dried saithe with additives (2.5% sucrose and 0.2% phosphate); freeze dried saithe without additives and freeze dried saithe with additives (2.5% sucrose and 0.2% phosphate) as 155.44, 189.72, 197.51, 152.54 and 185.34 per cent, respectively.

Foaming stability :

Foam stability depends on the nature of the film and indicates the extent of protein interaction within the matrix (Mutilangi *et al.*, 1996). In present study foaming stability of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 18.37, 20.47, 26.50, 18.87 and 21.42 per cent respectively (Table 5). The foaming stability was significantly ($p<0.05$) higher at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process. Chalamaiah *et al.* (2013) has showed the results of foam stability of dehydrated and defatted egg protein concentrates extracted from Mrigal, *Cirrhinus mrigala* on the basis of time such as after 30 min. were noted as 20.0 and 3.0 respectively; and after 60 min. were noted as 18.0 and 2.0, respectively.

Water holding capacity :

The functional properties of proteins in a food system depend in part on the water holding capacity (WHC) which refers to the ability of protein to imbibe water and retain it against a gravitational force within protein matrix. In present study water holding capacity of FPC extracted from ribbon fish (*Lepturacanthus savala*) by using five different methods (British process, Lever-brother process, Canadian process, Viobin process and Indian process) were found to be 2.78, 2.79, 4.27, 3.11 and 3.13 ml/g respectively (Table 5). The water holding capacity was significantly ($p<0.05$) higher at Canadian process of compared to British process, Lever-brother process, Viobin process and Indian process. Mahesh *et al.* (1993) has been reported the water holding capacity of FFPC extracted by using various treatments enzymes and different drying methods were Enzyme treated and vacuum dried FFPC, Enzyme treated (0.25%) and spray dried FFPC and Enzyme treated (0.5%) and spray dried FFPC as 232.50, 252.40 and 278.20 per cent, respectively.

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