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Characterization of Extrudate Prepared from Rice (*Oryza sativa* L) and Chapra (*Fenneropenaeus indicus*) by Twin Screw Extrusion

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Abstract

Rice (*Oryza sativa* L) and chapra (*Fenneropenaeus indicus*) mixture was extruded using a co-rotating fully intermeshing twin-screw extruder. The extrudates were analyzed for protein solubility, Water Absorption Index (WAI), Water Solubility Index (WSI) and fragmentation during twin-screw extrusion. Protein solubility significantly decreased with increase in process temperature. Phosphate buffer with added urea was found to extract more protein than plain buffer solution. SDS polyacrylamide gel electrophoresis indicated no fragmentation in protein part. Response surface methodology was used to determine the effect of barrel temperature (120-165°C) and feed moisture content (10-20%) on the WAI and WSI of the extrudate. WAI decreased with increase in temperature from 120-135°C and increased with further increase in temperature from 135-165°C. Similarly, decrease in WSI values with increase in temperature and moisture was observed.

Key words: Shrimp, fish protein, extrusion, viscosity, SDS page, protein solubility

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Introduction

Thermoplastic extrusion is widely used for continuous production of expanded products like breakfast cereals and snack (Alavi et al., 1999; Moraru et al., 2003; Singh & Gamlath, 2007). Marine food acquires importance because of its abundant availability and being the richest source of protein of low calorie. The demand for crustaceans like crab and shrimp is of special mention because of their relatively mild flavour, excellent taste and texture and as an excellent source of selenium and low-fat, low-calorie protein (Sasamoto et al., 1989).

Indian white shrimp locally known as chapra (*Fenneropenaeus indicus*) contains 20% protein, 1% fat, 76% moisture and 1.5% ash (USDA, 2002). A large amount of chapra is wasted every year due to lack of proper preservation. Chapra and rice flour were extruded to improve the nutritional quality and to study its related functionality. The objective of the present work was to study the effect of the extrusion variables on protein solubility, fragmentation pattern, water solubility and water absorption index of the extrudate.

Materials and Methods

Rice (*Oryza sativa* L) and salt procured from local market and chapra (*Fenneropenaeus indicus*) collected from coastal areas of West Bengal were used for the study. Chapra was brought to laboratory in iced condition, washed thoroughly in fresh water, drained and dried in an oven (800 W grill oven Sanyo, JP) at 60°C for 2 h. Rice collected from local market was also washed and dried under similar conditions. Dried shrimp and rice were finely ground into powder form with a blender (Mixer Grinder, Bajaj GM-550) separately. Rice and shrimp flour was mixed in 5:1 ratio, packed in polyethylene bags and stored at 4°C for conditioning.

A co-rotating fully intermeshing twin screw extruder was used (screw profile 12:1, barrel length 350 mm, barrel bore diameter 38 mm, screw diameter 37.8 mm, conveying angle 30°, intermeshing screws, 24 mm apart) for extrusion of the feed mixture using a 3 mm diameter die. The screw speed of the extruder was set at 475 rpm while the feed rate was maintained constant at 28 g min^{-1}. The extruder functioned properly with the said feed mixture at 110°C and at 11% feed moisture but stopped totally after 170°C and 19% feed moisture. Rice and shrimp flour mixture was extruded at four different process conditions. The temperature of the extruder barrel was thus maintained at 120, 130, 150 and 165°C respectively and the moisture was adjusted to 11, 13, 15 and 17% adding the required amount of water to the flour mixture and conditioned at room temperature for 48 h. Extrudate viscosity, protein solubility, fragmentation, Water Absorption Index (WAI) and Water Solubility Index (WSI) were studied for the extrudate obtained by four process conditions. Moisture content of control and extruded products was measured as per AOAC (2002). Protein solubility test was performed for both unextruded material and extrudate products using the method described by Lowry et al. (1951). WAI and WSI were determined using the method outlined by Anderson et al. (1969). Polyacrylamide gel was prepared according to Laemmlie's protocol (1970) to study the protein bands after extrusion.

Results and Discussion

The protein solubility in different extracting solutions of unextruded and extrudate are depicted in Table 1. Extractable protein decreased in all solvents as the extrudate temperature increased. Protein solubility was measured to investigate the forces that were responsible for stabilizing the extrudate during the extrusion. Moisture content of each sample was determined before protein extraction. The extractable protein decreased in all solvents after extrusion (Table 1). This may be due to the formation of new chemical linkages, such as non-disulphide chemical bonds that were not disrupted by the solvents used resulting in some polymers with very high molecular weight. The amount of protein extracted by phosphate buffer in both raw material and extrudate was significantly less than the amount extracted with addition of denaturing agent like mercaptoethanol and urea. This may be due to the fact that plain phosphate buffer solubilize only protein molecules that are in native state. When a second solvent mercaptoethanol was combined with phosphate buffer, protein solubility increased which suggest that protein aggregated with more than one type of chemical bond. Phosphate buffer plus urea was the highest extracting solvent indicating that significant portion of protein was linked with hydrogen bonds. For the same solvent, protein solubility decreased with increase in extrudate temperature as indicated in Table 1.

The ANOVA indicated that cooking temperature had significant effect on protein solubility in all solvents ($p<0.05$) whereas moisture condition did not affect the amount in extractable protein. With increase in temperature from 110-150°C the decrease in extractability of protein was due to cross-linking of protein structure. Extrusion at 165°C, caused structural damage of the extrudate and it became rigid and thus decrease in extractable protein was observed. The above result was in agreement with the result of Harvath & Czukor (1993). In their study, the cooking temperature significantly affected the amount of extractable protein below 20% moisture level. WAI is used to give an indication of degree of cooking. Both WAI and WSI can be used as an indication of degree of molecular damage *viz.*, these are two important parameters for defining the

Table 1. Protein solubility in different extracting solutions of unextrudate and extrudate

Samples	PB	Protein Solubility (%) PB+Mercaptoethanol	PB+Urea
Unextrudate	0.958 ± 0.004	2.98 ± 0.004	3.87 ± 0.003
A	0.667 ± 0.002	2.678 ± 0.003	3.17 ± 0.003
B	0.332 ± 0.003	2.123 ± 0.002	2.87 ± 0.002
C	0.228 ± 0.002	1.923 ± 0.003	2.85 ± 0.001
D	0.112 ± 0.001	1.123 ± 0.002	1.87 ± 0.003

A: Extrusion at 120°C; B: Extrusion at 135°C; C: Extrusion at 150°C; D: Extrusion at 165°C; PB: phosphate Buffer (pH 6.9); 8 molar urea
Values are mean ± SD (n=3)

applications of extrudates as ingredients and in predicting the material behaviour, if further processed (Sriburi & Hill, 2000).

Table 2 indicates the changes of WAI and WSI of rice and shrimp protein mixture at four different extrusion conditions. WAI increases with increasing moisture. While increasing extrusion temperature from 110-130°C, the decrease observed in WAI was probably due to an increase in starch degradation (Collonna & Mercier, 1983; Badrie & Mellowes, 1991b). The increase in WAI was observed when temperature increased from 130 -165°C. This effect of extrusion variables on WAI is shown in Fig.1. The result indicated significant effect ($p<0.05$) of extrusion variable. The said behaviour might have been caused by the structural modification of carbohydrate-protein interaction. Four different temperature and moisture range were described by fitting a quadratic, linear regression model. The resultant polynomial for the variable is as follows:

$$Y=0.17\, x_2^2+0.003\, x_2\, x_1+0.005\, x_1^2-0.553\, x_2-1.331\, x_1+96.858$$

The reduction of WAI indicated starch degradation, and the further increase at higher shear condition was probably due to structural modification of fibre as previously mentioned. Badrie & Mellowes (1991a) reported changes from a more sheet like microstructure to a more disrupted appearance when shear increased.

Table 2. WAI and WSI at different extrusion conditions

Temperature (°C)	Moisture %	WSI g g^{-1}	WAI g g^{-1}
120	10	10.80 ± 0.01	10.24 ± 0.01
120	15	9.56 ± 0.03	11.56 ± 0.02
120	17	9.05 ± 0.02	12.05 ± 0.03
120	20	8.07 ± 0.01	14.07 ± 0.04
135	10	9.56 ± 0.01	8.97 ± 0.05
135	15	9.12 ± 0.005	9.23 ± 0.03
135	17	8.89 ± 0.05	9.78 ± 0.05
135	20	8.04 ± 0.04	10.12 ± 0.06
150	10	8.78 ± 0.01	11.56 ± 0.02
150	15	8.45 ± 0.02	12.08 ± 0.01
150	17	8.12 ± 0.03	13.06 ± 0.03
150	20	8.06 ± 0.01	14.05 ± 0.04
165	10	8.56 ± 0.02	15.08 ± 0.01
165	15	8.45 ± 0.03	15.67 ± 0.02
165	17	8.23 ± 0.04	16.23 ± 0.04
165	20	8.10 ± 0.06	16.78 ± 0.01

WAI: Water Absorption Index; WSI: Water Solubility Index

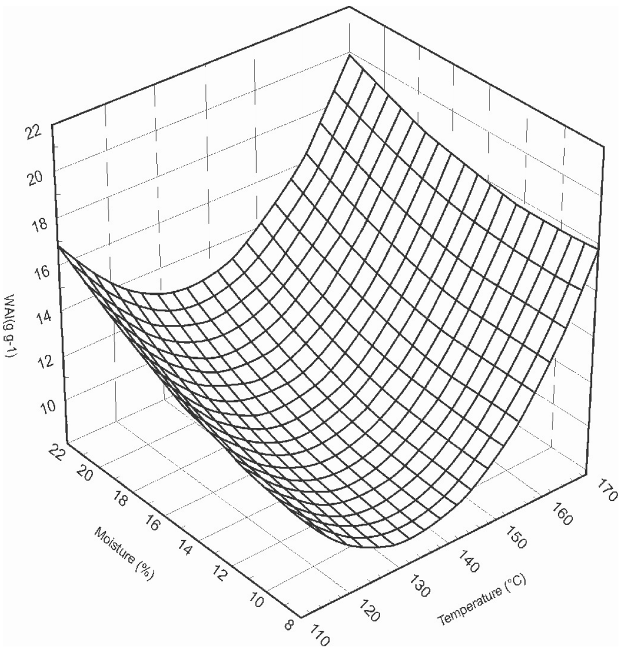

Fig. 1. Effect of extrusion variable on Water Absorption Index (WAI)

WSI decreases with increase in added moisture and temperature. Table 2 indicated four different temperatures and moisture range as described by fitting a quadratic, linear regression model. The effect of extrusion variable on WSI is explained in Fig. 2. ANOVA indicated significant ($p<0.05$) effect of two extrusion variables on WSI data. The resultant polynomial for the variable was as follows:

$$Y= 0.001\, x_1^2+0.005\, x_2\, x_1-0.005\, x_2^2-0.252\, x_1-0.686 x_2+34.717$$

Fig. 3 represented sodium dodecyl sulphate polyacrylamide gel electrophoresis of column fraction of unextruded and extruded rice and chapra mixture. Almost no difference in the polypeptide-banding pattern of unextrudate and extrudate was observed indicating that the process did not alter the pattern of protein. Polypeptide of 100, 70, 40, 25 kDA ranges were obtained in all the samples. Absence of new polypeptide provides evidence of no covalent breakage after extrusion.

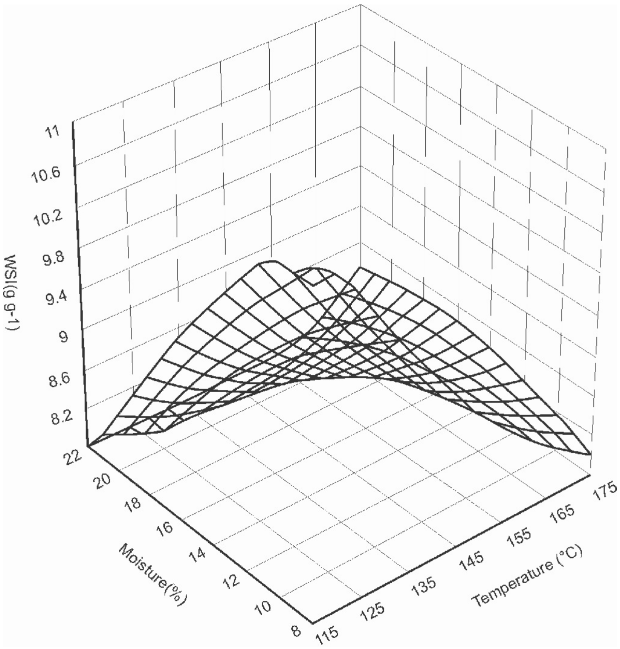

Fig. 2. Effect of extrusion variable on Water Solubility Index (WSI)

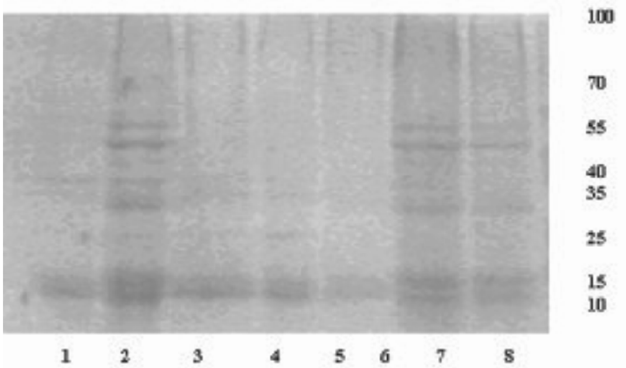

Fig. 3. Sodium dodecyl sulphate polyacrylamide gel electrophoresis of column fraction of unextruded and extruded rice and chapra mixture. 1: unextruded; 2, 3 & 4: extruded at 150°C; 5 & 6: extruded at 135°C; 7 & 8: extruded at 120°C

The extrusion process parameters (barrel temperature and moisture) markedly affect the protein solubility of rice and chapra mixture. Decrease of protein solubility with increase in temperature revealed the presence of chemical bond in extrudate. Protein solubility data predict the extent of soluble solid available after extrusion which is also an important criterion for fabrication of new food product. WAI and WSI are also two important parameters for defining the applications of extrudates as ingredients and in predicting the behaviour of material for further processing. High WSI is related to stickiness of extrudate while decrease in WSI made the product more acceptable at higher extrusion temperature.

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