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Enhancing Food Biotechnology Literacy through Informal Science Learning of Mozzarella Cheese-Making Workshop: A Case Study

Tiffany Safitri[1], Indriyani Rachman[2]*, Surti Kurniasih[3]
[1,3]Science Education, Post Graduate School, Universitas Pakuan, Indonesia
[2]Faculty of Environmental Engineering, Graduate School of Environmental Engineering, University of Kitakyushu, Japan

ABSTRACT

Biotechnology-based food processing holds strong potential to empower rural and peri-urban communities by enhancing local knowledge and skills. However, limited public understanding of its principles remains a significant challenge. This study aimed to evaluate the effectiveness of a community empowerment program focused on homemade cheese-making using biotechnology concepts. The activity was conducted through a hands-on workshop involving 20 participants aged 11–50 years, incorporating pretests and posttests to assess knowledge improvement, observation sheets to monitor engagement, and participant questionnaires. The results showed a high level of effectiveness, with an average normalized gain score of 0.78, indicating substantial improvement in understanding basic biotechnology. Feedback indicated that participants enjoyed the activity, gained confidence in applying the methods at home, and expressed interest in further food science workshops. The empowerment program facilitated not only science literacy but also community innovation, as seen in the use of household materials and local ingredients such as milk from nearby dairy farms. This study demonstrates that informal, context-based science education can successfully bridge knowledge gaps while fostering active participation. It suggests that similar initiatives focused on fermentation-based products may serve as a sustainable approach to community-based science learning and rural development.

ARTICLE INFORMATION

Keywords:
biotechnology; community empowerment; food processing; informal science education; rural development

Correspondent Author:
Indriyani Rachman

Email:
indriyani.rachman@unpak.ac.id

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INTRODUCTION

The limited public understanding of biotechnology-based food processing remains a persistent challenge in rural and peri-urban communities across Indonesia (Torres et al., 2006). Although traditional biotechnology practices—such as fermentation and natural acid coagulation—are embedded in many local culinary customs, their scientific foundations are often poorly understood by the general population (Saputra et al., 2023). In Indonesia, cheese consumption reached 89,478 metric tons in 2023, with approximately 85% of that comprising processed cheese, which is more widely available and familiar to consumers than natural cheese types such as mozzarella or cheddar (Kementerian Pertanian Republik Indonesia, 2023). This trend highlights not only the issue of limited access but also the general population's unfamiliarity with natural cheese and its health benefits, as processed cheese often contains preservatives, high sodium, and saturated fat that pose long-term health risks. Compounding this issue is the broader challenge of biotechnology literacy in Indonesia.

Afif et al. (2022) found that junior high school students scored an average of only 55.1 out of 100 in biotechnology literacy, with particularly low comprehension in interpreting basic statistics and understanding fermentation processes. The lack of access to science education in rural areas contributes to the misconception that cheese can only be produced using complex industrial

technology and imported rennet, raising additional concerns over halal status and affordability (Oštarić et al., 2022; Sitepu, 2020; Wibowo et al., 2020). Studies show that people engage in producing fermented or acid-coagulated foods, yet lack awareness of the biological and chemical principles involved (Imaduddin et al., 2020). In contrast, traditional biotechnology techniques using natural acids—such as lemon juice or vinegar—can effectively coagulate milk proteins like casein, offering safer, more affordable, and halal-friendly alternatives for household-level cheese production (Nayik et al., 2024; Nicosia et al., 2022; Rahma & Issustiarani, 2025; Wardhani et al., 2018). These simple, low-cost approaches align well with the principles of community-based food sustainability and can enhance domestic food security when introduced appropriately (Food and Agriculture Organization of the United Nations, 2019; World Health Organization, 2001). These gaps present an opportunity for introducing simple biotechnology education through food processing activities.

The Landbouw housing complex in Cipanas Village, located near the UKD Cipanas Dairy Farm, provides a suitable environment for local food processing initiatives. Despite the proximity to fresh milk sources, people—especially homemakers, teenagers, and early adults—have limited exposure to the principles of bioprocessing. Existing educational programs are scarce, and interventions that bridge biotechnology with everyday culinary practices are rarely implemented in low-resource rural households (Susanti et al., 2022). A preliminary observation conducted by the author in the Landbouw housing complex, Cipanas Village, revealed that although residents live near the UKD Cipanas Dairy Farm, most have never attempted home-based dairy processing. Informal interviews confirmed that the concept of homemade cheese was perceived as difficult or inaccessible.

Prior research has demonstrated that community-based training in local food processing can strengthen both nutritional awareness and scientific literacy when coupled with active participation (Queiruga-Dios et al., 2020; Sadler et al., 2016). Previous programs, such as Asriani et al. (2023), which introduced yoghurt-making to rural micro-entrepreneurs, demonstrated that hands-on, context-based bioprocessing training can significantly increase both interest and understanding among participants. These findings underscore the urgency and relevance of introducing practical, culturally appropriate biotechnology education through food-based interventions at the community level. However, many of these trainings are often limited to demonstrations rather than interactive, hands-on experience. Additionally, there is a lack of comparative learning involving different coagulants—such as lemon juice versus vinegar—even though their chemical actions significantly affect curd texture, acidity, and yield (Narayana & Palliyaguru, 2022; Wardhani et al., 2018).

To address these issues, we designed a one-day hands-on mozzarella-making workshop in collaboration with the Landbouw community. The training combined brief theoretical instruction with small-group experimentation, where participants used either lemon juice or vinegar to coagulate locally sourced milk. Participants were divided into four groups, allowing them to collaboratively observe and compare visual, textural, and procedural outcomes in the cheese formation process. Throughout the process—from milk heating to curd separation and tasting—emphasis was placed on inquiry-based learning and reflection. This initiative aimed to: 1) enhance foundational understanding of food-related biotechnology; 2) empower participants with practical skills for domestic dairy processing; and 3) increase appreciation for locally available resources such as milk from UKD Cipanas. The workshop also intended to promote safe, halal, and sustainable food practices grounded in scientific principles and aligned with community values (Mensah et al., 2024; UNESCO, 2020). This study offers a practical model for informal biotechnology education through hands-on dairy processing, highlighting its role in bridging science literacy and community empowerment.

METHOD

This community engagement program employed a community-based participatory model adapted from recent studies in informal food biotechnology education (Doustmohammadian et al., 2022). The activity was conducted at the Landbouw housing complex in Cipanas Village, Cianjur Regency, West Java, located near the UKD Cipanas Dairy Farm. The program took place on June 08, 2025, and lasted approximately 3 hours, divided into theoretical briefing, practical group work, and reflection sessions. Informal interviews with residents (n = 10) conducted prior to the program revealed limited knowledge of home-based dairy processing. Although fresh milk was accessible from the nearby UKD Cipanas Dairy Farm, most participants perceived cheese-making as an industrial process that required imported or unavailable ingredients. No prior training on food biotechnology had been delivered in this community.

Twenty participants (aged 11–54 years; 90% female) were selected purposively, focusing on homemakers, teenagers, and early adults interested in food processing or domestic cooking. The group was divided into four smaller groups of five members each to facilitate hands-on learning and observation. Data collection was conducted using three primary instruments: observation sheets, pretest-posttest questionnaires, and participant response questionnaires. Facilitators used the observation sheets during the practical session to document participant engagement, group interaction, and procedural accuracy throughout the cheese-making process. The pretest and posttest were administered to assess changes in participants' understanding of basic food biotechnology concepts, including the function of coagulants and the science behind milk protein coagulation. These instruments were tested for internal consistency, yielding a Cronbach's alpha score of 0.83. To evaluate participant satisfaction and perceptions, a response questionnaire was distributed at the end of the training. This instrument gathered feedback on the clarity of instruction, usefulness of the activity, and participants' interest in applying the learned skills at home.

The program structure consisted of three phases: briefing, guided experimentation, and discussion and reflection. The theoretical briefing introduced basic concepts of casein coagulation, halal considerations, and the role of acids in curdling milk proteins. Each group was assigned either lemon juice or vinegar as the coagulant and provided with the same volume of fresh milk (500 mL). Participants heated milk to 40–45°C, added the acid, and stirred until curdling occurred. Throughout the session, facilitators (including the author and the assistant) guided each group and documented the curd formation process. All participants completed feedback forms and participated in a group discussion comparing outcomes across treatments. Safety, hygiene, and halal compliance were emphasized during every step. Data analysis was conducted using a combination of quantitative and descriptive techniques, depending on the type of instrument employed. The results of the pretest and posttest were analyzed using the Normalized Gain (N-Gain) to evaluate the increase in participants' understanding of food biotechnology concepts. The N-Gain score was calculated using the formula from Hake (1998)—interpretation of the N-Gain criteria in Table 1.

Table 1. N-Gain criteria

N-Gain Interval	Category
≥ 0.70	High
0.30 – 0.69	Middle
< 0.30	Low

The observation checklist was developed by the researchers and inspired by community-based training models in informal science education, with indicators designed to capture collaborative, procedural, and hygienic competencies during practical activities. The structure of the instrument was

informed by experiential learning theory (Dewey, 1998; Kolb, 1984). Meanwhile, the participant response questionnaire, designed using a 4-point Likert-type scale (1 = strongly disagree, 4 = strongly agree), was analyzed using descriptive statistics, particularly the mean score and percentage distribution for each item. The questionnaire aimed to assess aspects such as instructional clarity, enjoyment of the activity, and motivation to replicate the practice at home. The indicators were adapted from Deros et al. (2012) and Verhougstraete et al. (2015) and modified for suitability in informal science education setting.

RESULTS AND DISCUSSION

The mozzarella cheese-making workshop successfully engaged participants in a meaningful science-based activity while promoting food biotechnology literacy in an informal education setting. The effectiveness of the workshop was measured using a pretest-posttest design, where the average N-Gain score was 0.78, indicating a high level of conceptual gain classified by Hake (1998). This finding demonstrates that informal science experiences, when designed with contextual and hands-on approaches, can substantially improve participants' understanding of scientific content (Kubheka & Photo, 2025; Tisza et al., 2020; Zhang et al., 2022). The inclusion of a comparative experiment using lemon juice and vinegar as coagulants provided participants with a deeper understanding of the biochemical process of milk coagulation, enhancing inquiry-based learning.



Figure 1. Participants in the Cheese-Making Activity

Figure 1 shows participants actively involved in the cheese-making process. Their high level of engagement was reflected in the post-workshop responses, where 97.5% of participants agreed that the activity was enjoyable and easy to follow, and 95% reported that they had learned how to make cheese at home. Moreover, 93.75% stated that the instructions were easy to understand (see Table 2). These results support the idea that inquiry-based, experiential learning fosters greater understanding and enjoyment of science concepts (Charles et al., 2024; Lozano & Solbes, 2021; Strat et al., 2024). The use of accessible, everyday materials such as lemon juice and household utensils helped demystify the process of cheese-making, making biotechnology feel relevant and approachable to participants. These outcomes demonstrate the potential of low-tech science interventions to foster confidence and scientific curiosity, particularly in non-formal educational settings.

Table 2. Post-workshop evaluation results (n=20)

Statement	Score (%)
I found this activity enjoyable and easy to follow.	97.5
I learned that cheese can be made at home.	95
The explanation of the cheese-making process was easy to understand.	93.75
I felt that the activity ended too quickly and was not very memorable.	66.25
I am interested in trying to make cheese at home again.	88.75
I think this workshop had nothing to do with science.	81.25
I gained a better understanding that science can be done in the kitchen.	91.25
I think this workshop was not beneficial for children.	62.5
I want to share this experience with my friends or family.	92.5
I want to participate again if there is another workshop like this in the future.	85

In line with this, Table 2 presents the post-workshop evaluation, showing that most participants perceived the workshop as relevant, comprehensible, and empowering. For instance, 88.75% expressed interest in making cheese at home again, and 91.25% agreed that science could be done in the kitchen, indicating a positive shift in their perception of science as accessible and practical. This aligns with findings from the National Research Council (2015), which emphasized that informal science learning environments are effective in increasing interest and identity in science. Observational checklists were completed for 20 participants divided into four groups during the practical sessions. Two groups used lemon juice as the coagulant, while the other two groups used vinegar (acetic acid). Observations revealed that curds formed with lemon juice tended to be softer and more fragile, often disintegrating during handling, whereas curds produced with vinegar were firmer and more cohesive. This difference in curd texture can be explained by the distinct acidification and coagulation properties of citric acid versus acetic acid, as supported by studies in dairy science (Wardhani et al., 2018). Citric acid's lower pH and different ionic interactions result in a looser protein network, affecting curd firmness (Ellwanger et al., 2024). Figure 2 shows the final cheese products made by participants. The visual success of their creations likely contributed to their confidence and satisfaction. This is corroborated by Santos et al. (2025) and Strat et al. (2024), who found that tangible outcomes in informal science programs significantly enhance participants' self-efficacy and willingness to engage further with scientific practices.

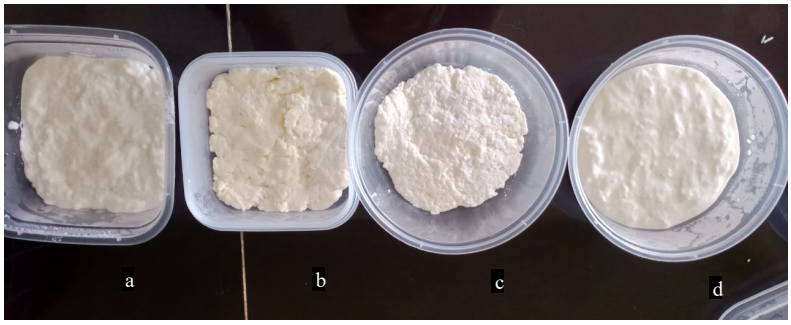


Figure 2. Cheese Product Made with Lemon Juice (a, b) and vinegar (c, d)

Figure 3 illustrates the aspects of the activity that are most appreciated. Notably, 30.43% of participants enjoyed directly making the cheese, and another 30.43% appreciated witnessing the cheese curd formation, highlighting the importance of concrete, hands-on experimentation in enhancing engagement. These findings align with those of Kuhlmann et al. (2024) and Munna and Kalam (2021), who noted that active participation in the scientific process leads to deeper cognitive

and emotional engagement with science. Such sensory-rich activities not only enhance memory retention but also promote positive attitudes toward science and increase self-efficacy in applying scientific concepts in daily life (Fuccio et al., 2025; Zhang & Song, 2022).

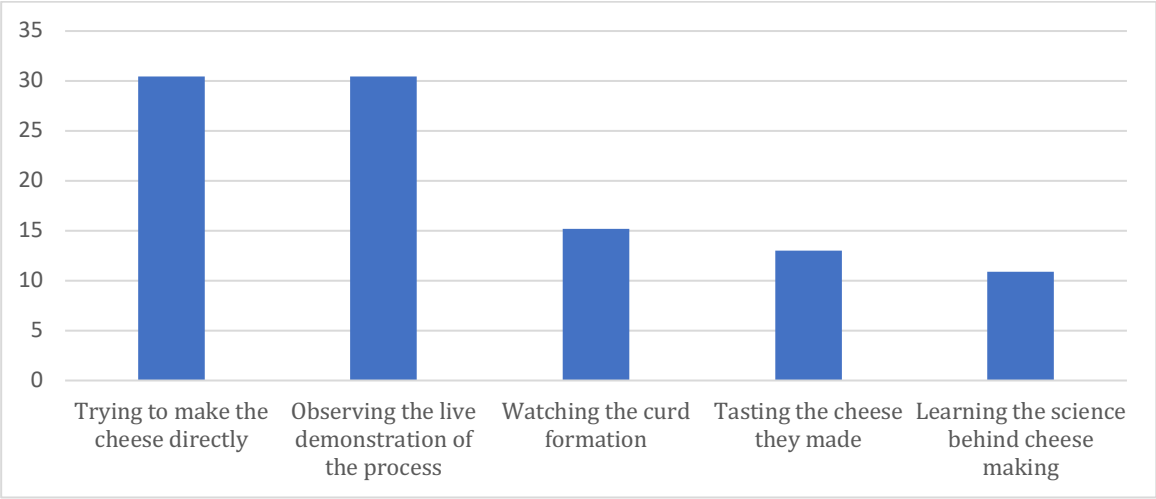


Figure 3. Most appreciated aspects of the workshop

Regarding future intentions, as presented in Figure 4, 40% of participants planned to recreate the cheese-making process at home, and 28.57% expressed their intention to share the experience with friends and family. These responses indicate not only individual empowerment but also the potential for science communication ripple effects within participants' social circles, a phenomenon also discussed in Rayhan (2023). Therefore, community-based science interventions, even when brief and informal, can initiate sustainable behavioral shifts and grassroots-level science dissemination. Such peer-to-peer sharing has been identified as a critical pathway for expanding science literacy beyond formal educational settings (Windsor et al., 2021).



Figure 4. Participants' intentions after the workshop

Additionally, when asked about future workshop topics (Figure 5), 53.13% of respondents selected homemade yogurt, followed by healthy chocolate and kitchen-based soap making. These preferences suggest that participants are not only interested in continuing science-based culinary experiences but are also seeking to explore themes of health, sustainability, and everyday science. Resonates with Trott and Weinberg (2020) and King and Ritchie (2012), who emphasize that science programs rooted in real-life contexts and sustainability issues yield stronger engagement and retention of knowledge. These results highlight the opportunity to co-design future informal science

programs with communities, ensuring that topics remain relevant, culturally meaningful, and driven by local interest (Durall et al., 2021).

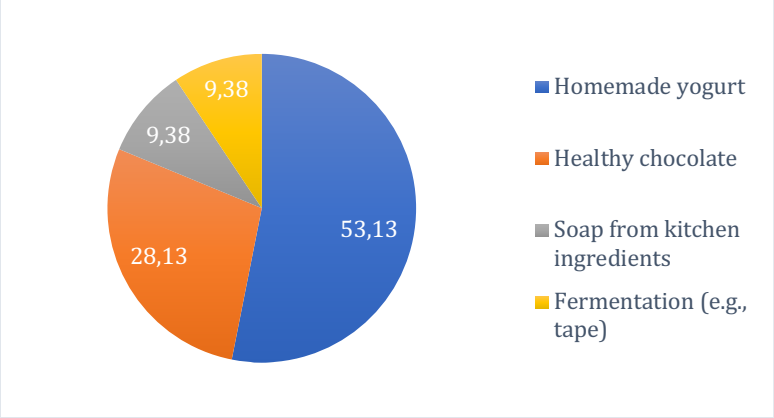


Figure 5. Preferred topics for future workshops

The community's high level of interest and knowledge gain, combined with their desire to replicate and share the activity, demonstrates the potential for empowerment through informal science education. The results show a successful shift from passive knowledge receivers to active learners and communicators of science (Ang et al., 2021). However, some participants noted the session was too short or not memorable enough (66.25%), which suggests that future iterations should allow for longer engagement time and possibly include additional reflective or creative components (e.g., journaling or recipe innovation). Integrating participant feedback into program design not only enhances the learning experience but also reinforces a sense of ownership and relevance, which are key drivers of sustained science engagement in community settings (Zhang & Hyland, 2022).

CONCLUSION

The mozzarella cheese-making workshop successfully achieved its objectives by significantly improving participants' understanding of food biotechnology, as reflected in the high average N-gain score of 0.78. Delivered through hands-on, inquiry-based methods in an informal community setting, the activity effectively addressed barriers such as low biotechnology literacy and lack of exposure to scientific practices in daily life. Participant responses showed high levels of enjoyment, comprehension, and motivation to replicate and share the activity at home, indicating both personal empowerment and the potential for broader dissemination of science literacy through peer networks. The initiative also demonstrated that simple, culturally relevant biotechnology applications using local materials can serve as powerful tools for community engagement and education. Beyond knowledge gain, the activity fostered confidence, curiosity, and a sense of ownership among participants, making science more accessible and meaningful. Moving forward, similar programs should be expanded to include a broader range of biotechnology topics, with extended engagement time and integrated feedback loops to ensure continuity, local relevance, and long-term impact.

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