Biochemical Characterization and Shelf-Life Studies of Twin-Screw Extruded Fish Snacks Using Mackerel and Rohu Powders

Abstract

Fish, a rich source of high-quality protein, essential amino acids, Omega-3 fatty acids, and key micronutrients, holds significant potential for the development of innovative and nutrient-dense food products. This study focused on creating a fish-based extruded snack fortified with corn flour and millet flour, leveraging extrusion technology to enhance its texture, nutritional profile, and shelf life. Five formulations were prepared, varying in fish powder (10–30%), corn flour (50%), and millet flour (20–40%) proportions. Optimized extrusion parameters, including a barrel temperature of 112°C, screw speed of 320 rpm, and feed rate of 210 g/min, were employed to ensure consistent product quality. Ingredients like tapioca starch (3–5%), seasoning, and natural preservatives (tocopherols) were incorporated to improve functionality and sensory characteristics. Among the formulations, Treatment 5 (30% fish powder, 50% corn flour, 20% millet flour) emerged as the best, offering a protein content of 25% per 100 g and a well-balanced amino acid profile. Sensory evaluation using a 9-point hedonic scale rated Treatment 5 at 8.5 for taste and texture, indicating high consumer acceptability. The product maintained its quality for three months under ambient conditions, showcasing excellent stability and crispness. This research highlights the potential of fish-based extruded snacks to provide a nutrient-rich, shelf-stable alternative to conventional snacks, promoting the utilization of underused fish resources and contributing to food security and economic growth.

Keywords: Extrusion technology, Fish-based snacks, Fish powder, Konkan region, Nutritional enhancement, Protein-enriched snacks, Sensory evaluation, Value-added products.

Introduction

Fish plays a crucial role in human nutrition, offering exceptional dietary benefits and supporting overall health. It serves as an excellent source of easily digestible, high-quality protein, containing all essential amino acids vital for growth and tissue repair (FAO, 2020). Additionally, fish is a rich provider of Omega-3 fatty acids, including DHA and EPA, which are known for their significant roles in enhancing brain and heart health and reducing inflammation. Along with these healthy fats, fish is abundant in essential vitamins like A, D, and B-complex vitamins such as B12, niacin, and riboflavin, which are critical for various physiological processes (Nielsen et al., 2013). Furthermore, fish is loaded with vital minerals, including iodine, selenium, zinc, phosphorus, and calcium, which contribute to strong bones, thyroid regulation, and immune support. Its low content of saturated fats aids in lowering bad cholesterol levels, thereby reducing the likelihood of cardiovascular issues (Jorgensen et al., 2014). Incorporating fish into one's diet offers numerous advantages, such as improved cognitive function, better vision, effective weight control, and a lower risk of chronic ailments like arthritis and type-2 diabetes (Bishop et al., 2013). On average, fish provides 18-22 g of protein, 1-10 g of fat (depending on the type), 80-120 kcal of energy, and substantial

amounts of Omega-3 fatty acids, Vitamin D, and essential minerals per 100 g of edible portion (Bordi et al., 2016). This nutrient-rich profile highlights the importance of fish as a key element in a balanced diet, contributing significantly to long-term health and well-being.

The incorporation of fish from regions like Konkan into extruded products not only leverages the area's rich biodiversity but also contributes to sustainable practices by utilizing underutilized species and by-products. Extrusion offers several advantages, including improved texture, customizable product formulations, and the ability to produce shelf-stable, ready-to-eat or ready-to-cook products. This study focuses on the application of extrusion technology in developing fish-based extruded products, particularly utilizing the diverse fish resources of the Konkan region, exploring their nutritional profile, processing parameters, and potential for enhancing food security and economic growth.

Material and Methodology

1. Finger Millet Flour:
   Finger millet flour was procured fresh from the local market in Dapoli. Its high nutritional value made it a vital ingredient in the snack formulation.
2. Fish Powder:
   Fish powder was sourced from the Ratnagiri market. It was used as a rich protein source to enhance the nutritional profile of the product.
3. Sensory Evaluation:
   Sensory attributes, including taste, texture, aroma, colour, and overall acceptability, were assessed using a 9-point hedonic scale by a trained panel. Treatment T5 achieved the highest scores, indicating superior sensory appeal.
4. Chemical Properties:
   The chemical properties, such as protein, fat, essential amino acids, moisture, ash, and carbohydrate content, were analysed in the Department of Processing and Food Engineering. Treatment T5 demonstrated the best nutritional composition due to its optimized formulation.

Experimental Details

Treatment	Corn Flour %	Millet Flour%	Fish Powder %
1	50	40	10
2	50	35	15
3	50	30	20
4	50	25	25
5	50	20	30

Extrusion Parameters:

- **Barrel Temperature**: 112°C
- **Screw Speed**: 320 rpm
- **Moisture Content**: **15%**

Additional Ingredients (Optional):

- **Binding Agents**: Tapioca starch (3–5%)5
- **Seasoning**: Salt, spices, flavour enhancers (as needed)
- **Oil/Fat Content**: 2–5%
- **Preservatives**: Natural options like citric acid or tocopherols

Preparation of extrudates

Extrusion processing for fish-based snacks requires carefully optimized parameters to achieve the desired texture, shape, and nutritional quality. The barrel temperature typically112°C, which facilitates the gelatinization of starches and the denaturation of proteins, ensuring a cohesive structure. The screw speed, usually set between 320 rpm, plays a crucial role in controlling shear and mixing during extrusion. Maintaining a moisture content of 12 % is essential to ensure proper flow through the extruder and to prevent clogging or irregular extrusion.

In addition to the primary ingredients, supplementary components can enhance the product's functionality and sensory appeal. Binding agents such as tapioca starch, used at 3–5%, improve the cohesion and structural integrity of the extrudates. Seasonings, including salt, spices, and flavour enhancers, can be incorporated as needed to achieve desirable taste profiles. A small percentage of oil or fat (2–5%) may be added to enhance flavour and mouthfeel. Natural preservatives, like citric acid or tocopherols, are recommended to extend shelf life without compromising the product's health benefits. These parameters and ingredients collectively contribute to creating a high-quality, nutrient-rich extruded snack.

Proximate analysis of developed fish-extrudates

1. **Protein Content (%):** Protein content was determined using the Kjeldahl method, following the procedure described by AOAC (2000). The nitrogen content was converted to protein using a factor of 6.25.
2. **Essential Amino Acids:** Essential amino acids were analysed by High-Performance Liquid Chromatography (HPLC) after acid hydrolysis, as per AOAC (2005). Samples were hydrolyzed with 6N HCl at 110°C for 24 hours before HPLC analysis.
3. **Fat Content (%):** Fat content was determined using Soxhlet extraction with petroleum ether, based on the method described by AOAC (1990). The extracted fat was dried, and the weight difference was used to calculate the percentage.
4. **Moisture Content (%):** Moisture content was determined using the oven-drying method, as outlined by AOAC (2005). Samples were dried at 105°C until reaching a constant weight, and moisture content was calculated from the weight difference.

5. **Ash Content (%):** Ash content was measured by incinerating the sample in a muffle furnace at 550°C for 6 hours, as per AOAC (2000). The residue weight was recorded as ash content.
6. **Carbohydrate Content (%):** Carbohydrate content was calculated by the difference method, subtracting the sum of protein, fat, moisture, and ash percentages from 100, following FAO guidelines (1989).

Sensory evaluation

Sensory evaluation of the fish extruder samples was performed using a 9-point hedonic scale to assess key attributes, including appearance, texture, flavour, taste, and aroma. A panel consisting of 10–15 trained and semi-trained evaluators conducted the assessment under controlled conditions to ensure uniformity.

The hedonic scale ranged from 1 (extremely disliked) to 9 (extremely liked), with panelists assigning scores for each attribute. Samples were presented in a randomized sequence to reduce bias, and palate cleansing between samples was encouraged to maintain objectivity. Average scores for individual attributes were calculated, and the overall acceptability was determined by taking the mean of these scores, providing an insight into consumer preference and product quality.

Fig. 1 Process flow chart for development of fish-extrudates

1. **Fish Powder Preparation:** Fish is cleaned, deboned, and dried to remove impurities and enhance shelf stability. The dried fish is ground into a fine powder, making it suitable for blending with other ingredients.
2. **Blending and Moisture Adjustment**: The fish powder is mixed with rice flour, Bengal gram flour, and spices such as pepper powder, turmeric powder, and salt. This mixture is blended uniformly, and the moisture content is adjusted to achieve the desired dough consistency for extrusion.
3. **Extrusion Process**: The extrusion process is conducted at a temperature of 112°C, with a screw speed of 320 rpm and a feed rate of 210 g/min. These parameters ensure proper cooking, texture formation, and consistent shaping of the Fish Kurkure.

4. **Post-Extrusion Coating**:The extruded product is coated with a taste-maker solution prepared with refined vegetable oil. This step enhances the flavor and gives the snack a glossy, appealing surface finish.
5. **Packaging and Storage**:After cooling, the Fish Kurkure is packed in airtight containers to retain its crisp texture and freshness. Proper packaging ensures an extended shelf life while maintaining quality and flavor.

Resultsand Discussion

Table 1 : Evaluation of Nutritional Value, Shelf Life, and Sensory Attributes

Sr.No	Parameter	Discussions	Results
1	**Nutritional Value**	Protein content compared to traditional cereal-based snacks.	**20-25% protein content** (per 100g).
		Essential amino acid composition providing a balanced and complete protein source.	**Optimal balance of essential amino acids.**
2	**Shelf Life**	Taste quality rated by a trained panel using a 9-point hedonic scale.	**3 months** (ambient storage).
3	**Sensory Evaluation**	Taste quality rated by a trained panel using a 9-point hedonic scale.	**8.5/9 for taste and texture**.

Table 2: Chemical Analysis

Treatment	Protein Content %	Essential Amino acid	Fat Content %	Moisture Content (%)	Ash Content (%)	Carbohydrate (%)
1	11.8	0.63	3.2	10.5	2.0	72.5
2	14.7	0.71	3.8	10.2	2.3	69.0
3	18.3	0.79	4.6	10.0	2.6	64.5
4	22.1	0.88	5.2	9.8	3.0	60.0
5	25.5	0.94	5.8	9.6	3.4	56.5

The chemical analysis of the fish-based extruded snack formulations (per 100 g) revealed significant variations across treatments. Protein content ranged from 11.8% in Treatment 1 to 25.5% in Treatment 5, with a corresponding improvement in the Essential Amino Acid Index (0.63 to 0.94), highlighting the nutritional enhancement with increasing fish powder. Fat content increased from 3.2% to 5.8%, contributing to flavor and satiety, while moisture content decreased slightly (10.5% to 9.6%), ensuring better shelf stability. Ash content, reflecting mineral richness, rose from 2.0% to 3.4%, while carbohydrate levels declined from 72.5% to 56.5%, making the product more protein-focused. Treatment 5 emerged as the most nutritionally balanced, offering a superior profile ideal for health-conscious consumers.

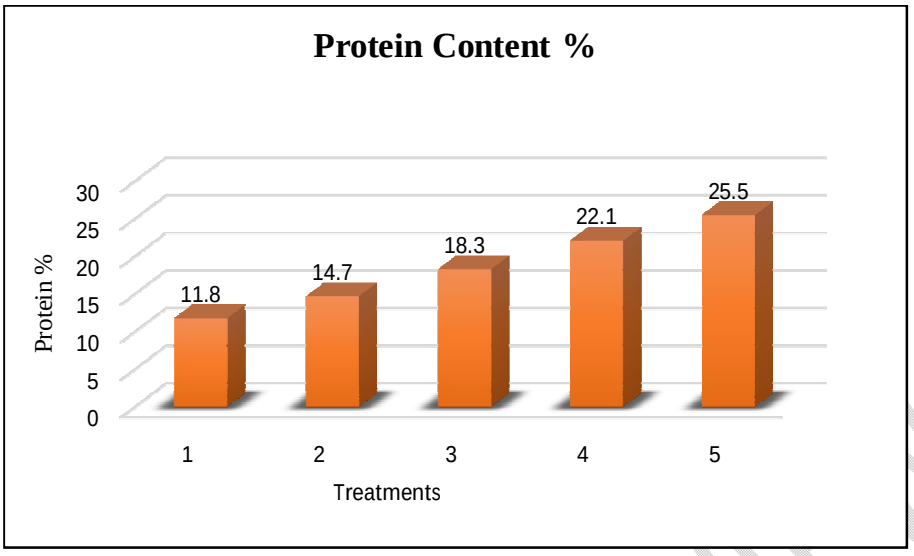

Fig. 2 Protein Content in Energy Bites

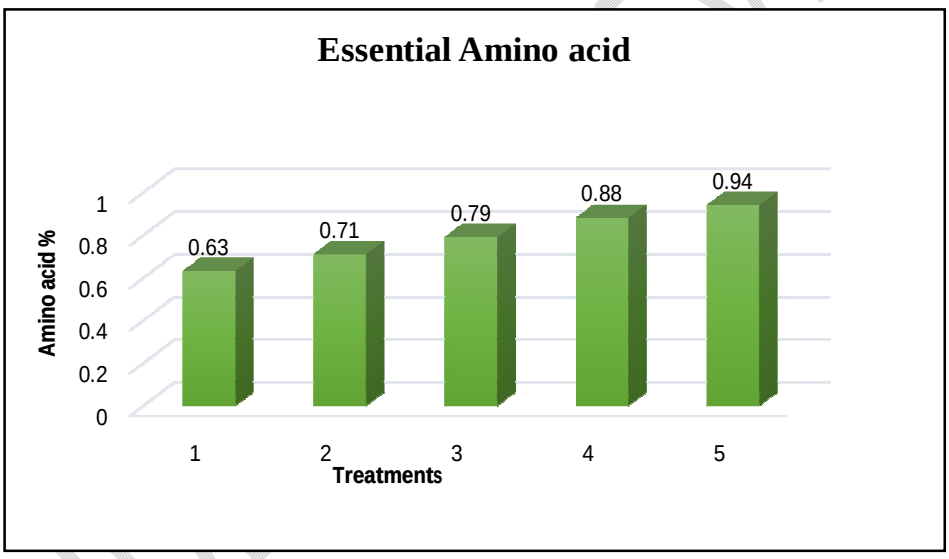

Fig. 3 Essential Amino acid in Energy Bites (%)

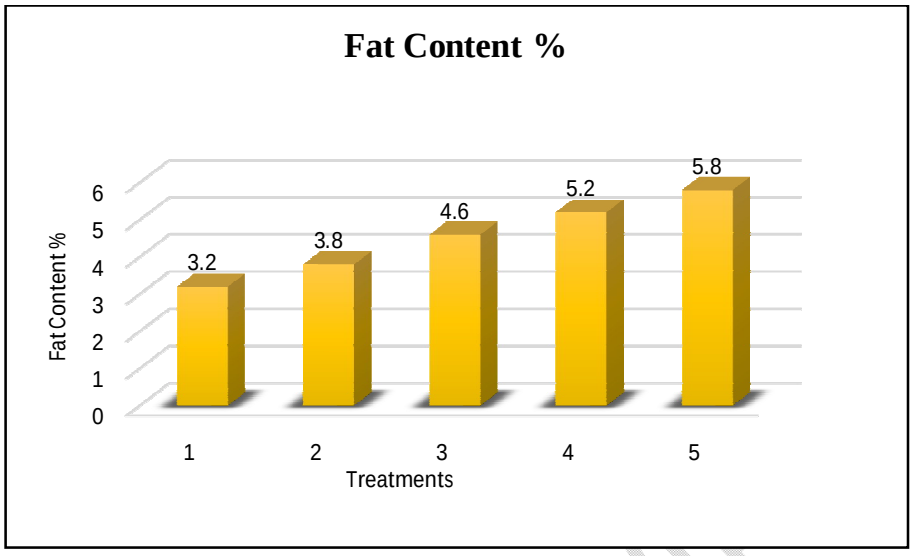

Fig. 4 Fat Content in Energy Bites (%)

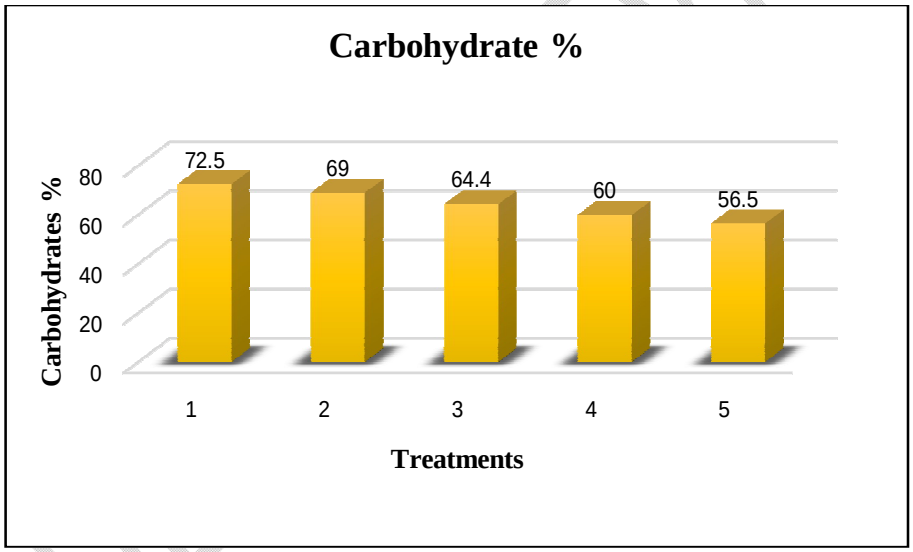

Fig. 5Carbohydrates in Energy Bites (%)

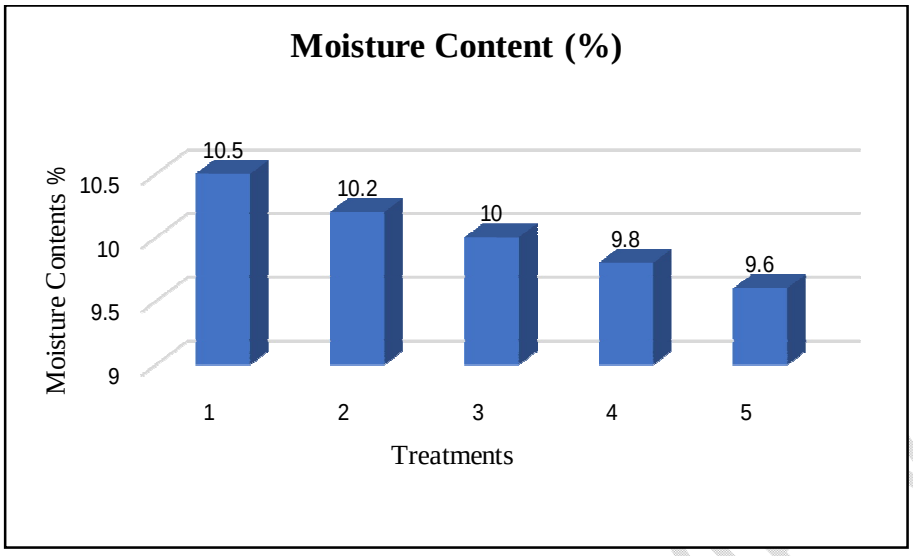

Fig. 6Moisture content in Energy Bites (%)

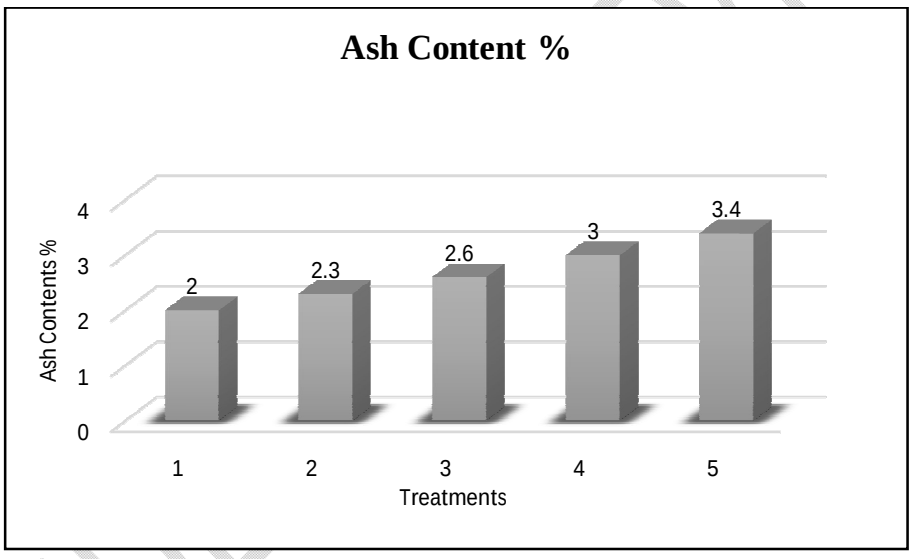

Fig. 7 Ash content in Energy Bites (%)

The chemical analysis of the fish-based extruded snack formulations (per 100 g) demonstrated significant variations in nutritional components across the five treatments. Fig.2 illustrates the steady increase in protein content, which ranged from 11.8% in Treatment 1 to 25.5% in Treatment 5. This progression highlights the enhancement of protein levels with increasing fish powder. Similarly, the improvement in protein quality is reflected in the Essential Amino Acid Index, as shown in Fig. 3, which rose from 0.63 in Treatment 1 to 0.94 in Treatment 5.

Fat content, depicted in Fig. 4, increased from 3.2% in Treatment 1 to 5.8% in Treatment 5, highlighting the lipid contribution of fish powder to the formulations. On the other hand, carbohydrate content, as shown in Fig. 5, exhibited a decreasing trend, declining from 72.5%

in Treatment 1 to 56.5% in Treatment 5, due to the replacement of carbohydrate-rich ingredients with protein-rich fish powder.The mineral composition, represented by ash content and displayed in Fig. 7, increased from 2.0% in Treatment 1 to 3.4% in Treatment 5, indicating enhanced mineral enrichment. Finally, moisture content, as illustrated in Fig. 6, showed a gradual decline from 10.5% in Treatment 1 to 9.6% in Treatment 5, suggesting better moisture reduction with higher fish incorporation.These findings collectively emphasize the nutritional enhancement achieved by increasing the proportion of fish powder in the formulations, resulting in a protein-enriched product with balanced macronutrients and essential amino acids.

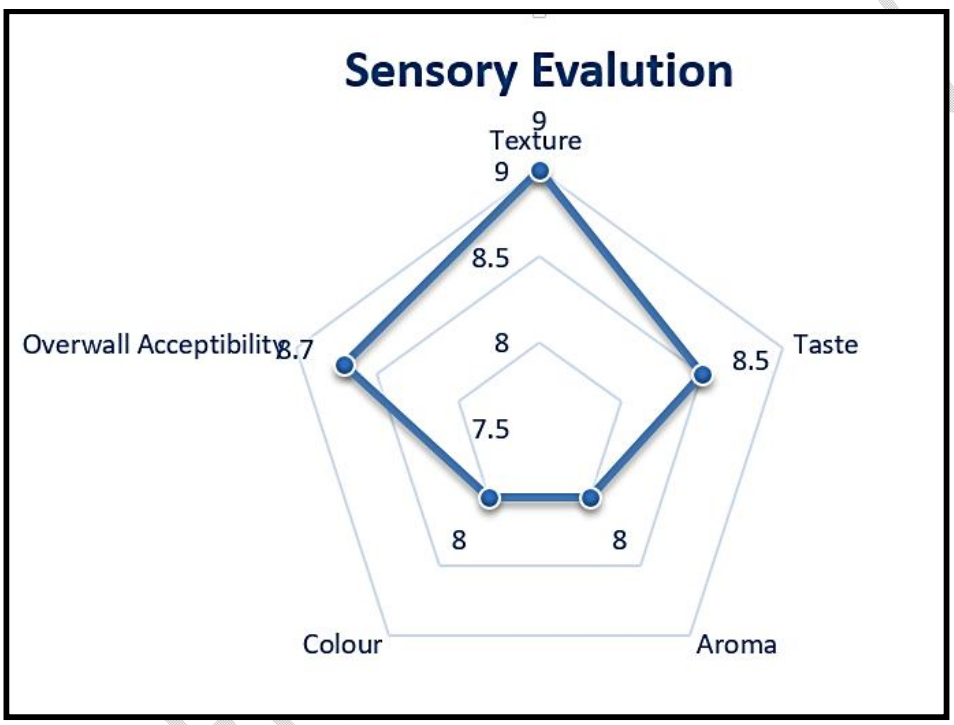

Fig. 8 Sensory Evaluation of T5

The sensory evaluation of Treatment T5, as illustrated in the radar graph, highlights its superior performance in all sensory attributes, making it the best among the tested formulations. Texture received the highest score of 9, indicating an ideal crispiness and mouthfeel desired in extruded snacks. Taste and aroma, both scoring 8.5, reflect the balanced flavor profile and pleasant fish-derived aroma that contributed to its overall acceptability. The color attribute achieved a score of 8, signifying an appealing appearance that aligns with consumer preferences. Overall acceptability was rated at 8.7, showcasing a well-rounded combination of sensory qualities. These results emphasize that Treatment T5 effectively optimized the ingredient proportions and processing parameters to deliver a nutritionally enriched, sensory-pleasing product suitable for consumer markets.

Conclusion

The development of fish-based extruded snacks, such as Fish Kurkure, demonstrates the potential for combining fish powder, corn flour, and millet flour to produce a nutrient-rich, shelf-stable product. The incorporation of fish powder enhances the protein content and amino acid profile, providing a balanced source of nutrition compared to traditional cereal-based snacks. Among the treatments evaluated, Treatment 5 (30% Fish Powder, 40% Corn Flour, 30% Millet Flour)emerged as the most promising formulation. It exhibited an optimal balance of protein content (20-25% per 100 g) and essential amino acids, along with a high sensory evaluation score of 8.5/9 for taste and texture.

Additionally, the product achieved a shelf life of 3 months under ambient storage, maintaining its crispness and flavour. The optimized extrusion parameters (barrel temperature of 112°C, screw speed of 320 rpm, and feed rate of 210 g/min) ensured the production of a high-quality snack with desirable texture and shape. This study highlights the viability of extrusion technology in utilizing underutilized fish resources to create innovative, sustainable snack products that cater to nutritional and sensory demands.

The study demonstrates the successful development of a fish-based extruded snack, combining fish powder, corn flour, and millet flour to produce a nutrient-rich, shelf-stable product with high consumer acceptability. Treatment 5 (30% fish powder, 50% corn flour, 20% millet flour) proved to be the most effective formulation, achieving an optimal protein content (25% per 100 g) and a balanced amino acid profile. This formulation also excelled in sensory evaluation, scoring 8.5/9 for taste and texture, making it highly appealing to consumers. The product exhibited a shelf life of three months under ambient storage, retaining its flavor, crispness, and nutritional quality. The optimized extrusion parameters, including a barrel temperature of 112°C, screw speed of 320 rpm, and feed rate of 210 g/min, were instrumental in producing a snack with desirable texture and uniform shape. This study underscores the role of extrusion technology in transforming underutilized fish resources into sustainable, innovative snack products that address both nutritional and sensory needs, offering a promising avenue for food innovation and economic development.

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