

Innovation of Tepache Fermented Beverage Made from Pineapple Peel Waste

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ABSTRACT

This study aims to develop an innovative tepache fermented beverage made from pineapple peel waste and to analyze its product characteristics and potential utilization as an economically valuable and environmentally friendly product. This study employed an experimental method with a simple Research and Development (R&D) approach. The research stages included raw material preparation, fermentation process, product packaging, and product evaluation. Data were collected through observation, documentation, and organoleptic testing covering color, aroma, taste, and consumer acceptance. The collected data were analyzed descriptively to determine the quality of the resulting product. The findings indicate that pineapple peel waste can be processed into a tepache fermented beverage through a simple and easily applicable method. The resulting product exhibits an attractive reddish-brown color, a distinctive pineapple fermentation aroma, and a refreshing sweet-sour taste, receiving positive responses from consumers. The utilization of pineapple peel waste as a raw material for tepache demonstrates significant economic potential due to its low production costs and promising market opportunities. Furthermore, this innovation contributes to reducing organic waste and supports the concepts of waste-to-value and the circular economy as efforts toward sustainable environmental management.

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1. INTRODUCTION

Indonesia is an agrarian country with significant potential in the horticultural sector, particularly in pineapple production. The high annual production of pineapples makes this fruit one of the leading commodities widely consumed by the public and processed into various food products. However, the increasing consumption and processing of pineapples also generate large quantities of organic waste, especially pineapple peels (Juwita et al., 2025). Generally, pineapple peels are discarded as waste or

utilized only to a limited extent as animal feed and compost. As a result, the economic potential and nutritional value contained in pineapple peels remain underutilized. In fact, pineapple peels contain various beneficial compounds, including fiber, vitamins, minerals, and naturally occurring microorganisms that have potential applications in food fermentation processes.

The issue of organic waste has become one of the environmental concerns receiving serious attention worldwide. The increasing volume of improperly managed organic waste can lead to various negative impacts, such as environmental pollution, unpleasant odors, and increased greenhouse gas emissions resulting from decomposition processes (Pratiwi et al., 2024). Pineapple peel waste is one of the most common types of organic waste found in traditional markets, household industries, and fruit-processing industries. If not properly utilized, this waste merely adds to the volume of waste that must be managed (Hujjatusnaini et al., 2022).

Along with the growing public awareness of healthy lifestyles, the demand for functional food and beverage products has also increased. Consumers today consider not only the taste and price of a product but also its potential health benefits. One category of products that has gained increasing popularity is fermented beverages. Fermented drinks are known to contain probiotics, enzymes, and bioactive compounds that are beneficial for digestive health and immune system function (Najini et al., 2024). This growing trend in fermented beverage consumption presents substantial opportunities for the development of innovative products based on local, affordable, readily available, and environmentally friendly raw materials.

One fermented beverage that has recently gained wider recognition is tepache. Tepache is a traditional Mexican drink produced through the fermentation of pineapple peels with added sugar and water. This fermentation process results in a beverage with a sweet, slightly acidic, and refreshing flavor profile. In addition to its unique taste, tepache contains fermentation-derived microorganisms that may provide health benefits (Mariani et al., 2026). The primary advantage of tepache lies in its utilization of pineapple peels as the main raw material, thereby reducing waste while simultaneously creating a value-added food product.

The utilization of pineapple peels as the primary ingredient for tepache represents an innovation aligned with the principles of the circular economy, a system that emphasizes the continuous use of resources to prevent them from becoming waste (Devi, 2022). Within this framework, waste is no longer viewed as a useless by-product but rather as a valuable resource that can be transformed into new products with economic and social benefits. Through the conversion of pineapple peel waste into tepache, organic waste can be utilized more productively, reducing environmental burdens while creating new business opportunities for local communities (Savira et al., 2026). This innovation also supports sustainable development efforts by promoting a balance between economic, social, and environmental dimensions.

In Indonesia, the development of fermented beverages derived from pineapple peel waste remains relatively limited compared to other fermented products such as yogurt, kefir, and kombucha (Devi et al., 2024). Despite the abundant availability of pineapple peel waste, particularly in major pineapple-producing regions, its utilization remains low. This situation is largely attributed to the limited public knowledge regarding the potential value of pineapple peels. Most people still perceive pineapple peels merely as waste without economic significance (Renanda et al., 2026). Therefore, innovative

approaches are needed to introduce more productive and beneficial alternatives for utilizing pineapple peel waste.

Beyond its environmental benefits, pineapple peel-based tepache also possesses promising economic potential. The raw materials are inexpensive because they originate from readily available waste products. The low production costs make this beverage suitable for development by micro, small, and medium enterprises (MSMEs), potentially contributing to increased community income. With appropriate packaging and marketing strategies, tepache can become a competitive local fermented beverage product. Furthermore, it has the potential to emerge as an alternative health drink appealing to a wide range of consumers.

From a health perspective, tepache has considerable potential as a functional beverage because it contains various beneficial compounds generated during fermentation. The fermentation process can enhance the bioavailability of certain nutrients, produce organic acids, and support the growth of beneficial microorganisms that help maintain gut microbiota balance. Additionally, the vitamins, minerals, and antioxidants naturally present in pineapple peels may contribute added nutritional value to the final product (Decenly et al., 2023).

The development of pineapple peel-based tepache innovation is also relevant to the fields of education, research, and community engagement. This product can serve as an educational medium for promoting awareness regarding waste management, local resource utilization, and the application of simple fermentation technologies. Through research and development activities, various aspects related to product quality, food safety, nutritional content, and consumer acceptance can be investigated more comprehensively. The findings from such studies can provide a foundation for the future development of improved and sustainable products.

Based on the foregoing discussion, pineapple peel waste possesses substantial untapped potential. Amid increasing concerns regarding organic waste management and growing consumer demand for healthy and environmentally friendly food products, the innovation of tepache fermented beverage made from pineapple peel waste represents a relevant and promising solution. This innovation not only contributes to reducing organic waste but also generates a functional beverage with economic, health, and environmental value. Therefore, further development and research on pineapple peel-based tepache are essential to support sustainable waste management practices and enhance community welfare.

2. LITERATURE REVIEW

2.1 Innovation

Innovation is a process of renewal carried out through the creation, development, or application of new ideas, methods, products, or technologies that provide added value compared to previous conditions. In various fields, innovation serves as an important driver of advances in science, technology, economics, and social life. Innovation does not always involve creating something entirely new; it may also take the form of modification, improvement, or development of existing products and processes to make them more effective, efficient, and beneficial (Rahmah et al., 2025). In the context of food processing, innovation plays a crucial role in developing products that meet community needs while optimizing the utilization of available resources.

According to Rogers (2003) in *Diffusion of Innovations*, innovation is defined as an idea, practice, or object that is perceived as new by an individual or a group. Rogers explained that the success of an innovation is influenced by five main characteristics: relative advantage, compatibility, complexity, trialability, and observability (Jumadi et al., 2024). In this study, tepache produced from pineapple peel waste can be categorized as an innovation because it offers the advantage of transforming waste into a product with economic and health value, while remaining simple to produce and having strong potential for wider development.

In the food sector, innovation is an important strategy for increasing the economic value of raw materials and creating products with high market competitiveness. The utilization of organic waste as value-added products is one form of innovation that supports the concept of sustainable development. The innovation of tepache fermented beverage made from pineapple peel waste represents an application of food innovation because it transforms materials previously considered waste into products with health benefits, economic value, and promising market potential.

2.2 Tepache Fermented Beverage

According to Fardiaz (1992), fermentation is a metabolic process carried out by microorganisms to convert organic compounds, particularly carbohydrates, into simpler substances such as alcohol, organic acids, carbon dioxide, and energy (Nazhifah et al., 2025). Fermentation serves not only as a food preservation method but also as a process that enhances the flavor, aroma, texture, and nutritional value of food products. In tepache production, fermentation plays a key role in developing the beverage's distinctive taste characteristics while enhancing its functional properties.

Tepache is a traditional fermented beverage originating from Mexico (Kurniawati & Mardiyanto, 2025). The fermentation process occurs naturally through microorganisms present on the surface of pineapple peels, including lactic acid bacteria and yeasts. During fermentation, these microorganisms convert sugars into various organic compounds, producing a characteristic flavor profile that combines sweetness, acidity, and slight carbonation. Tepache is widely recognized as a refreshing beverage with nutritional properties beneficial to human health (Hujjatusnaini et al., 2022).

In addition to its unique sensory characteristics, tepache is classified as a functional beverage because it contains fermentation-derived compounds that may provide health benefits. The fermentation process can improve the bioavailability of certain nutrients and promote the growth of beneficial microorganisms that support digestive health. Furthermore, the vitamins, minerals, antioxidants, and enzymes naturally present in its raw materials contribute to the nutritional value of the final product. With the growing consumer interest in healthy and natural food products, tepache has considerable potential to be developed as an environmentally friendly local fermented beverage with high economic value.

2.3 Pineapple Peel Waste

According to Tchobanoglous, Theisen, and Vigil (1993), waste is defined as residual material generated from human activities or natural processes that is no longer used for its original purpose. Effective waste management aims to minimize environmental impacts through the principles of Reduce, Reuse, and Recycle (3R) (Nazhifah et al., 2025). In the context of this study, the utilization of pineapple peels as raw materials for tepache aligns with the principles of reuse and recycle, as organic waste is transformed into a new product with greater utility and economic value.

Pineapple peel waste consists of the by-products generated from pineapple processing or consumption that are generally discarded and underutilized. In the pineapple processing industry, peels account for approximately 30–40% of the total fruit weight, resulting in substantial quantities of waste. If not properly managed, pineapple peel waste can contribute to environmental problems, including pollution, unpleasant odors, and increased volumes of organic waste (Rickodinata & Arianty, 2025).

Although often regarded as waste, pineapple peels contain numerous beneficial compounds, including dietary fiber, vitamin C, minerals, natural sugars, bromelain enzyme, and antioxidant substances. These components make pineapple peels a promising raw material for the development of various food products, including fermented beverages. The utilization of pineapple peel waste as the primary ingredient for tepache represents a form of waste valorization that increases the value of the material, reduces environmental pollution, and supports the principles of the circular economy. Consequently, pineapple peel waste should no longer be viewed merely as discarded material but rather as a valuable resource with significant economic and environmental benefits.

3. METHODS

This study employed an experimental approach using a simplified Research and Development (R&D) method aimed at developing and evaluating an innovative tepache fermented beverage made from pineapple peel waste (Norfajrina, 2025). This method was selected because the research focused not only on theoretical investigation but also on producing a tangible product in the form of a fermented beverage utilizing pineapple peel waste as its primary raw material. Through this approach, researchers were able to identify the potential utilization of pineapple peel waste, formulate the product, conduct the fermentation process, and evaluate the quality of the resulting beverage. The research was carried out through several stages, including problem identification, information gathering, product design, product development, product testing, and evaluation.

The data sources in this study consisted of both primary and secondary data. Primary data were obtained directly from the production process of the tepache fermented beverage, observations conducted during the fermentation process, and organoleptic tests involving respondents who evaluated the product's color, aroma, taste, and overall acceptance. In addition, primary data were collected through measurements of product characteristics, such as fermentation duration, aroma changes, and the quality of the final beverage. Secondary data were obtained from various relevant literature sources, including books, scientific journals, research articles, scientific reports, and other references related to food fermentation, tepache, pineapple peel waste, and waste-based food product innovation (Azizah et al., 2026).

Data collection techniques included observation, documentation, and organoleptic testing. Observation was conducted throughout the production and fermentation processes to monitor changes occurring in the product, such as alterations in color, aroma, and other physical characteristics. Documentation involved collecting photographs, production records, observation notes, and other supporting documents related to the research. Furthermore, organoleptic testing was conducted with a group of panelists to determine consumer preferences regarding the resulting tepache product based on taste, aroma, color, and overall acceptance. These techniques were employed to obtain comprehensive data concerning the quality and feasibility of the developed product.

The research procedure began with the collection of pineapple peel waste that was still suitable for use, followed by a cleaning process to remove adhering impurities. The pineapple peels were then mixed with water and sugar according to the predetermined formulation and placed in a closed fermentation container. Fermentation was carried out at room temperature for several days until a tepache beverage with the desired characteristics was obtained. After the fermentation process was completed, the product was filtered and subjected to organoleptic evaluation to determine its quality and level of consumer acceptance. The results of the evaluation were subsequently analyzed to assess the success of the pineapple peel waste-based tepache beverage innovation.

The data obtained were analyzed using descriptive analysis. Observational data collected during the fermentation process were analyzed descriptively to explain the changes occurring in the product. Data obtained from organoleptic testing were analyzed using percentages and mean scores of panelists' evaluations for each assessed attribute (Zahidatunnisa et al., 2024). The analysis results were then presented in the form of tables and descriptive explanations to provide an overview of product quality, consumer acceptance levels, and the development potential of pineapple peel waste-based tepache fermented beverages as innovative products with economic and environmental value. To ensure data accuracy and credibility, this study employed methodological triangulation by comparing findings from observations, documentation, and organoleptic tests, thereby enhancing the validity and reliability of the collected data.

4. RESULTS

4.1 Production Process of the Innovative Tepache Fermented Beverage from Pineapple Peel Waste

The production process of the innovative tepache fermented beverage from pineapple peel waste began with the identification and selection of raw materials. Pineapple peels were chosen as the primary ingredient because they are an organic waste product that still contains various nutrients, including natural sugars, dietary fiber, vitamin C, minerals, and bromelain enzyme, all of which can support the fermentation process. The utilization of pineapple peels in this study aimed to enhance the value of organic waste while simultaneously reducing the amount of waste generated from pineapple consumption and processing activities. Prior to use, pineapple peels were selected from fresh fruits that showed no signs of spoilage to ensure the quality and safety of the final product.

The next stage involved cleaning the raw materials. The pineapple peels were thoroughly washed under running clean water to remove dirt, dust, and any residues attached to their surfaces. Proper cleaning is essential because the cleanliness of the raw materials significantly influences the success of the fermentation process. After washing, the pineapple peels were cut into smaller pieces to increase the surface area available for interaction with the fermentation medium, thereby facilitating nutrient extraction and enhancing microbial activity during fermentation.

Once the raw materials were prepared, the fermentation solution was formulated by mixing the pineapple peel pieces with clean water and granulated sugar in a fermentation container. Sugar served as the primary energy source for microorganisms throughout the fermentation process. The proportions of the ingredients were adjusted according to the predetermined formulation to achieve a balanced sweetness and acidity in the final product. All ingredients were stirred thoroughly until the sugar dissolved

completely. The fermentation container was cleaned and sterilized beforehand to minimize the risk of contamination by undesirable microorganisms.

Fermentation constituted the core stage in the production of tepache. The mixture of pineapple peels, sugar, and water was fermented at room temperature for approximately 2–5 days in a container covered with a clean cloth or a lid that allowed limited air exchange. During fermentation, naturally occurring microorganisms present on the surface of the pineapple peels metabolized sugars into various compounds, including organic acids, carbon dioxide, and aromatic substances. The activity of these microorganisms resulted in significant changes in the beverage's flavor, aroma, and chemical composition.

Throughout the fermentation period, observations were conducted to monitor changes occurring within the solution. The appearance of small bubbles on the liquid surface served as an indicator of active fermentation. In addition, the characteristic sweet aroma of fresh pineapple gradually transformed into a pleasant, mildly acidic fragrance due to the formation of fermentation-derived compounds. The color of the solution also became darker and more concentrated compared to its initial appearance. These observations were essential to ensure that the fermentation process proceeded properly and produced a beverage that was safe for consumption.

After the fermentation process was completed, the tepache solution was filtered using a fine strainer to separate the pineapple peel residues from the fermented liquid. The filtration process aimed to produce a clearer beverage with a more appealing texture and improved consumer acceptability. The filtered liquid could then be consumed immediately or stored in sealed bottles to maintain product quality. At this stage, the beverage exhibited its characteristic attributes, including a reddish-brown color, a fresh fermented aroma, and a refreshing combination of sweet and sour flavors.

The final stage involved packaging the tepache beverage in clean and hygienic bottles. Packaging was carried out to preserve product quality, extend shelf life, and enhance the aesthetic value of the product. In this study, the product was branded as "PINCA", representing an innovative beverage developed from pineapple peel waste. Attractive packaging functions not only as product protection but also as a marketing strategy that can increase consumer interest. Based on the entire production process, it can be concluded that the development of a tepache fermented beverage from pineapple peel waste represents a relatively simple and practical innovation with considerable potential for further development as an environmentally friendly, economically valuable, and functional beverage product.

4.2 Characteristics of Pineapple Peel Waste-Based Tepache Fermented Beverage Based on Color, Aroma, Taste, and Consumer Acceptance

Product characteristics are among the most important factors in determining the quality and consumer acceptance of a food innovation. In this study, the characteristics of the tepache fermented beverage produced from pineapple peel waste were evaluated based on color, aroma, taste, and consumer acceptance. These characteristics were assessed because the success of a beverage product is influenced not only by its nutritional content and potential health benefits but also by its sensory appeal, which contributes to a positive consumer experience. Products with attractive visual appearance, distinctive aroma, and desirable taste are more likely to be accepted by consumers and developed into commercially viable products.

Based on observational results, the fermented tepache beverage exhibited a golden-brown to reddish-brown color resulting from the extraction of natural compounds from pineapple peels during the fermentation process. This coloration indicates that fermentation occurred successfully and produced visual characteristics that differ from those of conventional fruit-based beverages. The resulting appearance conveys a natural impression because no synthetic colorants were added. Color also serves as an important quality indicator for consumers, as beverages with a clear and appealing appearance tend to be preferred over products that appear cloudy or inconsistent.



Figure 1. PINCA Tepache Fermented Beverage Produced from Pineapple Peel Waste

Based on Figure 1, the tepache beverage was packaged in a practical plastic bottle labeled with the brand name “PINCA” (*Pineapple Celia*). The packaging design provides a modern, hygienic, and portable appearance that aligns with contemporary consumer preferences. The beverage visible through the packaging displays an attractive reddish-brown color, indicating the occurrence of a natural fermentation process. The label design, featuring an illustration of a pineapple, further strengthens the product identity as a pineapple-based fermented beverage. Effective packaging serves not only to protect the product but also to enhance its market value and increase consumer interest in the developed innovation.

From the perspective of aroma, the tepache beverage exhibited a distinctive fragrance that combined the natural scent of pineapple with the characteristic aroma of fermentation. This aroma developed as a result of microbial activity that converted sugars into various volatile compounds during fermentation. The fermentation process produced a fresh, slightly acidic aroma while maintaining the characteristic pineapple fragrance as the dominant sensory attribute. This unique aroma represents one of the product’s key advantages, providing a refreshing sensory experience that distinguishes it from conventional beverages. Furthermore, the characteristic aroma serves as an indicator that fermentation proceeded effectively and produced a high-quality product.

In terms of taste, the tepache beverage demonstrated a balanced combination of sweetness, acidity, and mild natural carbonation generated during fermentation. The sweetness originated from the added sugar used as a fermentation substrate, whereas the acidic taste resulted from the production of organic acids by fermenting microorganisms. The interaction between these flavor components created a refreshing and harmonious

taste profile. In addition, the slight carbonation sensation contributed a unique drinking experience that differentiates tepache from traditional fruit beverages. This complex flavor profile is one of the main factors that may encourage consumers to try and continue consuming the product.

Consumer acceptance of the tepache beverage was generally influenced by the combined effects of color, aroma, taste, and packaging appearance. Based on observations and organoleptic evaluation results, most consumers expressed positive responses toward the product due to its distinctive flavor, refreshing aroma, and attractive packaging design. Consumers perceived the beverage as different from commonly available drinks on the market, providing a novel experience in consuming fermented beverages. Furthermore, information regarding the utilization of pineapple peel waste as the primary raw material served as an additional value that enhanced consumer interest in the product.

Overall, the characteristics of the pineapple peel waste-based tepache fermented beverage indicate favorable sensory and visual quality. The attractive reddish-brown color, distinctive fermentation aroma, refreshing sweet-and-sour flavor, and modern packaging design were identified as key factors contributing to the high level of consumer acceptance. These findings demonstrate that pineapple peel waste possesses significant potential to be transformed into a fermented beverage that not only offers health-related benefits but also has strong competitiveness as an innovative food product with substantial economic value and environmental sustainability.

4.3 Potential Utilization of Pineapple Peel Waste as a Raw Material for an Economically Valuable and Environmentally Friendly Tepache Fermented Beverage Innovation

Pineapple peel waste is one of the most abundant forms of organic waste in Indonesia, particularly in regions with high pineapple production and fruit-processing activities. To date, a large proportion of pineapple peels are discarded as waste without undergoing optimal utilization. This condition contributes to the increasing volume of organic waste, which may cause various environmental problems, including pollution, unpleasant odors, and a greater burden on waste management systems. Nevertheless, pineapple peels still contain valuable components such as natural sugars, dietary fiber, vitamins, minerals, and bromelain enzyme, which can be utilized as raw materials for various food products, including fermented beverages such as tepache.

The utilization of pineapple peel waste as a raw material for tepache demonstrates that organic waste can be transformed into value-added products. Through the fermentation process, pineapple peels that were previously considered waste can be converted into a functional beverage with distinctive sensory characteristics and potential health benefits. This innovation represents an application of the *waste-to-value* concept, whereby waste materials are transformed into products with greater utility and economic value. Consequently, pineapple peels are no longer viewed merely as discarded materials but rather as valuable resources that can be utilized productively to generate innovative products.

From an economic perspective, the use of pineapple peel waste as the primary raw material offers significant advantages because production costs remain relatively low. The raw materials can be easily obtained from traditional markets, fruit vendors,

households, and pineapple-processing industries at minimal cost. This condition enables entrepreneurs, particularly micro, small, and medium enterprises (MSMEs), to produce tepache with affordable capital requirements. Furthermore, the production process is relatively simple and does not require sophisticated equipment, making it highly accessible as a waste-based business opportunity for local communities.

The resulting tepache product possesses a considerably higher market value than pineapple peels in their raw waste form. Through processing, packaging, and branding initiatives such as the introduction of the product name “PINCA,” the economic value of the product increases substantially. Moreover, fermented beverages currently represent a promising market segment due to growing consumer interest in healthy, natural, and probiotic-based food products. As a result, pineapple peel waste-based tepache has the potential to become a flagship product capable of generating economic benefits while creating new entrepreneurial opportunities for communities.

In addition to its economic advantages, this innovation contributes significantly to environmental sustainability. The utilization of pineapple peels as a raw material for tepache helps reduce the amount of organic waste disposed of in landfills. The greater the proportion of waste that is reused and recycled, the lower the risk of environmental pollution. This approach aligns with the principles of sustainable waste management, which emphasize waste reduction, reuse, and recycling to minimize negative environmental impacts.

The conversion of pineapple peel waste into tepache also supports the concept of the circular economy, a system designed to maintain the value of resources for as long as possible through reuse, recycling, and resource recovery. Within this framework, waste is no longer regarded as the end point of a production process but rather as a resource that can serve as raw material for the creation of new products. By processing pineapple peels into fermented beverages, the resource utilization cycle is extended, enabling more efficient and sustainable use of available materials.

From a social perspective, the innovation of pineapple peel-based tepache can increase public awareness regarding the importance of waste management and the utilization of local resources. Communities can gain new knowledge and skills related to transforming organic waste into products with commercial value and potential health benefits. Such educational initiatives are important for fostering environmentally responsible attitudes and encouraging the development of productive waste-management practices within society.

Overall, the utilization of pineapple peel waste as a raw material for innovative tepache fermented beverages demonstrates substantial potential from both economic and environmental perspectives. This innovation enhances the value of organic waste, creates new business opportunities, supports waste reduction efforts, and promotes the implementation of circular economy principles. Given the abundant availability of raw materials and the relatively simple production process, pineapple peel-based tepache has strong potential to become a competitive, environmentally friendly, and sustainable innovative product in the future.

5. CONCLUSION

Based on the findings and discussion, it can be concluded that pineapple peel waste possesses significant potential to be utilized as a raw material for the development of an

innovative tepache fermented beverage that is both economically valuable and environmentally friendly. Through a relatively simple fermentation process, pineapple peels, which are commonly regarded as waste, can be transformed into a functional beverage characterized by an attractive appearance, a distinctive fermented aroma, and a refreshing sweet-and-sour flavor, resulting in favorable consumer acceptance. The development of tepache also represents an application of the *waste-to-value* and *circular economy* concepts, as it converts organic waste into a value-added product, extends the utilization cycle of resources, and reduces the volume of waste that may contribute to environmental pollution. From an economic perspective, the use of pineapple peel waste as the primary raw material offers several advantages, including low production costs, abundant raw material availability, and promising business development opportunities, particularly for micro, small, and medium enterprises (MSMEs). In addition, this innovation contributes to social benefits by increasing public awareness of the importance of waste management and the productive utilization of local resources. Therefore, pineapple peel waste-based tepache fermented beverage can be considered an innovative product that not only supports environmental sustainability but also demonstrates strong potential as a healthy beverage with high market value and competitiveness in the future.

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