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Production of Flavored Kombucha with Butterfly Pea, Matcha, Rosella, and Local Herb Variants to Strengthen Functional Beverage Innovation among Micro, Small, and Medium Enterprises in Bukittinggi City

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ABSTRACT

Kombucha, a tea-based beverage fermented by a symbiotic culture of bacteria and yeast (SCOBY), has gained worldwide recognition as a functional beverage; however, its production among micro, small, and medium enterprises (MSMEs) in Bukittinggi City, West Sumatra, remained limited and largely unstandardized, even though the city receives a continuous flow of health-conscious domestic and international tourists. This community service program aimed to strengthen the capacity of local MSMEs to produce safe, standardized, and market-oriented kombucha with diversified flavor variants, namely butterfly pea (*Clitoria ternatea*), matcha, rosella (*Hibiscus sabdariffa*), and ginger–lemongrass. The program was held on 28 September 2026 in Bukittinggi and engaged five partner MSMEs and twenty-five participants through a participatory sequence of needs analysis, technology-diffusion training, hands-on practice of two-stage (primary and secondary) fermentation, quality control using pH and total soluble solids measurement, sensory evaluation, and guidance on packaging, labeling, and food-safety licensing. Average knowledge scores increased from 48.5 to 85.2 (a relative increase of 75.7%; normalized gain = 0.71, high category; Wilcoxon signed-rank test, $p < 0.001$), and 84% of participants (21 of 25) met the competency criterion in the practical assessment. All flavored kombucha prototypes had final pH values between 2.96 and 3.38, below the commonly recommended safety threshold of 4.2, and overall liking scores ranged from 6.2 (original) to 7.4 (butterfly pea) on a nine-point hedonic scale. Five new label designs were produced, and three of the five partner MSMEs initiated the home-industry food production permit (PIRT) process. Supporting factors included partner enthusiasm, locally available raw materials, and local stakeholder support, whereas limited fermentation and quality-control equipment, regulatory uncertainty, and the short training duration were the principal constraints. These findings demonstrate that integrating fermentation know-how, flavor innovation, food-safety control, and appropriate packaging can measurably strengthen the product quality and market readiness of functional-beverage MSMEs in tourism-oriented regional economies such as Bukittinggi.

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INTRODUCTION

Kombucha is a lightly sweetened tea beverage fermented by a symbiotic culture of acetic acid bacteria, yeasts, and, in some cases, lactic acid bacteria, commonly known as SCOBY. Over the past two decades it has moved from a household tradition to a rapidly expanding category of functional beverages in global markets (Kim & Adhikari, 2020). During fermentation, the microbial consortium converts sucrose into organic acids such as acetic and gluconic acid, together with ethanol in small quantities, carbon dioxide, vitamins, and a range of bioactive polyphenol derivatives (Jayabalan et al., 2014; Villarreal-Soto et al., 2018). The microbial community typically includes *Komagataeibacter* and *Acetobacter* species alongside yeasts such as *Brettanomyces* and *Zygosaccharomyces* (Marsh et al., 2014; Coton et al., 2017), and the resulting beverage has been reported to retain substantial antioxidant activity (Jakubczyk et al., 2020). At the same time, the evidence for health benefits in humans remains limited (Kapp & Sumner, 2019), so responsible product positioning should emphasize its character as a fermented, tea-based refreshment rather than make therapeutic claims.

Bukittinggi City, West Sumatra Province, is a leading tourist destination whose attractions, including Jam Gadang (the Clock Tower), Ngarai Sianok Canyon, and Pasar Atas (the Upper Market), draw a steady stream of domestic and international visitors. The city's food and beverage MSMEs are dominated by traditional Minangkabau products and by conventional drinks such as coffee, sweet tea, and *teh talua* (egg tea). Meanwhile, consumer interest in fermented and plant-based beverages is growing, which creates a diversification opportunity that remains largely untapped. Kombucha is an attractive option for small enterprises because it requires modest capital, relies on widely available raw materials (tea, sugar, and local herbs and flowers such as ginger, lemongrass, rosella, and butterfly pea), and lends itself to visually distinctive flavor variants suitable for souvenir and online markets.

However, preliminary observations and discussions between the service team and several prospective partners revealed that kombucha production in the city was mostly carried out at household scale without standardized procedures. Four priority problems were identified. First, producers had limited understanding of fermentation principles, SCOBY maintenance, and the factors that control fermentation time and acidity, particularly under the cool highland climate of Bukittinggi. Second, there were no standardized formulations or quality-control routines, which increases the risk of contamination, inconsistent acidity, and over-carbonation, hazards that have been highlighted in food-safety assessments of home-brewed kombucha (Greenwalt et al., 2000; Nummer, 2013). Third, skills in flavor diversification and product differentiation were minimal, so products were mostly sold as a single plain flavor. Fourth, awareness of packaging, labeling, halal, and licensing requirements was weak, including the issue of residual ethanol in fermented beverages, which is a particular concern for Muslim consumers (Majelis Ulama Indonesia, 2018; Republic of Indonesia, 2014). These four problems are interrelated and constrain the competitiveness and market readiness of potential kombucha products.

To address these problems, the service team proposed a community service program built on four components. First, technology-diffusion training on the principles of kombucha fermentation and hygienic production in line with the general principles of food hygiene (Codex Alimentarius Commission, 2020), designed according to the principles of diffusion of innovations (Rogers, 2003). Second, demonstration and hands-on practice of two-stage fermentation (primary fermentation and secondary flavoring fermentation), including simple quality control using pH and total soluble solids measurement. Third, mentoring in flavor formulation with butterfly pea, matcha, rosella, and ginger–lemongrass,

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followed by sensory evaluation. Fourth, mentoring in packaging, label design, and preliminary guidance on food-safety licensing and halal requirements. In line with adult-learning principles (Knowles et al., 2015), partners were active participants who prepared, observed, tasted, and evaluated the products themselves.

The intended outputs were as follows. First, an increase in participants' knowledge and skills in kombucha production, measured by pre-test and post-test scores and a practical skills checklist. Second, the availability of safe and acceptable flavored kombucha prototypes, evaluated by pH, total soluble solids, and sensory tests. Third, new, informative, and visually appealing label designs for at least one product of each partner MSME. Fourth, a follow-up action plan for obtaining PIRT permits and halal certification. By achieving these targets, food and beverage MSMEs in Bukittinggi are expected to diversify their product portfolio, expand market reach, and contribute more substantially to local economic growth grounded in the region's tourism potential.

METHODS AND IMPLEMENTATION

This community service activity was carried out in Bukittinggi City, West Sumatra Province, on 28 September 2026. It involved five partner MSMEs engaged in beverage, snack, and culinary production, represented by twenty-five participants consisting of business owners and workers with educational backgrounds ranging from secondary school to tertiary education and business experience ranging from less than one year to more than ten years. The activity comprised a preparation phase, a one-day training-and-mentoring phase, and an evaluation phase.

The implementation method consisted of several stages. The first stage was needs analysis and a preliminary survey in mid-September 2026, conducted through interviews and observation to map existing production practices, raw-material access, equipment, and market targets. The second stage was preparation. To allow a fully mature product to be used in a one-day format, the service team started a primary fermentation (F1) base on 18 September 2026 and prepared reference prototypes of each flavor variant through secondary fermentation (F2) starting on 25 September 2026. The third stage was technology-diffusion training in the morning session, covering kombucha microbiology and fermentation principles, SCOBY and starter management, hygiene and Good Manufacturing Practices, critical control points (pH, contamination, carbonation pressure), and an introduction to flavor chemistry and pigments of the selected ingredients, using lectures, interactive discussion, and demonstration videos. The fourth stage was hands-on mentoring in the afternoon session, in which participants directly practiced brewing the tea base, dissolving sucrose, cooling, inoculating with starter liquid and SCOBY, covering the vessels, and performing F2 flavoring and bottling, guided by the service team and students (Figure 1). The fifth stage was quality control and sensory evaluation of the reference prototypes. The sixth stage was mentoring on packaging, label design with simple design software, and consultation on food-safety licensing and halal requirements. The seventh stage was program evaluation.

The standardized F1 protocol used in the training was as follows: 1 L of water was brought to boiling, steeped with 5 g of tea (black or green) for 10 minutes, and sweetened with 80 g of sucrose. After cooling to below 30 °C, the tea was poured into a clean glass or food-grade vessel, mixed with 10% (v/v) mature starter liquid and a SCOBY pellicle, covered with a breathable cloth, and fermented at ambient temperature (approximately 20–26 °C in Bukittinggi) for 8–12 days until the pH was below 3.5. For F2, the SCOBY and part of the liquid were reserved as the next starter, and the remaining kombucha was

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strained, mixed with the flavoring materials listed in Table 2, bottled with 2–3 cm of headspace, and fermented for 48 hours before chilling at 4–5 °C. Participants were trained to discard any batch showing mold, to avoid metal contact with the acidic liquid except food-grade stainless steel, and to open pressurized bottles carefully.



[Figure 1. Documentation of the hands-on session: (a) measuring dried tea leaves, (b) brewing and stirring the sweetened tea base, (c) combining the cooled sweet tea with starter liquid in a fermentation jar, and (d) covering the jars with a breathable cloth for primary fermentation]

Evaluation consisted of four instruments. Knowledge was measured by a 100-point pre-test and post-test on four aspects and analyzed using the normalized gain (N-gain) (Hake, 1998) and the Wilcoxon signed-rank test. Practical competence was assessed by an observer using a ten-step checklist, with at least eight correctly executed steps defined as competent. The pH was measured with a calibrated digital pH meter and total soluble solids (TSS) with a hand refractometer, in triplicate. Sensory acceptance was evaluated by the participants as an untrained consumer-type panel using a nine-point hedonic scale (Peryam & Pilgrim, 1957; Lawless & Heymann, 2010). Finally, feedback interviews were held with partners about benefits and constraints. Materials and equipment included training modules, stainless-steel pots, glass fermentation jars, digital pH meter, hand refractometer, PET and glass bottles, labels, and label-design software.

RESULTS AND DISCUSSION

The program produced tangible outcomes that can be grouped into five aspects: improvement of participants' knowledge and skills, development and quality of flavored kombucha prototypes, improvement of packaging and labeling together with a preliminary business feasibility estimate, an initial understanding of regulatory and legality requirements, and the supporting and constraining factors. Each is described in the following subsections.

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Improvement in Participants' Knowledge and Skills

Pre-test and post-test measurements showed a significant improvement in participants' knowledge. The average pre-test score was 48.5 on a 100-point scale, indicating a low baseline understanding of fermentation and food-safety principles. After the training and mentoring, the average post-test score rose to 85.2, a relative increase of 75.7% and a normalized gain of 0.71 (high category). All twenty-five participants improved, and the difference was statistically significant (Wilcoxon signed-rank test, $Z = -4.37$, $p < 0.001$). Table 1 presents the scores by aspect.

Table 1. Comparison of Participants' Average Pre-Test and Post-Test Scores (n = 25)

Aspect Measured	Pre-Test	Post-Test	N-Gain	Category
Kombucha fermentation principles and SCOBY management	46.8	84.4	0.71	High
Hygiene, GMP, and food-safety control (pH, contamination)	52.4	86.0	0.71	High
Flavor-variant formulation (second fermentation)	44.2	88.0	0.78	High
Packaging, labeling, and legality (PIRT/BPOM/halal)	50.6	82.4	0.64	Medium
Average	**48.5**	**85.2**	**0.71**	**High**

Source: Processed data from participants' pre-test and post-test questionnaires, 2026

The largest gain occurred in flavor-variant formulation (from 44.2 to 88.0; N-gain 0.78), suggesting that this material was new to most participants yet readily understood through demonstration, tasting, and direct practice. The smallest gain occurred in packaging, labeling, and legality (N-gain 0.64, medium category), which is plausible given the number of administrative details involved. These results are consistent with the principles of adult learning, in which comprehension is optimized when material is delivered through authentic practical experience (Knowles et al., 2015). In the practical assessment, 84% of participants (21 of 25) achieved the competent category, and the most frequently missed steps were cooling the tea below 30 °C before inoculation and sanitizing the vessel before use, both of which are critical control points for preventing contamination.

Development and Quality of Flavored Kombucha Variants

Five kombucha variants were evaluated: an original control and four flavored variants. The F1 base reached a pH of approximately 3.2 after ten days, within the range commonly reported for kombucha (Jayabalan et al., 2014; Chakravorty et al., 2016). As shown in Table 2, the final pH of all variants ranged from 2.96 to 3.38, well below the threshold of 4.2 that is widely used as a safety criterion for kombucha production (Nummer, 2013). Total soluble solids were between 5.1 and 5.8 °Brix, reflecting residual sugar after fermentation and the contribution of the flavoring materials.

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Table 2. Characteristics and Sensory Acceptance of Kombucha Flavor Variants

Variant	Flavoring material (per liter)	Final pH	TSS (°Brix)	Overall liking (1–9)	Appearance
Original (control)	None	3.21 ± 0.04	5.4 ± 0.2	6.2 ± 1.3	Clear amber
Butterfly pea	5 g dried *C. ternatea* flowers	3.30 ± 0.05	5.1 ± 0.2	7.4 ± 1.0	Violet to magenta
Matcha	2 g matcha powder	3.38 ± 0.03	5.6 ± 0.3	6.9 ± 1.2	Opaque light green
Rosella	10 g dried *H. sabdariffa* calyces	2.96 ± 0.04	5.8 ± 0.2	7.1 ± 1.1	Deep ruby red
Ginger–lemongrass	15 g ginger and 10 g lemongrass	3.19 ± 0.05	5.3 ± 0.2	7.3 ± 1.0	Pale golden

Source: Processed data from reference prototypes (pH and TSS in triplicate; liking scores from 25 participants), 2026

Each variant had a distinct technical character. Butterfly pea produced the most striking visual appearance: its anthocyanin pigments (ternatins) are pH-sensitive (Lakshan et al., 2019), so the originally blue extract shifted to violet and magenta in the acidic kombucha, a color change that participants found attractive and that has strong storytelling value for tourist-oriented marketing. It obtained the highest liking score (7.4). Rosella contributed natural tartness, a deep red color, and phenolic compounds (Da-Costa-Rocha et al., 2014), and gave the lowest pH (2.96), so sweetness balance was important. Matcha produced an opaque green drink with a pronounced umami and slightly bitter profile (Koláčková et al., 2020); fine particles tended to sediment, so participants were advised to shake before serving, which partly explains its more moderate score (6.9). Ginger–lemongrass was well accepted (7.3) and is attractive because both ingredients are familiar in Minangkabau cuisine. The original control received the lowest score (6.2), mainly due to its strong acetic note, indicating that flavor diversification may help increase acceptance among consumers unfamiliar with kombucha. Because tea type also influences polyphenol profile and antioxidant capacity (Jakubczyk et al., 2020), the choice of base tea remains a variable for future optimization.

An important caution concerns the second fermentation. Sealed bottles can build up pressure, and kombucha can contain trace ethanol. Participants were therefore trained to use pressure-tolerant bottles, to leave headspace, to chill products after F2, and to open bottles slowly. Ethanol content was not measured in this program, and laboratory verification is recommended before the products are marketed, particularly in view of halal considerations (Majelis Ulama Indonesia, 2018).

Improvement in Product Packaging, Labeling, and Business Feasibility

Packaging and label design mentoring produced five new label designs, one for each partner MSME, each incorporating the mandatory information elements for processed food: product name and flavor, composition, net volume, producer name and address, production and best-before dates, and storage instructions, in line with the national regulation on processed-food labels (BPOM, 2018a). Because kombucha is a live-culture beverage, labels also carry a "keep refrigerated" instruction, a note that natural sediment or SCOBY fragments may be present, and a consumer advisory. The designs use colors and graphic motifs inspired by Minangkabau textile patterns and Bukittinggi landmarks, so that the products

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appear distinctive and appropriate for souvenir and online markets. Partners selected 250 mL PET or glass bottles as the initial pack size.

A preliminary cost analysis conducted with the partners estimated the cost of goods at approximately IDR 5,200 per 250 mL bottle (tea, sugar, flavoring, bottle, and label), compared with planned retail prices of IDR 15,000–18,000, which indicates a gross margin of about 65–71%. These figures are estimates that do not yet include labor, energy, cold storage, and distribution costs, and they should be validated through a pilot sales period.

Understanding of Regulatory and Legality Requirements

The legality session explained the requirements for the home-industry food production certificate (PIRT) (BPOM, 2018b), processed-food labeling, and halal certification under the national halal product assurance framework (Republic of Indonesia, 2014). A follow-up action plan was prepared for each partner, containing a checklist of administrative requirements, application stages, and a target timeline. Of the five partner MSMEs, three reported having begun document collection for the PIRT application by the end of the activity, while the remaining two were still consolidating their production-facility requirements. Because the eligibility of fermented beverages such as kombucha under the PIRT scheme may be subject to interpretation, partners were advised to confirm the category with the local District Health Office before submission. Full realization of the permits will require further time beyond the activity period.

Supporting and Constraining Factors

Several factors supported the program: the high enthusiasm and active participation of partners during demonstration and hands-on practice, the availability of tea, sugar, and local herbs and flowers, the growing interest in health-oriented beverages among tourists and urban consumers, and the support of local stakeholders that facilitated coordination. The involvement of students as technical assistants also strengthened knowledge transfer. On the other hand, several constraints warrant attention: limited availability of pH meters, refractometers, and cold-storage capacity at the MSME level; difficulty in obtaining healthy and consistent starter cultures; the cooler highland temperature that lengthens fermentation and complicates scheduling; uncertainty regarding regulatory classification and halal verification of ethanol content; and the short, one-day duration of the training, which means that some partners will need continued mentoring to maintain consistent quality.

Overall, the results demonstrate that combining fermentation know-how, flavor innovation, quality control, and appropriate packaging can produce measurable capacity-building effects for beverage MSMEs in Bukittinggi, across the dimensions of knowledge, product quality, packaging appearance, and awareness of legality. This is consistent with reports that fermented foods are a promising platform for value-added products (Marco et al., 2017). Several limitations should be acknowledged: the evaluation was conducted over a single day; the sensory panel consisted of untrained participants; shelf life, microbiological quality, and ethanol content were not measured; and market outcomes have not yet been observed. These aspects should be addressed in follow-up activities.

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CONCLUSION

This community service activity on kombucha production with butterfly pea, matcha, rosella, and ginger–lemongrass variants in Bukittinggi City was successfully implemented and yielded measurable outcomes. Pre-test and post-test results showed an increase in knowledge from 48.5 to 85.2 (normalized gain 0.71), and 84% of participants met the practical competency criterion. Flavored kombucha prototypes reached final pH values of 2.96–3.38 and were well accepted, with butterfly pea receiving the highest liking score. Five informative and visually appealing label designs were produced, and three of the five partners initiated the PIRT application process. The main supporting factors were partner enthusiasm, local raw materials, and stakeholder support, whereas the main constraints were limited quality-control and cold-storage equipment, regulatory uncertainty, and the short training duration. It is recommended that periodic follow-up mentoring be conducted, including laboratory testing of shelf life, microbiological quality, and ethanol content, facilitation of access to equipment and financing, and intensive guidance until PIRT and halal certification are fully realized, so that the competitiveness of functional-beverage MSMEs in Bukittinggi can be sustained over the long term.

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