Development of a Granulator Machine and Mixing Biological Fertilizer from Agricultural Waste.

Patcharin Intamas[a], Chatchai Sungpud[b]
and Uraiwun Wanthong[c*]

Received: October 23, 2024; Revi sed: November 9, 2024;
Accepted: December 16, 2024; Published Online: December 30, 2024

Abstract

This research focuses on developing an IoTs-enabled bio-fertilizer mixer using agricultural waste to address environmental and economic challenges in agriculture. The device efficiently repurposes waste such as goat manure and crop residues into high-quality organic fertilizers to promote sustainable farming practices. The mixer integrates an electrical conductivity (EC) sensor and IoTs to automate operations, ensuring optimal moisture levels and reducing human intervention. Key finding results indicate an average power consumption of 710.61 watts and a rotational speed of 28.58 rpm, achieving production rates of 28.53 kilograms per hour. Moisture content levels (40%, 50%, and 60% w.b.) were consistently attained within 19–23 minutes for 10-kilogram batches. This innovation not only reduces dependency on chemical fertilizers but also minimizes production costs and labor, supporting environmental conservation and enhancing soil quality. Future improvements in durability and precision will expand its applicability to broader agricultural contexts.

Keywords: bio-fertilizer mixer, agricultural waste, IoTs, organic farming, sustainability

Introduction

From an analysis of economic challenges within the agricultural sector as outlined in the three-year development strategy of Koh Phet subdistrict municipality, Nakhon Si Thammarat province, for the fiscal years of 2018 to 2020. It was determined that various agricultural issues were prevalent, including elevated production costs. The farmers in this region employ chemical fertilizers in their agricultural practices, which exacerbate production costs. The decline in product prices results in agricultural revenues that are insufficient to cover the production expenses, leading to economic failure at the household level. The use of chemical fertilizers has several drawbacks that affect both the environment and human health (Zhang, et al., 2018), as follows: 1. Soil degradation: It leads to the loss of soil fertility and the diversity of microorganisms in the soil, which are essential for organic matter decomposition and plant growth. 2. Water Pollution: For example, polluted water with high levels of nitrates or phosphates, can cause rapid algae growth (eutrophication) 3. Health issues: Certain substances in chemical fertilizers, such as nitrates, may contribute to cancer or other health problems. 4. Greenhouse gas emissions: Such as nitrous oxide (N_2O), which has a high potential to contribute to global warming. 5. Loss of biodiversity: For example, the decline of pollinators or other animals that play important roles in ecosystems. Therefore, adopting sustainable agricultural practices, such as using bio-fertilizers, could help to

[a] Department of Industrial Arts Faculty of Industrial Technology Nakhon Si Thammarat Rajabhat University, Nakhon Si Thammarat, Thailand

[b] Department of Agriculture, Faculty of Science and Technology, Nakhon Si Thammarat Rajabhat University, Nakhon Si Thammarat, Thailand

[c] Department of Medical Instrumentation Physics, Faculty of Science and Technology, Nakhon Si Thammarat Rajabhat University, Nakhon Si Thammarat, Thailand

* Corresponding Author: E-mail: Uraiwun_wan@nstru.ac.th

reduce these impacts (Martínez-Dalmau, et al., 2021). The Koh Phet subdistrict municipality in Nakhon Si Thammarat province thus encourages the adoption of biological fertilizers instead of chemical alternatives. By organizing agricultural collectives, the Khuan Chalik sub-district administrative organization facilitates the production of bio-compost, involving 200 members who utilize raw materials sourced from agricultural waste, including goat manure, coconut husks, palm residues, and neem, to manufacture bio-fertilizer. This initiative aims to enhance knowledge regarding the value-added potential of agricultural waste materials, thereby creating a product that can generate supplementary income within the community (Ko Phet Subdistrict Municipality Permanent Secretary's Office, 2017).

The bio-fertilizer mixer derived from agricultural waste represents a groundbreaking innovation aimed at harnessing agrarian by-products such as rice straw, branches, leaves, and various other organic materials through mixing and amalgamation to yield bio-fertilizer (Koul, Yakoob, & Shah, 2022). This process mitigates the quantity of agricultural waste necessitating disposal. It enhances the value of the residual materials employed instead of incineration, thereby reducing pollution and greenhouse gas emissions. Furthermore, the efficiency of bio-fertilizer production is augmented, as the processes of mixing and mixing waste materials significantly accelerate and optimize the composting process (Badagliacca, et al., 2024). This acceleration is attributable to the increased surface area of the pulverized material, which facilitates microbial decomposition, consequently diminishing production costs, assisting farmers in curtailing expenditures associated with the acquisition of chemical fertilizers, and fostering sustainable agricultural practices. The utilization of biofertilizers not only enhances soil quality but also diminishes dependence on chemical inputs in cultivation, thereby supporting the production of bio-fertilizers to fulfill community demands (Ishak, et al., 2023). Consequently, the researcher conceived the idea of developing a fertilizer mixer. Its operational methodology employs a sophisticated system that regulates the rotational power, mixing, and blending of fertilizers through an integrated motor apparatus, accompanied by a reduction gear and transmission mechanism featuring a control system. This system is designed with Swiss technology to manage the opening and closing processes (Sombat, 2013). Intelligent control of operations is facilitated through an Internet of Things (IoTs) framework, which enables manual intervention to deactivate the machine when the fertilizer achieves optimal humidity levels, thereby enhancing user convenience. As a result, a fully automated fertilizer mixing system equipped with an embedded computer has been conceived. Users can manage the system via a smartphone interface. Upon receiving data from the EC sensor indicating that the fertilizer has reached the requisite humidity, users can command the machine to cease operation through the smartphone application (Pattama, Phubet, & Piyawadee, 2023). This innovation seeks to provide a bio-fertilizer mixer derived from agricultural waste that is user-friendly and cost-effective, promoting a reduction in human labor in production, leading to sustainable enhancements and increased income for farmers.

Research Instrument

Developing an innovative bio-fertilizer mixer utilizing agricultural waste involves the regulation of fertilizer mixing through an EC sensor, which serves to measure the moisture content of the fertilizer. This sensor is integrated into a mechanical system that autonomously ceases operation once the fertilizer mixture attains the specified moisture level, thereby negating the necessity for human oversight during the mixing and mixing processes. This advancement significantly enhances user convenience. The system efficiently grinds and mixes biological fertilizer to achieve the desired humidity level.

1. The design of the operational principle encompasses a prototype mixer engineered for the amalgamation of bio-fertilizers derived from agricultural waste materials, characterized by its functional principles. The automatic rotating composting machine registers an average spindle speed of 18.5 rpm. This discrepancy can be attributed to variations in spindle dimensions, thereby resulting in differential average

speeds (Supakit, et al., 2010). The composting tank is designed to be detachable from the machine. The motor activates via a pulley mechanism, which transmits power to a belt drive that operates in conjunction with a reduction gear, alongside a chain gear transmission linked to a shaft that secures the tank assembly. As the motor engages, power is conveyed, enabling the tank's mounting grid to rotate in both counterclockwise and clockwise directions. The mixing process of the fertilizer is regulated by the EC sensor, which measures the moisture content of the fertilizer. This sensor is connected to the mechanical system and will automatically halt operations upon achieving the requisite humidity level, as depicted in Figure 1.

2. The materials and equipment required for the construction of the machine include 1) a 1 horsepower motor (220 volts), 2) a reduction gear and transmission utilizing chain gears, 3) an operational control unit, 4) a tank mounting grid, 5) a fertilizer receiving tray, 6) a machine frame, 7) a plastic bucket for mixing fertilizer, with a capacity of 20 liters (the empty bucket weighs 1.50 kg), 8) an embedded Arduino board circuit, 9) one Swiss relay, 10) an EC sensor 3 positions along the length of the pane at an angle of 45 degrees along the direction of rotation (which measures the moisture value of fertilizer), 11) one set of Micro USB cables, and 12) a computer with Windows or Mac OS, as illustrated in Figures 2

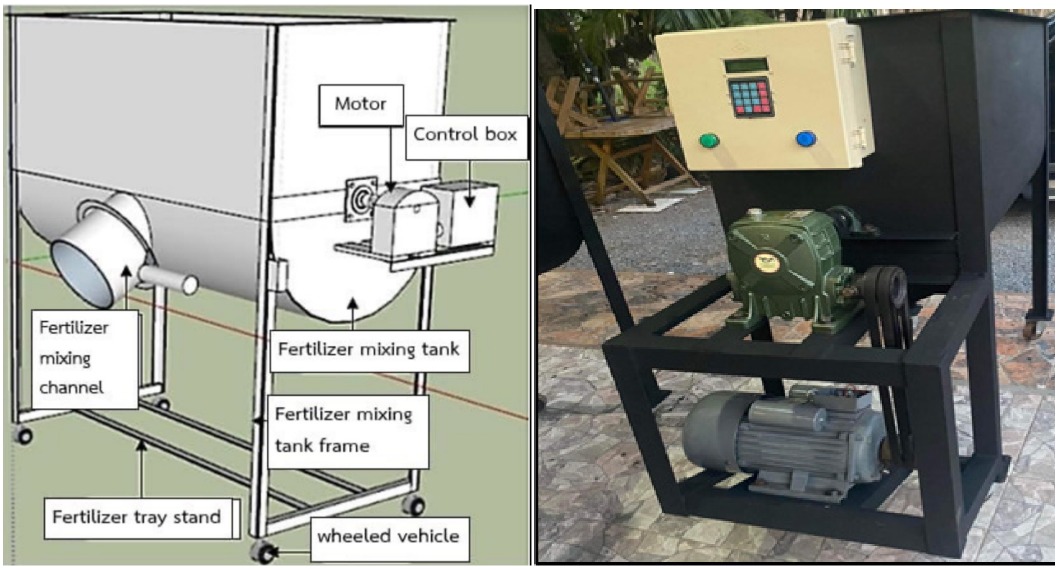


Figure 1. Innovative design of a bio-fertilizer mixer.

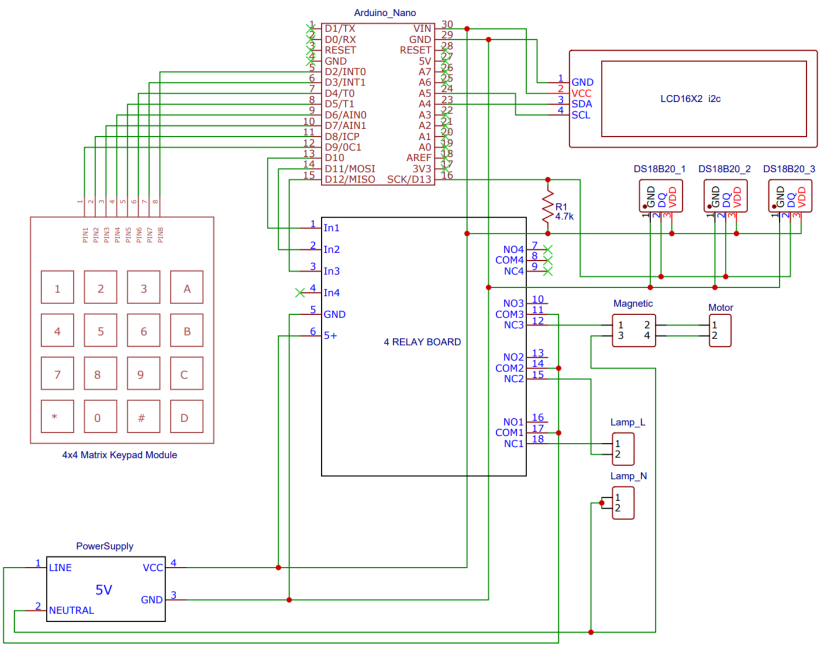


Figure 2. The control circuit of a bio-fertilizer mixer.

3. The design and development of an IoTs-enabled fertilizer mixer aimed at automating and optimizing fertilizer mixing for agriculture. The system consists of hardware and software components, using an ESP32S platform for control. Key features of the fertilizer mixer include the ability to mix fertilizers based on specific 3 formulas, schedule mixes, and monitor and control the device via a mobile app depending on 3 levels of %moisture content (40%, 50%, and 60% w.b.). The app allows users to select fertilizer formulas based on plant type or custom specifications, manage mixing schedules, monitor fertilizer levels, and preparation of raw materials for mixing to produce bio-fertilizer, each quantity is 10 kilograms of 3 bio-fertilizer prototypes.

PDM. 1 represents a bio-fertilizer developed by the Land Development Department of Thailand, which employs microorganisms to decompose organic materials, thereby yielding high-quality compost. This formulation is particularly effective for enhancing soil quality and fostering plant growth in regions characterized by poor or degraded soil conditions (Land Development Department, 2024). Ingredients of PDM.1 Fertilizer: Dry plant residues (e.g., scraps of coconut husks, palm bunches, scraps of acacia stalks) – 8.3 kilograms (Goat manure) – 1.6 kilograms, Nitrogen-fertilizer (46-0-0) – 0.1 kilograms, Super PDM.1 accelerator - 1 gram. The Super PDM.1 accelerator consists of cellulose-degrading microorganisms, including *Scytalidium thermophilum, Chaetomium thermophilum, Corynascus verrucosus, and Scopulariopsis breviacaulis.* It also contains cellulose-degrading actinomycetes, specifically two strains of *Streptomyces sp.,* and lipid-degrading microorganisms, including two strains of *Bacillus subtilis* (Land Development Department, 2024).

PDM. 2 represents a distinctive bio-fertilizer formulation that the Land Development Department of Thailand has innovated. Its primary objective is to facilitate the decomposition of organic materials, particularly in the context of producing organic fertilizers or enhancing soil quality. PDM. 2 exhibits notable efficacy in the breakdown of more resilient organic materials such as rice straw, corn stalks, and various other agricultural residues that present greater challenges in decomposition (Sahachai, Dulyawat, & Wichian, 2015). Ingredients for PDM. 2 Fertilizer: Dry plant residues (scraps of coconut husks, palm bunches, scraps of acacia stalks) – 4.6 kilograms, goat manure -3.1 kilograms, Molasses – 2.3 kilograms, Super PDM.1 - 1 gram.

PDM.3 is an organic fertilizer obtained from the use of various types of organic materials. Let's marinate urgently. We have supplemented *Bacillus* sp. and *Trichoderma* sp. microorganisms to help prevent root rot and stem rot diseases in vegetables and fruit trees. Ingredients for PDM. 2 Fertilizer: Dry plant residues (scraps of coconut husks, palm bunches, scraps of acacia stalks) – 9.9 kilograms, goat manure - 0.1 kilograms, Super PDM.1- 1 gram., *Bacillus* sp. - 10 gram. and *Trichoderma* sp 100 grams. Then add 4, 5, and 6 liters of water to achieve a moisture content of 40%, 50%, and 60% w.b., respectively.

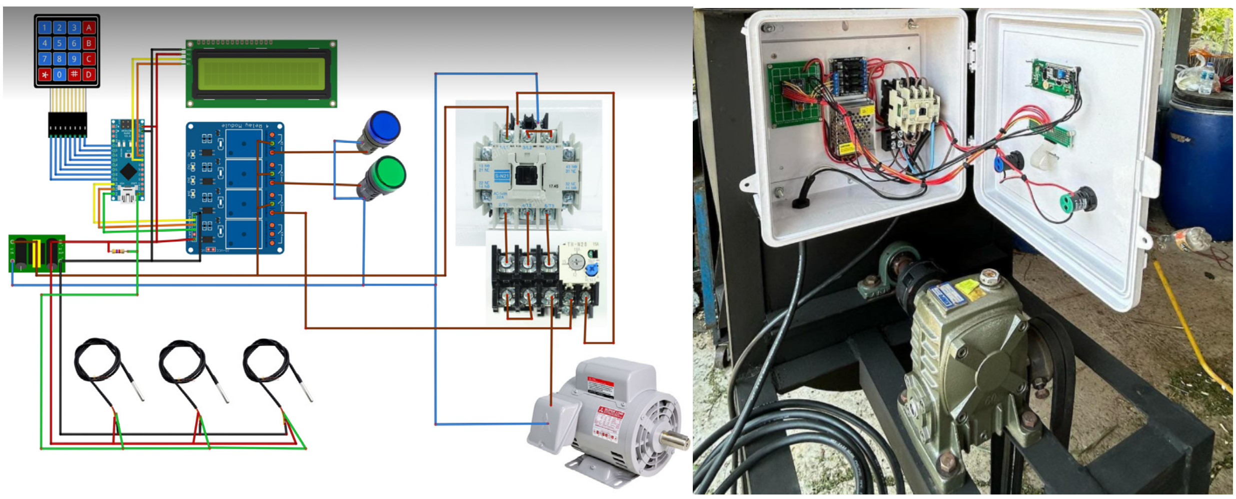


Figure 3. Prototype of a bio-fertilizer mixer.

4. Test procedure

4.1 The evaluation of the bio-fertilizer mixing motor's performance encompasses the assessment of charge voltage (V), electric current (A), power (W), and rotational speed (Rpm). The analysis of the test results was determined through averaging ( ) based on a motor specification of 1 horsepower (220 volts), by TIS 1515 2550 (2007), conducted over ten trials, each lasting 30 minutes, with the procedural steps delineated as follows. 1) The installation of a mixer designed for the amalgamation of bio-fertilizers derived from agricultural waste is to be executed. 2) The machine is to be activated to assess the motor's operational efficacy in mixing and mixing fertilizer. 3) An examination of the operational parameters of the power motor utilized for mixing and mixing fertilizer is to be conducted, with meticulous recording of the charge voltage (V), electric current (A), power (W), and rotational speed of the motor designated for the mixing and mixing of biological fertilizer, specified as 1 horsepower (220 volts), followed by the documentation of the results. The Fertilizer mixer can control devices through the ESP32S board, monitor the period / 10 kg. of the 3 formulas, and precisely mix fertilizer control.

4.2 The data is to be scrutinized and the test outcomes summarized accordingly-evaluation of Fertilizer mixing Rate Determination. The assessment of the duration required for the bio-fertilizer to achieve the requisite moisture content levels was conducted by measuring the mixing rate of 10 kilograms of fertilizer, categorized according to the mixing ratios of three distinct formulations combined with moisture values of 40%, 50%, and 60% w.b., and control the motor to stop working when the moisture content read from the sensor reaches the desired value. The analysis of the test data was performed utilizing the mean value ( ), alongside the operation of the relay switch that governs the motor's operating system, with data analyzed in terms of percentage. The compost bin was rotated vertically at a rotational velocity of 11.2 revolutions per minute. The experiment was conducted over ten times, each lasting 30 minutes, at a mixing rate of 10 kilograms of fertilizer, classified according to the mixing ratios of three different formulations.

Results

There exists a fundamental operational principle. This is achieved through the vertical rotation of the compost bin. At a rotational velocity of 11.2 rpm, the compost bin can be detached from the apparatus. The functional attributes of the machine initiate with the conveyance of power from the motor via a pulley system. Subsequently, the belt drive succeeds the gear reduction chain transmission, which is intricately linked to the shaft that is fixed to the tank. Consequently, upon the rotation of the motor, it effectively transmits energy to facilitate the rotational movement of the tank mounting grid, which can rotate in both counterclockwise and clockwise directions. The control of fertilizer mixing is managed by an EC sensor that quantifies the moisture content of the fertilizer, which is integrated into the mechanical system, and it will cease operation autonomously once the fertilizer has been blended to the requisite moisture level and has undergone analysis. The purpose of designing the operating principle of the device is to achieve optimal operation. The apparatus exhibits a fertilizer production capacity of 28.53 kilograms per hour, as illustrated in Figure 4 and Figure 5.

The experimental outcomes of the performance evaluation of the prototype bio-fertilizer mixing motor were derived from the assessment of the mixing rate for all three formulations of the fertilizer, which were mixed in quantities of ten kilograms. The purpose of designing the operating principle of the device is to achieve optimal operation. This is because the sensor (CE) measures the moisture content of fertilizer at the thresholds of 40%, 50%, and 60% w.b. according to the application. Test working times from different fertilizer conditions so that can program the machine to stop the machine appropriately. It will control the relay switch to stop working automatically. The mean duration recorded for this process was 19.43 minutes (Fertilizer moisture 40% w.b.), 19.83 minutes (Fertilizer moisture 50% w.b.), and 22.67 (Fertilizer moisture 60% w.b.), as illustrated in Figure 6, Figure 7, and Figure 8.

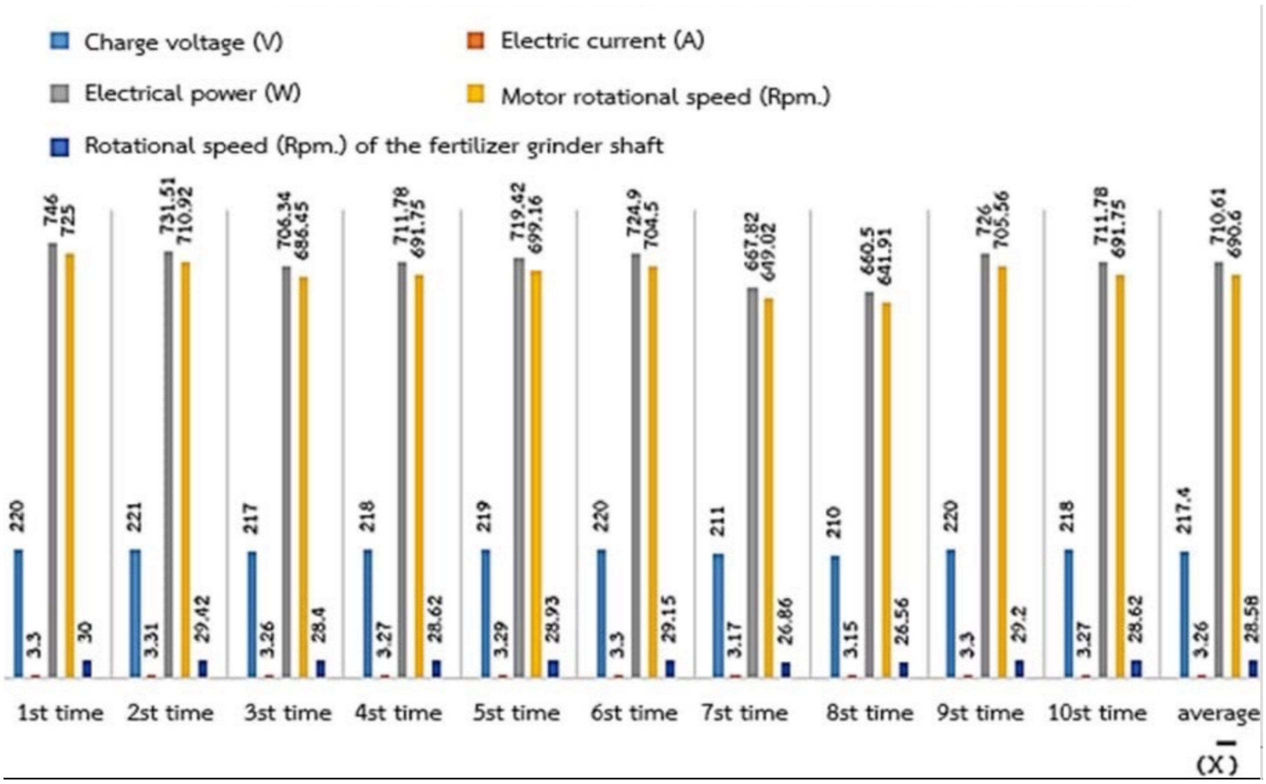


Figure 4. Results of testing the performance of the prototype bio-fertilizer mixing motor.

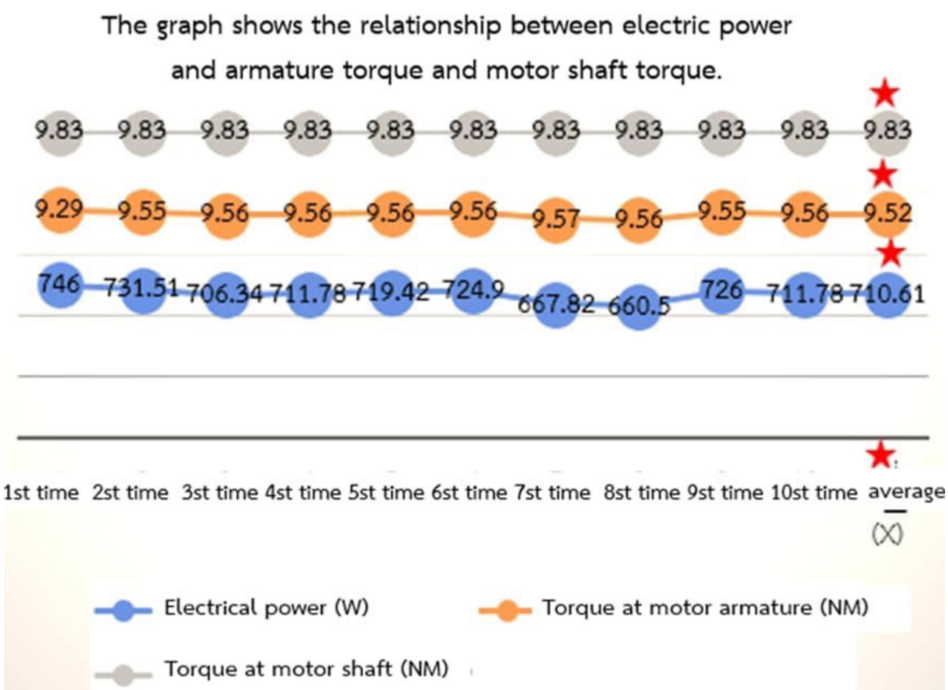
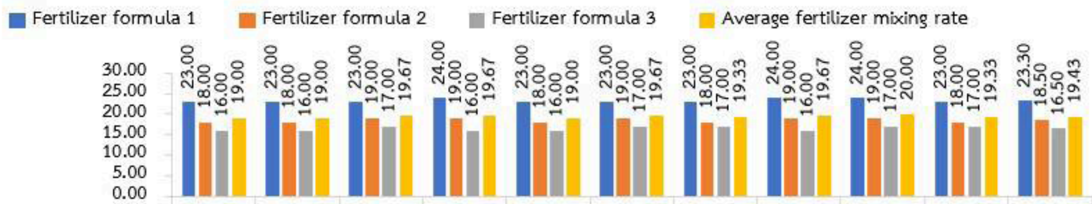
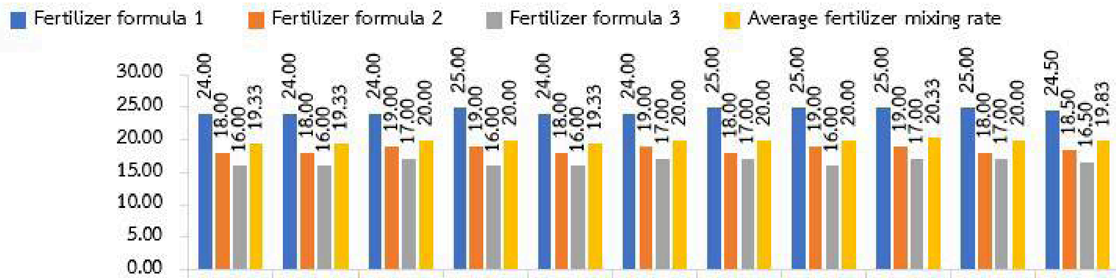


Figure 5. Relationship of electric power to armature torque and motor shaft torque.



	Test times 1	Test times 2	Test times 3	Test times 4	Test times 5	Test times 6	Test times 7	Test times 8	Test times 9	Test times 10	Average (X̄) fertilizer mixing rate, moisture content 40%
Fertilizer formula 1	23.00	23.00	23.00	24.00	23.00	23.00	23.00	24.00	24.00	23.00	23.30
Fertilizer formula 2	18.00	18.00	19.00	19.00	18.00	19.00	18.00	19.00	19.00	18.00	18.50
Fertilizer formula 3	16.00	16.00	17.00	16.00	16.00	17.00	17.00	16.00	17.00	17.00	16.50
Average fertilizer mixing rate	19.00	19.00	19.67	19.67	19.00	19.67	19.33	19.67	20.00	19.33	19.43

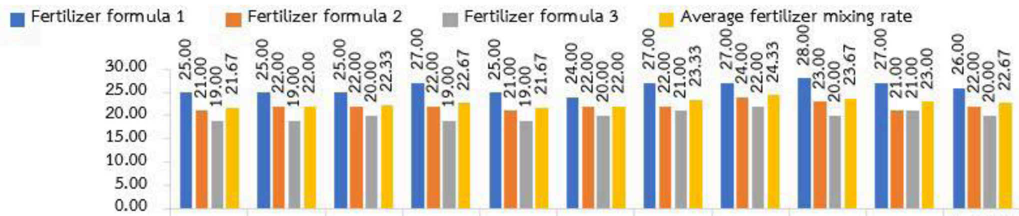
Figure 6. Results of the three formulas in 40 %, moisture



	Test times 1	Test times 2	Test times 3	Test times 4	Test times 5	Test times 6	Test times 7	Test times 8	Test times 9	Test times 10	Average (X̄) fertilizer mixing rate, moisture content 50%
Fertilizer formula 1	24.00	24.00	24.00	25.00	24.00	24.00	25.00	25.00	25.00	25.00	24.50
Fertilizer formula 2	18.00	18.00	19.00	19.00	18.00	19.00	18.00	19.00	19.00	18.00	18.50
Fertilizer formula 3	16.00	16.00	17.00	16.00	16.00	17.00	17.00	16.00	17.00	17.00	16.50
Average fertilizer mixing rate	19.33	19.33	20.00	20.00	19.33	20.00	20.00	20.00	20.33	20.00	19.83

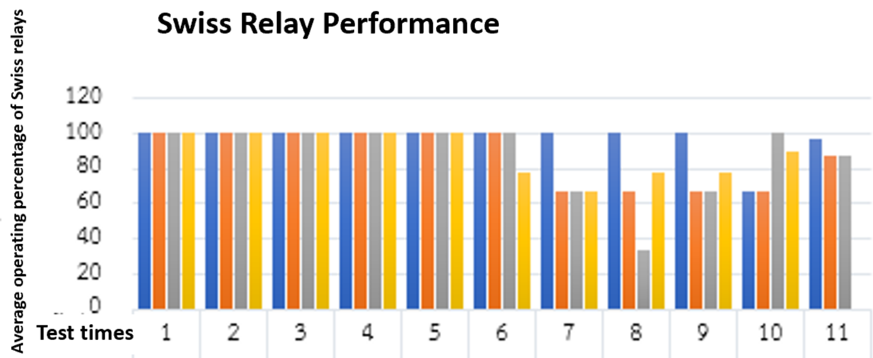
Figure 7. Results of the three formulas in 50 %, moisture.

The work results of Swiss Relay can control the machine to stop working when grinding fertilizer to the specified moisture value for all 3 mixed formulas, showing the results of the Swiss Relay test at 90 percent as shown in Figure 9.



	Test times 1	Test times 2	Test times 3	Test times 4	Test times 5	Test times 6	Test times 7	Test times 8	Test times 9	Test times 10	Average (X̄) fertilizer mixing rate, moisture content 60%
Fertilizer formula 1	25.00	25.00	25.00	27.00	25.00	24.00	27.00	27.00	28.00	27.00	26.00
Fertilizer formula 2	21.00	22.00	22.00	22.00	21.00	22.00	22.00	24.00	23.00	21.00	22.00
Fertilizer formula 3	19.00	19.00	20.00	19.00	19.00	20.00	21.00	22.00	20.00	21.00	20.00
Average fertilizer mixing rate	21.67	22.00	22.33	22.67	21.67	22.00	23.33	24.33	23.67	23.00	22.67

Figure 8. Results of the three formulas in 60 %, moisture.



Test times	1	2	3	4	5	6	7	8	9	10	11
Fertilizer formula 1	100	100	100	100	100	100	100	100	100	66.67	96.67
Fertilizer formula 2	100	100	100	100	100	100	66.67	66.67	66.67	66.67	86.67
Fertilizer formula 3	100	100	100	100	100	100	66.67	33.33	66.67	100.00	86.67
Average operating percentage of Swiss relays	100	100	100	100	100	77.78	66.67	77.78	77.78	90.00	0.00

Figure 9. Swiss Relay Performance.

iscussion

The development of a bio-fertilizer mixer utilizing agricultural waste underscores a significant leap toward sustainable agricultural practices. This innovation aligns with the dual goals of reducing environmental impact and enhancing economic viability for farming communities. By IoTs technology, the mixer demonstrates remarkable efficiency in producing high-quality organic fertilizers while minimizing labor and production time. The findings reveal that the mixer achieves consistent operational performance, with an average rotational speed of 28.58 revolutions per minute and precise moisture control through the integrated EC sensor. These features ensure the production of fertilizers with optimal moisture content, thereby improving the quality and utility of the end product.

A critical strength of this innovation is its use of agricultural waste materials such as goat manure, coconut husks, and other organic residues. This not only addresses waste management challenges but also transforms these by-products into valuable resources for soil enhancement. Furthermore, the IoTs-enabled control system allows for real-time monitoring and remote operation, significantly improving convenience for farmers. This approach reduces reliance on chemical fertilizers, lowering production costs and mitigating the environmental hazards associated with chemical inputs.

Despite its effectiveness, some areas for improvement remain. The machine's long-term durability and performance under continuous operation need further assessment. Employing more robust materials, such as corrosion-resistant metals, could extend the lifespan of the mixer and ensure sustained functionality in varying agricultural conditions. Additionally, fine-tuning the precision of moisture sensors and motor control mechanisms would further enhance the reliability and consistency of fertilizer production.

The study's findings align with prior research on sustainable agricultural technologies, indicating that innovations such as this mixer can substantially reduce the environmental footprint of farming activities. Compared to other existing devices, the mixer's higher spindle speed and automated moisture control highlight its superior efficiency and ease of use. However, variations in production times based on different fertilizer formulas suggest the need for further optimization to standardize performance across diverse applications.

In conclusion, the bio-fertilizer mixer presents a compelling solution for small-scale farmers seeking to adopt sustainable practices. Its ability to repurpose agricultural waste into high-value products while reducing labor and cost makes it an invaluable tool for fostering environmental and economic resilience. Future work should focus on enhancing the machine's scalability, robustness, and integration with broader agricultural systems to maximize its impact. The rate of fertilizer mixing, the duration required for the biological fertilizer to attain optimal moisture content levels of 40%, 50%, and 60% w.b., the variance explained by the differing raw materials employed in fertilizer production, and the relevance of the distinct categories of fertilizer utilized and averages 21.03 minutes per 10 kilograms of fertilizer (Boonlert, 2005).

The rate of fertilizer mixing, about the duration required for the biological fertilizer to attain optimal moisture content levels of 40%, 50%, and 60% w.b., is a variance explained by the differing raw materials employed in fertilizer production. The period of fertilizer utilized averages 21.03 minutes per 10 kilograms of fertilizer. We can have an improved organic fertilizer mixer based on IoTs technology capable of monitoring the status of fertilizer production remotely and providing updates and alerts to workers (Chaikhamwang, Janthajirakowit, , & Fongmanee, 2021).

Cunclusion

The development of an IoTs-enabled bio-fertilizer mixer from agricultural waste presents a promising advancement for sustainable agriculture. By utilizing a rotating motor system and integrating real-time, the prototype can effectively manage fertilizer moisture levels, achieving precise mixing with minimal labor. This mixer, powered by an ESP32S board and controlled via a mobile application, not only offers farmers ease of use but also enhances the efficiency of fertilizer production. The innovation demonstrates a practical solution to reduce reliance on chemical fertilizers, lower production costs, and transform agricultural waste into valuable bio-fertilizers, thus supporting environmental sustainability and improved soil health in farming communities. Further refinement with more durable materials and high-precision sensors would increase the device's robustness and operational accuracy, enabling broader adoption among local farmers and agricultural enterprises.

Recommendations

Relevant institutions ought to implement a project aimed at enhancing the understanding among farmers regarding the utilization of a prototype bio-fertilizer mixer derived from agricultural waste, which facilitates the production of bio-fertilizers characterized by suitable moisture content and quality for application within their respective agricultural domains. This can be achieved through the development of a comprehensive manual designed to disseminate knowledge to farmers who express interest. Local agricultural organizations should facilitate the transfer of bio-fertilizer production technology utilizing mixers from agricultural waste to farmer collectives that demonstrate an interest in adopting it as an ancillary profession within community enterprise frameworks.

Acknowledgements

This research was supported by the National Research Council of Thailand (NRCT), Fundamental Fund in Fiscal Year 2023, National Research Council of Thailand (NRCT).

References

Boonlert, P. (2005). *Teaching Materials for Electric Motors and Control*. Nakhon Phanom: Nakhon Phanom Technical College.

Chaikhamwang, S., Janthajirakowit, C., & Fongmanee, S. (2021, March). IoT for smart farm: A case study of the fertilizer mixer prototype. In *2021 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunication Engineering* (pp. 136–139). IEEE.

Badagliacca, G., Testa, G., La Malfa, S. G., Cafaro, V., Lo Presti, E., & Monti, M. (2024). Organic fertilizers and bio-waste for sustainable soil management to support crops and control greenhouse gas emissions in Mediterranean agroecosystems: A review. *Horticulturae*, 10(5), 427.

Ishak, A. H., Hajjaj, S. S. H., Gsangaya, K. R., Sultan, M. T. H., Mail, M. F., & Hua, L. S. (2023). Autonomous fertilizer mixer through the Internet of Things (IoT). *Materials Today: Proceedings*, 81, 295–301

Ko Phet Subdistrict Municipality Permanent Secretary's Office. (2017). *3-Year Staffing Plan, Ko Phet Subdistrict Municipality*, fiscal year 2018–2020, Nakhon Si Thammarat: Ko Phet Subdistrict Municipality.

Koul, B., Yakoob, M., & Shah, M. P. (2022). Agricultural waste management strategies for environmental sustainability. *Environmental Research*, 206, 112285.

Land Development Department. (2024). *Manual for Using PDM.1 Accelerator for Compost Production*. [Online]. Available: http://r07.ldd.go.th/nan01/amazing/puy/main-puy.html [2024, May 16].

Martínez-Dalmau, Javier., Berbel, Julio., & Ordóñez-Fernández, Rafaela. (2021). Nitrogen Fertilization. A Review of the Risks Associated with the Inefficiency of Its Use and Policy Responses. *Sustainability*, 13, 5625. https://doi.org/10.3390/su13105625.

Pattama, P., Phubet, P., & Piyawadee, Y. (2023). Development of an automatic rotating composting machine. *Journal of the Academic Conference and the 10th National and 8th International Research Presentation, Northeastern University*, 507–517.

Sahachai, L., Dulyawat, N., & Wichian, L. (2015). Project report on Automatic Hydroponic Fertilizer Mixing System with Embedded Computer. Phayao: Ratchaprachanukroh School 24 p.

Sombat, M. C. (2013). Research study on the development of a set of bio-fertilizer pellet machines for households. Phitsanulok: Department of Mechanical Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna.

Supakit, S., Pannathorn, P., Weena, C., Yaowalak, P., & Narin, C. (2010). Development of a prototype of a rotating drum compost mixer. Bangkok: King Mongkut's University of Technology Thonburi, Office of the Research Council National.

Zhang, Lu., Yan, Chengxi., Guo, Qing., Zhang, Junbiao., & Ruiz-Menjivar, Jorge. (2018). The impact of agricultural chemical inputs on environment: global evidence from informetrics analysis and visualization. *International Journal of Low-Carbon Technologies,* 13, 338–352.