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The Quality of Ethnic Fermented Bamboo Shoots (Lemea) From Bengkulu (Indonesia) by Using Different Fermentors

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Abstract

Background: Lemea is a traditional fermented food originating from Bengkulu, Indonesia, and is produced from bamboo shoots and fish. Traditionally, lemea has been fermented using various simple containers, which may affect the fermentation process and the quality of the resulting product. Differences in container materials may influence moisture retention, microbial growth, and sensory characteristics during fermentation.
Aims: This study aimed to determine the effect of different fermentation vessels on the physicochemical, microbiological, and sensory characteristics of lemea.
Methods: An experimental study was conducted using a Completely Randomized Design (CRD) consisting of five fermentation vessel treatments: glass jar, plastic jar, bamboo container, food-grade polypropylene (PP) plastic container, and Tupperware container. Each treatment consisted of bamboo shoots (*Dendrocalamus asper*) and tilapia fish (*Oreochromis mossambicus*) at a ratio of 2:1. The fermented products were analyzed based on moisture content, bacterial count, and sensory characteristics, including aroma, texture, and color.
Results: The results showed that the type of fermentation vessel affected the quality characteristics of lemea. The highest moisture content was observed in the Tupperware treatment (40.54%), while the lowest was recorded in the plastic jar treatment (38.74%). The highest bacterial count was found in the glass jar treatment (7.0×10^5 CFU/mL), whereas the lowest bacterial count was observed in the Tupperware treatment (1.1×10^5 CFU/mL). Sensory evaluation showed that lemea fermented in the bamboo container received the highest preference scores for aroma and texture, while the plastic jar treatment received the highest preference score for color.
Conclusion: The type of fermentation vessel influences the physicochemical, microbiological, and sensory characteristics of lemea. The findings demonstrate that fermentation vessel selection is an important factor in maintaining and improving the quality of traditional lemea products.

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INTRODUCTION

Traditional fermented foods and beverages play a crucial role in food resilience and human health across various cultures (Anyogu et al., 2021). These foods enhance nutritional content, digestibility, and microbial stability while providing food security, particularly in underdeveloped regions (Hariyadi, 2024). Fermentation, one of the oldest food preservation techniques, extends shelf life and improves organoleptic properties (Assan et al., 2026; Samantaray & Saha, 2026). Studies have shown that consuming traditional fermented foods is associated with numerous health benefits, including weight maintenance, reduced cardiovascular disease risk, improved glucose and lipid levels, and enhanced immune function (Gänzle et al., 2023; Zannou et al., 2023). Traditional and local knowledge in food practices contributes to food resilience, defined as the capacity of a food system to provide sufficient, appropriate, and accessible food in the face of disturbances (Marco et al., 2021; Materia et al., 2021). While traditional fermented foods offer significant potential for industrial growth, there is a need to improve ingredient quality and integrate food safety management systems (Ilıkkan et al., 2025).

Lemea is a traditional fermented food of the Rejang tribe in Bengkulu, Indonesia, made from bamboo shoots and fish (Kumar et al., 2022). The fermentation process is spontaneous and involves lactic acid bacteria, primarily Lactobacillus species (Deka et al., 2021). Different bamboo species yield different bacterial strains, with *L. fermentum* found in yellow bamboo and *L. plantarum* in both yellow and betung bamboo. Lemea production has been studied to improve quality through modifications like blanching and container selection (Goyal et al., 2024; Siddiqui et al., 2023). Beyond these process optimizations, researchers have successfully isolated probiotic-potential strains such as *Lactobacillus rossiae* LS6, which exhibit notable resilience to acidic environments and thermal stress (Aini & Mustakim, 2025; Utama et al., 2023).

Fermentation is a complex process influenced by various factors that affect the quality of fermented foods (Canoy et al., 2023; Marco et al., 2021). These factors include incubation time, pH, and microbial activity (Gabriele et al., 2026; Kalaiselvan et al., 2025). The fermentation process can enhance the nutritional and biochemical qualities of foods, leading to increased antioxidant activity, improved organoleptic properties, and reduced anti-nutrient levels (Sharma et al., 2020; Siddiqui et al., 2023). However, maintaining consistency and quality in small-scale fermentation processes remains challenging. Upgrading these technologies while preserving product authenticity is crucial (Gabriele et al., 2026). The use of fermentor has shown promise in improving production efficiency and quality control (Khan et al., 2025; Niyigaba et al., 2025). Additionally, the implementation of a consortium-based approach facilitates the necessary collaboration between industrial practitioners and scientists to refine traditional techniques without sacrificing unique regional characteristics (Muhammad, 2024; Suhaera et al., 2026).

A fermenter is a container for the growth of microorganisms whose conditions are regulated to prevent contamination and allow microorganisms to produce the desired product to the maximum. At the household level, Bengkulu residents use a variety of simple containers as traditional food fermenters, such as plastic jars, glass jars, and bamboo. This study was conducted to determine the effect of different fermenters on the quality of the resulting lemea.

METHOD

This study employed an experimental design using a Completely Randomized Design (CRD) with five treatments and five replicates. The treatments differed in the type of container used for the fermentation of bamboo shoots and tilapis (*Oreochromis mossambicus)*, as follows:

1. P1: Glass jar containing 80 g of bamboo shoots and 40 g of tilapia.
2. P2: Plastic jar containing 80 g of bamboo shoots and 40 g of tilapia.
3. P3: Bamboo container containing 80 g of bamboo shoots and 40 g of tilapia.
4. P4: Food-grade polypropylene (PP) plastic container containing 80 g of bamboo shoots and 40 g of tilapia.
5. P5**:** Tupperware container containing 80 g of bamboo shoots and 40 g of tilapia.

a. Preparation of Bamboo Shoot and Fish Materials

The raw materials used for *lemea* fermentation consisted of bamboo shoots (*Dendrocalamus asper*) and tilapia (*Oreochromis mossambicus*). The bamboo shoots were harvested from bamboo plants using a machete and collected in a clean container. The fish were cleaned and prepared prior to fermentation. The bamboo shoots and fish were used at a ratio of 2:1 (w/w).

b. *Lemea* Fermentation Experiment

The bamboo shoots were thoroughly washed and mixed with the cleaned Mozambique tilapia and an adequate amount of clean water. The mixture was then transferred into five different types of fermentation vessels: glass jars, plastic jars, bamboo containers, food-grade polypropylene (PP) plastic containers, and Tupperware containers. Each vessel was tightly sealed and incubated under controlled conditions for 3 days.

c. Determination of *Lemea* Moisture Content

The moisture content of the wet *lemea* was determined using the oven-drying method. A sample of wet *lemea* was weighed and dried in an oven at 105°C for 18–24 h. The dried sample was then cooled in a desiccator and weighed. The drying, cooling, and weighing steps were repeated until a constant weight was obtained. Moisture content was calculated based on the loss in sample mass following drying at 105°C.

d. Determination of *Lemea* pH

The pH of the *lemea* samples was measured using a calibrated pH meter. A 5-g sample of *lemea* was homogenized with 5 mL of distilled water. The pH electrode was then immersed in the resulting suspension, and the pH value was recorded once a stable reading was obtained.

e. Observation of Bacterial Colony Morphology

The macroscopic morphology of bacterial colonies was observed directly on agar media. The observed characteristics included colony color, shape, margin, surface, and elevation, following the criteria described (Pintavirooj et al., 2026).

f. Microbial Enumeration

The total bacterial count was determined using the serial dilution plate count method. Briefly, 20 g of homogenized *lemea* was aseptically transferred into 180 mL of sterile distilled water and homogenized thoroughly. Serial dilutions were then prepared from the homogenized sample. A 1-mL aliquot from the appropriate dilution was aseptically transferred into a sterile Petri dish, followed by the addition of 10 mL of sterile nutrient agar. The inoculum and medium were mixed thoroughly to ensure even distribution of the sample. The plates were incubated at 35°C for 48 h. After incubation, bacterial colonies were counted, and the microbial population was expressed as colony-forming units (CFU) per gram of sample.

g. Organoleptic Test

A sensory evaluation of *lemea* was conducted using a scoring method, in which higher scores indicated greater preference or better sensory quality. The sensory attributes evaluated included texture, color, and aroma. Panelists assessed each attribute using a predetermined rating scale and provided their individual evaluations of the *lemea* samples.

RESULTS AND DISCUSSION

Result:

The pH values of *lemea* fermented in five different types of vessels glass jars, plastic jars, bamboo containers, food-grade polypropylene (PP) containers, and Tupperware containers are presented in Table 1.

Table 1. Effect of Fermentation Vessel on the pH of *Lemea*

Treatment	pH
Glass jar	4
Plastic jar	4,2
Bamboo	4,2
Food-grade polypropylene (PP) containers	4
Tupperware container	4

The pH values of *lemea* fermented in the five different vessels were relatively similar, ranging from 4.0 to 4.2. This pH range is considered favorable for the fermentation process. The optimal acidity range for fermentation is approximately pH 4–5, whereas fermentation activity may decrease at pH values below 3. The decrease in *lemea* pH can be attributed primarily to the metabolic activity of lactic acid bacteria (LAB), which produce lactic acid as a major end product of carbohydrate metabolism. The accumulation of organic acids consequently lowers the pH of the fermented product. (Ibrahim et al., 2021) reported that an increase in the population of LAB is associated with greater utilization of fermentable sugars and increased organic acid production. Therefore, the greater the availability of metabolizable sugars, the greater the production of organic acids and the subsequent reduction in pH.

The moisture content of *lemea* also varied among the fermentation vessels. The highest mean moisture content was observed in the Tupperware container (P5), at 40.54%, whereas the lowest was recorded in the plastic jar (P2), at 38.74%. Statistical analysis indicated that the moisture content of *lemea* fermented in the Tupperware container did not differ significantly from that fermented in the food-grade polypropylene (PP) container. However, it differed highly significantly from the values obtained for the glass jar, bamboo container, and plastic jar treatments (Table 2).

Table 1. Effect of Fermentation Vessel on the Water Content of *Lemea*

Treatment	Water content
Tupperware container (P5)	40,54a
Food-grade polypropylene (PP) containers (P4)	38,99ab
Glass jar (P1)	38,84b
Bamboo (P3)	38,80b
Plastic jar (P2)	38,74b

The highest mean moisture content was observed in *lemea* fermented in the Tupperware container (P5), with a value of 40.54%. Tupperware is made of high-density polyethylene (HDPE), a material characterized by relatively high strength, hardness, and opacity, as well as good thermal resistance, making it suitable for freezer storage at temperatures as low as −50°C (Oliveira et al., 2020). The relatively high moisture content observed in P5 may be associated with the moisture barrier properties of the container. During fermentation, water can be lost through evaporation, which involves the transfer of water molecules from the liquid phase to the vapor phase (Suri et al., 2025). This mass transfer process is significantly influenced by the surrounding environmental conditions and the physical configuration of the storage system (Shrivastava et al., 2023). The relatively low permeability of HDPE to water vapor may limit moisture transfer between the *lemea* and the surrounding environment, thereby reducing evaporative water loss and contributing to the retention of moisture within the product.

This finding is consistent with (Giovani et al., 2024), who reported that a lower water vapor transmission rate (WVTR) of packaging materials limits the transfer of water vapor through the packaging. Therefore, packaging with low water vapor permeability can reduce moisture exchange between the product and its surroundings, resulting in greater moisture retention (Feng et al., 2025). In contrast, the lowest mean moisture content was observed in *lemea* fermented in the plastic jar (P2), at 38.74%. This result may be related to the relative humidity (RH) inside the container and the thickness and permeability of the plastic material. Thinner plastic packaging generally exhibits greater water vapor permeability, allowing water vapor to escape more readily and consequently increasing moisture loss from the product (Hosseini et al., 2020). Thus, the greater permeability of the plastic jar may have facilitated water vapor transfer and contributed to the lower moisture content observed in P2.

The bacterial colony counts obtained using the spread plate method are presented in Table 3.

Table 3. Bacterial Counts of *Lemea* Fermented in Different Types of Fermentation Vessels

(CFU/ml)	Bacterial Count (CFU/mL)
Tupperware container (P5)	1,1 x 10^5
Plastic jar (P2)	1,5 x 10^5
Bamboo (P3)	1,8 x 10^5
Food-grade polypropylene (PP) containers (P4)	5,2 x 10^5
Glass jar (P1)	7,0 x 10^5

The highest bacterial count, 7.0 × 10^5 CFU/mL, was observed in the glass jar treatment (P1), whereas the lowest count, 1.1 × 10^5 CFU/mL, was recorded in the Tupperware container treatment

(P5). The lower bacterial count observed in P5 may be associated with the limited availability of oxygen within the tightly sealed container. Oxygen availability is one of several environmental factors that can influence microbial growth in fermented foods, along with pH, nutrient availability, and storage and processing temperatures (In et al., 2026).

Macroscopic examination of bacterial colonies isolated from the fermented *lemea* revealed small, punctiform, white colonies with undulate margins and flat elevations. Gram staining further indicated that the isolates were Gram-positive, rod-shaped bacteria

The bacterial colonies exhibited yellowish-white coloration, regular undulate margins, flat elevation, and a regular colony shape. Gram staining indicated that the isolates were Gram-positive bacteria. Previous research on *lemea* fermentation by (Kurnia et al., 2020) identified lactic acid bacteria (LAB), particularly *Leuconostoc*, which are Gram-positive, non-motile, non-spore-forming cocci that typically occur in pairs or short chains. Based on the colony morphology and Gram-staining characteristics observed in the present study, the isolates were presumptively identified as LAB. This preliminary identification is consistent with the characteristics reported by (Sam et al., 2024), who described LAB colonies as white, opaque, and convex, with colony sizes of approximately 2–3 mm. LAB play an important role in fermentation by metabolizing fermentable substrates and producing lactic acid and other organic acids as metabolic products.

An organoleptic evaluation was conducted with 15 panelists to assess the color, aroma, and texture of the fermented *lemea*. The mean scores obtained for each sensory attribute are presented in Table 4.

Table 4. Sensory Evaluation Results for *Lemea*

Sensory Evaluation	Scoring	
	Most Preferred	**Least Preferred**
Color	Bamboo	Tupperware container
Aroma	Plastic jar	Tupperware container
Texture	Bamboo	Plastik PP foodgrade

Based on the results presented in Table 4, the highest color preference score was recorded for *lemea* fermented in the bamboo container, with a mean score of 55, whereas the lowest score was observed for the Tupperware container, with a mean score of 41. For aroma, the plastic jar treatment received the highest mean score (50), while the Tupperware treatment received the lowest score (33). In terms of texture, *lemea* fermented in the bamboo container received the highest mean score (56), whereas the food-grade polypropylene (PP) container received the lowest score (37).

Discussion:

Overall, the mean sensory scores indicated that *lemea* fermented in the bamboo container and plastic jar received the highest levels of panelist preference across the evaluated sensory attributes. In contrast, the Tupperware and food-grade PP plastic containers generally received lower preference scores. These findings highlight the importance of sensory characteristics in determining consumer acceptance of fermented food products. That even nutritionally valuable and palatable food products may be rejected if their appearance, particularly color, is perceived as unattractive or deviates from the expected characteristics (Rai et al., 2023). Color is an important quality attribute in food products because it strongly influences consumer acceptance, although it is not necessarily directly related to nutritional value, aroma, or other functional properties (Hassoun et al., 2022).

In the present study, *lemea* fermented in the bamboo container exhibited a cloudy-white color. This observation differs from the description reported by (Aziz & Aji, 2024), who noted that consumers in Bengkulu generally expect fermented bamboo shoots and fish (*lemea*) to have a yellowish-white color. Differences in color may be associated with the fermentation conditions, including the type of fermentation vessel and fermentation duration (Ritter et al., 2024). That both fermentation vessel and fermentation duration can influence the rate of fermentation and, consequently, the characteristics of the resulting product (Garrido-Galand et al., 2021). Thus, the selection of an appropriate fermentation vessel may contribute to the development of desirable sensory characteristics in *lemea*.

Aroma is another important determinant of food acceptability. Aroma plays a major role in sensory perception and is an important indicator of food quality (Kaur et al., 2025). In this study, *lemea* fermented in the plastic jar received the highest aroma preference score, which was characterized by a distinct acidic aroma without an excessively pungent odor. This characteristic may have contributed to its higher acceptance among the panelists (Borthakur et al., 2025).

Regarding texture, *lemea* fermented in the bamboo container received the highest preference score. The relatively firm texture may be associated with continued microbial activity during fermentation at room temperature. Temperature is an important factor influencing microbial growth and metabolic activity, which can subsequently affect the physical characteristics of fermented foods (Silande et al., 2025). These characteristics may have contributed to the higher texture preference observed among the panelists (Mefleh et al., 2024).

The findings of this study demonstrate that the type of fermentation vessel can influence the physical, microbiological, and sensory characteristics of *lemea*. Although the pH values remained relatively consistent across the five fermentation vessels, ranging from 4.0 to 4.2, differences in vessel material and design were associated with variations in moisture content, bacterial counts, and sensory acceptance. The Tupperware container treatment resulted in the highest moisture content but the lowest bacterial count, whereas the bamboo container treatment received the highest sensory preference scores for color and texture. In contrast, the glass jar treatment exhibited the highest bacterial count, suggesting more favorable conditions for bacterial growth under the experimental conditions. These findings indicate that the selection of a fermentation vessel should consider the intended quality characteristics of the final product and requires a balance between microbiological performance and sensory acceptance.

This study contributes empirical evidence on the relationship between fermentation vessel characteristics and the quality of *lemea*, providing useful information for traditional *lemea* producers when selecting fermentation vessels according to specific product-quality objectives. The findings also contribute to the growing body of knowledge on the role of packaging and vessel materials in traditional food fermentation. Furthermore, the results may provide a basis for developing alternative fermentation vessels that combine the sensory advantages associated with bamboo containers with the favorable microbiological characteristics observed in glass jars.

Several limitations should be considered when interpreting these findings. First, only five types of fermentation vessels were evaluated, and other materials, structural designs, and vessel capacities may produce different outcomes. Second, pH measurements were performed using pH paper, which provides lower measurement accuracy and resolution than a calibrated digital pH meter. Third, the sensory evaluation involved only 15 panelists, limiting the generalizability of the findings to a broader consumer population. Finally, environmental conditions, particularly fermentation temperature and relative humidity, were not strictly controlled, which may have introduced variability that could not be attributed solely to the type of fermentation vessel.

Future studies should employ more precise analytical instruments, including calibrated digital pH meters and moisture analyzers, and evaluate a broader range of fermentation vessel materials and designs. Increasing the number and diversity of sensory panelists would also improve the representativeness and generalizability of sensory evaluations. In addition, strict control and monitoring of fermentation conditions, including temperature, relative humidity, and fermentation duration, are recommended to better isolate the effects of fermentation vessel characteristics. Further characterization of the fermented product, including protein content, lactic acid concentration, and volatile compounds, would provide a more comprehensive understanding of how fermentation vessel characteristics affect the physicochemical, microbiological, and sensory quality of *lemea*.

Implications:

The findings provide practical implications for traditional lemea producers by showing that fermentation-vessel selection can be considered according to specific product-quality objectives. The differences in moisture retention, bacterial counts, and sensory acceptance indicate that vessel characteristics may be relevant when producers seek to maintain or improve particular quality attributes.

Research Contributions:

This study contributes empirical evidence on the relationship between fermentation-vessel characteristics and lemea quality. It adds to knowledge on the role of packaging and vessel materials in traditional food fermentation and provides a basis for considering alternative fermentation vessels that combine desirable sensory characteristics associated with bamboo containers with favorable microbiological characteristics observed in other vessels.

Limitations:

Several limitations should be considered. First, only five types of fermentation vessels were evaluated, and other materials, structural designs, and vessel capacities may produce different outcomes. Second, pH measurements were performed using pH paper, which provides lower measurement accuracy and resolution than a calibrated digital pH meter. Third, the sensory evaluation involved only 15 panelists, limiting generalizability to a broader consumer population. Finally, environmental conditions, particularly fermentation temperature and relative humidity, were not strictly controlled, which may have introduced variability that could not be attributed solely to the type of fermentation vessel.

Suggestions:

Future studies should employ more precise analytical instruments, including calibrated digital pH meters and moisture analyzers, and evaluate a broader range of fermentation-vessel materials and designs. Increasing the number and diversity of sensory panelists would improve the representativeness and generalizability of sensory evaluations. Strict control and monitoring of fermentation conditions, including temperature, relative humidity, and fermentation duration, are also recommended to better isolate the effects of vessel characteristics. Further characterization of the fermented product, including protein content, lactic acid concentration, and volatile compounds, would provide a more comprehensive understanding of how fermentation-vessel characteristics affect the physicochemical, microbiological, and sensory quality of lemea.

CONCLUSION

The type of fermentation vessel significantly affected the moisture content of *lemea*. The highest moisture content was observed in the Tupperware container (40.54%), whereas the lowest was recorded in the plastic jar (38.74%). The highest bacterial count was observed in the glass jar treatment (7.0×10^5 CFU/mL), while the lowest was recorded in the Tupperware treatment (1.1×10^5 CFU/mL). Sensory evaluation showed that *lemea* fermented in the bamboo container received the highest preference score for aroma and texture, whereas the plastic jar treatment received the highest preference score for color.

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AUTHOR CONTRIBUTION STATEMENT

All authors contributed to the development and completion of this study. The authors were involved in the conceptualization and design of the research, preparation and implementation of the fermentation experiment, collection and analysis of data, interpretation of the results, and preparation and revision of the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

REFERENCES

Aini, N. F., & Mustakim, A. (2025). Isolasi dan Identifikasi Bakteri Asam dari Rebung Fermentasi Tradisional dari Desa Panti. *Konstanta Jurnal Matematika Dan Ilmu Pengetahuan Alam*, *3*(3), 35–44. https://doi.org/10.59581/konstanta.v3i3.5409

Anyogu, A., Olukorede, A., Anumudu, C., Onyeaka, H., Areo, E., Adewale, O., Odimba, J. N., & Nwaiwu, O. (2021). Microorganisms and food safety risks associated with indigenous fermented foods from Africa. *Food Control*, *129*, 108227. https://doi.org/10.1016/j.foodcont.2021.108227

Assan, N., Marufu, H., Mapiliyao, L., & Mvumi, C. (2026). Beyond Technology: Gender and Indigenous Knowledge Systems as Foundations of Sustainable Food Innovation in Sub-Saharan Africa. *Global Multidisciplinary Perspectives Journal*, *3*(3), 33–41. https://doi.org/10.54660/gmpj.2026.3.3.33-41

Aziz, A., & Aji, O. R. (2024). Effect of An Additional Amount of Fish and Fermentation Time on The Sensory Properties of The Lemea. *Journal of Biotechnology and Natural Science*, *3*(1), 9–14. https://doi.org/10.12928/jbns.v3i1.8261

Borthakur, D. N., Sharma, B. K., & Upadhye, V. J. (2025). Probiotic and aroma-producing Bacillus sp. isolates from teles, a traditional fermented fish from Assam, India: functional characterisation and potential application in fermented foods. *BMC Microbiology*, *25*(1), 579. https://doi.org/10.1186/s12866-025-04312-w

Canoy, T. S., Wiedenbein, E. S., Bredie, W. L. P., Meyer, A. S., Wösten, H. A. B., & Nielsen, D. S. (2023). Solid-State Fermented Plant Foods as New Protein Sources. *Annual Review of Food Science and Technology*, *15*(1), 189–210. https://doi.org/10.1146/annurev-food-060721-013526

Deka, P., Mehetre, G. T., Lalnunmawii, E., Upadhyaya, K., Singh, G., Hashem, A., Al-Arjani, A.-B. F., Allah, E. F. A., & Singh, B. P. (2021). Metagenomic Analysis of Bacterial Diversity in Traditional Fermented Foods Reveals Food-Specific Dominance of Specific Bacterial Taxa. *Fermentation*, *7*(3), 167. https://doi.org/10.3390/fermentation7030167

Feng, N., Zhang, J., Tian, J., Zhang, Y., Li, M., Guo, X., Han, Q., Wang, Y., Gao, A., Wang, Y., Yan, L., Kong, J., & Yang, P. (2025). Preserving fruit freshness with amyloid-like protein coatings. *Nature Communications*, *16*(1), 5060. https://doi.org/10.1038/s41467-025-60382-4

Gabriele, M., Fabbri, L. P., Ventimiglia, M., & Łepecka, A. (2026). From Waste to Worth: The Role of Fermentation in a Sustainable Future. *Foods*, *15*(4), 664. https://doi.org/10.3390/foods15040664

Gänzle, M. G., Monnin, L., Zheng, J., Zhang, L., Coton, M., Sicard, D., & Walter, J. (2023). Starter Culture Development and Innovation for Novel Fermented Foods. *SPIRE - Sciences Po Institutional REpository*, *15*(1), 211–239. https://doi.org/10.1146/annurev-food-072023-034207

Garrido-Galand, S., Asensio-Grau, A., Calvo-Lerma, J., Heredia, A., & Andrés, A. (2021). The potential of fermentation on nutritional and technological improvement of cereal and legume flours: A review. *Food Research International*, *145*, 110398. https://doi.org/10.1016/j.foodres.2021.110398

Giovani, S., Oktafiani, Z. I., Komalasari, E., & Setiyoko, A. (2024). The Effect of Packaging Type and Storage Time on the Quality Characteristics of Chicken Nugget with Jack Bean (Canavalia ensiformis L.) Tempeh Flour Substitution. *Journal of Applied Food Technology*, *11*(1), 32–42. https://doi.org/10.17728/jaft.22983

Goyal, A. K., Usha, T., Kalita, M., Hemavathi, K. N., Hemalatha, P., Mushahary, S., Brahma, P., Middha, S. K., Dey, S. K., Basumatary, J., & Shah, A. (2024). Tradition meets technology: An overview of fermented bamboo shoots. *Advances in Bamboo Science*, *7*, 100078. https://doi.org/10.1016/j.bamboo.2024.100078

Hariyadi, P. (2024). Sustainability of Food Systems: The Role of Food Technology and Regulatory Science. *BIO Web of Conferences*, *98*, 3003. https://doi.org/10.1051/bioconf/20249803003

Hassoun, A., Jagtap, S., Garcia-Garcia, G., Trollman, H., Pateiro, M., Lorenzo, J. M., Trif, M., Rusu, A., Aadil, R. M., Šimat, V., Cropotova, J., & Câmara, J. S. (2022). Food quality 4.0: From traditional approaches to digitalized automated analysis. *Journal of Food Engineering*, *337*, 111216. https://doi.org/10.1016/j.jfoodeng.2022.111216

Hosseini, S. F., Ghaderi, J., & Gómez-Guillén, M. C. (2020). trans-Cinnamaldehyde-doped quadripartite biopolymeric films: Rheological behavior of film-forming solutions and biofunctional performance of films. *Food Hydrocolloids*, *112*, 106339. https://doi.org/10.1016/j.foodhyd.2020.106339
Ibrahim, S. A., Ayivi, R. D., Zimmerman, T., Siddiqui, S. A., Altemimi, A. B., Fidan, H., Esatbeyoglu, T., & Bakhshayesh, R. V. (2021). Lactic Acid Bacteria as Antimicrobial Agents: Food Safety and Microbial Food Spoilage Prevention. *Foods*, *10*(12), 3131. https://doi.org/10.3390/foods10123131
Ilıkkan, Ö. K., Bağdat, E. Ş., Yılmaz, R., Çetin, B., Çon, A. H., Erten, H., Göksungur, Y., & Şimşek, Ö. (2025). Bridging Tradition and Innovation: A Systematic Review and Bibliometric Analysis of Turkish Fermented Foods. *Foods*, *14*(24), 4324. https://doi.org/10.3390/foods14244324
In, S., Srun, S., Mey, K., Rithy, L., & Va, M. (2026). Factors influencing fermentation efficiency and product quality: A comprehensive review. *Zenodo (CERN European Organization for Nuclear Research)*. https://doi.org/10.5281/zenodo.17970975
Kalaiselvan, P., Devi, N. C., Deepti, M., Devi, A. A., Akamad, K., Dheeran, P., Debbarma, S., Vadivel, D., & Vekariya, R. D. (2025). Solid-state fermentation—a sustainable future technology in aquafeeds? *Frontiers in Marine Science*, *12*. https://doi.org/10.3389/fmars.2025.1669719
Kaur, M., Gray, C., & Barringer, S. A. (2025). Controlling Off-Odors in Plant Proteins Using Sequential Fermentation. *Foods*, *15*(1), 39. https://doi.org/10.3390/foods15010039
Khan, R., Ghazali, F. M., & Mahyudin, N. A. (2025). Advancing the extraction of bioactive compound from fruit by-products through solid-state fermentation: A review. *Journal of Food Nutrition and Diet Science*, 37–52. https://doi.org/10.55976/fnds.32025134237-52
Kumar, V., Naik, B., Sharma, S., Kumar, A., Khan, J. M., & Irfan, M. (2022). Molecular Diversity of Microbes Associated with Fermented Bamboo Shoots. *Tropical Life Sciences Research*, *33*(3), 151–164. https://doi.org/10.21315/tlsr2022.33.3.9
Kurnia, M., Amir, H., & Handayani, D. (2020). ISOLASI DAN IDENTIFIKASI BAKTERI ASAM LAKTAT DARI MAKANAN TRADISIONAL SUKU REJANG DI PROVINSI BENGKULU: “LEMEA.” *Alotrop/Alotrop: Jurnal Pendidikan Dan Ilmu Kimia*, *4*(1). https://doi.org/10.33369/atp.v4i1.13705
Marco, M. L., Sanders, M. E., Gänzle, M. G., Arrieta, M., Cotter, P. D., Vuyst, L. De, Hill, C., Holzapfel, W. H., Lebeer, S., Merenstein, D., Reid, G., Wolfe, B. E., & Hutkins, R. W. (2021). The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on fermented foods. *Nature Reviews Gastroenterology & Hepatology*, *18*(3), 196–208. https://doi.org/10.1038/s41575-020-00390-5
Materia, V. C., Linnemann, A. R., Smid, E. J., & Schoustra, S. E. (2021). Contribution of traditional fermented foods to food systems transformation: value addition and inclusive entrepreneurship. *Food Security*, *13*(5), 1163–1177. https://doi.org/10.1007/s12571-021-01185-5
Mefleh, M., Omri, G., Limongelli, R., Minervini, F., Santamaría, M., & Faccia, M. (2024). Enhancing nutritional and sensory properties of plant-based beverages: a study on chickpea and Kamut® flours fermentation using Lactococcus lactis. *Frontiers in Nutrition*, *11*, 1269154. https://doi.org/10.3389/fnut.2024.1269154
Muhammad, M. S. (2024). Food Fermentation: Traditional Practices and Modern Applications in Food Industry. *International Journal of Food and Fermentation Technology*, *14*(1). https://doi.org/10.30954/2277-9396.01.2024.1
Niyigaba, T., Küçükgöz, K., Kołożyn-Krajewska, D., Królikowski, T., & Trząskowska, M. (2025). Advances in Fermentation Technology: A Focus on Health and Safety. *Applied Sciences*, *15*(6), 3001. https://doi.org/10.3390/app15063001
Oliveira, J., Belchior, A., Silva, V. D. da, Rotter, A., Petrovski, Ž., Almeida, P. L., Lourenço, N. D., & Gaudêncio, S. P. (2020). Marine Environmental Plastic Pollution: Mitigation by Microorganism Degradation and Recycling Valorization. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.567126
Pintavirooj, C., Bunkum, M., Vongmanee, N., Nampeng, J., & Visitsattapongse, S. (2026). Bacterial Colony Counting and Classification System Based on Deep Learning Model. *Applied Sciences*, *16*(3), 1313. https://doi.org/10.3390/app16031313

Rai, S., Wai, P. P., Koirala, P., Bromage, S., Nirmal, N. P., Pandiselvam, R., Nor-Khaizura, M. A. R., & Mehta, N. K. (2023). Food product quality, environmental and personal characteristics affecting consumer perception toward food. *Frontiers in Sustainable Food Systems*, *7*. https://doi.org/10.3389/fsufs.2023.1222760

Ritter, S. W., Thiel, Q. P., Gastl, M., & Becker, T. (2024). Optimizing the fermentation parameters in the Lactic Acid Fermentation of Legume-based Beverages– a statistically based fermentation. *Microbial Cell Factories*, *23*(1), 253. https://doi.org/10.1186/s12934-024-02522-x

Sam, M. K. V., Jawan, R., & Chong, K. P. (2024). Characterization and Identification of Potential Lactic Acid Bacteria as Biological Control Agent against Ralstonia syzygii subsp. celebesensis of the Banana Blood Disease. *Journal of Pure and Applied Microbiology*, *18*(3), 1883–1893. https://doi.org/10.22207/jpam.18.3.38

Samantaray, P., & Saha, S. (2026). Decoding the Microbial Diversity of Indian Fermented Foods: Integrating Ethnobiology, Multi-Omics and Functional Insights. *Foods*, *15*(4), 687. https://doi.org/10.3390/foods15040687

Sharma, R., Garg, P., Kumar, P., Bhatia, S. K., & Kulshrestha, S. (2020). Microbial Fermentation and Its Role in Quality Improvement of Fermented Foods. *Fermentation*, *6*(4), 106. https://doi.org/10.3390/fermentation6040106

Shrivastava, C., Schudel, S., Shoji, K., Onwude, D., Silva, F. P. da, Turan, D., Paillart, M. J. M., & Defraeye, T. (2023). Digital twins for selecting the optimal ventilated strawberry packaging based on the unique hygrothermal conditions of a shipment from farm to retailer. *Postharvest Biology and Technology*, *199*, 112283. https://doi.org/10.1016/j.postharvbio.2023.112283

Siddiqui, S. A., Erol, Z., Rugji, J., Taşçı, F., Kahraman, H. A., Toppi, V., Musa, L., Giacinto, G. Di, Bahmid, N. A., Mehdizadeh, M., & Castro-Muñoz, R. (2023). An overview of fermentation in the food industry - looking back from a new perspective. *Bioresources and Bioprocessing*, *10*(1), 85. https://doi.org/10.1186/s40643-023-00702-y

Silande, C., Hickisch, A., Strube, A., Daniel, N., Maillard, M.-B., Chevalier, S., Henry, G., Aguiló-Aguayo, I., Jan, G., & Gagnaire, V. (2025). Mixing and fermenting chickpea and almond milk analogues to produce probiotic yoghurt analogues. *SPIRE - Sciences Po Institutional REpository*, *221*, 117576. https://doi.org/10.1016/j.foodres.2025.117576

Suhaera, S., Sammulia, S., Prayoga, D., Ramadhania, Z. M., Mita, S., Fristiohady, A., & Milanda, T. (2026). Fermented Plant-Derived Phytoconstituents in Biocosmetics: Pharmacological Enhancements and Applications. *Clinical Cosmetic and Investigational Dermatology*, 1–19. https://doi.org/10.2147/ccid.s602919

Suri, W. I., Ratnawati, B., Tunggadewi, A. T., Dellarosa, L., Hidiya, M., Prasetya, D. A., Paramitadevi, Y. V., Wahdi, E. W., Saputra, S. F. D., Jannah, N., Kartini, S. A., & Afigi, N. (2025). Eco-Enzyme Production from Household Organic Waste for Natural Cleaning Solutions. *Riwayat: Educational Journal of History and Humanities*. https://doi.org/10.24815/jr.v8i4.50660

Utama, R. S., Fajri, P. Y., Agustina, A., & Antonio, J. (2023). Lemea, The Rejang Tribe'S Traditional Food Made From Fermented Bamboo Shoots (Review). *AGRITEPA Jurnal Ilmu Dan Teknologi Pertanian*, *10*(1), 153–164. https://doi.org/10.37676/agritepa.v10i1.3836

Zannou, O., Chabı, I. B., Kpoclou, Y. E., Kayodé, A. P. P., Galanakis, C. M., & Selli, S. (2023). Traditional fermented foods of Benin Republic: microbiological safety and health benefits. *Discover Food*, *3*(1). https://doi.org/10.1007/s44187-023-00043-x