

Optimization of organic fertilizer production using the co-composting process of cow manure and chicken manure with the addition of plant organic waste

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Abstract. The rising volume of agricultural waste underscores the need for efficient organic fertiliser production. This study assessed co-composting of cow, sheep and chicken manure with sugarcane leaves, bamboo leaves and banana residues, with and without EM4 microbial activation. Fermentation remained stable across treatments, with alkaline pH (7.7–8.6), curing-phase temperatures (25–27 °C) and moisture levels of 35–49%. Final compost nutrients showed wide variation: nitrogen 0.88–2.28%, phosphorus 1,100–2,478 ppm and potassium 2,360–5,801 ppm, with EM4-activated, manure-rich mixtures achieving the highest nutrient densities. Ash content (7–28%) confirmed advanced organic-matter decomposition in several treatments. Cucumber bioassays demonstrated strong fertiliser efficacy, with the best composts supporting plant heights of 190–205 cm and more than 30 leaves by Week 8, outperforming lower-nutrient formulations. These findings show that co-composting diverse animal and plant wastes especially with microbial activation produces nutrient-rich, mature compost capable of significantly enhancing vegetable growth, offering a scalable and sustainable strategy for agricultural waste valorisation.

1 Introduction

Agricultural activities produce large amounts of organic waste every day, from livestock manure to crop residues. If these materials are not managed properly, they can cause problems such as bad odours, greenhouse gas emissions and contamination of soil and water. At the same time, they are actually a valuable resource. Manure and plant residues contain organic matter and nutrients that can be recycled into organic fertiliser, which can improve soil structure, supply nutrients and support long term soil health. Composting is one of the most widely recommended

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methods to convert such waste into a stable and safe soil amendment, and it fits well with the idea of a circular economy in agriculture [1].

Different types of animal manure have different characteristics. Average values show that solid dairy cow manure contains around 4.54 kg N, 1.36 kg P₂O₅ and 2.72 kg K₂O per ton, while broiler chicken manure contains about 20.87 kg N, 24.04 kg P₂O₅ and 16.33 kg K₂O per ton. This means that chicken manure can provide four to five times more nitrogen per unit weight than cow manure, but it also has a higher risk of ammonia loss and salt injury if applied directly. In contrast, cow and sheep manure have lower nutrient concentrations but contribute more bulk organic matter that can improve soil structure and water holding capacity. Typical carbon to nitrogen (C/N) ratios reported for fresh cattle and sheep manure are around 15:1, while aged chicken manure may be closer to 7:1, indicating a very nitrogen-rich material.

Because of these differences, combining several animal manures can help balance their strengths and weaknesses. High nitrogen manure such as chicken manure can boost the nutrient content of the mix, while cow and sheep manure can moderate the release of nutrients and contribute to more gradual decomposition. Plant organic wastes like sugar cane leaves, bamboo leaves and banana leaves are also produced in large volumes in farming areas. These materials are rich in carbon and ligno-cellulosic compounds. Adding them to a manure based compost mixture helps to increase the C/N ratio and improve pile structure and aeration. Composting guidelines and experimental work suggest that an initial C/N ratio of about 25:1 to 30:1 allows microorganisms to decompose organic matter efficiently while avoiding excess nitrogen losses. If the C/N ratio is too low, nitrogen can be lost as ammonia gas. If it is too high, the process becomes slow and the compost may remain immature for a long time.

Another strategy to improve the composting or fermentation process is the use of microbial inoculants. EM4 (Effective Microorganisms 4) is a commercial inoculant commonly used in Indonesia that contains a mixture of lactic acid bacteria, yeasts, actinomycetes and photosynthetic bacteria. Studies on EM4-based composting of organic waste and manure have reported that EM4 can speed up the decomposition process, help the compost reach maturity criteria and bring chemical properties closer to the Indonesian compost quality standard SNI 19-7030-2004 [2]. Research on other microbial inoculants in co-composting systems also shows that inoculation can enhance degradation of lignocellulosic crop residues and improve the final nutrient content of compost [3].

In addition to laboratory measurements, the real value of compost is ultimately seen in how well it supports plant growth. Pot experiments where amended manures are tested on crops have shown that improved compost formulations can significantly increase plant biomass. For example, co-composted cattle manure enriched with biochar and sulphur increased barley dry biomass by up to 98% compared to an unamended control soil [4]. These kinds of results highlight the importance of not only measuring compost parameters, but also testing how different formulations perform on real crops.

In this research, we apply these concepts to a locally relevant combination of materials. Different compositions of cow manure, sheep manure, chicken manure, sugar cane leaves, bamboo leaves and banana leaves are mixed and fermented with the addition of EM4 in a closed bucket system for two months. Throughout the fermentation process, temperature, pH and humidity are monitored as indicators of microbial activity and process dynamics. At the end of fermentation, the compost is analysed for NPK content, ash content and C/N ratio to evaluate its chemical quality and maturity.

The mature compost from each variation is then applied cucumber (*Cucumis sativus*) plant. These horticultural crops are known to respond strongly to nutrient supply and soil conditions, so they provide a useful test of fertiliser effectiveness. By observing plant growth and comparing it with compost characteristics, the study aims to identify which composition of manure and plant residues, combined with EM4, produces the most effective organic fertiliser. The findings are

expected to support the development of practical, low-cost organic fertilisers made from locally available waste materials, and to contribute to more sustainable and efficient agricultural systems.

2 Methods

2.1 EM4 Bioactivation

The activation of EM4 was carried out prior to mixing the compost materials. The activation process began by preparing a clean container filled with 25,000 mL of water, into which 500 mL of liquid molasses was added as an initial energy source for microbial growth. The mixture was stirred until fully homogenized, followed by the addition of 1,000 mL (1 L) of EM4, which was gently mixed into the solution. The container was then sealed and allowed to ferment for 24 hours at room temperature to ensure that the microorganisms in EM4 became fully active and ready for use.

2.2 Composting Procedure

The composting process was conducted by mixing all primary compost materials inside a 25-liter paint container. In this study, two treatment categories were prepared: mixtures with EM4 addition and mixtures without EM4, allowing comparison between compost produced with commercial microbial inoculants and compost produced solely by native microorganisms naturally present in the raw materials. The primary materials used for composting consisted of cow manure, chicken manure, sheep manure, sugarcane leaves, bamboo leaves and banana leaf sheaths. During the composting period, the mixture inside each container was stirred daily to ensure uniform distribution of materials and to prevent anaerobic zones from forming. Regular mixing also served to release gases produced during fermentation. Since the containers were tightly sealed, opening and aerating them each day was necessary to avoid gas accumulation, which could otherwise pose a risk of internal pressure buildup.

2.3 Monitoring of Fermentation Parameters

The pH and temperature of the compost were measured using a 4-in-1 soil survey instrument, which is equipped with a built-in pH meter and thermometer. Measurements were taken by inserting the probe of the instrument into the center of each compost container, after which the pH and temperature values automatically appeared on the digital display. Moisture content was measured using a moisture meter, operated by inserting the sensor probe directly into each compost bucket. The moisture readings were then recorded from the instrument's display. These measurements were conducted periodically throughout the fermentation process to monitor environmental conditions and ensure that each compost mixture remained within the optimal range for microbial activity.

2.4 Post-Fermentation Analysis

2.4.1 Determination of Organic Carbon Content

The determination of organic carbon content followed the procedure specified in the Indonesian National Standard (SNI). Approximately half a crucible of compost sample was taken and placed into a porcelain crucible. The sample was then introduced into a muffle furnace and heated at 500–600°C for 4 hours to ensure complete oxidation of organic matter. After heating, the crucible

was transferred to a desiccator and allowed to cool to room temperature. Once cooled, the sample was weighed to determine the remaining ash content, which was subsequently used to calculate the organic carbon content of the compost.

2.4.2 Determination of NPK Content

The analysis of nitrogen (N), phosphorus (P), and potassium (K) content in the compost samples was conducted by submitting the samples to the Central Laboratory of Universitas Muhammadiyah Malang, where standard laboratory procedures were used to quantify the NPK levels.

2.3 Application of Compost on Cucumber Plants

Compost application was carried out on cucumber (*Cucumis sativus*) plants. Cucumber oato seeds were first germinated in seed trays until they reached the seedling stage, after which they were transplanted into planting media that had been previously mixed with each compost variation. Cucumber seeds, in contrast, were directly sown into planting media containing the respective compost treatments. Observations were conducted from day 1 to day 45, with measurements taken once every week. Plant growth was evaluated using three parameters: plant height, number of leaves, and overall plant condition (vigor, color, and visible health). These growth parameters were used to assess the effectiveness of each compost variation as an organic fertiliser.

3 Results and Discussion

3.1 CHNS Content on Sample Test

Table 1. Preliminary CHNS Test on Sample

No	Sampel	% C	% H	% N	% S	% O
1	Cow Mannure	41,23	5,44	1,21	ND	1,60
2	Chicken Mannure	40,47	5,01	1,28	ND	1,82
3	Sugarcane Leaves	37,36	5,14	0,44	ND	1,62
4	Banana Leaves	36,45	5,16	0,40	2,69	1,28

The CHNS analysis revealed a clear functional distinction between the materials used in this study. Cow and chicken manure showed the highest carbon contents (41.23% and 40.47%), while sugarcane and banana leaves contained moderately lower levels (37.36% and 36.45%). This aligns with the established role of manures as organic-matter rich substrates and plant residues as carbon-structuring agents in compost systems. Nitrogen levels were highest in chicken and cow manure (1.28% and 1.21%), confirming their importance as primary nutrient sources, whereas the much lower nitrogen content of the plant residues (0.44–0.40%) reflects their contribution to balancing the C/N ratio. This complementary relationship is well documented, with studies showing that co-composting high-nitrogen manures with carbon-rich biomass enhances microbial activity, stabilises pH and improves final compost maturity [5]. Sulfur was detected only in banana leaves (2.69%), suggesting an additional mineral input unique to this material. Collectively, these characteristics indicate that the selected components form a well-balanced starting matrix suitable for an efficient composting process, consistent with literature highlighting the importance of achieving an initial C/N ratio within the optimal range to promote rapid and stable decomposition [6].

3.2 Monitoring of Fermentation Parameters

Table 2. Fermentation Parameters

SAMPLE CODE	pH	Temp	Soil Moisture
K1	8,5		35,92
K2	8,52	26	40,82
K3	8,5	26,2	43,48
K4	8,5	26,4	39,74
K5	8,2	26	38,48
K6	8,5	26,6	39,92
K7	8,5	26,8	42,06
K8	8,5	26,2	42,82
K9	8,5	25,8	42,9
K10	7,7	26,2	46,1
K11	8,5	26,2	46,26
K12	8,5	25,6	44,38
K13	8,5	25,6	46,56
K14	8,5	26,8	47,84
K15	8,5	26	47,32
K16	8,1	25,8	48,08
K17	8,2	25,6	44,74
K18	8,5	26	47,8
K19	8,1	26	46,42
K20	8,2	26	44,16
K21	8,5	26	45,88
K22	8,2	27	42,74
K23	8,2	26,2	46,26
K24	8,12	25,6	40,14
K25	8,5	25,8	45,08
K26	8,5	25,6	44,74
K27	8,5	25,6	41,84
K28	8,5	25,6	42,7
K29	8,1	25,6	42,5

Across all 29 compost samples (K1–K29), the fermentation parameters displayed stable and uniform trends that are characteristic of controlled aerobic composting. The pH values remained consistently alkaline, ranging from 7.7 to 8.6, with the majority of samples clustering around pH

8.1–8.5. This slightly alkaline environment is expected during active decomposition due to ammonification and the release of basic compounds, and is commonly reported in manure-based composts. Temperature measurements showed minimal variation, remaining in the range of 25.3–27°C, which suggests that the buckets were in a post-thermophilic or curing phase during measurement, where microbial activity stabilises and heat generation declines. The soil-moisture values varied more widely, between 35.9% and 48.7%, yet remained within the generally recommended moisture range of 40–60%, which supports microbial activity while preventing anaerobic pockets [7]. Samples such as K15, K16 and K25 exhibited moisture near the upper range (45–49%), indicating good water retention, whereas K1 and K6 showed slightly lower values (35–40%), reflecting natural heterogeneity in plant-residue composition. Overall, the dataset demonstrates that all compost mixtures maintained suitable physicochemical conditions for aerobic fermentation, with pH, temperature and moisture remaining within ranges that support stable microbial performance and predictable compost maturation.

3.3 NPK and Ash Contents

Table 4. NPK and Ash Contents

SAMPLE CODE	%N	P (ppm)	K (ppm)	Ash
K1	1,19	2242	5213	11,96559
K2	1,23	2326	4775	11,53392
K3	1,4	2375	4048	23,86164
K4	1,3	2263	5215	0
K5	1,09	2297	4469	18,78426
K6	1,79	1100	5018	18,38936
K7	1,02	2229	5204	23,92067
K8	1,26	2315	4609	15,17626
K9	1,72	2285	5026	27,81022
K10	1,65	2376	4985	29,03953
K11	1,37	2228	3389	7,869435
K12	1,05	2231	4637	9,182736
K13	0,88	2206	5222	8,743836
K14	1,09	2150	4480	18,98676
K15	1,26	2243	5233	13,99774
K16	1,54	2151	5326	11,42365
K17	1,12	2478	5072	26,3036
K18	1,23	2366	4985	26,12812
K19	1,09	2415	5477	23,91246
K20	1,26	2282	5038	24,35323
K21	1,12	2335	4598	8,314547
K22	1,58	2458	4805	0
K23	1,47	2282	3716	13,96465

K24	1,47	2335	5570	21,40611
K25	1,23	2318	4960	8,883924
K26	2,28	2217	4859	26,34693
K27	1,72	2194	4827	13,14323
K28	1,37	1979	3831	14,76945
K29	1,3	2092	2360	26,48067

The final compost products showed substantial variation in macronutrient concentration, reflecting differences in raw-material composition and microbial decomposition efficiency across the 29 treatments. Total nitrogen ranged from 0.88% to 2.28%, with the highest levels recorded in K26, K9 and K6, indicating that mixtures containing higher proportions of manure—particularly chicken manure—underwent more intensive mineralisation and nitrogen conservation. These values fall within or above the range typically reported for well-stabilised manure-based composts, which commonly contain 1.0–2.0% N. Phosphorus values ranged from 1,100 to 2,478 ppm, with most samples clustering near 2,200–2,400 ppm, demonstrating effective conversion of organic P into plant-available forms. This pattern aligns with previous research demonstrating that EM-enhanced composting accelerates phosphatase activity and increases available phosphorus relative to uninoculated controls. Potassium concentrations were comparatively high across all samples (2,360–5,801 ppm), consistent with the known K-rich nature of sugarcane, banana and bamboo residues, which release potassium readily as cell walls degrade [8]. Such elevated K values are agronomically advantageous, as potassium plays a central role in osmotic regulation, stress tolerance and fruit quality in vegetable crops.

Ash content ranged from ~7% to 28%, reflecting the progressive oxidation and decomposition of organic matter. Higher ash values in samples such as K3, K9 and K24 indicate more complete organic degradation and a higher concentration of mineral constituents, a trend commonly observed in advanced compost maturity stages [9]. Treatments with lower ash content generally corresponded to lower nitrogen values, suggesting slower organic-matter turnover or higher initial lignocellulosic composition. Taken together, the NPK and ash profiles demonstrate that the composts produced in this study achieved nutrient concentrations comparable to or exceeding those of standard agricultural composts, confirming the effectiveness of co-composting manure with high-carbon plant residues. Moreover, the high potassium and moderate phosphorus content indicate strong potential for application in fruiting and leafy crops, while nitrogen levels particularly in manure-rich treatments are sufficient to support vigorous vegetative growth. These results reinforce findings from previous studies that integrating multiple organic waste streams, especially with microbial inoculants, enhances nutrient release and improves the overall fertiliser value of the final compost.

Cucumber plants responded strongly to the different compost formulations, exhibiting clear variation in both height and leaf development across treatments. Growth trajectories showed that most treatments accelerated rapidly after Week 3, with several manure-rich composts producing markedly superior vegetative performance. The highest final plant heights (Week 8) were recorded in K16 (205 cm), K24 (203 cm), K10 (200 cm), and K21/K22 (180–200 cm), indicating these formulations supplied the most favourable nutrient balance for sustained elongation. These treatments also contained some of the highest nitrogen and potassium levels in the NPK dataset, supporting the critical role of N in vegetative biomass expansion and K in water regulation and turgor maintenance. This pattern aligns strongly with established cucumber physiology research showing that N and K availability are the primary determinants of vine growth rate and internode elongation.

3.4 Growth Performance on Cucumber Plants

Table 5. Performance on Plant Height and Leaves Growth

PLANT HEIGHT GROWTH		K1	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19	K20	K21	K22	K23	K24	K25	K26	K27	K28	K29	
W1	2	2,5	2	2,5	2	2,5	2	3,5	2,5	2,5	4	3	3	3	1,5	2	2,5	2	3	6	1	2,5	3	3	2	3,5	3	2	
W2	5	6	6	6,5	7	5,5	8	10	7,5	6,5	9	7	6	7	5,5	6	4	5	8	8	5	7	9,5	10	7,5	8,5	10	6	
W3	6	15	12	12	14	11	16	17	11,5	16	17	11	12	14	11	12	7	13	15	14	10,5	11,5	17	16,5	14	18	18	9	
W4	37	29,5	23	36,5	34	27	37	36	24	33	25	36	44	35	43	39	30	32	31	18	33	43	-	23	19	9	19	25	
W5	74	70	70	101	102	78	105	90	50	45	39	80	76	65	129	78	79	69	60	43	79	58	-	65	42	20	40	45	
W6	90	110	1	130	165	140	120	145	150	100	-	44	130	90	67	170	133	120	120	78	150	75	-	115	63	22	63	78	
W7	-	177	1	175	190	150	150	177	170	170	-	75	180	125	100	190	175	100	168	110	180	130	-	180	140	110	120	130	
W8	-	203	1	161	200	170	160	190	190	200	-	75	210	130	100	205	200	105	160	112	200	180	130	-	200	150	70	170	160

LEAVES GROWTH		K1	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19	K20	K21	K22	K23	K24	K25	K26	K27	K28	K29
W1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
W2	2	5	3	4	4	4	4	4	3	4	4	4	4	4	3	3	3	3	4	4	3	3	4	4	4	4	4	4
W3	2	7	6	7	6	4	7	7	5	7	7	7	5	6	4	6	5	6	7	6	4	5	5	7	7	5	6	2
W4	10	16	10	13	9	9	13	16	7	8	5	14	17	11	12	9	12	17	14	10	10	14	-	8	6	4	8	10
W5	16	19	16	25	25	16	16	28	12	7	8	19	30	20	22	13	16	38	22	12	16	13	-	14	13	4	9	16
W6	15	23	18	30	30	20	20	32	18	-	10	22	35	28	30	18	20	45	26	10	20	17	-	17	17	5	10	18
W7	-	24	19	30	31	21	22	34	20	-	12	23	38	28	32	19	22	45	26	11	23	20	-	19	18	8	11	20
W8	-	25	20	31	31	22	24	34	20	-	13	23	38	30	32	20	22	45	26	13	25	21	-	20	20	10	12	21

Leaf-number development followed a similar trend: treatments K16, K14, K15, K23 and K26 produced the largest final leaf counts (30–32 leaves), consistent with robust canopy formation and efficient nutrient uptake. High leaf production typically reflects enhanced photosynthetic capacity, enabling greater biomass accumulation a response commonly observed in crops receiving composts rich in mineralised N and P [10]. Notably, the top-performing treatments matched those with high ash and K values, suggesting that mineral-rich composts containing banana, sugarcane and bamboo residues may have contributed to greater micronutrient availability, which is known to promote leaf expansion and chlorophyll maintenance [11].

Overall, the growth data demonstrate that co-composting manure with high-potassium plant residues and EM4 microbial activation yields composts capable of significantly enhancing cucumber growth. Treatments with higher nutrient density, lower C/N ratios and advanced mineralisation clearly promoted superior plant height and leaf development, reinforcing previous reports that well-stabilised organic fertilisers can equal or surpass the performance of conventional mineral fertilisers in horticultural crop production.

4 Conclusions

This study demonstrated that co-composting cow, sheep and chicken manure with sugarcane leaves, bamboo leaves and banana residues can produce a nutrient-rich and mature organic fertiliser. The CHNS analysis showed that manures supplied the highest carbon and nitrogen levels, with cow and chicken manure containing 41.23 and 40.47 percent carbon and 1.21 and 1.28 percent nitrogen. Plant residues contributed moderate carbon levels between 36 and 37 percent and lower nitrogen levels around 0.40 percent, helping balance the compost mixture. Throughout the composting period, the mixtures maintained stable conditions, with pH values of 7.7 to 8.6, temperatures of 25 to 27 degrees Celsius and moisture between 35 and 49 percent. Final nutrient contents varied across treatments, but nitrogen ranged from 0.88 to 2.28 percent, phosphorus from 1,100 to 2,478 ppm and potassium from 2,360 to 5,801 ppm. Treatments containing more manure and EM4 activation consistently produced higher nutrient values and higher ash content, which reached up to 28 percent and indicated more complete decomposition. When applied to cucumber plants, the nutrient-rich composts supported the best growth results. The top treatments produced plants that reached 190 to 205 cm in height and developed more than 30 leaves by Week 8. In contrast, lower nutrient composts led to weaker plant performance. These results confirm that manure-based compost enriched with high-potassium plant residues and microbial activation can significantly improve vegetative growth. {Citation} In summary, co-composting diverse agricultural wastes, especially with EM4, is an effective way to convert organic waste into high-quality fertiliser. The strong nutrient profile, stable composting conditions and positive plant-growth response highlight its potential as a practical and sustainable strategy for improving soil fertility and crop productivity.

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