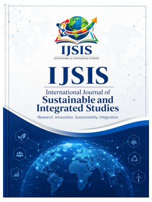

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Biodegradable Fertilizer Machine

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Abstract

This study aimed to design, fabricate, and evaluate a Biodegradable Fertilizer Machine for small-scale school-based management of biodegradable waste, particularly mowed grass and mango leaves. The study was anchored in the Product Development Life Cycle (PDLC) theory of Ulrich and Eppinger (2015), the Engineering Design Process (EDP) of Pahl and Beitz (2013), and the Technology Acceptance Model (TAM) of Davis (1989). It employed a developmental research design supported by a quantitative approach involving planning, fabrication, calibration, testing, revision, and evaluation of the prototype. The machine's efficiency was assessed through ten trials based on fertilizer output, operation time, and production rate, while its acceptability was evaluated using a validated Likert-like questionnaire administered to 60 respondents consisting of 54 teachers and six school utility workers from the Bansalan West District, Davao del Sur. Results showed that pure mowed grass produced the highest average fertilizer output at approximately 3.19 kg and the highest production rate at approximately 3.86 kg/h, while pure mango leaves produced the lowest average output at approximately 2.74 kg and production rate at approximately 2.99 kg/h. The mixed feedstock yielded moderate results, and the machine achieved approximately 60% recovery efficiency. The machine was rated Highly Acceptable in usability, with an overall mean of 4.55, and safety, with an overall mean of 4.77. The main areas requiring improvement were vacuuming and collection performance, noise, and vibration. The study concluded that the machine provides a practical, safe, and convenient approach to school-based biodegradable waste management and fertilizer production. Improvements to the screw conveyor, material loading system, power source, noise and vibration control, and testing with additional biodegradable materials were recommended. The study supports SDG 12 - Responsible Consumption and Production, SDG 4 - Quality Education, SDG 9 - Industry, Innovation and Infrastructure, and SDG 13 - Climate Action through waste reutilization, environmental learning, technological innovation, and environmentally responsible waste management. Its sustainability impact lies in reducing organic waste, supporting school gardening and environmental education, and promoting a practical technological solution suitable for resource-limited schools.

Keywords: Biodegradable Fertilizer Machine, Biodegradable Waste, Environmental Sustainability, Fertilizer Production, Organic Waste Management, School-Based Waste Management, Sustainability, Waste Reutilization

1. Introduction

Biodegradable waste management remains an environmental concern in the Philippines, particularly when food scraps, plant trimmings, grass, and leaves are improperly disposed of through dumping, burning, or unmanaged accumulation. Such practices contribute to pollution, unpleasant surroundings, greenhouse gas emissions, and potential health risks. A considerable portion of waste generated in the country is biodegradable and often remains unmanaged (Philippine Center for Investigative Journalism, 2024). This concern is also evident in rural schools, where mowed grass, mango leaves, and other plant materials accumulate and are commonly treated as waste despite their potential use as resources. The study addresses this concern through the design and development of a Biodegradable Fertilizer Machine intended for small-scale school use. The machine is designed to vacuum biodegradable materials, transport them through a screw conveyor, and process them into fertilizer for the school garden. Its development seeks to reduce manual collection of scattered leaves, improve organic waste management, support soil improvement, and provide students with practical exposure to environmental sustainability. The study specifically involves designing and fabricating the machine, evaluating its efficiency based on waste disposed, fertilizer produced, operation time, and production rate, and determining its acceptability in terms of usability and safety. The project is intended primarily for school-based operation rather than large-scale commercial production.

Schools generate biodegradable materials that can accumulate in waste bins and surrounding areas when appropriate processing systems are unavailable. In rural schools, mowed grass, mango leaves, and similar plant residues can create unsightly and unhygienic conditions when left unmanaged. Rather than treating these materials solely as waste, their conversion into fertilizer provides an opportunity to support waste reduction and school gardening. School-based environmental programs demonstrate the importance of combining waste management with environmental education. Matsumoto and Saizen (2017) found that school eco-centers and environmental education improved student awareness, participation in waste segregation, responsibility, and discipline. Proper segregation also provides a foundation for more advanced practices such as composting and waste reutilization. Similarly, Bagundang et al. (2024) found that although students generally possessed awareness and positive attitudes toward waste segregation, practical reutilization of biodegradable materials into compost or fertilizer remained limited. Their findings emphasized structured programs, teacher involvement, composting facilities, and hands-on activities. The conversion of biodegradable materials into fertilizer can also provide direct educational and environmental benefits. Mpuangnan et al. (2023) demonstrated that school composting reduces waste sent to landfills while producing nutrient-rich fertilizer for school gardens. Student participation in waste collection, decomposition monitoring, and compost application also strengthened environmental literacy, teamwork, and problem-solving. In the Philippine setting, Prisco and Cubillas (2022) reported that elementary schools successfully converted biodegradable waste into organic fertilizer for school gardens while increasing student participation and environmental responsibility. Scientific approaches further support the feasibility of converting organic waste into useful fertilizer. Akinbile et al. (2021) explained that aerobic composting relies on microbial activity to decompose biodegradable materials into nutrient-rich compost that can improve soil health and agricultural productivity. Ayilara et al. (2012) similarly described composting and vermicomposting as biological processes that transform organic matter into useful compost, providing environmental and agricultural benefits through improved soil fertility, enhanced crop production, and reduced pollution. Collectively, Matsumoto and Saizen (2017), Bagundang et al. (2024), Mpuangnan et al. (2023), Prisco and Cubillas (2022), Akinbile et al. (2021) and Ayilara et al. (2012) demonstrate that biodegradable waste reutilization can combine waste reduction, environmental education, and productive use of organic materials.

Existing waste-processing machines demonstrate how mechanical systems can reduce waste size, accelerate processing, and improve the usability of organic materials. Mindarta et al. (2018) developed a portable plastic waste chopper powered by a 4-horsepower electric motor and fitted with 12 carbon steel knives. Although designed for plastic waste, its portable configuration, input and output mechanisms, filtering system, and ability to reduce materials into smaller pieces illustrate mechanical principles relevant to small-scale waste-processing equipment. For organic waste, Wardhany and Hidayat (2019) developed a smart chopper and monitoring system that combines waste crushing with Arduino-based monitoring of temperature, humidity, waste level, and other composting conditions. The system reduced organic waste into smaller particles while monitoring decomposition and reportedly required around six days for the material to transition from solid to liquid form. Syahrorini et al. (2022) likewise developed an automated organic waste crushing machine using an Arduino microcontroller, load cell, motor, solenoid door lock, and cutting mechanism. The system efficiently processed a 1 kg organic waste load and reduced manual labor while supporting eco-enzyme production. User-centered mechanical design is also important in waste processing. Susanto and Sahroni (2024) designed a mini organic waste chopper using anthropometric and ergonomic considerations to reduce the difficulty of transporting bulky waste. Testing showed effective waste reduction, while 75% of respondents indicated that the design met their needs. Darmawa et al. (2023) examined the use of a flywheel in an organic waste chopping machine and found reductions in processing time for leaves, twigs, and branches. Productivity increased by 10% for leaves, 5% for twigs, and 12% for branches, demonstrating how mechanical modifications can improve processing efficiency. Related fertilizer-making technologies further demonstrate the potential for converting plant waste into useful agricultural inputs. A reviewed Food Waste Fertilizer Machine processes plant materials such as grass, sengon leaves, mango, tiara, and shrubs through chopping, grinding, and fermentation. It can process approximately 5 to 20 kg of organic waste per day, while its mechanical chopper has a reported processing capacity of 50 to 90 kg per hour. The processed material undergoes fermentation using 2% EM4 for approximately 21 days before becoming mature compost. Pawar et al. (2017) developed an organic fertilizer manufacturing machine intended as an affordable alternative to chemical fertilizers, particularly for rural farmers. The compact machine processes locally available organic materials without electricity and uses a hopper, stirrer, and agitation vessel to support decomposition. The fertilizer produced was associated with increased crop productivity, while residual slurry could also be reused as fertilizer or for biogas production. Ambade et al. (2022) developed a manually operated waste food shredder using a bicycle pedal mechanism to process vegetable peels, fruit scraps, grass, and other biodegradable materials. Its design reduces organic materials into smaller pieces for faster composting while emphasizing low maintenance, cost-effectiveness, and reduced dependence on electrical power. Existing patented technologies also provide relevant mechanical concepts. Bassile (2014) composting apparatus uses a hopper, shredding and grinding mechanisms, a rotating cylindrical drum, mixing and conveying vanes, and suction discharge to process organic waste. Jing Guoliang, Zhou Jing, Huang Jiqing, and Li Dapeng's Patent No. 202010046865.7 integrates squeezing, sorting, pulverizing, and aerobic composting to transform rural domestic waste into reusable crop fertilizer. Wenya (2022) incorporates crushing and compression mechanisms intended to reduce waste size, processing time, and manual effort. Gaudreault (2023) combines shredding, conveying, and baling, with sensors and computer-based controls for monitoring industrial-scale operation. Other systems illustrate integrated processing and material handling. Langston (2015) incorporates shredding, grinding, mixing, compacting, filtering, moisture monitoring, and bagging for compostable waste. The technology developed by Jun and Zhouyou (2018) under Patent No. 201711114745.0 connects crushing and dehydrating equipment, an organic fertilizer machine, screw conveying, vibration screening, and granulation to convert kitchen, fruit, and vegetable waste into useful granular products. These technologies collectively show that shredding, conveying, crushing, monitoring, compression, and fertilizer-processing mechanisms can be integrated in different configurations according to the intended scale and application.

Within the Philippines, the need for effective biodegradable waste management is supported by national concerns regarding the volume of unmanaged biodegradable materials (Philippine Center for Investigative Journalism, 2024). School-based evidence from Calamba City, Davao City, and Agusan del Norte further demonstrates that schools can serve as practical environments for waste segregation, composting, environmental education, and organic fertilizer production. The findings of Matsumoto and Saizen (2017) emphasize student participation and waste segregation, while Bagundang et al. (2024) identify the need to move beyond awareness toward structured waste reutilization activities. Prisco and Cubillas (2022) further demonstrate the feasibility of incorporating compost production and use into school practices. International studies complement these local findings by demonstrating different technological and educational approaches to waste processing. Mpuangnan et al. (2023) showed how composting could function as both a waste management strategy and a learning activity in South African schools. Meanwhile, developments in Indonesia have demonstrated automated crushing, ergonomic chopper design, and productivity improvements through mechanical modifications. These experiences indicate that effective organic waste management may combine technological processing, user-centered design, environmental education, and productive reuse of waste. The present study situates these practices within a rural school context in Bansalan, Davao del Sur. It focuses specifically on biodegradable materials available within the school, particularly mowed grass and mango leaves. Instead of addressing industrial or large-scale waste processing, the project concentrates on a simple, cost-conscious system suitable for school use and intended to convert available organic waste into fertilizer for the school garden.

The development of the Biodegradable Fertilizer Machine is anchored in three complementary frameworks. The Product Development Life Cycle (PDLC) theory, as outlined by Ulrich and Eppinger (2015), provides a systematic sequence of concept development, design, prototyping, testing, and refinement. The framework emphasizes progressive improvement through repeated evaluation so that a product can satisfy requirements related to functionality, usability, and practical application. Applied to the present study, the process begins with identifying the intended functions of vacuuming biodegradable materials and converting them into fertilizer, followed by designing, fabricating, testing, and refining the machine based on its performance. The Engineering Design Process (EDP), as proposed by Pahl and Beitz (2013), further supports the systematic resolution of technical problems through problem identification, idea generation, design, prototyping, testing, and improvement. For the Biodegradable Fertilizer Machine, this process guides decisions concerning materials, mechanical components, cost, energy efficiency, and functionality. Testing provides the basis for determining whether the machine can effectively collect biodegradable materials and convert them into fertilizer and whether modifications are required to improve its operation. User acceptance is supported by the Technology Acceptance Model (TAM), introduced by Davis (1989). TAM explains technology adoption through perceived ease of use and perceived usefulness. In this study, these principles relate to whether target users consider the machine practical and useful for school waste management. The design therefore considers usability and safety alongside technical efficiency to support its potential integration into routine school operations. The conceptual basis of the project follows an input-process-output structure. Inputs consist of ideas, reference materials, supplies and materials, tools and equipment, questionnaires, and labor. These inputs support the processes of planning, designing, calibrating, testing, revising, and evaluating, leading to the completed Biodegradable Fertilizer Machine as the project output.

Existing literature establishes the benefits of waste segregation, composting, organic fertilizer production, mechanical shredding, automated waste processing, and user-centered machine design. However, the reviewed school-based studies largely emphasize segregation, composting programs, environmental education, and student participation, while the reviewed machine-based studies focus on separate functions such as chopping, crushing, shredding, monitoring, fermentation, or large-scale waste treatment. Within the context presented in the study, there remains a practical need for a small-scale school-based machine specifically designed to collect biodegradable plant waste and process it for fertilizer production. The proposed Biodegradable Fertilizer Machine addresses this need by integrating the collection and processing of mowed grass, mango leaves, and other biodegradable school materials. It is intended to vacuum the materials, transport and compress them through a screw conveyor, and convert them into fertilizer that can be used in the Gulayan sa Paaralan. Its design emphasizes simplicity, maintainability, cost-conscious operation, and suitability for schools with limited resources. Accordingly, the study aims to design and fabricate the Biodegradable Fertilizer Machine and evaluate its efficiency based on the amount of waste disposed in kilograms, fertilizer produced in kilograms, operation time, and production rate in kilograms per hour. It also determines the machine's level of acceptability in terms of usability and safety. The project covers planning, designing, fabrication, testing, revision, and evaluation but is delimited to small-scale school-based application rather than large-scale commercial production.

The study is most directly aligned with SDG 12 - Responsible Consumption and Production because it promotes the reutilization of biodegradable school waste by converting discarded plant materials into fertilizer rather than allowing them to accumulate or be improperly disposed of. The conversion of organic waste into a useful resource supports more responsible material use and waste reduction within the school environment. The project also supports SDG 4 - Quality Education through its potential use as a practical environmental learning resource. Students can gain direct exposure to waste management, resource reutilization, gardening, and environmental responsibility. SDG 9 - Industry, Innovation and Infrastructure is also relevant because the study involves the design, fabrication, testing, and refinement of a technological solution intended to address a specific waste-management problem in a resource-limited school setting. In addition, the project's focus on reducing improper biodegradable waste disposal and associated greenhouse gas emissions relates to SDG 13 - Climate Action by encouraging more environmentally responsible waste-management practices.

The Biodegradable Fertilizer Machine contributes to environmental sustainability by reducing the accumulation of organic waste and transforming biodegradable materials into fertilizer that can be returned to the school garden. This approach encourages resource reutilization while supporting cleaner school surroundings and improved soil conditions. It also contributes to educational sustainability by providing students and teachers with a practical means of integrating environmental science, waste reduction, composting, and sustainable gardening into school-based learning experiences. From a technological perspective, the project demonstrates how engineering design and product development can be applied to a localized environmental problem through planning, fabrication, testing, revision, and evaluation. Its emphasis on efficiency, usability, safety, simplicity, and cost-conscious operation supports technological and institutional sustainability by seeking a solution appropriate for schools with limited resources. At the community level, the project encourages shared environmental responsibility and provides a possible model for other rural schools seeking practical approaches to biodegradable waste management. Thus, the study connects environmental management, engineering, education, school gardening, and community participation through the development of a school-based system for converting biodegradable waste into a useful resource.

2. Material and methods

2.1 Research Design

The study employed a developmental research design supported by a quantitative approach. It focused on systematically designing, developing, testing, revising, and evaluating the Biodegradable Fertilizer Machine as a practical and sustainable solution for managing organic waste in schools. The machine was designed to vacuum biodegradable materials, transport and compress them through a screw conveyor, and process them into fertilizer. The development process began with planning and designing the machine and identifying the required components, materials, tools, and equipment. The major components included a feed hopper, feeding pipe or barrel, pelletizing chamber housing, flat die plate, roller assembly, main shaft, bearing set, spring pressure system, belt and pulley system, 7.5 HP gasoline engine, gear reducer, screw conveyor, discharge chute, safety guard, and structural frame. The total material cost was Php 41,800.00, while fabrication and CAD drawing costs amounted to Php 18,220.00. Including Php 5,000.00 for miscellaneous expenses, the total project cost was Php 65,020.00. Tools and equipment such as an adjustable spanner, riveter, angle grinder, side cutter, hand drill, and welding machine were used during construction. Construction involved preparing and cutting the materials according to the design and welding the components to form the structural frame. Assembly included installing the engine and transmission system, gear reducer, screw conveyor, fertilizer-making components, chutes, and output containers. The machine was then calibrated and subjected to operational and safety testing. The entire development process was completed within eight weeks and covered planning and designing, fabrication, calibration, testing and revision, evaluation, and reporting. Testing identified problems involving the screw conveyor, power transmission, and vibration. The thin conveyor flight and its proximity to the extruder blade caused material jamming, so thicker metal flights were installed and the distance between components was adjusted. Loss of driving power was addressed by integrating a gear reducer to increase torque. Excessive vibration caused by the low and elongated screw conveyor configuration was corrected by raising and shortening the mechanism. The final prototype incorporated these revisions and used a gasoline engine to support operation in areas with limited electrical supply. The completed machine was evaluated through ten trials to determine its efficiency based on waste disposed, fertilizer produced, operation time, and production rate. A quantitative assessment was also conducted to determine its acceptability in terms of usability and safety.

2.2 Locale of the Study

The study was conducted in selected schools in Bansalan, Davao del Sur, where the Biodegradable Fertilizer Machine was intended to operate. Bansalan is a landlocked municipality with a land area of 157.75 square kilometers or 60.91 square miles, representing 7.29% of the total area of Davao del Sur. Based on the 2020 Census, the municipality had a population of 62,737, representing 9.22% of the provincial population and 1.20% of the population of the Davao Region.

2.3 Respondents of the Study

The respondents consisted of 60 participants from the Bansalan West District, Davao del Sur Division. These included 54 teachers and six school utility workers who served as end users in evaluating the acceptability of the Biodegradable Fertilizer Machine. Their assessment focused on the usability and safety of the machine.

2.4 Sample and Sampling Procedure

The study employed purposive sampling to select participants based on criteria relevant to the objectives of the research. Teachers involved in school gardening or waste management and school utility workers were selected because of their potential interaction with the machine and their ability to assess its usability and safety. A total of 60 respondents participated in the evaluation.

2.5 Research Instrument

The study used a questionnaire with a Likert-like scale to evaluate the acceptability of the Biodegradable Fertilizer Machine in terms of usability and safety. The questionnaire was divided into two parts and was answered using a five-point scale, where 5 represented highly acceptable, 4 acceptable, 3 fairly acceptable, 2 slightly acceptable, and 1 not acceptable. The instrument underwent validation based on six criteria rated using a five-point scale. It obtained an overall mean of 4.50, interpreted as "Highly Valid," indicating that the questionnaire was considered capable of providing unbiased data for the investigation with an allowable error of 8 to 10 percent. The validated instrument was used to obtain feedback from teachers and school utility workers regarding the machine's acceptability. Operational efficiency was also measured through ten trials. The amount of biodegradable waste processed and fertilizer produced was recorded in kilograms, while operation time was monitored for each processing cycle. Production rate was expressed in kilograms per hour.

2.6 Data Gathering Procedure

The study began with the design and fabrication of the Biodegradable Fertilizer Machine. After the necessary materials and components were acquired, the machine was constructed, assembled, calibrated, and tested. Problems identified during testing were corrected through revisions, and the machine was repeatedly evaluated until a functional prototype was completed. The performance evaluation involved ten trials measuring waste disposed, fertilizer produced, operation time, and production rate. For the acceptability evaluation, permission was first obtained from the school principal. After approval, the respondents were given an opportunity to operate the machine before answering the questionnaire so they could assess its actual usability and safety. The questionnaire was distributed in paper form, and the purpose of the study and questionnaire items were explained to the participants. After collection, the responses were organized and securely stored for analysis. The quantitative data were processed using the identified statistical techniques, and the findings were compiled to describe the efficiency and acceptability of the Biodegradable Fertilizer Machine.

2.7 Data Analysis Techniques

Descriptive statistics were used to analyze the data. Frequency count and mean were employed to determine the respondents' assessment of the level of acceptability of the Biodegradable Fertilizer Machine in terms of usability and safety. The efficiency of the machine was assessed using the results of the ten trials based on waste disposed, fertilizer produced, operation time, and production rate.

3. Results and Discussion

3.1 Design and Fabrication of the Biodegradable Fertilizer Machine

3.1.1 Machine Design

The Biodegradable Fertilizer Machine was designed as a practical system for collecting and processing biodegradable school waste, particularly mowed grass and mango leaves. The completed design incorporated a screw conveyor for transporting and compressing the collected materials and a fertilizer maker for processing the materials into fertilizer pellets. A gasoline engine powered the system, allowing operation in locations where electrical supply is limited. The design also emphasized simplicity, functionality, cost-effectiveness, and ease of operation and maintenance by teachers and school utility personnel. The completed design demonstrated the integration of waste collection, material transport, compression, and fertilizer production into a single machine. Its configuration addressed the intended school-based application by combining essential processing mechanisms with an independent gasoline-powered system. The resulting design provided the basis for fabrication and subsequent operational testing.

3.1.2 Fabrication and Prototype Development

The fabrication process was completed within eight weeks and included planning and designing, fabrication, calibration, testing and revision, evaluation, and reporting. Raw materials were prepared, cut according to the design, welded, and assembled to form the structural frame. The motor, transmission system, gear reducer, screw conveyor, fertilizer maker, chutes, output containers, gasoline engine, and control system were subsequently installed. Calibration and safety checks were conducted before the prototype underwent testing. Testing identified problems involving material jamming, insufficient driving power, and excessive vibration. The screw conveyor was redesigned using thicker metal flights and an adjusted distance from the extruder blade to reduce jamming. A gear reducer was installed to increase driving power, while the screw conveyor mechanism was raised and shortened to reduce vibration and improve material movement. These revisions were incorporated into the completed and operational prototype.

3.2 Efficiency of the Biodegradable Fertilizer Machine

The machine underwent ten trials using three feedstock conditions: 5 kg of pure mowed grass, 5 kg of pure mango leaves, and a 5 kg mixture consisting of 2.5 kg of mowed grass and 2.5 kg of mango leaves. Efficiency was assessed according to fertilizer produced, operation time, and production rate.

3.2.1 Fertilizer Production from Different Feedstock Types

Pure mowed grass produced between 3.00 kg and 3.40 kg of fertilizer, with an average output of approximately 3.19 kg. Pure mango leaves generated a lower output ranging from 2.60 kg to 2.88 kg, with an average of approximately 2.74 kg. The mixed feedstock produced between 2.85 kg and 3.30 kg, generally yielding around 3.0 kg of fertilizer from the original 5 kg input. Among the three feedstock types, pure mowed grass produced the highest average fertilizer output, while pure mango leaves generated the lowest. The higher output from mowed grass was associated with its softer structure, higher moisture content, and lower lignin composition. Bernal et al. (2017) explained that easily degradable organic materials such as grass can accelerate composting reactions and improve conversion efficiency, while Awasthi et al. (2020) emphasized that low-lignin substrates support microbial activity and shorter processing periods. In contrast, the lower output from mango leaves was associated with their fibrous and lignified structure. Kumar et al. (2018) explained that high lignin content limits microbial access and slows biodegradation, while Zhang et al. (2019) reported that lignified materials reduce composting rates and require longer processing. These differences support the observation of Díaz et al. (2021) that feedstock characteristics such as lignin content, moisture level, and structural composition influence bioconversion efficiency. For the mixed feedstock, the reduction from 5 kg of input to approximately 3 kg of fertilizer was associated with moisture loss (Awasthi et al., 2020) and the conversion of organic matter into gases during microbial degradation (Zhang et al., 2019). The resulting recovery of approximately 60% was considered realistic for small-scale composting systems (Sharma et al., 2017).

3.2.2 Operation Time

The operation time varied according to the type of biodegradable material processed. Pure mowed grass required 0.75 to 0.92 hours, representing the shortest processing duration. Pure mango leaves required 0.83 to 1.00 hours, making them the slowest material to process. The mixed feedstock required 0.75 to 0.97 hours, placing its processing duration between pure mowed grass and pure mango leaves. Despite these variations, the machine completed all trials across the three feedstock types. The shorter processing time for grass was consistent with its softer and less lignified structure. Awasthi et al. (2020) emphasized that low-lignin substrates support faster processing, while Zhang et al. (2019) confirmed that lignified plant materials require longer periods for mechanical degradation and composting. Variations in the mixed feedstock were also expected because organic materials differ in moisture content, particle size, and density, as noted by Kaza et al. (2018). Lim et al. (2016) further observed that moisture conditions can influence processing speed. Overall, the results indicate that the composition and physical characteristics of the feedstock influenced the amount of time required by the machine to complete each processing cycle.

3.2.3 Production Rate

Pure mowed grass recorded production rates ranging from 3.71 to 4.00 kg/h, with an average of approximately 3.86 kg/h. This was the highest average production rate among the feedstock types. Pure mango leaves recorded rates between 2.85 and 3.15 kg/h, averaging approximately 2.99 kg/h. The mixed feedstock achieved production rates ranging from 3.41 to 3.80 kg/h, with an average of approximately 3.60 kg/h. Thus, the machine produced fertilizer most efficiently when processing pure mowed grass, followed by the mixed feedstock and pure mango leaves. The high production rate of mowed grass was consistent with Bernal et al. (2017), who noted that easily degradable organic materials improve conversion efficiency. Conversely, the lower rate of mango leaves reflects their greater resistance to processing, consistent with Kumar et al. (2018), who explained that high lignin content slows biodegradation. The relatively stable performance of the mixed feedstock indicates that the machine maintained consistent production despite natural variations in organic materials. Groover (2020) noted that mechanical processing efficiency depends on both output and processing time, while Wang et al. (2021) observed that variations are expected because organic materials differ naturally in composition. Overall, the machine maintained practical production rates across all tested materials, supporting its potential for small-scale school-based fertilizer production, as affirmed by Awasthi et al. (2020).

3.3 Acceptability of the Biodegradable Fertilizer Machine

The Biodegradable Fertilizer Machine was evaluated by 60 respondents in terms of usability and safety. Both dimensions received positive assessments, with usability obtaining an overall mean of 4.55 and safety obtaining a higher overall mean of 4.77, both interpreted as Highly Acceptable.

3.3.1 Usability

The machine obtained an overall usability mean of 4.55, interpreted as Highly Acceptable. The highest-rated indicators were its readiness for collecting biodegradable waste and its ability to produce fertilizer in a single operation, both with means of 4.92. Proper functioning of the controls received 4.83, while the conversion of collected waste into pellet fertilizer and the production of granular fertilizer both obtained 4.75. The machine parts were rated highly usable, while transferability to different areas and smooth transition from waste collection to fertilizer production also received high ratings. Production within an acceptable amount of time obtained 4.17, interpreted as Acceptable. The lowest rating was 3.83 for effectively vacuuming and collecting organic waste, also interpreted as Acceptable. The high usability rating indicates that respondents generally considered the machine useful, functional, and practical for school-based biodegradable waste management. This supports the Technology Acceptance Model proposed by Davis (1989), which identifies perceived usefulness and perceived ease of use as important determinants of technology acceptance. The strong ratings for machine controls and fertilizer production are also consistent with the Engineering Design Process as proposed by Pahl and Beitz (2013), which emphasizes functionality, efficiency, testing, and refinement. Similarly, the positive assessments of operational continuity and portability reflect the Product Development Life Cycle theory outlined by Ulrich and Eppinger (2015), which stresses iterative development to improve functionality and usability. The comparatively lower rating for processing time corresponds with the longer operation required for lignified materials such as mango leaves, as confirmed by Zhang et al. (2019). The lowest rating for vacuuming performance identifies waste collection as the main area requiring further improvement, consistent with Bagundang et al. (2024), who stressed the importance of reliable collection systems in effective school-based waste management.

3.3.2 Safety

The machine received an overall safety mean of 4.77, interpreted as Highly Acceptable. Emergency stop mechanisms or safety switches, safety control during operation, and clearly visible safety operating procedures each received a mean of 5.00. Accident-prevention features obtained 4.97, while protective coverings and proper guarding of moving blades and gears both received 4.92. Minimal risk of injury received 4.83, prevention of waste spillage or scattering received 4.67, and prevention of bodily discomfort received 4.42. The lowest-rated safety indicator was noise and vibration reduction, which obtained 3.92 and was interpreted as Acceptable. The results demonstrate strong respondent acceptance of the machine's safety controls, protective mechanisms, and operating procedures. These findings support Davis (1989), whose Technology Acceptance Model indicates that perceptions of a technology's usefulness and ease of operation contribute to its acceptance, while the strong safety ratings reinforce confidence in its practical use. The Engineering Design Process outlined by Pahl and Beitz (2013) also emphasizes the incorporation and testing of protective mechanisms to minimize user risk. The positive ratings for physical safety and comfort are consistent with Prisco and Cubillas (2022), who highlighted the importance of safe and practical systems in sustaining school-based waste management initiatives. However, the comparatively lower rating for noise and vibration indicates an area for future improvement, particularly because the gasoline engine produces noticeable operational noise and vibration. Awasthi et al. (2020) noted that user acceptance of organic waste processing systems can be influenced not only by output performance but also by operating conditions such as noise, vibration, and user comfort.

4. Conclusion & Recommendations

The Biodegradable Fertilizer Machine was successfully designed and fabricated as a functional school-based system for converting biodegradable waste into usable fertilizer. The machine demonstrated acceptable efficiency across the tested materials, with pure mowed grass producing the highest fertilizer output and fastest processing time, pure mango leaves showing the lowest efficiency and longest operation time, and the mixed feedstock producing moderate results. The machine maintained an approximate 60% recovery efficiency and was rated Highly Acceptable in terms of usability and safety, particularly for its operational readiness, single-operation fertilizer production, emergency stop mechanisms, and visible safety procedures. These findings demonstrate that the machine can provide a practical, safe, and convenient approach to biodegradable waste management and fertilizer production in schools.

The screw conveyor mechanism should be improved to enhance the suction and collection of biodegradable waste, while a conveyor system may be incorporated to facilitate material loading. Future improvements should also address the noise and vibration produced by the gasoline engine and may consider alternative power sources, such as electric motors, particularly in schools with reliable electricity. The machine should also be tested using a wider range of biodegradable materials beyond mowed grass and mango leaves. Its adoption in schools may be considered as a practical means of managing organic waste and supporting environmental education.

The study was limited to selected schools in Bansalan West District and involved 60 respondents composed of teachers and school utility workers. Efficiency testing was conducted only on pure mowed grass, pure mango leaves, and a mixture of the two using a fixed five-kilogram input across ten trials. The prototype also relied on a gasoline engine, with vacuuming efficiency, noise, and vibration identified as areas that still require improvement.

5. Compliance with ethical standards

The study observed appropriate ethical and institutional procedures throughout the research process. Permission was obtained from the school principal before data collection, and the purpose of the study and questionnaire was explained to the participants before their evaluation of the Biodegradable Fertilizer Machine. The collected responses were properly organized and securely stored to ensure responsible handling of research data. The researchers also acknowledged the cooperation and participation of the school personnel who contributed to the completion of the study.

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