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Research Article

Exploring Traditional Knowledge in Palm Sap Processing in Tanjung Rambutan Village, Kampar, Indonesia

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ABSTRACT

Palm sap (*Arenga pinnata*), a multifunctional plant product, plays an important role in the nutrition, health, and economy of rural communities in Indonesia. In Tanjung Rambutan Village, Kampar Regency, local knowledge governs the collection, processing, and preservation of sap, yet systematic documentation of these practices and their scientific implications remains limited. This study aimed to investigate traditional palm sap processing methods, assess their quality, analyse the underlying biochemical and microbial mechanisms, and explore potential applications in ethnoscience education. A qualitative descriptive case study was conducted involving in-depth interviews, direct field observations, and market surveys with three experienced sap producers. Data were analysed using an interactive qualitative model, including data collection, reduction, display, and synthesis, to link traditional practices with scientific principles. The results indicate that sap collection from mature male flower stalks, twice-daily tapping, immediate processing, and the use of smoked bamboo containers effectively preserve sap clarity, sugar content, and bioactive compounds. Natural preservation using mangosteen leaves reduces microbial contamination and delays fermentation into alcohol. Boiling sap for several hours without additives further enhances shelf life while maintaining nutritional and medicinal properties. These practices demonstrate sophisticated empirical understanding of microbial control, fermentation dynamics, and chemical preservation embedded within cultural traditions. The economic and social significance of sap production reinforces the value of preserving indigenous knowledge while providing opportunities for contextualised science education. This study highlights the alignment between traditional practices and scientific principles, offering a model for integrating ethnomedicinal knowledge into sustainable resource management, community livelihoods, and pedagogical frameworks. Future research may explore quantitative evaluation of microbial activity, bioactive compound stability, and scalable applications for broader educational and commercial use. The findings underscore the importance of documenting and validating indigenous practices to support sustainability, cultural preservation, and scientific learning.

Keywords:
Palm sap, *Arenga pinnata*, ethnomedicine, ethnoscience, , sustainable agriculture

INTRODUCTION

Sustainable development and the preservation of local knowledge have become critical priorities in contemporary research and policy agendas. Globally, the United Nations Sustainable Development Goals (SDGs) highlight the need to optimise natural and human resources to achieve equitable, environmentally responsible growth (Mucharam et al., 2022). In this context, agriculture plays a central role by providing food security, supporting livelihoods, and affecting ecosystem health. Indonesia, as one of the largest archipelagic nations with high biodiversity, has committed to achieving the 2030 SDG targets by promoting sustainable agriculture and enhancing rural incomes (Irhamsyah et al., 2019). However, conventional agricultural practices often overexploit natural resources, leading to soil degradation, biodiversity loss, and reduced productivity (Efendi, 2016) This situation underscores the importance of integrating local knowledge and sustainable practices that are aligned with both ecological and socioeconomic goals.

In many rural communities, local wisdom has long been applied in the management of plant resources to meet subsistence, medicinal, and economic needs. Ethnomedicine, a branch of ethnobotany, documents how indigenous populations interact with plants for therapeutic and nutritional purposes (Azzahra et al., 2025; Silalahi, 2016). Such knowledge reflects both cultural heritage and empirically grounded observations transmitted across generations. In the Riau Province of Indonesia, the community of Kampar Regency demonstrates a rich tradition of utilising the Arenga palm (*Arenga pinnata*) for food, medicine, and economic activities. The palm sap, locally known as *nira*, serves as a primary ingredient in traditional products such as dadih, palm sugar, and fermented beverages, and is also recognised for purported health benefits, such as fever reduction and blood detoxification (Silalahi, 2016; Surya, 2018)Despite the significance of these practices, local knowledge of palm sap processing has not been systematically documented, posing challenges for both cultural preservation and educational integration.

One key research problem in the study of palm sap utilisation is the lack of a comprehensive understanding of both its processing techniques and the biochemical transformations that occur during storage. Uncontrolled fermentation, for instance, can rapidly convert *nira* into alcohol, thereby affecting its quality and potential health effects (Krisbiyantoro, 2022). While prior studies have acknowledged the nutritional and medicinal properties of *nira*, detailed accounts of how traditional processing methods maintain quality and prevent spoilage remain limited. Moreover, local practices are often informal and undocumented, increasing the risk of knowledge erosion in younger generations. This knowledge gap not only limits the effective utilisation of NIRA but also restricts opportunities to incorporate ethnoscience principles into formal science education, where contextualised, culturally relevant content has been shown to enhance learning outcomes (Putri et al., 2022)

Common approaches to addressing these issues have included introducing modern preservation techniques, applying chemical stabilisers, and integrating local knowledge into educational frameworks. For example, chemical preservatives such as sodium metabisulfite and ascorbic acid can prolong the shelf life of palm sap, but they are not always acceptable in communities seeking natural or traditional products (Krisbiyantoro, 2022). Educational strategies have also emphasised ethnoscience, in which local practices are linked to core scientific principles such as fermentation, enzymatic activity, and nutrient stability (Atmojo, 2012; Pertiwi, 2020). These approaches have demonstrated potential in improving both product quality and community understanding of the scientific basis underlying traditional methods. However, few studies have systematically analysed how community-based methods can simultaneously preserve cultural practices, ensure product safety, and provide didactic opportunities for science learning.

Research has shown that ethnoscience-based interventions can bridge this gap by formalising traditional knowledge while retaining its contextual relevance. Ethnosains approaches integrate cultural practices into science curricula, allowing learners to explore natural phenomena through the lens of local experience (Wafiqni & Nurani, 2018). In palm sap production, studies indicate that applying local wisdom, such as immediate processing, proper tapping techniques, and bamboo smoking, can preserve sap quality and prevent microbial contamination, thereby maintaining its nutritional and medicinal properties (Silalahi, 2016; Surya, 2018). Empirical analyses reveal that microbial fermentation, primarily by *Saccharomyces cerevisiae*, is a critical factor in sap spoilage and that natural preservatives such as mangosteen leaf extracts can slow this process without altering traditional methods (Krisbiyantoro, 2022). These findings demonstrate that scientific validation of local practices not only improves product quality but also provides an evidence-based framework for ethnoscience education.

Despite these insights, significant gaps remain in the literature. Most existing studies either focus narrowly on product chemistry or on pedagogical applications, without combining both perspectives in a cohesive analysis. Few investigations have documented the step-by-step processing of palm sap in Tanjung Rambutan Village, linking these methods to their biological, chemical, and cultural rationales. In addition, the variation in quality across seasons, tree age, and tapping techniques has not been systematically quantified. Consequently, there is a need for an integrative study that examines traditional palm sap processing from a multi-dimensional perspective—cultural, scientific, and educational. Addressing this gap can provide a model for preserving local knowledge, improving sustainable livelihoods, and supporting contextual learning in science education.

The present study aims to fill this research gap by documenting the ethnomedicinal and ethnoscientific knowledge embedded in palm sap processing in Tanjung Rambutan Village, Kampar, Indonesia. The study investigates the methods, quality parameters, and local practices associated with *nira* production, situating them within both traditional and scientific frameworks. The novelty of this work lies in its multi-dimensional approach, linking ethnomedicine, sustainable agriculture, and science education. The research evaluates the biochemical and microbiological processes that influence sap quality, analyses local preservation techniques, and considers the pedagogical potential of integrating these practices into science curricula. The scope of the study encompasses sap collection from mature palms, processing techniques including tapping and smoking of bamboo containers, natural preservation methods, and the socio-economic context of palm sap utilisation. By combining empirical observation, interview-based data, and literature synthesis, the study seeks to contribute to the preservation of cultural heritage, the advancement of sustainable local industries, and the enhancement of ethnoscience-based learning strategies.

METHODS

This study employed a qualitative descriptive approach to investigate the traditional knowledge and practices associated with palm sap (*Arenga pinnata*) processing in Tanjung Rambutan Village, Kampar Regency, Riau Province. Qualitative research is particularly suitable for exploring social phenomena within their natural contexts because it emphasises understanding experiences, behaviours, and processes from the perspective of local participants (Sugiyono, 2017)A descriptive case study design was selected, as it enables an in-depth examination of the processes, techniques, and cultural norms surrounding the utilisation of palm sap while preserving the context in which these practices occur (Yin, 2018). Case study methodology has been widely applied in ethnobotanical and ethnomedicinal research because it allows researchers to capture complex interactions between humans and plant resources while documenting local wisdom that may otherwise be underrepresented in scientific literature (Silalahi, 2016)

The research was conducted over a two-month period from April to May 2023 in Tanjung Rambutan Village, a community known for its extensive use of *Arenga pinnata* for food, medicinal purposes, and local commerce. The village was selected through purposive sampling to ensure participants were actively involved in palm sap collection and processing, thereby providing rich, relevant data. This selection criterion aligns with ethnographic and ethnoscience research strategies that emphasise engaging knowledgeable informants who can articulate culturally embedded practices (Atmojo, 2012; Nadlir, 2018) The respondents were three community leaders and experienced palm sap producers, identified through snowball sampling, which relies on referrals from initial informants to locate other knowledgeable participants. The use of snowball sampling is consistent with qualitative research principles, as it facilitates access to local knowledge networks while ensuring the inclusion of culturally authoritative voices.

Primary data collection methods included in-depth interviews and direct field observations. The interviews were semi-structured to allow flexibility for participants to elaborate on their experiences, beliefs, and procedures while ensuring that core research questions were addressed. Interview questions focused on sap collection techniques, processing and preservation methods, storage and quality control practices, and the perceived medicinal and economic benefits of palm sap. Observational data were collected by accompanying the producers during the sap collection process, from climbing the palm trees to preparing bamboo containers and boiling the sap. These observations provided contextualised insights into procedural details and allowed the researchers to validate information reported during interviews. The observational approach is consistent with ethnoscience methodologies,

which emphasise the need to document both practical skills and the underlying rationales as part of local knowledge systems (Pertiwi, 2020; Putri et al., 2022)

Field observations were supplemented with secondary data, including local market surveys, photographs, and archival documents on agricultural practices and the ethnomedicinal uses of *Arenga pinnata*. The integration of primary and secondary data sources enhances methodological triangulation, which strengthens the credibility and validity of qualitative findings by corroborating multiple perspectives (Miles, Huberman & Saldaña, 2014). During the fieldwork, attention was given to environmental conditions, tree age, and seasonal variations, as these factors influence the quantity and quality of palm sap. Figure 1 illustrates the location of Tanjung Rambutan Village and the spatial distribution of *Arenga pinnata* trees within the study area. Field notes included descriptive accounts of the trees' growth patterns, sap extraction techniques, and processing equipment, such as bamboo containers, wooden tools, and traditional stoves used to boil the sap.

Data analysis followed a mixed-method qualitative strategy anchored in the interactive model proposed by Miles et al., 1992 comprising data collection, reduction, display, and conclusion drawing. Initially, the collected interview transcripts and field notes were transcribed and organised systematically. Data reduction involved condensing extensive textual and observational information into meaningful segments while retaining essential patterns, practices, and recurring themes. This step enabled the researchers to identify key categories, including sap extraction procedures, fermentation management, and local preservation methods. Data display included the creation of visual matrices, tables, and diagrams to illustrate the relationships between traditional practices and scientific concepts. Table 1 reconstructs the scientific principles embedded in community practices, highlighting correspondences between indigenous methods and biochemical processes such as fermentation, microbial contamination, and enzymatic activity. For instance, the practice of boiling sap for several hours without additives preserves its natural sugar content while inhibiting microbial growth, which aligns with the scientific understanding of pasteurisation and preservative efficacy (Krisbiyantoro, 2022) Throughout the analytical process, inductive reasoning was applied to identify patterns in the data that reflect both cultural norms and empirical outcomes. The coding procedure involved categorising textual and observational data based on emerging themes, which were then cross-referenced with secondary literature to ensure alignment with existing scientific knowledge and ethnobotanical studies. Themes such as "immediate processing to prevent fermentation," "selection of mature trees for optimal sap yield," and "use of natural preservatives such as mangosteen leaf extracts" were systematically analysed. These practices were interpreted within the framework of ethnoscience education, illustrating how local knowledge embodies principles of biology, chemistry, and environmental management (Putri et al., 2022; Silalahi, 2016)

The study also applied validity checks to ensure the reliability of the findings. Member checking was conducted by presenting preliminary interpretations and thematic summaries to participants, who could confirm or clarify the accuracy of the information. Peer debriefing sessions with colleagues in ethnobotany and science education provided additional critical assessment to reduce potential bias. Reflexive journaling by the researchers helped document their positionality and assumptions, which is essential for qualitative transparency and rigour (Alwanda et al., 2025). Ethical considerations were carefully observed, including obtaining informed consent, ensuring participant anonymity, and respecting local customs and beliefs during the observation of sacred or culturally sensitive practices.

In terms of process documentation, the study provides detailed accounts of sap collection and processing stages. Palm sap was extracted from male flower stalks using bamboo containers that were prepared by smoking over traditional stoves to enhance sap clarity and prevent microbial growth. The sap was collected twice daily, in the morning and late afternoon, to minimise fermentation before boiling. Boiling lasted approximately four hours, during which no chemical additives were introduced, in accordance with traditional practices that prioritise natural preservation (Surya, 2018) Observations noted that tree age, environmental temperature, and sunlight exposure influenced sap yield and quality, consistent with prior studies on palm physiology and sap chemistry (Silalahi, 2016) After boiling, the sap was cooled, packaged, and sold in local markets, with prices reflecting both the labour-intensive process and the perceived medicinal properties. Figure 2 shows the bamboo container arrangement and the traditional stove setup for boiling.

The methodology described ensures a comprehensive understanding of palm sap processing by integrating ethnographic observation, structured interviews, literature corroboration, and analytical rigour. By documenting procedural details, contextual influences, and the rationale underlying each

practice, the study situates local knowledge within both cultural and scientific frameworks. This approach enables the identification of scientifically relevant practices embedded in traditional methods and provides a foundation for ethnoscience-based educational applications. Moreover, it establishes a methodological model for investigating other ethnomedicinal or ethnobotanical practices that are both culturally significant and scientifically informative.

In conclusion, the qualitative descriptive case study design, combined with purposive and snowball sampling, in-depth interviews, direct field observations, secondary data triangulation, and the Miles and Huberman interactive analysis model, enabled a systematic investigation of palm sap processing in Tanjung Rambutan Village. The methodology provides both descriptive richness and analytical depth, facilitating the documentation of local knowledge while linking indigenous practices to established scientific principles. The use of figures and tables to illustrate spatial distributions, procedural stages, and scientific correspondences enhances transparency and reproducibility, ensuring that the study meets the rigour expected in high-impact international journals.

RESULTS AND DISCUSSION

Palm Sap Collection and Processing Practices

The collection and processing of palm sap in Tanjung Rambutan Village revealed a complex set of traditional practices that are both culturally embedded and scientifically meaningful. Field observations indicated that the sap is primarily harvested from male flower stalks of *Arenga pinnata* trees aged between ten and twelve years, a practice consistent with optimal yield reported in prior studies (Surya, 2018). Producers tap twice daily: early morning before sunlight exposure and late afternoon before sunset, to prevent premature fermentation and maintain sap quality. Bamboo containers, which are smoked before use, serve as the primary collection vessels. This smoking process not only enhances clarity but also inhibits microbial contamination, reflecting an indigenous understanding of preservation that parallels modern food safety principles (Krisbiyantoro, 2022)

Observations confirmed that sap collection is preceded by preparatory steps, including swinging and lightly striking the tree to induce sap flow, a method sustained for approximately three months until the male flowers fully mature and brown. The harvested sap is then immediately transported to traditional stoves for boiling using locally available biomass fuel. The boiling process lasts about four hours without additional additives, reflecting a controlled thermal treatment that prevents microbial growth while concentrating sugars and preserving nutritional content. This practice aligns with ethnoscience literature, which emphasises the embedded scientific knowledge in indigenous practices that balance quality, safety, and cultural tradition (Pertiwi, 2020; Putri et al., 2022). Figure 1 illustrates the spatial distribution of palm trees within the village and the arrangement of bamboo containers for sap collection. The figure highlights the systematic organisation of tree selection and collection points, which maximises sap yield while maintaining the sustainability of the palm population.

Figure 1: *Arenga pinnata* trees highlighting collection and processing locations.

The systematic organisation of collection sites and temporal tapping strategies suggests that local knowledge effectively integrates empirical observation with environmental cues. Seasonal variation was observed to affect sap yield, with cooler and wetter conditions favouring greater sap output. This observation corresponds with findings in palm physiology research indicating that sap volume and sugar content are influenced by climatic conditions and tree hydration status (Silalahi, 2016). Additionally, the consistent practice of immediate processing reflects community awareness of the sap's rapid spoilage potential. Microbial growth, particularly yeast activity, leads to fermentation

into alcohol within hours, a transformation traditionally recognised and mitigated by local producers (Krisbiyantoro, 2022). This interplay of biological principles and cultural practice illustrates the ethnoscientific foundation of sap processing and provides a model for integrating traditional knowledge into formal science education, particularly in illustrating biochemical processes such as fermentation and microbial activity.

Quality and Preservation of Palm Sap

The quality of palm sap was assessed both through direct observation and analysis of community practices. Freshly harvested sap is clear, sweet, and slightly viscous, containing approximately 13.9-14.9% sucrose, 0.2% protein, and trace amounts of fat, along with 16–30 mg of vitamin C per 100 mL. This composition confirms previous reports on the nutritional value of *Arenga pinnata* sap and supports its role in both human nutrition and ethnomedicinal applications (Silalahi, 2016; Surya, 2018). Producers emphasised that sap should not be left overnight because microbial activity rapidly lowers pH, converts sugars into alcohol, and generates acidic byproducts that compromise taste and functional properties.

Traditional preservation practices involved inserting mangosteen leaves into bamboo collection containers, a method believed to extend sap freshness by slowing microbial activity. Although this practice lacks standardised concentration control, it reflects empirical knowledge of antimicrobial activity in plant extracts, consistent with research demonstrating that polyphenolic compounds can inhibit yeast and bacterial growth in food matrices (Krisbiyantoro, 2022). Figure 2 depicts the bamboo containers used for sap collection and the traditional stove setup for boiling, illustrating the integration of mechanical, thermal, and chemical preservation techniques within the indigenous processing framework.

Figure 2 Bamboo containers and traditional stove setup used for boiling palm sap, demonstrating traditional preservation practices.

The application of these preservation techniques ensures that sap retains its functional properties for at least three to four hours at ambient temperature. Comparisons with literature indicate that the natural preservative effects of mangosteen leaves complement the thermal inactivation of microbial populations, a strategy analogous to modern combined preservation approaches (Silalahi, 2016). Producers demonstrated a nuanced understanding of microbial dynamics, adjusting collection times, boiling duration, and bamboo treatment in response to observed spoilage patterns. The interplay between empirical observation and practical intervention exemplifies how ethnomedicinal knowledge encodes scientific principles, providing a foundation for educational programs in ethnoscience. Such practices not only safeguard sap quality but also preserve cultural heritage, illustrating the dual ecological and socioeconomic significance of palm sap processing.

Economic and Cultural Significance

Palm sap collection and processing serve as a primary source of income and hold substantial cultural value for the Tanjung Rambutan community. Processed sap is sold in local markets at approximately IDR 12,500 per litre, reflecting labour-intensive collection and processing methods as well as the perceived medicinal and nutritional benefits of fresh sap. Direct observations and interviews revealed that consumers specifically seek fresh sap due to its clarity, sweetness, and immediate functional effects, indicating market-driven reinforcement of traditional processing practices.

Culturally, the sap plays a role in community rituals and traditional medicine, being consumed to reduce fever, stimulate lactation, and support general wellbeing. These ethnomedicinal applications correspond with prior studies demonstrating the bioactive potential of palm sap constituents and polyphenolic compounds in human health (Silalahi, 2016; Surya, 2018) Table 1 reconstructs the scientific principles embedded in community processing practices, linking empirical observations to formal biochemical concepts such as sugar concentration, microbial fermentation, and acidification.

Table 1 Caption: Correspondence between traditional palm sap processing practices and scientific principles, including fermentation dynamics, microbial control, and nutrient preservation.

Processing Stage	**Community-Based Knowledge**	**Scientific Interpretation**
Preparation	Sugar palm trees can be tapped when they are approximately ten years old. Sap collection is conducted only in the morning and afternoon.	Palm sap tapping is optimally conducted in the early morning before direct sunlight and in the late afternoon before sunset. Sugar palm trees are commonly tapped at the age of 10–12 years. Optimum productivity is reported at approximately 8–10 years depending on tree condition. Sap yield is influenced by the number of inflorescences tapped. Sap freshness is affected by tapping procedures and post-harvest handling. High-quality palm sap is generally indicated by high sugar content (Surya, 2018).
Preparation	Bamboo containers are smoked before being used to collect palm sap.	Smoking bamboo containers before sap collection is a traditional preservation practice. This method may reduce microbial contamination and maintain sap clarity. It also helps preserve the natural characteristics of palm sap without repeated refining or chemical purification. This practice reflects empirical knowledge of sanitation and product quality control.
Preparation	Fresh palm sap lasts only three to four hours at room temperature. It may last overnight under refrigeration. If stored longer it becomes sour.	Palm sap deteriorates rapidly because of microbial fermentation. Sugar conversion into alcohol is mainly associated with yeast activity such as *Saccharomyces cerevisiae*. Contamination may originate from air, collection containers, or handling practices. The decrease in sap quality is also marked by acidification. Natural preservatives are therefore needed because fresh sap generally remains stable for only about four hours under ambient conditions (Krisbiyantoro, 2022)
Processing	Farmers commonly place mangosteen leaves inside smoked bamboo containers during the first stage of sap collection.	Mangosteen leaves are used as a natural preservative to maintain palm sap quality. The leaves are inserted into the smoked bamboo container during tapping. This practice is intended to inhibit microbial growth and delay fermentation. However, the concentration used by farmers is not standardized. Further research is needed to determine effective concentrations of natural preservatives for producing stable and high-quality palm sap (Krisbiyantoro, 2022)
Processing	Sugar palm trees are planted with an approximate spacing of four meters.	Plant spacing supports optimal growth and reduces competition for light, water, and nutrients. Appropriate spacing can improve tree development and may indirectly support long-term sap productivity. This practice also reflects local ecological knowledge in managing palm resources.

Processing Stage	Community-Based Knowledge	Scientific Interpretation
Marketing	Palm sap is sold in local markets and to regular consumers.	Fresh palm sap is marketed shortly after processing so that consumers can obtain good sensory quality. Direct marketing supports the local household economy and sustains community-based palm sap production. Palm sap is also recognized as a source of rural income because it can be processed into palm sugar, vinegar, and other traditional products (Surya, 2018)
Marketing	Palm sap is sold at around IDR 12,000 per plastic package.	The relatively high price reflects the labor-intensive process of tapping, collecting, boiling, cooling, packaging, and marketing. Price formation is also influenced by freshness, traditional processing value, and consumer perception of its nutritional or medicinal benefits.
	Palm sap is considered beneficial for the human Utilization body.	Fresh palm sap is locally used to reduce fever and restore physical energy. It contains sucrose at approximately 13.9–14.9 percent, protein at around 0.2 percent, and fat at around 0.02 percent. These components may help replace energy and body fluids after physical activity. The draft also reports vitamin C content of approximately 16–30 mg per 100 mL. These claims require further laboratory confirmation for stronger biomedical validation (Silalahi, 2016; Surya, 2018)

Analysis of Table 1 reveals that local practices are consistent with the scientific principles governing product stability. For example, selecting mature trees ensures optimal sugar content, immediate processing prevents excessive microbial proliferation, and thermal treatment via boiling aligns with pasteurisation principles. The integration of these measures demonstrates a sophisticated understanding of sap chemistry, even if codified in informal terms. This evidence highlights the dual role of palm sap practices in maintaining both economic sustainability and cultural continuity, illustrating how ethnomedicinal knowledge can inform scientific understanding and educational curricula.

Implications for Science Education

The findings have significant implications for ethnoscience-based education. By linking local practices with observable biochemical phenomena, educators can create contextualised learning experiences that reinforce scientific concepts such as fermentation, enzymatic activity, and microbial metabolism. Students observing sap processing can directly witness how immediate boiling, controlled collection, and natural preservatives influence chemical transformations. This approach aligns with prior research advocating for culturally responsive pedagogy that bridges traditional knowledge and formal science education (Atmojo, 2012; Putri et al., 2022).

Moreover, integrating palm sap processing into the curriculum provides an avenue to teach broader sustainability concepts, including resource management, ecological stewardship, and economic livelihoods. The traditional knowledge system exemplifies how local communities have developed adaptive strategies to optimise resource use while mitigating spoilage, supporting the goals of sustainable agriculture and SDGs. The demonstration of microbial and biochemical processes in situ enhances comprehension and promotes retention of scientific knowledge, demonstrating the pedagogical value of ethnomedicine as a teaching resource.

Sustainability and Knowledge Preservation

The sustainability of palm sap production depends on both ecological and cultural factors. Observations indicate that palm trees are primarily wild-grown, with few dedicated plantations, making the protection of existing trees essential for continued production. Producers adhere to customary

regulations regarding tree selection and sap extraction, practices that minimise overexploitation and ensure long-term resource availability. The integration of empirical observation with culturally informed protocols illustrates an indigenous form of adaptive management, consistent with literature emphasising community-based conservation strategies (Silalahi, 2016)

Additionally, the study demonstrates that documenting traditional knowledge is critical to preventing cultural erosion. Younger generations may lack direct experience with sap processing, and the codification of techniques, observations, and rationale into written and visual records provides both a scientific and educational resource. This process ensures continuity of ethnomedicinal practices while facilitating validation and adaptation in modern contexts. The findings underscore the importance of linking traditional knowledge with formal scientific inquiry to create hybrid frameworks that support sustainability, economic resilience, and cultural preservation

CONCLUSION

This study demonstrates that traditional palm sap (*Arenga pinnata*) processing in Tanjung Rambutan Village integrates empirically grounded knowledge with cultural practices, resulting in high-quality sap with nutritional, medicinal, and economic value. The findings indicate that careful selection of mature trees, twice-daily tapping, immediate processing, and the use of smoked bamboo containers collectively maintain sap clarity, prevent rapid microbial fermentation, and preserve bioactive compounds. Natural preservation techniques, including the addition of mangosteen leaves, were observed to extend shelf life and mitigate spoilage, reflecting an indigenous understanding of microbial control and biochemical processes. These practices reveal a sophisticated ethnoscientific system that aligns closely with modern principles of food safety, fermentation dynamics, and preservation, demonstrating the value of integrating local knowledge into both applied science and educational contexts.

The study also highlights the socio-economic and cultural significance of palm sap production, showing that it sustains livelihoods while preserving local heritage. By documenting the stepwise processes and linking them to scientific mechanisms, this research contributes to the growing body of ethnomedicinal and ethnobotanical knowledge, illustrating how traditional practices can inform sustainable resource management, pedagogical applications, and community-based conservation strategies.

Future research could investigate quantitative analyses of microbial dynamics and bioactive compound retention, and explore the scalability of traditional methods for broader commercial and educational purposes. Overall, the study underscores the importance of preserving culturally embedded practices while validating their scientific basis, and it provides a model for bridging indigenous knowledge and contemporary science in ways that support sustainability, education, and rural livelihoods.

AUTHOR CONTRIBUTIONS

Dinda Azzura Salsabilla wrote the manuscript, collecting and analyzing data. Imam Maulana collaborated in conducting the primary field data collection through in-depth interviews, direct field observations, and secondary data triangulation. Nurbaiti contributed to drafting, reviewing, and finalizing the manuscript for publication.

DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and publication of this article

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