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Diversification of Orange Fruit Processing into Zero Waste-Based Wine Products in Pengejaran Village, Kintamani, Bangli

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A B S T R A C T

Citrus fruits often experience overproduction, resulting in low prices, and even unmarketable fruit is frequently wasted. This innovation offers a sustainable solution through a zero-waste concept, where all parts of the citrus fruit, from the flesh and peel to the pulp, are optimally utilized. The program focuses on intensive training in producing high-quality orange wine, introducing proper fermentation techniques to create a high-value product. The orange peel and pulp, which are by-products of the winemaking process, are further processed into products such as jam, orange peel candy, or compost, so nothing is wasted. Community service not only provides farmers with new skills in creating innovative products but also teaches the principles of an environmentally friendly circular economy. The expected positive impacts include increased farmer incomes, new business opportunities, and more effective agricultural waste management, making Pengejaran Village a self-sustaining centre for processed citrus production.

Contribution to Sustainable Development Goals (SDGs):
SDG 8: Decent Work and Economic Growth
SDG 9: Industry, Innovation, and Infrastructure
SDG 12: Responsible Consumption and Production

1. INTRODUCTION

1.1. Research Background

As a village that produces tangerines (Citrus nobilis L.), Pengajaran faces challenges in the post-harvest process. Tangerines are susceptible to decay and damage [1]. Harvested tangerines are still undergoing life processes. Some important life processes in tangerines are respiration, transpiration, and fruit ripening. These biochemical processes degrade the tangerines' freshness, as evidenced by their appearance, weight loss, and reduced nutritional value [2]. Changes in the content of various substances that persist after harvest can reduce consumer appeal. Good-quality tangerines that meet standards are preferred by consumers and easily marketed. The quality of fruit sold outside the region must be maintained until it reaches consumers, requiring efforts to extend its shelf life [3]. Tangerine production challenges during harvest include lower selling prices and the lack of capacity to process them into marketable products.

Selling processed agricultural products as a marketing approach to support the tourism industry (e.g., Bali) requires a specific sales strategy [4]. This is intended not only to attract tourists to purchase processed agricultural products while travelling to Bali, but also to ensure that these products can compete with their counterparts [5]. One of the post-processing methods for citrus fruit is to develop it into wine [6]. Some of the health benefits of wine include preventing cancer, supporting brain health and memory function, supporting heart health, supporting dental and oral health, and lowering blood sugar levels.

Wine is made from fermented grapes or, sometimes, from other fermented fruits, so it is rich in antioxidants. Some factors that affect wine quality include citric acid content, pH, fixed acidity, and others. In addition to the content of the final wine, the quality of the wine can also be determined by the composition of the raw materials and the fermentation during fruit processing. Therefore, a safe, inexpensive, and easy-to-use manufacturing technique is sought that is applicable on a household scale [7].

Figure 1. Location Map of the Teaching Village

Given the market potential and demand for processed citrus products, particularly wine for health benefits, efforts are needed to master processing technology to develop new businesses and increase community income through various activities and platforms that bring residents together in Business Learning Groups. The combination of these two issues underscores the need for comprehensive interventions to educate housewives in Pengejaran Village about the health risks associated with plastic use and to increase the economic value of citrus. Health campaigns on the dangers of plastic, along with training in post-harvest technology and citrus processing to produce value-added products, such as wine, could be effective solutions to address these issues.

This community service program is designed to empower local communities to independently produce and market processed orange wine, thereby enhancing household income and overall family well-being. Funded by Warmadewa University in 2025, the program specifically targets housewives in Pengejaran Village, Bangli, to strengthen their skills, knowledge, and entrepreneurial capacity in managing local natural resources. By fostering an entrepreneurial mindset aligned with local conditions, this initiative is expected to generate sustainable business opportunities and contribute to significant improvements in community welfare and public health.

The priority issues faced by community partners in Pengejaran Village were identified within a broader regional context, encompassing challenges in natural resource management and the need to improve socio-economic well-being. One primary concern is the suboptimal utilization of the village’s abundant citrus agricultural potential. Despite relatively high production levels, citrus farmers frequently experience price volatility and significant post-harvest waste. In addition, emerging public health concerns highlight the need for innovative value-added products that offer both economic and health benefits.

In response to these challenges, the development of innovative citrus-based products—particularly through the processing of citrus into orange wine—was identified as a strategic solution. This approach not only increases the economic value of citrus crops and supports a zero-waste concept by reducing agricultural residues, but also introduces a functional beverage with potential health benefits. Consequently, the initiative addresses key partner priorities in Pengejaran Village, Bangli, including sustainable local resource utilisation, income diversification, and community health improvement.

The downstreaming of multidisciplinary research findings can be a driving force for comprehensive village progress. The orange wine development initiative in Pengejaran Village, Bangli, is not merely a product innovation, but rather a demonstration of the integration of various disciplines. In-depth research into the nutritional content of local Kintamani oranges, fermentation techniques that produce a safe, health-promoting product, and studies on managing production waste to create economically valuable products all contribute to improving the quality and quantity of village progress. Through this downstreaming, the potential of local natural resources is optimized, opening new economic opportunities for the community, raising awareness of the importance of health through natural products, and implementing the principle of sustainable zero waste. Thus, the development of this orange wine serves as a concrete example of how downstreaming multidisciplinary research can accelerate village progress in various aspects, from public health and the economy to environmental conservation.

The development of innovative products based on local natural resources, in this case Kintamani oranges, aligns with government efforts to increase the added value of agricultural products and promote the economic independence of rural communities. Furthermore, the focus on "zero waste" explicitly supports the government's agenda of environmental conservation and responsible community-level waste management. The linkage with the Key Performance Indicators (KPI) of Higher Education is realized through real contributions in increasing the relevance of study programs to the needs of society:

- KPI 2: Producing innovations that benefit society.
- KPI 3: Increasing the number of high-quality and impactful community service activities.
- KPI 4: This orange wine development activity has the potential to involve students in research and implementation, increasing research output and publications.
- KPI 5: Building sustainable partnerships with local governments and communities.
- KPI 7: Comprehensively supporting the achievement of the established KPI targets for higher education.

1.2. Literature Review

Pengejaran Village is located in Kintamani District, Bangli Regency, Bali Province. Geographically, Pengejaran Village is located midway between Mengening, Blantih, Selulung, and Catur Villages. The village covers an area of 666 hectares, comprising 222 hectares of dry fields and 444 hectares of forest. Pengejaran Village has a population of 811, comprising 416 men and 395 women. Most villagers work as farmers cultivating 150 hectares of fruit plantations, most of which produce tangerines. In addition to farming, some villagers work as traders selling agricultural products, daily necessities, and selling food.

Pengejaran Village in Kintamani, Bangli, is known for its abundant potential for citrus plantations. However, the citrus

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harvest often does not meet market standards, or orange peel waste is not optimally utilised, potentially creating environmental problems. Meanwhile, awareness of the importance of natural health and a sustainable lifestyle is growing in the community. This opportunity can be bridged through innovative citrus processing into value-added products that support health and zero-waste principles.

The development of orange wine in Pengejaran Village presents a promising innovative solution. In addition to the potential to create a unique beverage product with the health benefits of citrus, the production process can also be designed to minimize waste. Utilizing all parts of the orange, including the peel and pulp, is key to realizing the zero-waste concept. Therefore, this situational analysis indicates significant potential for the development of orange wine in Pengejaran Village, not only to diversify local products and improve the economy, but also to encourage better health practices and sustainable environmental management.

The primary target partners for the orange wine development initiative in Pengejaran Village, Bangli, consist of a group of local orange farmers with productive land and traditional knowledge of Kintamani orange cultivation. Data on this group includes an estimated membership of approximately 30-40 families, the total area of orange land they manage (perhaps 50-75 hectares), and the average yield per season (e.g., 5-7 tons per hectare). A village map showing the distribution of the farmers' productive orange land would be very informative.

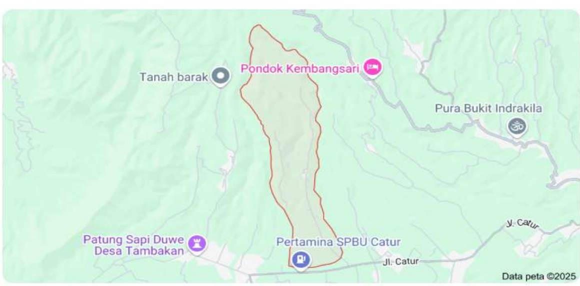

Figure 2. Map of the Pengejaran village area

Furthermore, orange harvest activities and portraits of farmer representatives provide a clear visualization of the partner's profile. The potential orange peel waste generated from this harvest is estimated to reach significant amounts (e.g., 2-3 tons per season), which is a key focus in implementing the zero-waste concept. The involvement of the Pengejaran village government is crucial in providing policy support, permits, and program facilitation. Relevant data include the village government's organisational structure, flagship village programs related to agriculture and the environment, and budget allocations for community empowerment.

1.3. Problems and Solutions

1.3.1 Problems

Pengejaran Village in Kintamani, Bangli, boasts abundant natural resource potential, particularly in the citrus farming sector. However, partners in this village face several regional challenges. In the agricultural sector, citrus production is often abundant during the harvest season, resulting in low selling prices and potential economic losses for farmers. Furthermore, the resulting orange peel waste is not optimally utilised, leading to environmental problems due to its accumulation.

In the health sector, the lack of diversification of processed citrus products has not significantly contributed to improving public health by maximising the nutritional potential of citrus fruits. Furthermore, the lack of innovation in local value-added products has contributed to the underdevelopment of the village's creative economy. In light of these regional challenges, particularly in the agricultural, economic, health, and environmental sectors, partners agreed to develop an innovative orange wine product.

Activities over the next three years will focus on several sub-issues. First, providing training and mentoring on safe and high-quality fermentation techniques and orange wine production to increase the added value of agricultural products and the community's economic potential and second, optimizing the use of orange peel waste as a supporting raw material or by-product in the wine production process, thereby contributing to zero-waste solutions and environmental conservation. Third, conducting outreach and education on the potential health benefits of moderate orange wine consumption to increase public health awareness. Thus, the development of this orange wine is expected to provide an integrated solution to agricultural, economic, health, and environmental issues in Pengejaran Village, Bangli.

1.3.2. Solutions

Recognising the priority challenges faced by target partners in Pengejaran Village, Bangli, including diversifying citrus agricultural products and managing waste from citrus harvesting and processing, the proposed solution is the development of an innovative citrus-based wine product.

This solution systematically addresses these two crucial issues. First, by processing citrus into wine, farmers and village communities have an alternative value-added product that can increase income and reduce dependence on fluctuating sales of fresh citrus. Second, the citrus winemaking process can utilise citrus peel and pulp waste as supporting raw materials or by-products, thereby significantly advancing the implementation of the zero-waste concept at the village level.

This development will be carried out through training, technical production assistance, and an integrated marketing strategy, ensuring sustainability and optimal positive impacts on public health through the potential antioxidant content of citrus wine, as well as improved environmental management through waste reduction.

1.4. Research Objective

1.1.1. Skills and Knowledge Enhancement:

Providing knowledge and skills to the community, especially citrus farmers, regarding techniques for diversifying citrus products, including fermentation processes and the production of safe and high-quality citrus wine.

1.1.2. Utilising Local Potential:

Optimising the use of abundant citrus harvests to ensure no fruit is wasted (zero-waste concept). This also includes utilizing leftover citrus peels for other products such as jam or preserves.

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1.1.3. Increasing Economic Value:

Creating new, high-value processed products, namely citrus wine, which can increase farmers' incomes and the overall local economy.

1.4.1. Strengthening Institutional Capacity:

Assisting community groups in establishing or strengthening micro, small, and medium enterprises (MSMEs) so they can independently and sustainably produce, package, and market citrus wine.

2. MATERIALS AND METHODS

2.1. Steps for Implementing the Proposed Solution

2.1.1. Socialization

This activity aims to comprehensively introduce the innovation of orange wine products to the village community. Through structured outreach programs, clear and engaging information will be disseminated regarding the health benefits of orange wine, its economic potential, and its role in supporting a zero-waste approach to citrus utilization. The outreach methods include direct, face-to-face discussions with community leaders and residents, the distribution of informative and user-friendly brochures, and the use of local communication media to broaden public engagement.

Through targeted, participatory outreach activities, the program seeks to build community awareness, understanding, and active involvement in the development of orange wine products. This process is expected to establish a strong social foundation that supports the effective implementation and long-term sustainability of the proposed solution in Pengejaran Village.

Figure 3. Socialization Activities

2.1.2. Training

The initial step in this training involves identifying and recruiting local villagers with an interest and potential to develop processed citrus products. This will then be followed by a series of comprehensive training sessions covering basic winemaking theory, hands-on practice in the fermentation and processing of citrus into wine, and aspects of quality control and safe, attractive product packaging. The training materials will also emphasise the importance of zero-waste principles, including the use of citrus production waste to produce economically valuable by-products or compost. Furthermore, the training will include case studies and visits to similar, successful businesses to provide participants with inspiration and practical insights. At the end of the training, there will be an evaluation session and ongoing mentoring to ensure participants can apply the knowledge and skills they have acquired, so that this citrus wine innovation can develop independently and have a positive impact on health and the environment in Pengejaran Village.

Figure 4. Training Activities

2.1.3. Application of Technology

Controlled fermentation technology will be implemented to ensure the quality and consistency of the resulting wine, while optimising fermentation by-products for further utilisation in line with the zero-waste principle. The production process will utilize efficient equipment and machinery to minimize resource use and reduce waste. Innovative, environmentally friendly packaging technology will also be selected to reduce the final product's environmental impact. Implementing a digital information and tracking system is also crucial for monitoring product quality, managing inventory, and ensuring supply chain transparency. Finally, digital marketing platforms can be used to reach a wider market and educate consumers about the health benefits and sustainability aspects of Kintamani orange wine.

2.1.4. Mentoring and evaluation

This mentoring process will be conducted through practical training, group discussions, and individual consultations to ensure effective transfer of knowledge and skills. Furthermore, periodic evaluations will be conducted to measure implementation progress, identify potential obstacles, and assess the impact of the orange wine innovation on public health and waste reduction in the village. The results of these evaluations will serve as the basis for adjustments and continuous improvement to achieve the desired goals: creating high-quality orange wine products that support health and a zero-waste ecosystem in Pengejaran Village.

2.1.5. Program Sustainability

Beginning with comprehensive outreach and education on the health benefits of orange wine and the zero-waste concept, the next step is intensive training and mentoring for selected

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community groups in safe, high-quality orange fermentation techniques, as well as in practices for managing production waste into value-added products such as compost or animal feed. Establishing an independent, legally incorporated production and marketing group will facilitate professional business management. Attractive, standardized product development and packaging are also crucial for market competitiveness. Furthermore, facilitating product licensing and certification will boost consumer confidence. To ensure long-term sustainability, the program needs to be supported by regular monitoring and evaluation, as well as diversification into other citrus derivative products to maximise the potential of local resources and minimise dependence on a single product. Finally, strategic partnerships with relevant parties such as local governments, academics, tourism players, and modern markets will expand marketing reach and support the program's economic sustainability.

2.2. *Concrete and complete stages to overcome the problem*

2.2.1. *Problems in the fields of Agriculture and Health*

First, an in-depth identification and analysis of the potential of local citrus resources in Pengejaran Village will be conducted, including varieties, quality, and availability. Simultaneously, a health study will be conducted on the potential benefits of moderate orange wine consumption, including antioxidant and vitamin C content, and an analysis of citrus agricultural waste to determine its volume and characteristics. Second, training and mentoring will be provided to citrus farmers on Good Agricultural Practices (GAPs) to improve crop quality and on processing citrus waste into compost or other valuable products. Third, the orange wine innovation and production process will be developed through research and development of appropriate formulas, involving food and health experts to ensure product safety and quality. This stage includes fermentation trials, production standardization, attractive packaging, and necessary permits. Fourth, outreach and education will be conducted for the Pengejaran Village community on the health benefits of orange wine and the importance of zero-waste practices, including the use of agricultural waste. Fifth, the marketing and distribution of orange wine products will be carried out in stages, both locally and more broadly, emphasising their health benefits and sustainability (zero waste). Sixth, regular monitoring and evaluation will be conducted to assess the impact of this program on public health, agricultural waste, and the local economy, ensuring long-term sustainability and effectiveness.

2.2.2. *Problems in the Environment and Economy*

Identification and detailed mapping of local citrus resource potential, including varieties, harvest seasons, and production volumes, are underway. The next step is the formation of farmer groups or cooperatives to drive this initiative, followed by intensive training in organic citrus cultivation techniques to improve yield quality and minimise environmental impact. In parallel, research and development of innovative citrus wine formulas with potential health benefits are underway, in collaboration with food experts or relevant universities. Once the right formula is found, the next step is to develop infrastructure for small-scale wine production in the village, including the procurement of standardised fermentation, packaging, and storage equipment. Legal and licensing aspects are also crucial, including obtaining permits for the production and sale of wine products. To support the economic aspect, a comprehensive marketing strategy needs to be developed, encompassing branding, attractive packaging, promotion through various channels (online and offline), and exploring collaborations with local markets, restaurants, and the tourism potential of Kintamani and Bali more broadly. To implement zero waste, wine production waste management must be planned from the outset, for example, utilizing citrus pulp as animal feed or compost. Finally, regular monitoring and evaluation of the economic, environmental, and health impacts of orange wine development are essential to ensure the program's sustainability and to make necessary improvements.

2.3. *Areas to be developed, steps taken to implement solutions to specific problems faced by partners*

Mapping the potential and specific challenges of partners, namely orange farmers and village communities. Identification revealed challenges such as fluctuating orange prices, underutilized orange peel waste, and growing awareness of the importance of natural health products. To address these challenges, strategic steps will be implemented. First, research and development of an orange wine formula will be conducted that not only has a unique flavor but also has the potential to provide health benefits, such as the antioxidant content of oranges. Second, training and mentoring will be provided to village communities, particularly farmer groups, regarding proper winemaking techniques, quality management, and attractive packaging. Third, a system will be established to collect and process orange peel waste into an economically valuable by-product, such as a raw material for organic fertiliser or craft products, thereby realising the zero-waste principle. Fourth, a comprehensive marketing strategy will be designed to leverage local potential and digital platforms to promote Kintamani orange wine as a superior, healthy, and environmentally friendly product. Through this holistic approach, it is hoped that the orange wine innovation will improve the welfare of the Pengejaran Village community, create a superior, competitive product, and manage natural resources sustainably.

2.4. *Evaluation of program implementation and program sustainability in the field after the activity has been completed.*

Aspects that need to be evaluated include the level of community adoption of orange wine-making practices, understanding and implementation of zero-waste principles in the production process and waste management, and the tangible impact on public health through consumption of this innovative product. The program's sustainability will depend heavily on active community participation, support from local government and community leaders, the availability of regional resources, and the ability to overcome challenges that may arise post-implementation. A thorough analysis of these factors will determine whether the orange wine development program can provide long-term health and environmental benefits in Pengejaran Village.

3. RESULT AND DISCUSSION

3.1. Socialization and Coordination Stage

The initial phase began with intensive meetings and discussions with village officials and community group representatives. This outreach aimed to introduce the economic potential of diversifying citrus products and to secure participants' commitment and support. The outcome of this phase was the formation of an enthusiastic target group ready to participate in all activities.

3.2. Technical Training Stage

This training is the core of the activity, where participants gain theory and hands-on experience in making orange wine. The material covered includes:

- Selecting quality raw materials (oranges).
- The fermentation process and the use of special yeast.
- Using simple technology to control temperature and humidity.
- Utilizing waste orange peel and pulp (a zero-waste concept) to process it into other products, such as preserves or animal feed. As a result, participants can independently make orange wine from start to finish and understand the importance of product cleanliness and standardisation.

3.3. Intensive Mentoring Stage

Following the training, the team provided ongoing mentoring to help participants apply the knowledge they had gained. This mentoring focused on:

- Troubleshooting during the production process.
- Improving product taste and quality.
- Recording the production process for standardization.
- Consistent application of the zero-waste concept. As a result, the target group successfully produced their first batch of orange wine with good quality and consistent flavor.

3.4. Marketing and Product Development Stage

This phase aims to help the community market their orange wine products. We provide training on:

- Digital marketing through social media and e-commerce platforms.
- Creating attractive and professional packaging.
- Determining competitive selling prices.
- Registering for Home Industry Food and Halal permits. As a result, orange wine products are becoming well-known in the local market, and several initial orders have been received, demonstrating promising market potential.

3.5. Evaluation and Reporting Stage

In the final stage, we conducted a comprehensive evaluation to measure the program's success. This evaluation included:

- **Economic Impact:** Increased income for the target group.
- **Program Sustainability**: The community's ability to continue independent production.
- **Social Impact**: Increased community skills and confidence in innovation. The evaluation results showed that the program successfully developed innovative products, created new economic opportunities for the community, and significantly reduced agricultural waste. This program has great potential for further development by the Pengejaran Village community independently.

3.6. Application of Technology and Innovation to Society

3.6.1. Relevance

Orange wine production is relevant to the Pengejaran Village community because they face the challenge of a bountiful harvest but insufficient market absorption. This results in many oranges going unsold and wasted, thus harming farmers. Through this Community Service Program (PKM), technology and innovation in processing oranges into wine introduce an effective solution to address this problem. This product diversification opens new opportunities and can increase the economic value of citrus fruits, ultimately stabilizing farmers' incomes.

3.6.2. Impact

Increased Sales Value of Agricultural Products: Farmers now have another option for processing their citrus fruit, beyond just selling it fresh. By turning oranges into orange wine, the selling value increases significantly, far exceeding the selling price of raw fruit.

Increased Farmer Income: This product diversification directly contributes to increased farmer income. Orange wine has a higher profit margin, thus stabilizing and even improving the economic well-being of farming families.

Reducing Agricultural Waste (Zero Waste): This processing method implements the zero-waste concept. Orange peels, pulp, and other residues no longer become waste that pollutes the environment. This waste can be processed into other by-products such as compost, animal feed, or essential oils, creating a sustainable production cycle.

Knowledge and Skills Transfer: This Community Service activity successfully transferred new knowledge and skills to the community. Residents, especially farmers and women in the Family Welfare Movement, now can produce orange wine from fermentation through packaging independently. These skills are valuable assets for developing new micro, small, and medium enterprises in the village.

Enhanced Promotion of Local Potential: Pengejaran Village now boasts a unique, high-value specialty product. Orange wine is not only a commercial product but also a new identity that can attract tourists, opening up opportunities for future agrotourism.

4. CONCLUSION

This community service activity has successfully implemented a zero-waste orange wine diversification program in Pengejaran Village, Kintamani, Bangli. This program significantly improved the knowledge and skills of the local community, particularly orange farmers, in processing grade C oranges into high-value products. Through training and mentoring, the community is now

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able to produce high-quality orange wine, from fermentation to packaging. The use of orange pulp waste as compost has also been successfully implemented, truly realizing the zero-waste concept. This not only reduces agricultural waste but also establishes a sustainable, environmentally friendly production cycle.

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