Development of an extruded snack product containing fish flour and shrimp head exudate by ingredient optimization and its quality analysis

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Abstract

An experiment was conducted to utilize the fish powder made from low-value fish and shrimp exudate to enhance the protein content and flavour of the extruded product. The nutritious extruded Ready-to-eat (RTE) snack was developed using fish powder (0, 2.5%, 5% and 7.5%), shrimp head exudate (0.25%, 0.5%, 0.75% and 1%) and cereal flour such as cornflour and rice flour. The fish powder, shrimp head exudate and cereal mixture were extruded using the extrusion cooking method to a moisture content of 10% with screw speed 350 rpm, sectional barrel temperature of 60°C and 120°C and 2 mm diameter of the die. A total of 8 extruded products were analyzed to optimize the incorporation rate for extruded products. The resulting extruded product was analyzed for nutritional and organoleptic characteristics. Among the extruded products, extruded products incorporated with 2.5% fish protein and 0.75% shrimp head exudate had higher physical characteristics and sensory scores individually. Hence, these concentrations individually can be used for the preparation of extruded snacks with increased protein content and flavour.

Key words: Extruded product, Nutritional value, Organoleptic characteristics, Shrimp head exudate, Trash fish powder

INTRODUCTION

Fish is much valued for its nutritional value, which provides the consumer high-quality protein and essential amino acids. It is an incomparable source of omega 3 fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and at the same time, it is a good source of B-complex vitamins and minerals (Ariño *et al.*, 2013). Fish is rich in all major nutrients except carbohydrates and vitamin C (Mohanty, 2015). Due to the extremely perishable nature of the fish and the development of technology for its proper utilization, a significant portion of the fishery source remains unutilized as human food (Venugopal *et al.*, 1995). Commercial marine fish catch from the trawlers generally consists of edible and inedible fish species. The collection of inedible low-value

fishes and juveniles of commercially important fishes are known as trash fishes and also called rough fish. The trash fish, which are caught as a by-catch accounts for 50% of the total catch and are generally rich in nutritive value. The nutritive value of these fish is not often utilized properly and discarded as a waste (Chandrapal, 2005). The low economic value/trash fish can be utilized for the development of new value-added products by using low-cost technology (Joshi *et al.*, 2015) and snack product is an excellent choice as its consumption rate is constantly increasing nowadays. The snack products are high in fat and carbohydrates and comparatively low in protein (Rhee *et al.*, 1999). Good snacks must be inexpensive, nutritious, low in fat, convenient to consume and have a long shelf life (Wangcharoen *et al.*, 2002).

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Extrusion processing is a widely used technology in the food industry for restructuring starchy and proteinaceous ingredients in preparing ready-to-eat foods (Gogoi *et al.*, 1996). Several researchers and dieticians have reported the incorporation of high protein ingredients for the nutritional improvement of snacks using different cereals to enrich the nutritional quality of the product (Shah *et al.*, 2014). On a global basis, the shrimp processing industry produces over 7,00,000 million tons of shell wastes and the seafood processing industry in India generates 8.5 million tons of shell waste per year (Singh *et al.*, 2018). The shrimp head was utilized to obtain the exudate for flavour enhancement. The present study was aimed at incorporating trash fish powder and shrimp head exudate for the preparation of extruded snacks to increase their nutritional value and as a way of value addition.

MATERIALS AND METHODS

Raw material: Shrimp head waste and low-value fish (*Pellona ditchella*) were brought from fish market in Muthukur, Sri Potti Sri Ramulu Nellore District, Andhra Pradesh and were iced immediately at the ratio of 1:1 (fish and ice) and were in chilled condition till they were brought to the laboratory within 30 min. The low-value fishes were washed thoroughly in chilled potable water and beheaded, gutted, and used for the preparation of fish powder.

Preparation of fish protein powder: The fishes

were washed and boiled in hot water for 10-15 minutes and the water was drained off. Then the fishes were dried in a mechanical drier at 50°C till the fishes have attained a moisture content of 20%. The dried fishes were sieved/pulverized and fine milled. Further packed in high density polyethylene (HDPE) pouch and stored at room temperature.

Preparation of shrimp head exudate: The washed shrimp head waste was boiled in water (1:1 shrimp head : water) for about 30 minutes to extract the exudate for the purpose of enhancing the flavour of the product. The prepared exudate was filtered and was mixed in the raw material at different concentrations replacing the respective concentration of water to be added.

Preparation of extruded product: The ingredients used for the preparation of extruded snacks were maize flour, rice flour, fish powder (FP) and shrimp head exudate (SHE) at different concentrations. For preparation of extruded snack, fish powder at a concentration of 0, 2.5, 5 and 7.5% and shrimp head exudate at 0.25, 0.5, 0.75% and 1% were added. The details of the composition of each extruded snack are given in Table 1. The ingredients of each treatment were taken, and 10% water was added and mixed properly. It was then sieved and kept for preconditioning for 30 min. The preconditioned mixtures were used for the preparation of extruded snacks. The conditions of the extruder are given in Table 2.

Table 1. Standardization of conditions for preparation of extruded snack using fish powder (FP) and shrimp head exudate (SHE) formulation of extruded fish snacks

Material	Control (%)	2.5%FP (%)	5%FP (%)	7.5%FP (%)	0.25% SHE	0.5% SHE	0.75% SHE	1% SHE
Maize flour	50	48.75	47.5	46.25	50	50	50	50
Rice flour	50	48.75	47.5	46.25	49.75	49.5	49.25	49.0
Fish powder	0	2.5	5	7.5	0	0	0	0
Shrimp head exudate (%)	0	0	0	0	0.25	0.5	0.75	1.0
Total	100	100	100	100	100	100	100	100
Moisture level (%)	10	10	10	10	10	10	10	10

Table 2. The operation conditions of the equipment

Parameter	Value
Die diameter	3 mm
Barrel screw speed	350 rpm
Barrel temperature	Heater 1 Heater 2
	120°C 60°C
Feeding rate	21 rpm
Cutter speed	420 rpm
Line voltage	450 voltage

Proximate composition analysis of the product:

Moisture, protein and ash content were determined by the methods as described in AOAC (2000). The crude fat content was determined by the method of Folch *et al.* (1957). Ash content was determined by AOAC (2000) method. Total carbohydrates in the samples were estimated by hydrolysis method as described in (AOAC, 2000). The energy was calculated by multiplying protein, fat and carbohydrate values obtained from analysis by 4, 9 and 4 respectively and expressed as Kcal/100g (AOAC, 2000).

Physical parameters of the extruded product:

The expansion ratio was determined by the Ding *et al.* (2005) method as shown in the equation below.

Expansion ratio = Extrudate diameter/ Die diameter (mm)

Bulk density was calculated according to Hood-Niefer and Tyler (2010) method as shown in the equation.

Bulk density = Mass/ volume (g/cm³)

Porosity (PO) was calculated according to Wang *et al.* (1999) method as shown in the equation.

Porosity = particle density-bulk density/ particle density ×100

Particle density was calculated according to the method of Gujska and Khan (1990) as shown in the equation.

Particle density = $4m/\pi d^2 l$

The water solubility index was measured following the method of Anderson *et al.* (1969) as shown in the equation.

Water solubility index = weight of the dissolved solids in supernatant/ weight of dry solids (g)

The water absorption index (WAI) was determined by the method of Anderson (1982) as shown in the equation.

Water absorption index = weight of sediments/ weight of dry solids (g)

Biochemical analysis: Peroxide value was determined according to the method of Jacobs (1958). Free fatty acid was determined by following the method of Olley and Lovern (1960). TVBN and TMA were determined by the Conway method (1962) and expressed as mg of N/100 g of sample. TBA was determined by Kohn and Liversedge (1944), and expressed as µg/g. Water activity was determined by using a Hydrolab water activity meter manufactured by Rotronic systems Pvt Ltd. For pH determination, 5 g of sample was taken and 45 mL distilled water was added and was homogenized using Polytron PT2100 (Luzan) homogenizer. The pH of homogenate was recorded using a digital pH meter (M/s. Oakton, Eutech instruments, Malaysia).

Microbiological analysis: In this study, total plate count (TPC) and total fungal count (TFC) were enumerated. *Staphylococcus aureus*, *Escherichia coli*, faecal streptococci, *Vibrio* spp. and *Salmonella* spp. were quantified by following the methods as described by APHA (1992).

Sensory evaluation: The sensory assessments were conducted in the College of Fishery

Science, Muthukur by 10 trained panellists. Panellists evaluated all samples based on their flavour, texture, taste, colour and overall acceptability using a nine-point hedonic scale (1= dislike very much to 9 = like very much) (Meilgaard *et al.*, 2007).

Statistical analysis: All data were subjected to a one-way analysis of variance (ANOVA) using SPSS 22.0 followed by the Duncan test. The results were expressed as mean $\pm$ SD (Standard Deviation). $P < 0.05$ was considered as statistically significant.

RESULTS

Changes in proximate composition: The moisture content, protein, fat and ash content has increased significantly with the increase in the concentration of fish powder (0, 2.5, 5 and 7.5%) and shrimp head exudate (0.25, 0.5, 0.75 and 1.0%) in the extruded product, but a significant decrease in carbohydrate and energy value was observed with increase in the concentration of fish powder and shrimp head exudate in the extruded product (Table 3). The moisture, protein, fat, ash, carbohydrate and energy values of extruded product incorporated with fish powder and shrimp head exudate ranged from $7.92 \pm 0.03\%$ to $9.87 \pm 0.11\%$, 9.61 ± 0.05 to $12.92 \pm 0.03\%$, 1.23 ± 0.04 to

$1.98 \pm 0.06\%$, 1.03 ± 0.03 to $1.78 \pm 0.03\%$, 74.34 ± 0.04 to $80.37 \pm 1.54\%$ and 362.64 ± 0.07 to 372.21 ± 0.23 Kcal respectively.

Changes in physical characteristics: The expansion ratio decreased significantly with an increase in the concentration of fish powder and shrimp head exudate, and the values ranged from 2.52 ± 0.04 to 3.24 ± 0.04 mm (Table 4). The bulk density of the extruded product increased significantly with an increase in the concentration of fish powder and shrimp head exudate and the values ranged between 0.072 ± 0.04 and 0.112 ± 0.05 g/cm³ (Table 4). The porosity of extruded snacks decreased significantly with the increase in the concentration of fish powder and shrimp head exudate. The control sample had a porosity value of 38%. The values of samples added with fish powder and shrimp head exudate ranged from 11% to 35% (Table 4). WSI of the extruder snacks decreased significantly with an increase in the concentration of fish powder and shrimp head exudate, and the values ranged from 7.45 ± 0.05 to $10.72 \pm 0.05\%$ (Table 4). The water absorption index of extruded snacks has increased significantly with the concentration of fish powder and shrimp head exudate, with values ranging from 4.21 ± 0.03 to $5.05 \pm 0.04\%$ (Table 4).

Table 3. The proximate composition of extruded snack incorporated with fish flour (FP) and shrimp head exudate (SHE)

Sample	Moisture (%) [*]	Protein (%) [*]	Fat (%) [*]	Ash (%) [*]	Carbohydrate (%) [*]	Energy (k/Cal) [*]
Control	7.92 ± 0.03^a	9.61 ± 0.05^a	1.37 ± 0.08^a	1.03 ± 0.03^a	80.37 ± 1.54^d	372.21 ± 0.23^d
FP 2.5%	8.11 ± 0.01^b	10.46 ± 0.05^b	1.53 ± 0.03^b	1.32 ± 0.03^b	78.58 ± 0.03^c	369.93 ± 1.11^c
FP 5%	8.54 ± 0.02^c	11.54 ± 0.02^c	1.70 ± 0.02^c	1.56 ± 0.03^c	76.66 ± 0.03^b	368.10 ± 0.05^b
FP 7.5%	8.98 ± 0.03^d	12.92 ± 0.11^d	1.98 ± 0.06^d	1.78 ± 0.03^d	74.34 ± 0.04^a	366.86 ± 0.12^a
SHE 0.25%	8.72 ± 0.03^a	9.89 ± 0.03^a	1.23 ± 0.04^a	1.12 ± 0.04^a	79.04 ± 0.05^d	366.79 ± 0.08^d
SHE 0.5%	9.11 ± 0.02^b	9.92 ± 0.04^b	1.32 ± 0.04^b	1.25 ± 0.04^b	78.42 ± 0.06^c	365.24 ± 0.05^c
SHE 0.75%	9.56 ± 0.05^c	10.01 ± 0.08^c	1.42 ± 0.04^c	1.35 ± 0.04^c	77.66 ± 0.04^a	363.46 ± 0.04^b
SHE 1%	9.87 ± 0.07^d	10.11 ± 0.04^d	1.56 ± 0.04^d	1.42 ± 0.04^c	77.04 ± 0.05^a	362.64 ± 0.07^a

^{*}Each value is represented by the mean $\pm$ SD of n=3

^{abcd} Indicate significant difference among treatments ($p < 0.05$)

Biochemical changes: The peroxide value of the extruded product incorporated with fish powder and shrimp head exudate varied from 0.24 ± 0.05 to 1.02 ± 0.06 Meq O_2 /kg (Table 5). The TBA value of extruded product incorporated with fish powder and shrimp head exudate increased significantly with an increase in concentration, and the values varied from 0.03 ± 0.005 to 0.957 ± 0.003 μ g/g (Table 5). Free fatty acid (FFA) content of the extruded product incorporated with fish powder and shrimp head exudate increased significantly with an increase in concentration and FFA values ranged from 0.345 ± 0.004 to $0.926 \pm 0.002\%$ of oleic acid (Table 5). The water activity content of the

extruded product incorporated with fish powder and shrimp head exudate increased significantly with an increase in concentration and ranged from 0.67 ± 0.04 to 0.75 ± 0.03 . The pH value was found to increase significantly with an increase in concentration and found to be 6.54 ± 0.04 to 6.76 ± 0.05 (Table 5). A significant increase in the TVBN value of the extruded product incorporated with fish powder and shrimp head exudate was observed with increased fish concentration and the values varied from 18.93 ± 0.06 to 19.20 ± 0.04 (Table 5).

Microbiological characteristics: In the prepared extruded snacks, *Staphylococcus*

Table 4. Physical characteristics of extruded snack incorporated with fish flour (FP) and shrimp head exudate (SHE)

Sample	Expansion ratio (mm)*	Bulk density (g/cm ³)*	Porosity (%)*	Water solubility index (%)*	Water absorptive index (%)*
Control	3.33 ± 0.04^d	0.08 ± 0.03^a	38 ± 2.65^d	10.72 ± 0.05^d	4.21 ± 0.03^a
FP 2.5%	3.24 ± 0.04^c	0.09 ± 0.03^a	25.63 ± 0.04^c	9.23 ± 0.04^c	4.56 ± 0.03^b
FP 5%	2.76 ± 0.03^b	0.103 ± 0.04^a	15.63 ± 0.03^b	8.05 ± 0.05^b	4.72 ± 0.05^c
FP 7.5%	2.52 ± 0.04^a	0.112 ± 0.03^a	11.99 ± 2.64^a	7.45 ± 0.05^a	5.02 ± 0.05^d
SHE 0.25%	3.13 ± 0.04^d	0.084 ± 0.05^b	35.00 ± 3.60^b	10.76 ± 0.03^d	4.25 ± 0.05^a
SHE 0.5%	3.01 ± 0.03^b	0.072 ± 0.04^a	33.25 ± 0.04^b	10.68 ± 0.03^c	4.59 ± 0.04^b
SH 0.75%	2.95 ± 0.05^b	0.108 ± 0.04^c	31.25 ± 0.05^a	10.54 ± 0.05^b	4.86 ± 0.04^c
SHE 1%	2.68 ± 0.04^a	0.112 ± 0.05^c	29.85 ± 0.04^a	10.45 ± 0.04^a	5.05 ± 0.04^d

*Each value is represented by the mean $\pm$ SD of n=3

abcd Indicate significant difference among treatments ($p < 0.05$)

Table 5. The biochemical and microbial characteristics of the fish powder (FP) and shrimp head exudate (SHE) optimized extruded snack

Sample	Peroxide value (milliequivalent of O_2 /kg of fat)	Free fatty acids (% of oleic acid/kg of fat)	Thiobarbituric acid reactive substances	Water activity (a_w)	pH	Total plate countlog (CFU/g)**	Total volatile base nitrogen (mgN/100g)
Control	0.24 ± 0.05^a	0.345 ± 0.004^a	0.03 ± 0.005^a	0.65 ± 0.04^a	6.15 ± 0.06^a	1.03	18.85 ± 0.04^a
FP 2.5%	0.36 ± 0.04^b	0.542 ± 0.006^b	0.08 ± 0.004^b	0.67 ± 0.04^a	6.54 ± 0.04^b	1.23	18.93 ± 0.06^b
FP 5%	0.60 ± 0.03^c	0.724 ± 0.004^c	0.31 ± 0.003^c	0.72 ± 0.05^a	6.67 ± 0.06^c	1.52	19.00 ± 0.04^c
FP 7.5%	1.02 ± 0.06^d	0.926 ± 0.002^d	0.96 ± 0.003^d	0.75 ± 0.03^b	6.76 ± 0.05^c	1.63	19.20 ± 0.04^d
SHE 0.25%	0.26 ± 0.04^a	0.372 ± 0.005^a	0.042 ± 0.004^a	0.69 ± 0.04^a	6.15 ± 0.04^a	1.05	18.99 ± 0.04^a
SHE 0.5%	0.31 ± 0.04^{ab}	0.396 ± 0.003^b	0.049 ± 0.004^b	0.72 ± 0.03^a	6.19 ± 0.03^{ab}	1.09	19.08 ± 0.05^b
SHE 0.75%	0.36 ± 0.03^{bc}	0.405 ± 0.004^c	0.055 ± 0.003^b	0.76 ± 0.03^b	6.23 ± 0.03^{bc}	1.15	19.23 ± 0.03^c
SHE 1%	0.41 ± 0.04^c	0.415 ± 0.003^d	0.062 ± 0.004^c	0.82 ± 0.03^c	6.27 ± 0.03^d	1.23	19.36 ± 0.04^d

*Each value is represented by the mean $\pm$ SD of n=3

abcd Indicate significant difference among treatments ($p < 0.05$)

** Each value indicates a mean of n=2

Table 6. Sensory characteristic profiles of fish extruded snacks

Sample	Appearance and colour*	Crispiness*	Odour*	Taste*	Texture*	Overall acceptability*
Control	8±1.00 ^b	9±0.50 ^b	8±0.95 ^c	9±0.10 ^d	8±0.76 ^c	8.4±0.10 ^b
FP 2.5%	8±0.66 ^b	9±0.07 ^b	8±0.88 ^c	7±0.70 ^c	8±0.19 ^c	8±0.02 ^b
FP 5%	6±0.65 ^a	6±0.24 ^a	3±0.00 ^b	2±0.00 ^b	5±0.17 ^b	4.4±0.76 ^a
FP 7.5%	6±0.11 ^a	6±0.26 ^a	2±0.00 ^a	1±0.76 ^a	4±0.46 ^a	3.8±0.79 ^a
SHE 0.25%	8±0.36 ^b	9±0.17 ^a	8±0.20 ^b	8±0.26 ^b	8±0.26 ^b	8.2±0.35 ^b
SHE 0.5%	8±0.19 ^b	9±0.43 ^a	8±0.77 ^b	7±0.30 ^b	8±0.21 ^b	8±0.17 ^b
SHE 0.75%	8±0.16 ^b	9±0.13 ^a	8±0.25 ^b	8±1.51 ^b	9±0.11 ^c	8.4±0.53 ^b
SHE 1%	6±0.36 ^a	9±0.15 ^a	7±0.52 ^a	4±0.95 ^a	5±0.78 ^a	6.2±0.35 ^a

*Each value is represented by the mean ± SD of n=3

^{abcd} Indicate significant difference among treatments (p<0.05)

FP-Fish powder, SHE-Shrimp head exudate

aureus, *Escherichia coli*, faecal streptococci, *Vibrio* spp. and *Salmonella* spp. were absent. The TPCs of the extruded snacks varied from 1.03 log cfu/g to 1.63 log cfu/g (Table 5). The TFCs were lower than the detectable range in all samples.

Sensory characteristics: The sensory scores of extruded snacks incorporated with fish powder and shrimp head exudate are presented in Table 6. From the results, it was observed that extruded products incorporated with 0% fish powder and 0.75% shrimp head exudate had higher sensory scores (8.4±0.1) followed by extruded snack incorporated with 2.5% fish powder and 0.5% shrimp head exudate (8.0±0.02).

DISCUSSION

Changes in proximate composition: The moisture, protein, fat and ash content increased significantly with the increase in the concentration of fish powder (0, 2.5, 5 and 7.5%) and shrimp head exudate (0.25, 0.5, 0.75 and 1.0%) in the extruded product, but a significant decrease in carbohydrate and energy value was observed with increase in the concentration of fish powder and shrimp head exudate in the extruded product. Similar results were reported by Chakraborty *et al.* (2020) in extruded fish snacks incorporated with Bombay

duck fish meal concentrate at different concentrations and Mulye and Zofair (2015) in extruded products incorporated with croaker fish flour at 12, 15, 18 and 21%.

Changes in physical characteristics: The expansion ratio decreased significantly with an increase in the concentration of fish powder and shrimp head exudate. The decrease in expansion ratio may be due to the increase in protein concentration, as it affects the distribution of water and its molecular structure and confirmation (Chakraborty *et al.*, 2020). Similar results were reported by Mulye and Zofair (2015) in extruded products incorporated with croaker fish flour at a concentration of 12, 15, 18 and 21%.

The bulk density of the extruded product increased significantly with an increase in the concentration of fish powder and shrimp head exudates. It was observed that the results of expansion ratio and bulk density were inversely proportional. Similar results were reported by Chakraborty *et al.* (2020) in extruded fish snacks incorporated with Bombay duck fish meal concentrate at different concentrations. Mulye and Zofair (2015) also reported an increase in bulk density with increased concentration in extruded product incorporated with croaker fish flour at 12, 15, 18 and 21%.

The porosity of extruded snacks decreased

significantly with the increase in the concentration of fish powder and shrimp head exudates. The decrease in porosity may be correlated with the increase in protein content which prevents the expansion of the product. A similar trend was recorded by Mulye and Zofair (2015) that 15% of fish flour enriched snacks have more porosity value (21.65%) followed by 12% fish flour (20.09 %), 18% fish flour (17.13%) and 21% fish flour (15.87 %).

WSI of the extruder snacks decreased significantly with an increase in the concentration of fish powder and shrimp head exudates. Similar results were reported by Ali *et al.* (2016) in corn grits from common carp. Kaur *et al.* (2018) reported that WSI values for Normal Maize (NM) and Quality Protein Maize (QPM) ranged from 22.32 to 33.79 % and 28.02 to 38.61% respectively.

The water absorption index of extruded snacks has increased significantly with the concentration of fish powder and shrimp head exudates. Ali *et al.* (2016) found that raising the replacement levels of carp fish enhanced the water absorption index (≤ 0.05). Similar results were observed by Chakraborty *et al.* (2020) and Mulye and Zofair (2015).

Biochemical changes: The peroxide value of extruded product incorporated with fish powder and shrimp head exudate increased significantly with an increase in concentration. The lower PV in the samples indicates low oxidation of fat in the extruded product. The maximum acceptable level for PV of corn snacks in the National standard is only 2 Meq/kg (ISIRI, 2009). Hence the results indicate that the PV of the extruded product was within the acceptable limits.

The thiobarbituric acid (TBA) value of extruded product incorporated with fish powder and shrimp head exudate increased significantly with an increase in concentration. The lower TBA values indicate lower oxidation of fat in the product. Similar results were observed by Ali *et al.* (2016) in corn grits-corn starch incorporated with common carp.

FFA content of the extruded product incorporated with fish powder and shrimp head exudate increased significantly with an increase in concentration. The increase in FFA may be correlated to the increase in fat content with an increase in concentration.

The pH value of the extruded product incorporated with fish powder and shrimp head exudate increased significantly with an increase in concentration. The increase in pH is related to a rise in calcium content which is present in the fish powder. Murphy *et al.* (2003) reported that the pH of the extrudates ranged from 6.1 in the control treatment to an average of 8.7 in the treatment with 400 g kg⁻¹ dry Crab by-products.

The water activity of the extruded product incorporated with fish powder and shrimp head exudate increased significantly with an increase in fish powder and shrimp exudate. The rise in water activity might be attributed to a change in the humidity levels of the surrounding environment and due to an increase in the concentration of fish powder and SHE. According to Jalgaonkar *et al.* (2017), the rise in water activity may be attributed to the product's hygroscopic behaviour, the permeability of packing material and the altering external environmental conditions.

The TVBN value of the extruded product incorporated with fish powder and shrimp head exudate increase significantly with an increase in fish powder and shrimp exudate. TVBN is a marker of quality and freshness. Increased levels of TVBN indicate spoilage by either enzymatic or bacterial degradation. The low TVBN value (ranging from 10-20) indicates that the product was prepared by following good manufacturing practices.

Microbiological characteristics: In the prepared extruded snacks, *E. coli*, *Staphylococcus aureus* and *Salmonella* spp. were absent. The TPCs of the extruded snacks varied from 1.03 log cfu/g to 1.63 log cfu/g. Very low TPC present in the study proves the microbial safety of the product. Similar results

were observed by Mulye and Zofair (2015) but higher TPC values were observed by Ali *et al.* (2016) in corn grits-corn starch incorporated with common carp. The total fungal count was lower than the detectable range.

Sensory characteristics: The sensory characteristics of the prepared extruded snack varied with concentration. In the extruded snack incorporated with fish powder, there was a decrease in odour, taste and texture. With the increase in concentration, the texture of the product has become harder and had a bitter taste. Only the control and fish powder incorporated at 2.5% extruded snacks were acceptable. The decrease in texture, colour and odour of the product might be due to do browning reactions and the increase in the concentration of a fish powder. The sensory characteristics of extruded snack incorporated with SHE varied with an increase in concentration. It was observed that extruded snack incorporated with SHE at 1% concentration had bitter taste and texture was very hard whereas the extruded product incorporated with 0.75% SHE had good flavour and texture when compared to other extruded snacks incorporated with 1% SHE. The decrease in texture, odour and taste of the product might be due to browning reactions. The higher sensory scores observed in FP 0% and 0.75% SHE incorporated snack might be due to the higher crispiness, appearance, texture and flavour of the product. Though sensory scores of 0% fish powder incorporated extruded product was

higher, the protein content (fish powder) was not incorporated and it was considered as control. Among the extruded snacks incorporated with fish powder, 2.5% incorporated snacks had higher acceptability and 0.75% SHE incorporated extruded snack had higher flavour and acceptability.

The present study was conducted to optimize/standardize the incorporation rate of fish powder and shrimp head exudate to improve the protein content and flavour of extruded snacks. Considering the sensory score, physical characteristics and proximate composition, 2.5% fish powder incorporated extruded snack was selected as the product with improved protein content and good acceptability. 0.75% SHE incorporated snack had good flavour, better sensory score and was the most acceptable. Hence these concentrations i.e., 2.5% fish powder and 0.75% shrimp head exudate individually can be considered as the best formulation for developing cereal-based extruded snacks with improved protein content and flavour.

Conflict of interest: Authors have no conflict of interest in this study.

ACKNOWLEDGEMENTS

The authors are thankful to the Vice-Chancellor, Sri Venkateswara Veterinary University, Tirupati; the Dean, Faculty of Fishery Science, SVVU, Tirupati and the Associate Dean, College of Fishery Science, Muthukur for providing the facilities for conducting research.

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Received – 06.07.2021, Accepted – 23.10.2021, Published – 01.12.2021

Section Editor: Prof. T. J. Abraham, Associate Editor