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Management of Tree Branch Waste into Liquid Smoke as an Agricultural Biopesticide: A Social Innovation of Pertamina EP Sangatta Field's CSR Program

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A B S T R A C T

This community service activity is part of the BINTANG PERTIWI Program (Empowering Climate-Friendly and Innovative Agriculture Villages), implemented by PT Pertamina EP Sangatta Field in Pinang Raya Village, South Sangatta District, East Kutai Regency. The main challenge faced by farmers in this area is the high cost of agricultural production, largely due to their dependence on chemical fertilisers and pesticides, as well as the underutilization of abundant organic waste, particularly tree branches that are often burned, resulting in air pollution and an increased risk of land fires. The innovative solution introduced is the management of tree branch waste through a pyrolysis process to produce grade-3 liquid smoke, which is then used as an eco-friendly bio-pesticide. The activities were carried out through awareness campaigns, technical training, mentoring, and continuous monitoring and evaluation. The program results show pesticide cost savings of approximately Rp600,000 per year, improved community awareness in waste management, and strengthened farmer group capacity in adopting semi-organic farming practices. The program not only has economic benefits but also contributes to mitigating land fire risks and fostering a more sustainable environment. These findings demonstrate that social innovations based on local potential can be replicated in other regions to support sustainable agriculture.

Contribution to Sustainable Development Goals (SDGs):
SDG 1: No Poverty
SDG 2: Zero Hunger
SDG 3: Good Health and Well-Being
SDG 8: Decent Work and Economic Growth
SDG 12: Responsible Consumption and Production
SDG 13: Climate Action

1. INTRODUCTION

1.1. Research Background

Agriculture is one of the strategic sectors in supporting national food security. However, farmers in many regions face challenges such as limited access to production inputs, high prices of chemical fertilisers and pesticides, and environmental degradation resulting from conventional farming practices. A similar condition occurs in Pinang Raya Village, South Sangatta District, East Kutai Regency. Most of the community relies on agriculture for their livelihood, yet production costs remain high due to their reliance on chemical fertilisers and pesticides. Data show that in a single harvest cycle, farmers spend up to IDR 3,439,000, with the majority of this amount allocated to purchasing fertilisers and chemical pesticides.

On the other hand, Pinang Raya Village has abundant organic waste resources, particularly oil palm fronds, empty fruit

bunches, and tree branches. However, utilization of this waste remains low. Most of it is openly burned, causing air pollution, increasing greenhouse gas emissions, and creating risks of forest and land fires. This problem highlights the urgent need for innovative solutions that harness local potential to reduce farmers' dependence on chemical inputs while addressing environmental concerns.

In this context, PT Pertamina EP Sangatta Field, through its CSR program, has designed an innovation to manage tree branch waste into liquid smoke. The liquid smoke produced from tree branch pyrolysis has great potential as an environmentally friendly biopesticide. Thus, this approach is expected to address two critical issues at once: the high cost of agricultural production and the management of organic waste.

1.2. Literature Review

Liquid smoke is the condensed product of the pyrolysis process of biomass [1, 2], including wood waste or tree branches. Chemically, liquid smoke contains phenolic compounds, acetic acid, carbonyls, and various other organic compounds with natural antimicrobial and insecticidal properties [3, 4]. Previous studies have demonstrated that liquid smoke can inhibit the growth of pathogenic bacteria, deter pest attacks, and prolong the shelf life of agricultural products.

According to research by [5], liquid smoke derived from biomass waste can be applied as a plant-based biopesticide effective against horticultural pests. In addition, studies [6, 7, 8] have emphasised that the use of liquid smoke can reduce the reliance on chemical pesticides while simultaneously improving the quality of the agricultural environment. From a sustainability perspective, this innovation aligns with the concept of organic farming, which prioritises the efficient use of local resources and minimises environmental impact.

Beyond the technical aspects, the application of social innovation in transforming waste into value-added products also strengthens community capacity. According to [9], community-based development must emphasize the utilization of local assets (asset-based community development). This approach is consistent with the BINTANG PERTIWI Program, which not only highlights economic aspects but also promotes social empowerment and environmental conservation.

1.3. Research Objective

Based on problem identification, local potential, and community needs assessment in Pinang Raya Village, the main objectives of managing tree branch waste into liquid smoke as an agricultural biopesticide are as follows:

1. To reduce the dependence of Pinang Raya farmers on chemical pesticides by utilizing liquid smoke as a biopesticide.
2. To minimize the practice of open burning of tree branch waste, which poses risks of pollution and forest and land fires.
3. To improve the efficiency of agricultural production costs by substituting chemical pesticides with plant-based biopesticides.
4. To empower community groups, particularly farmer groups and women's groups, in managing local potential sustainably.

2. MATERIALS AND METHODS

2.1. Location and Time of Activities

The activity was conducted in Pinang Raya Village, South Sangatta District, East Kutai Regency, East Kalimantan. Oil palm plantations predominantly characterise the village, but it also possesses considerable farmland for food crops and horticulture. The program commenced in 2023 and is continuing in 2025 as part of the BINTANG PERTIWI Program roadmap.

2.2. Target Participants

The primary targets of this community service activity are farmer groups and women's groups in Pinang Raya Village, South Sangatta District. The Bahagia Farmer Group (POKTAN) is one of the partners that previously relied heavily on chemical pesticides in horticultural practices. Through this program, they were encouraged to utilize liquid smoke as a plant-based biopesticide, thereby reducing production costs and improving the quality of agricultural products. In addition, the Berseri Women Farmers Group (KWT), which has been actively engaged in oyster mushroom cultivation, also became an important target, as liquid smoke helps maintain the quality of harvests and reduces the risk of pest and disease attacks. The involvement of KWT Berseri not only strengthens the technical capacity of women's groups but also provides opportunities to enhance household economic independence. The program also inclusively engages vulnerable groups such as housewives, the elderly, and women at socio-economic risk, ensuring that its benefits are more widely distributed within the village community. Thus, the program's objectives extend beyond improving agricultural productivity to strengthening the community's overall socio-economic capacity.

2.3. Implementation Stages

The implementation of a program to manage tree branch waste into liquid smoke as a biopesticide was carried out through several structured stages with active community participation. The stages included:

1. Problem identification and mapping of local potential
   The initial stage involved social mapping in Pinang Raya Village to identify the main challenges faced by the community as well as the local resources that could be utilized. The results showed that farmers struggled with high production costs due to their dependence on chemical pesticides, while abundant tree branch waste was often burned without being utilised. These findings formed the basis for designing an innovative solution through the conversion of tree branch waste into liquid smoke.
2. Program socialization to the community
   Following social mapping, the program was introduced to farmer groups, women's groups, and the broader community. The socialisation aimed to raise awareness about the health and environmental risks associated with chemical pesticide use and to introduce the benefits of liquid smoke as an alternative biopesticide. At this stage, a general overview of the liquid smoke production process was also presented to motivate the community to participate actively in the program.

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3. Technical training on liquid smoke production
   The next stage involved technical training, with direct participation from the target groups. Participants were taught how to collect tree branches as raw material, conduct the pyrolysis process through indirect combustion using drums, and condense the smoke into liquid form. The training emphasised occupational safety, quality standards, and storage methods to ensure that the liquid smoke produced could be applied optimally in agriculture.
4. Trial application of liquid smoke
   After training, the community conducted trials of liquid smoke application directly on horticultural farmland and oyster mushroom cultivation media. Joint observations were conducted to evaluate the effectiveness of liquid smoke in controlling crop pests and preserving mushroom quality against microbial attacks. These trials provided concrete evidence for the community that liquid smoke could substitute for chemical pesticides while simultaneously reducing production costs.
5. Intensive mentoring
   To ensure that the skills acquired did not stop at the trial stage, the implementation team provided intensive mentoring. Mentoring activities included regular visits to farmer groups, facilitating discussions, and offering technical advice in both the production and application of liquid smoke. This mentoring was intended to build community confidence in independently producing and utilizing liquid smoke and to ensure the program's long-term sustainability.
6. Monitoring and evaluation
   The final stage involved monitoring and evaluation, which assessed the effectiveness of liquid smoke in pest control, the cost savings achieved by farmers, and changes in community attitudes toward waste management and the adoption of environmentally friendly agricultural practices. The evaluation also examined socio-economic impacts, including increased household income, the inclusion of vulnerable groups, and a decrease in open burning practices that pose environmental risks.

2.4. Methodological Approach

The method employed was participatory (Participatory Rural Appraisal), in which the community served not only as the object but also as the primary subject of the activities. This approach enabled more effective knowledge transfer and ensured program sustainability. Additionally, an action research method was employed, which involved direct observation of changes in behaviour, productivity, and cost efficiency.

3. RESULT AND DISCUSSION

The implementation of a program for managing tree branch waste into liquid smoke as a biopesticide in Pinang Raya Village yielded several important outcomes, which can be examined from technical, social, economic, and environmental perspectives.

3.1 Production Cost Efficiency

Before the program's implementation, farmers in Pinang Raya Village incurred significant expenses to purchase chemical pesticides. This expenditure was particularly burdensome for smallholder farmers with limited land area. Through the innovation of processing tree branch waste into liquid smoke, an annual expense of approximately IDR 600,000, previously allocated for pesticides, can be saved. Such savings are highly significant, as farmers' profit margins are largely dependent on production cost efficiency. With reduced financial burdens, farmers' net income increased, thereby strengthening household economic resilience. Moreover, production cost efficiency serves as an entry point toward sustainable agriculture, where farmers are no longer fully dependent on costly external inputs but can instead utilise locally available resources as substitutes.

3.2 Increased Environmental Awareness

One of the most important changes resulting from the program is the growing awareness among community members of the ecological value of tree branch waste. Before the program, branches were regarded as useless waste and were often openly burned. This practice not only polluted the air but also heightened the risk of forest and land fires. With training and mentoring, the community began to understand that tree branches could be processed into valuable products. This new awareness gradually shifted community behavior from a "discard and burn" mindset to a "process and utilize" mindset. Such behavioral change is a key indicator of program success, as the transformation encompasses not only technical aspects but also collective consciousness of the importance of environmental stewardship.

Picture 1. Liquid Smoke Production

3.3 Effectiveness of Liquid Smoke as a Biopesticide

The application of liquid smoke in horticultural farming and oyster mushroom cultivation has demonstrated tangible benefits, including reduced pest attacks and improved product quality. In horticultural fields, liquid smoke was used as a substitute for chemical pesticides to protect crops from pest infestations. Meanwhile, in oyster mushroom cultivation, it helped prevent microbial contamination that could compromise harvest quality. These outcomes confirm the effectiveness of liquid smoke not only as a biological control agent but also as a tool supporting the transition toward semi-organic farming. Semi-organic agriculture offers dual advantages: reducing the use of hazardous chemicals while producing safer food products. Thus, liquid smoke offers both practical benefits and added market value, as consumers are becoming increasingly aware of the importance of healthy food.

Picture 2. Aplication of liquid smoke as a biopesticide

3.4 Empowerment of Vulnerable Groups

The active involvement of vulnerable groups, particularly women organized under the *Kelompok Wanita Tani (KWT) Berseri* or Women Farmers Group, was a critical element of the program. Women were not merely passive participants but became key actors in oyster mushroom cultivation as well as in the production and application of liquid smoke. Their involvement created new economic opportunities and enhanced household financial independence. Furthermore, women's empowerment fostered a strong sense of ownership over the innovation. This sense of ownership is crucial for ensuring program sustainability, as communities are more likely to continue the initiative even after external support concludes. Socially, the empowerment of vulnerable groups reflects efforts to ensure equitable distribution of program benefits, extending advantages not only to dominant groups but also to those who historically had limited access to economic opportunities.

3.5 Contribution to Forest and Land Fire Mitigation

South Sangatta is an area with a relatively high risk of land fires, particularly during the dry season. One contributing factor is the practice of openly burning agricultural waste. Through this program, tree branch waste that was previously burned has been repurposed as raw material for liquid smoke production. Consequently, the likelihood of open burning has been significantly reduced. This reduction benefits the local environment and contributes to global efforts to curb greenhouse gas emissions. In other words, the program's relevance extends beyond the village scale, linking directly to broader climate change mitigation agendas. This contribution illustrates how simple, community-based innovations can contribute to the solution of larger environmental challenges.Overall, these findings demonstrate that the CSR program initiated by Pertamina EP Sangatta Field has produced multiple impacts: economic benefits through cost efficiency, social benefits through the empowerment of vulnerable groups, and ecological benefits through the reduction of open burning and the promotion of environmentally friendly agriculture. The synergy among these three dimensions aligns with the principles of sustainable development, which emphasize balance between economic, social, and environmental priorities.

4. CONCLUSION

The program for managing tree branch waste into liquid smoke as a biopesticide has proven effective in addressing the challenges faced by the Pinang Raya Village community, both economically and environmentally. This innovation reduces production costs, decreases dependence on chemical inputs, and enhances community awareness of the importance of responsible waste management. The program's success demonstrates that locally driven social innovations can serve as practical and sustainable solutions for environmentally friendly agriculture. Moreover, this model has the potential to be replicated in other regions facing similar challenges.

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