

Production of kombucha from citrus leaf waste to improve economy and health in Cigugurgirang KBB

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ABSTRACT

Cigugurgirang Village, located in Parongpong District, West Bandung Regency, has abundant citrus farming potential. However, the utilization of citrus leaf waste as a commodity with economic and health value remains very limited. In fact, citrus leaves contain bioactive compounds that have the potential to be used as raw materials for functional beverages such as kombucha. Kombucha, in addition to having high nutritional value, is also a fermented drink with strong market potential. This community service program aims to improve public health and economic independence by transforming citrus leaf waste into a functional kombucha product through the active participation of local farmer groups. The method used is a Participatory Action Research (PAR) approach combined with the Asset-Based Community Development (ABCD) approach, involving citrus farmer groups as the main partners. Data were collected through field observations, interviews, and Focus Group Discussions (FGD). The results showed that kombucha fermented for 8 days had the highest nutritional value and was most preferred in terms of taste, aroma, and color. Through a participatory assistance process and the utilization of local assets, the community is able to produce a functional kombucha beverage that not only supports health but also creates new environmentally friendly economic opportunities.

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1. INTRODUCTION

Cigugurgirang Village, located in the Parongpong District of West Bandung Regency, is an agrarian region with substantial potential for horticultural production, particularly in citrus fruits. Data from the West Bandung Agricultural Office in 2023 indicates that citrus cultivation in this area covers over 60 hectares, primarily consisting of tangerine and Siamese orange varieties. These commodities are more than just a source of household income; they represent a local economy built upon natural resource strengths (Akbar, 2020; Khoerunisa, 2020; Watawana et al., 2015).

In practice, however, citrus farming produces a significant amount of organic waste, specifically citrus leaves that have yet to be utilized effectively. These leaves are typically discarded or burned, which can lead to environmental degradation. Phytochemical research reveals that citrus leaves are rich in flavonoids, polyphenols, and essential oils, making them valuable raw materials for health-related

products and functional drinks (Coelho et al., 2020; Greenwalt et al., 2000; Jayabalan et al., 2014; Kumar & Joshi, 2016; Villarreal Soto et al., 2018).

Simultaneously, the residents of Cigugurgirang Village face health and nutritional challenges linked to modern lifestyles and dietary habits. A 2022 report from the Parongpong Health Center noted a high frequency of digestive complaints and fatigue among the productive age population. This suggests a need for functional food interventions, such as the development of kombucha, a fermented tea known for supporting gut health and the immune system (Mehta et al., 2012; Widyantari, 2020).

Given the potential of citrus leaves as a base for kombucha and the public demand for natural, sustainable health drinks, a community service initiative is essential. This program aims to empower the community by converting citrus leaf waste into functional kombucha through participatory guidance. By doing so, the initiative seeks to improve public health awareness while generating new economic opportunities based on local resources.

2. METHODS

The community service methodology was conducted in three distinct stages as shown in Figure 1, are pre-implementation, implementation, and post-implementation.

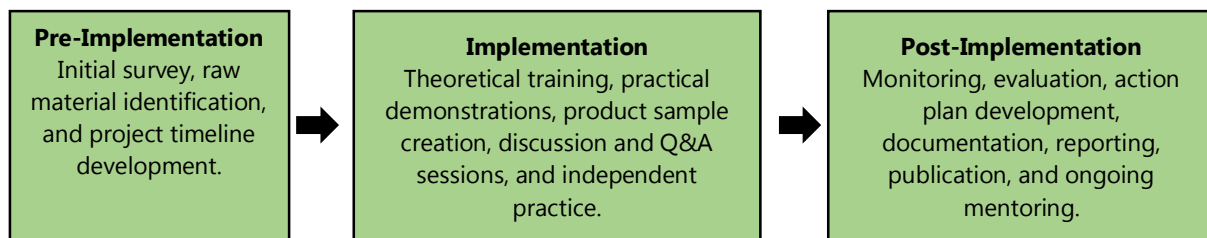


Figure 1. Community service activity methods

The operational planning matrix in this community service program is designed to facilitate a systematic and measurable implementation of activities. Each week includes tasks that support the program's objectives, beginning with planning and coordination, asset mapping, and community participation, followed by technical training and the initial production of functional kombucha drinks. The early stages focus on socialization, identifying local potential, specifically citrus leaf waste, and the active involvement of citrus farming groups as primary partners, utilizing the Participatory Action Research (PAR) method (Al-Kautsari, 2019; Harrison et al, 2019; Kretzmann & McKnight, 1993; Mathie & Cunningham, 2003; McTaggart, 1991; Xu & Maitland, 2017).

During the second month, activities shift toward capacity building through intensive training. Farming groups participate in workshops covering kombucha fermentation, raw material sanitation, packaging techniques, and branding. Necessary equipment and materials, such as fermentation jars, SCOBY starter cultures, and bottles, are distributed at this stage. Regular mentoring is provided by the service team and subject matter experts to ensure that skills are applied immediately. Initial evaluations are conducted by measuring active community participation and the achievement of basic skill targets.

By the third month, the focus moves toward guided production, strengthening the farming groups' organizational structure, and marketing simulations. Product promotion initiatives are also launched, including sales trials at local markets or village fairs. Within the matrix, each activity has a designated person in charge, detailed lists of tools and materials, cost estimates, and success indicators

such as increased capacity, active engagement, and the production of consumable goods. This planning ensures that the project remains efficient, adaptive to field dynamics, and sustainable after the program concludes.

Location and Partners

This activity was conducted across three locations: the Chemistry Laboratory of the Faculty of Science and Technology at UIN SGD Bandung for the data analysis of kombucha characteristics, the HAS Farm Hall in Cigugur Village for training sessions, and the Cigugur Village Posyandu for sample distribution and hedonic testing. The stakeholders involved, along with their characteristics and roles in this community service project, are detailed in Table 1.

Table 1. Related stakeholder

Stakeholder	Characteristics	Resources/Expertise	Program Requirements
Service Team (Lecturers & Students)	Academics with backgrounds in health, agriculture, and engineering; experienced in research and community service	<ul style="list-style-type: none"> - Knowledge of kombucha & fermentation technology - Expertise in PAR & ABCD methods - Access to laboratories & campus facilities 	<ul style="list-style-type: none"> - Active community participation - Local data - Adequate operational funding
Citrus Farming Group	Local farming community; strong farming skills but limited product innovation	<ul style="list-style-type: none"> - Access to raw materials (citrus leaves) - Strong local social networks 	<ul style="list-style-type: none"> - Technical kombucha training - Business & marketing knowledge - Basic production tools
Cigugur Village Government	Local government officials; deep understanding of community conditions	<ul style="list-style-type: none"> - Legitimacy & village policy support - Access to public facilities (village hall, population data) 	<ul style="list-style-type: none"> - Active community participation - Program success for resident welfare
Experts / Resource Persons	Practitioners or academics in fermentation, nutrition, and branding	<ul style="list-style-type: none"> - Expertise in kombucha fermentation - Knowledge of product branding & positioning 	<ul style="list-style-type: none"> - Participant commitment to learning - Facilities for hands-on or online training
Health Center / Health Institutions	District-level health services; understanding of residents' health status	<ul style="list-style-type: none"> - Knowledge of nutrition & kombucha functions - Public health data 	<ul style="list-style-type: none"> - Collaboration for health education - Validation of fermented product safety
Local MSMEs / Trading Partners	Small business owners; potential distribution partners	<ul style="list-style-type: none"> - Access to local/digital market networks - Experience in packaging & promotion 	<ul style="list-style-type: none"> - High-quality & consistent products - Long-term partnership with kombucha producers

Fermentation Design

In this project, the kombucha was prepared using a ratio of 75–100 grams of white granulated sugar and 10–15 grams of dried citrus leaves per 1 liter of water. The diameter of the SCOBY varied depending on the volume, ranging from 9–15 cm for 1 liter of water to 25 cm or more for 8 liters of water. It was critical to ensure the citrus leaf tea solution had cooled completely before adding the

SCOBY and the starter culture (100–200 ml). The fermentation process was carried out over a period of 0–12 days (F0–F6) with sampling conducted at two-day intervals (Antolovich et al., 2002; Fahilah et al., 2024; Hapsari et al., 2021; Hassmy et al., 2017; Karadag et al., 2009).

Test Parameters and Data Analysis

Laboratory analyses included the measurement of pH, total titratable acidity, reducing sugar levels, and total phenolic content using the Folin–Ciocalteu method (Blainski et al., 2013; Fadhilah et al., 2020). Organoleptic testing involved 25 untrained panelists utilizing a 5-point hedonic scale. Data were analyzed descriptively and statistically at a 95 percent confidence level ($P < 0,05$).

3. RESULTS AND DISCUSSION

Results

Survey, licensing, and identification of raw materials

The initial visit to Parongpong Village was received by the Village Head, Mr. Priana, who welcomed the collaboration aimed at maximizing village potential and human resources, particularly among the women in the local health center (*Posyandu*) networks. During this meeting, the Village Head outlined the region's existing potential, geographical conditions, and ongoing community activities. The community service team introduced the concept by presenting samples of the citrus leaf kombucha product.



Figure 2. Meeting with the Head of Parongpong Village

Geographically, Cigugurirang Village is situated in the Parongpong District of West Bandung Regency, encompassing an area of approximately 4.66 km^2 , which represents about 10.32 percent of the district's total territory. The village shares borders with several neighboring areas, including Cihideung to the north and east, Ciwaruga to the south, and Karyawangi to the west. The majority of the population earns their livelihood through farming. Additionally, the village has established itself as a destination for tourism and culinary experiences, featuring attractions such as Rumah Strawberry and Kampung Jeruk.

The community service team subsequently visited a local health center (*Posyandu*) in Cigugurirang Village, bringing samples of kombucha made from citrus leaves and fruit peel waste. These packaged samples were distributed to mothers who were present for their toddlers' routine growth monitoring. The recipients responded positively to the kombucha samples and actively contributed numerous ideas regarding additional plants that they believed would be flavorful and widely enjoyed.



Figure 3. One of the residents' citrus orchards has been developed into an agrotourism destination, known as HAS Farm

Kombucha drink making theory and practice training

Several residents of Cigugur Village, particularly the women, are already familiar with and have even produced fermented beverages such as yogurt, though many were not yet acquainted with kombucha. Consequently, the community service team conducted theoretical training by providing education to community members regarding the production of tea from various plants that can serve as a base for kombucha (Li et al., 2020). The educational materials included identifying plant species capable of neutralizing free radicals (Bhattacharya et al., 2011; Nimse & Pal, 2015), which function as antioxidants (Yadav et al., 2016) and serve as raw materials for making kombucha.



Figure 4. Theoretical presentation on kombucha ingredients and the production process

The response from the *Posyandu* mothers in particular, and the community in general, was remarkably positive and enthusiastic. Most participants showed a keen interest in kombucha products, as several residents were already accustomed to brewing herbal teas, specifically from tea leaves and soursop leaves. By introducing alternative botanical sources, especially citrus leaves and the abundant fruit peel waste, the community expressed hope in producing their own tea and kombucha for daily consumption.

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Kombucha is a fermented beverage where the fermentation process yields distinct flavor profiles over time (Neffe-Skocińska et al., 2017). To achieve a taste that is generally well-received, it is typically harvested on the 7th day. Consequently, the community service team provided samples of 6-day old kombucha for all participants to taste. The flavor, characterized by a balanced sweetness and a slight acidity, was favored by all training participants.



Figure 5. Training participants tasting the 6-day fermented kombucha prepared by the community service team

Throughout the training process, all participants were actively engaged. They participated in discussions and asked numerous questions regarding both the theory and the practical steps of kombucha production. Common inquiries included how to rejuvenate the SCOBY and the consequences of fermenting the liquid for more than 14 days. The session concluded with a group photo.



Figure 6. Group photo of the UIN Sunan Gunung Djati community service team with training participants from the Cigugurgirang Village Posyandu, Parongpong District, West Bandung Regency

Laboratory and organoleptic evaluation of kombucha beverages

Analysis of kombucha characteristics

The results of the chemical characteristics analysis, which include pH value, total titratable acidity, reducing sugars, and total phenolic content of citrus leaf kombucha across various fermentation durations.

The initial pH (pre-fermentation) and final pH (post-fermentation) of the citrus leaf kombucha decreased during the fermentation process, ranging from 5.1 to 1.95. This decline in pH is attributed to the growth and metabolism of the kombucha starter such as bacteria and yeast which results in an increase in organic acids (Neffe-Skocińska et al., 2017). According to Kombucha Brewers International,

the standard pH for kombucha ranges between 2.2 and 3.8. Therefore, the pH values that meet this standard were found from F2 to F5. As the fermentation duration increased, the total titratable acidity also increased. The total acidity of the citrus leaf kombucha tea was initially 0.31 percent at day 0 (F0) and rose to 1.16 percent by day 8 (F4). The total acidity determines the flavor profile and is a key quality indicator of the product. According to Kombucha Brewers International, the standard for total titratable acidity in kombucha tea ranges from 0.27 percent to 2.03 percent. In this study, the optimum total titratable acidity was obtained on the 8th day of fermentation (F4) at 1.16 percent.

Table 2. Chemical characteristics of lime leaf kombucha

Sample	Test Parameters			Total Phenol mgGAE/g
	pH Level	Total Acid	Reducing Sugar	
F0	5.10 ± 0.141 ^a	0.30 ± 0.000 ^e	27.99 ± 0.247 ^a	55.45
F1	3.85 ± 0.070 ^b	0.62 ± 0.000 ^d	20.72 ± 0.000 ^b	63.79
F2	3.60 ± 0.000 ^c	0.78 ± 0.000 ^{cd}	18.82 ± 0.247 ^c	71.42
F3	3.30 ± 0.141 ^d	0.93 ± 0.000 ^{bc}	16.08 ± 0.000 ^d	78.73
F4	2.90 ± 0.000 ^e	1.16 ± 0.106 ^a	14.88 ± 0.000 ^e	86.87
F5	2.50 ± 0.000 ^f	1.02 ± 0.106 ^{ab}	11.28 ± 0.240 ^f	69.71
F6	1.95 ± 0.070 ^g	0.86 ± 0.106 ^{bc}	9.05 ± 0.000 ^g	54.79

The initial reducing sugar level at day 0 (F0) was 27.99 percent, which began to decrease by day 2 (F1). As fermentation progressed, the reducing sugar levels continued to decline, reaching 8.95 percent by day 12 (F6). The best reducing sugar level was observed on day 8 (F4) at 14.88 percent, which correlates directly with the pH of the kombucha tea. Fermentation time significantly influenced the total phenolic content of the citrus leaf kombucha. The total phenolic content increased from an initial 55.45 mg GAE/g at day 0 (F0) to an optimal level of 86.87 mg GAE/g on the 8th day of fermentation (F4). Subsequently, the total phenolic content decreased during the 10th (F5) and 12th days (F6) of fermentation to 69.71 mg GAE/g and 54.79 mg GAE/g, respectively.

Organoleptic

Organoleptic testing analysis of the citrus leaf kombucha was conducted using a hedonic quality test. The hedonic quality testing involved 25 untrained panelists. The parameters observed included color, aroma, and taste. Color was observed using the sense of sight, aroma was identified through the sense of smell, and taste was identified through the sense of taste. Among all fermentation time variations, the kombucha harvested on day 8 (F4) was the most preferred by the panelists in terms of color, aroma, and taste.

Table 3. Organoleptic results of guava leaf kombucha

Sample	Parameters		
	Color	Scent	Flavor
F0	4.76 ± 0.436ab	3.12 ± 1.166c	3.64 ± 0.952cd
F1	4.84 ± 0.374a	3.20 ± 0.866bc	3.76 ± 0.779bcd
F2	4.84 ± 0.374a	3.68 ± 0.802ab	4.12 ± 0.600abc
F3	4.88 ± 0.332a	3.92 ± 0.812a	4.16 ± 0.688ab
F4	4.92 ± 0.277a	4.20 ± 0.913a	4.52 ± 0.653a
F5	4.68 ± 0.476ab	3.08 ± 0.909c	3.48 ± 1.005d
F6	4.56 ± 0.507b	2.20 ± 0.957d	2.36 ± 0.952e

Note: *) Values followed by different notations in the same row indicate significant differences (P<0.05). Assessment scores: (1) Dislike; (2) Slightly Dislike; (3) Slightly Like; (4) Like; (5) Like Very Much

Monitoring and evaluation of activities

Broadly speaking, there were no significant problems in the implementation of this community service activity. One aspect of monitoring kombucha production is the use of SCOBY, which cannot be made independently and must be purchased from online stores. While many sellers offer it at relatively low prices, this generates waste. This SCOBY waste can be utilized as fertilizer, although additional training is required to process it. The fermentation process in kombucha is also difficult to control; the process does not stop immediately at harvest, causing the acidity of the beverage to continue changing.

As an evaluation, the community service team provided further guidance and mentoring on replacing the SCOBY and suggested using it as a natural fertilizer for plants. Another challenge faced is the consistency of Posyandu members and the general community in continuing to consume functional beverages that are beneficial for health.

Discussion

The community of Cigugurirang Village, specifically the Posyandu administrators, successfully utilized citrus leaf waste to produce tea, which was then used as the raw material for kombucha. This beverage is highly beneficial for health; based on laboratory results, kombucha harvested on the 8th day (F4) has total acidity and reducing sugar levels that comply with SNI standards, as well as a high phenolic content (86.87 mgGAE/g).

These nutritional properties are beneficial for digestive health. This is consistent with reports from mothers received by Posyandu volunteers during toddler weighing activities. On average, they reported that after drinking the kombucha, not only was the taste refreshing with a balanced level of acidity and sweetness, but their stomachs also felt more comfortable compared to drinking regular tea or even yogurt, which can be too acidic. These findings are supported by organoleptic data showing that kombucha harvested on the 8th day (F4) was the most preferred by panelists in terms of color, aroma, and taste.

Residents who participated in the training applied their knowledge by making their own kombucha using SCOBY starters distributed by the team. This SCOBY can be used continuously as long as it is rejuvenated by replacing the starter liquid. The taste of this beverage is comparable to commercially available bottled teas and is nutritionally superior. Consequently, it can support family health as it is suitable for all ages. If packaged attractively, it could serve as a marketable beverage product.

Beyond the laboratory findings, this program demonstrated a social impact. Posyandu volunteers showed increased confidence in producing kombucha independently and expressed interest in small-scale commercialization. The integration of laboratory validation and participatory training reinforced community trust in the product's safety and quality. This indicates that combining scientific evidence with empowerment strategies enhances the sustainability and acceptance of functional food innovations at the village level.

4. CONCLUSION AND RECOMMENDATIONS

This community service program successfully demonstrated that citrus leaf waste can be processed into a functional kombucha beverage with optimal characteristics at 8 days of fermentation (F4), supported by both laboratory and organoleptic results. Participatory mentoring increased the community's knowledge and skills in fermentation technology and raised awareness of functional drinks. This program provides a model for the sustainable utilization of local assets that contributes to improving public health and community-based economic empowerment.

This community service activity can be carried out sustainably, with several points requiring attention, including the need for standardization of fermentation procedures to ensure consistent product quality. Furthermore, the development of packaging, branding, and digital marketing strategies is necessary. Facilitating halal certification and product safety permits (PIRT/BPOM) is also required so that the product can be marketed more broadly. Equally important is business incubation support to transform these activities into a sustainable micro-enterprise.

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