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Assessing the effectiveness of livestock waste management training in promoting technology adoption among farmers

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ABSTRACT

Livestock waste is an environmental challenge that has the potential to provide benefits if managed effectively. However, suboptimal waste management in various regions of Indonesia indicates a need for targeted training programs for farmers. This study investigated the key factors that affect how farmers adopt livestock waste management technologies after participating in training programs. A quantitative research approach focusing on causal relationships is employed using training and adoption theories. Interviews and online questionnaires are administered to 240 participants from the Animal Husbandry Training Centre in Songgoriti, Batu. The collected data were analyzed using linear regression to assess the effects. The factors examined in this study include research progress, business scale (number of livestock), type of livestock, age, farming experience, education level, and family size. The results of the study indicate that technology adoption is significantly influenced by three main factors, namely training effectiveness, farm scale (number of livestock), and type of livestock. In contrast, age, farming experience, education level, and family size do not significantly affect the adoption of waste management technologies.

Introduction

Poor management of animal waste is now a major global problem that threatens the long-term health of the environment. Bad practices can have a number of bad effects, such as more greenhouse gas emissions, pollution of water and soil, and loss of biodiversity (Syaharani *et al*., 2024). Specifically, the global livestock production system is one of the main sources of methane emissions, a highly potent greenhouse gas (Scoones, 2023). Various global efforts are now focused on reducing methane emissions, which have a significant impact. This is being done by establishing a standardized system for measuring, verifying, and reporting (MVR) emissions (Scoones, 2023). This problem is further worsened by limited infrastructure and waste management technology in developing countries. In India, livestock waste amounts to 1,095 million metric tons annually (Parihar *et al*., 2019). In Indonesia, the Indonesian Central Statistics Agency reports an estimated 372,000 tons of cattle manure daily, not including urine and hair (Kacprzak *et al*., 2023).

Furthermore, communities often complain about the odour from poultry waste due to the ammonia gas emitted from the excreta (Kacprzak *et al*., 2023). Cattle waste could be converted into biogas and organic fertilizer through a circular economy system, which could also serve as a renewable energy solution (Samadamaeng *et al*., 2024). Intensive livestock production systems are a significant contributor to environmental pollution, affecting soil, water, and air on a large scale. Water pollution is often caused by runoff from livestock areas, which risks contaminating clean water sources and surface waters, as well as spreading disease-causing pathogens (Syaharani *et al*., 2024). Inadequate waste management, such as through accumulation practices, can trigger the decomposition of organic materials, potentially causing air pollution. The application of a circular economy approach enables livestock waste to be reused as a valuable resource, such as biogas that functions as renewable energy or organic fertilizer to support sustainable agricultural practices (Doyeni *et al*., 2023). Conversely, if waste is not managed properly, the decomposition process will produce harmful gas emissions and pungent odors that have negative implications for human health (Turcea and Mihai, 2019).

Through proper management, livestock waste has the potential to be transformed into various value-added products, such as renewable energy sources, organic fertilizers, and raw materials for industry. One standard method of waste management is to convert into biogas, which accelerates compost production and generates methane gas as a fuel source while also reducing environmental pollution (Pizarro-Loaiza *et al*., 2021; Wahyuni *et al*., 2018). Methane has a strong potential to replace fuel gas in rural areas (Sahara, 2024). The strategic potential of biogas can be developed to motivate community investment in the livestock sector, particularly cattle farming. Therefore, effective livestock waste management requires knowledge and skills. However, converting livestock waste into biogas remains challenging for small-scale farmers who lack the necessary materials and equipment to transform waste into biogas (Roubík and Mazancová, 2020). Training is one method to enhance these skills, improve human resources, and build the capacity of farmers (Mariyono, 2018).

Training is critical in increasing farmers' adoption of waste management technologies. Training is a crucial instrument for encouraging farmers to adopt waste management technologies through three main mechanisms: increasing knowledge, awareness, and positive perceptions. First, training directly improves the knowledge and technical skills needed to apply specific technologies such as organic fertilizer production (Setianto, 2020). Second, extension programs have proven effective in raising public awareness, particularly among cattle farmers, about the importance of waste management (Odoniyi *et al*., 2023). Third, technical training has been shown to change farmers' perceptions of the economic and health benefits of an innovation, which ultimately significantly boosts adoption rates (Liu *et al*., 2022). Overall, training interventions can be seen as a determining factor in the successful adoption of technology, as they play a

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role in building two key foundations simultaneously: increasing technical capacity and strengthening farmers' positive perceptions of innovation.

In addition, the Diffusion of Innovations Theory (Rogers, 2003) provides a comprehensive conceptual framework for analyzing the effectiveness of training programs in facilitating the adoption of waste management technology. This theory emphasizes that the adoption of innovations is influenced by factors such as relative advantage, compatibility with farmers' values or needs, complexity, trialability, and observability. In other words, practical training should address these factors to drive behavioural change significantly among farmers.

However, the literature still shows a significant research gap regarding the effectiveness of training in promoting the adoption of waste management practices, particularly in the context of farmers in developing countries. Most previous studies have focused on the technical aspects of waste management or the environmental benefits of biogas usage. However, studies that specifically examine the relationship between training and the process of technology adoption from the perspective of farmer behavior are still very limited. Furthermore, there is insufficient empirical evidence regarding the factors that influence the sustainability of these practices post-training.

This study aimed to fill this gap by specifically analyzing how training provided by the Animal Husbandry Training Centre in Songgoriti influences farmers' adoption of waste management practices. Referring to Rogers (2003), innovation adoption framework, this study also evaluated various success factors for adoption, such as perceived benefits, ease of use, and social support. Through this approach, the study hopes to contribute theoretically and practically to developing more effective training strategies in the livestock sector.

Materials and methods

This study used a survey method with a structured questionnaire as the main instrument for collecting primary data. The research respondents were a representative sample taken from the total population of training participants. The distributed questionnaire contained statements corresponding to the variables examined in this study. The research variables were grouped into several categories. The main variable was participation in training. Meanwhile, the control variables included demographic characteristics (farmers' age, education level, household size), experience (length of time farming), and farming characteristics (scale of business/number of livestock, type of livestock, and business objectives)..

This study was conducted at the Indonesian Center for Livestock Training in Songgoriti, one of the institutions actively organizing livestock waste management training. By focusing on livestock waste management, this study emphasizes the importance of education and training to enable farmers to manage waste sustainably. Livestock waste management training provides technical knowledge to farmers and raises awareness of the importance of a proper waste management system, which positively impacts the community and the environment. This platform can also serve as a space to share experiences and best practices for waste management among farmers, creating a supportive learning community. Through this collaborative approach, livestock waste management is expected to improve significantly, benefiting the community and the environment in the long term.

The target population in this study included all individuals who participated in the livestock waste management training program during the period 2019–2023. From this population, 240 participants were selected as the final sample using purposive sampling. This method was chosen to ensure that the respondents met certain criteria relevant to the research objectives, so that the data obtained would be both in-depth and representative.

The research instrument used was a questionnaire. Validity testing was conducted using Pearson's Product-Moment correlation, and the results showed that the correlation value of each item (r-calculated) was higher than the critical value (r-table), so all items were declared valid. Furthermore, the reliability test using Cronbach's Alpha showed that all variables had acceptable reliability values ($\alpha > 0.60$), confirming the internal consistency of the instrument.

The entire quantitative data analysis process was conducted using SPSS (Statistical Package for the Social Sciences) version 26 software. The collected data were analyzed using multiple linear regression to test the effect of training participation and other independent variables on the adoption of waste management technology (dependent variable). Before the main analysis, the regression model was confirmed to have met the classical assumption tests, which included a normality test using the Kolmogorov-Smirnov method, a multicollinearity test by examining the Variance Inflation Factor (VIF) value, and a heteroscedasticity test by analyzing the pattern in the scatterplot of the residuals.

The regression model used is as follows:

$$Y = a + b1\ X1 + b2\ X2 + b3\ X3 + b4\ X4 + b5\ X5 + b6\ X6 + b7\ X7 + b8\ X8 + e$$

Where:Y = Level of technology adoption in livestock waste management, measured on a scale from 0 to 4:

0 = No action taken
1 = Waste collected/sorted
2 = Raw compost produced
3 = Mature organic fertilizer processed
4 = Processed into biogas
X_1 = Training progress
X_2 = Farmer's age
X_3 = Farming experience
X_4 = Education level
X_5 = Business scale (number of livestock)
X_6 = Type of livestock
X_7 = Number of household members
X_8 = Business objectives

The study tested the following hypotheses at a significance level of $\alpha < 0.05$. The study tested these variables' overall and individual effects on the dependent variable. A significance level of $\alpha < 0.05$ was used. To test for simultaneous effects, the model evaluated whether all independent variables jointly had a statistically significant impact on the level of adoption. The null hypothesis is rejected if the resulting p-value was less than or equal to 0.05, indicating a significant joint effect. Conversely, a p-value greater than 0.05 indicating that the variables had no significant simultaneous effect. To assess partial effects, individual significance tests were conducted for each variable. A p-value of less than or equal to 0.05 indicating that the variable had a statistically significant individual effect on the dependent variable. In contrast, a p-value greater than 0.05 indicated no significant individual influence.

Results

The study involved 240 respondents, all of whom were livestock farmers. The majority of participants were male and under the age of 45. The data were analyzed using multiple linear regression. The classical assumption tests were not presented in table format per reporting standards. The regression analysis results show that there are several variables that significantly influence the level of adoption of livestock waste treatment technology.

Participant characteristics

All 240 participants were actively engaged in livestock farming and had attended training programs between 2019 and 2023. Most of the respondents had participated in training in 2019. The participants' age range varied from under 45 to over 60. Most had 7–8 years of farming experience and a junior high school education level.

Farmers' adoption Levels

The adoption levels following the training can be summarized as follows: 1 farmer (0.4%) did not adopt any practices, 40 farmers (16.7%) sorted or collected livestock waste, 73 farmers (30.4%) processed the waste into raw compost, 87 farmers (36.3%) processed it into mature compost, and 39 farmers (16.3%) converted the waste into biogas.

Results of the simultaneous significance test

Using the F-test, it was found that the variables—including training progress, age, farming experience, education level, business scale, livestock type, household size, and business objective—simultaneously had a statistically significant effect on the adoption level of livestock waste processing technologies ($p < 0.05$).

Results of the partial coefficient test

The partial significance test revealed that training progress, business scale, livestock type, and business objective significantly affected adoption levels. On the other hand, age, education level, farming experience, and number of household members did not show significant effects. For example, training progress was significant ($\beta = 0.018$, $p < 0.05$), whereas the other variables were not statistically significant.

Linear regression equation

The linear regression model describing the relationship between the independent variables and the adoption of livestock waste processing technologies is expressed as: $Y = 1.916 + 0.006\ X1 + 0.011\ X2 + 0.005\ X3 + 0.064\ X4 + 0.027\ X5 + 0.395\ X6 – 0.046\ X7 + 0.280\ X8 + e$.

Y = Adoption level of livestock waste processing technology
X1 = Training progress
X2 = Farmer's age
X3 = Farming experience
X4 = Education level
X5 = Business scale (number of livestock)
X6 = Type of livestock
X7 = Number of family members
X8 = Business objective

From the equation, the base adoption score is relatively low (1.916). Farmers who showed more progress in training were more likely to adopt waste processing technologies. Higher age, education level, farming experience, and business scale contributed positively to adoption. The results confirm that livestock type (dairy cows) and commercial business orientation are positively correlated with technology adoption rates. Conversely, household size has a significant negative effect, indicating that larger families can be an obstacle to the adoption of waste treatment technology.

Discussion

The quality and design of training programs are key determinants that significantly influence the adoption rate of livestock waste processing technology. Training that is comprehensively designed—covering the presentation of relevant material and the application of innovative teaching methods—has proven to be more effective in equipping farmers with the in-depth understanding and practical skills they need (Ensor and de Bruin, 2022). A thorough understanding of the benefits and operational mechanisms of such technology, in turn, strengthens farmers' confidence in implementing it and minimizes resistance to change.

This finding is consistent with various empirical studies that consistently show that farmers who participate in high-quality, focused training programs tend to have higher rates of technology adoption (Mgendi *et al*., 2021; Czaker *et al*., 2024; Pandey *et al*., 2025). The practical implication is that training programs must be designed to be progressive and adaptive. To maximize their impact, regular content updates, the use of interactive methods, and the adaptation of materials to real-world challenges and technological developments in the field are necessary to promote more efficient waste management practices in the livestock sector (Ramirez *et al*., 2021).

Programs must adapt to farmers' specific needs and challenges and technological advancements to maximize the impact of training. Relevant and interactive training materials and ongoing support will help farmers comprehend and utilize livestock waste processing technologies more effectively (Nurhapsa *et al*., 2024). Therefore, investing in advanced and relevant training is key to fostering broader and more effective technology adoption in the livestock industry (Papakonstantinou *et al*., 2024).

The results of this study indicate that age does not have a statistically significant effect on the adoption rate of livestock waste treatment technology. This finding challenges the common assumption that older farmers tend to be resistant to innovation. Although younger farmers are relatively quicker to learn new things, older farmers have experience and in-depth understanding that enable them to evaluate the benefits of new technologies more critically and meaningfully (Adawiyah, 2017). This practical experience often compensates for cognitive limitations or resistance to change often associated with age (Wahyuni *et al*., 2018). Thus, it can be concluded that adoption decisions are more determined by practical needs and the relevance of technology to the operational context of agriculture than solely influenced by chronological age (Chavas and Nauges, 2020).

Factors that have been proven to be more decisive in the adoption process are farmer motivation and the quality of external support such as training. Factors that have been proven to be more decisive than age are internal motivation and external support. Farmers' attitudes toward innovation are not always tied to age, but rather shaped by their perceptions of direct benefits, such as increased efficiency or compliance with environmental standards (Hannus and Sauer, 2021; Granado-Díaz *et al*., 2024). In addition to motivation triggered by perceived benefits, external support in the form of effective and relevant training programs has been shown to play a crucial role in strengthening adoption intentions and ensuring successful implementation (Hermawan *et al*., 2024; Xiuling *et al*., 2023). With the implementation of the appropriate training and support approach, age is no longer a significant barrier in the technology adoption process (Pang *et al*., 2021).

In conclusion, although age may influence the way individuals receive and process information, factors such as prior knowledge, practical experience, and the quality of training are more decisive in enabling the adoption of livestock waste processing technologies (Izuchukwu *et al*., 2023). Therefore, strategies to enhance technology adoption should focus on improving training quality and technical support while aligning approaches with farmers' practical needs—without overemphasizing age as a determining factor (Xiuling *et al*., 2023).

The results of this study indicate that farming experience does not have a statistically significant effect on the level of adoption of waste treatment technology (Sheets *et al*., 2015). This finding indicates a paradox, namely that although practical experience provides a valuable foundation of knowledge about agricultural operations (Fountas *et al*., 2020), such experience does not always correlate positively with the level of openness to innovation. There are two main reasons for this phenomenon. First, long-term experience in traditional methods does not guarantee exposure to or understanding of modern technological developments (Bolatan *et al*., 2024). The knowledge possessed may be highly relevant to everyday practices, but it often does not include the specific technical skills needed to implement innovative systems (Lam *et al*., 2021).

More than just the length of experience, farmers' attitudes and internal motivation have proven to be stronger drivers of technology adop-

tion. Attitudes toward innovation can vary significantly among farmers and do not always correlate with the length of farming experience (Yagüe-Perales *et al*., 2020). Experienced farmers accustomed to traditional methods tend to exhibit more conservative and cautious attitudes, especially when the practices they employ have proven successful (Abdul-Majid *et al*., 2024). Conversely, farmers with relatively less experience often show greater openness to change, especially when they identify clear and immediate benefits from the application of new technologies (Liu and Liu, 2024). These findings confirm that adoption decisions are more influenced by perceptions of usefulness and motivation to improve operational effectiveness, factors that can arise among farmers at various levels of experience.

Ultimately, external factors such as training quality and technical support proved to be more influential variables than farming experience itself (Liu *et al*., 2022). The availability of relevant training, adequate technical support, and access to accurate information tended to reduce the significance of experience in determining the level of technology adoption. High-quality external interventions directly equip farmers with the competencies and confidence needed to adopt innovations. This shows that when farmers-regardless of their experience-receive adequate support, various obstacles rooted in habits and conservative attitudes can be effectively overcome.

The results of this study indicate that the level of formal education does not have a statistically significant effect on the level of waste treatment technology adoption. This finding suggests that this factor is not the main determinant in farmers' decisions to adopt new technology (Pandeya *et al*., 2025). The decision to adopt technology in this context is more influenced by practical factors, such as technical skills and operational understanding, which do not always correlate directly with the level of formal education (Ley *et al*., 2022). While formal education can provide a valuable foundation of basic knowledge, readiness to implement new innovations is more determined by practical experience in the field than by theoretical knowledge gained through school education (Serebrennikov *et al*., 2020). Technology adoption often depends on practical experience, hands-on skills, and an understanding of specific operational needs, which are not always measured by formal education level (Gerli *et al*., 2022). Farmers with varying education levels may possess similar levels of understanding and skill regarding waste processing technology if they have received relevant practical experience or training (Park *et al*., 2025). It indicates that practical experience, rather than formal education alone, plays a more significant role in readiness to adopt technology.

Farmers who are highly motivated and open to innovation may adopt new technologies more quickly, regardless of their level of education (Kusnandar *et al*., 2023). The motivation to innovate and seek more efficient solutions may surpass the constraints of formal education, which is often influenced by personal factors and more immediate operational needs. Individual attitudes and motivations have been shown to be stronger predictors of technology adoption than formal education levels alone. For example, individuals with high levels of education but who lack motivation or are reluctant to change long-established habits may not automatically adopt new innovations (Basileo and Lyons, 2024). This situation highlights the crucial role of external intervention, where practical training and adequate technical support serve as determining factors in encouraging adoption. Such programs are able to bridge the gap that arises due to differences in educational backgrounds by equipping all farmers at various educational levels with the understanding and skills necessary to implement waste management technology (Daniel *et al*., 2023).

With appropriate training, farmers with lower levels of education can overcome challenges arising from a lack of formal knowledge and quickly adopt new technologies. With the proper support, farmers with lower educational levels can effectively adopt new technology, while farmers with higher educational levels may also require additional guidance to adapt to new technologies (Wang *et al*., 2020). This emphasizes that training and technical support quality is far more critical in technology adoption than the farmer's formal education level.

The scale of the business, measured by the number of livestock, significantly influences the adoption of waste processing technology, as the size of the operation affects the needs, capacity, and priorities in waste management (Sahara, 2024). Larger-scale farmers face more complex and significant waste management challenges (Haque *et al*., 2023). Therefore, they are more likely to adopt technologies that can handle large volumes of waste (Mukherjee *et al*., 2020).

More extensive operations typically have excellent resources and financial capacity to invest in advanced and costly waste processing technologies (Zyder *et al*., 2024). The scale of the business has proven to be one of the main factors influencing the level of adoption of waste management technology. Farmers with larger numbers of livestock generally have stronger financial capacity, making them more capable and willing to invest in technologies that offer efficiency and long-term sustainability (Huang *et al*., 2024). Additionally, their motivation is reinforced by the fact that the economic benefits of such innovations—such as biogas or compost production—are most significant when implemented at a large production scale (Devi *et al*., 2022). Thus, business scale not only provides the capital for initial investment but also ensures the economic viability of implementing such technologies. Farmers with more extensive operations can leverage this economic potential to reduce operational costs and increase revenue (Sahara, 2024). Furthermore, technologies designed to manage large amounts of waste with systematic systems can simplify processes and reduce workload (Bhat *et al*., 2020). In line with these findings, several other studies also confirm that farmers with large-scale operations tend to be more proactive in adopting waste treatment technologies. This trend is primarily driven by the urgent need to manage large volumes of waste efficiently and to meet more complex operational standards (Ruzzante *et al*., 2021).

Larger-scale farmers are also more likely to have better access to information and resources about new technologies, thanks to broader networks and involvement in industry communities (Pandeya *et al*., 2025). This facilitates their ability to evaluate and implement waste processing technologies that best suit their needs (Monira *et al*., 2022). They often have more significant opportunities to engage in research and development and trial new technologies before they are widely applied to their operations (Al-Emran and Griffy-Brown, 2023).

Unlike large-scale farmers, small-scale farmers often face significant obstacles that hinder technology adoption. These limitations include investment capital, limited resources, and simpler operational needs (Pandey *et al*., 2021). As a result, farmers with smaller-scale operations tend to choose waste management solutions that are more economical and easier to implement, or even face limitations in accessing more advanced technologies (Benyam *et al*., 2021). These various limitations collectively form the main barriers to the adoption of waste treatment technologies among small-scale farming businesses (Pandeya *et al*., 2025).

As a result, scalability is a key factor that technology developers and policymakers must consider when designing waste management solutions (Boffardi *et al*., 2021). Offering a diverse portfolio of technologies tailored to different business scales will increase the overall adoption rate and effectiveness of implementation (Tseng *et al*., 2023). A comprehensive understanding of the diverse needs and capacities among farmers will facilitate the development of more targeted technologies, thereby supporting the implementation of more effective and sustainable waste management practices in the livestock sector (Wahyuni *et al*., 2024a).

The type of livestock raised is a crucial factor influencing the level of adoption of waste management technology. The physical and chemical characteristics of livestock waste directly determine the most appropriate type of technology to be applied. Cattle waste, for example, with its large volume and high density, is better suited for processing using biogas or composting systems. Conversely, poultry waste, which is rich in nitrogen and has fine particles, requires a different approach, such as separation

systems or rapid composting (Wahyuni *et al*., 2024b). These technical differences have implications for operational priorities: cattle farmers tend to choose technologies that can handle large volumes of waste, while poultry farmers prioritize solutions that are effective for waste with high nitrogen content (Pandey *et al*., 2021). Thus, the relevance and feasibility of a technology are greatly influenced by the type of livestock being raised, while technologies requiring specialized equipment or complex procedures tend to face adoption barriers if they do not align with the specific waste management needs of farmers. Implementing technologies that require specialized equipment or complex processes may be more difficult for farmers with specific waste management needs.

Empirical research supports the idea that farmers adopt waste processing technologies best suited to the type of livestock they manage (Iskakov and Sugirbay, 2023). The practical implications of these findings are clear: the development and application of waste management technologies must specifically consider the type of livestock being raised. Targeted technologies—those designed specifically for the unique characteristics of waste from particular livestock—have proven to be more effective and more readily accepted by farmers (Herrera *et al*., 2023). A more targeted approach not only increases technology adoption rates but also contributes significantly to operational efficiency and the sustainability of livestock businesses (Vlaicu *et al*., 2024). Therefore, to achieve optimal waste management, technology developers and policymakers need to abandon the "one size fits all" paradigm and shift to modular and contextual solutions. Waste treatment systems designed based on the specific characteristics of livestock types have proven capable of optimizing the entire process, from reducing environmental impact to enhancing economic benefits. Furthermore, technology tailored to the unique nature of waste not only improves processing efficiency but also maximizes the potential of high-value byproducts, such as high-quality compost or renewable energy (Abdul-Majid *et al*., 2024).

Therefore, considering the diversity of livestock types is a crucial aspect for technology providers and policymakers in designing and implementing waste management innovations, so that the solutions offered are truly relevant and effective (Serebrennikov *et al*., 2020). Adapting technology to the specific needs of farmers not only facilitates adoption (Boffardi *et al*., 2021), but also strengthens efforts toward sustainable waste management systems and more environmentally friendly agricultural practices (Bhat *et al*., 2020).

The results of the study indicate that family size does not have a statistically significant effect on the level of adoption of waste treatment technology. These findings suggest that farmers' decisions to adopt innovations are determined more by rational operational and economic considerations than by household demographic factors. In practice, farmers tend to choose technologies based on their suitability to the characteristics of the waste produced, the level of efficiency of the solutions offered, and their potential economic benefits (Eni *et al*., 2019).

In addition, external factors such as resource availability and quality of technical support have been shown to play a more decisive role in driving technology adoption decisions (Supinganto *et al*., 2022). Access to training programs, financial incentives, and adequate technical assistance are much stronger drivers of technology adoption than the size of a farmer's household (Eni *et al*., 2019). Thus, it can be concluded that technical relevance and the supporting ecosystem are the primary determinants of adoption, overshadowing the influence of household size variables. This indicates that external factors like policies and institutional support are more influential than internal factors like family size. Farmers with adequate support can implement technologies more effectively without being heavily influenced by the size of their families.

Factors directly related to technology implementation—such as relevance, investment costs, and ease of use—play a much more significant role in the adoption process than family size. Farmers tend to prioritize practical technologies, namely those that offer efficient and cost-effective solutions tailored to their operational needs, regardless of family size. Adoption decisions, therefore, are driven more by economic and operational considerations than by social factors such as family demographics. A farmer's attitude and internal motivation have proven to be stronger drivers of technology adoption than demographic factors. Farmers who have a positive attitude toward innovation and high motivation to improve operational efficiency will adopt technology more quickly, regardless of the size of their family. This shows that the most effective strategy for increasing adoption rates is to align technology with specific user needs, accompanied by adequate technical support and relevant incentives, rather than simply focusing on demographic factors.

Economic and operational factors have been shown to have a more significant influence on technology adoption rates than family size. Considerations related to investment costs, infrastructure availability, and ease of use are key determinants in farmers' decision-making processes (Fosu-Mensah *et al*., 2022). Farmers will generally prioritize innovations that offer efficient and cost-effective solutions to their practical needsTwo main factors determine whether a farmer will adopt new technology: accessibility and internal motivation. If a technology is affordable and highly compatible with agricultural operating systems, the probability of its adoption tends to increase, regardless of household size. In addition, farmers' attitudes and motivation also play a crucial role in determining the success of adoption. Farmers with a positive attitude toward innovation and a strong motivation to improve operational efficiency are more likely to adopt technology faster, regardless of the size of their families (Wang *et al*., 2020; Herrera *et al*., 2023). This decision to adopt is often reinforced by the support of the farming community and accumulated personal experience, which together have a greater influence than demographic characteristics alone.

The objectives of farming businesses have proven to be a significant determining factor in the adoption of waste treatment technologies. This is because a farmer's motivation and priorities are directly shaped by the orientation of their business—whether commercial or subsistence—which ultimately influences decisions to invest in new technologies (Wahyudi *et al*., 2024). Commercially oriented farmers, for example, tend to be more motivated to adopt waste management technologies that can improve efficiency while turning waste into value-added products. This is in line with their main orientation, which is to maximize profits and strengthen business competitiveness. Farmers who aim to improve operational efficiency are often more inclined to adopt technologies that can optimize waste management, reduce time and labour, and enhance production processes (Chavas and Nauges, 2020). Technologies that offer automation or the integration of waste into value-added products are desirable to farmers focused on efficiency (Udourioh *et al*., 2025).

Furthermore, farmers oriented toward achieving environmental standards or regulatory compliance often adopt waste processing technologies to meet these requirements (Papakonstantinou *et al*., 2024). Environmentally friendly technologies reduce greenhouse gas emissions and are more relevant to farmers' environmental goals, enabling them to comply with regulations and improve their reputation as responsible managers (Liu and Liu, 2024).

The objective of reducing operational costs and increasing profits also influences the decision to adopt technology (Ramirez *et al*., 2021). Economic motivation is a crucial factor in technology adoption. Farmers who aim to reduce operational costs and maximize profits will prioritize innovations that can reduce waste management costs while converting waste into value-added products, such as compost or renewable energy (Dayoub *et al*., 2024; Vlaicu *et al*., 2024).

In addition to financial gains, improving the quality of the final product is also an important motivation for farmers. For those who focus on this goal, waste management technologies that can reduce contamination will be highly sought after to support the production of high-quality products (Czaker *et al*., 2024). Innovations that can improve product standards and competitiveness in the market will always be attractive to farmers. This is because such technologies directly support their long-

term business strategies (Udourioh *et al*., 2025).

Overall, the decision to adopt waste treatment technology is largely determined by the principle of alignment, which refers to the extent to which an innovation can support a farmer's specific business objectives (Pandey *et al*., 2025). Technologies that directly address key objectives—such as improving operational efficiency, environmental compliance, cost reduction, and product quality improvement—have a much higher chance of adoption and implementation. This level of alignment is a strong predictor of successful technology implementation and the achievement of expected business results (Iskakov and Sugirbay, 2023).

Business objectives play a direct role in determining the selection and implementation of waste management technologies, as farmers tend to choose solutions that align with their desired outcomes (Rabbani *et al*., 2021). For example, farmers focused on increasing production or diversifying products will prioritize technologies that can convert waste into value-added products. Generally, technologies that offer additional benefits and align with long-term business strategies will be given greater priority (Zeebroeck *et al*., 2021).

External support and incentives have proven to be important catalysts in the technology adoption process (Ensor and de Bruin, 2022). Farmers who receive support from the government, non-governmental organizations, or subsidy programs will be more motivated to implement technologies that are aligned with their business objectives (Hong *et al*., 2024). In particular, financial incentives—such as subsidies for equipment purchases or free training—can significantly reduce cost barriers. This support makes waste management technology more affordable and attractive, especially for farmers who are focused on operational cost efficiency or meeting environmental compliance standards (Rabbani *et al*., 2021).

Therefore, integrating waste management technology that aligns with farmers' business objectives has the potential to strengthen their strategies in achieving the desired results (Hossain *et al*., 2021). Technologies that directly support operational, environmental, or economic targets will be easier to adopt and have a higher likelihood of successful implementation (Monira *et al*., 2022). Ultimately, an approach that considers these business objectives will ensure that the innovations implemented are always relevant and effective in supporting the overall achievement of farming operations (Rabbani *et al*., 2021).

Overall, it can be concluded that business objectives have a significant impact on the adoption rate of waste treatment technology (Jimoh *et al*., 2022).Ensuring that the innovations introduced are aligned with the specific objectives of farmers is crucial to facilitating the adoption process and increasing its effectiveness in supporting business targets (Alemayehu *et al*., 2022). Ultimately, it is this approach of aligning technology with business strategies that will contribute to the success of waste management and the achievement of desired outcomes in agricultural practices (Ayi, 2022).

Although this study provides valuable insights, there are several limitations that need to be acknowledged. First, this study has limitations in terms of geographical coverage because it only took samples from one specific region. As a result, the generalizability of these findings to the entire population of farmers in Indonesia is limited. Second, the analysis focuses more on internal farmer variables, such as demographic characteristics and experience. This means that potentially significant external factors-such as government policy, financial incentives, and market dynamics-have not been explored comprehensively.

Given these limitations, future research is recommended to pursue several directions of development. First, it is necessary to expand the sample coverage to include various regions in Indonesia in order to obtain a more comprehensive understanding. Second, future research needs to integrate analysis of external factors—such as policy support, market access, and incentive schemes—to gain a more holistic understanding of the adoption ecosystem. Finally, future studies could also explore in greater depth the influence of social and cultural factors, which often play a significant role in the decision-making process of farmers from diverse backgrounds.

Conclusion

There are three determining factors that significantly influence adoption decisions, namely: the effectiveness of the training attended, the scale of the business (number of livestock), and the type of livestock raised. In contrast, demographic factors such as age, education, and farming experience are not significant. These findings underscore the importance of carefully designed and relevant training programs as key drivers of sustainable technology adoption. Therefore, future programs and policies should prioritize improving the quality of training and ensuring that existing support systems-such as incentives and technical assistance-are truly aligned with the real needs of farmers in the field.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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