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Empowering Farmer Communities through Coffee Husk Utilization: Training on Organic Fertilizer and Fermented Livestock Feed Production in Desa Wanagiri, Bali

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A B S T R A C T

The increasing volume of coffee husk waste in rural production centres has become a significant challenge to environmental sustainability. In Desa Wanagiri, Bali, coffee processing generates large amounts of husks that are often discarded or burned, resulting in soil and water pollution. This community empowerment program was designed to transform coffee husks into valuable products through training and practice in organic fertiliser production and the formulation of fermented livestock feed. The activities were carried out in three integrated stages: preparation, training and practice, and mentoring and evaluation. Farmer groups were trained to produce organic compost using bio-activators and to formulate fermented feed from coffee husks enriched with bran and mineral supplements. The results indicate that 100% of participants successfully applied the techniques, with 90–95% retaining the knowledge delivered during training. Approximately 95% of farmers tested fermented feed on their livestock and confirmed its safety, while 90% applied compost to their crops and observed improvements in soil structure and plant growth. Despite some technical challenges, all respondents expressed a strong commitment to continuing the practices. Beyond technical outcomes, the program fostered knowledge sharing, increased community cohesion, and opened opportunities for additional household income.

Contribution to Sustainable Development Goals (SDGs):
SDG 2 - Zero Hunger
SDG 12 - Responsible Consumption and Production
SDG 15- Life on Land

1. INTRODUCTION

1.1. Research Background

Coffee is one of Indonesia's most strategic plantation commodities, contributing significantly to the national economy and the livelihoods of farming communities in major production centers. Bali Province, particularly Buleleng Regency, is among the most productive regions for smallholder coffee cultivation. High levels of coffee production are accompanied by an increasing volume of husk waste, which can account for 40–45% of the fresh fruit weight. The accumulation of this waste may

cause soil and water pollution, unpleasant odors, and increased greenhouse gas emissions if not properly managed [1], [2].

Coffee husks contain lignocellulose, protein, fat, and essential minerals such as potassium and magnesium, making them a high-value biomass material [3]. This potential underlines the need for processing into useful products, one of which is organic fertilizer through composting. Coffee husk compost has been reported to increase soil nitrogen, phosphorus, and potassium content, improve cation exchange capacity, and support the productivity of horticultural and plantation crops [4], [5]. Other studies have shown that the application of coffee husk compost helps maintain soil moisture, suppresses weed growth, and improves soil structure [6]. Innovations in composting processes continue to evolve, such as combining husks with a solid decanter enriched with EM4 to accelerate decomposition [4], [7]. The adoption of such simple technologies supports the availability of organic fertilizers while reducing farmers' dependence on synthetic chemical fertilizers.

In addition to serving as fertilizer, coffee husks can also be utilized as livestock feed after undergoing fermentation. The high fibre, lignin, and caffeine content limit their direct use; however, fermentation offers a solution by increasing crude protein content, reducing fibre levels, and improving feed digestibility. This process produces feed that is safe for both ruminants and poultry and can enhance weight gain and feed efficiency [8], [9].

The utilization of coffee husks for organic fertilizer and fermented feed aligns with the principles of zero-waste agriculture. This system emphasizes the reintegration of agricultural by-products into productive inputs, thereby improving resource efficiency and reducing environmental pollution [10]. The concept also supports the green economy agenda, which promotes energy efficiency, carbon emission reduction, and the generation of added value from agricultural waste. Recent studies highlight that utilizing coffee husk biomass can reduce CO_2 emissions by up to 72% while also creating new economic value for farming households [3], [11].

Transforming coffee husk management into value-added products generates multidimensional impacts. Environmentally, this practice reduces waste accumulation and mitigates pollution. Economically, it creates opportunities for new enterprises based on organic fertilizers and fermented livestock feed. Socially, it strengthens community solidarity, enhances skills, and facilitates knowledge sharing among farmer groups. Evidence suggests that the success of agricultural waste management programs is strongly influenced by active community participation and continuous mentoring support.

The urgency of coffee husk utilization has increased alongside rising coffee production and the limited capacity of farmers to manage waste. Training and practice in processing coffee husks into organic fertilizers and fermented livestock feed represent strategic steps to empower farmers. These activities not only address environmental challenges but also improve household income, strengthen food security, and support sustainable agricultural development in Wanagiri Village.

1.2. Literature Review

1.2.1. Characteristics of Coffee Husk Waste

Coffee processing generates solid waste in the form of husks, which account for 40–45% of the total weight of the fruit. Coffee husks contain lignocellulose compounds, protein, fat, and essential minerals such as potassium, calcium, and magnesium, as well as several bioactive compounds. Their high organic matter content makes them a valuable resource for conversion into value-added products, although the presence of lignin, caffeine, and tannins may limit direct utilization [12], [13]. If not managed properly, the accumulation of husks poses significant environmental risks, including soil and water pollution, as well as the release of greenhouse gases. Developing sustainable agricultural strategies for husk utilisation has therefore become a pressing need in coffee production centres.

1.2.2. Utilization of Coffee Husk as Organic Fertilizer

The potential of coffee husks as an organic fertiliser has been widely recognised due to their rich nutrient composition. Composting reduces lignin levels, stabilizes organic matter, and enhances the availability of essential nutrients [14], [15]. Coffee husk compost enhances soil nitrogen, phosphorus, and potassium levels, while also increasing cation exchange capacity. The application of husk-based compost has produced crop growth comparable to that of inorganic fertilisers, thereby reducing farmers' dependence on external inputs.

The use of coffee husk compost also improves soil structure. Its application maintains soil moisture, enhances porosity, and suppresses weed growth, all of which are critical for sustaining productivity in dry or marginal lands. Enriching compost with bio-activators or combining it with other organic matter, such as livestock manure, further improves quality and accelerates decomposition [16]. Organic fertilizers derived from coffee husks align with efforts to reduce reliance on synthetic fertilizers, which are known to contribute to soil degradation and environmental pollution. Diversifying organic fertilizer sources from agricultural residues supports environmentally friendly farming systems while reducing production costs. Hence, the use of husk-based compost provides not only ecological but also economic and social benefits for farmers.

1.2.3. Utilization of Coffee Husk as Fermented Livestock Feed

In addition to serving as fertilizer, coffee husks can be processed into fermented livestock feed. Their relatively high crude protein content makes them a promising material; however, limiting factors such as caffeine, tannins, and high fibre content need to be addressed. Fermentation is an effective method as it breaks down complex compounds into simpler forms, enhances digestibility, and reduces anti-nutritional factors.

Fermentation of agricultural residues increases protein content, decreases fiber, and improves amino acid profiles [17]. Fermented coffee husk feed is safe for both poultry and ruminants, and its use has been shown to improve body weight gain and feed efficiency [18]. These findings confirm that fermentation not only enhances nutritional quality but also creates a more economical alternative to commercial feed products.

Successful processing of coffee husks into fermented feed carries significant implications for smallholder livestock farming. The availability of affordable and high-quality local feed is a critical factor in increasing livestock productivity. By adopting simple fermentation technology, farmers can transform previously underutilized husks into an alternative feed source, thereby reducing production costs and alleviating pressure on conventional feed resources.

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1.2.4. Relevance of Zero-Waste Agriculture and Green Economy

The processing of coffee husks into organic fertilizer and fermented feed reflects the application of zero-waste agriculture principles. This system emphasizes the reutilization of all agricultural residues to form a closed production cycle. Such an approach reduces pollution, enhances resource efficiency, and strengthens the ecological resilience of farming systems.

Zero-waste agriculture contributes to the green economy by promoting efficient resource management, reducing carbon emissions, and creating added value at the community level [19]. The conversion of coffee husks into useful products also provides opportunities for farmers to diversify their enterprises, thereby contributing to household income. Utilizing coffee husks for fertilizer, feed, or bioenergy represents a tangible application of the circular economy that integrates ecological, economic, and social dimensions [14].

1.2.5. Knowledge Gaps and Urgency of Activities

Theoretical insights confirm the high potential of coffee husks to be processed into organic fertilizer and fermented feed. Nevertheless, utilization at the farmer level remains limited. Much of the husk waste is still left to accumulate or is openly burned, causing environmental problems. Knowledge transfer and practical skills training for farmers are crucial to ensuring the sustainable utilisation of husk waste. Training and hands-on practice are necessary to enable farmers to independently apply processing technologies while also fostering collective awareness of the importance of waste-free farming.

On this basis, activities promoting the utilisation of coffee husks through training in organic fertiliser production and the formulation of fermented livestock feed are expected to provide dual benefits: reducing environmental burdens and improving farmer welfare. Such initiatives also support the transformation of agriculture toward more efficient, environmentally friendly systems consistent with green economy principles.

1.3. Research Objective

The main objective of this study is to empower local farmer groups in Desa Wanagiri through capacity building in managing coffee husk waste by applying the zero-waste concept. Specifically, this program aims to; (1) Enhance farmers' knowledge and skills in producing organic fertilizer from coffee husks through composting techniques using bio-activators; (2) Develop practical competencies of farmers in formulating fermented livestock feed from coffee husks enriched with bran and mineral supplements; (3) Strengthen the sustainability of waste utilization practices through continuous mentoring, quality monitoring of the products, and small-scale trials on plants and livestock; (4) Support the creation of alternative income sources for farmer groups while simultaneously reducing environmental pollution, in line with the principles of green economy and sustainable agriculture.

2. MATERIALS AND METHODS

Activities were implemented through three interrelated stages. Preparation involved engaging Jagra Wana and Leket Sari farmer groups to introduce program objectives and expected benefits, compiling training modules that combined technical and practical content, and providing essential inputs such as bio-activators and fermentation microbes. Training and practice focused on guiding participants in producing organic fertilizer from coffee husk waste using EM4-assisted composting techniques, alongside formulating fermented livestock feed by combining husks with bran and mineral supplements to improve nutritional value. Mentoring and evaluation emphasized monitoring compost quality based on texture, odor, and nutrient content, while small-scale trials of fermented feed were conducted on poultry and ruminants. Evaluation also assessed farmers' ability to master production processes, ensuring that skills acquired could support program continuity.

3. RESULT AND DISCUSSION

The implementation of training and practice on coffee husk utilisation in Wanagiri Village proved effective in enhancing farmers' skills and knowledge. All participants (100%) took part in the program and were able to reproduce both organic fertiliser production and the formulation of fermented livestock feed. Around 90–95% of respondents retained the training content, indicating that knowledge transfer occurred optimally. These findings highlight that the program provided not only theoretical understanding but also practical competencies that could be directly applied in the field.

Regarding livestock feed, the majority of respondents (95%) had tested the processed coffee husk on their animals, and all of them (100%) acknowledged its safety once properly fermented. This outcome reflects a solid internalization of skills in applying simple fermentation-based technology. Nevertheless, 15% of respondents encountered technical barriers such as limited fermentation facilities and a lack of experience, while only 20% engaged in active communication with other farmers. Such conditions highlight the need for ongoing mentoring to strengthen farmer-to-farmer networks, thereby ensuring the broader adoption of fermented feed practices. Despite these challenges, full commitment from respondents (100%) to continue using husk-based fermented feed provides strong evidence of the program's sustainability potential. These results align with those of Oropeza-Mariano et al. [18], who confirmed that coffee husks can serve as livestock feed after processing, and with Shah et al. [9], who emphasised the crucial role of agro-industrial by-products in supporting sustainable livestock productivity.

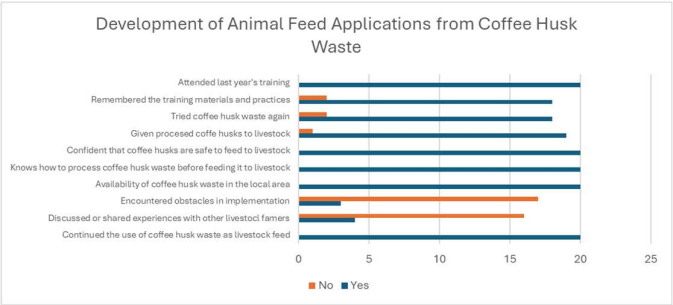

Figure 2. Coffee husk waste for animal feed

The utilisation of coffee husk waste as an organic fertiliser also demonstrated promising outcomes. Approximately 90% of respondents applied the compost to their crops, with 75% reporting direct benefits, including improved soil structure and enhanced vegetative growth. However, 25% did not perceive

significant improvements, likely due to variations in soil conditions, crop type, and application techniques. Only 20% experienced technical difficulties, indicating that most participants were able to process and apply the compost independently. Positive social impacts were also evident, as 60% of respondents shared their knowledge with surrounding communities, thereby strengthening dissemination at the grassroots level. All respondents (100%) expressed interest in participating in further training and supporting program continuity in the village. These findings are consistent with those of Nguyen et al. [16] and Takala [2], who reported that coffee husk compost improves soil fertility and supports the productivity of plantation crops. Moreover, Sharma et al. [7] highlighted that modern composting innovations can enhance compost quality, while Ratnaningsih et al. [6] emphasised the importance of organic approaches in achieving sustainable community-based farming.

Overall, the results reinforce evidence that utilising coffee husks as an organic fertiliser and fermented livestock feed provides not only agronomic and nutritional benefits but also strengthens the socio-economic aspects of farming households. This aligns with the concept of zero-waste agriculture, which redefines waste as a valuable resource. As noted by Popovski et al. [8] and Ahmed et al. [20], the circular economy approach to coffee waste management can reduce pollution, lower carbon emissions, and create sustainable added value.

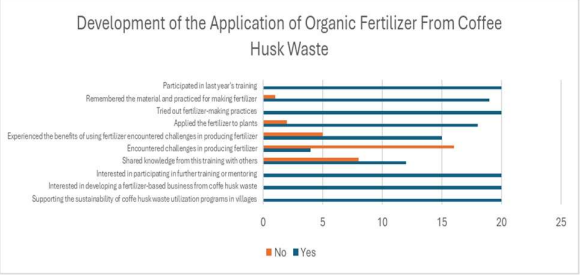

Figure 3. Coffee Husk Waste For Fertilizer

Overall, this second year of activities has not only succeeded in improving the technical skills of the community but also fostered a spirit of entrepreneurship and environmental awareness. The use of coffee waste as organic fertilizer and fermented animal feed has provided economic added value while reducing the potential for environmental pollution. Some farmers have even started selling simple organic fertilizers and fermented feed to local livestock farmers, which has led to an increase in income, with additional turnover reaching millions of rupiah per month. These results demonstrate that the integration of training, appropriate technology, and community participation can strengthen farmers' independence while supporting the implementation of the green economy concept. Thus, this program highlights the importance of the circular economy in the agricultural sector as a strategy to minimise waste, enhance resource efficiency, and create new sustainable business opportunities.

Figure 4. Outreach programs

4. CONCLUSION

The PM-UPUD program in Desa Wanagiri successfully demonstrated that coffee husk waste can be transformed into valuable products through community training and practice. The participants not only improved their technical capacity in producing organic fertiliser and formulating fermented livestock feed but also demonstrated a strong commitment to applying these skills in their daily farming practices. The utilisation of coffee husks contributed to improved soil fertility, provided an alternative source of affordable animal feed, and opened up opportunities for additional household income. Beyond the technical outcomes, the program fostered greater environmental awareness and encouraged knowledge sharing within the community, supporting the adoption of a zero-waste approach in local agricultural practices. These achievements underline the role of farmer empowerment and sustainable waste management as key drivers in strengthening the green economy and building resilient rural communities.

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