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# Comparative Effects of Cellulolytic Bacteria on Compost Quality and Production Cost

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## ABSTRACT

**Background:** Bacteria play a crucial role in converting agricultural waste into compost. Rice straw and corn waste show promise as organic fertilizers. This study aims to compare the effectiveness of different decomposer bacteria in the composting process of straw and corn waste.

**Methods:** Conducted in Bowan, Klaten, from February to April 2024, the study utilized a factorial completely randomized design with eight treatments and four replications. The first factor examined was the type of bacteria, which included: No bacteria; a combination of cellulolytic, rhizomonas, subtilisand cattle rumen bacteria; a mix of cellulolytic, rhizomonasand subtilis and only cellulolytic bacteria. The second factor was the type of composting media, specifically straw and corn waste. Observations focused on compost pH, weight shrinkage, water holding capacityand water content. An economic analysis was conducted to compare the cost of producing compost with the best decomposer bacteria and the cost of using commercial compost.

**Result:** Results indicated that straw combined with cellulolytic bacteria produced compost that best met the quality standards outlined in SNI 19-7030-2004. The type of compost material influenced compost pH and water content, while the type of bacteria affected all parameters, including pH, weight shrinkage, water holding capacityand water content. Additionally, the interaction between compost materials and bacteria types impacted water holding capacity and water content. The cost of derived straw waste compost input is IDR52,709,000 per hectare for two planting seasons, which is lower than the commercial compost which amounts to IDR72,000,000, making self-produced compost a more economical choice.


**Key words:** Cellulolytic bacteria, Compost, Corn waste, Decomposers, Straw waste.

## INTRODUCTION

Organic farming is a cultivation method that relies on natural ingredients and excludes synthetic chemicals (Li *et al.*, 2024). One effective way to practice organic farming is by using organic fertilizers. Transforming organic waste into compost can enhance plant growth (Li *et al.*, 2024; Murumkar, 2021; Okoli *et al.*, 2024). Composting is a traditional method for reducing organic waste and incorporating compost into soil enhances aggregate formation while improving permeability and porosity (García-Rández *et al.*, 2025; Kumar *et al.*, 2024). During decomposition, microbes convert organic materials into energy and simpler inorganic elements such as carbon, nitrogen, phosphorus, sulfurand potassium through mineralization (Liu *et al.*, 2024). The rate of decomposition is strongly influenced by the abundance and diversity of decomposers microorganisms, which can accelerate organic matter mineralization and improve compost quality (Zhang *et al.*, 2024; Obour *et al.*, 2025; Gogoi *et al.*, 2026). Using agricultural waste, particularly rice straw, as organic fertilizer is an effective strategy to increase soil organic matter and meet plant nutrient needs (Ninkuu *et al.*, 2025). However, its high carbon-to-nitrogen (C/N) ratio limits its direct application as a soil amendment (Lubis, 2020; Noor *et al.*, 2024). Intensive corn cultivation also generates substantial biomass including stalks, leaves, cobsand silk, which accounts for more than 70% of total plant biomass yet remains largely underutilized (Zhang *et al.*, 2024).

The bacterium Bacillus, is known for its ability to produce crucial enzymes like amylase, cellulaseand protease, which facilitate the breakdown of organic matter (Dumitru *et al.*, 2022; Gudina and Teixeira, 2022; Barros *et al.,* 2013). Similarly, Rhizomonas is a powerful bacterium capable of transforming various raw materials into valuable

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products (Agustin *et al.*, 2025). Cow rumen contents, which are often discarded, hold significant potential as a source of beneficial microorganisms (Fernandes *et al.*, 2019). These contents can be harnessed to cultivate bacteria or microbes that serve as starters in composting or organic fertilizer production, while also increasing the population of decomposing microorganisms in the soil (Putri *et al.*, 2024).

SNI 19-7030-2004 is the Indonesian National Standard that establishes quality specifications for compost derived from domestic organic waste, serving as the primary reference for ensuring compost maturity and safety (Badan Standardisasi Nasional, 2004). The standard sets key parameters including a pH range of 6.8-7.49, a C/N ratio between 10 and 20, a maximum water content of 50%and minimum nutrient contents of 0.4% N, 0.1% $P_2O_5$ and 0.2% $K_2O$ (Badan Standardisasi Nasional, 2004). This study aims to explore the effects of different types of decomposer bacteria in composting media on compost outcomes, using cellulolytic bacteria as a benchmark for comparison.

## MATERIALS AND METHODS

This research was conducted in Bowan Village, Delanggu, Klaten, at an altitude of 130 meters, from February to April 2024, using materials straw, corn waste, dolomite, bran, molasses, cellulolytic bacteria, rhizomonas subtilis and cow rumen. Tools included plastic sacks, trowels, choppers, treatment nameplates, scales, scissors, labels, ovens, raffia, tarpaulins, MMT, pipettes, beakers, gallons, stationery, buckets, gloves, distilled water, pH meters and plastic.

### Research design

This study utilized a qualitative and quantitative descriptive approach, employing a factorial completely randomized design with eight treatments and four replications. The first factor examined was the type of decomposer bacteria, which included: No bacteria (B0), cellulolytic+rhizomonas+ subtilis+cattle rumen bacteria (B1), cellulolytic+rhizomonas +subtilis (B2) and cellulolytic bacteria alone (B3). The second factor considered the type of waste, specifically rice straw (L1) and corn waste (L2).

### Research procedures

The procedure involved mixing 0.7 kg of straw or corn waste, 0.1 kg of bran, 0.1 kg of dolomiteand 100 ml of molasses in each sack. Each sack contained 0.25 cc of bacteria. The groups of bacteria were as follows: $B_1$ (1.25 cc of cellulolytic bacteria+1.25 cc of rhizomonas bacteria), $B_2$ (1.25 cc of cellulolytic bacteria + 1.25 cc of BRS bacteria), $B_3$ (1.25 cc of rhizomonas bacteria + 1.25 cc of subtilis bacteria)and $B_4$ (2.5 cc of subtilis bacteria). Compost material was turned and mixed with molasses water every four days for observation.

### Measurement

Parameters observed included compost pH, weight loss, water holding capacityand water content.

### Statistical analysis

Data were analyzed using variance analysis. If significant differences between treatments were found, further examination was conducted using the Duncan multiple range test (DMRT) at a <5% significance level.

### Economic analysis

Economic analysis was conducted on the production cost of compost using the best type of compost material and decomposer bacteria. The cost was then compared to the input cost when using commercial compost.

## RESULTS AND DISCUSSION

Variance analysis (Table 1) shows that compost material significantly affected compost water content and pH but not weight loss or water holding capacity. Conversely, the type of bacteria used significantly influenced weight loss, water holding capacity, water content and pH. Furthermore, the interaction between compost material and bacteria type notably impacted water holding capacity and water content, though it did not significantly affect pH or weight loss.

### Effects on compost pH

Compost materials significantly affected pH due to differences in lignin, cellulose and acidic compounds, which influenced decomposition and organic acid formation (Du *et al.*, 2025; Anayet *et al.*, 2024). Differences in compost quality among organic residues are associated with

**Table 1:** Variation of observation parameters.

| Observation parameters | Compost material (L) | Types of decomposer bacteria (B) | L×B interaction | Mark | |
|---|---|---|---|---|---|
| | | | | Highest | Lowest |
| Compost pH | * | * | ns | 6.60 (L1B3) | 6.05 (L1B1) |
| Compost weight loss (g) | ns | ** | ns | 0.42 (L1B3) | 0.29 (L1B0) |
| Capacity water retention (%) | ns | ** | ** | 33.91 (L1B3) | 30.47 (L1B0) |
| Compost water content (%) | ** | ** | ** | 59.85 (L1B3) | 50.65 (L1B0) |

ns= Non-significant; * = Significant and ** = Very significant.

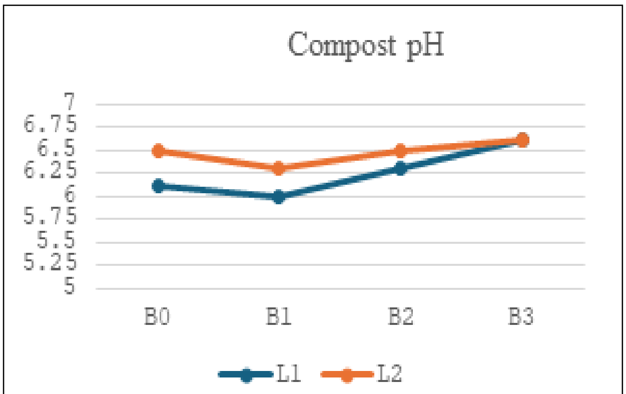
variations in their chemical composition and decomposition characteristics (Kapila *et al.*, 2024). As presented in Table 2, corn waste showed a higher pH (6.47) than straw (6.28). Decomposer bacteria also influenced pH through enzymatic activity producing acidic or basic compounds (Vaz-Moreira *et al.*, 2025). The highest pH (6.58) was observed in cellulolytic bacteria alone treatment, higher than no bacteria (6.35), cellulolytic+rhizomonas+subtilis+cow Rumen Bacteria (6.15) and cellulolytic+rhizomonas+subtilis (6.40). Compost pH was influenced by feedstock and microbial activity. Corn waste had higher pH than straw due to lower recalcitrance (Du *et al.*, 2025), while decomposer bacteria altered pH through enzymatic processes (Anayet *et al.*, 2024; Vaz-Moreira *et al.*, 2025). The highest pH (6.58) in cellulolytic treatment was linked to nitrogen mineralization, whereas lower pH (6.35-6.40) in mixed treatments reflected organic acid accumulation.

The interaction between compost materials and bacteria did not significantly affect pH. The highest pH (6.60) was observed in straw with cellulolytic bacteria. Although this is below the SNI standard of 6.8-7.5 (Badan Standardisasi Nasional, 2004), it still falls within the typical maturity range (6-8), indicating the compost is mature and safe for use (Badan Standardisasi Nasional, 2004; Kurniawan and Gusmawartati, 2021; Sokaè Cvetnić *et al.*, 2024). Compost pH generally approaches neutral values as composting progresses and maturity increases (Lalremruati and Devi, 2023).

Table 2 and Fig 1 showed pH trends in straw and corn waste compost treated with different bacteria. Straw pH increased from no bacteria to B3 (pH 6.17,6.05, 6.29, 6.60). Corn waste reached its highest pH in B3 (pH 6.56) and its lowest in B1 (pH 6.28). Straw had lower pH than corn waste in no-bacteria to B2 treatments but matched or slightly exceeded it in B3, indicating greater responsiveness to bacterial treatment. These trends reflected differences in decomposition dynamics. The pH rise in B3 suggested intensified microbial activity and production of alkaline compounds such as ammonia, indicating more favorable conditions for compost maturity (Chang *et al.*, 2021).

### Effects on compost weight loss

Compost material type did not significantly affect weight loss because the organic content of the materials was




B0= No bacteria; B1= Cellulolytic+rhizomonas+subtilis +Cow Rumen Bacteria; B2= Cellulolytic+ rhizomonas+ subtilis; B3= Cellulolytic; L1= Rice straw; L2= Corn plant waste.

**Fig 1:** Graph of compost pH analysis.

**Table 2:** Effect of compost materials, types of decomposer bacteria and their interactions on compost pH, compost weight loss, water storage capacity and moisture content of compost.

| Treatment | pH compost | Compost weight loss (kg) | Capacity storing water (%) | Compost water content (%) |
|---|---|---|---|---|
| **Compost materials** | | | | |
| L1 | 6.28a | 0.36 | 31.38 | 54.52b |
| L2 | 6.47b | 0.34 | 31.32 | 52.93a |
| **Types of bacteria decomposers** | | | | |
| B0 | 6.35a | 0.30a | 30.97a | 51.20a |
| B1 | 6.15a | 0.33a | 31.48a | 52.78a |
| B2 | 6.40a | 0.38b | 30.55a | 53.15a |
| B3 | 6.58b | 0.39c | 32.40b | 57.78b |
| **Interaction of compost materials with decomposer bacteria** | | | | |
| L1B0 | 6.17 | 0.29 | 30.69a | 50.65a |
| L1B1 | 6.05 | 0.35 | 30.47a | 54.78a |
| L1B2 | 6.29 | 0.39 | 30.47a | 52.80a |
| L1B3 | 6.60 | 0.42 | 33.91b | 59.85b |
| L2B0 | 6.53 | 0.31 | 31.25a | 51.75a |
| L2B1 | 6.28 | 0.31 | 32.50a | 50.78a |
| L2B2 | 6.51 | 0.37 | 30.64a | 53.50a |
| L2B3 | 6.56 | 0.36 | 30.89a | 55.70a |

The numbers that follow notation the same letter shows no different significantly at the 5% level.

relatively similar, resulting in comparable decomposition rates and mass reduction. In contrast, the type of activator bacteria significantly influenced compost weight loss due to differences in their decomposition efficiency. Bacteria with high enzymatic activity accelerated organic matter breakdown, increasing mass loss through water evaporation and gas release (Anayet *et al.*, 2024). Table 2 shows that the highest weight loss (0.39 kg) occurred with cellulolytic bacteria, compared to 0.30 kg without decomposers, 0.33 kg with a mixed bacterial treatmentand 0.38 kg with cellulolytic, *Rhizomonas* and *Bacillus subtilis*.

The interaction between compost materials and decomposer bacteria did not significantly affect weight loss, indicating that no synergistic effects occurred between treatments. The highest overall weight loss (0.42 kg) was observed in straw compost treated with cellulolytic bacteria. Weight reduction mainly resulted from microbial activity that enhanced water evaporation and material shrinkage, leading to a final mass substantially lower than the initial weight (Guntoro, 2012; Gudiña and Teixeira, 2022).

Table 2 and Fig 2 showed that straw compost exhibited a greater increase in weight loss, from 0.29 kg without bacteria to 0.42 kg with cellulolytic treatment, while corn waste compost increased more gradually from 0.31 kg without bacteria to 0.36 kg with cellulolytic + rhizomonas + subtilis. The higher responsiveness of straw, particularly under cellulolytic treatment, indicated faster decomposition, greater mass reduction and a composting process closer to optimal maturity.

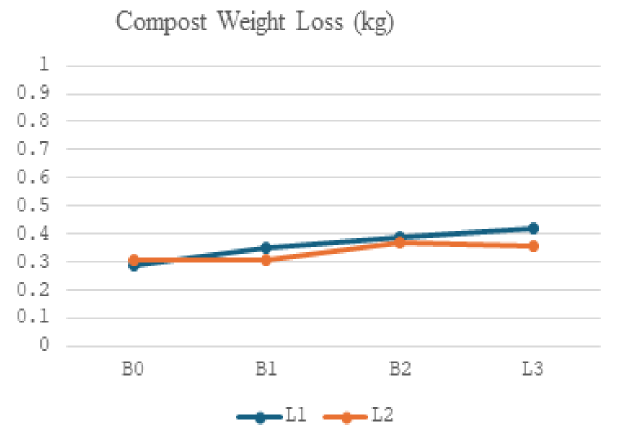
**Effects on water holding capacity**

Composting materials did not affect water holding capacity because their physical properties and textures were relatively similar, producing final compost with comparable structure and therefore similar water retention (Guo *et al.*, 2018). In contrast, activator bacteria significantly increased water holding capacity. Different bacteria decomposed organic matter at varying efficiencies, increasing organic matter content and improving pore structure. Based on Table 2, the highest value, 32.40% in the cellulolytic treatment, was significantly higher than no activator (30.97%), cellulolytic + rhizomonas + subtilis + cattle rumen bacteria (31.48%) and cellulolytic+rhizomonas + subtilis (30.55%).

The interaction between compost materials and activator bacteria also had a highly significant effect. This resulted from synergy between material characteristics and bacterial decomposition ability, producing more stable and porous compost (Almulla *et al.*, 2024). As showed on Table 2, the highest value, 33.91%, occurred in straw with cellulolytic bacteria, indicating that cellulose-rich straw responded strongly when paired with cellulolytic microbes capable of breaking down coarse fibres and improving pore structure. Water holding capacity is essential for maintaining soil moisture. Compost treated with effective bacteria demonstrates better moisture retention and nutrient availability, supporting plant growth (Li *et al.*, 2024).

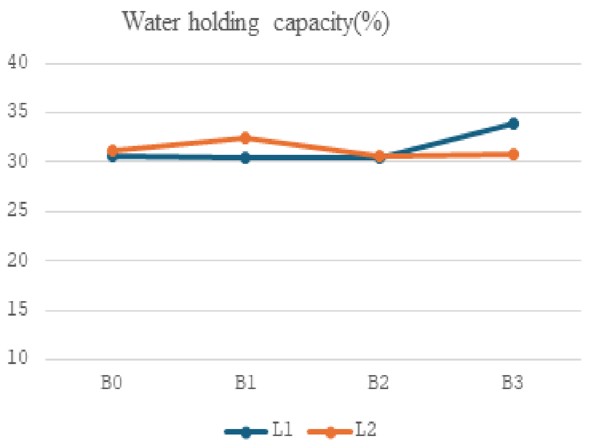
Decomposer bacteria can also increase soil porosity, organic carbon, microbial activity and available phosphorus, improving soil quality (Guntoro, 2012; Sari and Nurrasyid, 2024; Xing *et al.*, 2024).

Table 2 and Fig 3 showed water holding capacity patterns for straw and corn waste compost under different bacterial treatments. Straw showed values of 30.69 (B0/no bacteria), 30.47 (B1), 30.47 (B2) and 33.91 (B3). Corn waste displayed a different pattern, with 31.25 (B0/no bacteria), 32.50 (B1), 30.64 (B2) and 30.89 (B3). Overall, straw showed a strong increase under cellulolytic bacteria, indicating high effectiveness in improving its compost structure. Corn waste showed less consistent responses, with a peak at B1, suggesting straw was more responsive to microbial activation in enhancing water holding capacity (Almulla *et al.*, 2024).




B0 = No bacteria; B1 = Cellulolytic+rhizomonas+subtilis+Cow Rumen Bacteria; B2 = Cellulolytic+rhizomonas+subtilis; B3 = Cellulolytic; L1 = Rice straw; L2 = Corn plant waste.

**Fig 2:** Graph of compost weight loss analysis.




B0 = No bacteria; B1 = Cellulolytic+rhizomonas+subtilis+Cow Rumen Bacteria; B2 = Cellulolytic+rhizomonas+subtilis; B3 = Cellulolytic; L1 = Rice straw; L2 = Corn plant waste.

**Fig 3:** Graph of water holding capacity analysis.

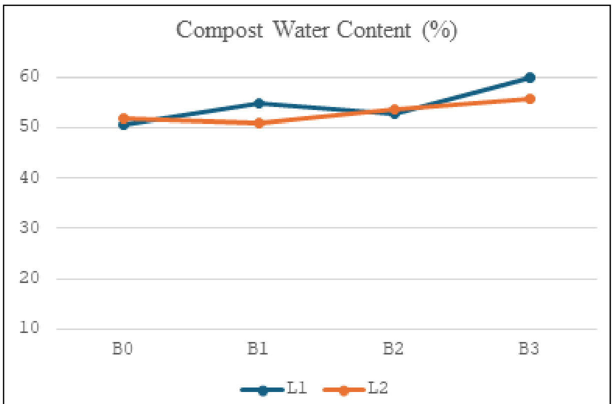
### Effects on compost water content

The characteristics of the treatment materials used in composting significantly affected the depreciation parameters related to water content. These variations stemmed from the physical and chemical properties of each compost ingredient, such as initial water content, fiber structure and levels of decomposability (Gudiña and Teixeira, 2022; Mekonnen, 2024). Materials that decompose more easily tended to experience faster water evaporation and organic material degradation, leading to a more significant reduction in water content during the composting process. Notably, as shown in Table 2, the highest straw content, at 54.52%, had a substantial impact on the corn plant waste, which had a straw content of 52.93%.

The type of bacterial activator used significantly affected the reduction of compost water content, as different bacteria vary in their ability to decompose organic matter efficiently. More active and enzymatic bacteria enhance microbial activity, generated heatand accelerate decomposition, leading to increased water evaporation (Lu *et al.*, 2005). Compost treated with a cellulolytic bio-activator had a water content of 57.78%, compared to 51.20% without a bioactivator. Combinations of cellulolytic bacteria with *Rhizomonas* and *Bacillus subtilis* resulted in water contents ranging from 52.78% to 53.15%.

Interactions between compost materials and bacterial activators further influenced water content through differences in enzymatic activity, microbial intensity and water absorption.The highest water content (59.85%) occurred in straw compost treated with cellulolytic bacteria, as fiber-rich materials combined with effective cellulose-degrading microbes accelerated decomposition, increased temperature and enhanced water evaporation (Mekonnen, 2024; Angeles-de Paz *et al.*, 2024; Sokaè Cvetnić *et al.*, 2024).

Table 2 and Fig 4 showed that bioactivator treatments generally increased water content in both straw and corn waste composts, though with different patterns. As shown in Table 2, straw compost exhibited a sharp increase from 50.65% (B0) to 59.85% (B3), while corn waste compost increased more gradually from 50.78% (B1) to 55.70% (B3). The increase in water content in the bioactivator treatment can be explained by higher microbial activity during the composting process. Microorganisms require water as a medium to dissolve nutrients and support metabolic processes; therefore, the presence of bioactivators can enhance decomposition activity and influence the dynamics of moisture content in the compost (Yang *et al.*, 2023). Overall, straw compost was more responsive to bioactivator treatment. Adequate water content supports microbial activity, but excessive moisture can inhibit composting, making optimization essential for efficient decomposition and high-quality compost production (Hefner *et al.*, 2024; Obour *et al.*, 2025).




B0 = No bacteria; B1 = Cellulolytic+rhizomonas+subtilis+Cow Rumen Bacteria; B2 = Cellulolytic+rhizomonas+subtilis; B3 = Cellulolytic; L1 = Rice straw; L2 = Corn plant waste.

**Fig 4:** Graph analysis compost water content.

### Cost analysis of compost production in small scale farmers

Accumulated rice straw waste can promote pests and diseases in subsequent crops while burning it causes environmental pollution. However, this low-value agricultural waste can be converted into standardized compost that met SNI requirements with the help of cellulolytic bio-activators. Composting offers farmers an opportunity to reduce straw-burning pollution and lessen dependence on chemical fertilizers, supporting sustainable agriculture. Utilization of rice straw as compost not only reduces waste accumulation but also contributes to soil fertility improvement and sustainable crop production (Goyal *et al.*, 2026). Compost produced from rice straw

**Table 3:** Costs of compost production from straw waste with cellulolytic bio activator.

| Cost components | Total cost (IDR) |
|---|---|
| **Depreciation** | |
| a. Compost mixer | 60,000 |
| b. Hand sprayer | 40,000 |
| c. Compost shredder | 60,000 |
| d. Shovel | 32,000 |
| e. Tarpaulin | 30,500 |
| f. Hoe | 8,000 |
| g. Bucket | 5,500 |
| h. Scales | 13,000 |
| **Inputs** | |
| a. Bran | 11,400,000 |
| b. Dolomite | 4,275,000 |
| c. Molasses | 28,500,000 |
| d. Cellulotic bio activator | 7,125,000 |
| e. Plastic sacks | 1,140,000 |
| f. Raffia | 20,000 |
| Total cost | 52,709,000 |
| Cost per kg | 3,189 |

Source: Primary data analysis (2025).

**Table 4:** Costs of compost inputs per hectare for two planting seasons.

| Information | Compost from straw waste | Commercial compost |
|---|---|---|
| Cost per kg of compost (IDR) | 3,189 | 4,500 |
| Quantity of compost (ton) | 16,5* | 16** |
| Total cost per 1 hectare (IDR) | 52,709,000 | 72,000,000 |

Source: Primary data analysis (2025); * = Compost self-production by farmers; ** = Compost requirement per hectare.

and cellulolytic bacteria meets SNI 19-7030-2004 standards and could be made at the household level. At larger scales, such as farmer groups, production costs per unit decreased due to economies of scale (Yang *et al.*, 2024).

Establishing a compost manufacturing requires relatively low investment and financing. To meet fertilizer needs at either the household or group farming level, an economic analysis was conducted based on the following assumptions: (1) the straw is not considered as a cost since it is sourced from the farmer's own land; (2) the composting land is owned by the farmer, eliminating land rental costs; (3) labor is provided by family members and (4) production occurs twice a year (Gastaldi *et al.*, 2024). Table 3 shows the cost of compost production. Waste straw from one hectare of rice fields could be processed into 16.5 tons of compost per year. This production quantity could meet the average compost needs for one hectare of rice fields for two planting seasons, which is approximately 16 tons of compost. The calculation indicated that the total cost of self-produced compost was IDR52,709,000 with a production volume of 16.5 tons.

The market price of commercial compost is approximately IDR4,500 per kg. The total input cost when using commercial compost is IDR72,000,000. Table 4 shows that the cost of commercial compost is higher than using self-produced compost from straw waste and cellulolytic bio activator, which amounted to IDR52,709,000. Consequently, compost production by small scale farmers using straw waste has proven to be more economical for farmers. These findings suggest that processing straw waste enhance farmer independence in supplying organic fertilizer, thereby reducing reliance on chemical fertilizers. Additionally, utilizing agricultural waste supports the transition toward sustainable green agriculture. (Xu *et al.*, 2024).

## CONCLUSION

The materials used in composting influence both the pH and moisture content of the compost. The type of bacteria involved affects all parameters, including compost pH, weight shrinkage, water holding capacity and moisture content. The interaction between compost materials and bacterial type plays a crucial role in determining water holding capacity and moisture content. By using a *cellulolytic* bacteria bio activator to make compost from straw, the cost of compost input was reduced to IDR52,709,000 per hectare for two planting seasons, which is lower than the commercial compost which amounted to IDR72,000,000, making self-produced compost production a more economical choice.

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### Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

### Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

### Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

## REFERENCES

Agustin, D.R., Suprapti, E. and Wiyono. (2025). The influence of types of bacteria and types of compost materials on composting results. *Journal of Rural and Urban Community Studies*. **3:** 11-20.

Almulla, L., Thomas, B.M., Jallow, M.F.A., Al-Roumi, A., Devi, Y. and Jacob, J. (2024). Rotary drum composting of organic school wastes and compost valorization. *Sustainability (Switzerland*). **16:** 6. https://doi.org/10.3390/su16062428.

Anayet, A.H., Hamzah, M.M.H. and Najib, M.Z.M. (2024). Optimizing food waste decomposition through pH, moisture content and temperature control: A comprehensive study. *Civil and Sustainable Urban Engineering*. **4:** 42-54. https://doi.org/10.53623/csue.v4i1.411.

Angeles-de Paz, G., León-Morcillo, R., Štovícek, A., Sagova-Mareckova, M., Robledo-Mahón, T., Calvo, C. and Aranda, E. (2024). Dynamic population changes during a bioaugmented sewage sludge composting process: Improvement of pharmaceutical active compounds degradation and conversion into an organic soil amendment. *Journal of Environmental Chemical Engineering*. **12:** 3. https://doi.org/10.1016/j.jece.2024.112937.

Badan Standardisasi Nasional. (2004). SNI 19-7030-2004: Spesifikasi kompos dari sampah organik domestik. Jakarta: BSN.

Barros, F.F.C., Simiqueli, A.P.R. and Andrade, C.J. (2013). Production of enzymes by Bacillus species and their application in the food industry. *Journal of Food Processing and Technology*. **4:** 1-5.

Chang, H.C., Zhu, X.H., Wu, J., Guo, D.Y., Zhang, L.H. and Feng, Y. (2021). Dynamics of microbial diversity during the composting of agricultural straw. *Journal of Integrative Agriculture.* **20:** 1121-1136. https://doi.org/10.1016/S2095-3119(20)63341-X.

Du, L., Bauke, S.L., Mörchen, R., Schmittmann, O. and Amelung, W. (2025). Fungal necromass is vital for the storage of subsoil C after deep injection of compost. *Soil and Tillage Research*. **245.** https://doi.org/10.1016/j.still.2024.106325.

Dumitru, M., Lefter, N., Idriceanu, L. and Habeanu, M. (2022). Evaluation of enzymatic potentialities of *Bacillus subtilis* using as substrate different animal raw materials feed. *Scientific Papers Animal Science and Biotechnologies*. **55:** 118-125.

Fernandes, T., Carvalho, B.F., Mantovani, H.C., Schwan, R.F. and Ávila, C.L.S. (2019). Identification and characterization of yeasts from bovine rumen for potential use as probiotics. *Journal of Applied Microbiology*. **127:** 845-855.

García-Rández, A., Orden, L., Marks, E.A.N. Andreu-Rodríguez, J., Franco-Luesma, S., Martínez-Sabater, E., Antonio Saéz-Tovar, J. *et al.* (2025). Monitoring of greenhouse gas emissions and compost quality during olive mill waste co-composting at industrial scale: The effect of N and C sources. *Waste Management*. **193:** 33-43. https://doi.org/10.1016/j.wasman.2024.11.039.

Gastaldi, E., Buendia, F., Greuet, P., Benbrahim Bouchou, Z., Benihya, A., Cesar, G. and Domenek, S. (2024). Degradation and environmental assessment of compostable packaging mixed with biowaste in full-scale industrial composting conditions. *Bioresource Technology*. **400**. https://doi.org/10.1016/j.biortech.2024.130670.

Gogoi, D., Nath, D.J. and Borah, D.K. (2026). Augmentation of the fertilizer values of compost through beneficial microbes amid rock phosphate amendments during curing stage. *Indian Journal of Agricultural Research*. **47(4):** 304-310.

Goyal Sneh, Dalel, S., Sunita, S. and Kapoor, K.K. (2026). Effect of rice straw compost on soil microbiological properties and yield of rice. *Indian Journal of Agricultural Research*. **43(4):** 263-268.

Gudiña, E.J. and Teixeira, J.A. (2022). *Bacillus licheniformis:* The unexplored alternative for the anaerobic production of lipopeptide biosurfactants? *Biotechnology Advances.* **60**. https://doi.org/10.1016/j.biotechadv.2022.108013.

Guntoro, S. (2012). Instructions Practical Mixing Animal Feed from Plantation Waste. AgroMedia.

Guo, T., Zhang, Q., Ai, C., Liang, G., He, P. and Zhou, W. (2018). Nitrogen enrichment regulates straw decomposition and its associated microbial community in a double-rice cropping system. *Scientific Reports*. **8:** 1-12. https://doi.org/10.1038/s41598-018-20293-5.

Hefner, M., Amery, F., Denaeghel, H., Loades, K. and Kristensen, H.L. (2024). Composts of diverse green wastes improve the biological soil quality, but do not alleviate drought impact on lettuce (*Lactuca sativa* L.) growth. *Soil Use and Management*. **40:** 1-14. https://doi.org/10.1111/sum.13016.

Jihad, A. and Arif, C. (2024). Design and evaluation of reusable materials-based aerobic composter for domestic organic waste management. *IOP Conference Series: Earth and Environmental Science.* **1416:** 012025. https://doi.org/10.1088/1755-1315/1416/1/012025.

Kapila, R., Verma, G., Sen, A. and Nigam, A. (2024). Compositional Evaluation of vermicompost prepared from different types of organic wastes using *Eisenia fetida* and studying its effect on crop growth. *Indian Journal of Agricultural Research*. **58(3):** 468-473. doi: 10.18805/IJARe.A-5708.

Kumar, K.G., Husain, R., Mishra, A., Vikram, N., Dwivedi, D.K., Pandey, S. and Singh, A. (2024). Rice crop residue management by the microbial consortium for rapid decomposition of straw. *3 Biotech*. **14:** 136. https://doi.org/10.1007/s13205-024-03982-z.

Kurniawan, C.A. and Gusmawartati. (2021). Isolate test bacteria cellulolytic as decomposers in the decomposition of empty bunches coconut palm oil. *Journal Agrotek*. **5:** 55-62.

Lalremruati, M. and Devi, A.S. (2023). Duration of composting and changes in temperature, pH and C/N ratio during composting: A review. *Agricultural Reviews*. **44(3):** 350-356. doi: 10.18805/ag.R-2197.

Li, H., Lehmann, A., Rongstock, R., Xu, Y., Kunze, E., Meidl, P. and Rillig, M.C. (2024). Diversity of organic amendments increases soil functions and plant growth. *Plants People Planet.* **7(1):** 80-86. https://doi.org/10.1002/ppp3.10588.

Liu, Q., Wu, C., Wei, L. *et al.* (2024). Microbial mechanisms of organic matter mineralization induced by straw in biochar-amended paddy soil. *Biochar*. **6:** 1. https://doi.org/10.1007/s42773-024-00312-7.

Lu, W.J., Wang, H.T., Yang, S.J., Wang, Z.C. and Nie, Y.F. (2005). Isolation and characterization of mesophilic cellulose-degrading bacteria from flower stalks-vegetable waste co-composting system. *J. Gen. Appl. Microbiol.* **51:** 353-360.

Lubis, Z. (2020). Utilization microorganisms local (MOL) in manufacturing Compost. Proceedings of the National Seminar on Community Service Results. 361-374.

Mekonnen, A.M. (2024). Enhancement of Biogas Production from Organic Wastes Using Rumen Fluid: Case Study Enhancement of Biogas Production from Organic Wastes Using Rumen.

Murumkar, S.K. (2021). Growth of composting fungi on agricultural waste. *The Planta RBS*. **2:** 559-563.

Ninkuu, V., Liu, Z., Qin, A., Xie, Y., Song, X. and Sun, X. (2025). Impact of straw returning on soil ecology and crop yield: A review. *Heliyon.* **11:** e41651. https://doi.org/10.1016/j.heliyon.2025.e41651.

Noor, R.S., Shah, A.N., Tahir, M.B., Umair, M., Nawaz, M., Ali, A., Ercisli, S., Abdelsalam, N.R., Ali, H.M., Yang, S.H., Ullah, S. and Assiri, M.A. (2024). Recent trends and advances in additive-mediated composting technology for agricultural waste resources: A comprehensive review. *ACS Omega*. **9:** 8632-8653. https://doi.org/10.1021/acsomega.3c06516.

Obour, P.B., Xia, Y., Ugarte, C.M., Grift, T.E. and Wander, M.M. (2025). Soil physical properties and water dynamics under contrasting management regimes at the Morrow Plots. *Soil and Tillage Research*. **248**. https://doi.org/10.1016/j.still.2024.106422.

Okoli, F.A., Chukwura, E.I. and Mbachu, A.E. (2024). Agro wastes compost quality parameters and effect on the growth of *Amaranthus amaranthus*. *Technology in Agronomy*. **4:** 1-07. https://doi.org/10.48130/tia-0024-0010.

Padhan, K., Patra, R.K., Patra, A.K. *et al.* (2022). Microbial inoculation influencing physical properties of composts produced from different agro-wastes. *International Journal of Plant and Soil Science*. **34:** 1428-1435.

Putri, Y.E., Akmal, N., Elfita, A. and Anugerah, A.I. (2024). Development of E-Modules in Sanitation Hygiene and K3 Courses in the Culinary Study Program. pp. 22-29. https://doi.org/10.2991/978-2-38476-232-3_4.

Sari, I. and Nurrasyid, A. (2024). Effect of decomposer agent on C/N ratio, N and P content of empty palm oil bunches palm (*Elaeis guenensis jaq*). *Journal of Palm Oil Sustainability.* **1:** 1-6. https://doi.org/10.31849/JSOP.vxxx.

Sokaè Cvetnić, T., Krog, K., Lisak Jakopović, K., Vallinger, D., Gajdoš Kljusurić, J., Benković, M., Jurina, T., Jakovljević, T., Redovniković, R.I. and Tušek, A.J. (2024). Grape skin composting process to recycle food waste: Kinetics and optimization. *Foods*. **13:** 6. https://doi.org/10.3390/foods13060824.

Vaz-Moreira, I., D'Arnese, A., Knoll, M., Teixeira, A.M., Barbosa, J.B., Teixeira, P. and Manaia, C.M. (2025). Bacteriological safety and quality of composted products from animal, urban or sewage sludge wastes. *Environmental Pollution.* **364**. https://doi.org/10.1016/j.envpol.2024.125329.

Xing, W., Hu, N., Li, Z., Feng, L., Zhang, W., Du Preez, G., Zhang, H., Li, D., Lu, S., Chang, S., Zhang, Q. and Lou, Y. (2024). Soil enzyme profile analysis for indicating decomposer micro-food web. *IMeta Wiley*. **3:** 1-18. https://doi.org/10.1002/imt2.161.

Xu, P., Shu, L., Yang, Y., Kumar, S., Tripathi, P., Mishra, S., Qiu, C., Li, Y., Wu, Y. and Yang, Z. (2024). Microbial agents obtained from tomato straw composting effectively promote tomato straw compost maturation and improve compost quality. *Ecotoxicology and Environmental Safety.* **270**. https://doi.org/10.1016/j.ecoenv.2023.115884.

Yang, Q., Yan, W. and Agrawal, A. (2024). Enhancing Multi-agent Multi-modal Collaboration with Fine-grained reward modeling. Conference on Neural Information Processing Systems.

Yang, Q., Zhang, S., Li, X., Rong, K., Li, J. and Jiang, L. (2023). Effects of microbial inoculant and additives on pile composting of cow manure. *Frontiers in Microbiology*. **13:** 1084171. https://doi.org/10.3389/fmicb.2022.1084 171.

Zhang, Z., Gu, Y., Wang, S., Zhen, Y., Chen, Y., Wang, Y., Mao, Y., Meng, J., Duan, Z., Xu, J. and Wang, M. (2024). Effective microorganism combinations improve the quality of compost-bedded pack products in heifer barns: Exploring pack bacteria-fungi interaction mechanisms. *BMC Microbiology*. **24:** 1-15. https://doi.org/10.1186/s12866-024-03447-6.