Design and Implementation of an Internet of Things (IoT)-Based Smart Composter with Automated Mixing System

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Abstract — **The increase in the volume of household organic waste has become a significant environmental issue, particularly in urban areas, as improper management can lead to environmental pollution, unpleasant odors, and harmful gas emissions. Conventional composting methods generally require continuous manual monitoring and lack effective mechanisms to maintain optimal composting conditions. This study proposes the design and implementation of an Internet of Things (IoT)-based Smart Composter equipped with an ESP32 microcontroller as the main controller, a temperature and humidity sensor (DHT22), a soil moisture sensor, a gas sensor (MQ135), and a motorized mixing mechanism powered by an AC induction motor that users operate via an on/off switch and an AC dimmer. Environmental data is transmitted in real-time to the Blynk platform, while the water pump is automatically activated via a relay module based on soil moisture thresholds. Test results show that the DHT22 sensor has an average temperature error of 0.23% and a humidity error of 8.86%; the soil moisture sensor was able to distinguish between dry, moist, and wet compost conditions, the MQ135 sensor responded to gas changes within the range of 7.5%-92.7%, and the automatic irrigation system and Blynk communication operated reliably throughout all tests. These results demonstrate that the developed system is capable of supporting more efficient and sustainable management of household organic waste.**

Keywords— Organic Waste, Smart Composter, Internet of Things, ESP32, Motorized Stirring, Real-Time Monitoring.

I. INTRODUCTION

Composting is one of the most effective methods for managing organic waste, as it can improve soil fertility whilst reducing the volume of household waste that ends up in landfill sites. Although its benefits are fairly well known, the uptake of household-scale composting amongst the general public remains relatively low [1]. Conventional methods are often considered troublesome, time-consuming, and impractical, as they require users to turn or stir the compost heap manually and at regular intervals to ensure oxygen is distributed evenly [1], [2]. When stirring is neglected, the interior of the compost material is prone to anaerobic conditions, which cause unpleasant odors and slow down decomposition.

In addition to the issue of mixing, poorly managed household organic waste also causes environmental pollution in the form of methane emissions and leachate, which can contaminate soil and groundwater, whilst increasing public health risks [3], [4], [5]. Several automatic composters are already available on the market, but they generally still face challenges such as limited capacity, long processing times, sub-optimal mixing mechanisms, and a lack of real-time compost condition monitoring features [2]. Research on IoT-based composters also indicates that devices capable of both monitoring and controlling the composting process, including user-operated mechanical mixing mechanisms remain limited in availability for domestic use [6].

Therefore, this research aims to design and implement an IoT-based smart composter equipped with a motorised mixing mechanism, in order to provide a more practical and efficient solution for household composting, complete with real-time environmental monitoring.

II. LITERATURE REVIEW

A. Key Parameters of the Composting Process

Composting performance is greatly influenced by temperature, moisture content, microbial activity and mechanical aeration through mixing. Research confirms that microbial activity is most effective within the thermophilic temperature range of 40–65°C, and that adequate aeration is generally achieved by periodically turning or mixing the compost material to distribute oxygen evenly whilst preventing the formation of anaerobic pockets [7], [8]. Controlled moisture levels also support microbial decomposition whilst minimising anaerobic conditions and unpleasant odours [8].

B. User Behaviour and Needs

Research into composting practices within communities has shown that a lack of knowledge and awareness regarding composting procedures is one of the main barriers preventing households from composting consistently [9]. These findings underscore the need for a system that provides easy to operate motorised mixing, real-time updates on conditions, and clear notifications for users with no prior composting experience.

C. IoT-Based Monitoring and Control System

Developments in IoT-based compost monitoring

systems indicate that combining environmental sensors with automated control mechanisms can improve the reliability of the composting process, as demonstrated by the Smart Compost Guardian prototype, which integrates temperature and humidity sensors with wireless notifications [10], and a web-based monitoring system that sets an ideal humidity range of 60–80 per cent and detects methane as an indicator of anaerobic conditions [11]. In addition to monitoring, actuation mechanisms are also a key consideration: research on IoT-based automated irrigation systems shows that actuation mechanisms such as water pumping can improve the ability to maintain optimal moisture conditions within biological systems [12]. These scientific insights form the primary basis for determining system specifications, covering the monitoring of temperature, humidity, soil moisture and gases, motorised stirring mechanisms, and automatic humidity control.

III. METHOD

This study employed a design and implementation approach to develop an Internet of Things (IoT)-based smart composter for household organic waste management. The methodology consisted of system design, hardware and software implementation, and experimental evaluation to verify the functionality and performance of the proposed system.

A. System Design

The proposed IoT smart composter consists of a hardware subsystem integrates an ESP32 microcontroller with a DHT22 temperature and humidity sensor, a soil moisture sensor, an MQ135 gas sensor, a relay-controlled DC water pump, and a ¼ HP AC induction motor for stirring and shredding the compost material. The software subsystem utilizes WiFi communication and the Blynk platform for real-time data transmission, while the user monitoring interface enables users to monitor environmental parameters remotely. The integrated control system also performs automatic watering based on soil moisture threshold.

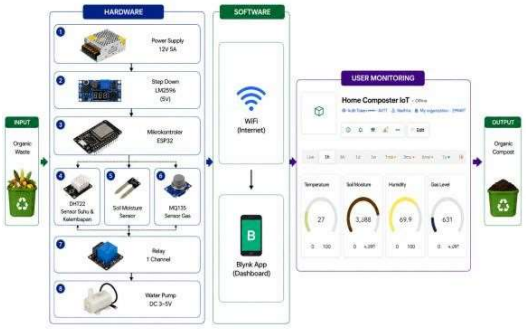

FIGURE 1
Block Diagram of the IoT Smart Composter System

B. Hardware and Software Implementation

The hardware implementation consists of an ESP32 microcontroller integrated with environmental sensors, actuators, and power management modules to support real-time monitoring and automatic moisture control. A 12 V power supply and an LM2596 step down converter provide the required operating voltage for the ESP32 and supporting devices. The software was developed using the Arduino IDE for sensor data acquisition, actuator control, and wireless communication, while the Blynk platform enables real-time monitoring through a web dashboard. The detailed hardware components and their functions are summarized in Table 1.



FIGURE 2
Developed Smart Composter Prototype

Figure 2 shows the developed IoT-based smart composter prototype, which integrates the sensing, control, and actuation modules into a single household composting system. The detailed hardware components and their respective functions are summarized in Table I.

TABLE 1
System Component Specifications

No	Component	Function
1	ESP32	Main controller: sensor data acquisition, actuator control, Wi-Fi communication.
2	DHT22	Measures the temperature and relative humidity of the composting chamber.
3	Soil Moisture	Measures the moisture content of compost.
4	MQ135	Monitors changes in gas concentrations during composting.
5	AC Induction Motor ¼ HP	Operates a stainless steel blade to mix or chop compost material; activated manually via an on/off switch, with speed controlled via an AC dimmer.
6	Relay + DC Water Pump	Enables automatic watering based on soil moisture thresholds.
7	Blynk Dashboard	Displays environmental data in real time for remote monitoring.

and moisture conditions were tested. The average sensor readings obtained from each sample are summarized in Table 2. The recorded environmental parameters include temperature, humidity, soil moisture under different conditions, and gas concentration measured by the MQ135 sensor.

TABLE 2
Summary of Average Sensor Readings

Parameter	Sampl e A (Telko m Matur e)	Sampl e B (Semi Matur e)	Sample C (Commun ity Mature)	Sample D (Wet Compo st)
Temperat ure (°C)	27.3	26.1	25.7	26.3
Humidity (%)	84.1	96.2	95.4	95.4
Soil Moisture (Dry)(%)	42.2	48.3	60.2	-
Soil Moisture (Moist)(%)	52.2	56.7	63.4	-
Soil Moisture (Wet)(%)	62.8	60.5	74	73.3
Gas Level (%)	62.4	32.7	7.5	92.7

C. Operating Procedures and Test Schemes

Once powered on, the ESP32 initializes all connected hardware components, establishes a WiFi connection, and connects to the Blynk platform. The system continuously acquires data from the DHT22, soil moisture, and MQ135 sensors at 10 seconds intervals. The acquired data are transmitted to the Blynk platform for real-time monitoring through a web dashboard. Soil moisture readings are processed using a hysteresis control algorithm, where the relay activates the DC water pump when the ADC value reaches 3500 or higher and deactivates it when the value falls below 3000, preventing frequent relay switching caused by minor sensor fluctuations.

The experimental evaluation consisted of two stages. The first stage validated the performance of each sensor individually by comparing the DHT22 measurements with an HTC-1 digital thermohygrometer and evaluating the soil moisture and MQ135 sensors under controlled conditions. The second stage evaluated the integrated system using four compost samples with different maturity and moisture levels, including mature compost from Telkom University, semi mature compost from Telkom University, mature compost from a local composting community, and wet compost. The experimental results were used to evaluate the functionality and reliability of the proposed smart composter.

IV. Results and Discussions

A. Sensor Testing

Calibration of the DHT22 sensor was carried out by comparing its temperature and humidity readings with those of the HTC-1 digital thermohygrometer under identical environmental conditions. The test results showed an average temperature error of 0.23 per cent and an average humidity error of 8.86 per cent, indicating that the DHT22 sensor provides sufficiently reliable environmental data to support the monitoring of the composting process.

To evaluate the performance of the developed smart composter, four compost samples with different maturity

As presented in Table 2, each compost sample exhibited distinct environmental characteristics according to its maturity and moisture condition. Sample A (Telkom mature compost) recorded the highest average temperature of 27.3 °C, while Sample B (semi-mature compost) exhibited the highest relative humidity at 96.2%. Among the soil moisture measurements, the highest value was observed in Sample C under the wet condition (74.0%), whereas Sample D was evaluated only under the wet condition because of its naturally high moisture content, resulting in an average soil moisture of 73.3%. In addition, the MQ135 sensor produced the highest response in Sample D (92.7%), indicating a substantial difference in gas conditions compared with the other compost samples. These results demonstrate that the proposed IoT-based smart composter can effectively distinguish different compost conditions and provide reliable real-time environmental monitoring throughout the composting process.

B. Actuator and Communication Testing

The actuator and communication subsystems were evaluated to verify the reliability of the developed smart composter during operation. The tests included the performance of the mixing motor, automatic watering system, Wi-Fi connectivity, and real-time data transmission through the Blynk platform. The summary of the test results is presented in Table 3.

TABLE 3
Summary of Actuator and Communication Test Results

Parameter	Result
Mixing Mechanism	The AC induction motor operated normally in trials.
Automatic Watering	The relay-controlled DC water pump activated at 3500 ADC and deactivated at 3000 ADC in all trials.
WiFi Connectivity	Successfully connected in all trials with an average connection time of 4.10 s.
Blynk Communication	All sensor readings were successfully transmitted and matched the values displayed on the Blynk platform.

As summarized in Table 3, all actuator and communication subsystems operated reliably throughout the testing process. The mixing mechanism and automatic watering system functioned according to the predefined control logic, while stable Wi-Fi connectivity and successful data transmission through the Blynk platform verified the reliability of the proposed IoT-based monitoring system.

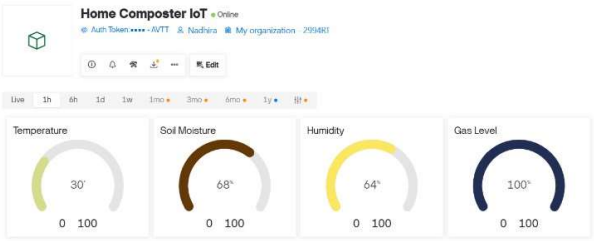

FIGURE 3
Real-Time Monitoring Interface on the Blynk Dashboard

Figure 3 illustrates the real-time monitoring interface implemented on the Blynk platform. Environmental data collected by the sensors are transmitted from the ESP32 via Wi-Fi and displayed instantly on the dashboard. The successful visualization of all monitored parameters confirms the reliability of the IoT-based communication system for remote compost monitoring. The communication performance and actuator functionality are further summarized in Table III.

V CONCLUSION

This study successfully designed and implemented an IoT-based smart composter with a motorized mixing mechanism to support the management of household organic waste. The DHT22 sensor is capable of monitoring temperature and humidity with average errors of 0.23% and 8.86%, respectively, while the soil moisture sensor and the MQ135 gas sensor proved capable of distinguishing compost conditions at various levels of maturity and humidity. The motorized mixing mechanism, based on an AC induction motor operated via an on/off switch and an AC dimmer, proved to be reliable, while the automatic watering system successfully maintained compost moisture levels within empirically determined thresholds. The IoT communication subsystem also successfully transmitted all sensor data to the Blynk platform in real time and reliably. Overall, the developed system shows potential as a practical and sustainable solution for household organic waste management, although further development is still needed, particularly regarding simplifying power distribution, ease of compost retrieval, and long-term testing with various types of organic waste.

REFERENCES

[1] R. A. Afla, D. N. Martono, and S. Wahyono, "Behaviour of Food Waste Home Composting," Jurnal Penelitian Pendidikan IPA, vol. 9, no. 9, pp. 6848–6853, 2023, doi: 10.29303/jppipa.v9i9.4294.

[2] A. Sujata, "Smart Composting IOT Solution For Waste Reduction," Journal of Scientific Research and Technology, no. 7, pp. 188–193.

[3] I. R. Abubakar, K. M. Maniruzzaman, U. L. Dano, F. S. Alshihri, and T. I. Alrawaf, "Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South," 2022.

[4] World Health Organization, "Throwing Away Our Health: The Impact of Solid Waste on Human Health – Evidence, Knowledge Gaps, and Health Sector Responses," WHO, Geneva, Switzerland, 2025.

[5] D. I. Omang, G. E. John, S. A. Inah, J. O. Bisong, and G.
E. John, "Public health implication of solid waste generated by households in Bekwarra Local Government area," vol. 21, no. 3, pp. 1467–1473, 2021.

[6] S. F. Mujiyanti, P. Y. Aisyah, A. F. Salsabilla, and T. R. Darmawan, "IoT-based for Monitoring and Control System of Composter to Accelerate Production Time of Liquid Organic Fertilizer," vol. 8, no. 2, pp. 49–55, 2022.

[7] R. S. Noor et al., "Recent Trends and Advances in Additive-Mediated Composting Technology for Agricultural Waste Resources: A Comprehensive Review," ACS Omega, 2024, doi: 10.1021/acsomega.3c06516.

[8] D. Roy, S. Kumar, and C. Kumar, "Rapid composting of groundnut residues through novel microbial consortium: Evaluating maturity, stability, and microbial activity," Curr. Res. Microb. Sci., vol. 7, p. 100277, 2024, doi: 10.1016/j.crmicr.2024.100277.

[9] N. A. Salleh, M. Wira, M. Shafiei, A. Anwar, and F. Zulhumadi, "Sustaining the Environment: Critical Success Factors and Barriers of Solid Waste Management through Composting Practices by Rural Communities in Malaysia," 2022.

[10] G. R. Ap, C. S. E. Kangeyam, T. P. Hridhya, and B. E. Cse, "Smart Compost Guardian: An IOT-Based Real-Time Compost Monitoring and Alert System."

[11] J. B. C. Fiel, A. J. C. Lemindog, V. B. Patao Jr., and D.A. Ilisan, "Compost Master: A Web-Based IoT System for Real-Time Household Compost Monitoring and Crop Recommendation," in 2025 IEEE Int. Conf. Agrosystem Eng., Technol. & Appl. (AGRETA), Shah Alam, Malaysia, 2025, pp. 17–24, doi: 10.1109/AGRETA68375.2025.11474168.

[12] K. A. Saragih and R. Kurniawan, "Sistem Penyiraman Otomatis Berbasis IoT dengan Logika Fuzzy Sugeno untuk Pengendalian Kelembaban Tanah di Greenhouse," pp. 808–819, 2025, doi: 10.33364/algoritma/v.23-1.2327.