International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(8): 202-207
www.biochemjournal.com
Received: 02-06-2025
Accepted: 09-07-2025

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Standardization and development of pearl millet-based fish cookies from low cost fish *Saurida tumbil* (Bloch, 1795)

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i8c.5137

Abstract
Functional cookies were developed and standardized using pearl millet flour and fish powder obtained from *Saurida tumbil*, low value marine species valued for its high quality protein and nutritional benefits. The objective was to create a protein enriched bakery product using cost-effective, locally available ingredients to support improved nutrition and promote sustainable food innovation. Fish powder was prepared from greater lizardfish (*Saurida tumbil*) meat and pearl millet flour served as the primary cereal base. Various cookie formulations were developed by altering the proportions of pearl millet, fish powder and other ingredients followed by sensory evaluation. The standardized pearl millet cookies incorporated with 7.5 g fish powder per 100 g of total flour (total flour composed of 40 g pearl millet flour and 60 g refined wheat flour) received the highest overall acceptability. Proximate analysis of the standardized pearl millet-based fish cookies showed that moisture content of 3.45±0.03%, protein 12.34±0.04%, fat 23.53±0.03%, ash 1.42±0.03% and carbohydrate 59.26±0.02%. The developed pearl millet-based fish cookies are not only sensorially acceptable but also nutritionally enhanced and offering a promising option for functional food products targeting improved dietary protein intake.

Keywords: Pearl millet, fish powder, *Saurida tumbil*, functional cookies, value added product

Introduction
Undernourishment remains a major barrier to development in many countries, even though its effects are not always immediately visible. In 2022, approximately 735 million people around 9.3% of the global population suffered from undernourishment [9]. Protein-energy malnutrition (PEM) and micronutrient deficiencies are pressing public health concerns. Addressing these issues requires diversifying protein sources including both animal-based options like fish, meat, poultry, eggs, dairy and plant-based alternatives [15]. Among animal sources, fish offers superior nutritional benefits providing high quality protein, essential amino acids and omega-3 fatty acids [2, 41].

India's marine fish landings reached 3.53 million tonnes in 2023, showing a 1.2% increase from the previous year and a 15.75% rise compared to 2021. Lizardfish accounted for 7.4% of the total demersal finfish landings with 61,555 tonnes landed in 2023 [8]. Its white meat, pleasant flavour and excellent gel-forming capacity make it ideal for surimi and value-added products [39, 42]. Rich in protein and omega-3 fatty acids, it supports brain function, heart health and tissue repair. Moreover, bioactive compounds from seafood discards offer antioxidant, anti-inflammatory, antimicrobial and immune-boosting properties [15, 25]. Despite rising demand for fish, nearly 30% of India's marine catch consists of low-value, underutilized species [31]. Developing value-added products from such resources enhances sustainability and food diversity.

Millets are inherently free from gluten and act as prebiotics, promoting digestive health. This makes them a suitable and safe dietary option for people with celiac disease. India produced 17.60 million metric tonnes of millets in 2022, accounting for 19% of global production [5]. However, per capita consumption has dropped from 30.94 kg in 1990 to 3.87 kg in 2022. Pearl millet (bajra), India's fourth most important cereal, is linked to reduced risks of diabetes,

cardiovascular disease and other chronic conditions. It has been successfully used in bakery products with improved nutritional and sensory profiles [19, 36, 3].

Cookies are low moisture baked goods, ready-to-eat, offer long shelf life and wide consumer appeal [18]. This study aims to develop pearl millet-based cookies fortified with *Saurida tumbil* flour, combining nutrition, taste and sustainable resource use. Keeping in view of the nutritional and health benefits of both *Saurida tumbil* and pearl millet, the present work intends to develop a lizardfish flour incorporated with pearl millet based cookies. This functional food product not only promotes sustainable resource utilization but also provides a tasty and healthy snack option.

Materials and Methodology

Raw material collection

The Greater lizardfish (*Saurida tumbil*) was sourced from the Mirkarwada landing center in Ratnagiri and Bhaucha Dhakka in Mumbai, Maharashtra. The collected fish were then transported under chilled conditions to the processing facility at the College of Fisheries in Shirgaon, Ratnagiri. The fish was preserved using an ice to fish ratio of 1:1 in insulated containers to maintain its freshness during transportation.

Preparation of fish (*Saurida tumbil*) powder

The fish was thoroughly cleaned, dried and ground into a fine powder Pagarkar *et al*. (2008) [42]. Fish powder was then packed in a high density polyethylene (HDPE) bag with a thickness of 100 microns and stored in a dry environment to maintain its quality.

Sample preparation and standardization

Cookies were made using Greater lizardfish (*Saurida tumbil*), pearl millet, and other essential ingredients. Cookies were baked using fish powder, pearl millet flour, refined wheat flour, sugar powder, fat, milk powder and vanilla powder. All readily available ingredients used in the formulation were specifically standardized for pearl millet-based fish cookies, resulting in the highest overall acceptability. Ingredients for cookies were mixed together uniformly, make a sheet, shape it and baked at 180 ºC for 16 minutes in microwave oven.

Proximate composition

The developed pearl millet-based fish cookies were analyzed for their proximate viz., moisture content was calculated using the difference method, crude protein by Kjeldahl method, crude fat content by Soxhlet extraction and ash content [4].

Sensory evaluation

A semi-trained panel evaluated the sensory qualities of the pearl millet-based fish cookies-such as appearance, colour, texture, flavour, taste and overall acceptability using a 9-point hedonic scale, where 9 meant “like extremely” and 1 meant “dislike extremely.” A score of 5 was set as the minimum level for acceptability [26].

Statistical analysis

All collected data were statistically analyzed using analysis of variance (ANOVA) tool available in SPSS version 27. A 5% level of significance (p<0.05) was used to determine if observed differences were statistically meaningful, following the procedures described by Snedecor and Cochran [35].

Results and Discussion

Yield of fish (*Saurida tumbil*) powder (%)

The fish powder yield from the wet fish weight was 10.69% (Table 1). Similar yields have been reported for some fish species (silver bellies, lizardfish, pink perch, croaker and tilapia) with the yield ranging from 10 to 16% respectively (Pagarkar *et al*. 2008, Rathnakumar and Pancharaja, 2018, Shanavas *et al*. 2021) [42, 31, 33].

Proximate composition of fish (*Saurida tumbil*) powder

The proximate composition of fish (*Saurida tumbil*) powder was moisture (6.27%), protein (86.96%), fat (1.12%) and ash (2.97%) (Table 2). Rathnakumar and Pancharaja (2018) [31] reported that fish powder contained around 6.02% moisture, 89.63% crude protein, 1.05% fat and 16.05% ash in cooked meat powder and 7.01% moisture, 88.61% crude protein, 0.78% fat and 3.06% ash in hydrolyzed meat powder.

Standardization of pearl millet-based fish cookies

A tentative recipe of Anandhan *et al*. 2025 [39] was adopted to standardize the formulation for pearl millet-based fish cookies with slight modifications (Table 3). Sensory evaluation showed that pearl millet cookies with a 40:60 ratio of pearl millet to refined wheat flour was the most preferred among the different formulations as it had balanced flavour, appealing colour, desirable texture and received the highest ratings for overall acceptability (Table 5). A comparable ratio of pearl millet to refined wheat flour (40:60) has also been used in the cookies developed by Kulthe *et al*. (2018) [17]. Additionally, Ranasalva and Visvanatha (2014) [30] employed a slightly higher proportion using a 50:50 (w/w) ratio of cooked fermented pearl millet flour to refined wheat flour for the preparation of pearl millet cookies. An increase in the proportion of pearl millet flour (PMF) in the cookie formulation led to a noticeable gritty texture in the final product and also changing in colour compare to cookies without pearl millet (Kulkarni *et al*. 2021) [16]. Sensory evaluation showed that 50:100 (w/w) ratio of sugar to total flour was identified as the most suitable formulation for pearl millet cookies, offering a balanced sweetness and enhanced taste. A comparable ratio of sugar to refined wheat flour (50:100) has also been used in the cookies developed by Abraha *et al*. (2018) [2], Patimah *et al*. (2019) [28], Amulya and Ramu (2022) [3]. Sensory evaluation showed that 50:100 (w/w) ratio of fat to total flour was found as optimal for achieving better texture and sensory quality in the pearl millet cookies. Chin (2016) [7] who noted that excessive fat acts as a lubricant resulting in softer cookie texture. Lower fat content resulted in reduced spreading ratio and harder texture in the cookies. Some studies done by Maache-Rezzoug *et al*. (1998) [20] and Sudha *et al*. (2007) [37] who also noted that reducing fat content in cookie formulations tends to increase dough firmness. Based on the sensory evaluation, the 16:100 (w/w) ratio of milk powder to total flour was found as optimal for achieving better texture, taste and sensory quality in the cookies. Dairy by-products like whey protein concentrate (WPC), milk powder and skimmed milk powder have long been utilized in various food applications due to their distinct functional and nutritional properties (Morr, 1984; Morr and Ha, 1993; Nunes *et al*. 2009) [23, 24, 25]. Perez *et al*. (2013) [29] observed that substituting wheat flour with whey protein concentrate (WPC) and soy flour in cookie formulations influenced colour formation, primarily due to the Maillard reaction. Milk is commonly incorporated in cookie

formulations as a binding agent, helping to integrate and stabilize the ingredients during mixing and baking. Sensory evaluation showed that pearl millet cookies prepared using 7.5:100 ratio of fish powder to total flour was the most preferred among the different formulations. Silmilarly, Abraha *et al*. (2018) [2] adding 7% sturgeon fillet powder to the biscuits produced a protein-enriched, fortified snack with good sensory and quality attributes. During sensory evaluation, panellists noted that increasing fish powder proportion in the cookie formulation resulted in a fishy odour and slight bitter taste and noticeable texture differences. However, the inclusion of fish powder up to 7.5% did not impart that much fishy odour and taste. Previous studies showed that incorporating fish-based ingredients into food products can adversely affect sensory attributes particularly flavour and aroma when used in unsuitable concentrations (Shaviklo *et al*. 2014; Ikasari *et al*. 2020) [34, 13]. When fish powder is incorporated at higher levels (above 10%) in cookies, several notable changes occur in terms of sensory, physical and chemical properties. One of the most evident effects is the intensification of fishy odour and taste which can negatively impact consumer acceptability. This is due to the inherent aroma of fish powder which becomes more pronounced upon baking. Ikasari *et al*. (2020) [13] reported that cookies with 10% fish protein concentrate showed lower sensory preference compared to those with 5%, primarily due to a stronger odour and flavour profile. Colour changes are another visible effect of high fish powder inclusion. Fish powder contains natural pigments that react differently during baking, often resulting in a darker product. On the positive side, increasing fish powder levels significantly enhances the nutritional value of cookies. Higher inclusion boosts protein, calcium and omega-3 fatty acid content making the product more functional and suitable for nutritionally targeted applications. Mori *et al*. (2020) [22] studied the research on incorporating fish powder into oats cookies yielded promising results. The cookies colour darkened with higher fish powder content, as indicated by decreasing lightness (L*) values. Additionally, fish powder caused cookies to spread more during baking. The overall acceptability scores from the sensory evaluation, the 7.5:100 (FP3) ratio of fish powder to total flour was found as optimal for achieving better texture, taste and sensory quality in the cookies (Table 6) and was subsequently used for baking pearl millet-based fish cookies. Sensory evaluation revealed that pearl millet-based fish cookies baked at 180 °C temperature was the most preferred among the different temperature. Similar findings were reported by Jeyanth Allwin *et al*. (2018) [14] baked fish cookies at 180 °C and Amulya and Ramu (2022) [3] baked multi millet cookies at 180 °C, Abraha *et al*. (2018) [2] baked fish cookies at 175 °C, Kulthe *et al*. (2018) [17] baked the pearl millet cookies at 180 °C-200 °C, Sharma and Riar (2020) [32] employed a baking temperature of 185 °C in their formulation of cookies made with minor millet blend flour. During sensory evaluation, panellists observed cookies baked at higher temperatures developed an overly dark appearance and showed signs of burning on the exterior. Baking at 190 °C and 200 °C also resulted in a dark appearance, slight hard texture and altered taste. Baking temperature significantly influences the overall quality of cookies, affecting key attributes such as moisture retention, texture, colour and chemical composition. Increasing the baking temperature resulted in greater moisture and weight loss, decreased pH and increased cookie hardness (Panghal *et al*. 2018; Hawng and Moon, 2022) [27, 11]. Sensory evaluation showed that pearl millet-based fish cookies baked at 180 °C for 16 minutes was the most preferred among the different time. The ideal baking time and temperature for cookies vary based on the formulation and the texture preferences. Biscuits baked at lower temperatures for extended durations exhibited the lowest moisture content. In general, higher baking temperatures require shorter durations, whereas lower temperatures necessitate longer baking times.

Proximate composition of pearl millet-based fish cookies

The proximate composition of pearl millet-based fish cookies such as moisture (3.45±0.03%), protein (12.34±0.04%), fat (23.53±0.03%), ash (1.42±0.03%) and carbohydrates (59.26±0.02%) (Table 4). Abraha *et al*. (2018) [2] added sturgeon fillet protein concentrate (SFPC) by replacing low gluten wheat flour at levels of 5%, 7% and 10% to examine its effect on biscuit quality and consumer acceptability. The analysis showed that fortifying biscuits with SFPC enhanced their nutritional profile. Moisture content ranged between 4.75±0.08 and 4.76±0.11%, protein increased from 14.63±0.12 to 19.52±0.12%, fat content ranged from 16.20±0.06 to 16.50±0.17% and ash content increased from 1.53±0.04 to 1.66±0.12%. The total amino acid content increased from 6.93 g per 100 g in the control biscuits to 17.20 g per 100 g in biscuits enriched with 10% sturgeon fillet protein concentrate (SFPC). Patimah *et al*. (2019) [28] studied the potential of foxtail millet and flying fish as functional food ingredients by developing cookies with varying ratios of wheat, foxtail millet and flying fish flours. The proximate analysis of fish cookies containing 15% fish powder showed that they comprised 11.89% protein, 45.19% carbohydrate, 4.51% crude fibre, 21.30% fat, 5.94% moisture and 1.26% ash. Variations in the proximate composition of cookies reported by different researchers can be attributed to factors such as the quality and type of ingredients used, baking conditions and storage environments including relative humidity (Igbabul *et al*. 2018) [12]. Ikasari *et al*. (2020) [13] incorporated fish protein concentrate (FPC) into cookie formulations at different concentration that resulted in a noticeable increase in protein content compared to the control sample. Cookies enriched with 5% and 10% FPC recorded protein contents of 9.57% and 11.4% respectively. Kulkarni *et al*. (2021) [16] reported a fat content of 24.9 ± 0.05% in cookies made using pearl millet. Pearl millet is known to have a higher fat content than cereals like wheat and rice (Abdalla *et al*. 1998) [1]. Additionally, the elevated fat levels in cookies may also result from the inclusion of added fat during their formulation. Amulya and Ramu (2022) [3] found that cookies prepared with a multi-millet blend contained 20.46% fat. Differences in the fat content of cookies reported by various researchers could be attributed to variations in the quantity of shortening used, the specific recipe formulations and the baking conditions applied during preparation.

Table 1: Yield of different stages of fish processing of fish (*Saurida tumbil*) (%)

Yield of different stages of fish processing	Yield (%)
Raw fresh fish	100±0.00
Dressed fish	71.38±0.66
Yield of fish powder	10.69±0.35

Mean ± SD of parameters for raw fish and fish powder. Each value is the average of three determinations (n = 3).

Table 2: Proximate composition of fish (*Saurida tumbil*) powder (%)

Parameter	Moisture	Protein	Fat	Ash
Percentage (%)	6.27±0.09	86.96±0.03	1.12±0.05	2.97±0.06

Mean ± SD of parameters fish powder. Each value is the average of three determinations (n = 3).

Table 3: Standardized recipe for preparation of pearl millet-based fish cookies

Sr. No	Ingredients (g)	Quantity (g)	Quantity (%)
1	Fish powder	7.5	3.41
2	Pearl millet flour	40	18.18
3	Refined wheat flour	52.5	23.86
4	Sugar	50	22.73
5	Fat	50	22.73
6	Milk powder	16	7.27
7	Vanilla powder	4	1.82
Total		220	100

Table 4: Proximate composition of standardized final pearl millet-based fish cookies

Sr. No	Parameter	Final pearl millet-based fish cookies
1.	Moisture (%)	3.45±0.03
2.	Protein (%)	12.34±0.04
3.	Fat (%)	23.53±0.03
4.	Ash (%)	1.42±0.03
5.	Carbohydrate (%)	59.26±0.02

Mean ± SD of parameters for final pearl millet-based fish cookie. Each value is the average of three determinations (n=3).

Table 5: Mean sensory scores of pearl millet cookies made up with different ratios of pearl millet flour to refined wheat flour

Sr. No	Sensory characteristics	Replacement of refined wheat flour by pearl millet flour				
		PM1 (0:100)	PM2 (20:80)	PM3 (40:60)	PM4 (60:40)	PM5 (80:20)
1.	Appearance	8.50±0.53a	8.40±0.52a	8.20±0.79ab	7.90±0.74ab	7.50±0.71b
2.	Colour	8.40±0.70a	8.20±0.63ab	8.10±0.74ab	7.90±0.74ab	7.40±0.70b
3.	Flavour	8.10±0.74ab	8.30±0.48ab	8.70±0.48a	8.00±0.67ab	7.70±0.67b
4.	Taste	8.10±0.74ab	8.40±0.52ab	8.70±0.48a	8.20±0.63ab	7.80±0.63b
5.	Texture	8.40±0.70a	8.30±0.67a	8.10±0.57ab	7.70±0.48ab	7.40±0.70b
6.	Overall acceptability	7.90±0.32bc	8.10±0.57bc	8.80±0.42a	8.20±0.42b	7.60±0.52c

Mean ± SDa-c in the same row followed by different superscripts are significantly different (p<0.05) (n=10); PM: Pearl Millet flour.

Table 6: Mean sensory scores of standardized pearl millet cookies incorporated with different percentages of fish powder by replacing refined wheat flour

Sensory characteristics	Replacement of refined wheat flour by fish powder					
	FP1 (0%)	FP2 (5%)	FP3 (7.5%)	FP4 (10%)	FP5 (12.5%)	FP6 (15%)
Appearance	8.40±0.70abc	8.50±0.53ab	8.70±0.48a	7.90±0.57bcd	7.70±0.48cd	7.30±0.67d
Colour	8.20±0.63ab	8.50±0.53ab	8.60±0.52a	8.10±0.57ab	7.80±0.42bc	7.20±0.63c
Flavour	8.30±0.67ab	8.60±0.52a	8.70±0.48a	7.70±0.48b	6.80±0.63c	5.70±0.67d
Taste	8.20±0.63ab	8.30±0.67ab	8.50±0.53a	7.70±0.67b	6.70±0.67c	5.10±0.31d
Texture	8.10±0.57ab	8.20±0.63ab	8.40±0.52a	7.80±0.63abc	7.60±0.52bc	7.20±0.63c
Overall acceptability	8.20±0.63ab	8.50±0.53a	8.60±0.52a	7.50±0.71b	6.60±0.52c	5.30±0.48d

Mean ± SDa-d in the same row followed by different superscripts are significantly different (p<0.05) (n=10); FP: Fish Powder.

Conclusion

The successful formulation and standardization of pearl millet-based fish cookies using pearl millet flour and fish powder derived from *Saurida tumbil* highlight the promising use of underutilized millet and marine resources in developing nutrient rich bakery items. The optimized recipe, incorporating 7.5% fish powder and 40% pearl millet flour to total flour received high sensory acceptability. These pearl millet-based fish cookies not only offer enhanced nutritional benefits but are also economical to produce, making them a nutritious food option suitable for regular consumption.

Acknowledgement

The authors sincerely thank the officials of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (DBSKKV) for granting permission to carry out this study and for providing the necessary facilities at the College of Fisheries. Their support played a significant role in the successful completion of this research.

Conflict of interest

The author declares no conflict of interest. However, future research is planned to include a detailed qualitative analysis of the samples with a particular focus on their storage study under ambient temperature conditions.

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