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Research Article

Functional and Biochemical Characteristics of Extruded Snacks Flourished with Fish Powder and Shrimp Head Exudate During Storage Conditions

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Abstract

An experiment was attempted to utilize the fish powder made from the low-value fish to enhance the protein content and shrimp head exudate was utilized to increase the flavour of the extruded product. The nutritious extruded Ready-to-eat (RTE) snack was developed using fish powder (0, 2.5%, 5%, 7.5%) and cereal flour such as cornflour and rice flour and shrimp head exudates (0.25%, 0.5%, 0.75%, 1%). The fish powder, shrimp head exudate, and cereal mixtures were extruded using the extrusion cooking method consisting of moisture content of 10 percent, screw speed 350 rpm, sectional barrel temperature of 60˚C, and 120˚C and 2 mm diameter of the die. The prepared 8 extruded products were analyzed to optimize the incorporation rate for extruded products from the results, an extruded product with fish protein powder incorporated at 2.5% and shrimp head exudate incorporated at 0.75% were selected as optimized incorporation rates. The resulting extruded product was analyzed for physical, biochemical, and mineral contents. Among the extruded products, extruded products incorporated with 2.5% fish protein and 0.75% shrimp head exudate had good physical characteristics and higher sensory scores. individually. Hence these concentrations may be used for the preparation of extruded snacks in combination as treatments for storage studies. (T1-FP0%, T2-FP2.5% T3-FP2.5%+0.75%SHE).

Novelty Impact Statement

- The low-value edible fish was utilized for the preparation of fish powder which is considered a protein enhancer in the extruded RTE snack product.
- The shrimp head usually discarded as waste was used for the preparation of shrimp head exudate which is considered a flavour and nutrition enhancer in the extruded RTE snack product.
- Optimization of the incorporation rate of fish powder and shrimp head exudate into the extruded product.
- Analysis of functional, biochemical properties and mineral content of the extruded snack product

Keywords: Extruded snack product; Functional properties; Biochemical properties; Mineral content; Shrimp head exudate; Fish powder

Introduction

Fish is much valued for its nutritional value, providing the consumer with the high-quality protein and essential amino acids and it is an incomparable source of lipid-containing omega 3 fatty acids, especially Eicosapentaenoic acid and Docosahexaenoic acid and at the same time, it is a good source of B-complex vitamins and minerals [1]. Fish is rich in all major nutrients except carbohydrates and vitamin C [2]. Fish have relevant nutritional value due to their high protein and minerals level (calcium, phosphor and iron) [3,4]. Ten percent of the total catch of world consists of fish that are underutilized because of undesirable features like small size, dark meat, strong flavour, unacceptable textural properties. Utilisation of low value fishes is of great importance in developing countries. Due to the extremely perishable nature of the fish and inherence of technology for its proper utilisation, a significant portion of the fishery source remains unutilised as human food [6]. Commercial marine fish catch from these trawlers generally consists of edible fish species 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 as rough fish. The trash fishes which are caught as a by-catch accounts for 50% of the total catch and generally rich in nutritive value. The nutritive value of these fish is not often utilized properly and discarded as a waste [7]. However, due to their high biological value, fish residues have been studied for possible use in human consumption [8] by including them in other processed foods, such as snacks [9]. The low economic value/ trash fish is utilised for the development of the new value- added product by using low-cost technology [10] and snack product is excellent choice as its consumption rate is constantly increasing now-a-days. The snack products are high in

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fat and carbohydrates and comparatively low in protein [11]. Good snacks must be inexpensive, nutritious, low in fat, convenient to consume and have a long shelf life [12]. Extruded products based on cereals and grains were the most widely consumed snack food items, and many of these were low in nutrient density and high in calories and/or fat content hence their protein content must be improved to convert these into healthy products [13]. Extrusion processing is a widely used technology in the food industry for restructuring starchy and proteinaceous ingredients in preparing ready-to-eat foods [14]. Extrusion technology has been extensively used in the production of cereal RTE snacks due to its ease of operation and ability to produce a variety of textures and shapes which appeal to consumers [14]. Many manufactured snacks are high in calories and fat but low in protein, vitamins, and other nutrients [15]. Several researchers and dieticians have reported the incorporation of high protein ingredients for the nutritional improvement of the snacks using different cereals to enrich the nutritional quality of the product [16]. The incorporation of fish flesh or fish powder in to starchy material to produce nutritious extruded snacks that is acceptable by the consumer through the extrusion process [17-19]. On a global basis, the shrimp processing industry produces over 7,00,000 million tons of shell waste, and the seafood processing industry in India generates 8.5 million tons of shell waste per year [20]. The shrimp head was utilized to obtain the exudate for flavor enhancement. The present study was aimed at incorporating low-value fish powder and shrimp head extrudate in the preparation of extruded snacks to increase their nutritional value and value addition and to assess the shelf life of the product in the storage condition.

Materials and Methods

Raw Material

Shrimp head waste and low-value fish (Pellona ditchella) of length 3.5 cm - 5.5 cm and weight 25 g - 40 g were brought from the fish market in Muthukur, Sri Potti Sriramulu Nellore District, Andhra Pradesh and were iced immediately at the ratio of 1:1 (fish and ice) and transported to the laboratory in chilled condition within 30 mins. The low-value fish were washed thoroughly in chilled potable water and beheaded, gutted and used for the preparation of fish powder.

Preparation of fish 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/pulverised and fine milled and packed in High-density polyethene pouches, 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 exudates to enhance the flavour of the product.

Preparation of extruded Product

The ingredients used for the preparation of extruded snacks were maize flour, rice flour, Fish Powder (FP), Shrimp Head Exudates (SHE) used at different concentrations. For the preparation of extruded snack, fish powder at a concentration of 0, 2.5, 5 and 7.5 % and shrimp head exudate was added at 0.25, 0.5, 0.75% and 1%. 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, 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. Because of the good physical characteristics and higher sensory scores, from the optimised incorporation rates, three concentrations were selected for storage studies (T1-FP0%, T2-FP2.5% T3-FP2.5%+0.75%SHE).

Physical parameters of the extruded product

The expansion ratio was determined by the Ding method. Expansion ratio = Extrudate diameter/ Die diameter(mm). Bulk density was calculated according to Hood-Niefer and Tyler. Bulk density= Mass/ volume(g/cm^3). Porosity (PO) was calculated according to Wang. Porosity = particle density-bulk density/ particle density ×100. Particle density was calculated according to the method of Gujska and Khan. Particle density=4m/πd^{2}l. The water solubility index was measured following the method of Anderson. 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. Water absorption index= weight of sediments/weight of dry solids(g).

Bio-Chemical analysis and mineral content analysis

Peroxide value was determined according to the method of Jacobs. Free fatty acid was determined by following the method of Olley and Lovern. TVBN and TMA was determined by the Conway method and expressed as mg of N/100 g of sample TBA was determined by Kohn and Liversedge and expressed as μg/g. Water activity was determined by using water activity meter by taking 10 g of sample for 15 minutes and then the values were recorded which was displayed on water activity meter. For pH determination 5 grams of sample was taken and 45 ml distilled water was added and was homogenised using Polytron PT2100 (Luzan) homogeniser. The pH of homogenate was recorded using a digital pH meter (M/s. Oakton, Eutech instruments, Malaysia). Determination of minerals like Calcium and Phosphorus was carried out according to AOAC.

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 ± SD (Standard Deviation). $P<0.05$ was considered statistically significant.

Results and Discussion

Optimization of the final concentration of extruded snacks incorporated with fish powder and shrimp head exudate for storage studies

The optimization of the incorporation rate of the extruded product was done by preparing products at different concentrations (FP0%, FP2.5%, FP5%, FP 7.5%, and 0.25%SHE, 0.5%SHE, 0.75%SHE and 1%SHE). From the results of optimization of incorporation rate (Table 3) for preparing extruded snack products incorporated with FP and SHE, three concentrations were selected for storage studies (90 days). They were FP 0%, FP 2.5%, FP 2.5%+0.75%SHE. The concentrations are represented as T1 (FP 0%), T2 (FP 2.5%), T3(FP 2.5%+0.75%SHE) respectively (Table 3).

Physical characteristics of extruded product incorporated with Fish powder (FP) and Shrimp Head Exudate (SHE) during storage studies

The expansion ratio, porosity, water solubility index, water absorption index showed negative correlation with the increase in fish

Table 1: Standardisation 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	50	50	50	50
Fish powder	0	2.5	5	7.5	0	0	0	0
Total	100	100	100	100	100	100	100	100
Moisture level (%)	10	10	10	10	9.75+0.25%	9.50+0.5%	9.25+ 0.75%	9%+1%

powder and shrimp head exudate and storage time. The bulk density showed positive relationship with the increase in fish powder and shrimp head exudate and storage time.

Expansion ratio (ER)

The expansion ratio of extruded product incorporated with FP and SHE was dropped during storage and found to be 3.33 ± 0.05 to 3.12 ± 0.06, 3.24 ± 0.04 to 2.98 ± 0.09 and 3.14 ± 0.05 to 2.88 ± 0.07 for T1, T2 and T3 respectively. 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 [21,22]. Rao reported a decrease in expansion ratio, WSI, WAI, and an increase in bulk density of sorghum-based extruded product after 90 days of storage (Table 4).

Bulk density (BD)

The bulk density of extruded product incorporated with FP and SHE was shown increasing tendency during storage and found to be 0.100 ± 0.01 to 0.134 ± 0.01, 0.109 ± 0.01 to 0.151 ± 0.007 and 0.143 ± 0.09 to 0.184 ± 0.01 for T1, T2 and T3 respectively. The bulk density of the extruded product increased with an increase in the concentration of fish powder and shrimp head exudates. Ali observed an increase in bulk density (0.358 to 0.377) over a 3-month storage period in Extruded Products Prepared from Corn Grits – Corn Starch Incorporated with Common Carp (Table 5) [23].

Table 2: The operation conditions of the equipment.

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

Table 3: Optimization of the final concentration of extruded snacks incorporated with fish powder (FP) and shrimp head exudate (SHE) for storage studies,

Material	T1	T2	T3
Maize flour	50	48.75	48.75
Rice flour	50	48.75	48.75
Fish powder	0	2.5	2.5
Total	100	100	100

Table 4: Expansion Ratio (ER).

Storage period (days)	Expansion Ratio*		
	T1	T2	T3
0	3.33 ± 0.05^{b}	3.24 ± 0.04^{b}	3.14 ± 0.05^{a}
30	3.29 ± 0.06^{c}	3.19 ± 0.07^{b}	3.09 ± 0.04^{a}
60	3.22 ± 0.06^{c}	3.10 ± 0.08^{bc}	2.95 ± 0.11^{ab}
90	3.12 ± 0.06^{c}	2.98 ± 0.09^{b}	2.88 ± 0.07^{a}

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments(p<0.05)

Porosity (PO)

The porosity of extruded product incorporated with FP and SHE indicated decreasing tendency during storage from 32.00 ± 0.08% to 20.12 ± 0.08%, 22.00 ± 0.09% to 13.21 ± 0.07%, 18.00 ± 0.10% to 12.74 ± 0.10% respectively for T1, T2 and T3 respectively. 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 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%), 21% fish flour (15.87 %) (Table 6) [24].

Water solubility index (WSI)

The water solubility index of extruded product incorporated with FP and SHE was dropped during storage and found to be 8.50 ± 0.08% to 8.10 ± 0.09%, 8.30 ± 0.06% to 8.02 ± 0.10% and 8.10 ± 0.08% to 7.81 ± 0.09% for T1, T2, and T3 respectively. The decrease in water solubility index during storage is due to an increase in moisture content. Ali observed a decrease in WSI (18.05 to 17.99) over a 3-month storage period in Extruded Products Prepared from Corn Grits – Corn Starch Incorporated with Common Carp (Table 7) [25].

Water absorption index (WAI)

The water absorption index of extruded product incorporated with FP and SHE was showed decreasing tendency during storage from 5.10 ± 0.01% to 4.90 ± 0.09%, 5.21 ± 0.08% to 4.97 ± 0.10%,

Table 5: Bulk Density (BD) (g/cm^{3}).

Storage period (days)	Bulk density (g/cm^{3}) *		
	T1	T2	T3
0	0.100 ± 0.01^{a}	0.109 ± 0.01^{a}	0.143 ± 0.09^{b}
30	0.105 ± 0.06^{a}	0.119 ± 0.08^{a}	0.154 ± 0.09^{b}
60	0.121 ± 0.009^{a}	0.140 ± 0.13^{a}	0.172 ± 0.009^{b}
90	0.134 ± 0.01^{a}	0.151 ± 0.007^{b}	0.184 ± 0.01^{c}

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75% SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments(p<0.05)

Table 6: Porosity (PO) (%).

Storage period (days)	Porosity (%) *		
	T1	T2	T3
0	32.00 ± 0.08^{c}	22.00 ± 0.09^{b}	18.00 ± 0.10^{a}
30	26.20 ± 0.11^{c}	16.60 ± 0.05^{b}	14.50 ± 0.72^{a}
60	24.15 ± 0.10^{c}	15.48 ± 0.09^{b}	13.92 ± 0.15^{a}
90	20.12 ± 0.08^{c}	13.21 ± 0.07^{b}	12.74 ± 0.10^{a}

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments(p<0.05)

and 5.32 ± 0.08% to 5.08 ± 0.09% correspondingly for T1, T2 and T3. The decrease in water absorption index during storage is attributed to an increase in moisture content Ali observed a decrease in WAI (5.94 to 5.70) over a 3-month storage period in Extruded Products Prepared from Corn Grits – Corn Starch Incorporated with Common Carp (Table 8) [26].

Biochemical characteristics and mineral content of extruded product incorporated with Fish powder (FP) and Shrimp Head Exudate (SHE) during storage studies

The pH, peroxide value, thiobarbituric acid, free fatty acid, and water activity were increased with an increase in the concentration of Fish Powder (FP) and Shrimp Head Exudate (SHE), and minerals like calcium and phosphorus decreased with an increase in the concentration of FP and SHE.

pH

The pH of extruded product incorporated with FP and SHE was found to be in an increasing trend during storage from 5.85 ± 0.10 to 6.41 ± 0.09, 6.13 ± 0.09 to 6.54 ± 0.14 and 6.25 ± 0.08 to 6.71 ± 0.07 for T1, T2, T3 respectively. The pH of surimi gel increased during storage due to breakdown products such as volatile bases and amines produced by the autolytic and microbiological activity of proteins and other components during storage. According to Ali, the pH of maize snacks containing common carp rose from 6.23 to 6.33 after a three-month storage period (Table 9) [27-29].

Peroxide value

The peroxide value of extruded product incorporated with FP and SHE rose during storage from 0.24 ± 0.06% to 0.54 ± 0.07%, 0.35 ± 0.05% to 0.65 ± 0.12%, 0.44 ± 0.52% to 0.73 ± 0.05% milliequivalent of O2/kg of fat for T1, T2 and T3. According to Shaviklo, the peroxide values of maize snacks containing rainbow trout mince, silver carp mince, and saithe protein rose (0.0 to 2.8 meq kg^{-1}) during 6-months of ambient storage. Shankar [1], Senthil, Sharma and Riar, Verardo, Shoba, and Jalgaonkar showed a similar rise in PV during storage in fish and rice-based extruded products, commercial extruded snack, and millet flour-incorporated cookies (Table 10) [30-32].

Free fatty acid

The free fatty acid of extruded product incorporated with FP and SHE found to be in increasing tendency from 0.75 ± 0.07% to 1.25 ± 0.08%, 0.95 ± 0.04% to 1.49 ± 0.08%, 1.15 ± 0.08% to 1.58 ± 0.09% of oleic acid/kg of fat for T1, T2 and T3. The increase in free fatty acids during storage might be due to the breakage of the long fatty acid chain into individual fatty acid moieties and also increased lipid hydrolysis at elevated temperatures. Nkubana and Dusabumuremyi reported that the free fatty acid content of the fish-rice and fish-maize incorporated extruded snacks was found to be 0.38 and 0.42% which rose to 0.75 and 0.87% at the end of the storage period (Table 11).

Thiobarbituric acid

The thiobarbituric acid of extruded product incorporated with FP and SHE increased during storage and found to be 0.039 ± 0.08%, 0.053 ± 0.009% and 0.092 ± 0.07% to 0.071 ± 0.006%, 0.082 ± 0.013% and 0.125 ± 0.01% of µg/g of fat for T1, T2 and T3 respectively. The increase in TBA value could be due to an increase in TBA reactive compounds resulted from lipid oxidation and production of volatile metabolites. No sufficient data to compare the result (Table 12).

Water activity

The water activity of extruded product incorporated with FP and SHE increased during storage and found to be 0.564 ± 0.09 to 0.582 ± 0.006, 0.568 ± 0.009 to 0.589 ± 0.007, 0.572 ± 0.001 to 0.594 ± 0.10

Table 7: Water Solubility Index (WSI) (%).

Storage period	Water solubility index (%) *		
(days)	T1	T2	T3
0	8.50 ± 0.08^c	8.30 ± 0.06^b	8.10 ± 0.08^a
30	8.42 ± 0.09^c	8.28 ± 0.06^b	8.05 ± 0.06^a
60	8.21 ± 0.07^c	8.14 ± 0.08^b	7.91 ± 0.06^a
90	8.10 ± 0.09^c	8.02 ± 0.10^b	7.81 ± 0.09^a

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments(p<0.05)

Table 8: Water Absorption Index (WAI) (%).

Storage period	Water absorption index (%) *		
(days)	T1	T2	T3
0	5.10 ± 0.01^a	5.21 ± 0.08^{ab}	5.32 ± 0.08^c
30	5.05 ± 0.06^a	5.17 ± 0.06^b	5.28 ± 0.06^c
60	4.98 ± 0.09^a	5.04 ± 0.07^{ab}	5.14 ± 0.05^{ab}
90	4.90 ± 0.09^a	4.97 ± 0.10^a	5.08 ± 0.09^b

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments(p<0.05)

Table 9: pH.

Storage period	pH*		
(days)	T1	T2	T3
0	5.85 ± 0.10^a	6.13 ± 0.09^b	6.25 ± 0.08^c
30	5.92 ± 0.06^a	6.20 ± 0.05^b	6.36 ± 0.08^c
60	6.10 ± 0.08^a	6.42 ± 0.16^b	6.52 ± 0.16^b
90	6.41 ± 0.09^a	6.54 ± 0.14^a	6.71 ± 0.07^b

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments(p<0.05)

Table 10: Peroxide Value (PV) (milliequivalent O_2/kg of oil).

Storage period	Peroxide value (milliequivalent O_2/kg of oil)*		
(days)	T1	T2	T3
0	0.24 ± 0.06^a	0.35 ± 0.05^b	0.44 ± 0.52^c
30	0.36 ± 0.06^a	0.45± 0.06^{ab}	0.49 ± 0.06^b
60	0.44 ± 0.09^a	0.56 ± 0.11^a	0.62 ± 0.11^a
90	0.54± 0.07^a	0.65 ± 0.12^b	0.73 ± 0.05^c

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments(p<0.05)

Table 11: Free Fatty Acid (FFA) (% of oleic acid).

Storage period	Free Fatty acid (% of oleic acid)*		
(days)	T1	T2	T3
0	0.75 ± 0.07^a	0.95 ± 0.04^b	1.15 ± 0.08^c
30	0.83 ± 0.03^a	0.98 ± 0.06^b	1.25 ± 0.06^c
60	0.93 ± 0.05^a	1.22 ± 0.08^b	1.39 ± 0.09^c
90	1.25 ± 0.08^a	1.49 ± 0.08^b	1.58 ± 0.09^b

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments(p<0.05).

Table 12: Thiobarbituric acid (TBA) (µg/g).

Storage period	Thio-barbituric acid (µg/g)*		
(days)	T1	T2	T3
0	0.039 ± 0.08^a	0.053 ± 0.009^a	0.092 ± 0.07^b
30	0.045 ± 0.008^a	0.059 ± 0.007^b	0.095 ± 0.007^c
60	0.055 ± 0.01^a	0.068 ± 0.009^a	0.115 ± 0.001^b
90	0.071 ± 0.006^a	0.082 ± 0.013^a	0.125 ± 0.01^b

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments(p<0.05)

for T1, T2 and T3 respectively. The rise in a_w might be attributed to a change in the humidity levels of the surrounding environment. According to Hussain the initial water activity of rice-based snack extrudates was 0.40 and rose to 0.56 after three months of storage. (Table 13).

Calcium

The calcium content of extruded product incorporated with FP and SHE indicated decreasing tendency during storage from 0.30 ± 0.05% to 0.19 ± 0.04%, 0.40 ± 0.06% to 0.26 ± 0.04%, 0.44 ± 0.08% to 0.35 ± 0.03% for T1, T2 and T3 respectively. Similarly, Franco reported calcium levels ranging from 0.038 to 2.36 g/ 100 g in homemade cookies with the addition of 0 and 30% fish flour, respectively. Thus, the use of fish flour may be an alternative to add nutritional value to the food product, when mineral enrichment is desired (Table 14).

Phosphorus

The phosphorus content of extruded product incorporated with FP and SHE indicated decreasing during storage from 0.18 ± 0.04%, 0.21 ± 0.03%, 0.24 ± 0.04% to 0.08 ± 0.03%, 0.10 ± 0.04%, 0.15 ± 0.06% for T1, T2, T3 respectively. Kuna reported that phosphorus content was lower in fish powder incorporated extrudates than control samples (Table 15).

Conclusion

Development of extruded products using cereal flour, with fish flour, without compromising on the quality of final product, would help to improve the nutritional quality of cereal and pulse- based snack food apart from adding distinct flavour and taste. The under-utilized fishes will not only be utilized for value addition but also for development of products with enhancing the nutritional value of ready to eat snack foods. The overall acceptability of the product decreased during storage. However, the products were found shelf stable as they did not undergo drastic quality changes. It can be concluded that fish powder and shrimp head exudate incorporated products are fit for consumption when stored in aluminium packing for three months of storage. As a consequence, shrimp head exudate has improved the protein content of extruded items, potentially offering greater nourishment to customers, particularly children. The product is also made using just natural ingredients, with no chemicals added. There will be no adverse effects from ingesting the product because it is extruded. This product is indicated for all age groups, ranging from 5 to 60 years, to supplement protein, calcium, and phosphorus. Increasing the protein and fibre content in the product resulted in decreased expansion ratio but the snack products still obtained good sensory characteristics. Thus, utilizing the low-value fish can minimize the waste in the fish supply chain and reduce the environmental impact.

Table 13: Water activity (a_w).

Storage period (days)	Water activity (a_w)*		
	T1	T2	T3
0	0.564 ± 0.09^a	0.568 ± 0.009^a	0.572 ± 0.001^{ab}
30	0.568 ± 0.07^a	0.573 ± 0.006^a	0.579 ± 0.05^a
60	0.571 ± 0.008^{ab}	0.579 ± 0.008^{bc}	0.588 ± 0.007^c
90	0.582 ± 0.006^a	0.589 ± 0.007^b	0.594 ± 0.10^c

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments($p<0.05$)

Table 14: Calcium (%).

Storage period (days)	Calcium (%) *		
	T1	T2	T3
0	0.30 ± 0.05^a	0.40 ± 0.06^b	0.44 ± 0.08^c
30	0.29 ± 0.10^a	0.38 ± 0.07^b	0.42 ± 0.09^c
60	0.25 ± 0.04^a	0.31 ± 0.08^b	0.39 ± 0.03^b
90	0.19 ± 0.04^a	0.26 ± 0.04^a	0.35 ± 0.03^b

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments($p<0.05$)

Table 15: Phosphorus (%).

Storage period (days)	Phosphorus (%) *		
	T1	T2	T3
0	0.18 ± 0.04^a	0.21 ± 0.06^b	0.24 ± 0.04^b
30	0.15 ± 0.03^a	0.19 ± 0.03^b	0.23 ± 0.04^b
60	0.10 ± 0.03^a	0.17 ± 0.05^b	0.20 ± 0.04^b
90	0.08 ± 0.03^a	0.10 ± 0.04^a	0.15 ± 0.06^a

Notes: T1-FP0%, T2-FP2.5%, T3-FP2.5%+0.75%SHE
*Each value is represented by the mean ± SD of n=3
abc Indicate significant difference among treatments($p<0.05$)

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