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Influence of Sugarcane (Saccharum officinarum L.) Molasses (SOM) on Aerobic Compost Quality Using an Integrated Soil Sensor

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ABSTRACT:

Physico-biochemical conditions and nutrient composition are important considerations in evaluating aerobic compost. This study investigated the influence of sugarcane (Saccharum officinarum L.) molasses (SOM) on the physico-biochemical properties of aerobic compost using an integrated soil sensor. A quantitative experimental design was employed with an SOM-treated experimental group and an untreated control group, each comprising five independent compost samples (n = 5). The pH, moisture content, temperature, nitrogen (N), phosphorus (P), and potassium (K) were monitored over a 14-day composting period, with Day 14 designated as the sampling endpoint for statistical comparison. The Mann–Whitney U test showed no significant differences between groups in pH (U = 3, p = .056), moisture content (U = 12, p = 1.000), and temperature (U = 3, p = .056). Significant differences were observed in N, P, and K (all U = 0, p = .008), with higher mean concentrations in the SOM-treated group. Effect-size analysis indicated complete separation of the observed N, P, and K values between groups (rrb = 1.00). At Day 14, mean N, P, and K concentrations were 278.40, 744.20, and 705.20 mg/kg, respectively, in the SOM-treated group, compared with 139.00, 208.00, and 188.80 mg/kg in the control group. Overall, SOM treatment primarily influenced the measured nutrient parameters under the conditions of this study. Further studies with longer composting periods, laboratory validation of sensor measurements, microbial and maturity indicators, and larger independent samples are recommended.

Keywords: sugarcane (Saccharum officinarum L.) molasses (SOM), aerobic compost, physico-biochemical parameters, Mann-Whitney U-test

INTRODUCTION

Saccharum officinarum L., commonly known as sugarcane, is one of the most widely cultivated crops worldwide. In addition to its global value as the main source of sucrose, sugarcane possesses a variety of bioactivities owing to its myriad constituents (Ezz, S., Farag, M., & Shengpeng, W., 2021). Sugarcane byproducts, such as molasses, are an ideal source of carbon for biorefinery and microbial growth. The sugarcane industry is a primary sector of the agricultural industry (Lee et al., 2023). Due to the limited functional potential of the microbial decomposer community in tropical sandy soils, a significant proportion of organic inputs with a high C/N ratio and cellulose (CL) content may remain undecomposed. Moreover, high C/N ratio organic inputs led to N immobilization and suppressed succeeding crop yield. Inoculation of competent microbial decomposers to such soils could constitute a promising approach to overcome this problem, with beneficial effects on soil organic carbon (SOC) accumulation (Phukongchai, W., Kaewpradit, W., & Rasche, F., 2022).

Molasses is versatile and extends to applications in beverages, acetic acid production, baker's yeast cultivation, fermentation processes, and utilization as a component in animal feed and fertilizer. In its high solid content, molasses has advantages for enhancing the microbiological quality of fruits and vegetables, and serves as an

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effective medium for osmotic dehydration (Abera, B. D., Alemu Teferi, D., Asemu, A. M., Belachew, M. T., Geremew Kassa, M., & Satheesh, N., 2024).

Aerobic composting is the decomposition of organic wastes in the presence of oxygen (air); products from this process include CO2, NH3, water, and heat. This can be used to treat any type of organic waste, but effective composting requires the right blend of ingredients and conditions. These include moisture contents of around 60-70% and carbon-to-nitrogen ratios (C/N) of 30/1. Any significant variation inhibits the degradation process. Generally, wood and paper provide a significant source of carbon while sewage sludge and food waste provide nitrogen. To ensure an adequate supply of oxygen throughout, ventilation of the waste, either forced or passive, is essential (Huvaneshwari, M & Indian Raj, N., & Kumar, S., 2022).

Although previous studies have examined the use of sugarcane molasses in composting, limited evidence is available on its influence on the physico-biochemical properties of aerobic compost using integrated soil sensor technology, particularly at a predefined Day-14 sampling endpoint. To address this gap, the present study investigated the influence of sugarcane (*Saccharum officinarum* L.) molasses (SOM) on the pH, moisture content, temperature, nitrogen, phosphorus, and potassium of aerobic compost over a 14-day composting period. The experimental group treated with SOM and the untreated control group were monitored using an integrated soil sensor, with Day 14 designated as the predefined sampling endpoint for statistical comparison. Differences between the groups were evaluated using the Mann–Whitney U test. It was hypothesized that SOM treatment would significantly influence the measured physico-biochemical properties of aerobic compost, particularly its nitrogen, phosphorus, and potassium concentrations.

Significance of the Study

This study is important as it provides insights into the impact of SOM on the physico- biochemical parameters of aerobic compost. By analyzing the physico-biochemical parameters such as pH level, moisture, temperature, nitrogen, phosphorus, and potassium at the day 14 sampling endpoint using an integrated soil sensor, the researcher contributes to optimizing composting practices for more nutrient-rich organic production.

The findings will help farmers and waste management practitioners determine whether SOM can enhance compost quality. Additionally, the use of integrated soil sensors promotes the integration of low-cost, real-time monitoring technology in sustainable agriculture and environmental management.

LITERATURE REVIEW

Sugarcane (*Saccharum officinarum* L.) molasses (SOM) has gained considerable attention as an organic additive because of its high nutritional value and ability to stimulate microbial activity during biological processes. Chemical analyses have shown that molasses is primarily composed of sugars, nitrogenous compounds, carbohydrates, sucrose, amino acids, and bioactive compounds such as phenolics and flavonoids, which collectively enhance microbial metabolism and antioxidant activity (Abas et al., 2022; Djordjević et al., 2025). These properties have also led to its application as a substrate for beneficial microorganisms capable of promoting plant growth and improving soil health (Brito Bispo, 2023). Consequently, the nutrient-rich composition of molasses makes it a promising amendment for accelerating aerobic composting and enhancing compost quality.

The effectiveness of composting largely depends on maintaining favorable physico-biochemical conditions that support microbial succession and organic matter decomposition. Studies consistently report that moisture content, pH, total carbon, and nitrogen availability significantly influence bacterial and fungal communities throughout the composting process (Cheng et al., 2022). Carbon and nitrogen provide essential substrates for microbial growth (Ali et al., 2022), while phosphorus and potassium contribute to nutrient stabilization and compost maturity. Furthermore, additives containing potassium and phosphorus have been shown to accelerate the thermophilic phase, improve degradation of soluble organic compounds, reduce carbon loss, and enhance nutrient retention during composting (Aiguo et al., 2019; Duan et al., 2023). These findings suggest that nutrient supplementation can improve both composting efficiency and the quality of the final compost product.

Maintaining optimal composting parameters is equally important for producing mature and nutrient-rich compost. Previous studies recommend phosphorus concentrations of 30–50 ppm, pH values between 5.5 and 8.0, nitrogen levels below 500 mg/kg, potassium concentrations above 280 mg/kg, and moisture content between 20% and 60% to maximize microbial activity and nutrient availability while minimizing environmental risks (Beegle & Durst, 2017; Ho et al., 2022; Permies, 2022; Stehouwer et al., 2022; Zakarya et al., 2021). These threshold values serve as important reference points for evaluating compost maturity and quality. To improve compost quality and shorten the composting process, it is important to understand microbial communities, their interactions, and their responses to the physicochemical properties of compost, including temperature, which plays an important role in microbial activity during the different phases of composting (Finore et al., 2023).

The duration and management of aerobic composting also influence decomposition efficiency. Frequent turning promotes oxygen availability and shortens composting time, allowing mature compost to be produced within approximately two to three weeks under favorable conditions (Raabe, 2007). Compost maturity, however, is more appropriately determined by physicochemical characteristics rather than composting duration alone, as maturity standards may be achieved before the curing phase is completed (Composting Consortium, 2024). To ensure reliable interpretation of composting outcomes, adequate replication and appropriate statistical analyses are essential. Replication improves the precision of treatment estimates and provides a basis for estimating experimental error (Montgomery, 2012). When sample sizes are small and data violate normality assumptions, the Mann–Whitney U test provides a robust nonparametric approach for comparing independent groups (Batucan et al., 2025).

Recent advances in composting technology have integrated automation and real-time monitoring through smart composting systems. Jocosol (2025) demonstrated that an automated composting machine equipped with environmental sensors successfully maintained optimal composting conditions and produced compost with acceptable moisture, pH, nitrogen, phosphorus, and potassium levels. Similarly, multi-parameter soil sensors capable of simultaneously measuring temperature, moisture, pH, electrical conductivity, and NPK concentrations have become valuable tools for monitoring compost dynamics (Raju et al., 2023). Nevertheless, because nutrient measurements are often estimated indirectly through conductivity algorithms, calibration against standard laboratory methods remains essential to ensure measurement accuracy and scientific reliability (Dhamu et al., 2025; Musanase et al., 2023).

The reviewed literature establishes that sugarcane molasses provides a rich source of readily available nutrients capable of stimulating microbial activity, while optimal physicochemical conditions and accurate monitoring are fundamental to successful aerobic composting. Although previous studies have independently investigated molasses supplementation, compost quality parameters, sensor-based monitoring, and automated composting technologies, limited research has integrated these components into a single experimental framework. This gap provides the rationale for the present study, which evaluates the physico-biochemical parameters of aerobic compost at the Day 14 sampling endpoint with and without sugarcane molasses using an integrated multi-parameter soil sensor. By combining nutrient supplementation with real-time sensor monitoring, the study aims to provide a more comprehensive assessment of the influence of sugarcane molasses as a composting enhancer.

METHODOLOGY

Research Design

This study employed a quantitative experimental research design to determine the influence of sugarcane (*Saccharum officinarum* L.) molasses (SOM) on the physico-biochemical properties of aerobic compost. The experiment consisted of two groups: an experimental group treated with SOM and an untreated control group. Each group comprised five independent compost samples ($n = 5$), with each sample weighing approximately 0.5 kg. Both groups underwent aerobic composting for 14 days under the same experimental conditions. The sample size of five independent compost samples per group was determined based on time constraints and material availability.

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Six physico-biochemical parameters such as pH, moisture content, temperature, nitrogen (N), phosphorus (P), and potassium (K) were monitored using an integrated soil sensor throughout the 14-day composting period. Day 14 was designated as the predefined sampling endpoint for statistical comparison between the experimental and control groups. An NBL-S-TMC-7 7-in-1 Soil Integrated Sensor (Changsha Zoko Link Technology Co., Ltd., n.d.) was used for sensor-based monitoring. According to the manufacturer's specifications, the measurement ranges were −40 to 80 °C for temperature, 0–100% for moisture, 0–10 for pH, and 0–2,000 mg/kg for NPK, with stated accuracies of ±0.5 °C, ±5%, ±1 pH unit, and ±2%, respectively.

Differences between the experimental and control groups at Day 14 were evaluated using the Mann–Whitney U test at a significance level of $\alpha = .05$. The nonparametric test was selected because the study involved two independent groups with a small sample size ($n = 5$ per group), for which the assumptions required for parametric testing could not be reliably established.

Sampling Size and Materials

Fig.1 2.**5** kilograms of brown Carbon-rich materials (Abas, P. E., Choo, M., & Suhaimi, H., 2023).

Fig.2 1 kilogram of Greens. Nitrogen-rich materials (Abas, P. E., Choo, M., & Suhaimi, H., 2023). The compost mixture followed the recommended carbon-to-nitrogen (C: N) ratio, with materials carefully weighed to maintain microbial balance and support efficient decomposition (Aboutayeb, R., El-mrini, S., & Zouhri, A., 2022).

Fig.3 1.5 kilograms of loam soil. (Abas, P. E., Choo, M., & Suhaimi, H., 2023).

Fig.4 75 ml of SOM. (Abas, P. E., Choo, M., & Suhaimi, H., 2023).

Fig.5 Plastic Cups as an Alternative to Plastic Storage Container. This environmental agency guide includes clear instructions on using plastic storage containers for composting or vermicomposting. It recommends drilling

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air holes around the top and drainage holes at the bottom to ensure proper aeration and drainage (U.S. Environmental Protection Agency, 2023).

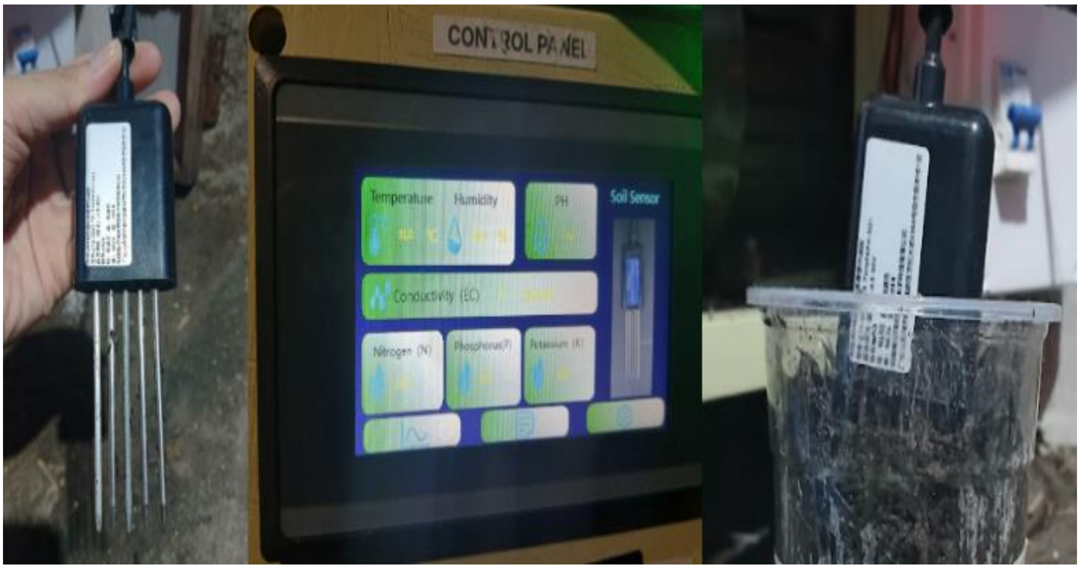

Fig.6 Integrated Soil Sensor with Control Panel. After the mixing procedure, an integrated soil sensor was inserted into the center of each compost sample, ensuring adequate contact between the sensor probes and the compost material. The sensor was connected to the HMI touchscreen system for monitoring and recording the measured parameters. Positioning the sensor at the core was essential, as it allowed for accurate measurement of internal compost conditions, particularly pH, moisture, temperature and NPK parameters that are most active and variable at the thermal center of the compost pile (Pavan Kumar, Y., Jaswanth, P., Pavan Kumar, G., Ajay Raj, G., & Vishnu Vardhan, M., 2024). Sensor readings were automatically recorded and logged daily over 14 days using the Human-Machine Interface (HMI) touchscreen display.

Table 1: Technical Specifications of the NBL-S-TMC-7 7-in-1 Soil Integrated Sensor

Parameters	Measurement Range	Stated Accuracy
Temperature	−40 to 80 °C	±0.5 °C
Moisture	0–100%	±5%
NPK	0–2,000 mg/kg	±2%
pH	0–10	±1 pH

Source: Changsha Zoko Link Technology Co., Ltd. (n.d.).

The technical specifications of the integrated soil sensor used in the study are presented in Table 1. The sensor was used to measure six physico-biochemical parameters: pH, moisture content, temperature, nitrogen (N), phosphorus (P), and potassium (K). The measurement ranges and stated accuracies were based on the specifications provided by the manufacturer (Changsha Zoko Link Technology Co., Ltd., n.d.).

Fig.7 Shredded Organic Matter. The input materials used for composting were manually shredded using an organic material shredder. The shredded organic matter was standardized to a particle size of approximately 3 to 4 millimeters to ensure uniformity and increase the surface area available for microbial degradation (Resmi, G., & Vinod, V., 2022).

Fig.8 This setup enabled real-time monitoring of compost dynamics and supported the physico-biochemical assessment of sugarcane syrup degradation (Kota, S. K. & Kumar, N. D., 2022).

Aerobic Composting Procedure at the Day 14 Sampling Endpoint With and Without SOM

The composting experiment was systematically conducted to analyze and determine the physico-biochemical properties of aerobic composting over 14 days in five independent samples per group (n = 5). Each step was designed to ensure consistency in aerobic compost formulation, accurate sensor-based data collection, and reliable analysis of aerobic compost behavior at the end of the 14-day composting period (Geisel, P.M. and Unruh, C.L., 2007)

1. The green and brown organic materials were shredded into uniform sizes of approximately 3–4 mm using an organic material shredder (Belyaeva, O. N., Haynes, R. J., & Zhou, Y.F., 2015).

2. Each input material was weighed according to the recommended carbon-to-nitrogen (C: N) ratio: 2.5 kg of browns, 1 kg of greens, and 0.5 kg of loam soil, totaling 4.0 kg of compost mixture (Aboutayeb, R., El-mrini, S., & Zouhri, A., 2022).

3. The entire 5 kg compost mixture was placed into a stainless-steel mixing tub. The moisture content of the loam soil was adjusted to 30%–60% using a measured volume of water before mixing (Devendra, R. et al., 2024).

4. The compost materials were thoroughly mixed for 5 minutes to ensure uniform distribution and proper aeration.

5. After mixing, the 5 kg mixture was evenly divided into 10 samples, each weighing approximately 0.5 kg.

6. The 10 samples were assigned into two groups:

○ Group 1 (Experimental): 5 samples, each added with 7.5 ml of SOM after sample division.

○ Group 2 (Control): 5 samples, no SOM added.

7. For Group 1, SOM was manually added, and each sample was remixed briefly to ensure even distribution of the treatment (Chen, L. et al., 2020).

8. An integrated soil sensor was manually inserted into the center of each sample. The HMI (Human-Machine Interface) touchscreen was activated to begin data logging.

9. All aerobic compost samples were incubated under aerobic conditions for 14 days, without further intervention or addition of materials during the aerobic composting process.

10. From Day 1 to 14, the aerobic compost parameters, such as pH, moisture, temperature and NPK levels, were measured for each of the 10 samples using the sensor system.

11. All data were exported via SD card and card reader for statistical analysis.

12. To determine whether there were statistically significant differences between the experimental and control groups, a Mann-Whitney U test was performed. This nonparametric statistical method was applied due to the small sample size and to accommodate any non-normal data distributions in the measured parameters.

13. All findings were tabulated and used for the final interpretation of results.

Data Collection of the Experimental and Control Groups at the Day 14 Sampling Endpoint

Data collection in this study was conducted over a 14-day aerobic composting period to analyze the physico-biochemical properties of compost samples. The compost was divided into two groups: experimental and control. Each group consisted of five independent samples, with each sample weighing 0.5 kilograms. The experimental group was treated with SOM at a practical application rate of 15 milliliters per kilogram, equivalent to 7.5 milliliters per 0.5-kilogram sample, based on small-scale composting practices (Chen, L. et al., 2020). The control group did not receive any SOM molasses treatment. This setup allowed for a comparative analysis of compost behavior between the treated and untreated samples.

To monitor aerobic compost parameters, an integrated soil sensor was inserted into the center of each compost sample, ensuring adequate contact between the sensor probes and the compost material. The sensor was connected to the HMI touchscreen system for monitoring and recording the measured parameters. This placement ensured accurate detection of the core aerobic compost activity, where microbial degradation was expected to be most active. The soil sensor measured physico-biochemical parameters, such as pH, moisture, temperature, nitrogen (N), phosphorus (P), and potassium (K), throughout the 14-day composting period.

The sensor system was connected to a Human-Machine Interface (HMI) touchscreen device, which enabled real-time monitoring and automatic data logging. The HMI device was capable of storing up to 1,000 log entries, allowing for comprehensive data capture across all samples. This sensor-based setup ensured consistent and efficient tracking of physico-biochemical changes in the compost throughout the experiment.

Following the 14-day composting period, the raw data at the day 14 sampling endpoint, including pH, moisture, temperature and NPK values, were collected from the integrated soil sensor via the SD card installed in the HMI device. The day 14 sampling endpoint data were organized for subsequent statistical analysis.

To determine whether statistically significant differences existed between the experimental and control groups, the Mann-Whitney U test was employed (Emerson, 2023). This non-parametric statistical test was chosen due to the small sample size and to account for non-normal distribution in the collected aerobic compost parameters.

Data Analysis of the Experimental and Control Groups at the Day 14 Sampling Endpoint

The data collection was then systematically prepared for statistical treatment. To address the study's objective of analyzing the significance of SOM on aerobic compost parameters, a Mann-Whitney U test was performed for each measured parameter, including pH, moisture, temperature and NPK levels. This non-parametric statistical method was specifically selected due to the non-normal distributions within the measured data sets and the relatively small sample size of 5 aerobic compost samples per group across five independent samples per group ($n = 5$).

The Mann-Whitney U test facilitated a direct comparison between the group of experimental aerobic compost samples and the group of control aerobic compost samples, thereby determining whether statistically significant differences existed between the two groups for each physico-biochemical parameter at the day 14 sampling endpoint.

This approach was critical in objectively analyzing the significance of SOM and overall physico-biochemical parameters of aerobic compost, directly contributing to the achievement of the study's aims. All statistical findings were subsequently tabulated and served as the basis for the comprehensive interpretation of results.

FINDINGS AND DISCUSSION

The discussion that follows details the analysis of the composting process with SOM. The input materials ratio was guided by the standard proportions summarized in Table 1 below.

Table 2: Standard Ratio for Aerobic Compost

Organic compost (kg)	Browns (kg)	Greens (kg)	Loam soil (kg)	Moisture level (ml)	Sugarcane (Saccharum officinarum L.) Molasses (ml)
Standard ratio	2 parts (Trautmann, Richard, & Krasny, 1996).	1 part (Trautmann, Richard, & Krasny, 1996).	1.5% (Rosen, et al., 2018).	60% (Ge et al., 2022).	1.5% (Shrirao & Hedaoo, 2020).
5	2.5	1	1.5	3000	75

Source: Hashamabad, D., Kaviani Livani, B., Mohammadi-Torkashvand, A., & Sedaghathoor, S. (2009). Cane molasses: An ammonia suppressant in composting manure and municipal wastes. Research Journal of Environmental Sciences, 3(5), 567–573. https://doi.org/10.3923/rjes.2009.567.573

The analysis highlights the physico-biochemical parameters, the results of statistical tests, and their implications for compost stability and nutrient maturity.

Summary of Data Readings

The data presented in Figures 9–14 illustrate the changes in the physicochemical and biochemical properties of the aerobic compost throughout the 14-day composting period. Daily measurements of pH, moisture content, temperature, nitrogen, phosphorus, and potassium were recorded for both the experimental group treated with sugarcane (Saccharum officinarum L.) molasses (SOM) and the untreated control group. These measurements were used to monitor and compare the changes in compost properties between the two groups over time.

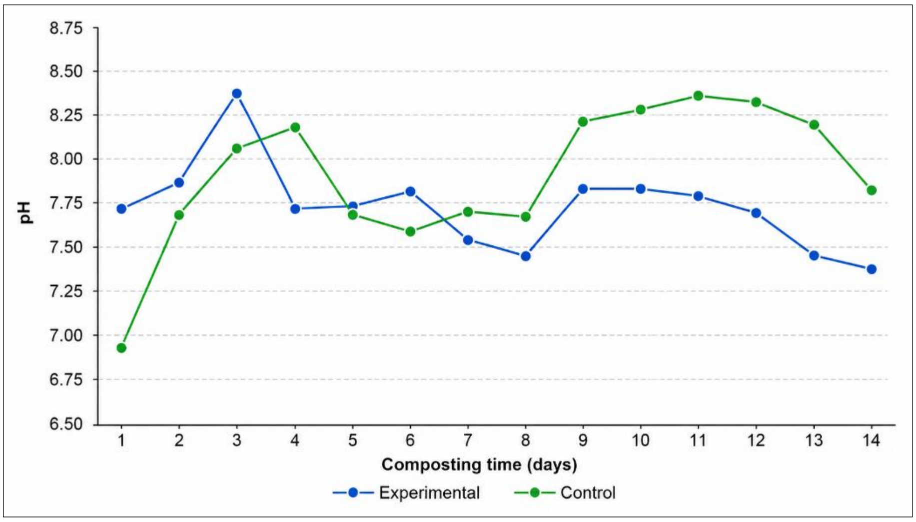

Fig. 9 Daily mean pH of the experimental and control groups during the 14-day composting period.

Source: Own processing

The pH values fluctuated throughout the 14-day composting period in both groups. The experimental group generally maintained neutral to slightly alkaline conditions, while the control group showed relatively higher pH values during the latter part of the monitoring period. By Day 14, mean pH values were 7.34 and 7.80 for the experimental and control groups, respectively.

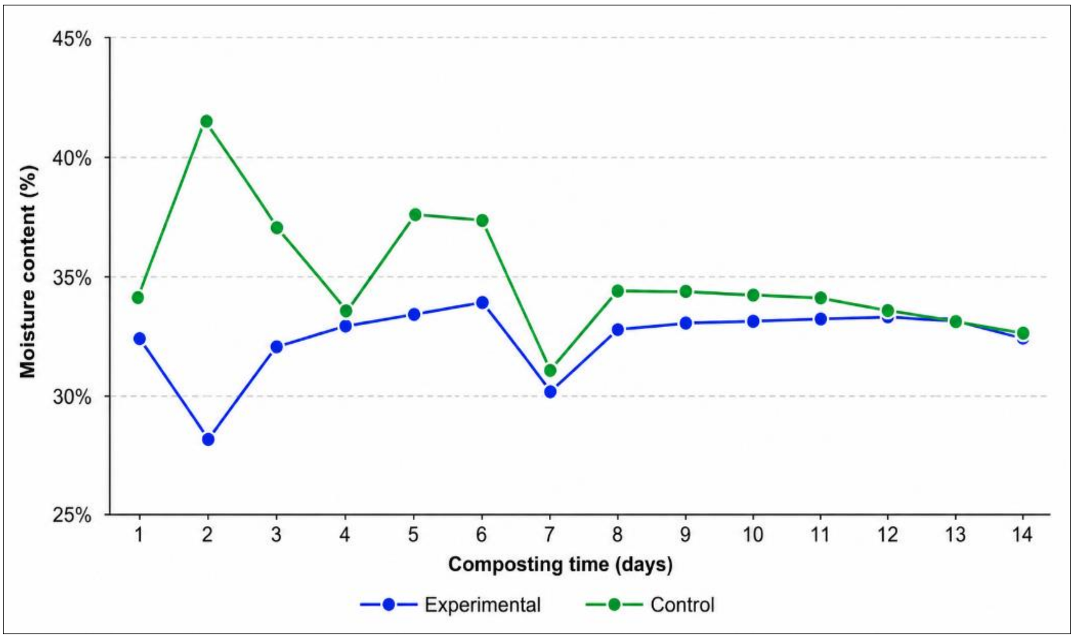

Fig. 10 Daily mean moisture content (%) of the experimental and control groups during the 14-day composting period.

Source: Own processing

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Moisture content varied during the early days of composting but became relatively similar between the two groups toward the end of the monitoring period. On Day 14, the experimental and control groups recorded mean moisture contents of 32.56% and 32.76%, respectively.

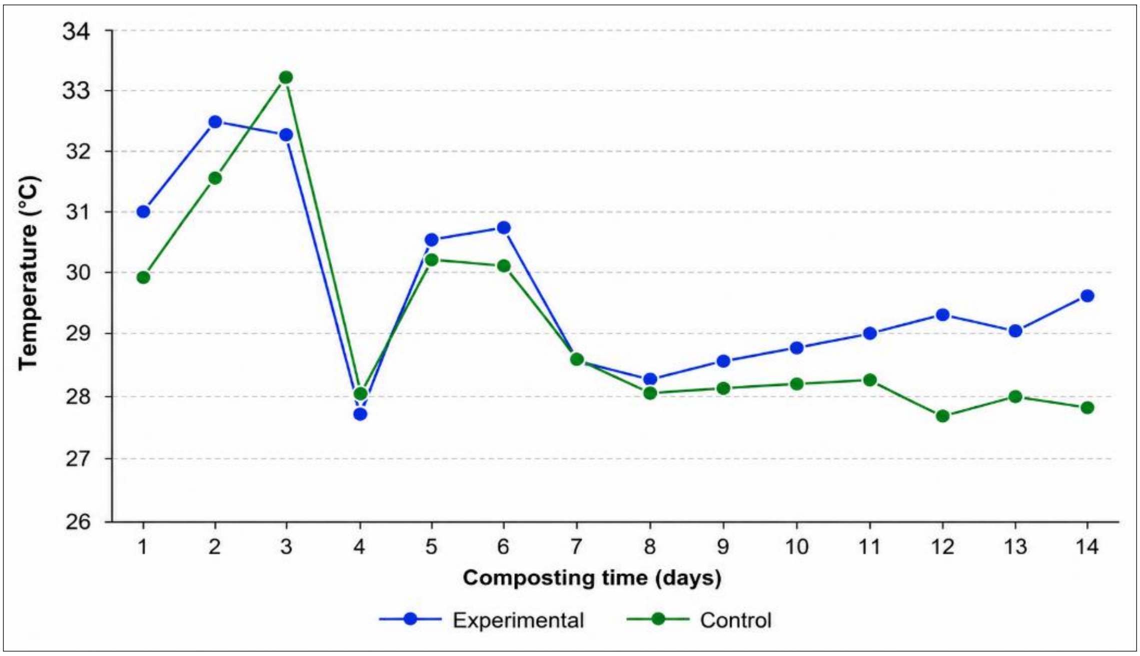

Fig. 11 Daily mean temperature (°C) of the experimental and control groups during the 14-day composting period.

Source: Own processing

Temperature fluctuated in both groups during the 14-day monitoring period. Toward the latter days, the experimental group generally maintained slightly higher temperatures than the control group, reaching mean temperatures of 29.54 °C and 27.72 °C, respectively, on Day 14.

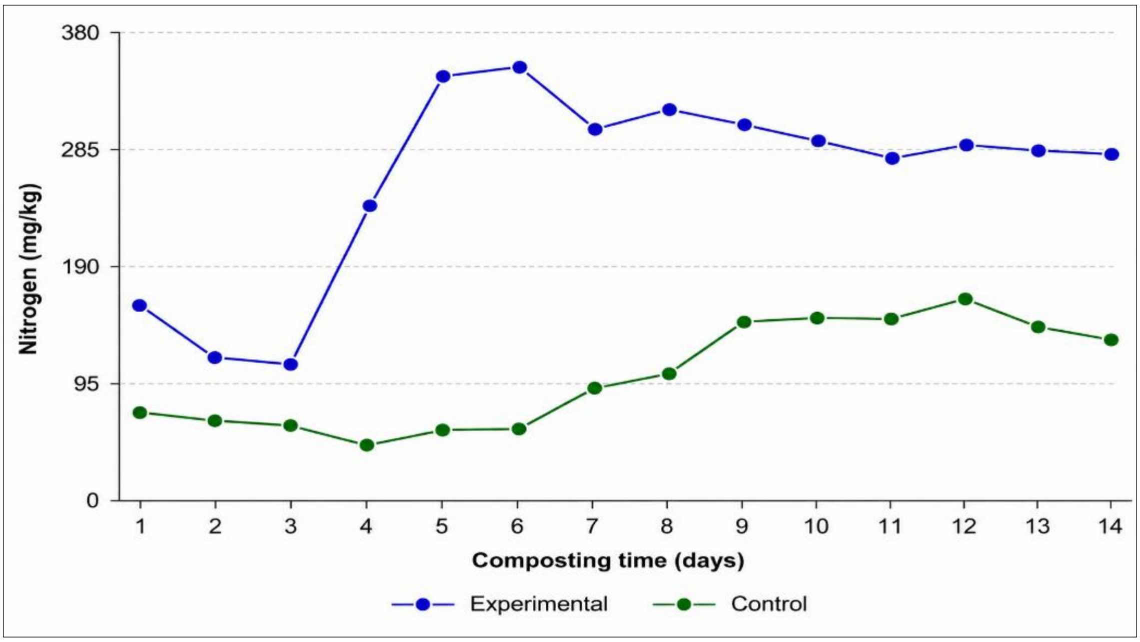

Fig. 12 Daily mean nitrogen (N) concentration of the experimental and control groups during the 14-day composting period.

Source: Own processing

Nitrogen concentrations showed a marked increase in the experimental group beginning around Day 4, while the control group remained considerably lower throughout most of the monitoring period. At Day 14, mean nitrogen concentrations were 278.40 mg/kg in the experimental group and 139.00 mg/kg in the control group.

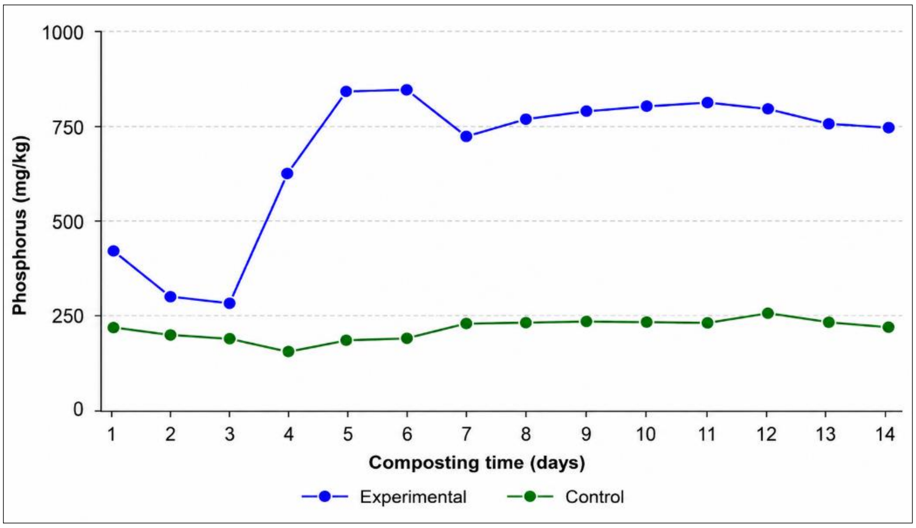

Fig. 13 Daily mean phosphorus (P) concentration of the experimental and control groups during the 14-day composting period.

Source: Own processing

Phosphorus concentration increased substantially in the experimental group during the early phase of composting and remained consistently higher than in the control group. At Day 14, the experimental and control groups recorded mean concentrations of 744.20 mg/kg and 208.00 mg/kg, respectively.

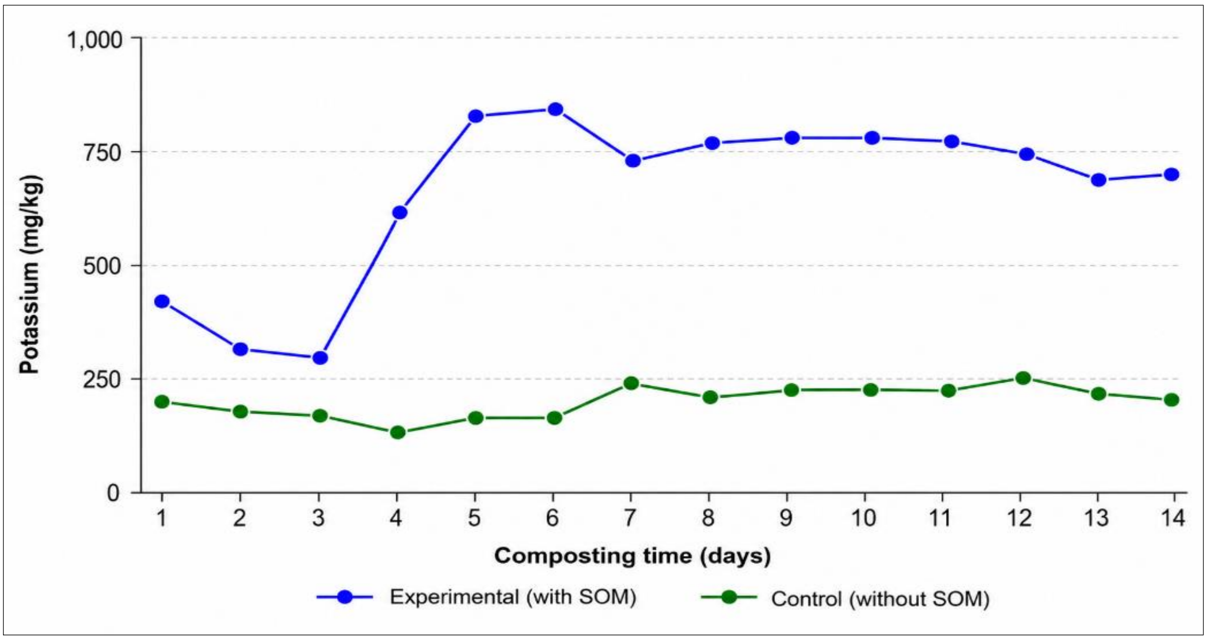

Fig. 14 Daily mean potassium (K) concentration of the experimental and control groups during the 14-day composting period.

Source: Own processing

Potassium followed a pattern similar to phosphorus, with substantially higher concentrations observed in the experimental group during most of the composting period. By Day 14, mean potassium concentrations were 705.20 mg/kg in the experimental group and 188.80 mg/kg in the control group.

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Interpretation and Implications

A Mann–Whitney U test was conducted to compare the SOM-treated experimental group and untreated control group in terms of pH, moisture content, temperature, nitrogen, phosphorus, and potassium at the Day-14 sampling endpoint.

Parameter	Experimental Group Mean ± SD	Control Group Mean ± SD	Mann–Whitney *U*	Exact *p*-value	Effect Size (rrb)	Decision
pH	7.34 ± 0.40	7.80 ± 0.16	3	.056	−0.76	Not significant
Moisture (%)	32.56 ± 1.38	32.76 ± 0.67	12	1.000	−0.04	Not significant
Temperature (°C)	29.54 ± 1.47	27.72 ± 0.60	3	.056	0.76	Not significant
Nitrogen (mg/kg)	278.40 ± 32.21	139.00 ± 8.54	0	.008	1.00	Significant
Phosphorus (mg/kg)	744.20 ± 49.28	208.00 ± 9.03	0	.008	1.00	Significant
Potassium (mg/kg)	705.20 ± 60.01	188.80 ± 8.70	0	.008	1.00	Significant

Table 3: Comparison of Physico-Biochemical Parameters Between Experimental and Control Groups at Day 14

Note. Values are based on the researchers' experimental data (n = 5 per group). The Mann–Whitney U test was used to compare the experimental and control groups at the Day-14 sampling endpoint. Rank-biserial correlation (rrb) was reported as the effect-size measure. Positive rrb values indicate higher values in the SOM-treated group, whereas negative values indicate higher values in the control group. Statistical significance was evaluated at $\alpha = .05$.

As shown in Table 3, the Mann–Whitney U test indicated that the influence of sugarcane (*Saccharum officinarum* L.) molasses (SOM) varied across the measured physico-biochemical parameters at the Day-14 sampling endpoint. No statistically significant differences were observed between the experimental and control groups in pH ($U = 3$, $p = .056$), moisture content ($U = 12$, $p = 1.000$), and temperature ($U = 3$, $p = .056$). In contrast, significant differences were observed in nitrogen, phosphorus, and potassium (all $U = 0$, $p = .008$).

The effect-size analysis indicated large observed group differences for pH ($r$rb = −0.76) and temperature ($r$rb = 0.76), although these differences did not reach statistical significance. The effect size for moisture content was negligible ($r$rb = −0.04). Nitrogen, phosphorus, and potassium each showed complete separation between the observed values of the two groups ($r$rb = 1.00), with higher values in the SOM-treated group. Given the small sample size ($n = 5$ per group), this effect size should be interpreted cautiously.

From a practical perspective, the findings suggest that SOM applied at 15 mL/kg may be considered for further evaluation as an organic amendment during the early stage of aerobic composting. The higher sensor-derived N, P, and K values observed in the SOM-treated group indicate its potential for influencing nutrient-related compost parameters. However, the present study did not determine the optimal SOM application rate, economic feasibility, or effectiveness across different compost feedstocks and larger-scale composting systems. Therefore, practical application beyond the conditions tested in this study should be approached cautiously.

Limitations of the Study

The study was limited to a 14-day aerobic composting period and five independent samples per group (n = 5), which may limit the assessment of complete compost maturation and the generalizability of the findings. In addition, the sensor measurements were not independently validated using standard laboratory methods. As the sensor-derived NPK values are estimated from electrical conductivity using manufacturer-defined conversion factors, these values should be interpreted as sensor-derived estimates rather than direct laboratory measurements. Microbial and biological parameters were not measured; therefore, the mechanisms underlying the observed nutrient differences could not be directly evaluated.

CONCLUSION

The study demonstrated that the influence of sugarcane (Saccharum officinarum L.) molasses (SOM) on aerobic compost varied across the measured physico-biochemical parameters. At the Day-14 sampling endpoint, no statistically significant differences were observed between the SOM-treated and control groups in pH, moisture content, and temperature. In contrast, nitrogen, phosphorus, and potassium were significantly higher in the SOM-treated group, with effect-size analysis indicating complete separation of the observed N, P, and K values between the two groups. Overall, SOM treatment primarily influenced the measured nutrient parameters under the conditions of this study. Given the small sample size and sensor-based measurements, the findings should be interpreted within the methodological limitations of the study.

RECOMMENDATIONS

Based on the findings of this study, several recommendations were proposed to enhance composting practices and guide future research:

1. conduct further studies on long-term effects to determine the quality and maturity indicators like humus, C: N ratio, and microbial activity;

2. incorporate microbial and biological tests to support the hypothesis that SOM stimulates microbial-driven nutrient transformation;

3. extend the composting and temperature-monitoring period to determine whether the compost reaches and maintains the thermophilic phase required for effective compost stabilization and pathogen reduction;

4. compare sensor measurements with standard laboratory methods to further establish measurement accuracy; and

5. future studies should include more independent experimental replicates to improve statistical robustness.

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Declarations

Funding

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Ethics Declaration

Not applicable.

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