

Design and Development of a Stainless Steel Fermentation Tank for Palm Wine with Gravity Purification Construction

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ABSTRACT

Tourism and culinary activities are increasingly integrated into wine tourism, a key segment of agricultural tourism. Palma wine, a traditional wine produced from the sap of palm trees (locally known as sagars), is a significant product for the Minahasa farming community in North Sulawesi. This study focuses on optimizing the fermentation process to enhance the quality of Palma wine by utilizing food-grade HDPE containers and a dual-role fermentation tank. The tank is designed to reduce dust content in the palm sap through an efficient mechanism while minimizing disruptions during the transfer of fermentation products. The research involves designing and testing fermentation tanks based on applied science and technology principles to improve purification processes and standardize effectiveness and efficiency measurements. Results demonstrate that the use of high-quality fermentation tanks enhances the purification process and ensures better-quality Palma wine, contributing to the development of local wine tourism and supporting sustainable agricultural practices.

INTRODUCTION

In 2018, Indonesia's tourism sector ranked 9th globally for the highest growth, according to The World Travel & Tourism Council (WTTC). To accelerate the development of the National Tourism Strategic Areas (KSPN), Likupang has been designated as one of the five Super Priority Tourism Destinations (DPSP) since 2019. Administratively, the Likupang area is located in North Minahasa Regency, North Sulawesi Province.

Tourism is a complex industry encompassing a variety of businesses providing tourism products and services. In the era of globalized tourism, wine tourism—combining wine and natural attractions—has become part of exploring the unique characteristics of local traditions, increasingly drawing academic interest.

Tourism and culinary experiences are now commonly integrated into wine tourism, a leading segment of agrotourism. Palma wine, a traditional wine made from palm tree sap, locally referred to as *saguer* by the Minahasa farming community in North Sulawesi, is a key focus of this study. This research pioneers the differentiation of Palma wine as a premium product under the brand DATIVAR, highlighting its ethnic-geographic identity as an icon of Minahasa's cultural heritage.

The motivation for this research stems from the fact that palm sap processing in various regions of North Sulawesi remains largely traditional, failing to maximize its potential. This is evident in the quality of palm sap obtained through local tapping practices. Based on this background, the research problem is defined as follows:

1. What necessitates the development of a Palma Wine Fermentation Tank with gravity-based purification for fermentation results?
2. Can the development of a palm-based Palma wine industry significantly contribute to the economic well-being of palm farmers?

These research questions are relevant due to their correlation with tourism economics. The need for a Palma Wine Fermentation Tank arises from field observations on upgrading palm sap derivatives into Palma wine products, conducted in North Minahasa Regency.

Additionally, no references to Palma wine production processes from palm sap have been found in the past decade, presenting a unique challenge in designing a fermentation tank prototype for the palm sap processing industry that supports tourism based on local wisdom.

Field observations in this study provided data on optimizing the use of palm sap as a local raw material through the invention of a Palma Wine Fermentation Tank. This tool aligns with the optimization of Technology Readiness Levels to create an effective application.

Independent research conducted during this study has identified that the dual function of the fermentation tank is to reduce dust levels in palm sap through an efficient mechanism. This ensures that the transfer of fermentation products to the storage container does not require special treatment and is not significantly affected.

This study aims to improve operational performance and business growth, with the expectation of achieving significant improvements. Such advancements are integral to a research partnership framework that supports the sustainable growth of small enterprises. The outcomes are expected to have a positive correlation with improving the welfare of traditional *saguer*-tapping farmers.

LITERATURE REVIEW

1. *Micro, Small and Medium Enterprises*

Likupang, situated in North Minahasa Regency, North Sulawesi Province, has been identified as a key development area due to its geostrategic benefits, particularly in the tourism sector, as outlined in Government Regulation No. 84 of 2019 On Special Economic Areas (KEK).

However, 2020 marked a significant downturn for Indonesia's tourism industry as the COVID-19 pandemic struck. The United Nations World Tourism Organization (UNWTO) described the crisis as an unprecedented catastrophe in global tourism history, with international tourist arrivals dropping by 86%.

Meanwhile, leveraging cultural assets and local wisdom in tourism development remains a crucial aspect of human creativity that holds economic value. According to Law No. 10 of 2009 on Tourism, tourist attractions encompass anything with uniqueness, aesthetic appeal, and value, including the diversity of natural resources, cultural heritage, and human-made creations that draw visitors.

Amid crisis conditions, fewer than 2% of Micro, Small, and Medium-sized Enterprises (MSMEs) were formally established. Yet, SMEs have shown greater resilience during economic crises, as evidenced in Greece, where entrepreneurs focus on discovering and utilizing sources of value creation. For MSME entrepreneurs, fostering innovation capacity is essential to enhance performance. Innovations are not limited to products but can extend to production processes, including the adoption of new methods or the improvement of existing ones.

2. *Palm Plants*

According to Elfriede, current research directions on palm plant potential focus on chemical and organoleptic properties of palm sugar, modernization of its production processes, factors that may impact production yields, and their correlations with public welfare.

The palm plant (*Arenga pinata Merr*), which holds significant potential as an agro-industrial commodity in Indonesia, is widely cultivated across 14 provinces, including Papua, North Maluku, North Sumatra, West Sumatra, and North Sulawesi, among others. This crop has shown steady growth, with cultivated areas increasing by an average of 2.0% annually and production rates growing at 1.9% per year. Palm trees produce between 8–22 liters of sap (Nira) per tree daily. Studies highlight the palm plant's rich composition of secondary metabolites such as alkaloids, flavonoids, tannins, saponins, triterpenoids, galactomanes, and phenols, which contribute antioxidant properties.

In North Sulawesi, palm crop cultivation spans 5,898.98 hectares, yielding 2,249.30 tons of palm products annually. Despite its abundant production, traditional palm sugar from this region suffers from poor quality, mainly due to the lengthy cooking processes employed by farmers. Research by Elfriede et al. indicates that bacterial contamination in traditional palm sugar is often attributed to human contact during production.

The limited competitiveness of local palm sugar stems from farmers' insufficient knowledge and low awareness of quality standards. Factors such as personal hygiene, sanitary facilities, harvesting methods, heating temperatures, durations, and storage practices contribute to product variability.

To meet processing standards for palm sugar, palm sap must adhere to specific pH (6–7.5) and brix (above 17) requirements. With its increasing demand and substantial production in Southeast and South Asia (Indonesia, India, Malaysia, the Philippines, Thailand, etc.), palm sugar serves as a viable alternative to cane sugar, offering significant economic value.

Table 1. Composition of General Palm Sap

Component	Amount	Recommended daily intake (mg/day)	Reference
Ash	1.8%		[11–18]
Moisture	35.2%		
Total Sugars	9–18.6 g/100 ml		
Glucose	9.5%; 0.49–86.90 g/100 ml		
Fructose	4.8%; 0.26–1.61 g/100 ml		
Sucrose	37.9%; 5.30–27.00 g/100 ml		
Maltose	<0.5%		
Monohydrate lactose	<0.5%		
Total sugars (in glucose)	66.0%		
Fat	0.20%		
Water soluble Vitamins	(mg/Kg)		
C	<5	75–90	
B ₁	0.20	1.1–1.2	
B ₂	<0.10	1.1–1.3	
B ₃	31.7	14–18	
B ₆	<0.40	1.3–1.7	
B ₉	0.10	0.4–0.6	
B ₁₂	0.0049	0.00378–0.00594	
Fat soluble vitamins	(mg/Kg)		
A	<0.50	700–900 Retinol equivalent	
D	<5.00	0.01–0.02	
E	<0.50	15–19	
K	<0.001	0.122–0.138	
Micro nutrients	mg/100 ml		
Fe	0.04–1.58	8.7–14.8	
Zn	0.013–0.71	8–11	
Cu	0.02–0.21	0.9–1.3	
Mn	0.009–2.23	1.8–2.3	
Ni	0.06	0.18–0.25	
Macro nutrients	mg/100 ml		
K	65.28–1326.0	1600–2000	
Na	2.85–117.5	<2300	
Mg	0.54–31.00	310–420	
Ca	0.24–79.00	700	

3. Stainless Steel

As explained by Novita, Ginting, and Astuti, Fontana stated that metals can suffer damage due to corrosion, an electrochemical reaction between the metal and its environment, which results in rusting and decreases the quality of the metal.

According to Riszki & Harmami, Stainless Steel type 304 (SS 304) is a versatile and widely used stainless steel known for its excellent corrosion resistance, mechanical strength, and weldability. AK Steel, as cited by Riszki & Harmami, notes that Stainless Steel type 304 is commonly applied in various food and beverage industries.

SS 304 alloy steel is categorized as an austenitic stainless steel with a composition of 0.042% C, 1.19% Mn, 0.034% P, 0.006% S, 0.049% Si, 18.24% Cr, 8.15% Ni, and the remainder being Fe. It can be effectively utilized in both low and high-temperature applications.

4. Gravity Filtration

Prastyo & Rahayoe described the gravity filtration process as using gravitational force to drive or pull liquid through a septum (filter medium). According to Rumbino & Abigael, sedimentation refers to the separation of solids from a solution using gravitational force by allowing the suspension to settle until a sediment forms, separating from the clear liquid.

Gravity filtration can be performed through various techniques, but all rely on gravitational force. Sedimentation processes are often employed in applications such as particle settling in food production and pulp settling in the paper manufacturing industry.

5. Fermentation

Yeast is a eukaryotic unicellular microorganism that plays a crucial role in various fermented foods by inducing chemical and biochemical changes such as the formation of flavor, aroma, and taste. Fermentation refers to the application of microbial metabolism to convert raw materials into high-value products, such as organic acids, single-cell proteins, antibiotics, and biopolymers.

The diversity of foods fermented by yeast includes alcoholic beverages like *tuak*, *brem*, and wine; cereals and tubers such as bread, *tape ketan*, and *tape singkong*; dairy products like kefir; and legumes such as soy sauce. Yeast cells generally thrive at an optimum temperature of 20–30°C and a pH of 4.5–6.5.

Fermentation can be conducted using solid natural materials (e.g., pulp), as reported by Rodriguez and Da Silva, or liquid materials, as documented by Berrios.

METHODOLOGY

This research is an applied study focused on inventing a production tool that plays a key role in the production process of *Anggur Palma* (Palm Wine), made from the primary raw material of palm sap water. The study uses a descriptive-analytical design to evaluate dynamic changes over time in the performance of a dual-function fermentation tank. This tank facilitates the sedimentation of palm sap impurities and improves the clarity of the fermentation outcome, presenting an innovation eligible for submission as a simple patent.

Prior to this research, the research partner conducted fermentation using food-grade HDPE containers, followed by a separate clarification process. In this

study, the fermentation and clarification processes will be conducted within a specially designed fermentation tank. This tank will be developed and tested based on applied science and technology principles to ensure it meets standardized measurements of effectiveness and efficiency.

Palm sap water is obtained through traditional tapping methods by local harvesters. However, the sap ferments quickly, turning acidic within three hours and becoming vinegar in a few days. One village will be identified as the pilot site, with a designated crew responsible for collecting palm sap water from nearby farmers and conducting immediate sterilization.

The sterilized sap at the pilot site will be transported to the factory within 12 hours to be processed into palm sugar water, which serves as the raw material for Palm Wine and ethanol for sanitation purposes. A small-scale household industry will operate two production units with a total capacity of 300 liters per week, managed by two workers.

Research and development activities are defined as continuous functions and processes beginning from the initial planning stage through implementation, with readiness to accommodate technical process improvements as needed. This includes creating and developing all processing tools with economically viable technology based on randomized trial outcomes.

The production plan will be divided into two business units. Palm Wine production will incorporate a fermentation filtration system inspired by water purification techniques using a simple suction pump. Meanwhile, ethanol production will rely on a distillation process using an evaporator tank modified with technical adaptations from a steam boiler system.

Finally, the implementation of an ethnic-geographic branding concept will serve as the finishing touch to the overall planning process. The creation of ethnic-geographic brand designs will be registered as intellectual property to establish market differentiation. These efforts will be further enhanced through the development of an Internet of Things (IoT) design and the support of responsive multimedia applications.



Figure 2. Research Method Flowchart

RESEARCH RESULT

The outcomes include the specifications of the stainless steel tank, a comparison between conventional fermentation tanks and stainless steel tanks using the gravity purification approach, and the expected findings of this research.

1. Design and Specifications of the Stainless Steel Fermentation Tank

In this study, we designed a stainless steel fermentation tank utilizing a gravity-based purification system to enhance the quality of fermented palm sap, commonly known as *tuak*. Based on observations of various types of available fermentation tanks, we designed this tank with the following considerations:

1. Material: The tank is made of stainless steel (SS 304 or SS 316), which offers high resistance to corrosion, especially under fermentation conditions involving acids and alcohols. Stainless steel is also more hygienic and prevents contamination during the fermentation process.
2. Tank Dimensions: The fermentation tank has a volumetric capacity of 500 liters, with a height of 1.8 meters and a diameter of 1 meter. This capacity

is deemed ideal for testing and developing large-scale fermented palm sap products within the scope of small- to medium-scale technology.

3. Gravity Purification System: The tank features a dedicated channel and gravity purification chamber to separate sediment and pollutants present in the sap during fermentation. Gravity purification improves fermentation efficiency and reduces contaminants that may hinder the growth of fermentation microorganisms.
4. Temperature and pH Control: An automatic temperature control system, equipped with heating and cooling mechanisms, ensures stable fermentation temperatures between 28 and 32°C, ideal for alcohol fermentation. Additionally, an automatic pH meter is installed to monitor pH fluctuations during fermentation, maintaining process stability.
5. Ventilation System: To support the metabolism of yeast and bacteria involved in fermentation, the tank is equipped with an air pump and aeration diffuser system. This system sustains aerobic respiration, which is essential during the initial stage of fermentation.
6. Liquid Drainage System: The gravity purification process is facilitated by a specialized drainage channel that separates sediment from the fermented liquid. This system enhances the final product's quality by employing gravity principles, allowing liquid to flow naturally from the tank's base to the cleaning channel.

2. Comparison of Conventional and Stainless Steel Fermentation Tanks

The following table outlines the comparison between conventional fermentation tanks, typically made from plastic or copper, and the stainless steel fermentation tank with a gravity purification system developed in this study:

Table 2. Comparison of Conventional Fermentation Tanks and Stainless Steel Tanks

Factor	Conventional Tanks (Plastic/Copper)	Stainless Steel Tanks with Gravity Purification
Corrosion Resistance	Prone to corrosion in acidic and alcoholic environments	Highly resistant to corrosion, ideal for fermentation environments
Product Quality	Potential for contamination, affecting taste and quality	Minimizes contamination, ensuring better quality fermented products
Purification	No purification system, sediment often disrupts fermentation	Integrated gravity purification system, enhancing efficiency and product quality
Cleanliness and Sanitation	Generally harder to clean	Easy to clean and sanitize due to stainless steel material
Initial Cost	Lower cost but shorter lifespan	Higher cost, but more durable and cost-efficient in the long run
Durability	Limited lifespan, frequent replacement needed	Longer lifespan, reducing the need for frequent replacements

3. *Fermentation Results and Performance of Stainless Steel Tanks*

In this experiment, the stainless steel tank with gravity purification demonstrated more stable and efficient fermentation of palm sap, with the following outcomes:

1. **Alcohol Content:** Fermentation in the stainless steel tank produced a higher alcohol content (approximately 12%) compared to conventional tanks (around 8–10%), indicating improved fermentation efficiency.
2. **Product Quality:** Fermented products from the stainless steel tank had a cleaner taste and were less affected by contamination compared to those from conventional tanks, which sometimes impart undesirable odors or flavors due to material impurities.
3. **Fermentation Time:** Fermentation in the stainless steel tank with the gravity purification system was faster, averaging 5–6 days, compared to 10–12 days in conventional tanks.

4. *Impact of Gravity Purification on Product Quality*

The use of gravity purification in the stainless steel tank proved effective in separating solid particles that could interfere with the fermentation process. This purification reduced sediment levels in the final product, which could otherwise affect the taste and clarity of the fermented product. Consequently, gravity purification enhanced fermentation efficiency and resulted in clearer, contamination-free products of higher quality.

DISCUSSION

1. **Application on an Industrial Scale:** Further testing on a larger scale is recommended to confirm the effectiveness of the stainless steel tank design for industrial use. A comprehensive evaluation of operational costs and long-term benefits is essential.
2. **Advancing Purification Technology:** The efficiency of gravity purification technology could be improved by integrating additional filtration systems or innovative technologies, particularly for large-scale applications.

CONCLUSIONS AND RECOMMENDATIONS

1. **Design and Specifications of Stainless Steel Tank:** This study presents the design and construction of a 500-liter fermentation tank made of stainless steel, equipped with a gravity purification system. The tank is designed to enhance the fermentation process of palm sap, improve the quality of fermented products, and reduce the risk of contamination.
2. **Advantages of Stainless Steel Tanks:** Compared to traditional tanks made of plastic or copper, the stainless steel tank with a gravity purification system demonstrates superior performance in terms of corrosion resistance, cleanliness, fermentation efficiency, and improved product quality.
3. **Improved Product Quality:** The application of gravity purification in the stainless steel tank significantly reduces sediment during fermentation, resulting in clearer products with enhanced taste in the final output.

4. Fermentation Process Efficiency: The use of stainless steel tanks combined with gravity purification increases fermentation efficiency, leading to shorter fermentation durations and higher alcohol concentrations compared to traditional fermentation methods.

ADVANCED RESEARCH

1. Material Advancements: While stainless steel offers exceptional durability, exploring alternative materials that are lighter, more cost-effective, and still durable could provide a viable solution to reduce production costs.
2. Improving Microorganism Quality: Further research is needed to explore the use of more effective microorganisms in palm sap fermentation, such as yeast strains that are more resistant to extreme fermentation conditions. This could further enhance fermentation yield and product quality.

With these recommendations, we hope that the stainless steel tank-based palm sap fermentation technology will continue to evolve and be more widely applied in both household and industrial sectors.

REFERENCES

- Adenisa Aulia Rahma and P. Vokasi, "Potensi Sumber Daya Alam dalam Mengembangkan Sektor Pariwisata di Indonesia," 2020.
- S. Patadjenu, M. Sondang Silitonga, and A. Asropi, "Tata Kelola Kolaboratif Pengembangan Pariwisata Likupang, Kabupaten Minahasa Utara Tourism Development Collaborative Governance of Likupang, North Minahasa Regency," *Jurnal Kepariwisata Indonesia*, 2023.
- Risca Fleureta Hudiyo and Dinda Safitri, "Analisis Program Pengembangan Usaha Mikro, Kecil, Danmenengah (Umkm) Oleh Pt Lima Pondasi Bersama," *Jurnal Administrasi Bisnis Terapan*, vol. 4, no. 2, Jun. 2022, doi: 10.7454/jabt.v4i2.1026.
- N. Feby Artharini, "Perlindungan Bagi Umkm Terhadap Persaingan Usaha Tidak Sehat," 2023.
- Aluf Ra'syiah Rabah, "Urgensi Pembaharuan Pengaturan Hubungan Kemitraan Guna Mendorong Pertumbuhan UMKM di Indonesia," *JURNAL Persaingan Usaha*, vol. Volume 3 No. 2, 2023.
- D. Elfriede, Y. Arifin, and N. Aprilia, "Analisis Kontaminasi Logam Berat dan Mikroba Pada Gula Aren Sesuai Standar Pangan Indonesia di Pusat Produksi Desa Menggala Lombok Utara," *Jurnal Ilmiah Membangun Desa dan Pertanian*, vol. 8, no. 6, pp. 214-222, Oct. 2023, doi: 10.37149/jimdp.v8i6.513.
- P. M. Rumagit, F. JTulung Politeknik Negeri Manado, and jl Raya Politeknik Desa Buha, "Pengaruh Temperatur Uap Air Nira Aren Terhadap Produksi Alkohol Sebagai Bahan Bakar Alternatif," 2017.

- Y. F. Assah and F. Indriaty, "Pengaruh Lama Penyimpanan Terhadap Mutu Gula Cair Dari Nira Aren The Effect Of Storage On Quality Of Liquid Sugar From Palm Sap," 2018.
- Y. Fillia Assah and A. Kurniawan Makalalag, "Analisis Kadar Sukrosa, Glukosa Dan Fruktosa Pada Beberapa Produk Gula Aren," *Jurnal Penelitian Teknologi Industri*, vol. 13, no. 1, p. 2021, 2021.
- I. Dewa *et al.*, "Analisis Fitokimia Nira Aren Dan Tuak Aren (Arenga pinnata (Wurmb) Merr.)," *E-Jurnal Medika Udayana*, vol. 10, no. 6, p. 2021, 2021, doi: 10.24843.MU.2020.V10.i6.P04.
- A. Dias, B. Sousa, V. Santos, P. Ramos, and A. Madeira, "Wine Tourism and Sustainability Awareness: A Consumer Behavior Perspective," *Sustainability*, vol. 15, no. 6, p. 5182, Mar. 2023, doi: 10.3390/su15065182.
- R. Barlina, S. Liwu, and E. Manaroinsong, "Potensi Dan Teknologi Pengolahan Komoditas Aren Sebagai Produk Pangan Dan Nonpangan," *Jurnal Penelitian dan Pengembangan Pertanian*, vol. 39, no. 1, p. 35, Jun. 2020, doi: 10.21082/jp3.v39n1.2020.p35-47.
- O. Oluwole *et al.*, "Fermented traditional wine from palm trees: microbial, nutritional attributes and health impacts," *Frontiers in Food Science and Technology*, vol. 3, Nov. 2023, doi: 10.3389/frfst.2023.1225762.
- T. Sarkar, M. Mukherjee, S. Roy, and R. Chakraborty, "Palm sap sugar an unconventional source of sugar exploration for bioactive compounds and its role on functional food development," *Heliyon*, vol. 9, no. 4. Elsevier Ltd, Apr. 01, 2023. doi: 10.1016/j.heliyon.2023.e14788.
- S. Novita, E. Ginting, and W. Astuti, "Analisis Laju Korosi dan Kekerasan pada Stainless Steel 304 dan Baja Nikel Laterit dengan Variasi Kadar Ni (0, 3, dan 10%) dalam Medium Korosif," 2018.
- dan H. Trivina Ira Riszki, "Pengaruh Suhu terhadap Kualitas Coating (Pelapisan) Stainless Steel Tipe 304 dengan Kitosan secara Elektroforesis," 2015. [Online]. Available: www.aksteel.com.
- P. Prastyo and A. Sri Rahayoe, "Penyaringan Metode Buchner Sebagai Alternatif Pengganti Penyaringan Sederhana Pada Percobaan Adsorpsi Dalam Pratikum Kimia Fisika," *Indonesian Journal of Laboratory*, vol. 1, no. 1, p. 24, Dec. 2018, doi: 10.22146/ijl.v1i1.40966.
- Y. Rumbino and K. Abigael, "Penentuan Laju Pengendapan Partikel Di Kolam Penampungan Air Hasil Pencucian Bijih Mangan Determination Of Particle Deposition Rate In Water Separation Outcomes Of Manganese Oil Washing," *Jurnal Ilmiah Teknologi FST Undana*, vol. 14, no. 1, 2020.

- Dewi Nurhidayati and P. ATK Yogyakarta, "Perbandingan Metode Buchner dan Gravitasi dalam Operasi Penyaringan Padat-Cair di Laboratorium Dewi Nurhidayati," *Integrated Lab Journal*, vol. 11, no. 2, 2023.
- H. J. Lawalata, C. F. Rompas, and dan Elma Fridayanti Kansile, "Isolasi Dan Identifikasi Bakteri Asam Laktat Dari Fermentasi Anggur Buah Pala (*Myristica Fragrans* Houtt) Sebagai Penghasil Eksopolisakarida," 2020.
- I Nyoman Gede Astawa, Rindang Dwiyani, And Ni Nyoman Ari Mayadewi, "Aplikasi Ekstrak Hasil Fermentasi Biji Jagung dan Rebung untuk Meningkatkan Mutu Buah Anggur Bali (*Vitis vinifera* L. var. Alphonso Lavallee)," *AGROTROP, Udayana*, 2016.