ABDIMAS: Jurnal Pengabdian Masyarakat Universitas Merdeka Malang
Vol.11(2) May 2026, ...-....
p-ISSN: 2721-138X e-ISSN: 2548-7159
http://jurnal.unmer.ac.id/index.php/jpkm

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BIOPLASRI: Innovative bio-pellets from plastic waste and corn cobs meeting Indonesian National Standards

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ARTICLE INFO:

Received: 2026-06-18
Revised: 2026-07-21
Accepted: 2026-08-10
Published: 2026-08-30

Keywords:

Alternative energy, Bio-pellets, Community empowerment, Corn cob waste, Plastic waste

ABSTRACT

Plampangrejo Village, as a part of Banyuwangi Regency, has abundant potential of corn cob waste and household plastic waste that has not been optimally utilized, resulting in environmental problems. This condition encourages the need for waste management initiatives through the BIOPLASRI program, including the utilization of corn cobs and plastic waste into bio-pellets as an alternative energy source with economic value. This program aims to improve the community's capacity to processing waste into bio-pellets, subsequently reduce environmental pollution, while supporting the development of renewable energy based on local potential. The implementation method employed a participatory approach through socialization, technical training on bio-pellet production, assistance in quality control in accordance with the Indonesian National Standard (SNI), business management assistance, and program sustainability evaluation. The results showed that 25 participants experienced an increase in understanding from an average of 51.2 to 92.8 percent. The pellet mill, that serves as appropriate technology, was able to process 3–6 kg of plastic waste and 7–14 kg of corn cobs per day, with a bio-pellet production capacity of 10–20 kg/day. The resulting bio-pellets had a calorific value of 4,331.61–5,467.26 cal/g, meeting the requirements of SNI 8966:2021. In addition, product packaging and branding were developed, along with the involvement of Karang Taruna (Youth Group) and BUMDes to support the sustainability of BIOPLASRI production and marketing. Ultimately, the BIOPLASRI program is expected to become a community empowerment model capable of supporting sustainable waste management, strengthening local energy security, and improving the welfare of the people of Plampangrejo Village.

How to cite: Rahmawati, I., Rizkiana, M. F., Palupi, B., Reza, M., Wulandari, F., Sebastiansyah, Y., Annisaa'., & Ibad, A. I. (2026). BIOPLASRI: Innovative bio-pellets from plastic waste and corn cobs meeting Indonesian National Standards. *Abdimas: Jurnal Pengabdian Masyarakat Universitas Merdeka Malang, 11*(2), xxx-xxx.
https://doi.org/10.26905/abdimas.v11i2.17463

1. INTRODUCTION

Plampangrejo Village is located in the Cluring District of Banyuwangi Regency. The village sits at an elevation of approximately 71 meters above sea level. The majority of the local population works as farmers, supported by the village's extensive agricultural land with intensive corn production. The estimated corn cultivation area is approximately 306 hectares, with a production of around 2,064 tons per harvest season (Badan Pusat Statistik Kabupaten Banyuwangi, 2021). Of this amount, approximately 15–20 percent consists of corn cob waste. This waste is generally burned or discarded, causing pollution

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while also resulting in the loss of potential biomass energy, with a dry matter calorific value of 17.58–17.79 MJ/kg (Wojcieszak et al., 2022).

Household consumption has also contributed to the increasing number of non-degradable plastic waste that has not been effectively managed, particularly within villages with limited waste management infrastructure and capacity (Frigo et al., 2025). Household waste generation, which estimated around 0.3–0.5 kg/person/day rate including the population of 2,500–3,000 people, the amount of waste generated in the village is therefore estimated at 750–1,500 kg/day, of which 15–20 percent is plastic waste, equivalent to approximately 110–300 kg/day. As a non-biodegradable material, plastic waste contributes to soil, water, and air pollution by accumulating over time, as a result of inadequate waste management (Elvania et al., 2023). One approach that can be implemented is to utilize certain types of plastic waste as a feedstock additive in the production of solid fuel, thereby reducing waste volume while also increasing the value of the waste (Wei et al., 2024).

Furthermore, many residents of Plampangrejo Village still use firewood as an energy source for cooking and small-scale businesses. High dependence on firewood may increase pressure on forest resources and generate smoke emissions that are less environmentally friendly due to the direct combustion of biomass (World Health Organization, 2025).

These conditions indicate both an environmental problem and an opportunity to develop alternative energy based on locally available resources. Corn cob waste requires a relatively long time to decompose naturally. However, its high lignocellulosic content makes it a potential raw material for various value-added products, such as bio-pellets, briquettes, activated carbon, biochar, and other biomass-based materials (Molo et al., 2023).

The Farmer Association (*Kelompok Tani*) and the Youth Group (*Karang Taruna*) of Plampangrejo Village, which act as program partners. play strategic roles in social activities and community empowerment. Upon observation, however, the partners lack adequate knowledge, skills, and technology to process corn cob waste and plastic waste into value-added products. Plastic waste generated from household activities has not been utilized productively, while corn cob waste from agricultural activities has also not been managed as an energy source. In addition, some residents still continue to use firewood as fuel for household activities and even small-scale businesses.

Dependence on firewood may increase pressure on forest resources and generate smoke emissions from direct biomass combustion. These conditions indicate the partners' need for simple, practical technology that is appropriate to local resource availability for producing alternative fuel. Based on the results of problem identification conducted jointly with the partners, the Farmer Group and the Youth Group of Plampangrejo Village require capacity building in waste sorting and processing, feedstock formulation, equipment operation, and quality control of bio-pellet products.

Bio-pellets are solid fuels derived from biomass and formed into pelletized products with uniform characteristics, including size, shape, moisture content, density, and energy content, resulting in more consistent quality (Lukmanto & Banowati, 2024). Bio-pellets generally have a cylindrical shape with standardized dimensions, typically measuring approximately 6–25 mm in length and 3–12 mm in diameter (Saragih, 2013). Their uniform shape and size provide several advantages, including easier storage, packaging, and transportation, as well as improved combustion efficiency (He et al., 2024). In addition, bio-pellets have relatively high calorific values and low moisture content and produce lower greenhouse gas emissions and ash residues compared with unprocessed biomass fuels (Tumuluru et al., 2011). Therefore, bio-pellets are considered an environmentally friendly renewable energy source with the potential to replace fossil fuels and firewood in various sectors, including households and industries (He et al., 2024).

The community service program addresses the need for an integrated solution that can simultaneously tackle agricultural waste and plastic waste while supporting the transition toward environmentally friendly energy. Corn cobs have potential as an energy biomass feedstock due to their high lignocellulosic content (Okeke et al., 2024), while plastic waste can be utilized as a feedstock additive to increase the calorific value and mechanical strength of bio-pellets (Wei et al., 2024). These initiatives are aligned with efforts to reduce waste, strengthen local energy resilience, and promote rural economic development.

This program aims to enhance the capacity of the Plampangrejo Village community to process corn cob waste and plastic waste into bio-pellets as an environmentally friendly alternative fuel that is compliant with the Indonesian National Standard, SNI 8675:2018, for wood pellets/bio-pellets, while also promoting the development of sustainable renewable energy-based enterprises. The innovation, BIOPLASRI (Plastic Waste-Corn Cob Bio-pellets), is an alternative fuel that utilizes corn cob waste and plastic waste to produce bio-pellets with high calorific value and environmentally friendly characteristics, with the potential to reduce dependence on conventional fuels.

2. METHODS

Location and Partners

The activities were conducted in Plampangrejo Village, Cluring District, Banyuwangi Regency. The Appropriate Technology (TTG) equipment was installed at the Plampangrejo Village Hall, where the production process also took place. The project partners included 15 members of the Youth Group and 8 members of the Village-Owned Enterprise (BUMDes), for a total of 23 community members. In addition, the program will collaborate with a Farmer Association as the primary supplier of corn cob waste as the main feedstock.

Solution Framework

The solution framework will be implemented through two main activities: socialization and technical training on bio-pellet production, followed by product marketing. The implementation adopted a participatory approach through socialization, hands-on practical training, intensive assistance, and evaluation of program success based on improvements in the partners' knowledge, skills, and production capacity.

The targeted outputs, including bio-pellet products made from corn cobs and plastic waste that meet the required quality parameters, increased community capacity and independence in waste processing, and the establishment of an initial alternative energy business unit in Plampangrejo Village. The program targets the capacity increase of at least 20–25 community members, establishing one village-level alternative energy business unit, subsequently reducing agricultural and plastic waste by approximately 10–15 percent during the first year of implementation.

The program also targets the processing of at least 1–2 tons of corn cob waste and 200–400 kg of plastic waste per month into SNI-compliant bio-pellets, with an initial production capacity of approximately 10–20 kg/day. The appropriate technology provided to the partners will include a pellet-making machine that converts the mixture of plastic waste and corn cobs into pellets, as well as an oven used to dry the products after pelletization. Details of the appropriate technology are presented in Figure 3. This innovation is expected to strengthen local energy resilience while increasing the sustainable economic value generated by the community.

Implementation Stages

Implementation of activities is carried out in three stages with details written in Table 1.

Table 1. Implementation stages

Stages	Activities	Results	Timeframe
1st Activity	Initial observation	To identify initial conditions, raw material potential, challenges, and partner needs as the basis for designing the BIOPLASRI program.	May 2026
2nd Activity	Socialization on waste-related issues, the potential utilization of waste as a feedstock for bio-pellet production, the benefits of bio-pellets as an alternative energy source, and an introduction to bio-pellet quality standards based on SNI 8966:2021, with calorific value and moisture content as the analysis parameters.	To increase community knowledge of waste-related issues and waste utilization, bio-pellets as an alternative energy source, and bio-pellet quality standards, as indicated by improvements in questionnaire scores.	June 2026
3rd Activity	Demonstration and technical training on bio-pellet production, covering feedstock sorting and processing, size reduction, mixing, pelletization, drying, and an introduction to bio-pellet quality testing.	To improve community members' skills in bio-pellet production and their understanding of the basic stages of bio-pellet quality testing, as demonstrated by the availability of bio-pellet products that comply with SNI standards.	July 2026
4th Activity	Assistance on quality control	To ensure the available bio-pellet products are compliant with SNI.	
5th Activity	Business management and organizational support	To ensure the availability of packaging for bio-pellet products and an organization responsible for the sustainability process.	
6th Activity	Program sustainability is ensured through the availability of appropriate technology, specifically a bio-pellet press, that enables partners to continuously produce bio-pellets.	To ensure the availability of one appropriate technology for producing bio-pellets.	August 2026

Based on the situational analysis and the problems observed among the community of Plampangrejo Village, the program focuses on reducing corn cob waste and plastic waste by utilizing them as feedstocks for bio-pellet production. The program is implemented in stages, as shown in Figure 1, consisting of observation, socialization and education, technical training on bio-pellet production, quality control assistance, and program evaluation. These stages are designed to ensure the effective implementation of the BIOPLASRI program and to ensure that the community not only gains knowledge of waste management and bio-pellet production but also acquires the ability to apply the introduced technology and independently develop a sustainable bio-pellet business.

Observation Stage

The observation stage constitutes the initial step in identifying partner conditions and the problems faced by the community of Plampangrejo Village (Kemmis et al., 2014). The observation was conducted

through a preliminary study involving a review of data from the official village government website, scientific publications, data from the Central Bureau of Statistics (BPS), and other relevant references. This was followed by field visits, interviews with village officials, corn farmers, and local community members, as well as direct observation of environmental conditions.

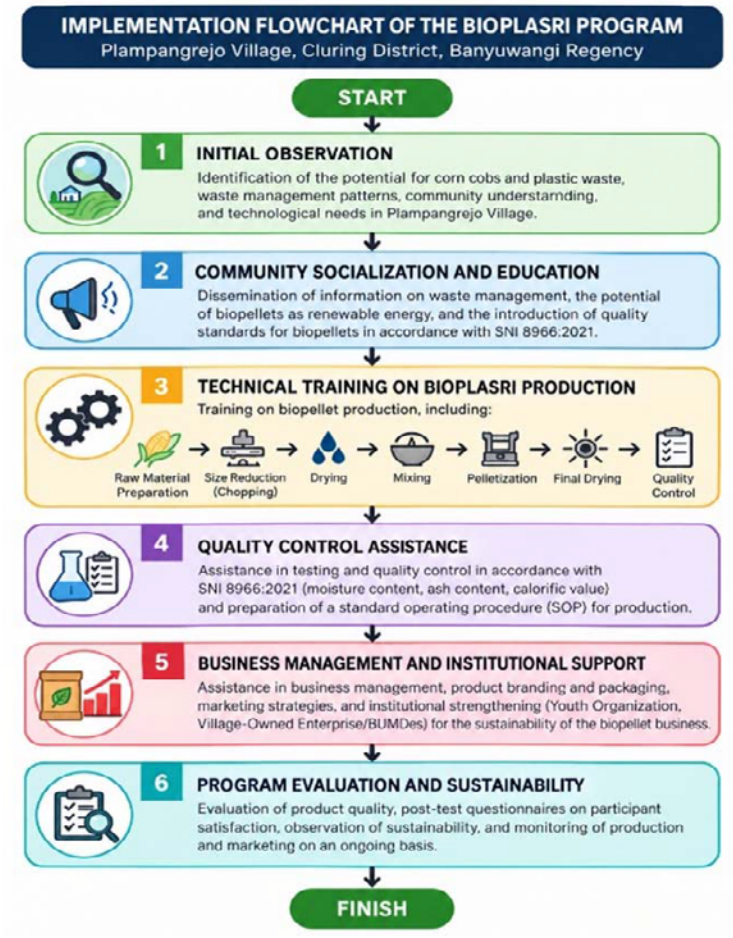

Figure 1. Stages of the community service program implementation in Plampangrejo Village

The activities aimed to identify the potential of corn cob waste and plastic waste, existing waste management practices, the community's level of understanding, and the need for waste processing technology to produce bio-pellets. The observation results will subsequently serve as the basis for developing socialization materials, bio-pellet production demonstrations, and technical assistance activities to ensure that the BIOPLASRI program is aligned with the conditions and needs of the Plampangrejo Village community.

Socialization and Education Stage

Socialization and education are carried out in order to provide information about the use of corn cob and plastic waste as renewable energy bio-pellets. The materials to be used in these activities are listed in Table 3.

Table 2. Socialization and education materials

Education Materials	Goals	Participants
The Urgency of Managing Corn Cobs and Plastic Waste as Sources of Renewable Energy for Villages	This material aims to enhance the understanding and awareness of the Plampangrejo village community regarding the environmental impact of corn cobs and plastic waste, as well as their potential utilization as bio-pellets, thereby encouraging behavioral changes in sustainable waste sorting and management.	- Farmer representatives from Plampangrejo Village - Housewives - Village officials - Waste bank/Village-Owned Enterprise (BUMDes) managers
Lack of resident knowledge regarding equipment for processing corn cobs and plastic into bio-pellets.	This material aims to provide a technical understanding of the village-scale bio-pellet production process and the importance of adhering to quality standards set by the National Standardization Agency (SNI 8966:2021), in order to enhance product quality, competitiveness, and community commitment to the sustainable development of bio-pellet enterprises.	- Farmer groups as biomass suppliers - Village officials as local policy-makers - Community representatives committed to driving the program - -

Technical training on the production of national-standardized bio-pellets based on local waste

The production of bio-pellets from corn cobs and plastic waste was carried out systematically, beginning with feedstock preparation and preliminary processing, followed by mixing, pelletization, and quality testing to ensure that the resulting bio-pellets had good and stable quality and complied with the applicable solid fuel standards. The detailed process is presented in Figure 2.

The bio-pellet production process from corn cobs and plastic waste consisted of the following stages. Corn cobs were first cleaned to remove organic and inorganic contaminants, while the plastic waste was sorted, particularly thermoplastic materials such as HDPE, LDPE, and PP, while avoiding PVC. The corn cobs were then size-reduced to less than 2 mm to improve pellet homogeneity and density, followed by drying until the moisture content reached approximately 8–12 percent. The plastic waste was also separately size-reduced to less than 2 mm to improve pellet homogeneity and density. Subsequently, the dried corn cobs were thoroughly mixed with plastic waste at a ratio of 70 percent corn cobs to 30 percent plastic. The mixture was then fed into a pellet mill, and the resulting bio-pellets were cooled to room temperature. The bio-pellets were subsequently dried again to ensure physical stability, prevent cracking, and maximize durability during storage. This process produced bio-pellets with calorific values ranging from 4,331.61 to 5,467.26 cal/g, which comply with SNI 8966:2021, requiring a calorific value of >4,000 cal/g. The bio-pellets were then packaged in 1 kg packages and prepared for commercialization. The indicators of successful production are presented in Table 2.

Table 2. Indicators of production success

Success Indicators	Results
Processing capacity for plastic waste	1,5-3.75 kg/day
Processing capacity for corn cobs	3,5-8.75 kg/day
Minimum pellet machine output	5-12,5 kg (50 percent machine capacity)
Quality of the resulting product	Compliant with SNI 8966:2021

The systematic bio-pellet production process is presented in Figure 3, which illustrates the bio-pellet production flow, consisting of several interconnected stages from feedstock preparation to product quality testing in accordance with SNI standards. The appropriate technology and the

equipment components used in the BIOPLASRI program are also presented in Figure 3. The appropriate technology supports the bio-pellet production process through several main pieces of equipment designed according to the needs of village-scale production.

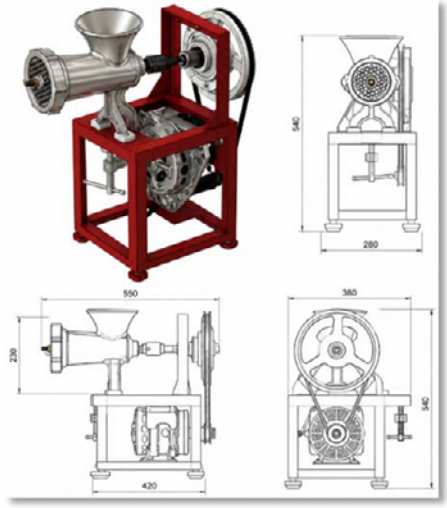

Figure 2. Bio-pellet production flowchart
Figure 3. Appropriate technology: bio-pellet production and pellet mill machine components

Table 3. Detailed specifications

Part Name	Description
Upper collection hopper	Steel
Crusher	Type 125 Single Unit
Pelletizer input hopper	Stainless steel
Pelletizer machine	Type 125, 4kW, copper wire, 60 Hz
Motor	1 Hp (220v)
Pelletizer output hopper	Stainless steel
Production capacity	10-25 kg

Assistance with quality control and standardization of wood pellets in accordance with SNI 8966:2021

The quality control and standardization assistance for bio-pellets in accordance with SNI 8966:2021 was conducted as a follow-up stage after the training to ensure that village-scale bio-pellet production was carried out consistently, measurably, and in compliance with the quality parameters established by the National Standardization Agency of Indonesia. The assistance focused on strengthening the community's technical capacity to control calorific value and on developing a quality control system and production SOPs. The calorific values obtained from sample testing ranged from 4,331.61 to 5,467.26 cal/g.

Evaluation of program achievements and sustainability plan for the village-based wood pellet business

Process controls are implemented periodically. Production process oversight involves ensuring that both the production process and the final product meet established standards. Meanwhile,

marketing oversight entails monitoring marketing activities, both in offline and online settings, and analyzing consumer feedback to determine necessary improvements.

Evaluation

An evaluation was conducted to measure the success of the BIOPLASRI program in enhancing the knowledge, skills, and self-reliance of the Plampangrejo village community regarding the processing of plastic waste and corn cob waste into bio-pellets (Clarke et al., 2022). Evaluation is carried out at every stage of the activity, starting from socialization, demonstration of bio-pellet production, to quality assurance and business management. The evaluation covered the following aspects:

Questionnaire

A pre-test is an initial assessment administered to participants before the program is implemented to measure their baseline knowledge or skills. It can therefore serve as a basis for evaluating program effectiveness by comparing the results with those of the post-test (Alessandri et al., 2017). The pre-test covered waste management of plastic waste and corn cob waste, the utilization of bio-pellets as an alternative fuel, and the bio-pellet production process. The pre-test results served as baseline data for measuring improvements in participants' knowledge after the program and helped the implementation team tailor the delivery of materials to participants' needs.

The post-test was administered after the completion of the socialization and bio-pellet production demonstration activities. The evaluation aimed to determine improvements in participants' understanding of the materials provided by comparing the pre-test and post-test results. In addition, the evaluation results were used to assess the effectiveness of the instructional methods and the overall success of the community service activities.

A questionnaire was administered to participants to obtain feedback on the implementation of the activities, including the quality of the materials, instructional methods, bio-pellet production demonstration, and benefits of the program to the community. The questionnaire was also used to assess participant satisfaction, the relevance of the materials to community needs, and suggestions for improving the implementation of future programs (Sujarweni, 2018).

Environmental sustainability observation

Observation was conducted after the completion of the community service activities to assess the sustainability of the BIOPLASRI program in the community. The observation focused on the utilization of corn cob waste and plastic waste as feedstocks for bio-pellet production, the community's ability to independently produce bio-pellets, and the involvement of the Youth Group and BUMDes in supporting product management and marketing. The observation results served as indicators of the program's success in generating sustainable impacts.

The evaluation covered the following aspects: (1) The amount of waste processed and the bio-pellet production capacity of the bio-pellet production equipment; (2) The quality of the bio-pellets produced in accordance with the applicable SNI standard; (3) The achievement of business management assistance activities; and (4) the implementation of training and socialization on bio-pellet appropriate technology.

3. RESULTS AND DISCUSSION

Results

The BIOPLASRI program was implemented in stages through socialization, technical training, quality control assistance, business management assistance, and program evaluation. The entire series of activities aimed to strengthen the capacity of the Plampangrejo Village community to process corn cob waste and plastic waste into bio-pellets as an economically valuable alternative fuel. The program stages were systematically designed to ensure that participants not only acquired theoretical knowledge but also developed practical skills in producing bio-pellets in accordance with quality standards. The results of the implementation are described as follows.

Implementation

Observation

The observation stage was conducted as the initial step to identify partner conditions, resource potential, waste management practices, and the need for waste processing technology in Plampangrejo Village. The observation involved field surveys, interviews with village officials, the Farmer Group, and community members, as well as direct observation of the availability of corn cob waste and plastic waste. Based on regional potential data, Plampangrejo Village has approximately 306 ha of corn cultivation area, with production reaching approximately 2,064 tons per harvest season. With an estimated corn cob waste proportion of 15–20 percent, the resulting waste is estimated at approximately 309.6–412.8 tons per harvest season. In addition, household waste generation is estimated at approximately 750–1,500 kg/day, with plastic waste accounting for approximately 15–20 percent, equivalent to approximately 110–300 kg/day. These data indicate that the availability of feedstock for BIOPLASRI development is relatively substantial, although its utilization remains suboptimal.

The observation results also showed that the main challenge faced by the partners was not the limited availability of feedstock, but rather limited knowledge and skills in processing waste into value-added energy products. This condition served as the basis for determining the socialization and training materials, particularly those related to feedstock sorting, size reduction, drying, mixing, pelletization, and bio-pellet quality control.

Socialization and education

Based on the observation results, the program continued with socialization and education on the management of corn cob waste and plastic waste as feedstocks for bio-pellet production. The materials covered environmental problems associated with waste, the concept of renewable energy, the benefits of bio-pellets as an alternative fuel, and an introduction to Indonesian National Standard (SNI) 8966:2021 as a reference for product quality. The materials were delivered interactively through presentations and discussions, enabling participants to understand the importance of converting waste into economically valuable products. Participant enthusiasm was evident from the numerous questions regarding the production process, bio-pellet quality, and potential product marketing.

Figure 4 documents the implementation of BIOPLASRI socialization and education activities for partners in Plampangrejo Village. The activity was conducted face-to-face through presentation-based material delivery, followed by an interactive discussion. The documentation shows participants directly engaging with the materials as an initial stage for building understanding before the hands-on production and operation of the bio-pellet appropriate technology. The socialization materials are

available at the provided link: https://drive.google.com/file/d/1J2-5vtgKxnKKVFsZX0wIsvw9CDDmfbWR/view?usp=sharing.

Figure 4. BIOPLASRI program socialization and education

Training on bio-pellet production techniques

The training stage constituted the core activity of the BIOPLASRI program. Participants received direct assistance throughout the bio-pellet production process, including feedstock sorting, size reduction of corn cobs and plastic waste, feedstock drying, mixing according to the predetermined composition, pelletization using a pellet mill, and final product drying. During the training, participants not only learned the production procedures but also gained an understanding of factors affecting bio-pellet quality, such as particle size, feedstock moisture content, and mixture homogeneity. Through hands-on practice, participants were able to operate the production equipment independently under the guidance of the implementation team. The resulting bio-pellet products are presented in Figure 5.

Figure 5. Bio-pellet end products

Quality control assistance

The next activity involved quality control assistance. The assistance focused on the application of quality parameters in accordance with SNI 8966:2021, particularly the calorific value, which was measured at 4,331.61–5,467.26 cal/g, exceeding the minimum requirement of >4,000 cal/g. In addition, participants were provided with an understanding of the importance of implementing standard operating procedures (SOPs) at each stage of production to maintain consistent product quality. Through this activity, the community began to recognize that bio-pellet quality is a key factor in improving product competitiveness in the market.

Business management and organizational support

The next activity resulted in the development of BIOPLASRI product packaging, which was designed to improve the neatness, storage safety, and visual appeal of the bio-pellet products. The packaging was also equipped with product branding as part of the preparation for BIOPLASRI development and marketing. In addition, the Youth Group and BUMDes of Plampangrejo Village were involved as institutional partners supporting the sustainability of the program, particularly in production management, marketing, and the long-term development of the bio-pellet business. This activity was in line with the program plan, which included assistance in packaging, branding, and marketing, as well as strengthening collaboration with BUMDes and the village government. The packaged products are presented in Figure 6.

Figure 6. Bio-pellet packaging design

Evaluation

An evaluation was conducted at the conclusion of the activity using a five-question questionnaire, which included questions regarding participants' understanding of the BIOPLASRI material. The questionnaire was administered to all 25 participants to assess their level of understanding after completing the entire series of outreach, training, and mentoring sessions.

Table 4. Pre-test and post-test results

Indicators	Correct Answers for the Pre-Test	Percentage (%)	Correct Answers for the Post-Test	Percentage (%)
Identifying the main ingredients of bioplastics	10	40	24	96
Understanding the initial stages of bio-pellet production	15	60	22	88
Recognizing the advantages of bio-pellets	12	48	23	92
Understanding the applications of bio-pellets	16	64	24	96
Understanding the economic benefits of bioplastics	11	44	23	92

The evaluation was also conducted based on the stages of activities that had been implemented. The pellet mill was used to process corn cobs and plastic waste into bio-pellets with a production capacity of 10–20 kg/day, resulting in the processing of 3–6 kg/day of plastic waste and 7–14 kg/day of corn cobs. The resulting bio-pellets had a calorific value of 4,331.61–5,467.26 cal/g, thereby meeting the calorific

value requirement of >4,000 cal/g in accordance with SNI 8966:2021. Business management assistance covered packaging, branding, and marketing, as well as strengthening the roles of the Youth Group and BUMDes in supporting the sustainability of BIOPLASRI production and business development, as demonstrated by the availability of packaged bio-pellet products. In addition, 25 participants attended the BIOPLASRI appropriate technology (TTG) training and socialization activities, with an average level of understanding of 94 percent.

Discussion

The implementation of the BIOPLASRI program demonstrates that a community empowerment approach combining observation, education, technical training, assistance, and evaluation can enhance the community's capacity to manage agricultural and plastic waste and convert it into valuable alternative energy products. The success of the program was demonstrated by the completion of all planned activities and also by the improvement in participants' understanding, with an average correct response rate of 94 percent in the final evaluation. This result indicates that practice-based learning through a learning-by-doing approach was more effective than purely theoretical instruction, as participants were directly involved in each stage of bio-pellet production.

The observation stage provided an important basis for determining the program implementation strategy. Field identification showed that Plampangrejo Village has an abundant supply of corn cob waste, but it has not been optimally utilized, with much of it still being burned or discarded. Meanwhile, household plastic waste has also not been managed sustainably. These conditions indicate that the community's primary challenge lies not in the availability of feedstock but in limited knowledge of waste processing technologies for converting waste into value-added products.

An increase in community knowledge became evident following the socialization and education activities. The evaluation showed that 96 percent of participants understood the main feedstocks used in BIOPLASRI, while 92 percent understood the benefits of bio-pellets as an alternative energy source. These percentages indicate that the materials delivered were able to shift the community's perception of waste from a residual material to a resource with economic value and potential as a renewable energy source. This change in mindset is an important aspect of successful community empowerment, as it provides a foundation for the sustainability of innovation at the community level.

The technical training on bio-pellet production was the stage that had the most tangible impact on improving participants' skills. Through hands-on practice, community members gained experience in feedstock sorting, size reduction, mixing, pelletization, and product drying. Participants' involvement in each stage of the production process facilitated effective knowledge transfer, enabling them not only to understand the underlying concepts but also to independently apply the production techniques. This was reflected in the final evaluation, in which 88 percent of participants correctly answered questions regarding the initial stages of bio-pellet production.

Quality control assistance was an aspect that distinguished the BIOPLASRI program from similar training activities. The program went beyond developing the ability to produce bio-pellets by introducing the importance of quality standardization through moisture content and calorific value parameters in accordance with the Indonesian National Standard. The calorific value testing results ranged from 4,331.61 to 5,467.26 cal/g. This approach provided participants with an understanding that product quality is a key factor in increasing consumer confidence and product competitiveness in the market. Thus, the community not only acquired the ability to produce bio-pellets but also understood the importance of maintaining consistent product quality for business development.

In terms of program impact, these achievements demonstrate that the BIOPLASRI program contributed to its primary objective of increasing partner capacity to utilize local waste as an alternative energy source. The average understanding score of 94 percent among the 25 participants indicates that knowledge transfer regarding feedstocks, production processes, utilization, and the economic benefits of bio-pellets was successfully achieved. In addition to knowledge acquisition, participants developed practical skills in operating the appropriate technology (pellet mill) and gained an understanding of the bio-pellet production process. Therefore, the impact of the program extends beyond the availability of bio-pellet products to include increased human resource capacity, which serves as an important foundation for sustainable waste management and the development of the BIOPLASRI business at the village level.

The results of this program are consistent with Tumuluru et al. (2011), who explained that biomass densification into pellets can improve fuel uniformity and facilitate storage, transportation, and utilization as an energy source. The BIOPLASRI results also support the findings of He et al. (2024), which demonstrated that biomass densification produces solid fuels with more uniform characteristics and has the potential to improve the efficiency of biomass utilization. In the context of plastic waste utilization, the results of this activity are also consistent with Wei et al. (2024), who reported the potential use of polyethylene waste as a blending material in biomass-based pellet fuels. Thus, the combination of corn cobs and plastic waste in BIOPLASRI is consistent with recent research on the utilization of biomass and plastic waste as solid fuels.

Compared with these previous studies, the main advantage of the BIOPLASRI program lies in its direct application at the village community level through a community empowerment approach. The program not only produced bio-pellets with a calorific value of 4,331.61–5,467.26 cal/g but also integrated education, appropriate technology training, quality control, packaging, branding, and institutional development. Thus, this community service program extends the application of biomass densification from a primarily technical concept to a community-based waste utilization model with potential for development into a village-scale alternative energy business.

The BIOPLASRI program successfully integrated environmental, technological, and economic aspects into a single community empowerment model. The utilization of corn cob waste and plastic waste to produce bio-pellets not only contributes to reducing environmental pollution but also enhances the community's capacity to produce value-added renewable energy products. This community service model has the potential to be replicated in other areas with similar biomass waste characteristics, thereby supporting the development of a circular economy and local potential-based energy resilience.

4. CONCLUSION AND RECOMMENDATIONS

The BIOPLASRI community service program successfully supported the implementation of appropriate technology (TTG) for bio-pellet production as an effort to sustainably manage corn cob waste and plastic waste in Plampangrejo Village. Assistance activities covering socialization, technical training, pellet mill operation, quality control, and business management enhanced the partners' capacity to process waste into alternative fuel. This was demonstrated by an increase in participants' understanding, with the average correct response rate in the post-test reaching 93 percent, compared with 50.4 percent in the pre-test, among 25 participants. The implementation of the appropriate technology resulted in a bio-pellet production capacity of 10–20 kg/day, using 3–6 kg of plastic waste and 7–14 kg of corn cobs per day. The resulting bio-pellets had a calorific value of 4,331.61–5,467.26 cal/g and met the calorific value requirement of >4,000 cal/g in accordance with SNI 8966:2021. In addition to producing

bio-pellets, the program strengthened sustainability through packaging, branding, marketing, and the involvement of the Youth Group and BUMDes in business management and development. Therefore, the BIOPLASRI appropriate technology implementation assistance not only improved the partners' capacity to process waste but also encouraged the development of a value-added waste utilization system with the potential to reduce unmanaged waste and support the sustainable development of alternative energy based on local resources.

To improve the effectiveness and sustainability of the BIOPLASRI Program, continued assistance should be provided to the community, covering both technical production and business management aspects. Bio-pellet production should be scaled up to meet market demand and generate broader economic benefits. In addition, more comprehensive quality testing of the bio-pellets should be conducted, including moisture content, ash content, density, mechanical strength, and combustion emissions, to ensure product compliance with the Indonesian National Standard (SNI). Stronger collaboration with BUMDes, the village government, and other stakeholders should also be established to support the sustainability of production, marketing, and business development of bio-pellets as an alternative energy source based on local resources.

ACKNOWLEDGEMENTS

Acknowledgements are addressed to all parties who supported the implementation of this community service program. Special appreciation is extended to the Plampangrejo Village Government, Cluring District, Banyuwangi Regency, along with all village officials, the Farmer Group, Youth Group, BUMDes, and the people of Plampangrejo Village for actively participated throughout the planning, implementation, and evaluation of the BIOPLASRI Program. Gratitude is also extended to the Institute for Research and Community Service (LPPM) of the University of Jember through the Dosen Mengabdi di Desa Asal Program for the funding support, facilities, and opportunity provided, which enabled the successful implementation of this program.

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