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Development of protein enriched shrimp croquette from shrimp industry wastes

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Abstract

Protein fortified and tasty shrimp croquette was developed from different component parts of shrimp wastes by using a combination of vegetables (potato, Colocasia, green banana, green papaya and spinach), spices (green chili, onion, garlic, turmeric, red pepper and ginger) and other ingredients (salt, wheat flour, egg, sugar and milk powder). The ingredients were mixed with variable quantities of shrimp shell powder (3, 5 and 10%), shaped and covered with egg and bread crumb. Proximate composition of shrimp shell powder (SSP) and shrimp croquette was determined as crude protein, crude lipid, ash and moisture. It was observed that the SSP contained 47.48±0.74% crude protein indicating its potentiality as a good protein source for the food industry. The lipid content of SSP was 10.50±0.71% and 19.61±0.64%. When SSP was used in the croquette, protein content increased with the higher levels of SSP. The final protein content found were 7.22±0.66, 9.39±0.37 and 11.73±0.61% in the croquettes added with 3, 5 and 10% SSP, respectively. The suggested recipes containing 5% SSP were preferred by the panelists on the basis of their overall quality. Sensory, chemical and microbiological quality changes of shrimp croquette were determined to evaluate the shelf life and storage stability under different storage conditions. At room temperature shelf life of shrimp croquette was very short, in fact not more than 24 hours. On the other hand, at refrigeration temperature it remained in good condition up to 10 days. At frozen storage it remained in good condition for 1 month. The research reveals that good quality protein fortified shrimp croquette could be manufactured from shrimp shell wastes.

Keywords: Shrimp, Shrimp industry wastes, Shrimp croquette

Introduction

Shrimp and prawn are the most valuable seafood in international trade and considered to be the most important products of aquaculture in Bangladesh. Total production of shrimp and prawn in Bangladesh in 2007-2008 was 2,23,095 metric tons (MT) as against 57,656 MT two decades ago (DoF, 2009). Most of the cultured and captured shrimps are processed as frozen products and exported to the United States, EU and Japanese markets. A total of 49,907 MT of frozen shrimp products were exported in 2007-2008 earning about 409 million US dollar (DoF, 2009). The shrimp processing industries produce a vast amount of wastes varying from 40-80% depending upon species and process (Suparno and Nurchaya, 1984; Suparno and Susana, 1984; Suparno and Poernomo, 1992; Irianto and Giyatmi, 1997). The solid waste comprises mainly head, tail, vein/viscera and shell. In the processing factories of Bangladesh, except larger sized head of freshwater prawn, other shrimp wastes are generally treated as garbage and dumped out side the factory premises within the compound. This unauthorized dumping of wastes has always been paving the way of serious environmental pollution. In each factory, additional manpower is employed and money spent to dispose such valuable wastes from the factory premises (Nowsad, 2005). After trimming, a 40-50% of the shrimp is eventually wasted in the form of leg, appendages, head, shell and tail. The percentage of head, shell and meat portion of black tiger shrimp are found to be 38, 7 and 55 %, respectively. So processing of large bulk of shrimp produces a corresponding large bulk of wastes and for the disposal of those wastes, processing plant has to bear some extra cost. According to an estimate, country's shrimp processing industries are dumping 30,000 tons of shrimp waste annually (Nowsad, 2005). Generally shrimp wastes contain 63.8% protein (Hunwatanawuthi, P. 1994). So there has been a golden opportunity to utilize these shrimp wastes in the manufacture of value added product like shrimp croquette. Beyond the boarder of the country, however, the utilization of wastes of shrimp processing industries in human and animal food production has been very successful, particularly in many Asian shrimp producing countries. Traditionally, shrimp wastes have been processed into petis (shrimp paste), terasi (fermented shrimp paste) and second quality shrimp crackers (Suparno and Poernomo, 1992) in Indonesia. Meanwhile, the shrimp waste can also be converted into shrimp loaves, protein hydrolysate, shrimp waste meal and silage, chitin and chitosan (Irianto and Giyatmi, 1997). If the bulk shrimp wastes of the processing plants are utilized in the production of shrimp croquette, it will serve the following important purposes where the country is worst suffering: i)Utilization of the shrimp wastes in the factory could minimize the cost of waste disposal that would realize substantial savings ii) The shrimp

processing factory could earn handsome profit by introducing simple process-line for shrimp croquette iii) Effective waste recycling could develop an environment-friendly waste management technique to improve plant sanitation and minimize environmental pollution iv) Shrimp wastes products could be utilized as alternative protein source to compensate malnutrition v) Rural women could involve risk-free business to generate additional income for the family. So the objective of this research was to develop a low cost and environment-friendly technique to utilize the waste of shrimp processing industries and to manufacture protein fortified shrimp croquettes for human consumption.

Materials and Methods

The experiments were conducted in the laboratories of the Department of Fisheries Technology of the Faculty of Fisheries, Bangladesh Agricultural University (BAU), Mymensingh during July 2008 to June 2009. Fresh shrimp wastes (head, shell, carapace, telson, appendages, antennae, etc.) were collected from a processing plant, Lokpur Seafood Ltd., situated in Khulna. Shrimp wastes were washed and immediately iced properly with crushed ice in an insulated ice box (Cosmos Ltd., Seoul, Korea, 20 kg capacity) and then transported to the laboratory of the Faculty of Fisheries, Bangladesh Agricultural University. Immediately after brought to the laboratory, shrimp shell wastes were thoroughly washed several times with cold freshwater. The shrimp head were removed from the meat and washed thoroughly. Shrimp shell waste components (head, thoracic & abdominal shell, carapace, telson, appendages, antennae and maxillary case) were separated and washed again. They were then packed in airtight polythene pouch and frozen stored at -20^0 C until processing.

Chemical quality evaluation of shrimp shell wastes

Proximate composition of shrimp shell wastes was determined as crude protein (AOAC, 1990), crude lipid (Bligh and Dyer, 1959), ash (AOAC, 1990) and moisture (Ludorff and Meyer, 1973). In crude protein estimation, about 1g of comminuted sample was employed for Kjeldahl apparatus. A factor of 6.25 was used for converting the total nitrogen to crude protein. Lipid content was determined by extracting a given quantity of sample with acetone in Soxhlet apparatus for 2 to 3 hours. Moisture content was determined by drying a 5g sample in an oven at 105°C for 24 hours. Ash content was determined by igniting the sample in a muffle furnace at 550°C for 6 hours. The pH was determined for the homogeneous mixtures of sample and distillated water (1:10, w/v) using a digital Mettler Toledo pH meter. The pH was measured at room temperature. All analyses were made in three replicates.

Preparation of shrimp shell powder

The procedure for the preparation of shrimp croquettes was divided into two steps. First, production of shrimp shell powder from shrimp shell wastes and then preparation of shrimp croquettes incorporating shrimp shell powder to the vegetable pastes. Shrimp shell wastes were thoroughly washed several times with cooled freshwater. The shrimp head were removed from the meat and washed thoroughly. Shrimp shell waste components (head, thoracic & abdominal shell, carapace, telson, appendages, antennae and maxillary case) were separated and washed again. Shrimp head and waste samples were dried in a hot air oven at 60^0C for 24 hours. Dried shrimp's head and shell waste samples were finely ground by using a blender 3 times for 2-3 minutes. Ground shrimp shell wastes were screened by fine mesh sieve to obtain fine shrimp shell powder. The powder was then packed in air tight glass bottles and stored in a refrigerator at 4^0C. The process of preparation of shrimp shell powder is shown in Fig. 1.

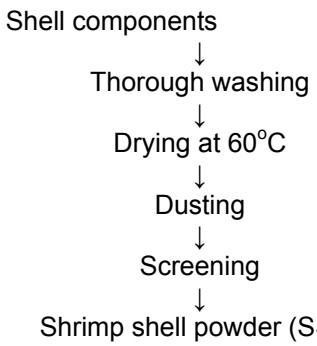

Fig-1: Scheme for the preparation of shrimp shell powder

Procedure of shrimp croquettes

Vegetables used for shrimp croquettes: Shrimp croquette was developed by incorporating shrimp shell powder to the basal vegetable paste where spices and other ingredients were also added. Emphasis was given to add to the products a Bangladeshi known taste so that the products could attract local consumer's acceptance. Fresh vegetables such as potato, *Colocasia* (*Colocasia esculenta*), green banana, green papaya, spinach (*Basella alba*, *Spinacia oleracea* and *Ipomoea*) were collected from local market. After brought to the laboratory, vegetables were thoroughly washed with cooled freshwater and boiled for 30 minutes. After boiling, vegetables were processed and pasted separately. Various vegetable contents and composition were used to obtain an adhesive, choppy and tasty basal vegetable paste. The possibility of the various vegetable pastes was searched for the preparation of a choppy and tasty base to which shrimp proteins to be fortified. Colocasia considerably contributed to increase the adhesiveness of the basal paste. After a series of experiments conducted with different vegetable contents and compositions, the following final composition of the vegetables was obtained that gave good textured acceptable vegetable croquette.

Table 1. Contents and compositions of vegetables for croquette

Vegetables	Percentage (%)
Potato	50
Colocasia (*Colocasia esculenta*)	20
Green banana	10
Green papaya	10
Spinach (*Spinacia oleracea*)	10

Spices **(**green chili, onion, garlic. turmeric, red pepper and ginger powder) were collected and brought to the laboratory. These spices were dried by using hot air oven at 65^0C for 24 hours. Then spices were powered by using grinder and stored into separate air tight bottles in the refrigerator. Various spices contents and compositions were used to obtain an acceptable flavor and good texture of the croquette.

Standardization of the spices contents for basal vegetable paste: The possibility of the various spices was searched for the preparation of a good textured and nice flavoured croquette. The texture and flavor of the croquette added with different contents of spices were evaluated through sensory panel test. Final contents of spices that obtained best texture and flavor of the croquette have been given in Table 2.

Table 2. Contents and compositions of spices for vegetable croquette

Spices	Percentage (%)
Garlic	0.2
Onion	0.5
Ginger	0.2
Green chili	0.1
Turmeric	0.2
Red pepper	0.3

Standard batter formulation, developed by Nowsad *et al.* (2000) was used for battering the croquette before frying. The formulation is given in Table 5.

Table 3. Batter formulation for shrimp croquette

Ingredients	Percentage (%)
Wheat flour	34.0
Salt (NaCl)	1.0
Monosodium glutamate	1.0
Spices mix (green pepper , ginger, garlic, cumin, onion powder)	1.0
Egg	19.0
Water	44.0

Quantity of shrimp shell powder used: The shrimp shell powder was used in variable levels (3%, 5% and 10%) in order to determine the effect of shrimp shell powder on the protein fortified and the quality of the product.

Preparation of shrimp croquettes

Different component parts of the wastes were dried at 45^0C in an electric oven, powdered and kept refrigerated and used as nutrition supplement to the shrimp croquettes. For shrimp croquette, a combination of vegetables (potato, colocasia, green banana, green papaya, spinach etc.), spices (green chili, onion, garlic. turmeric, red pepper, ginger powder etc.) and other ingredients (salt, wheat flour, egg, sugar, milk powder etc.) are mixed with variable quantities of shrimp shell powder, shaped and covered with egg emulsion and bread crumb. Then it was packed in air tight polythene bag and kept in a deep freezer at -20^0C. Prior to panel test it was thawed and fried in dip oil.

Assessment of quality of shrimp croquette

The quality of the products was evaluated by subjective sensory analysis, viz., texture (chewiness/ rubberiness), taste/mouth feel and flavor, while objective methods included instrumental measurements of biochemical parameters and aerobic plate count.

Sensory evaluation: A panel of nine-person of students, teachers and staffs of the Department of Fisheries Technology provided the sensory assessments of the products.

Chewiness/Rubberiness and mouth feel (MF) tests

Chewiness /rubbriness (C/R) was defined as the amount of effort the panelist had to exert in chewing to prepare the sample for swallowing. The quality was evaluated by the numerical scores up to 10, where for C/R, 1= not chewy/rubbery; 10= extremely chewy/rubbery. The mouth feel was measured by a numerical score of 1-5, where 1 is poor and 5 is very good taste. The panel scores for the variable levels of shrimp shell powder were recorded in the score sheet shown in Table 6. The chewiness/rubberiness and mouth feel of the variable levels of vegetables paste and spices were determined through panelists.

Table 4. Scoring sheet for C/R and MF test

Variable levels of shrimp shell powder	C/R score (1-10)	MF score (1-5)	Comments on quality
3%			
5%			
10%			

*The average of the 9 scores were used for C/R and MF

Color and flavor test

Color and flavor of shrimp croquette were evaluated organoleptically. Scores used were from the range of 10 to 1; where 10 = desired color and flavor; 1 = absent of color and flavor. The panel scores were recorded in the score sheet shown in Table 5 and 6.

Table 5 . Scoring sheet for color test

Score	Description	Comment on color quality
1 to 3	Content considerably colored (Dark gray)	Poor color
4 to 7	Content moderately colored (Brown/Light gray)	Moderately good color
8 to 10	Contents finely colored (Bright brown)	Excellent color

Table 6. Scoring sheet for flavor test

Score	Description	Comment on flavor quality
1 to 3	Contents have strong abnormal odor and a markedly poor flavor.	Poor flavor
4 to 7	Contents have slightly raw or scorched odor or flavor; seasoning seems to be somewhat inadequate.	Moderately good flavor
8 to 10	Contents have no abnormal flavor and have a good characteristics flavor and seasoning.	Excellent flavor

Biochemical evaluation

Proximate composition and Shelf life estimation: The proximate composition of shrimp croquettes were determined using the same procedure applied as in case of shrimp shell wastes. Shelf life of the shrimp croquette was determined in terms of sensory, chemical and microbial characteristics. Shrimp croquettes prepared with shrimp shell powder were stored at -20°C, 5°C and 28°C and the quality was evaluated by monitoring the changed in bacterial load.

In order to analyze the shelf life of shrimp croquette aerobic plate count was done by spread plate count method. Peptone diluents (0.2%) and plate count agar of commercial preparations were used in the shelf life study of shrimp croquette. Aerobic plate count was done by consecutive decimal dilution technique. Samples for the APC was accurately weighed and added with required amount of water and liquefied in a sterile blender jar and consecutive ten fold dilutions were made in the test tubes. From all the dilutions spread plate cultures were made in duplicates and incubated at 35˚C for 24 to 48 hours. Colonies developed on the plates were counted in a colony counter and plates having 30 to 300 colonies were selected for APC. According to International Standard Organization (ISO, 1965) APC was calculated by the following formula:

APC/g = C × D × V ×10/S CFU/g

Where C is the Number of colonies found, D is Dilution factor, V is the Volume of the sample, S is weight of sample in grams and CFU means Colony forming unit.

Results and Discussion

In order to understand the quality of raw material, the nutrient contents of each part of shrimp wastes were analyzed. Fig. 1 shows the proximate compositions and pH of different parts of shrimp wastes. Shrimp shell waste components were found to have very good nutritional contents. Shrimp shell wastes (dried head or shell) were found to have very high level of protein, comprising 40 to 50% and high level of lipid. The amount varied in different shell waste components with lowest in antennae and carapace and highest in telson. The results are in well agreement with Shahidi (1994) and Revanker (1978). This high protein content could represent a good protein source for the food industry. Shahidi (1994) found that the shrimp's discards contained 44.12±0.79% crude protein.

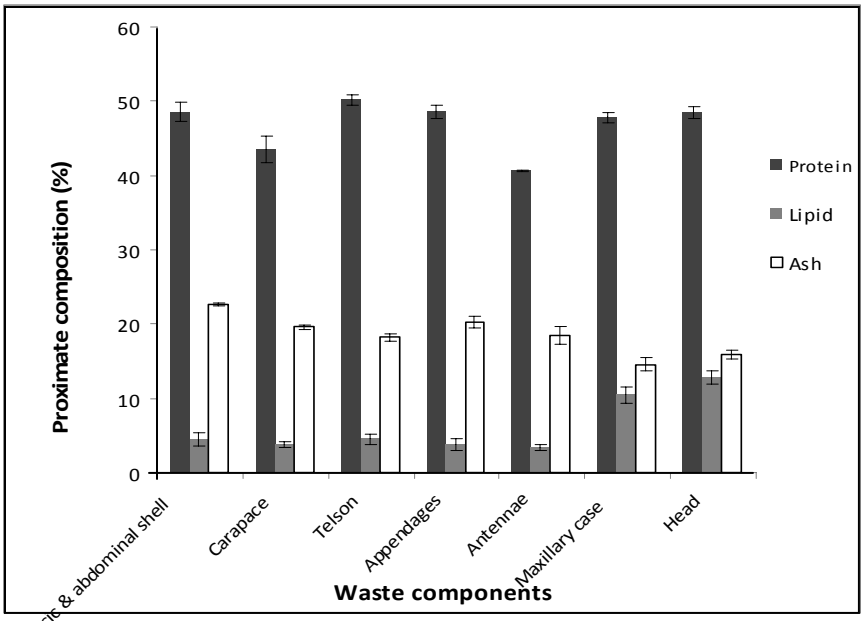

Fig. 2. Proximate composition (%) on dry weight basis of different component parts of shrimp waste

Fig. 3. Shrimp croquette after bread-crumbing and after dip-frying

Antennae which were supposed to have low nutritional content and always been thrown outside or ground for silage in waste processing plants were found to have 40.7% protein on dry weight basis. The protein content in the whole shell wastes was 47.48±0.74%. This extremely high level of protein found in the shrimp wastes widened the scope of utilization of such valuable nutrient, in addition to chitin and chitosan, as functional nutritive component in human food. The lipids content of shrimp's head was 12.8% and that of the true shell (carapace, appendages, etc) was 3.4 to 3.8% as shown in Table 7. Jacquot (1961), Gordon and Roberts (1977) and Kinsella (1988) reported that the lipid content in shrimp shell could be demonstrated to be related to the seasonal variations, species, physiological status, diet as well as sexual maturity of the shrimp. The ash contents were 19.61±0.64% (Table 7) for the shrimp's head and shell. This relatively high percentage could be attributed to the presence of some tissues within the shrimp's waste residue. Shahidi (1994) found that the content of ash in shrimp discards was 29.0±0.4 on dry weight basis. Revanker (1978) reported that the percentage of total ash was as high 19.6% for the dried shrimp waste.

Table. 7 Proximate composition of shrimp shell powder

Components	Composition on dry weight basis (%)
Protein	47.48±0.74
Lipid	10.5±0.71
Ash	19.61±0.64
pH	7.2

* mean value ± standard error of triplicate determinations

Development of shrimp croquette

A kind of vegetable croquette was developed and enriched with protein by incorporating with shrimp shell powder as SSP contained very high level, as much as 47-50%, of protein. The chewiness / rubberiness and mouth feel of the developed croquettes were determined through sensory evaluation. On the basis of texture development, only potato, mukhi kachu, green banana, green papaya and palong shak were used for shrimp croquette (Table 2). It was found that higher content of green banana and Colocasia (*Colocasia esculenta*) increased adhesiveness and hardness of the shrimp croquette, while ipomoea and spinach (*Spinacia oleracea*) increased the moisture content and softness of the product. A balance was maintained between the hardness and softness of the product by incorporating boiled mashed potato. Potato starch is supposed to have the ability to absorb water from the surrounding environment and swell up to make the product soft and elastic (Nowsad *et. al.,* 2000a). Colocasia increased the adhesiveness of the shrimp croquette. Addition of Colocasia also made the product cheaper and affordable to the common buyers. Various spice contents and compositions were searched for the development of an appealing texture, flavour and colour in the croquette (Table 3). Finally, fine powders of garlic, onion, ginger, green chili, turmeric and red pepper at the rate of 0.2, 0.5, 0.2, 0.1 and 0.3%, respectively gave best textured, flavoured and colored products (Table 4). This recipe was used for protein fortification from

SSP and as such suggested for the preparation of shrimp croquette. The data have been presented in Table 9.Various levels of SSP (having the protein content of 47-50%) were added to the basal vegetable pastes, ranging from 3 to 10%. After incorporation of protein the proximate composition of the shrimp was measured once again. The data have been presented in Table 11.

Table 8. Proximate composition of shrimp croquette prepared from shrimp shell powder (SSP)

Shrimp croquette	Proximate composition in dry weight basis (%)		
	Protein	Lipid	Ash
Control*	4.46±0.56	2.90±0.37	17.92±0.13
3% SSP	7.22±0.66	3.52±0.61	18.21±0.19
5% SSP	9.39±0.37	3.99±0.15	18.27±0.23
10% SSP	11.73±0.61	4.51±0.59	19.97±0.29

Each value is mean ± standard error of triplicate determinations.
- Control: Croquettes recipe without any shrimp's waste additions.

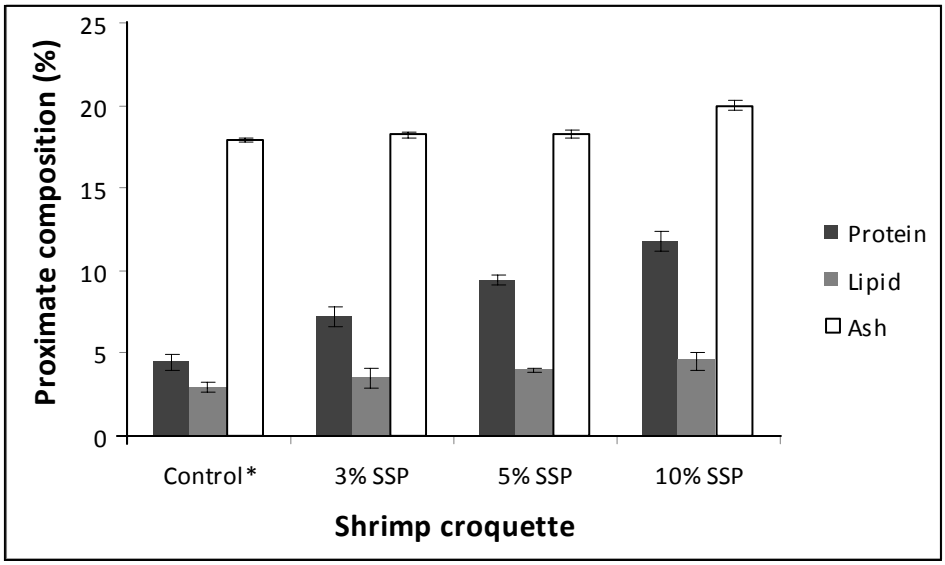

Fig. 4. Proximate composition of shrimp croquette prepared from SSP

Control croquette contained very low amount of protein on dry weight basis (Table 8). But when SSP was used in the croquette, protein content increased with the higher levels of SSP. The final protein content found were 7.22±0.66, 9.39±0.37 and 11.73±0.61% in the croquettes added with 3, 5 and 10% SSP, respectively. Lipid content was low in the control croquette as well, but it remained constant or slightly increased with the addition of increased concentration of SSP. This was expected due to the higher percentage of total lipids in dried shrimp's head, and also could be attributed to the used cooking method (frying).

Sensory evaluation

Sensory qualities of the shrimp croquettes produced with nutrient supplement by dried form of waste components (thoracic and abdominal shell powder; antennae and appendage powder) were better compared to those added with raw head meat paste. Best flavour development was achieved in products supplemented with antennae and appendages powder. The possibility of use of various vegetable pastes was searched for the preparation of a base to which shrimp proteins to be fortified. Effects of various vegetable compositions and contents on the sensory quality of the basal croquettes are presented in Table 9. Five different recipes were tested to find out the most desired textured and flavored croquette.

Addition of potato was kept constant. As stated earlier, all the three varieties of colocasia had good impact on the sensory attributes of croquette. In the final recipe ipomoea and one type of spinach (*Basella alba*) were omitted because of very low sensory attributes shown by these two leaf vegetables. Recipe 2 with the content of potato, mukhi kachu, green banana, green papaya and palong shak at the rate of 50, 20, 10, 10 and 10% obtained best C/R values.

The possibility of use of various spices was searched for the preparation of a good textured and nice flavoured croquette. The effects of various spices composition and contents on the sensory quality of the shrimp croquettes have been presented in Table 13. Nine different recipes were tested to find out most desired content and composition for obtaining best textured and flavoured products. The spice series were selected in order to add local taste and flavour to the products. Addition to higher concentration of garlic and ginger increased pugnacity in flavour. A balance between good flavour and increased firmer (C/R value) was maintained by combination the spice contents and compositions. Out of the 9 recipes tested, best texture and flavour was found in the croquette obtained by incorporating garlic, onion, ginger, green chili, turmeric and red pepper at the concentration of 0.2, 0.5, 0.2, 0.1, 0.2 and 0.3% respectively (Table 10).

Table 9. Effect of the vegetable composition and contents on the sensory quality of croquette

Recipe	Vegetable composition (%)									Sensory score
	Potato	Colocasia			Green banana	Green papaya	Spinach		Ipomoea	
		Mukhi	Chara	Narikel			Palong	Pui		
R-1	50	-	20	-	10	5	15	-	-	7.5±0.05
R-2	50	20	-	-	10	10	10	-	-	8.7±0.12
R-3	50	10	-	-	10	15	-	10	5	8.0±0.12
R-4	50	-	-	20	10	10	-	-	10	7.9±0.05
R-5	50	10	10	10	10	5	5	-	-	7.6±0.12

*Each value is mean ± standard error of triplicate determinations.

Table 10. Effect of the spice contents and composition on the sensory quality of croquette

Recipe	Spice composition (%)						Sensory score	Flavour
	Garlic	Onion	Ginger	Green chili	Turmeric	Red pepper		
R- Control*	-	-	-	-	-	-	8.7±0.12	7.2±0.10
R-1	0.1	0.5	0.2	0.1	0.2	0.3	8.0±0.21	7.5±0.21
R-2	0.2	0.5	0.2	0.1	0.2	0.3	8.9±0.27	8.7±0.45
R-3	0.3	0.5	0.2	0.1	0.2	0.3	8.3±0.05	8.0±0.25
R-4	0.2	0.3	0.1	0.1	0.2	0.3	8.1±0.15	7.9±0.76
R-5	0.2	0.4	0.1	0.1	0.2	0.3	7.9±0.38	7.6±0.17
R-6	0.2	0.5	0.2	0.1	0.2	0.3	8.1±0.04	7.2±0.19
R-7	0.2	0.5	0.2	0.05	0.1	0.1	8.2±0.1	7.9±0.33
R-8	0.2	0.5	0.2	0.1	0.2	0.2	8.4±0.05	8.1±0.17
R-9	0.2	0.5	0.2	0.15	0.3	0.3	8.1±0.15	8.0±0.26

Each value is mean ± standard error of triplicate determinations.

Control: Croquettes recipe without any spice additions.

Sensory attributes of the products due to addition of SSP in the croquettes in terms of C/R, color, flavour and taste appeal are presented in Table 14. Increased contents of SSP reduced the sensory attributes in all cases of firmness, color and flavour. However sensory attributes of the croquettes added with 3 and 5% SSP were almost similar. When 10% SSP was added, firmness of the product reduced, while the strong shrimp flavour was developed. Strong shrimp flavour was less accepted by the panelists. As the objective of the study was to develop a good textured and flavoured shrimp croquette with enriched protein content, addition of 5% SSP can be suggested.

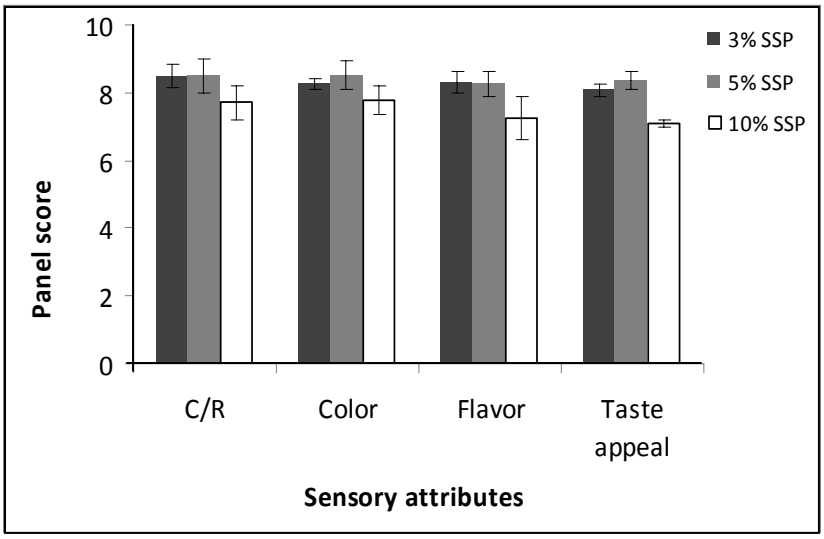

Fig. 5. Effect of the shrimp shell powder (SSP) on sensory quality attributes of shrimp croquette

Shelf life of shrimp croquette

Dried powder of different shrimp waste components had a bacterial load of 9.2 × 10^4 CFU/g sample (Nowsad *et al*., 2005b). Therefore, dried components of the shrimp wastes were appeared to be safe for possible use as food additives. Bacterial loads (CFU/g) of shrimp croquette in both room (28°C), refrigerated (5°C) and frozen temperature (-20°C) have been presented in Table 15. In both temperatures, the bacterial load was increased throughout the storage period. Initial bacterial load of shrimp croquette prepared from shrimp shell powder was 1.52×10^3 CFU/g. Bacterial growth in shrimp croquette kept at room temperature rapidly increased with the progress of storage time and after 1 day bacterial load increased to 4.46×10^5 CFU/g, after 3 days these values reached to 5.1×10^8 CFU/g in shrimp croquette. On the other hand, same shrimp croquette kept at refrigeration and frozen temperature the bacterial growth pattern was somewhat different. In these cases, rate of bacterial growth was slower. During refrigerated and frozen temperature no big change were observed in APC and after 30 days bacterial load reached to 3.84×10^7 and 1.78×10^6 CFU/g in shrimp croquette respectively. Therefore, the results showed that shrimp croquette made with 5% SSP had an acceptable bacterial load in refrigeration for up to 10 days and in frozen temperature more than 30 days.

Table 11. Effect of the storage period on bacterial load of shrimp croquette prepared from 5% shrimp shell powder stored at different storage temperature

Product	Storage temperature	Storage time (day)	Bacterial load	
			CFU/g	Log CFU/g
Shrimp croquette (5% SSP)	28°C	0	1.52 ×10_3	3.18
		1	4.46×10_5	5.64
		3	5.1×10_8	8.70
	5°C	0	1.52×10_3	3.18
		5	7.42×10_4	4.87
		10	4.38×10_6	6.64
		30	3.84×10_7	7.58
	-20°C	0	1.52×10_3	3.18
		5	4.74×10_4	4.67
		10	8.26×10_4	4.91
		30	1.86×10_5	5.26
		40	1.78×10_6	6.25

Conclusion

It was observed that the flavor, texture and overall acceptability of shrimp croquette produced by incorporating 5% SSP was more acceptable by the panelists. Study reveals that trade with value added products like shrimp croquette at national and international market has a very good prospect and it would bring economic benefit to the producer. Utilization of the shrimp wastes could minimize the cost of waste disposal that would realize substantial savings and protein fortified shrimp croquette could be served as a high quality protein source for the people suffering from malnutrition. Shrimp shell powder could be a remarkable source of high quality protein, because of its abundance and low cost and it may be used in other food items for protein enrichment; further research is needed in this area.

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