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Effect of Freshwater Fish Species on *Lemea* Chemical and Organoleptic Characteristics for Ethnoscience-Based Chemistry Learning

Syera Verlita[1], Dewi Handayani[2]*, Annisa Puji Astuti[3], Bhakti Karyadi[4], Aprina Defianti[5], and Deni Parlindungan[6]
[1.3.5.6]*Department of Science Education, University of Bengkulu, Bengkulu*
[2]*Department of Chemistry Education, University of Bengkulu, Bengkulu*
[4]*Master of Science Education, University of Bengkulu, Bengkulu*

Email: d.handayani@unib.ac.id

Abstract: *This study examined the effects of freshwater fish species on the chemical and organoleptic characteristics of lemea and its potential as an ethnoscience-based chemistry learning context. Previous studies have focused on fermentation time, fish proportion, or its use as a learning resource, while comparative evidence involving freshwater fish species under standardized conditions remains limited. A randomized design was applied using four fish treatments: Cyprinus carpio (P1), Oreochromis niloticus (P2), Oreochromis mossambicus (P3), and Channa striata (P4). Each treatment had three replications and was fermented for seven days. Organoleptic characteristics were evaluated using a five-point hedonic scale, while pH and protein content were determined through laboratory procedures. P4 achieved the highest preference scores for color (95%), aroma (91%), taste (97%), and texture (93%). Mean pH values ranged from 4.23 to 4.62, with no significant differences among treatments based on Welch's ANOVA ($p = 0.660$). Protein content differed significantly ($p = 0.020$), with P4 showing the highest value (23.98%) and P3 the lowest (11.04%). These findings indicate that fish species were associated with differences in sensory characteristics and protein content, whereas pH remained stable.. Fermentation provides a basis for connecting Rejang knowledge with fermentation, microorganisms, acidity, and protein transformation in chemistry learning.*

Keywords: *lemea; fermentation; ethnoscience; organoleptic; protein*

INTRODUCTION

Indonesia has a wide diversity of traditional fermented foods in which community practices preserve food and produce distinctive chemical and sensory characteristics. Fermentation involves microbial metabolism that converts available substrates into organic acids, peptides, amino acids, alcohols, and other metabolites, thereby producing measurable changes in food properties. These transformations make fermented foods relevant to chemistry education because they provide observable examples of chemical change in everyday cultural contexts (Mulyani *et al*., 2022).

Lemea is a traditional fermented food of the Rejang community in Bengkulu made from young bamboo shoots and freshwater

fish. The fermentation generally lasts 3–7 days and produces characteristic sourness, aroma, taste, and texture (Utama *et al*., 2023). Knowledge concerning the selection of bamboo shoots and fish and the appropriate fermentation duration is transmitted within the community. Such practices provide a local context in which fermentation, microbial activity, acidity, and protein transformation can be explained scientifically (Marcellina *et al*., 2021).

Previous studies have examined *lemea* from several perspectives. Aziz and Aji (2024) investigated the effects of fish amount and fermentation time on *lemea* sensory properties (Aziz & Aji, 2023), while Marcellina *et al* (2024) described bamboo shoots as an important local raw material for *lemea* production. Marcellina *et al* (2021) also developed *lemea*-based learning resource for junior high school biotechnology learning. These studies establish the relevance of raw materials, fermentation conditions, and local knowledge in *lemea*; however, they do not provide a simultaneous comparison of several freshwater fish species using the same bamboo-shoot substrate and fermentation duration.

The research gap is therefore the limited comparative evidence on how different freshwater fish species influence the chemical and organoleptic characteristics of *lemea* under standardized processing conditions, together with the limited interpretation of these findings for chemistry education. The novelty of this study lies in the simultaneous evaluation of four freshwater fish species, namely *C. carpio*, *O. niloticus*, *O. mossambicus*, and *C. striata*, using organoleptic, pH, and protein analyses, followed by the interpretation of the resulting fermentation chemistry as an ethnoscience-based chemistry-learning context. This contribution is relevant because local wisdom can become a meaningful learning resource when community practices are explicitly connected with scientific concepts (Cahyani & Fadly, 2024). This is consistent with Purba *et al*. (2024), who reported the need for chemistry learning media based on local wisdom, indicating that local contexts can support the development of more meaningful and contextual chemistry learning (L. S. L. Purba *et al*., 2024).

Accordingly, this study aimed to determine the association of four freshwater fish species with the organoleptic characteristics, pH, and protein content of *lemea* and to explain the educational significance of the findings. The use of local wisdom as a context for chemistry learning is also supported by previous studies showing that local knowledge can be incorporated into chemistry teaching materials to provide contextual learning experiences (Marditha *et al*., 2022). The study is expected to contribute scientific evidence about *lemea* fermentation and provide a contextual example for chemistry learning, particularly for fermentation, microorganisms, acidity, protein transformation, and the relationship between local knowledge and scientific knowledge.

LITERATURE REVIEW

Etnoscience in chemistry education places community knowledge in dialogue with scientific explanations. showed that an ethnoscience approach can be used in chemistry learning to connect local practices with scientific literacy. Cahyani and Fadly (2024) this perspective is relevant to *lemea* because students can begin with a familiar food-making practice and reconstruct the underlying scientific concepts (Cahyani & Fadly, 2024) .

Cahyani and Fadly (2024) reviewed the integration of local wisdom in chemistry learning and reported that ethnoscience can support contextual and meaningful learning. Their review also indicates that local wisdom can function as a learning resource rather than merely as cultural information. In the present study, *lemea* is positioned in this way: the traditional process becomes the context for interpreting fermentation chemistry (Cahyani & Fadly, 2024).

Wahyudiati and Qurniati (2023) similarly demonstrated that local wisdom can be explored through ethnochemistry as a source of chemistry learning, allowing culturally familiar practices to be connected with scientific concepts. This approach supports the use of local food practices as meaningful contexts for introducing chemistry concepts (Wahyudiati & Qurniati, 2023).

Sumarni and Supanti (2021) developed a food-chemistry textbook integrated with ethnoscience and found it feasible as a learning resource. Their work demonstrates that food practices can be transformed into structured chemistry-learning materials. The present study extends this idea by providing experimental evidence on *lemea* that can be used as the scientific content of a contextual learning activity (Sumarni & Supanti, 2021). Setyorini *et al*. (2022) also developed chemistry learning materials based on local wisdom and reported their potential to support students' scientific literacy. These findings reinforce the use of culturally relevant materials as a means of connecting scientific concepts with students' local experiences (Setyorini *et al*., 2022).

Nenohai *et al*. (2022) further showed that an ethnoscience approach can be incorporated into chemistry practicum e-modules, providing a connection between local knowledge and practical chemistry learning. This is relevant to the present study because the fermentation process of *lemea* can provide an observable context for practical learning activities (Nenohai *et al*., 2022).

Cristy and Pamenang (2023) demonstrated that ethnoscience can also be incorporated into chemistry worksheets, allowing local contexts to be integrated into structured student learning activities. Such approaches support the development of chemistry learning resources that connect scientific concepts with culturally familiar phenomena (Cristy & Pamenang, 2023).

Purba *et al*. (2024) analyzed students' needs for chemistry learning media based on local wisdom and found that students generally supported the use of learning media integrating local wisdom. Their findings indicate that local cultural contexts can provide relevant foundations for developing meaningful chemistry-learning resources. This supports the use of *lemea* as a local cultural context for connecting chemistry concepts with students' everyday experiences (L. S. L. Purba *et al*., 2024).

Marditha *et al*. (2022) developed a basic biochemistry teaching-material supplement based on the local wisdom of the Pasti Jaya community. Their study demonstrates that community knowledge can be incorporated into scientific teaching materials while maintaining the connection between local practices and biochemical concepts. This approach is relevant to the present study because the biochemical processes occurring during *lemea* fermentation can also be interpreted as chemistry-learning content (Marditha *et al*., 2022).

Purba and Sembiring (2023) developed a project-based learning module for chemical equilibrium using a research and development approach. The module was assessed for content, presentation, language, and graphic feasibility and received positive student responses. This study supports the use of project-based modules as structured learning resources and is relevant to the present study because *lemea* can provide a concrete local context for project-based chemistry learning (J. Purba & Sembiring, 2023).

Salelatu and Rohaeti (2023) similarly developed a chemistry module based on local natural resources within a project-based learning framework. Their work supports the use of locally available resources as contextual materials for chemistry learning and strengthens the relevance of local products as learning contexts (Salelatu & Rohaeti, 2023).

Rambe and Sutiani (2024) developed learning media integrated with a project-based learning model for reaction-rate material using the 4D development model. The

developed media was reported to be feasible and well received by students. Their findings reinforce the potential of combining project-based learning with contextual chemistry resources, while the present study contributes a local-food fermentation context that can be connected to observable chemical changes (Rambe & Sutiani, 2024).

Siswanto *et al*. (2025) reported that teachers and students need innovative chemistry teaching materials integrated with ethnopedagogy and oriented toward 21st-century learning. Their findings emphasize the importance of contextual and culturally grounded learning materials. The present study responds to this need by providing scientific information on *lemea* that can be transformed into a contextual chemistry learning resource (Siswanto *et al*., 2025).

Lemea is a traditional fermented food of the Rejang community in Bengkulu that is primarily prepared from young bamboo shoots and freshwater fish. The selection of raw materials and fermentation conditions contributes to the characteristics of the final product. Utama *et al*. (2023) described *lemea* as a traditional Rejang food produced through bamboo-shoot fermentation and highlighted the role of raw materials and fermentation practices in its production (Utama *et al*., 2023). Marcellina *et al*. (2024) also reported that bamboo shoots are an important local food resource and the main raw material used in *lemea* production.



Figure 1. *Lemea as a traditional fermented food of the Rejang community*

Previous research has examined several factors affecting *lemea* characteristics. Aziz and Aji (2023) investigated the effect of additional fish amount and fermentation time on the sensory properties of *lemea*, indicating that processing conditions can influence its sensory quality (Aziz & Aji, 2023). Marcellina *et al*. (2021) also developed *lemea*-based learning resource for junior high school biotechnology learning, demonstrating the potential of *lemea* as a contextual source for science education. However, previous studies have not specifically compared several freshwater fish species under the same bamboo-shoot composition and fermentation conditions while simultaneously examining pH, protein content, and organoleptic characteristics.

Taken together, these studies show the value of contextual, project-based, and culturally grounded chemistry learning resources. However, previous studies have not specifically examined how differences among freshwater fish species affect the chemical and organoleptic characteristics of *lemea* while simultaneously positioning the findings as a chemistry-learning context based on Rejang ethnoscience. This gap provides the basis for the present study.

Fermentation chemistry is strongly related to microbial metabolism. Xu *et al*. (2023) found that changes in microbial communities during bamboo-shoot fermentation were associated with changes in pH, titratable acidity, texture, and volatile compounds (Xu *et al*., 2023). These findings help explain why fermented bamboo shoots can simultaneously show changes in acidity and aroma during fermentation. Similarly, Zhang *et al*. (2024) reported that microbial succession during bamboo-shoot fermentation was associated with changes in volatile compounds that contribute to the characteristic sensory properties of the fermented product (Zhang *et al*., 2024).

Protein transformation is another important chemical aspect of fermented fish products. An *et al* (2022) reported that lactic-acid-bacteria fermentation of fermented fish

can improve product quality through changes in biochemical and sensory characteristics. Proteolysis during fermentation can hydrolyze proteins into smaller peptides and free amino acids, which may contribute to flavor development, while changes in protein structure may influence texture (An *et al*., 2022). Wang *et al*. (2022) also demonstrated that lactic acid bacteria can promote protein metabolism and flavor formation in fermented fish (Wang *et al*., 2022). These findings provide a scientific basis for examining fish species as a variable in *lemea* fermentation.

Organoleptic evaluation provides an accessible way to connect chemical transformation with human perception. Junianto *et al*. (2024) showed that fermentation duration affected the pH and hedonic quality of fermented tilapia, including appearance, aroma, taste, and texture. In *lemea*, the same sensory dimensions are useful for comparing how different fish species interact with the bamboo-shoot fermentation matrix. (Junianto *et al*., 2024)

METHODS

This experimental study was conducted from January to April 2026. *lemea* was produced in Suban Ayam Village, Selupu Rejang District, Rejang Lebong Regency, Bengkulu Province, where bamboo shoots and freshwater fish are locally available and the traditional practice of making *lemea* is still maintained. pH and protein analyses were conducted at the Biology Laboratory, Faculty of Mathematics and Natural Sciences, University of Bengkulu. The experimental unit was one closed fermentation container containing one treatment composition. The fermentation containers were kept under the same local ambient conditions; fermentation temperature was not instrumentally recorded and is therefore treated as an uncontrolled limitation.

The independent variable was fish species: *C. carpio* (P1), *O. niloticus* (P2), *O. mossambicus* (P3), and *C. striata* (P4). The dependent variables were organoleptic preference, pH, and protein content. Controlled variables included the bamboo species (G. robusta), bamboo-shoot mass, fish-to-bamboo ratio, water addition, salt addition, fermentation duration, container type, and processing sequence. A completely randomized design with four treatments and three replications was used.

Research Procedure

This study used a completely randomized design with four treatments and three replications, as shown in Table 1.

Table 1. Experimental treatments of *Lemea* fermentation

Treatment	Composition
P1	*G. robusta* 75% + *C. carpio* 25%
P2	*G. robusta* 75% + *O. niloticus* 25%
P3	*G. robusta* 75% + *O. mossambicus* 25%
P4	*G. robusta* 75% + *C. striata* 25%

G. robusta bamboo shoots measuring approximately 30–60 cm were cleaned, sliced, chopped, washed three times, drained, and weighed at 750 g for each treatment. Four glasses of boiled water were added until the bamboo shoots were submerged, and the shoots were fermented in a tightly closed container for three days. Each fish species was prepared at 250 g, boiled for 10 minutes with water and salt, cooled, and combined with the pre-fermented bamboo shoots. The mixture was supplemented with 5 grains of cooked rice and 1 red chili, with the same amounts used in all treatments, mixed uniformly, and fermented in sealed containers for a further seven days. Thus, the fish species was the only intended treatment difference.

The experimental procedure represents the scientific evidence base for chemistry-learning interpretation rather than a direct student protocol. The process illustrates biotechnology through microbial fermentation, acidity through organic-acid formation, protein chemistry through hydrolysis and nitrogen-containing compounds, and sensory change through the formation of volatile and non-volatile metabolites. In classroom implementation, the evidence can be simplified into safe observation and measurement activities rather

than requiring students to reproduce the entire food-production process.

All treatments were fermented under the same environmental conditions and fermentation duration to minimize environmental variation among treatments. The fermentation containers were placed at the same location and were maintained under room conditions throughout the seven-day fermentation period.

Data Analysis

The data obtained in the study included organoleptic characteristics, acidity (pH), and protein levels in *lemea* resulting from the fermentation of different freshwater fish species. Data analysis was used to evaluate the quality of *lemea* fermentation by examining organoleptic parameters, acidity levels measured by pH, and protein content. The data were then processed and compiled into a diagram to make it easier to interpret the research results.

Organoleptic testing used a five-point hedonic scale (1 = dislike very much, 2 = dislike, 3 = neither like nor dislike, 4 = like, 5 = like very much). Ten panelists who had experience making and consuming *lemea* assessed color, aroma, taste, and texture. The panelists evaluated coded samples using the same assessment form for all treatments. The percentage of the panelists' preference level is calculated using the following formula:

$$\text{Percentage (\%)} : \frac{\sum \text{Score } obtained}{Maksimum\ score} \times 100 \qquad (1)$$

Because the individual panel-level scores were not retained in the final dataset, inferential statistical testing and standard-deviation error bars for the sensory data could not be reconstructed; the organoleptic results are therefore presented descriptively.

Each treatment was measured three times for pH. Mean and standard deviation were calculated. Normality and variance homogeneity were considered before inferential testing. Because the pH groups did not satisfy the homogeneity assumption, Welch's one-way ANOVA was used at $\alpha = 0.05$ as a robust alternative to ordinary one-way ANOVA. Protein data were not normally distributed; therefore, the Kruskal–Wallis test was used at $\alpha = 0.05$. When the Kruskal–Wallis test was significant, pairwise comparisons with Bonferroni adjustment were used to identify treatment pairs that differed. The Kruskal–Wallis epsilon-squared effect size was also estimated to describe the magnitude of the treatment effect.

Protein content was determined using the Kjeldahl method through digestion, distillation, and titration, with total nitrogen converted to protein content. Laboratory analyses were performed at the Biology Laboratory of FMIPA, University of Bengkulu. The laboratory record for pH and protein analysis was documented under Letter No. 077/UN.30.12.Lab.Biology/2026.

RESULTS AND DISCUSSION

The four treatments produced visibly different fermented *lemea* samples, indicating differences in appearance after fermentation. The samples were subsequently evaluated for organoleptic characteristics, pH, and protein content. The results are discussed by relating the observed differences to possible biochemical changes during fermentation and to previous findings on fermented food products.



Figure 2. Documentation of *Lemea* fermentation results

Note :
P1 : *G. robusta* 75% + *C. carpio* 25%
P2 : *G. robusta* 75% + *O. niloticus* 25%
P3 : *G. robusta* 75% + *O. mossambicus* 25%
P4 : *G. robusta* 75% + *C. striata* 25%

Organoleptic Tests

The organoleptic results showed differences in panelists' preference among the four fish treatments. P4 (*G. robusta* 75% + *C. striata* 25%) consistently obtained the highest preference percentages for color (95%), aroma (91%), taste (97%), and texture (93%). P3 (*G. robusta* 75% + *O. mossambicus* 25%) showed the lowest percentage for color (71%), aroma (82%), and texture (80%), while its taste score was also the lowest (87%). Because individual panelist scores were not retained, these sensory results are presented descriptively and should not be interpreted as statistically significant differences.

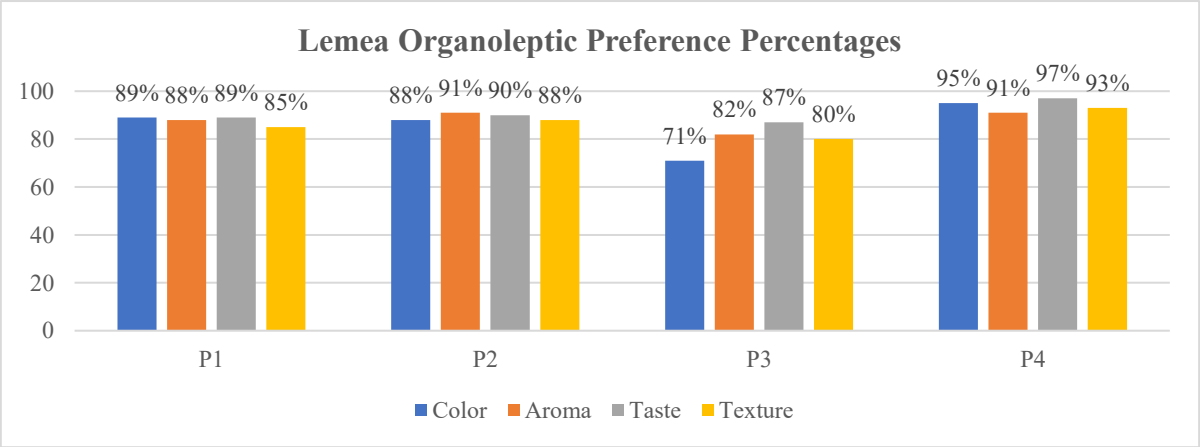


Figure 3. Organoleptic Test Results Color, Aroma, Taste, Texture

Color

Color is an important sensory attribute because it provides an initial visual impression of a food product. In fermented foods, changes in color may be associated with raw-material composition, microbial activity, and biochemical reactions during fermentation (Chan *et al.*, 2023). Fermentation can modify the chemical characteristics of food matrices through microbial and enzymatic activity, although the specific compounds responsible for color changes depend on the raw materials and fermentation conditions.

The highest color preference was observed in P4 at 95%, followed by P1 at 89% and P2 at 88%, whereas P3 had the lowest score at 71%. The difference in color

preference may be related to differences in the composition of the fish used, including protein and lipid characteristics, which interact with the common bamboo-shoot substrate during fermentation (Chan *et al*., 2023). However, the present study did not directly measure color compounds or specific biochemical reactions responsible for the visual differences. Therefore, the observed variation in color should be interpreted as an association with the fish treatment rather than evidence of a specific chemical mechanism.

The relatively high preference for P4 indicates that the fermented product containing *C. striata* produced a visual appearance that was more acceptable to the panelists. This result indicates that changing the fish species was associated with differences in the sensory profile of *lemea* under the standardized conditions used in this study.

Aroma

Aroma is influenced by volatile compounds formed or modified during microbial and enzymatic reactions during fermentation. Studies of fermented bamboo shoots have identified alcohols, esters, aldehydes, ketones, acids, phenols, and other volatile compounds that contribute to the characteristic fermented aroma (Li *et al*., 2022).

The aroma preference percentages were 88% for P1, 91% for P2, 82% for P3, and 91% for P4. Thus, P2 and P4 showed the highest preference, whereas P3 showed the lowest preference. The differences may reflect interactions between the fish composition and the bamboo-shoot fermentation matrix, which can influence the formation and perception of volatile compounds. Wei *et al*. (2024) reported that microbial succession during bamboo-shoot fermentation was closely associated with changes in volatile compounds and the development of characteristic aromas. The involvement of microorganisms in aroma formation has also been demonstrated in fermented bamboo shoots, where Lactobacillus and other microbial genera were associated with the formation of characteristic volatile compounds.

The similar aroma preference for P2 and P4 suggests that high acceptance was not limited to one fish species. Because volatile compounds were not directly identified in this study, the specific compounds responsible for the differences among treatments cannot be determined. Nevertheless, the results indicate that fish species can contribute to differences in the perceived aroma of *lemea* when fermented under the same processing conditions.

Taste

Taste preference reflects the combined effects of compounds produced or modified during fermentation. In fermented fish products, biochemical changes during fermentation can alter free amino acids, organic acids, peptides, and volatile compounds, which contribute to flavor and sensory perception (Rachmawati *et al*., 2024). Free amino acids, particularly glutamic acid and aspartic acid, can contribute to the umami taste of fermented fish products, while other compounds formed during fermentation may influence the overall flavor profile (Setiarto & Herlina, 2024).

P4 obtained the highest taste preference at 97%, followed by P2 at 90%, P1 at 89%, and P3 at 87%. Although all treatments showed relatively high preference percentages, P4 had the highest value. The higher preference may be associated with differences in the composition of the fish and compounds formed during fermentation. Differences in fish composition may influence the biochemical changes that occur during fermentation and consequently affect the flavor characteristics perceived by panelis.

However, the present study did not directly measure free amino acids, peptides, or volatile flavor compounds. Therefore, the higher taste preference of P4 cannot be attributed to a specific compound or enzymatic reaction. The result instead indicates that the combination of *C. striata*

with the bamboo-shoot substrate produced a sensory profile that was highly accepted by the panelists.

Texture

Texture is an important sensory attribute that contributes to the overall acceptability of fermented fish products. Differences in fish species can result in different textural characteristics of the fermented product. Ezzat *et al*. (2021) reported differences in consumer acceptability of fermented fish produced from black tilapia and Javanese carp, with the Javanese carp product receiving higher overall acceptability associated with its more tender flesh and muscle texture. These findings indicate that the characteristics of the fish used as raw material can contribute to differences in the texture perceived by consumers after fermentation (Ezzat *et al*., 2021).

The texture preference percentages were 85% for P1, 88% for P2, 80% for P3, and 93% for P4. P4 therefore showed the highest texture preference, while P3 showed the lowest. The difference may be related to differences in the structural properties of the fish proteins and their interaction with the bamboo-shoot matrix during fermentation. Nevertheless, the study did not directly measure texture profile, protein degradation, or gel structure, so a specific mechanism cannot be confirmed.

The high texture preference for P4, together with its high taste and color scores, indicates that the treatment produced a sensory profile that was consistently well accepted. These findings support the use of fish species as an important variable when investigating the sensory characteristics of *lemea*.

pH Test

pH testing is carried out to determine the acidity level of *lemea* products after seven days of fermentation. The pH value is an important indicator of the success of the fermentation process because it is related to microbial activity and the formation of organic acids. pH testing was carried out at the Biology Laboratory of FMIPA, University of Bengkulu, based on Letter No. 077/UN.30.12.Lab.Biologi/2026.

Table 2. pH Test

Treatment	N	pH ($\bar{x}$ ± SD)
P1	3	4.23 ± 0.37
P2	3	4.62 ± 0.77
P3	3	4.55 ± 0.07
P4	3	4.42 ± 0.35

Note : N : number of samples, $\bar{x}$: average, SD : standard deviation

Based on Table 2, the mean pH values ranged from 4.23 to 4.62. P1 had the lowest mean pH value (4.23 ± 0.37), whereas P2 had the highest mean pH value (4.62 ± 0.77). P3 and P4 had mean pH values of 4.55 ± 0.07 and 4.42 ± 0.35, respectively. These values indicate that all *lemea* treatments remained under acidic conditions after seven days of fermentation.

To determine whether the differences in pH among treatments were statistically significant, Welch's one-way ANOVA was performed because the variance among treatments was not homogeneous. The results are presented in Table 3.

Table 3 Welch's ANOVA Results for pH

	Statistic[a]	df1	df2	Sig.
Welch	0.584	3	3.508	0.660

The Welch's ANOVA result showed a significance value of p = 0.660 (>0.05). Therefore, the null hypothesis was not rejected, indicating that there was no statistically significant difference in pH among P1, P2, P3, and P4. Although P1 had the lowest mean pH and P2 had the highest mean pH, the numerical differences were not statistically significant. Thus, the fish species did not significantly affect the final pH of *lemea* under the standardized fermentation conditions used in this study.

The acidic condition observed in all treatments is consistent with changes commonly observed during bamboo-shoot fermentation. Singhal *et al*. (2021) reported that the pH of fermented bamboo shoots decreased progressively during fermentation, while titratable acidity increased. The decrease in pH was associated with the

accumulation of acidic compounds during the fermentation process. This finding supports the observation that all *lemea* treatments in the present study remained under acidic conditions after seven days of fermentation (Singhal *et al*., 2021).

The development of acidity during bamboo-shoot fermentation can also be associated with the activity of lactic acid bacteria. Tanganurat and Chareonchai (2022) reported that fermented bamboo shoots inoculated with Pediococcus pentosaceus and Lactobacillus plantarum showed lower pH and higher total acidity than the control treatment. These results indicate that microbial fermentation can promote acid formation and consequently reduce the pH of fermented bamboo-shoot product (Tanganurat & Chareonchai, 2022).

Microbial activity may also contribute to changes in the physicochemical characteristics of fermented bamboo shoots. Kumar *et al*. (2022) identified several bacterial groups associated with fermented bamboo shoots and reported changes in pH and titratable acidity after fermentation. The presence and activity of microorganisms during fermentation can therefore contribute to biochemical changes in the substrate and the development of acidic conditions (Kumar *et al*., 2022).

The dynamics of pH during bamboo-shoot fermentation may vary according to the microorganisms involved and the fermentation stage. Chen *et al*. (2024) found that pH decreased rapidly during the initial stage of bamboo-shoot fermentation and subsequently stabilized, while titratable acidity increased. This pattern indicates that acid production is particularly active during the early stages of fermentation before the acidity reaches a relatively stable condition (Chen *et al*., 2024).

However, microbial populations and organic-acid concentrations were not directly measured in this study. Therefore, the contribution of lactic acid bacteria and specific organic acids should be regarded as a possible explanation rather than a directly demonstrated mechanism. Overall, the pH results indicate that changing the fish species did not significantly alter the acidic condition of *lemea* under the conditions applied in this study.

Protein Test

Protein content analysis was conducted to assess the nutritional quality of fermented *lemea* (Pakerti & Purnama, 2022). The measurement was carried out using the Kjeldahl method, which quantifies total nitrogen to determine protein levels. This analysis was carried out at the Biology Laboratory of FMIPA, University of Bengkulu, based on letter number 077/UN.30.12.Lab.Biologi/2026.

Table 4. Protein Test

Treatment	N	Protein (%) ($\bar{x}$ ± SD)
P1	3	14.33 ± 3.29
P2	3	20.38 ± 0.33
P3	3	11.04 ± 0.18
P4	3	23.98 ± 1.58

Note : N : number of samples, $\bar{x}$: average, SD : standard deviation

Based on Table 4, the measured protein content ranged from 11.04% to 23.98%. P4 showed the highest mean protein content at 23.98 ± 1.58%, followed by P2 at 20.38 ± 0.33% and P1 at 14.33 ± 3.29%. P3 showed the lowest protein content at 11.04 ± 0.18%. Thus, the treatment containing *C. striata* had the highest measured protein content, whereas the treatment containing *O. mossambicus* had the lowest.

The differences in protein content were statistically analyzed using the Kruskal–Wallis test because the data did not meet the assumptions required for parametric analysis. The results are presented in Table 5.

Table 5. Kruskal–Wallis Test Results for Protein Content

	Data
Kruskal-Wallis H	9.804
df	3
Asymp. Sig.	0.020

The Kruskal–Wallis test showed a significance value of p = 0.020 (<0.05), indicating a statistically significant

difference in measured protein content among the four treatments. Therefore, fish species were associated with differences in the measured protein content of *lemea* under the fermentation conditions used in this study.

Table 6. Bonferroni-Adjusted Pairwise Comparisons of Protein Content

Comparison	Interpretation
P1 vs P2	Significant
P1 vs P3	Not Significant
P1 vs P4	Significant
P2 vs P3	Significant
P2 vs P4	Not Significant
P3 vs P4	Significant

The Bonferroni-adjusted pairwise comparisons showed significant differences between P1 and P2, P1 and P4, P2 and P3, and P3 and P4. In contrast, the differences between P1 and P3 and between P2 and P4 were not significant. These results indicate that the significant overall difference in protein content was not observed in every pair of treatments.

The protein content of fermented fish products can vary according to the fish species and processing conditions used. Narzary *et al*. (2021) reported considerable variation in the nutritional composition of fermented fish products prepared from different fish species and fermentation methods. This variation indicates that the raw material and processing conditions can contribute to differences in the final protein content of fermented fish products (Narzary *et al*., 2021).

The type of fish used as the raw material can therefore contribute to differences in the measured protein content of fermented products. Surya *et al*. (2024), in their study of Indonesian fermented seafood paste (terasi), reported differences in physicochemical and nutritional characteristics associated with the raw materials and fermentation process. This finding supports the possibility that differences in the fish species used in *lemea* may contribute to the variation in measured protein content among treatments (Surya *et al*., 2024).

Fermentation may also cause changes in fish proteins through microbial and enzymatic activity. Zhao *et al*. (2022) demonstrated that microbial metabolism in fermented grass carp was associated with protein hydrolysis and changes in protein profiles. Such hydrolysis can break proteins into smaller peptides and amino acids during fermentation. However, these changes do not necessarily indicate an increase in total protein content (Zhao *et al*., 2022).

Changes in the protein content of fermented fish products may occur during the fermentation process as a result of biochemical changes in the fish matrix. Koesoemawardani *et al*. (2023) investigated the chemical characteristics of joruk made from wader fish and reported changes in its chemical properties during fermentation. These findings indicate that fermentation can affect the chemical composition of fermented fish products. However, because the present study did not measure changes in protein content at different fermentation stages, the specific mechanism responsible for the differences in measured protein content among the *lemea* treatments cannot be determined directly (Koesoemawardani *et al*., 2023).

The interpretation of the present protein results should therefore focus on the measured total protein values obtained using the Kjeldahl method. Mayta-Apaza *et al*. (2022) demonstrated that fermentation of fish waste can generate different proteolysis products, showing that protein hydrolysis changes the nitrogen-containing compounds present in fermented materials. Because the initial protein content of each fish species, protease activity, peptide concentration, and free amino acid composition were not measured in this study, the specific biochemical mechanism responsible for the differences among treatments cannot be determined directly (Mayta-Apaza *et al*., 2022).

Overall, the protein results demonstrate that fish species were associated with significant differences in the measured protein content of *Lemea*. P4 containing *C. striata* had

the highest measured protein content at 23.98 ± 1.58%, whereas P3 containing *O. mossambicus* had the lowest value at 11.04 ± 0.18%.

Implications For Ethnoscience-Based Chemistry Learning

Lemea provides a culturally meaningful context for explaining chemistry through an observable local practice. Students can identify the traditional process, ask why the product becomes sour, measure pH, discuss the role of microorganisms, and relate protein transformation to taste and texture. (Anzalina *et al*., 2023) showed that local wisdom can be explored as a contextual basis for ethnochemistry learning, reinforcing the idea that community practices can be reconstructed into scientific learning contexts.

The findings also support the development of practical teaching materials. (Elfina Salsabila & Eli Rohaeti, 2024) demonstrated that local wisdom can be integrated into chemistry teaching materials to create contextual learning activities. Similarly, JIPK studies have emphasized contextual learning resources and ethnopedagogical materials. In the *lemea* context, the present results can therefore be translated into a practicum or project activity in which students observe fermentation evidence, measure pH, interpret organoleptic data, compare fish treatments, and connect the results with Rejang local knowledge. The learning design should use the research findings as a context and should not require students to reproduce unsafe or unnecessarily complex food-production and Kjeldahl procedures.

CONCLUSION

This study indicates that freshwater fish species were associated with differences in the organoleptic characteristics and protein content of *lemea*, while pH did not differed significantly under standardized fermentation conditions. *C. striata* produced the highest preference percentages for color, aroma, taste, and texture and the highest measured protein content (23.98%). The pH values remained acidic, ranging from 4.23 to 4.62. These findings provide an ethnoscience-based context for chemistry learning by connecting Rejang local knowledge with fermentation, microorganisms, acidity, protein transformation, and sensory characteristics. Further research should involve a larger sensory panel with retained individual scores and examine microbial communities, organic acids, and biochemical mechanisms during fermentation.

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