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Enhancing Family Health Literacy Through Kombucha Fermentation Education at SMA Negeri 1 Kota Bangun, East Kalimantan

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A B S T R A C T
This community service program addressed a specific educational need among teachers and teachers' spouses at SMA Negeri 1 Kota Bangun, East Kalimantan, where 80% of the 30 participants entered the activity with limited knowledge of kombucha and no previous preparation experience. The program aimed to improve basic knowledge of kombucha and fermentation, develop practical skills in household-scale preparation, introduce locally accessible flavoring materials, and assess immediate changes in understanding and willingness to prepare kombucha at home. The findings indicate that combining scientific explanation with demonstration and direct practice can support immediate household food and health literacy. Because the evaluation measured immediate learning rather than long-term retention or product quality, future programs should incorporate validated individual-level assessments, follow-up evaluation, and basic physicochemical and microbiological monitoring.

INTRODUCTION

Fermentation is one of the oldest food-processing strategies and remains important for improving sensory characteristics, extending shelf life, and generating metabolites that differ from those present in the original raw materials. Kombucha is a fermented tea beverage produced from sweetened tea through the activity of a microbial consortium commonly referred to as a Symbiotic Culture of Bacteria and Yeast (SCOBY). The consortium generally contains yeasts and acetic acid bacteria, with lactic acid bacteria reported in some preparations. During fermentation, yeasts hydrolyze sucrose and metabolize the resulting sugars to produce ethanol and carbon dioxide, while acetic acid bacteria oxidize ethanol and contribute to the formation of organic acids such as acetic and gluconic acids (Villarreal-Soto et al., 2018; Jayabalan et al., 2014).

The resulting beverage contains organic acids, tea-derived polyphenols, microbial metabolites, and other compounds whose concentrations can vary with tea type, sugar concentration, microbial composition, temperature, oxygen availability, and fermentation duration (Villarreal-Soto et al., 2018; Leal et al., 2018). Recent reviews report antioxidant and antimicrobial potential associated with kombucha, but also emphasize variability in artisanal products and the need for stronger human evidence before health claims are generalized (Massoud et al., 2024; Prajapati et al., 2024). Accordingly, community education should present kombucha as a fermented beverage with potential functional properties rather than as a proven treatment or preventive therapy.

Household health literacy is particularly relevant to food preparation because family members make decisions about food selection, preparation, hygiene, storage, and consumption. However, information alone may not be sufficient when the intended outcome is a practical household skill. Education that integrates scientific explanation, demonstration, and direct practice can help participants connect a scientific concept with an observable process and a reproducible household procedure. Previous community-service programs involving kombucha have reported increased knowledge and interest in independent preparation after combining education, demonstration, and hands-on practice (Yunita et al., 2023; Chandra et al., 2023).

The present program addressed a specific educational problem among teachers and teachers' spouses at SMA Negeri 1 Kota Bangun, Kota Bangun Ulu, Kutai Kartanegara, East Kalimantan. The target group had limited exposure to kombucha fermentation as a household food-processing practice; this was reflected in the pre-test, in which 24 of 30 participants (80%) were categorized as having limited understanding and no previous preparation experience. Thus, the problem was not simply a lack of information about kombucha, but a combined gap in conceptual understanding and practical familiarity with fermentation procedures. The intervention was therefore designed around four linked needs: understanding the role of SCOBY and fermentation, recognizing the chemical basis of acidification and carbonation, learning a basic household preparation procedure, and understanding hygienic and safe handling practices. The use of telang flower and pandan was included to make the training locally relevant and

to demonstrate how familiar plant materials can be incorporated into formulation without presenting untested health claims.

The specific objectives were to: (1) improve participants' basic understanding of kombucha and SCOBY; (2) explain the biochemical basis of kombucha fermentation and the formation of organic acids and carbon dioxide; (3) provide hands-on training in first fermentation (F1) and an optional second fermentation (F2); (4) introduce locally accessible formulation options using telang flower and pandan leaves; and (5) evaluate immediate changes in participants' understanding and willingness to prepare kombucha independently at home. The contribution of this community service activity lies in integrating chemistry-based food education with practical household training and food-safety literacy, while explicitly distinguishing potential functional properties from clinically established health effects.

IMPLEMENTATION AND METHODS

Setting and Participants

The community service activity was conducted on 28 November 2025 at SMA Negeri 1 Kota Bangun, Kota Bangun Ulu, Kota Bangun District, Kutai Kartanegara Regency, East Kalimantan, Indonesia. A total of 30 participants consisting of teachers and teachers' spouses took part in the activity. The program used a one-group pre-test/post-test descriptive educational evaluation embedded within a participatory community-service training. The participants were involved in the full sequence of educational explanation, demonstration, hands-on preparation, discussion, and post-training evaluation. The activity was designed as a food-education intervention and not as a clinical or therapeutic intervention.

Training Team and Activity Structure

The introductory session on the scientific basis, potential functional properties, and preparation of kombucha was delivered by Dr. Winni Astuti, M.Si. The practical session was facilitated by Prof. Dr. Eva Marliana, M.Si., Ritbey Ruga, PhD, and Rita Hairani, PhD, with assistance from three undergraduate and master's chemistry students. The activity was implemented in seven operational stages: (1) opening and orientation; (2) explanation of kombucha, fermentation, SCOBY, and potential health-related properties; (3) administration of the pre-test before instruction; (4) demonstration of preparation; (5) guided hands-on practice; (6) question-and-answer and troubleshooting focused on common household-processing problems; and (7) administration of the post-test and reflection. This sequence was intended to move participants from baseline knowledge assessment to conceptual learning, procedural learning, supervised practice, and immediate evaluation.

Kombucha Preparation

The training used sweetened tea as the fermentation substrate and introduced telang flower (Clitoria ternatea) and pandan leaves (Pandanus amaryllifolius) as plant-based flavor and formulation variants. The general procedure was adapted from established descriptions of kombucha

fermentation, with household-scale simplification for training purposes (Villarreal-Soto et al., 2018; Coelho et al., 2020). The procedure was demonstrated step by step so that participants could observe the critical points affecting fermentation and household safety.

First fermentation (F1). Water was heated and used to brew tea, after which granulated sugar was dissolved as the fermentable substrate. The tea leaves or tea bags were removed, and the sweetened tea was allowed to cool completely to room temperature before inoculation. The cooled tea was transferred into a clean glass jar, followed by the addition of kombucha starter liquid and a SCOBY. The mouth of the jar was covered with a clean breathable cloth or tissue secured with a rubber band to allow gas exchange while limiting contamination. Fermentation was carried out in a shaded, relatively cool location for approximately 7–12 days, with sensory observation of the developing sour-sweet profile. Participants were instructed that the duration was a practical guide rather than a universal endpoint because fermentation rate and final composition depend on processing conditions.

Second fermentation (F2; optional). After F1, the fermented beverage was filtered and transferred into clean bottles. Plant-based flavoring materials such as telang flower infusion and/or pandan, as demonstrated during the training, could be incorporated according to the formulation prepared by the participants. The bottles were capped and kept at room temperature for approximately 1–3 days to promote natural carbonation and were then refrigerated to slow further fermentation before serving. Participants were specifically advised that pressure can accumulate during sealed secondary fermentation; therefore, clean bottles suitable for carbonated beverages and careful handling are essential. The training emphasized that household preparation should prioritize hygienic handling, controlled fermentation, and safe storage rather than relying only on taste or appearance.

Educational Evaluation

A simple one-group pre-test/post-test approach was used to evaluate immediate changes in participants' understanding. The pre-test was administered before the educational intervention, and the post-test was administered after the explanation, demonstration, practical activity, and discussion. The assessment addressed basic knowledge of kombucha, fermentation, SCOBY, preparation steps, and potential health-related properties. Participants were also asked about their willingness to prepare kombucha at home after the training. Before the intervention, 80% of participants (24/30) were categorized as having limited understanding and no previous preparation experience, while 20% (6/30) were categorized as understanding the topic. After the intervention, all 30 participants (100%) were categorized as understanding the topic, and 100% expressed an intention to try independent household preparation. Data were summarized descriptively as participant counts and percentages. Because individual-level scores, instrument validation data, and a longitudinal follow-up were not available, no inferential statistical analysis or claim of long-term learning retention was made. Participant engagement was

documented qualitatively from participation in demonstrations, hands-on practice, questions, and troubleshooting discussions.

RESULTS AND DISCUSSION

Implementation of the Training and Participant Engagement

All 30 participants attended the educational and practical components of the program. The implementation followed the planned sequence from orientation and scientific explanation to pre-test, demonstration, hands-on practice, discussion, and post-test/reflection. During the practical stage, participants asked questions about the role of sugar, the function of the SCOBY, fermentation duration, acid development, flavor incorporation, and safe handling. Facilitators used these questions to address critical household-processing points, particularly the need to cool tea before inoculation, maintain cleanliness, allow appropriate gas exchange during F1, and handle sealed bottles cautiously during F2. Thus, the activity did not merely provide information; it linked the underlying chemistry and microbiology of fermentation to observable preparation steps that participants could reproduce at household scale.



Figure 1. Documentation of the community service activities: (a) opening session and introduction to kombucha; (b) explanation of kombucha fermentation and its potential health-related properties; (c) demonstration of kombucha preparation; and (d) participant involvement in the preparation process.

The sequence of explanation, demonstration, and guided practice is consistent with experiential approaches used in previous community-service programs. Yunita et al. (2023) reported increased knowledge following kombucha and probiotic education that combined pre-test, education, post-test, and demonstration, while Chandra et al. (2023) described community training in which practical preparation was used to strengthen participants' familiarity with kombucha production. In the present activity, the value of the participatory

format lies in connecting conceptual knowledge with procedural knowledge: participants learned not only what kombucha is, but also why temperature, cleanliness, fermentation duration, and packaging matter. This distinction is important for household health literacy because knowledge that cannot be translated into safe practice may have limited practical value.

Baseline Problem and Immediate Learning Outcome

The baseline assessment identified the specific educational gap targeted by the intervention. Before training, 24 of the 30 participants (80%) were categorized as having limited understanding and no previous experience preparing kombucha, whereas 6 participants (20%) were categorized as understanding the topic. After the intervention, all 30 participants (100%) were categorized as understanding kombucha and its preparation. The proportion categorized as understanding therefore increased by 80 percentage points, from 20% to 100% (Table 1; Figure 2). All participants also reported willingness to try preparing kombucha at home after the training.

Table 1. Participants' Understanding and Willingness to Prepare Kombucha Before and After the Community Education Program

Outcome	**Pre-test**	**Post-test**	**Change**
Understanding of kombucha	20% (6/30)	100% (30/30)	+80 percentage points
Limited understanding / no previous preparation	80% (24/30)	0% (0/30)	−80 percentage points
Willingness to prepare kombucha at home	Not assessed	100% (30/30)	Not applicable

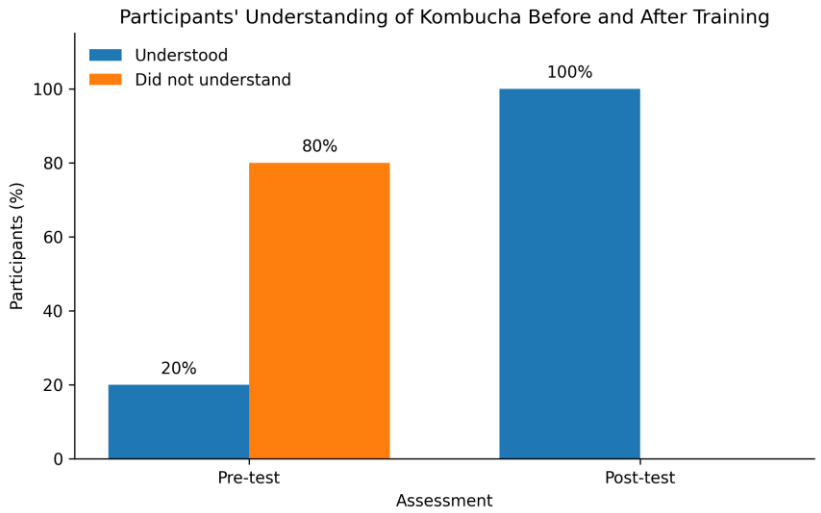


Figure 2. Change in participants' understanding before and after the kombucha training.

The immediate shift from 20% to 100% indicates that the intervention met its short-term educational objective within the limits of the evaluation design. The result is particularly relevant because the training targeted both a conceptual gap and a practical barrier: most participants had limited knowledge and no prior preparation experience at baseline. The combination of explanation, demonstration, and supervised practice plausibly supported learning by allowing participants to see the relationship between the scientific concept of fermentation and the physical steps required for household preparation. However, the result should be interpreted as immediate post-training understanding rather than proof of durable knowledge retention. Without individual pre/post scores and follow-up assessment, it is not possible to determine how much each participant improved, which learning components contributed most strongly to the outcome, or whether the knowledge was retained over time. Future programs should therefore use a validated or clearly scored instrument and conduct follow-up assessment after several weeks or months.

Scientific Interpretation of the Fermentation Process

The training was strengthened by explaining the chemistry and microbiology underlying the observed changes. In the sweetened tea substrate, yeast hydrolyzes sucrose into glucose and fructose and can metabolize these sugars through fermentative pathways to produce ethanol and carbon dioxide. Acetic acid bacteria subsequently oxidize ethanol to acetic acid under aerobic conditions. These linked metabolic activities contribute to acidification, the characteristic sour taste, and the development of carbonation during suitable secondary-fermentation conditions (Villarreal-Soto et al., 2018; Kumar & Joshi, 2016). For participants, this explanation provided a scientific basis for understanding why sugar is required, why the tea must be cooled before inoculation, and why oxygen availability differs between F1 and sealed F2.

The decrease in pH during fermentation is a consequence of organic-acid formation rather than simply a change in taste. Acetic acid is generally one of the dominant acids in kombucha, while gluconic acid and other organic acids may also accumulate depending on the substrate and fermentation conditions (Jayabalan et al., 2014; Villarreal-Soto et al., 2018). Recent literature emphasizes that acid concentrations vary with tea type, starter culture, fermentation duration, and other processing variables (Massoud et al., 2024). Consequently, the 7–12-day period used in the training should be understood as an operational guide for demonstration, not a fixed standard that guarantees a particular chemical composition or safety outcome. This interpretation strengthens the educational message by encouraging participants to understand fermentation as a dynamic biochemical process rather than a recipe with a universally fixed endpoint.

Tea also contributes polyphenolic compounds to kombucha. Fermentation can modify the chemical profile of tea-derived compounds and may influence measured antioxidant activity; however, the magnitude and direction of these changes depend on the tea substrate and fermentation conditions (Leal et al.,

2018; Coelho et al., 2020). Therefore, the program appropriately introduced kombucha as a beverage with potential functional properties rather than making disease-treatment claims. The chemistry discussion was intended to build scientific literacy and support informed household decisions, not to establish a therapeutic effect of the product prepared during the training.

Family Health Literacy: Potential Benefits and Evidence Boundaries

The health-oriented message of the program was based on the composition of kombucha and the broader literature on fermented beverages. Kombucha may contain organic acids, tea polyphenols, microbial metabolites, and microorganisms derived from the fermentation consortium. These components have been associated in experimental and review literature with antioxidant and antimicrobial activities, while gastrointestinal and metabolic effects have also been investigated (Leal et al., 2018; Massoud et al., 2024). For family health literacy, the important educational point is therefore not that kombucha guarantees a health benefit, but that participants understand what the beverage contains, how it is produced, and what uncertainties remain regarding health effects.

The available evidence does not justify describing kombucha as a substitute for medical therapy or as a guaranteed means of increasing immunity or preventing disease. Prajapati et al. (2024) highlighted the need for standardized production and additional clinical studies to validate many health-related claims, while recent reviews also emphasize substantial variability in composition and the need for stronger human evidence. Accordingly, the present program framed kombucha as one possible component of a balanced dietary pattern and food-literacy strategy, not as a therapeutic product. This cautious framing is especially important in community education because participants may otherwise interpret statements about antioxidant, antimicrobial, gastrointestinal, or metabolic potential as established clinical outcomes.

Local Formulation Options: Telang Flower and Pandan

The use of telang flower and pandan leaves was intended to demonstrate that kombucha can be adapted using plant-based ingredients that are familiar and accessible in Indonesia. Telang flower (Clitoria ternatea) is particularly useful for educational demonstration because its anthocyanin pigments produce a visually distinctive blue color and can respond to acidity. This visible response provides an accessible way to connect fermentation-induced acidification with an observable chemical phenomenon. Pandan (Pandanus amaryllifolius) was introduced primarily as a locally familiar aromatic ingredient. Because the activity did not include chemical analysis of the flavored products, no quantitative claim is made regarding changes in antioxidant capacity or other bioactive constituents caused by these additions. The educational value of these ingredients therefore lies in local relevance, sensory diversification, and demonstration of chemistry rather than in an unverified functional-health claim.

Household Food Safety and Quality Considerations

Food safety is an essential component of household kombucha education. Fermentation should be performed using clean equipment and safe water, and participants should avoid visibly contaminated cultures or beverages. The fermentation environment, duration, temperature, sugar concentration, and microbial composition can influence the final product, and artisanal kombucha can vary substantially in chemical and microbiological characteristics (Villarreal-Soto et al., 2018; Coelho et al., 2020). Because the present activity did not include physicochemical or microbiological testing, the training appropriately emphasized preventive household practices rather than certifying the safety of the products produced during the demonstration. For future training, routine pH measurement should be incorporated so that participants can monitor acidification rather than relying exclusively on taste or appearance. Secondary fermentation in tightly sealed bottles also requires caution because carbon dioxide accumulation can generate pressure.

These considerations are particularly relevant when kombucha is promoted as a family beverage. The desired outcome is informed household practice, including hygienic handling, controlled fermentation, appropriate refrigeration, and recognition of abnormal growth or spoilage. Accordingly, the activity integrates health literacy with basic food-science and food-safety literacy, which is more scientifically defensible than presenting kombucha simply as a "healthy drink." The safety component also provides a clear direction for subsequent community programs: participants should be trained to use simple monitoring tools, especially pH measurement, and future program evaluations should include objective quality indicators where feasible.

Willingness to Transfer the Practice to the Household and Study Limitations

Beyond the pre-test/post-test outcome, active questioning and direct participation provided qualitative evidence of engagement. All participants stated that they wanted to try making kombucha at home after the training. This intention is relevant to community empowerment because the intervention was designed to transfer a practical skill rather than merely deliver information. However, intention should not be interpreted as evidence of subsequent behavior. Future program development could include follow-up assessments to explore the continued application of participants' knowledge and skills in household kombucha production. Further evaluation may also incorporate individual-level learning data and basic physicochemical and microbiological assessments of the fermented products, providing a broader understanding of learning outcomes and product quality. These efforts would support the continuous improvement of community-based fermentation training.

CONCLUSIONS AND RECOMMENDATIONS

The community service program addressed a specific household food-literacy problem among teachers and teachers' spouses at SMA Negeri 1 Kota Bangun. At baseline, 80% of the 30 participants had limited understanding of kombucha and no previous preparation experience. After a structured sequence of scientific explanation, demonstration, hands-on practice, discussion, and

evaluation, 100% were categorized as understanding kombucha and its preparation, and all participants expressed willingness to try household preparation. These findings support the use of practice-oriented fermentation education to achieve immediate gains in knowledge and practical familiarity. The introduction of telang flower and pandan provided locally relevant formulation options and an accessible context for discussing fermentation chemistry. Nevertheless, further evaluation would be valuable to better understand the longer-term retention of knowledge, the potential application of learning in household practices, and the quality of the fermented products. Future programs could build on the current evaluation by incorporating clearly scored or validated knowledge instruments, individual-level pre- and post-intervention data, follow-up assessments, routine pH monitoring, and basic physicochemical and microbiological quality assessments.

Recommendation. For subsequent community training, a short validated knowledge questionnaire, individual-level pre/post scoring, follow-up after several weeks or months, and simple pH monitoring should be incorporated to strengthen evidence of sustained learning and safe household application.

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