Research Article

Development of an IoT-Based Monitoring System for Food Waste Composting to Enhance BRIS Soil Quality

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Abstract | Food waste composting offers a sustainable approach to improving the fertility and water-holding capacity of BRIS soil, which is inherently low in nutrients and agricultural productivity. However, conventional composting practices often lack real-time monitoring and control, which leads to inefficiencies in maintaining optimal conditions for microbial activity and nutrient stabilization. To overcome this limitation, this study presents the development of an IoT-based monitoring system designed to optimize composting processes for enhancing BRIS soil quality. Four composting techniques were analysed that is Control, Vermicomposting, Black Soldier Fly (BSF) composting, and Effective Microorganisms (EM) composting were evaluated using a Randomized Complete Block Design (RCBD). Temperature and moisture were monitored across the mesophilic, thermophilic, and curing phases by using DS18B20 temperature sensors and HD-38 soil moisture sensors with a Wemos D1 R32 microcontroller by enabling real-time data collection and cloud-based logging via Google Sheets. Systems performance were validated using Two-Way ANOVA and Bivariate correlation analyses between IoT system and manual measurements at a significance level of 0.05. Results show that the IoT system achieved higher accuracy, with lower standard deviations for temperature (1.77˚C) and moisture (12.36%) compared to manual measurements (2.05 ˚C and 13.76%) respectively. Significance differences were observed among composting techniques and BSF composting techniques proving the most effective ($F(3, 403) = 6.824$, $p < 0.001$), followed by vermicomposting, EM composting, and the Control. BSF composting exhibited the fastest decomposition rate and high-quality compost production due to the active role of BSF larvae. the ability of IoT systems to provide real-time data enables remote monitoring, reduces labour costs, and improves decision-making for users. Overall, the study demonstrates the potential of IOT-enabled monitoring to enhance composting efficiency and support sustainable agriculture. Future research should explore advanced sensor integration and machine learning applications to further strengthen data-driven decision-making and promote sustainable agriculture.

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Introduction

The increasing demand for food which is driven by urbanization and global population growth has variously impacted the environment, such as greenhouse gas emissions, air and water pollution, biodiversity loss, altered land use, and threats for food security and sustainability. Projection by Food and Agriculture Organisation (FAO) and the United Nations (UN) estimate that the world's food demand will increase substantially to feed an expected population of 10 billion people by 2050 (Berners-Lee *et al*., 2018; Muhsin and Safuan, 2025). At the same time, approximately 3 billion tonnes of food are lost or wasted annually, approximately one-third of the food produced for human consumption (Gustavsson *et al*., 2011; Iskandar *et al*., 2025). The disposal of food waste in landfills intensifies environmental problems, as its decomposition generates methane, a potent greenhouse gas that contributes significantly to climate change. Therefore, composting represents a sustainable waste management strategy that not only mitigates these impacts but also supports agricultural productivity, environmental health, and long-term sustainability.

In this regard, utilizing food waste compost as soil amendment provides a dual benefit by reducing environmental burdens from waste disposal while simultaneously addressing the agricultural limitations of marginal soils such as Beach Ridges Interspersed with Swales (BRIS). BRIS soil is commonly found in coastal regions such as Peninsular Malaysia, is characterized by its high sand content of over 90%, resulting in poor agricultural suitability due to low fertility, minimal cation exchange capacity, and inadequate water retention (Yusoff *et al*., 2017; Jahan & Chowdhury, 2015; Ettaleb *et al*., 2025). However, integrating compost into BRIS soil significantly increases its organic matter content and microbial population, improving its quality and fertility. For instance, research by Heng *et al*. (2017) states that sandy soil typically contains an average sand content larger than 50% and clay content lower than 20% at a depth of 30 cm. In particular, the defining characteristics of sandy soil include its granular size, low clay content, and dominance of large particles.

By mitigating the limitations of BRIS soil like rapid drainage, low fertility, and structural instability composting not only enhances its agronomic potential but also supports the sustainable management of food waste. During the composting process, the microbial community structure changes during composting, with beneficial bacteria promoting the degradation of organic matter and improving compost quality (Miao *et al*., 2023; Gao *et al*., 2021; Sutariati and Muhidin, 2025). During composting process, the decomposition process can generally be categorized into two distinct processes: aerobic and anaerobic. In aerobic composting, oxygen plays a vital role by facilitating the breakdown of organic matter into stable end products such as heat, water, ammonia, and carbon dioxide. In contrast, anaerobic composting predominantly produces methane, organic acid, and hydrogen sulphide as intermediate compunds (Misra *et al*., 2003). Beyond waste stabilization, compost application improves soil quality by enhancing aggregation, increasing water-holding capacity, reducing bulk density, and expanding pore volume (Adugna, 2016). These improvements are particularly beneficial for sandy soils, which are highly susceptible to rapid drainage since humus and organic matter from compost increase both retention and stability (Chen *et al*., 2011; Tiwari *et al*., 2025). BRIS soil, however, present additional constraints due to its coarse texture, elevated surface temperatures and fragile structure, necessitating innovative approaches for agricultural adaptation. In response to these challenges, applying food waste compost, rich in organic matter and vital nutrients, is an effective strategy to replenish nutrient-deficient BRIS soil while mitigating the environmental consequences of food waste disposal.

Composting efficiency is primarily governed by key physicochemical parameters, notably moisture content and temperature. Microbial activity is maximized when moisture levels are maintained within the optimal range of 50–60%, as deviations from this range can limit oxygen diffusion and consequently suppress microbial metabolic processes (Ameen *et al*., 2016). Temperature plays multi-role by accelerating organic matter decomposition while simultaneously inactivating harmful pathogens (Hafeez *et al*., 2018). The absence of real – time monitoring for parameters such as temperature, and moisture often results in suboptimal compost quality and prolonged decomposition (Bhoir *et al*., 2020). Manual data collection is labour-intensive and prone to human error and lacks continuous visibility, thereby delaying timely interventions and increasing operational costs. These challenges make scaling up composting operations into larger scale difficult (Jo *et al*., 2019).

The incorporation of Internet of Things (IoT) technology presents an innovative approach to composting management. IoT-based systems utilize sensor networks to monitor critical environmental parameters in real–time continuously, ensuring optimal conditions are maintained throughout the composting process. This automation reduces dependence on manual labor, minimizes human errors and improve overall efficiency (Riazulhamed *et al*., 2024). Recent developments have further advanced IoT applications by incorporating machine-learning capabilities, enabling predictive adjustment and faster maturity of the compost while preventing complications like odours or delayed decomposition. Besides, these systems can interface with cloud and mobile platforms, allowing for remote control and management (Filipescu *et al*., 2024).

Despite these advantages, the practical implementation and large-scale adoption of IoT-based composting systems in agriculture remain limited. This research focuses on developing an IoT-based monitoring system that is designed to track important composting parameter in real time by integrating with cloud platform such as Google Sheets for real-time data logging (Balaganesh *et al*., 2022), automate data collection and provide remote monitoring while promoting IoT systems to reduce the human error and improve data accuracy (Riazulhamed *et al*., 2024).

Materials and Methods

Experimental location

The experiment was conducted at Universiti Sultan Zainal Abidin (UniSZA), Malaysia, where the location was characterized by BRIS soil. The geographical coordinates of the site were recorded as N5°45'10.718", E102°37'43.281" to ensure accurate location reference. To provide a controlled environment, a shelter measuring 5 m x 2 m (10m^2) was constructed. The structure minimized the influence of weather disturbances, while black sunshade netting was installed to reduce heat accumulation and provide a protective barrier against pests, instead of ensuring a stable and undisturbed composting process.

Experimental design

A Randomized Complete Block Design (RCBD) was employed with the composting technique as the main treatment factor: Control, Effective Microorganisms (EM), Vermicompost, and Black Soldier Fly (BSF) compost and time (days of composting) as the blocking factor to account for temporal variability during the decomposition process. Each treatment was replicated three times per block, resulting in a total of twelve (12) experimental units. Replications were included to ensure robust statistical analysis and enhance the reliability of the results. The experiment was conducted under natural conditions, with compost bins arranged to allow adequate aeration with 0.5 m spacing between bins on the sides and 1.0 m spacing between rows. This setup minimized cross-contamination and ensured uniform airflow across treatments. The layout of the experimental design is illustrated in Figure 1.

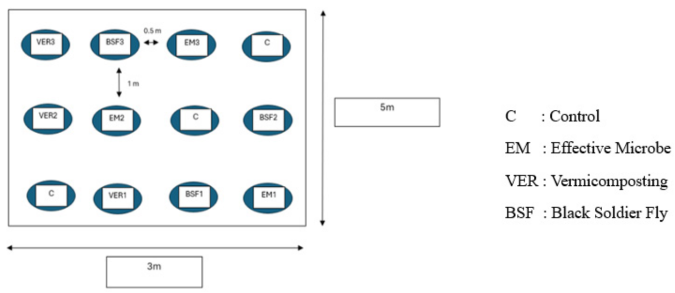

Figure 1: *Layout of the randomized complete block design (RCBD) for composting treatments in the experiment.*

Kitchen waste collection

The food waste used for this study was sourced from nearby restaurants and hypermarkets. Collection was carried out daily for seven consecutive days, and the materials were shredded prior to composting to accelerate decomposition. This selected green waste primarily consisted of fruit and vegetable residue, which are nutrient rich and highly suitable for composting. Eggshells were also included as a supplementary material during composting process, which may enriches the nutrient composition of the final product by contributing calcium, thereby enhancing soil quality and promoting healthy plant growth (Sobieraj et. al., 2022). To maintain compost quality and reduce risks, unsuitable wastes were excluded. These included meat, fish and bones which could attract pests and produce foul odours as well as eggs, dairy products, grease, fats and oils, which decompose poorly and cause odour problems. Additionally, diseased plant materials were avoided to prevent the spread of pathogens within the compost. Careful selection of appropriate food waste was therefore essential to ensure safe handling, improve composting efficiency and minimize potential environmental pollution.

Composting techniques

In-vessel composting involved an enclosed system requiring mechanical aeration, making it labour intensive and costly but effective in a controlled environment. Windrow composting placed raw materials in long piles turned regularly for aeration, with pile heights ranging from 3 to 12 feet depending on material density. While maintenance and costs were high, it allowed rapid composting. Static composting used passive aeration without turning, resulting in slow decomposition but requiring less labour and equipment, making it cost-effective for small-scale use. A layer of a layer of brown waste (dried leaves and cardboard) was added as a carbon source with ration carbon to nitrogen 3:1 to balanced carbon-to-nitrogen level for effective composting and support microbial activity. This experiment used vermicomposting, BSF composting, and EM composting due to their affordability and suitability for small-scale applications. The compost was aerated weekly by manual turning, while moisture and temperature levels were monitored twice daily at 9:00 am and 6:00 pm throughout the decomposition period.

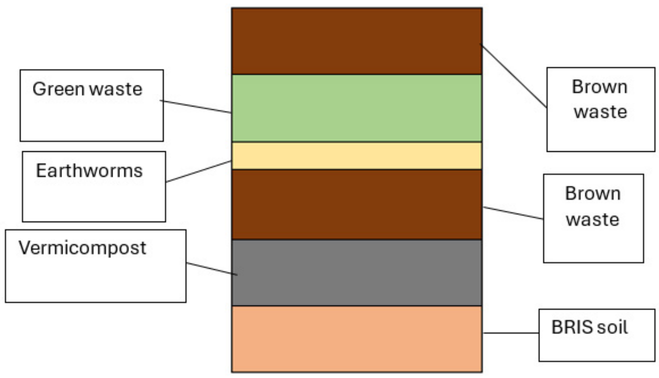

Figure 2: *Layering process of composting with ANC earthworms.*

Vermicomposting is an environmentally sustainable technique for converting organic waste into nutrient-rich compost through the activity of earthworms. As earthworms consumed organic matter, their digestive processes produced worm castings that significantly enhanced soil fertility. In this study, African Night Crawler (ANC) worms were obtained from a certified supplier. The composting setup began with a 10cm layer of BRIS soil placed at the bottom of each compost bag, followed by vermicompost to create a suitable environment for the worms. Moisture was maintained by sprinkling water, after a layer of brown waste (dried leaves and cardboard) was added as a carbon source. Subsequently, green waste was incorporated along with 50 ANC worms (Shrestha *et al.*, 2024), ensuring a carbon-to-nitrogen ratio of 3:1 to support worm activity. A final layer of brown waste and light watering was applied to retain moisture. Figure 2 shows the layering setup of vermicomposting technique.

Black Soldier Fly (BSF) composting is an organic waste management technique that utilizes BSF larvae as decomposers. A composting bag was set up with layered materials: BRIS soil was placed at the bottom to form the bedding, followed by an initial layer of brown waste and green waste. Subsequently, 150 BSF larvae were introduced by gently burying them within the composting substrate (Amrul *et al.*, 2022). The larvae were fed with fed regularly with the collected organic waste. Throughout the process, the composting environment was closely monitored to maintain suitable moisture conditions and ensure larval health. Figure 3 shows the layering setup of BSF technique.

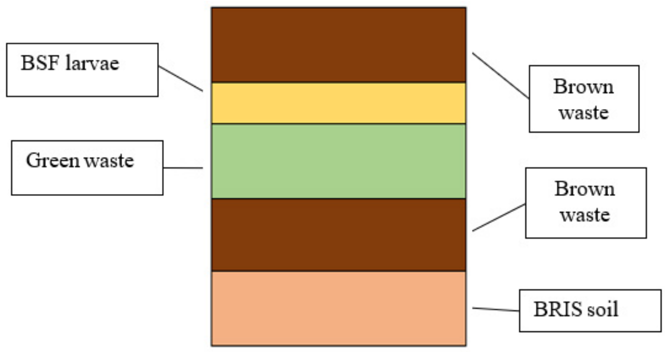

Figure 3: *Layering process of composting with BSF.*

Effective Microorganisms (EM), a microbial inoculant developed by Teruo Higa in the 1970s, was applied in this study to enhance the decomposition process (Saravanan *et al.*, 2013). A standard EM solution was prepared by mixing 1L of EM with 1L of molasses and 10L of water. The layering process was prepared with a layer of BRIS soil as bedding at the based and followed by brown waste and green waste . Subsequently, 3L of of EM solution was applied by pouring directly onto the compost layers (Oseni *et al.*, 2012). The compost pile was turned regularly to provide aeration, distribute microorganisms evenly, and speed up decomposition while reducing odour.

Figure 4 shows the layering setup of EM technique.

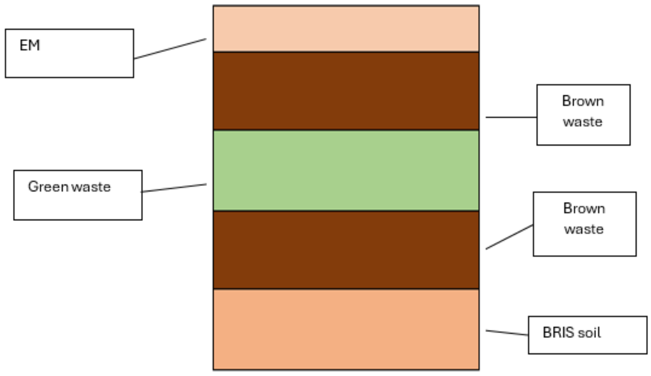

Figure 4: *Layering process of composting with EM.*

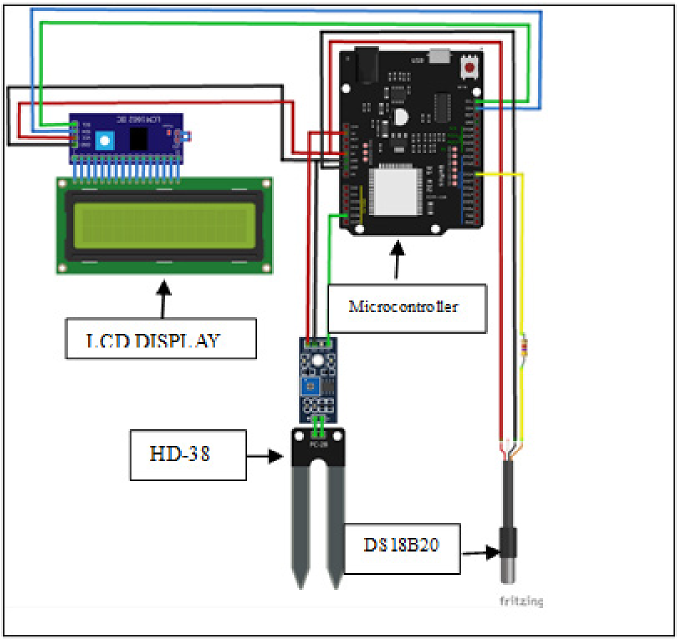

Figure 5: *Schematic diagram of the prototype.*

System design and deployment

The IoT-based monitoring system was developed using Wemos D1 R32 microcontroller, selected for its build in Wi-Fi capabilities and compatibility with Arduino IDE. Environmental parameters were recorded using two types of sensor: DS18B20 temperature sensor which provided digital readings with ±0.5°C accuracy and HD-38 soil moisture sensor, which generated analog signals proportional to soil water content. To ensure long – term durability under composting conditions, both sensors were equipped with anti – corrosion probes. A 16x2 LCD display was integrated into the system to provide real – time on – site feedback of temperature and moisture values. All electronic components were securely housed within waterproof junction box. TO simplify circuit assembly, an I2C interface was employed, requiring only four connections (VCC, GND, SDA, and SCL). Sensor data were transmitted via Wi-Fi to a Google Sheets platform, by enabling automated logging and remote monitoring of composting parameters in real time. Figure 5 shows the schematic diagram of the prototype.

Sensor calibration and testing

The DS18B20 temperature sensors were calibrated using an oil bath against a mercury thermometer (Koestoer *et al*., 2019). During calibration the sensors were immersed at multiple temperature points, and their readings were adjusted according to deviations from the ASTM 117C standard thermometer, as illustrated in Figure 6. The HD-38 soil moisture sensors were validated through comparison with gravimetric moisture measurements obtained from compost samples at known water contents (Chowdhury *et al*., 2022; Mutungi *et al*., 2025). A calibration curve was established to correct for potential effects of salinity and compaction on sensor response. Post-calibration testing confirmed measurement accuracy within ±0.5 °C for temperature and ±3% for moisture, ensuring reliable data collection under composting conditions.

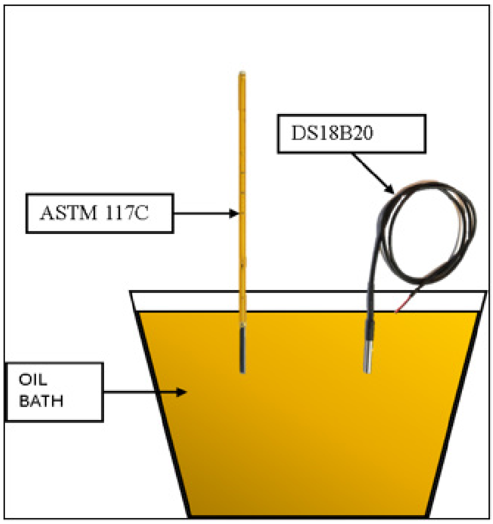

Figure 6: *Calibration process of DS of DS18B20 in an oil bath.*

Statistical analysis

A Two-Way ANOVA with a significance level of α=0.05 was employed to examine the interaction effects between monitoring IoT based system and manual method for temperature and moisture parameters. This approach allowed adjustment for temporal variations and provided accurate estimation of treatment effects. In addition, bivariate correlation analysis was conducted to assess the strength and direction of the relationships between IoT-based measurements and manual readings (Khan *et al.*, 2022; Srivani *et al.*, 2021; Mollasadegh *et al.*, 2017; Khanal, 2015).

Results

IoT Design and development

The IoT based monitoring system effectively tracked moisture and temperature in real time, demonstrating its practical applicability in compost management. A 16 x 2 LCD display was integrated to provide direct on-site feedback by displaying readings with clear labels (“M” and “T”) with units respectively. This feature enabled users to monitor compost condition without rely solely on remote access, which is particularly valuable in areas with limited internet access (Jo *et al.*, 2019). Furthermore, the compact and waterproof design enhanced the system’s durability, making it suitable for harsh composting environments (Subendran *et al.*, 2024). The data was recorded for every 10 minutes at at 98.5% data transmission success rate which consistent with findings of Balagnesh *et al.*, (2022) who highlighted the IoT’s capability to provide continuous, real-time monitoring in agriculture applications. Figure 7 shows the prototype of the monitoring system. The cloud integration with Google Sheets allowed users to visualize trends and make data-driven decisions that enable users to track fluctuations and detect anomalies effectively. For instance, sudden drops in moisture or sharp temperature increases could be identified promptly, allowing immediate corrective measures such as re-watering the compost. This aligns with findings by Senadheera *et al.* (2024), who underscored the significance of real-time data for compost management.

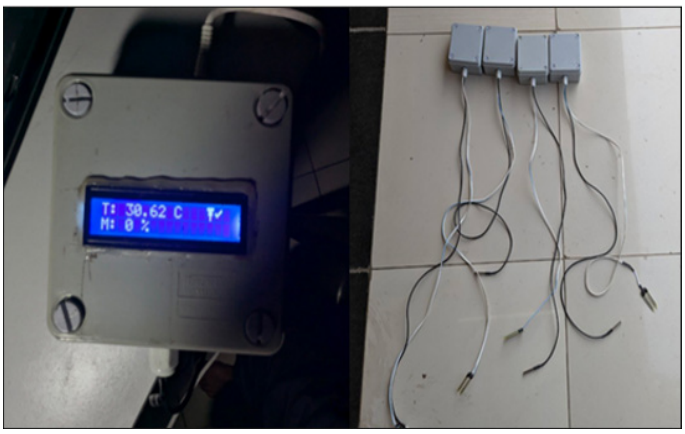

Figure 7: *LCD Visualize real-time data for temperature and moisture and replication of the prototype*

Intervention between IoT based monitoring system and manual method

The Estimated Marginal Means (EMMs) of compost temperature and moisture levels, adjusted for the covariate “days,” and comparing IoT and manual monitoring methods across four composting treatments are illustrated in Figure 8. For temperature, IoT and manual present close alignment, with IoT record slightly lower means and smaller error margin (SE = 0.36 for both). This data highlight IoT ability to minimize variability, due to high amount of data collected that reduce human error (Bhoir *et al.*, 2020). Correspondingly for moisture IoT consistently recorded higher levels of means, which detect subtle fluctuations missed by the manual method (Ameen *et al.*, 2016). These parallel trends throughout treatments supported by Two-Way ANOVA result in Table 1.

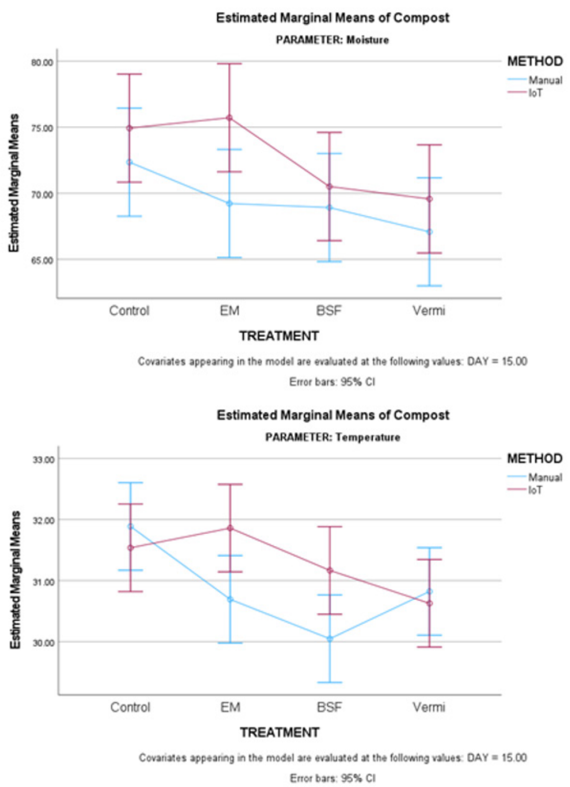

Figure 8: *Estimated marginal means of compost for temperature and moisture across methods and treatments.*

Table 2 shows data analysis for temperature and moisture correlation between method and treatment. The statistical data for temperature shows strong positive correlations between IoT and manual system across most of the treatment. The recorded environmental temperature 27.5 ˚ C which was lower than the temperatures observed in all composting process. This difference highlights the effect of microbial activity within the compost piles, where

Table 1: *A two-way ANOVA was conducted to examine the effects of method and treatment on a) Temperature and b) moisture of composition while controlling for days.*

Temperature						
Source	df	SS	MS	F	p	ηP2
Day	1	.335	.335	0.082	.775 NS	.000
Method	1	11.758	11.758	2.867	.092 NS	.012
Treatment	3	48.808	16.269	3.966	.009***	.047
Method X Treatment	3	31.217	10.406	2.537	.057 NS	.031
Error	239	980.351	4.102			
Total	248	240642.083				
b) Moisture						
Source	df	SS	MS	F	p	ηP2
Day	1	454.231	454.231	3.394	.067 NS	.014
Method	1	670.338	670.338	5.009	.026*	.021
Treatment	3	1113.039	371.013	2.772	.042*	.034
Method X Treatment	3	221.636	0.552	0.552	.647 NS	.007
Error	239	31985.599	133.831			
Total	248	1285994.886				

IoT based monitoring system VS manual monitoring consistency

Table 2: *Bivariate correlation of (a) Temperature data and b) Moisture data between method and treatment.*

	Temperature (°C)					
Treatment	Environmental	Method (M±SE)		r	P value	Interpretation
		IoT	Manual			
Control	27.5	31.54±0.56	31.95±0.30	0.692	<0.001***	Strong positive, correlation
EM	27.5	31.86±0.44	30.92±0.35	0.676	<0.001***	Strong positive, correlation
BSF	27.5	31.17±0.32	30.16±0.36	0.744	<0.001***	Strong positive, correlation
Vermi	27.5	30.62±0.21	31.08±0.28	0.252	0.172	weak, correlation
	Moisture (%)					
Treatment	Environmental	Method (M±SE)		r	P value	Interpretation
		IoT	Manual			
Control	86.1	74.93±1.88	72.51±1.40	.755	<0.001***	Strong positive, correlation
EM	86.1	75.36±2.17	71.37±1.84	.794	<0.001***	Very strong positive, correlation
BSF	86.1	71.47±2.58	70.10±1.74	.828	<0.001***	Very strong positive, correlation
Vermi	86.1	70.17±1.73	68.29±1.40	.699	<0.001***	Strong positive, correlation

the decomposition of organic matter generates heat, resulting in higher internal composting temperatures compared to the ambient environment. Whilst, the recorded environmental moisture was 86.1%, which was slightly higher than the moisture levels observed during the composting process. This difference can be attributed to the heat generated and microbial activity during decomposition, which often reduces moisture content within the compost compared to the surrounding environment. BSF treatment exhibited a highest correlation coefficient (r) for temperature of 0.744 with $p < 0.00$, that shows strong positive relationship (Khan *et al*., 2022; Srivani *et al*., 2021). Same goes for control and EM also have strong positive relationship. However, Vermiculture compost treatment showed the lowest correlation $r = 0.252$, $p = 0.172$, indicating that IoT and manual methods of temperature measurement might be inconsistent. These differences could be due to specific nature of vermicomposting since microbial activity can be slow or irregular, thereby causing an uneven temperature distribution. The findings align with Seal *et al.* (2011), who reported variability in temperature dynamics within vermiculture compost.

Statistical analysis revealed that the effect of monitoring method on compost temperature was not statistically significant ($p = 0.092$), indicating that both IoT-based and manual measurements produced comparable temperature readings. Nevertheless, the IoT system exhibited lower variability and greater consistency across treatments, suggesting improved measurement stability and reduced human error during data acquisition. Although the temperature trends recorded by both methods were closely aligned, the enhanced consistency of IoT readings demonstrates its operational advantage in continuous, real-time monitoring under composting condition. In contrast, the analysis of moisture data showed a stronger and statistically significant correlation between IoT and manual measurements, particularly in treatments exhibiting more dynamic composting behavior. The BSF composting treatment recorded the highest correlation ($r = 0.828$, $p < 0.001$), followed by EM, control, and vermicomposting, indicating that the IoT system was more responsive in detecting subtle moisture fluctuations. These findings align with those of Chowdhury *et al.* (2022), who reported that IoT-based sensors outperformed other sensors in capturing real-time variations in compost moisture. Nonetheless, extending the composting period in future studies is recommended to capture a wider range of decomposition patterns and enhance the robustness of long-term data interpretation (Kraut-Cohen *et al.*, 2023).

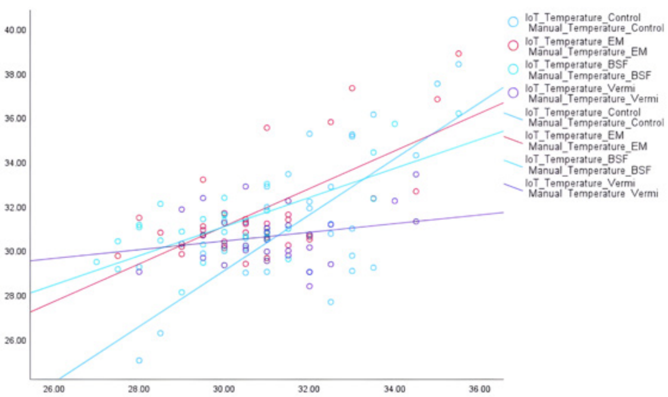

Figure9: *Bivariate correlation of temperature data between method and treatment scatterplot.*

Graphical trends

Temperature scatterplot, showing a clear alignment of IoT and manual measurement for most treatments. The regression line of Control, EM and BSF treatments are steeper, with all data points clustering tightly along the line, a reflection of the strong correlation observed in the statistical analysis relationship (Khan *et al.*, 2022; Srivani *et al.*, 2021). However, the scatter of Vermi is much greater (Figure 9), the line much flatter compared to other treatments, reflecting the weaker correlation in Vermi. It might require more calibration for the vermiculture composting condition. Overall, the scatter plot confirm that IoT provides consistent and reliable temperature reading that aligned with manual reading.

Figure 10 shows scatterplot for moisture further substantiates the consistency and reliability of The IoT systems. Treatments EM and BSF are presenting data points that are tightly aligned along the regression line, visually confirm the strong correlation between IoT system and manual system. This scatterplot highlights the capability of IoT for tracking moisture levels and show significant advantages of IoT over manual method in monitoring moisture and temperature which important key in composting process.

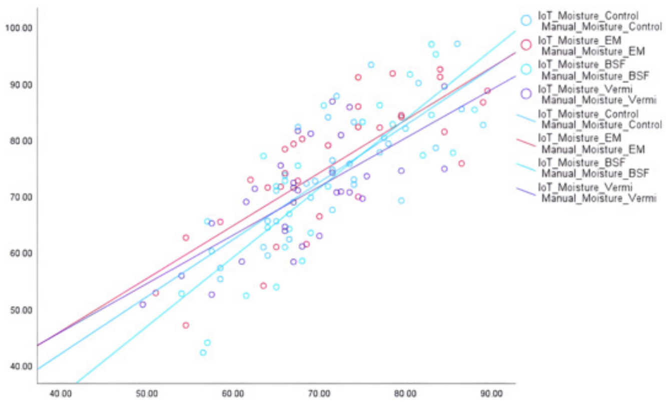

Figure10: *Bivariate correlation of moisture data between method and treatment scatterplot*

Table 3 presents the mean temperature and moisture content of compost across the four treatments monitored using the IoT-based system. Among all treatments, the BSF composting technique recorded the highest temperature and showed the most efficient decomposition, attributable to the active bioconversion of organic matter by BSF larvae. The EM treatment also demonstrated favorable results, maintaining higher moisture content that supports microbial activity and nutrient transformation. In contrast, vermicomposting exhibited comparatively lower temperature and moisture levels, likely due

Table 3: *Mean compost temperature (°C) and moisture (%) by treatment*

Treatment	Mean temperature (°C)	Standard deviation (°C)	Mean moisture (%)	Standard deviation (%)	Remarks
Control	31.54	0.56	74.93	1.88	Baseline treatment; moderate composting performance.
Effective Microorganisms (EM)	31.86	0.44	75.36	2.17	Balanced temperature and high moisture retention due to microbial inoculation.
Black soldier fly (BSF)	31.17	0.32	71.47	2.58	Highest temperature rise and fastest decomposition; most effective composting method.
Vermicomposting	30.62	0.21	70.17	1.73	Lower temperature and moisture levels; slower and less uniform decomposition.

Summary of compost temperature and moisture dynamics by treatment

to reduced microbial and earthworm activity under fluctuating environmental conditions. The control treatment showed moderate temperature and moisture values, serving as a baseline for comparison. Overall, the data confirm that BSF composting was the most effective in achieving rapid compost stabilization, while EM composting contributed to improved moisture retentionboth essential indicators of compost quality.

Conclusions and Recommendations

This study successfully developed an IoT-based monitoring system for composting that continuously tracked temperature and moisture with high reliability, producing results closely aligned with manual readings while reducing errors and variability. Real-time monitoring not only ensured more consistent data but also revealed composting trends across different treatments, supporting better decision-making for process optimization. The system's compact and durable design demonstrated its suitability for agricultural applications, particularly in improving BRIS soil through effective composting. Future work could expand sensor integration and data analytics to further enhance control and efficiency, highlighting the potential of IoT to transform composting into a more precise, scalable, and sustainable practice.

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Novelty Statement

The study lies in the integration of IOT-based real time monitoring with multiple composting techniques to improve BRIS soil sustainability. Unlike previous research, the study demonstrates scalable system that transforms food waste into nutrient-rich compost while addressing the unique challenges of BRIS soil through precise, cloud-enabled monitoring of composting parameters (moisture and temperature).

Author's Contribution

Muhammad Hazim Yahya: Experiment conduction, data curation and analysis, manuscript writing
Nor Azi Asminda Johari: Supervising, experiment conduction, data curation and analysis, manuscript writing
Nurul Izni Kamalrulzaman: Supervising and manuscript editing.
Mohd Fahmi Abu Bakar: Supervising and manuscript editing.

Generative AI or AI assisted technology statement
The authors delare that no AI or technology was used for this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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