

Training on Biopellet Production from Sawdust Waste as a Renewable Energy Innovation

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Abstract: *Sawdust waste can be processed into biopellets as an alternative solid fuel, yet the technology is not widely known among young people in Maluku. This community service program aimed to improve the knowledge and skills of members of the Angkatan Muda Gereja Protestan Maluku (AMGPM), North Ambon Island Region, in making biopellets from sawdust with sago starch binder, and to foster their interest in renewable energy based on local waste. The activity was held on 30 May 2026 in Hatu Village, West Leihitu District, Central Maluku Regency, with 40 participants, using an andragogical approach combining lectures, discussions, demonstrations, and hands-on practice. Effectiveness was assessed with pre- and post-tests of knowledge and a before-and-after skills assessment. Mean biopellet knowledge scores increased from 20.00 to 87.00 (N-gain 0.84, high), and mean skill scores increased from 1.87 to 3.70 on a 1–4 scale, with the highest facilitator observation score for molding and drying biopellets (3.90). About 80% of participants were interested in replicating the training. This training can strengthen church youth as actors in waste processing and renewable energy based on local resources.*

Introduction

Maluku is an archipelagic region whose landscape is dominated by forest and coastal areas, and most of its people depend on the agriculture, plantation, and forestry sectors for their livelihoods. Wood-processing activities generate biomass waste, such as sawdust, twigs, and logging residues, which becomes an environmental burden if left unutilized. On the other hand, the development of alternative fuels from biomass is considered capable of reducing greenhouse gas emissions and dependence on fossil fuels (Shaputri *et al.*, 2025; Verma *et al.*, 2012).

Biopellets are solid fuels produced by compacting biomass, such as sawdust, rice husks, and wood waste. This product has a high calorific value and is more environmentally friendly than fossil fuels (Kamperidou, 2022; Lehtikangas, 2001). Sawdust has been studied as a raw material for pellets as a renewable biomass energy source (Hidayat *et al.*, 2026). Biopellet quality is generally assessed by moisture content, density, and calorific value, and in Indonesia it refers to the national standard (SNI 8675:2018).

One of the determining factors in successful biopellet production is the binder. Natural starch-based binders, such as sago flour, are relatively easy to obtain and safe for household users (Falua *et al.*, 2022; Imran *et al.*, 2025; Mondal *et al.*, 2026). Sago is a local staple food in Maluku, so the material is familiar to the community. Even so, biopellet production as a solution for both waste processing and alternative household energy is not yet widely known among the public (Yuliandewi & Putri, 2024).

Angkatan Muda Gereja Protestan Maluku (AMGPM; Youth Movement of the Protestant Church of Maluku) is a church-based youth organization with an extensive network reaching the level of congregation branches and villages (negeri), making it a strategic partner as an agent of change in natural resource management (Pongtambing *et al.*, 2024). The situation analysis identified three partner problems: (1) limited member knowledge about utilizing biomass waste into value-added products such as biopellets; (2) a lack of practical skills in biopellet production; and (3) low awareness and involvement of young people in environmental conservation.

This article reports a training on biopellet production from sawdust waste for members of AMGPM, North Ambon Island Region. The objectives of the activity were (1) to improve participants' knowledge of biopellets, (2) to improve participants' skills in making simple biopellets with sago flour binder, and (3) to foster young people's awareness of and interest in utilizing local waste as renewable energy. The reporting focuses on evidence of improvement in participants' understanding and skills based on a comparison of the initial and final evaluations. This activity supports the *Sustainable Development Goals* (SDGs) 7, 8, and 15 (Leal Filho *et al.*, 2023; Unga, 2015).

Methods

Target, Time, and Location

The target of the activity was 40 AMGPM members from the North Ambon Island Region representing various congregation branches. The activity took place on Saturday, 30 May 2026, from 09:00 to 15:00 WIT (Eastern Indonesia Time). The lecture session was held in the Hall of SMA Negeri 14 Hatu (State Senior High School 14 Hatu), and the practical session in the yard of the same school, in Hatu Village, West Leihitu District, Central Maluku Regency. This biopellet training was one part of a series of agroforestry community service activities for AMGPM held on the same day.

Approach and Stages of the Activity

The activity used an andragogical approach that emphasizes participatory, two-way, and practice-oriented learning because the participants were young adults who already had local experience (Knowles, 1980; Spoto, 2025). The learning design followed the experiential learning cycle (Kolb, 1984), namely delivery of concepts, demonstration and hands-on practice, and then joint reflection. The stages of the activity included:

- **Preparation and coordination** with AMGPM leaders, preparation of materials, preparation of practical materials and tools (dry sawdust, sago flour, 40-mesh sieve, simple PVC pipe molds, and iron plunger), and preparation of evaluation instruments.
- **Initial evaluation** (*pre-test*) at participant registration, before the material was delivered, to measure initial knowledge and skills.
- **Interactive lecture and discussion** on biopellet production (resource person Sofia Mustamu, S.Hut., M.Si.), moderated by Dr. Irwanto, S.Hut., M.P.
- **Demonstration and hands-on practice of biopellet production** in groups, from raw material preparation to molding simple biopellets, with guidance from the resource person.
- **Final evaluation** (*post-test*) and participatory evaluation in the form of participant feedback, followed by closing of the activity.

Table 1. Schedule of activities

Time (WIT)	Activity
09:00–09:15	Participant registration and initial evaluation (<i>pre-test</i>)
09:15–10:30	Welcome remarks (Advisor, Secretary of the Central Board, and Regional Chair of AMGPM) and introduction to the activity by the Team Leader
11:30–12:15	Lecture and discussion: biopellet production
12:15–13:00	Break and lunch
13:00–14:00	Demonstration and practice of biopellet production
14:00–14:30	Final evaluation (<i>post-test</i>) and participant feedback
14:30–15:00	Closing

The schedule is shown in part; other sessions held on the same day are outside the scope of this article.

Initial and Final Evaluation Instruments

Improvement in participants' capacity was measured using a *one-group pretest–posttest* design. Two instruments were used, with identical items in the initial and final evaluations so that the results could be compared.

- **Knowledge test:** 10 multiple-choice questions on biopellets (raw materials, process stages, quality standards, and economic value). Scores were calculated on a 0–100 scale and categorized as low (<60), moderate (60–79), and high (≥80).
- **Skills assessment:** four indicators of practical biopellet-making skills (Table 3), rated on a 1–4 scale (1 = unable to perform; 2 = able with full assistance; 3 = able with minimal assistance; 4 = able to perform independently). In the initial evaluation, participants rated their own abilities. In the final evaluation, the assessment was

supplemented with a facilitator observation sheet during the practice so that it did not rely solely on self-assessment.

Table 2. Skill indicators assessed

Code	Skill indicator
K1	Preparing and sorting biomass raw materials
K2	Drying and chopping/pulverizing raw materials
K3	Mixing materials with a natural binder in the appropriate proportions
K4	Molding and drying biopellets

Indicator codes follow the activity assessment instrument.

Data Analysis

The data were analyzed using simple descriptive methods. For each aspect, the mean initial and final scores, the difference in means, and the percentage of relative improvement were calculated, namely $(\text{final mean} - \text{initial mean}) / \text{initial mean} \times 100\%$. For knowledge scores, the normalized *N-gain* was also calculated, $g = (\text{final score} - \text{initial score}) / (100 - \text{initial score})$, with the categories high ($g \geq 0.7$), moderate ($0.3 \leq g < 0.7$), and low ($g < 0.3$) (Hake, 1998). Qualitative data in the form of participants' responses and suggestions were analyzed using descriptive-thematic analysis.

Result and Discussion

Implementation of the Activity

The activity was attended by 40 AMGPM members from the North Ambon Island Region and proceeded as planned. The welcome remarks from the Advisory Pastor, the Secretary of the Central Board, and the Regional Chair of AMGPM expressed appreciation for the university's concern for the empowerment of church youth in natural resource management. The biopellet material covered the definition and biomass raw materials, production stages (drying, chopping/grinding, binder mixing, molding, and final drying), quality standards (moisture content, density, calorific value), and the potential for group enterprises.



(a) The resource person provides information about the benefits of biopellets.

(b) Participants

Figure 1. Implementation of the Lecture and Discussion

In the practical session, the resource person demonstrated the biopellet production stages (Table 2), after which participants carried them out themselves with guidance from the resource person, from raw material preparation to molding simple biopellets. Participants were directly involved in every stage, rather than merely observing.



(a) Demonstration by the resource person

(b) Practice by participants

Figure 2. Implementation of the Biopellet Production Practice

Technical Stages of Biopellet Production

The biopellets practiced were made from sawdust with sago flour binder using simple equipment. The training material covered the definition and biomass raw materials, production stages, quality standards (moisture content, density, calorific value), and the potential for group enterprises. The technical stages of biopellet production practiced by participants are presented in Table 2.

Table 3. Technical stages of biopellet production practiced

Stage	Activity practiced	Principle and purpose
1. Material preparation	Preparing dry sawdust (avoid wood coated with paint or chemicals), sago flour as a natural binder, and sufficient water.	Clean, dry materials avoid contaminants and keep moisture content low.
2. Sieving the sawdust	Sieving the sawdust with a 40-mesh sieve.	Uniform particle size facilitates mixing and compaction.
3. Binder preparation	Dissolving 9 grams of sago flour in cold water, then adding hot water while stirring until it thickens and forms a gel-like consistency.	Heated starch becomes a sticky gel that can bind the sawdust.
4. Mixing	Mixing the sawdust with the sago binder at a mixture ratio of 30 grams: 30% binder and 70% sawdust, then stirring until evenly mixed.	Evenly dispersed binder produces compact biopellets.

Stage	Activity practiced	Principle and purpose
5. Molding	Putting the mixture into a mold made from a PVC pipe section (length 30 mm, diameter 12 mm), pressing with an iron plunger until compact, then pushing it out.	Compaction produces biopellets of uniform shape and sufficient density.
6. Drying	Sun-drying the biopellets until completely dry and hard.	Low moisture content prevents mold and makes the biopellets easy to burn.
7. Storage	Storing the biopellets in a dry, closed, non-humid place, in a sack or airtight plastic container.	Preventing the biopellets from reabsorbing moisture.

1. Material Preparation

Sawdust is obtained from sawmill or wood-processing waste. The sawdust used should come from wood that has not been coated with paint, varnish, preservatives, or other chemicals. The sawdust needs to be inspected to ensure that it is not mixed with soil, stones, metal pieces, plastic, or other impurities. If the sawdust is still wet, carry out preliminary drying before the sieving process.

Sago flour is used as a natural binder. The starch in sago flour undergoes gelatinization when heated with water, forming a gel that can bind wood particles.

Water is used to dissolve the sago flour and to help the gel-forming process. The amount of water needs to be controlled so that the mixture is moist enough to be molded but not too wet.

Equipment that can be used includes:

- A digital scale for weighing materials.
- A 40-mesh sieve.
- A mixing container and a stirrer.
- A measuring cup or water-measuring container.
- A heating device for preparing the binder.
- A mold made from a PVC pipe section and an iron pressing plunger.
- A drying container.

2. Sieving the Sawdust

Sieving is carried out to obtain a relatively uniform sawdust particle size. Particle size affects the ease of mixing with the binder, the density of the pellets, and the strength of the biopellets after drying. The steps are as follows.

- Prepare sawdust that has been cleaned of impurities.
- Gradually put the sawdust into the 40-mesh sieve.
- Gently shake the sieve until the appropriate particles pass through the openings.
- Separate particles that are too coarse and wood lumps that do not pass through the sieve.

- Collect the sawdust that passes through the sieve in a clean, dry container.

Points to note: sawdust that is too coarse can cause the biopellets to crack easily or be insufficiently compact. Conversely, sawdust that is too fine may require more binder or adjustment of the moisture content.

3. Binder Preparation

Binder preparation aims to convert sago flour into a gel that can bind sawdust particles. In this initial procedure, 9 grams of sago flour are used. The preparation steps are:

- Weighing the sago flour. Weigh 9 grams of sago flour using a digital scale.
- Making the initial suspension. Put the sago flour in a container, then add a little cold water. Stir until the flour is evenly mixed and free of lumps.
- Heating the water. Heat water separately until it is near boiling.
- Adding hot water. Pour the hot water little by little into the sago flour suspension while stirring continuously. Gradual addition helps prevent lumps from forming.
- Further heating. If necessary, heat the mixture over low heat while stirring until it thickens and forms a relatively homogeneous gel.
- Cooling the binder. Once the gel has formed, let the binder cool until warm before mixing it with the sawdust.

A good binder has a thick texture, is not too runny, and contains no lumps of uncooked flour.

4. Mixing

Mixing is carried out to ensure that all sawdust particles are evenly coated with the binder. A homogeneous mixture helps produce biopellets with more consistent shape and density. The mixing steps are as follows:

- Weigh the sawdust that has passed through the 40-mesh sieve.
- Prepare the sago flour binder that has been made and cooled.
- Put the sawdust into the mixing container.
- Add the binder gradually while stirring the sawdust.
- Continue stirring until the binder coats the sawdust particles evenly.
- Check the texture of the mixture before molding.

A mixture that is ready for molding is generally moist enough to hold its shape when squeezed in the hand, but does not release water when pressed. If it is too dry, the pellets tend to crack easily; if it is too wet, the pellets may be difficult to remove from the mold and require a longer drying time. The composition used is a ratio of 70% sawdust to 30% binder. However, it is necessary to distinguish between dry sago flour and sago binder that has formed a gel.

Table 4. Component Proportions in Biopellet Production

Component	Proportion	Weight
Sawdust	70%	21 grams
Sago binder	30%	9 grams
Total	100%	30 grams

5. Molding

Molding aims to shape the mixture of sawdust and binder into cylindrical pellets of relatively uniform size. In this simple method, the mold uses a PVC pipe section 30 mm in length and 12 mm in diameter, with an iron plunger as the pressing tool. The molding steps are:

- Prepare a pipe mold 30 mm in length and 12 mm in diameter.
- Make sure the inside of the mold is clean and free of residual mixture from previous molding.
- Gradually put the sawdust and binder mixture into the mold.
- Compact the mixture using an iron plunger or pressing rod whose size matches the inner diameter of the mold.
- Apply pressure gradually and evenly to reduce air voids between particles.
- Slowly push the biopellet out of the mold using the plunger.
- Place the biopellets on a clean tray or drying surface.
- Repeat the process until all the mixture has been molded.

During molding, try to keep the pressure and the amount of mixture in each mold relatively constant. This is important to maintain uniformity in the size, shape, and density of the biopellets.

6. Drying

Drying aims to reduce the water content of the biopellets after molding. High moisture content can reduce combustion quality, increase the risk of mold growth during storage, and make the biopellets more prone to damage. The drying steps are as follows:

- Arrange the biopellets separately on a tray or drying base, not stacked.
- Dry them in the sun in a clean place with good air circulation.
- Turn the biopellets periodically so that drying proceeds evenly.
- Protect the biopellets from rain, excessive dew, dust, and contamination.
- Continue sun-drying until the biopellets feel hard and do not crumble easily when handled.
- Cool the biopellets after drying before placing them in a storage container.
- If available, measure the moisture content using an appropriate moisture meter.

The drying time cannot be determined precisely because it is influenced by sunlight intensity, air humidity, biopellet size, the amount of binder, and initial moisture content. Therefore, drying should be determined based on measurement results, not merely on the length of sun exposure.

7. Storage

Storage is carried out to maintain biopellet quality after drying. Dried biopellets can reabsorb water vapor from the environment if stored in a humid place. The storage steps are as follows:

- Make sure the biopellets are cool and sufficiently dry before packaging.
- Separate biopellets that are cracked, crumbled, or moldy from those that remain intact.
- Put the biopellets into a clean, dry container, such as a closed bag or airtight container.

- Label them with the type of raw material, binder composition, date of production, and sample code.
- Store in a dry place, not exposed to rain, and protected from moisture.
- Avoid storing biopellets near heat sources or open flames.
- For research purposes, periodically check for changes in shape, color, hardness, and signs of mold growth.

Storage in closed containers helps reduce the reabsorption of water from the air. However, the biopellets must be sufficiently dry before packaging so that moisture trapped inside the container does not trigger mold growth.

Improvement in Understanding (Knowledge)

A comparison of the initial and final evaluation results is presented in Table 4. The mean biopellet knowledge score increased from 20.00 in the initial evaluation to 87.00 in the final evaluation, a rise of 67 points (relative improvement of 233,33%). The *N-gain* value of 0.84 is classified as high (Hake, 1998). By category, the participants' mean shifted from the low level (<60) in the initial evaluation to the high level (≥ 80) in the final evaluation.

Table 5. Participants' knowledge scores in the initial and final evaluations

Knowledge aspect	Initial mean	Final mean	Gain	Relative gain (%)	<i>N-gain</i>
Biopellet production (10 items)	20.00	87.00	67.00	233.33	0.84

Scores on a 0–100 scale ($n = 40$). *N-gain* ≥ 0.7 = high. Source: primary data, 2026.

This large improvement is understandable because the topic of biopellets was relatively new to the participants (Yuliandewi & Putri, 2024). Concepts such as biopellet quality standards (moisture content, density, calorific value) are new knowledge that requires systematic explanation, whereas raw materials such as sawdust and sago were already familiar to participants in their daily lives. This pattern is consistent with the andragogy principle that adults learn most effectively when the material relates to real experience and needs (Knowles, 1980; Yahya *et al.*, 2024).

Improvement in Skills

The results of the skills assessment in the initial and final evaluations are presented in Table 5. The overall mean skill score (K1–K4) rose from 1.87 (the “unable to perform” category) to 3.70 (the “able to perform independently” category), with a facilitator observation score in the final evaluation of 3.82. The largest improvements occurred in K2 (drying and pulverizing raw materials) and K4 (molding and drying biopellets), each rising by 2.88, and the highest observation score was recorded for K4 (3.90). The smallest improvement occurred in K1 (preparing and sorting raw materials), which was the most familiar to participants (initial score 1.96).

Table 6. Participants' skill scores in the initial and final evaluations (1–4 scale)

	Indicator	Initial mean	Final mean	Change	Facilitator score
K1	Preparing and sorting biomass raw materials	1.96	3.72	1.76	3.80
K2	Drying and chopping/pulverizing raw materials	1.92	3.80	1.88	3.80
K3	Mixing materials with a natural binder in the appropriate proportions	1.80	3.60	1.80	3.78
K4	Molding and drying biopellets	1.80	3.68	1.88	3.90
	Mean	1.87	3.70	1.83	3.82

For indicator descriptions, see Table 2. Initial scores are self-assessments; observation scores are available only for the final evaluation. Source: primary data, 2026.

The improvement in skills was supported by the substantial share of practice in the activity design, namely one hour of hands-on practice after the lecture session. Learning through concrete experience, reflective observation, and re-application (Kolb, 1984) enables participants to turn conceptual knowledge into working ability. Biopellet production demands precision in binder proportions, gel viscosity, and compaction pressure, which are most easily learned by trying them directly. Guidance from the resource person in small groups gave participants the opportunity to try, correct mistakes, and ask questions directly.

It should be noted that skills in the initial evaluation were self-assessed by participants. Self-assessment at the initial stage is potentially overestimated because participants did not yet know the correct work standards, so the apparent improvement may be smaller than the actual improvement. For this reason, the final assessment was supplemented with facilitator observation.

Participant Feedback and Interest

In the participatory evaluation session, participants expressed high enthusiasm for the potential of developing biopellets as an alternative source of income for families and congregations. Participants also asked follow-up questions and provided input showing an interest in applying and replicating the training outcomes in their respective villages. Several participants said that they wanted to try making biopellets in their own areas.

Based on the evaluation results, about 80% of participants stated that they were interested in applying or replicating the training results in their respective communities, while the remaining participants expressed interest in continuing the discussion and obtaining technical support before implementation. This high response indicates that the training not only improved knowledge and skills but also opened participants' insight into the link between environmental conservation and economic opportunity. This finding is in line with the third objective of the activity, namely to foster young people's awareness of and interest in utilizing local waste as renewable energy.

Innovation and Implications for Renewable Energy and Conservation

This activity introduced three forms of innovation to the partner. **First**, a simple technological innovation in the form of biopellet production from sawdust with sago flour binder, PVC pipe molds, and sun drying, so that it can be replicated without expensive machinery. This utilization applies the principle of *zero waste* and has the potential to reduce tree felling for firewood (Hidayat *et al.*, 2026). **Second**, a social innovation in the form of church youth empowerment. The AMGPM network of branches and congregations allows the training outcomes to be replicated widely, and the value of caring for creation (*eco-theology*) provides a moral foundation for conservation efforts. **Third**, an economic innovation in the form of group enterprise opportunities based on waste and local materials.

In terms of economic resilience, biopellets open up group enterprise opportunities based on local waste. In terms of the environment, biomass-based energy reduces dependence on fossil fuels and firewood (Hidayat *et al.*, 2026; Shaputri *et al.*, 2025; Verma *et al.*, 2012). This contribution is in line with SDG 7 (affordable and clean energy), SDG 8 (decent work and economic growth), and SDG 15 (life on land), as well as the role of youth organizations in supporting the achievement of the SDGs (Pongtambing *et al.*, 2024; Unga, 2015).

Limitations and Follow-up

This activity has several limitations. The *one-group pretest–posttest* design without a comparison group cannot separate the effect of the training from other factors, and the measurements were taken on the same day, so they do not yet reflect long-term retention. In addition, the biopellets produced in the practice were small-scale and made with manual molds, and their quality (moisture content, density, calorific value) and combustion characteristics have not yet been tested.

The planned follow-up includes quality testing of the biopellets against applicable standards, combustion tests, adjustment of the binder composition, a feasibility study of group enterprises, and technical assistance for participants who wish to apply it in their respective communities. This technical support responds to the request of some participants and is important for sustaining the impact of the activity.



Figure 3. Group Photo with Training Participants

Conclusion and Recommendation

The biopellet production training from sawdust waste for 40 AMGPM members of the North Ambon Island Region was carried out successfully on 30 May 2026 in Hatu Village. The comparison of the initial and final evaluations showed an improvement in biopellet knowledge (mean from 20.00 to 87.00; *N-gain* 0.84) and skills (mean from 1.87 to 3.70). About 80% of participants were interested in applying or replicating the training results. The combination of lectures, discussions, demonstrations, and hands-on practice using an andragogical approach was effective in building the capacity and awareness of church youth regarding the use of waste as renewable energy. The sustainability of the impact needs to be maintained through product quality testing, mentoring, and long-term partnerships.

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