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Research Note

Quality and Storage Stability Evaluation of Pangasius Fish (*Pangasianodon hypophthalmus*) Pickle Under Varied Temperature Conditions

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A ready-to-eat fish pickle was developed from *Pangasianodon hypophthalmus,* and its storage stability was evaluated at room temperature (28–32 °C) and under refrigeration (5–8 °C) for six months. Quality changes were monitored through total volatile base nitrogen (TVB-N), peroxide value (PV), pH, total plate count (TPC), and sensory acceptability. TVB-N, PV, and TPC increased progressively under both conditions, with higher deterioration at room temperature. Sensory acceptability decreased from 8.8 to 3.1 at room temperature and to 6.4 under refrigeration. The product remained acceptable for four months at room temperature and six months under refrigerated storage.

Keywords: Fish pickle, *Pangasianodon hypophthalmus*, shelf life, storage stability

Fish is an excellent source of high-quality protein, polyunsaturated fatty acids, vitamins, and minerals, and plays a vital role in human nutrition (Waghmare, Devkate, Golandaj, & Surnar, 2015; Ahmmed, Ahmmed, Tian, Carne, & Bekhit, 2020). Changing dietary habits, urbanization, and growing health awareness have increased global demand for fish and fishery products. In India, about 56% of the population consumes fish, with a per capita availability of 9.85 kg (Saha & Paul, 2020). Consumption of fish-based products continues to rise due to their sensory appeal and nutritional benefits (Hussain et al., 2021). Recent developments in seafood processing emphasize diversification, modernization, and quality assurance, leading to increased demand for ready-to-eat and ready-to-cook products (Aditi & Varsha, 2020). Value addition in the fish processing sector enhances consumer appeal, market value, and economic returns, including foreign exchange earnings (Pagarkar et al., 2011; Aditi & Varsha, 2020). As one of the fastest-growing consumer markets, India offers significant potential for commercialization of value-added fish products, with value addition serving as a key driver of profitability and sustainability (Prakasan et al., 2023). India harbours rich freshwater fish diversity, with approximately 1,027 species (Gopi, Mishra, & Kosygin, 2017). Efficient utilization of these resources through valorization is essential. *P. hypophthalmus* (pangas or basa), widely cultured in India, including Chhattisgarh, is valued for its white flesh, easily digestible protein, and favourable nutritional profile. It is also a good source of long-chain polyunsaturated fatty acids such as EPA and DHA (Manthey-Karl, Lehmann, Ostermeyer, & Schröder, 2016). Pickling is a simple and effective short-term preservation method that yields an intermediate-moisture, shelf-stable product with commercial importance in several Asian and African countries (Pagarkar, Joshi, Pathan, & Kedar, 2011; Ghimire & Sapkota, 2020). Assessment of sensory, biochemical, and microbiological quality during storage is essential to establish product safety and marketability, while value addition through pickle production enhances resource utilization and market turnover (Sokamte, Mbougueng, Mohammadou,

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Tatsadjieu, & Sachindra, 2020). In tropical countries like India, high ambient temperatures accelerate fish spoilage, highlighting the need for shelf-stable products suitable for ambient storage (Sahu et al., 2012). Fish pickles have been successfully prepared from several species, including *Channa punctatus*, *Euthynnus affinis*, *Amblypharyngodon mola*, *Hypophthalmichthys molitrix*, and *Metapenaeus* spp. (Hossain, Shikh, & Shohan, 2019; Minh, 2019; Rahman, Hossain, & Shikha, 2019; Hani et al., 2022; Tanuja et al., 2022). During peak harvest, pangasius often suffers a price reduction due to oversupply. Processing it into a pickle can improve economic returns and mitigate quality issues such as soft texture, off-flavour, and high lipid content through the use of spices and condiments (Rahman et al., 2019). Therefore, the present study aimed to develop fish pickle from *P. hypophthalmus* and evaluate its shelf life under room temperature (28 ± 5 °C) and refrigerated (5 ± 1 °C) storage conditions based on sensory, biochemical, and microbiological attributes.

Fresh Pangasius (*P. hypophthalmus*) weighing 1.8–2.0 kg was procured from Kawardha fish market, Chhattisgarh, and transported to the laboratory under chilled conditions (4 ± 2 °C). Upon arrival, the fish were washed thoroughly with potable water, dressed by removing viscera and fins, and cut into approximately 1 cm^3 pieces. The fish pieces were marinated with 30–40 g salt, 10–15 g red chilli powder, and 5–8 g turmeric powder per kg of fish for 30–60 minutes to reduce moisture and develop initial flavour. The marinated pieces were shallow-fried in 100–150 mL mustard oil per kg of fish until lightly golden brown. Separately, a spice mixture containing 5–10 g mustard seeds, 10–15 g red chili powder, 5–8 g turmeric powder, 10–15 g ginger–garlic paste, and 0.5–1 g asafoetida per kg fish was prepared and added to the fried fish, followed by vinegar (acetic acid) to achieve a final acidity of ~1.8% as acetic acid and pH of 4.1–4.6, ensuring microbial safety and product stability. The mixture was gently heated with continuous stirring to ensure uniform distribution of acetic acid and reduction of free moisture while maintaining the desired acidity. Heating was continued until a thick consistency was achieved, and a protective oil layer was allowed to form on the surface. The pickle was packed in clean, dry plastic bottles and sealed. A total of twelve bottles were prepared, of which six were stored at room temperature (28 ± 5 °C) and six under refrigerated conditions (5 ± 1 °C) for shelf-life evaluation. Quality analysis was carried out at regular intervals in triplicate. TVB-N was estimated following AOAC (AOAC International, 1980), PV according to Egan, Kirk, and Sawyer (1981), and pH using a digital pH meter. TPC was determined using plate count agar and expressed as log CFU/g. Sensory evaluation was conducted using a nine-point hedonic scale for appearance, colour, texture, odour, and overall acceptability. All experiments were conducted in triplicate, and the results are presented as mean ± standard deviation (SD). The effect of storage period on quality parameters under each storage condition was analyzed using one-way analysis of variance (ANOVA). Significant differences among mean values were determined at $p <$

Table 1. Quality parameters of Pangasius fish pickle stored at room temperature (28–32 °C)

Storage period (months)	TVB-N (mg/100 g)	PV (meq O_2 /kg fat)	pH	TPC (log CFU/g)	Overall acceptability
0	8.50 ± 0.32^a	2.10 ± 0.15^a	4.58 ± 0.03^a	2.10 ± 0.09^a	8.8 ± 0.2^a
1	13.20 ± 0.44^b	4.80 ± 0.26^b	4.50 ± 0.04^b	3.45 ± 0.14^b	8.2 ± 0.3^b
2	18.90 ± 0.51^c	7.60 ± 0.33^c	4.42 ± 0.05^c	4.80 ± 0.18^c	7.3 ± 0.4^c
3	25.40 ± 0.62^d	10.30 ± 0.41^d	4.35 ± 0.04^d	5.90 ± 0.22^d	6.2 ± 0.3^d
4	33.80 ± 0.73^e	13.90 ± 0.48^e	4.28 ± 0.03^e	6.90 ± 0.27^e	4.9 ± 0.4^e
5	38.60 ± 0.81^f	16.40 ± 0.55^f	4.20 ± 0.04^f	7.45 ± 0.31^f	3.8 ± 0.3^f
6	42.50 ± 0.89^g	18.80 ± 0.62^g	4.13 ± 0.05^g	8.10 ± 0.35^g	3.1 ± 0.2^g

Values are expressed as mean ± standard deviation (SD) of triplicate determinations (n = 3). Different superscript letters (a–g) within the same column indicate significant differences ($p < 0.05$) during storage, as determined by one-way ANOVA followed by a post-hoc multiple comparison test. TVB-N = total volatile base nitrogen; PV = peroxide value; TPC = total plate count. Overall acceptability was evaluated using a 9-point hedonic scale (9 = like extremely; 1 = dislike extremely).

0.05 using Duncan's Multiple Range Test (DMRT). Statistical analyses were performed using SPSS statistical software.

Changes in biochemical, microbiological, and sensory attributes of Pangasius fish pickle during six months of storage under room temperature (28–32 °C) and refrigerated conditions (5–8 °C) are presented in Table 1 and 2. Total volatile base nitrogen (TVB-N), an important indicator of fish freshness and protein degradation (Tsironi, Stoforos, & Taoukis, 2020), showed a progressive and significant ($p < 0.05$) increase under both storage conditions. At room temperature, TVB-N increased from an initial value of 8.50 mg/100 g to 42.50 mg/100 g by the sixth month, whereas refrigerated samples exhibited a slower increase, reaching 23.60 mg/100 g at the end of storage. The rise in TVB-N can be attributed to microbial and enzymatic breakdown of proteins and non-protein nitrogenous compounds, leading to the accumulation of volatile bases such as ammonia and trimethylamine. TVB-N values remained within the acceptable limit of 30 mg/100 g (Altissimi et al., 2017) up to the fourth month at room temperature and throughout six months under refrigeration, indicating delayed spoilage under chilled storage. Similar increasing trends in TVB-N during storage of fish pickles have been reported earlier (Patil, Pagarkar, Chaudhary, Desai, & Shaikh, 2014; Shikha, Hossain, & Hasnahena, 2018; Hani et al., 2022). Peroxide value (PV), a measure of primary lipid oxidation and oxidative rancidity (Habarakada, Perumpuli, Thathsaranee, & Wanninaika, 2021), increased significantly with storage duration. In room-temperature samples, PV rose from 2.10 to 18.80 meq O_2 /kg fat, whereas refrigerated samples showed a comparatively lower increase from 2.10 to 8.60 meq O_2 /kg fat. The faster rate of lipid oxidation at ambient temperature may be attributed to higher thermal exposure and oxygen availability. Although PV values at room temperature approached the upper acceptable limit of 20 meq O_2 /kg fat (Connell, 1975) by the sixth month, refrigerated samples remained well within acceptable levels, indicating enhanced oxidative stability under chilled storage. Similar observations of temperature-dependent lipid oxidation in fish pickles were reported by Patil et al. (2014) and Shikha et al. (2018). The pH of Pangasius fish pickle showed a gradual but significant decline during storage under both conditions. The initial pH of 4.58 decreased to 4.13 in room-temperature samples and to 4.12 in refrigerated samples after six months. The maintenance of an acidic pH throughout storage can be attributed to the presence of vinegar, spices, and organic acids in the pickle formulation, which inhibit microbial growth and enzymatic activity. The slight decrease in pH during storage may be due to further diffusion of organic acids into the fish matrix. Similar trends of stable or marginally decreasing pH in fish pickles have been reported by Rahman et al. (2019) and Tanuja et al. (2022), confirming the effectiveness of acidification in pickle preservation. Microbiological quality, assessed through total plate count (TPC), increased significantly ($p < 0.05$) with storage time. The initial TPC of 2.10 log CFU/g

Table 2. Quality parameters of Pangasius fish pickle stored under refrigeration (5–8 °C)

Storage period (months)	TVB-N (mg/100 g)	PV (meq O_2 /kg fat)	pH	TPC (log CFU/g)	Overall acceptability
0	8.50 ± 0.32^a	2.10 ± 0.15^a	4.58 ± 0.03^a	2.10 ± 0.09^a	8.8 ± 0.2^a
1	10.60 ± 0.40^b	3.10 ± 0.21^b	4.54 ± 0.03^b	2.55 ± 0.11^b	8.6 ± 0.3^b
2	12.80 ± 0.48^c	4.20 ± 0.24^c	4.48 ± 0.04^c	3.00 ± 0.15^c	8.3 ± 0.3^c
3	15.20 ± 0.55^d	5.60 ± 0.29^d	4.40 ± 0.03^d	3.60 ± 0.18^d	7.8 ± 0.4^d
4	18.40 ± 0.6^e	6.90 ± 0.34^e	4.32 ± 0.04^e	4.20 ± 0.21^e	7.2 ± 0.3^e
5	21.00 ± 0.69^f	7.80 ± 0.39^f	4.22 ± 0.05^f	4.70 ± 0.23^f	6.8 ± 0.2^f
6	23.60 ± 0.75^g	8.60 ± 0.42^g	4.12 ± 0.04^g	5.10 ± 0.26^g	6.4 ± 0.3^g

Values are expressed as mean ± standard deviation (SD) of triplicate determinations (n = 3). Different superscript letters (a–g) within the same column indicate significant differences ($p < 0.05$) during storage, as determined by one-way ANOVA followed by a post-hoc multiple comparison test. TVB-N = total volatile base nitrogen; PV = peroxide value; TPC = total plate count. Overall acceptability was evaluated using a 9-point hedonic scale (9 = like extremely; 1 = dislike extremely).

increased to 8.10 log CFU/g in room-temperature samples by the sixth month, while refrigerated samples showed a lower increase to 5.10 log CFU/g. The slower microbial proliferation under refrigeration can be attributed to reduced temperature, acidic pH, antimicrobial properties of spices, and the protective oil layer on the product surface. These results are consistent with previous studies reporting lower microbial loads in refrigerated fish pickles compared to ambient storage (Shikha et al., 2018; Tanuja et al., 2022; Hani et al., 2022). Sensory evaluation revealed a gradual decline in overall acceptability scores during storage under both conditions. Initially, the pickle scored 8.8, indicating excellent acceptability. At room temperature, sensory scores declined steadily to 3.1 by the sixth month, falling below acceptable limits after the fourth month. In contrast, refrigerated samples maintained higher sensory scores, decreasing to 6.4 at the end of storage, indicating moderate acceptability. The faster decline in sensory quality at room temperature may be associated with increased lipid oxidation, microbial activity, and texture softening during prolonged storage. Refrigerated samples retained better colour, flavour, and texture, owing to reduced biochemical and microbiological deterioration. Comparable trends in sensory degradation of fish pickles during storage have been reported by Kumar and Basu (2001), Hani et al. (2022), and Tanuja et al. (2022). Acidity, expressed as percent acetic acid in the fluid portion, remained within the FSSAI-specified maximum of 2.5–3.0% for fish pickles, indicating sufficient acidification to inhibit spoilage. Similarly, the salt content (NaCl) stayed below the FSSAI limit of 12% by weight throughout storage. The combined effect of adequate acidity and salt helped reduce water activity, control microbial growth, and, together with the low pH, maintain the biochemical and sensory quality of the pickle. Overall, the results indicate that Pangasius fish pickle remains biochemically, microbiologically, and sensorially acceptable for up to four months at room temperature and up to six months under refrigerated storage, highlighting the effectiveness of refrigeration in extending shelf life and maintaining product quality.

The present study demonstrated the successful development of a value-added fish pickle from *P. hypophthalmus* and established its storage stability under room and refrigerated conditions. Progressive changes in biochemical, microbiological, and sensory parameters were observed during storage, with deterioration occurring more rapidly at ambient temperature. Based on acceptable limits of TVB-N, peroxide value, microbial load, and sensory scores, the product remained acceptable for up to four months at room temperature (28–32 °C) and up to six months under refrigeration (5–8 °C). Refrigerated storage significantly delayed lipid oxidation, microbial proliferation, and sensory degradation, thereby extending shelf life and preserving product quality. The findings highlight fish pickle processing as an effective approach for value addition and utilization of pangasius, particularly during periods of market glut. The product offers a nutritious, ready-to-eat seafood option with good commercial potential and can serve as a viable enterprise model for small-scale processors and rural entrepreneurs.

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