Development and Quality Evaluation of Fish Sauce (Patis) from Lantern Fish (*Benthosema pterotum*): Physicochemical, Sensory, and Microbiological Analyses

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Publication Date: 2026/07/07

Abstract: This study evaluated the physicochemical, sensory, and microbiological qualities of fish sauce (patis) produced from lantern fish (*Benthosema pterotum*), locally known as "Sirum-sirum," an underutilized by-catch species commonly found in the coastal waters of Pasacao, Camarines Sur, Philippines. The study aimed to determine the most acceptable fish-to-salt ratio for fish sauce production and assess the nutritional and microbial quality of the resulting product. Fresh lantern fish were fermented using three fish-to-salt ratio treatments: Treatment 1 (1:3), Treatment 2 (1:4), and Treatment 3 (1:5) for a period of 90 days. The fermented fish sauce was subjected to sensory evaluation, proximate analysis, and microbiological examination. Results of the sensory evaluation revealed significant differences among treatments in flavor, odor, and saltiness, while no significant difference was observed in color. Treatment 3 obtained the highest ratings for appearance (7.93), flavor (8.15), texture (8.10), aroma (7.93), and general acceptability (8.24), indicating the highest level of consumer preference. Proximate analysis showed that Treatment 3 had the highest protein content (10.80%) and ash content (24.67%), reflecting its favorable nutritional quality. Microbiological analysis revealed that all treatments had coliform, *Escherichia coli*, yeast and mold counts below detectable limits (<1.0 CFU/mL) and aerobic plate counts below 30 CFU/mL, indicating product safety and compliance with acceptable microbiological standards. The findings demonstrate that lantern fish can be successfully utilized as a raw material for fish sauce production. Treatment 3 was identified as the most acceptable formulation, producing a nutritious, safe, and value-added fishery product with potential for commercial development and sustainable utilization of underexploited marine resources.

Keywords: *Lantern Fish,* Benthosema Pterotum*, Fish Sauce, Patis, Fermentation, Sensory Evaluation, Proximate Analysis, Microbiological Quality.*

How to Cite: Glend S. Sales; Myrna C. Bigueja; Christine B. Formanes; Tomas C. Sales Jr. (2026) Development and Quality Evaluation of Fish Sauce (Patis) from Lantern fish (Benthosema pterotum): Physicochemical, Sensory, and Microbiological Analyses. *International Journal of Innovative Science and Research Technology*, 11(6), 2773-2779. https://doi.org/10.38124/ijisrt/26jun1158

I. INTRODUCTION

The lantern fish, *Benthosema pterotum* (Family Myctophidae), is a mesopelagic fish species widely distributed in tropical and subtropical waters of the Indo-Pacific region, including the Arabian Sea, Oman Sea, East China Sea, and western Pacific Ocean. It is among the most abundant mesopelagic fish species and plays an important ecological role in marine food webs as both a predator of zooplankton and a prey species for larger commercially important fishes. Lantern fish exhibit diel vertical migration, ascending to surface waters at night to feed and descending to deeper waters during the day (Hussain, 1992; Valinassab et al., 2007; Yasuma et al., 2013) [1,2,3].

Despite its abundance, *Benthosema pterotum* remains largely underutilized for human consumption. Previous studies have described lantern fish as an underexploited marine resource with considerable potential for value-added processing because of its availability throughout the year and favorable nutritional characteristics (Gopakumar et al., 1983) [4]. Research on the biochemical composition and nutritional

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1158

quality of lantern fish demonstrated that it can be processed into fish meal, protein hydrolysates, and other fishery products with good nutritional properties, suggesting its potential as an alternative raw material for food and feed applications.

The species has attracted increasing attention due to its enormous biomass and potential for commercial exploitation. Biomass assessments in the Oman Sea estimated stocks ranging from one to four million metric tons, highlighting its importance as a largely untapped fishery resource (Valinassab et al., 2007) [2]. Furthermore, recent studies have identified *B. pterotum* as one of the most abundant lantern fish species globally and an important component of marine ecosystems because of its role in energy transfer and nutrient cycling within the mesopelagic zone.

Many fermented fish products are produced in different parts of the world, with processing methods varying according to factors such as the availability of raw materials, consumer preferences, and the climatic conditions of a particular region (Al-Jedah et al., 2000) [5]. Among these products, fish sauce is a widely consumed fermented condiment that can be produced economically from various fish species, including those that are not commonly utilized for direct human consumption. Fish sauce is a brown-colored liquid seasoning extensively used throughout Southeast Asia and is known by different names across countries. It contains a complex mixture of amino acids and other protein degradation products that contribute to its characteristic flavor and nutritional value (Ijong & Ohta, 1995; Ruiz-Capillas et al., 2000; Gildberg, 2001; Sanceda et al., 2001; Aquerreta et al., 2001; Fukami et al., 2002; Ichimura et al., 2003) [6,5,8,9,10,11,12].

Fish sauce is a brown to gray liquid condiment characterized by its distinctive aroma and flavor, produced through the fermentation of fish. It is widely used as a flavor enhancer in cooking and is frequently consumed as a condiment in daily meals (Saisithi, 1994; Rosma et al., 2009; Montero et al., 2017) [13,14,15]. Fish sauce is recognized as a valuable source of protein and essential amino acids, particularly lysine. It also contains significant amounts of vitamins and minerals, including vitamin B12, sodium, calcium, magnesium, iron, manganese, and phosphorus. During fermentation, fish proteins are hydrolyzed into smaller peptides and amino acids through the action of microbial enzymes, contributing to the product's characteristic taste and nutritional value. The chemical composition of fish sauce, including protein content, free volatile bases, and salt concentration, undergoes considerable changes throughout the fermentation process (Ranjbar et al., 2017) [16].

Despite its nutritional benefits, fish sauce may contain biogenic amines, which are considered anti-nutritional compounds. The high protein content of fish, together with the activity of microbial transaminase and decarboxylase enzymes, promotes the formation of biogenic amines from amino acids during fermentation (Zarei et al., 2012) [17]. The major biogenic amines identified in fish sauce include tyramine, cadaverine, putrescine, histamine, spermine, and spermidine. Among these compounds, histamine is regarded as the predominant biogenic amine and is of particular concern due to its potential adverse effects on human health when present at elevated concentrations (Mah & Hwang, 2009) [18].

The lantern fish, locally known as "Sirum-sirum" (*Benthosema pterotum*), is a small marine fish species that is commonly used only in dried form. Despite its limited food applications, this species has significant potential as a raw material for value-added fish products. Consequently, this study aimed to utilize *Benthosema pterotum* as a by-catch resource for fish sauce production. Specifically, the study sought to determine the optimum fish-to-salt ratio for fermentation, evaluate the proximate chemical composition and nutritional value of the resulting fish sauce, and assess its microbial quality and safety. The findings of this study are expected to contribute to the development of a value-added fish product that can provide economic opportunities for Bicolanos while offering a nutritious and acceptable condiment for Filipino consumers.

II. METHODOLOGY

A. Collection of Samples.

Lantern fish (*Benthosema pterotum*), locally known as "Sirum-sirum," were purchased directly from fishermen in the coastal barangays of Dalupaon and Tinalmud, Pasacao, Camarines Sur, Philippines. These barangays were selected as sampling sites due to the abundance of lantern fish catches in the area. Freshly harvested fish were transported to the Pasacao Livelihood Facility for processing and fermentation.

B. Fish Sauce Production and Fermentation.

The collected lantern fish were washed thoroughly using seawater to remove adhering impurities. The fish were then mixed with salt at three different fish-to-salt ratios to serve as experimental treatments as (one-part salt to three, four and five parts fish, by weight): Treatment 1 (T1): 1:3, Treatment 2 (T2): 1:4, Treatment 3 (T3): 1:5. Each mixture was homogenized thoroughly and packed in food-grade plastic bags before being placed in covered plastic fermentation drums. The samples were allowed to ferment naturally for 90 days.

During fermentation, fish muscle proteins were progressively hydrolyzed into smaller peptides and amino acids through the action of endogenous proteolytic enzymes and halotolerant microorganisms (Montero et al., 2017) [15]. The resulting compounds served as substrates for fermentative microorganisms, contributing to flavor development and product maturation (Hall, 2002; Devanthi et al., 2019) [8,19]. Salt was added at high concentrations to reduce water activity, inhibit spoilage microorganisms, and promote the growth of desirable halotolerant bacteria responsible for continued protein degradation (Martin, 1994; Steinkraus, 1997; Ohshima & Giri, 2014) [20,21,22]. At the end of the 90-day fermentation period, the brown liquid supernatant was collected, filtered through a clean filter cloth, and subjected to physicochemical, sensory, and microbiological analyses.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1158

C. Sensory Evaluation.

The fish sauce samples from all treatments were subjected to sensory evaluation to determine the most acceptable fish-to-salt ratio. A panel of evaluators assessed the samples based on appearance, color, aroma, flavor, and overall acceptability using a 9-point Hedonic Scale, where 9 = Like Extremely and 1 = Dislike Extremely

D. Physicochemical Analysis.

The physicochemical properties of the fish sauce samples were determined following standard analytical procedures. Proximate composition, including moisture, crude protein, crude fat, ash, and carbohydrate contents, was analyzed according to the methods prescribed by the Association of Official Analytical Chemists (AOAC, 2016) [23]. Mineral analysis was performed using Microwave Plasma–Atomic Emission Spectroscopy (MP-AES), while nutrient analyses were conducted in accordance with the protocols of the United States Food and Drug Administration (USFDA), National Laboratory Reference (NLR), and the Department of Science and Technology–Food and Nutrition Research Institute (DOST-FNRI, 2015) [24].

E. Microbiological Analysis.

Microbiological analyses were conducted at the Department of Science and Technology (DOST) Regional Office V Laboratory. The microbial quality of the fish sauce samples was evaluated through the determination of: a) Total Coliform Count (CFU/mL) b) *Escherichia coli* Count (CFU/mL) c) Aerobic Plate Count (CFU/mL) d) Rapid Yeast and Mold Count (CFU/mL). The results were compared with established microbiological standards for fermented fish products to assess product safety and quality.

F. Statistical Analysis.

Data obtained from the sensory evaluation, physicochemical analyses, and microbiological tests were subjected to statistical analysis using the Statistical Package for the Social Sciences (SPSS) software. One-Way Analysis of Variance (ANOVA) was employed to determine significant differences among the three fish-to-salt ratio treatments at a 5% level of significance ($p < 0.05$). When significant differences were detected, Tukey's Honest Significant Difference (HSD) test was used as a post hoc analysis to identify which treatment means differed significantly.

III. RESULTS AND FINDINGS

A. Sensory Qualities of the Fish Sauce "patis"

Table 1 presents the mean sensory ratings of fish sauce produced from lantern fish (*Benthosema pterotum*) using different fish-to-salt ratios. The sensory attributes evaluated included appearance, flavor, texture, aroma, and general acceptability. Results showed that all treatments received favorable ratings from the panelists, with mean scores ranging from 6.06 to 8.24 on the hedonic scale.

Table 1. Sensory Evaluation of Fish Sauce (Patis) Produced from Lantern fish (*Benthosema pterotum*)

Attributes	Treatments					
	T1	**D**	**T2**	**D**	**T3**	**D**
Appearance	7.84	LVM	7.77	LVM	7.93	LVM
Flavor	6.06	LS	7.96	LVM	8.15	LVM
Texture	6.11	LS	7.92	LVM	8.1	LVM
Aroma	7.07	LM	7.25	LM	7.93	LVM
General Acceptability	7.19	LM	7.96	LVM	8.24	LVM

Legend: LVM-Like Very Much, LE Like Extremely, LM- Like Moderately, LS- Like Slightly D-Description

For appearance, Treatment 3 obtained the highest mean score (7.93), followed by Treatment 1 (7.84) and Treatment 2 (7.77), all interpreted as "Like Very Much." This suggests that the varying fish-to-salt ratios had minimal effect on the visual quality of the fish sauce. The characteristic brown color of fish sauce is primarily attributed to protein hydrolysis and browning reactions that occur during fermentation (Saisithi, 1994) [13].

In terms of flavor, Treatment 3 obtained the highest mean score (8.15), followed by Treatment 2 (7.96), both interpreted as "Like Very Much." Treatment 1 received the lowest rating (6.06), corresponding to "Like Slightly." The superior flavor of Treatment 3 may be attributed to enhanced protein degradation during fermentation, resulting in increased production of amino acids and peptides that contribute to the desirable umami taste of fish sauce (Fukami et al., 2002; Montero et al., 2017) [11,15].

Similarly, Treatment 3 recorded the highest score for texture (8.10), followed by Treatment 2 (7.92), while Treatment 1 received the lowest score (6.11). The breakdown of fish tissues through enzymatic hydrolysis during fermentation contributes to the smooth consistency and desirable mouthfeel of fermented fish products (Hall, 2002) [18].

For aroma, Treatment 3 achieved the highest mean score (7.93), while Treatments 1 and 2 obtained mean scores of 7.07 and 7.25, respectively. The development of desirable aroma compounds is associated with microbial and enzymatic activities that occur during fish fermentation. These processes generate volatile compounds responsible for the characteristic aroma of fish sauce (Steinkraus, 1997; Devanthi et al., 2019) [25,19].

With respect to general acceptability, Treatment 3 obtained the highest mean score (8.24), followed by Treatment 2 (7.96), both interpreted as "Like Very Much." Treatment 1 received a mean score of 7.19, corresponding to "Like Moderately." The higher overall acceptability of Treatment 3 suggests that its fish-to-salt ratio produced a more desirable balance of sensory attributes, including appearance, flavor, texture, and aroma. Previous studies have reported that salt

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1158

concentration significantly influences the sensory quality and consumer acceptance of fermented fish products by affecting microbial activity, protein hydrolysis, and flavor development (Saisithi, 1994; Montero et al., 2017) [13, 15].

Finally, Treatment 3 was the most preferred formulation among the three treatments, consistently obtaining the highest ratings across all sensory attributes. The findings indicate that the fish-to-salt ratio used in Treatment 3 produced a fish sauce with superior sensory quality and greater consumer acceptability compared with the other formulations.

B. Significant Difference Among Treatments on the Qualities of Fish Sauce (Patis)

Table 1 presents the results of the Friedman Two-Way Analysis of Variance by Rank conducted to determine the differences in the sensory attributes of fish sauce produced from lantern fish (*Benthosema pterotum*) under varying fish-to-salt ratios.

Table 2. Summary of Freidman Two-Way Analysis of Variance by Rank on the Physical Attributes of the Treatments of Fish Sauce

	Flavour			Odour			Colour			Saltiness		
	X^2C	TV	C	X^2C	TV	C	X^2C	TV	C	X^2C	TV	C
Treatment 1	6.993	5.99	S	8.164	5.99	S	5.98	5.99	NS	6.62	5.99	S
Treatment 2	9.281	5.99	S	10.107	5.99	S	5.617	5.99	NS	7.557	5.99	S
Treatment 3	7.993	5.99	S	7.164	5.99	S	5.78	5.99	NS	6.52	5.00	S

^{X2}Computed X ^{TV} Tabular value ^{C} Conclusion ^{S} Significance ^{NC} Not Significance

The results revealed that significant differences existed among the treatments with respect to flavor, odor, and saltiness, as indicated by the computed chi-square (X^2c) values exceeding the tabular value (5.99) at the 5% level of significance. For flavor, the computed X^2 values of Treatments 1, 2, and 3 were 6.993, 9.281, and 7.993, respectively, all greater than the tabular value of 5.99, indicating significant differences among treatments. Similarly, the odor attribute showed computed X^2 values of 8.164, 10.107, and 7.164 for Treatments 1, 2, and 3, respectively, which were also higher than the tabular value, signifying significant differences. Saltiness likewise exhibited significant variation among treatments, with computed X^2 values ranging from 6.52 to 7.557.

In contrast, no significant differences were observed in the color attribute among the treatments. The computed X^2 values for color were 5.98, 5.617, and 5.78 for Treatments 1, 2, and 3, respectively, all of which were below the tabular value of 5.99. This indicates that variations in the fish-to-salt ratio did not significantly affect the color of the fish sauce. The relatively uniform brown coloration observed among treatments may be attributed to similar biochemical reactions occurring during fermentation, particularly protein hydrolysis and Maillard-type reactions, which contribute to the characteristic color of fish sauce [26].

The significant differences observed in flavor, odor, and saltiness may be attributed to the varying salt concentrations used during fermentation. Salt plays a critical role in regulating microbial activity, enzymatic hydrolysis, and the formation of volatile compounds that contribute to the sensory characteristics of fermented fish products. Higher salt concentrations may enhance the development of characteristic fish sauce flavors and aromas while also influencing the perceived saltiness of the final product. These findings are consistent with previous studies which reported that salt concentration significantly affects the sensory quality and acceptability of fermented fish sauces (Saisithi, 1994; Montero et al., 2017) [13,15].

Generally, the results suggest that the fish-to-salt ratio significantly influences several important sensory attributes of lantern fish fish sauce, particularly flavor, odor, and saltiness

C. Physicochemical Analysis of Fish Sauce (Patis)

Fish sauce is a fermented condiment produced through the enzymatic and microbial hydrolysis of fish proteins in the presence of salt. The quality and nutritional composition of fish sauce are influenced by several factors, including the fish species used, salt concentration, fermentation conditions, and duration of fermentation (Amano, 1962; Saisithi, 1994; Gildberg, 2001) [27,13,8].

Table 3. The Proximate Analysis of "Sirum sirum" Fish Sauce

Samples	Moisture	Protein	Carbohydrates	Crude fat	Ash
T1	64.33	10.76	.15	.19	23.71
T 2	63.75	10.15	.12	.23	23.00
T3	64.12	10.8	0.13	0.18	24.67

Table 3 presents the proximate composition of fish sauce produced from lantern fish (*Benthosema pterotum*) using different fish-to-salt ratios. The results showed that moisture content ranged from 63.75% to 64.33%. Treatment 1 exhibited the highest moisture content (64.33%), followed by Treatment 3 (64.12%) and Treatment 2 (63.75%). The relatively high moisture content is typical of fish sauce products, which consist primarily of the liquid fraction generated during fermentation. Similar moisture levels have been reported in traditional fermented fish sauces produced in Southeast Asia (Saisithi, 1994)[13].

Protein content ranged from 10.15% to 10.80%, with Treatment 3 obtaining the highest value (10.80%), followed by Treatment 1 (10.76%) and Treatment 2 (10.15%). The protein content reflects the extent of protein hydrolysis during

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1158

fermentation, wherein fish proteins are broken down into soluble peptides and amino acids. These compounds contribute significantly to the nutritional value and characteristic umami flavor of fish sauce (Gildberg, 2001; Fukami et al., 2002) [8,11]. The relatively high protein content observed in all treatments indicates that lantern fish is a suitable raw material for fish sauce production.

Carbohydrate content was very low across all treatments, ranging from 0.12% to 0.15%. The low carbohydrate concentration is expected since fish muscle naturally contains minimal carbohydrate reserves. Similar findings have been reported in fermented fish products where carbohydrates contribute only a small fraction of the overall composition (Ruddle & Ishige, 2010) [28].

Crude fat content ranged from 0.18% to 0.23%, with Treatment 2 having the highest value (0.23%), followed by Treatment 1 (0.19%) and Treatment 3 (0.18%). The low fat content may be attributed to the lean nature of lantern fish and the breakdown of lipids during fermentation. Low fat levels are advantageous because they reduce the likelihood of oxidative rancidity, thereby enhancing product stability and shelf life (Hall, 2002) [18].

Ash content, which represents the total mineral content of the product, ranged from 23.00% to 24.67%. Treatment 3 recorded the highest ash content (24.67%), followed by Treatment 1 (23.71%) and Treatment 2 (23.00%). The elevated ash values are primarily due to the high salt concentration used during fermentation, as sodium chloride contributes substantially to the mineral fraction of fish sauce (Saisithi, 1994) [13]. High ash content is a common characteristic of fermented fish sauces and serves as an indicator of mineral richness and preservation effectiveness.

Overall, the proximate analysis revealed that fish sauce produced from lantern fish (*Benthosema pterotum*) is characterized by high moisture and protein contents, low levels of carbohydrates and fat, and substantial mineral content. Among the treatments, Treatment 3 exhibited the highest protein and ash contents, suggesting superior nutritional quality. These findings demonstrate the potential of lantern fish as an alternative raw material for the production of nutritious and value-added fish sauce.

D. Microbiological Analysis of Sirum-sirum Fish Sauce

Microbiological analysis is an important quality and safety parameter for fermented fish products because it determines the presence of indicator microorganisms and potential pathogens that may affect product quality and consumer health. The reference of the Microbiological analysis was based on the United States Food and Drug Administration (USFDA,2022) [29] The microbial counts of fish sauce produced from lantern fish (*Benthosema pterotum*) are presented in Table 4.

Table 4. Microbial Count of "Sirum sirum" Fish Sauce

Treatment	**Coliform Count (CFU*/ml)**	**E. coli Count (CFU*/ml)**	**Rapid Yeast & Mold Count (CFU*/ml)**	**Aerobic Plate Count (CFU*/ml)**
Treatment 1	<1.0	<1.0	<1.0	<30
Treatment 2	<1.0	<1.0	<1.0	<30
Treatment 3	<1.0	<1.0	<1.0	<30
Method used	TM-M-008 with reference to AOAC 991.14, 21st Ed.	TM-M-008 with reference to AOAC 991.14, 21st Ed.	TM-M-008 with reference to AOAC 2014.05, 21st Ed.	TM-M-008 with reference to AOAC 990.12, 21st Ed.

*CFU- Colony Forming Unit

Results showed that all treatments exhibited very low microbial counts. Coliform counts and *Escherichia coli* counts were less than 1.0 CFU/mL in all treatments. Similarly, Rapid Yeast and Mold Counts were below 1.0 CFU/mL, while Aerobic Plate Counts were less than 30 CFU/mL for all samples. The results also showed that Coliform count and E. coli count and Coliform Count was recorded less than ten (<10 CFU*/g). On the other hand, Aerobic Plate Count was recorded <30 CFU*/g. The result is below recommended microbiological limits for Fish sauce (ICMSF, 1986) [30]. Furthermore, the results of microbial load in Table 4 were confirmed with Dissaraphong et al. (2006) [31] who reported that microbial load of fish sauce decreased with increased fermentation period, possibly caused by high concentration of salt.

The absence of detectable coliforms and *E. coli* indicates good sanitary conditions during processing and suggests that the fish sauce was free from fecal contamination. Coliform bacteria are commonly used as indicators of hygienic quality in food products, while the presence of *E. coli* may indicate contamination from human or animal waste (Jay et al., 2005) [32]. The results therefore demonstrate that the production process maintained acceptable hygienic standards throughout fermentation and handling.

The very low yeast and mold counts further indicate the microbiological stability of the fish sauce. High salt concentrations used during fermentation reduce water activity, creating conditions unfavorable for the growth of spoilage microorganisms, including most yeasts and molds (Steinkraus, 1997) [31]. Salt also acts as a natural preservative by inhibiting microbial growth and extending product shelf life.

Likewise, the Aerobic Plate Count of less than 30 CFU/mL observed in all treatments indicates a very low population of aerobic microorganisms. The low microbial load may be attributed to the combined effects of salt concentration, prolonged fermentation, enzymatic hydrolysis, and the production of antimicrobial metabolites during fermentation.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun1158

These factors collectively contribute to the safety and preservation of fermented fish products (Hall, 2002; Montero et al., 2017) [18,15].

The uniform microbial results among treatments suggest that the different fish-to-salt ratios used in the study did not adversely affect the microbiological quality of the fish sauce. All treatments complied with acceptable microbiological standards for fermented fish products and were considered microbiologically safe for consumption.

Overall, the findings demonstrate that fish sauce produced from lantern fish (*Benthosema pterotum*) possesses excellent microbiological quality, characterized by the absence of detectable coliforms, *E. coli*, yeasts, and molds, as well as very low aerobic bacterial counts. These results indicate that the fermentation process and salt concentrations employed were effective in ensuring product safety, stability, and shelf-life quality.

IV. CONCLUSION

This study successfully demonstrated the potential of lantern fish (*Benthosema pterotum*), locally known as "Sirum-sirum," as an alternative raw material for the production of fish sauce (patis). The fermentation of lantern fish using different fish-to-salt ratios resulted in a product with acceptable sensory qualities, desirable nutritional composition, and excellent microbiological quality.

The sensory evaluation revealed significant differences among treatments in terms of flavor, odor, and saltiness, while no significant difference was observed in color. Among the treatments, Treatment 3 consistently obtained the highest ratings for appearance, flavor, texture, aroma, and general acceptability, indicating superior consumer preference.

The proximate analysis showed that the fish sauce contained high moisture content, appreciable protein levels, low carbohydrate and fat contents, and substantial mineral content as indicated by ash values. Treatment 3 exhibited the highest protein and ash contents, suggesting better nutritional quality compared with the other treatments.

Microbiological analysis revealed that all treatments were microbiologically safe for consumption, with coliform count, *Escherichia coli* count, yeast and mold count, and aerobic plate count all below detectable or acceptable limits. These findings indicate that the fermentation process and salt concentrations effectively inhibited the growth of undesirable microorganisms.

Generally, the results indicate that lantern fish (*Benthosema pterotum*) can be utilized as a value-added fishery resource for fish sauce production. Among the treatments evaluated, Treatment 3 produced the most acceptable and nutritionally favorable fish sauce while maintaining excellent microbiological quality. The study therefore highlights the potential of Sirum-sirum fish as an underutilized marine resource that can contribute to food innovation, fisheries sustainability, and livelihood opportunities in coastal communities.

Based on the findings of the study, the following recommendations are proposed:

- Treatment 3 should be adopted as the preferred fish-to-salt ratio for the production of lantern fish fish sauce due to its superior sensory acceptability, favorable nutritional composition, and excellent microbiological quality.
- Further studies should be conducted to evaluate the shelf life and storage stability of lantern fish fish sauce under different packaging and storage conditions.
- Future research should include detailed analyses of amino acid profiles, mineral composition, histamine content, and other quality parameters to further establish the nutritional and safety characteristics of the product.
- Consumer acceptability studies involving a larger and more diverse group of respondents from different regions should be conducted to validate market potential.
- Economic feasibility and commercialization studies should be undertaken to determine the profitability and scalability of lantern fish fish sauce production for small-scale and community-based enterprises.
- Government agencies, local government units, fisheries organizations, and academic institutions should promote the utilization of underexploited fish species such as lantern fish as raw materials for value-added products to reduce post-harvest losses and enhance the income of coastal fishing communities.
- Economic feasibility and commercialization studies should be undertaken to determine the profitability and scalability of lantern fish sauce production for small-scale and community-based enterprises.
- Training programs on fish sauce processing, quality assurance, and food safety practices should be provided to fisher folks and local entrepreneurs to encourage sustainable production and commercialization of lantern fish-based fish sauce.

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