EFFECT OF INDIGENOUS MICROORGANISM (IMO) ON DECOMPOSING KITCHEN ORGANIC WASTE: A COMPARATIVE STUDY

ẢNH HƯỞNG CỦA VI SINH BẢN ĐỊA (IMO) ĐẾN SỰ PHÂN HUỶ RÁC BẾP HỮU CƠ

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Abstract - This study investigated the effects of Indigenous Microorganisms (IMO) on kitchen organic waste decomposition. Results showed that the M1 treatment (IMO added, aeration) resulted in faster and more efficient carbon decomposition compared to the M2 treatment (IMO added, no aeration) and the CT treatment (no IMO and no aeration). The M1, M2 and CT treatments achieved 60.3, 50.4 and 29.8% reduction in total organic carbon (TOC), respectively. The concentrations of NO_3^- decreased gradually, approximately a 50% reduction observed after 44 days in both the M1 and M2 treatments, but were stable in CT during the process. Meanwhile, NH^{4+} was mainly significantly higher in CT compared to M1 and M2. In conclusion, the inclusion of IMO with aeration improved the waste decomposition, resulting in faster carbon reduction and enhanced nitrogen transformation. These findings highlight the potential of IMO and aeration as effective approaches for efficient kitchen waste management.

Key words - Carbon decomposition; continuous aeration; decomposition efficiency; Indigenous Microorganisms (IMO); kitchen organic waste

Tóm tắt – Nghiên cứu này nhằm khảo sát ảnh hưởng của vi sinh vật bản địa (IMO) đến sự phân hủy chất thải hữu cơ nhà bếp. Kết quả cho thấy, nghiệm thức M1 (bổ sung IMO, sục khí) làm cho việc phân hủy carbon nhanh hơn và hiệu quả hơn so với nghiệm thức M2 (bổ sung IMO, không sục khí) và nghiệm thức CT (không bổ sung IMO, không sục khí). M1, M2 và CT lần lượt đạt được mức giảm carbon hữu cơ (TOC) là 60,3, 50,4 và 29,8%. NO_3^- giảm khoảng 50% sau 44 ngày ở cả M1 và M2 nhưng ổn định ở CT trong suốt quá trình. Trong khi đó, NH_4^+ cao hơn đáng kể ở CT so với M1 và M2. Như vậy, việc kết hợp IMO và sục khí đã dẫn đến giảm carbon nhanh hơn và tăng cường chuyển hóa nitơ. Do vậy việc sử dụng IMO và sục khí có tiềm năng tăng hiệu quả trong xử lý chất thải hữu cơ nhà bếp.

Từ khóa – Phân hủy cacbon; sục khí liên tục; hiệu quả phân hủy; vi sinh vật bản địa (IMO); chất thải hữu cơ nhà bếp

1. Introduction

Effective management of kitchen organic waste is essential for sustainable waste disposal and environmental conservation. The disposal of organic residues by composting being one of the most attractive methods because of its low environmental impact and cost [1-3]. Traditional waste management methods often fall short in terms of decomposition efficiency and odor control [4-6]. As a result, there is a growing interest in exploring alternative approaches, such as the utilization of Indigenous Microorganisms (IMO), to enhance the decomposition process and reduce environmental impacts [7, 8]. An IMO is an organism that can increase the soil quality [9]. It contains beneficial microorganisms as bacterial fungi that plays an important role in the decomposition of organic matter. Several studies have investigated the application of IMO in waste management, demonstrated the positive impact of IMO on the decomposition of agricultural residues, resulting in improved nutrient availability and reduced greenhouse gas emissions, or it is found that IMO supplementation accelerated the breakdown of organic matter in composting systems, enhancing the overall compost quality.

Understanding the impact of IMO on kitchen organic waste decomposition is crucial for developing sustainable waste management strategies. The findings from this study will provide valuable insights into the potential benefits of utilizing IMO and continuous aeration in waste treatment processes. This research contributes to the existing knowledge on organic waste management and offers practical solutions for reducing environmental impacts while effectively managing kitchen organic waste [10, 11]. In addition, this study builds upon previous research examining microbial community dynamics during composting, the evaluation of IMO for waste composting), and the effects of IMO on organic waste decomposition under different conditions. Furthermore, the microbial and enzymatic analysis of indigenous microorganisms on waste decomposition and the influence of IMO on decomposition dynamics and nutrient release provide relevant insights for this study.

Despite the existing research on IMO in waste management, there is a lack of comprehensive studies focusing specifically on kitchen organic waste decomposition. Understanding the effects of IMO on carbon reduction rates in this context is crucial for developing efficient and sustainable waste management strategies. The rationale behind this study stems from the need to address the challenges associated with kitchen organic waste management. By investigating the impact of IMO on decomposition rates, we aim to provide valuable insights into the potential benefits of utilizing indigenous microorganisms in waste treatment processes. The findings from this research will contribute to the existing knowledge on sustainable waste management and offer practical solutions for reducing environmental impacts while effectively managing kitchen organic waste [12, 13].

Therefore, the present study aims to assess the effect of

IMO on decomposing kitchen organic waste. By comparing three treatment methods: (1) IMO addition and continuous aeration, (2) IMO addition and manual stirring twice a day, and (3) water addition and manual stirring twice a day). We seek to determine the most effective approach for reducing carbon content.

2. Material and methods

2.1. IMO preparation

The materials to make IMO included Table 1.

Table 1. *The materials for IMO produce*

Input material	*Amount*
Tap water, chlorine removed (L)	10
Yellow sugar (kg)	1
Rice bran (g)	50
Yogurt (g)	200
Wine yeast (tablets)	5
Boiled pumpkin (kg)	0.5
Ripen banana	2

The process for preparing IMO involved several steps. Initially, 10 liters of clean water were added to a 20-liter capacity container, followed by the addition of yellow sugar and thorough stirring until dissolved. Next, a mixture of crushed pumpkin, ripe banana, wine yeast, and yogurt was added to the container, and the contents were stirred well. Subsequently, rice bran was incorporated into the mixture and stirred thoroughly. The container's lid was closed, leaving a small opening to prevent insects and rain from entering while keeping it in the garden, away from direct sunlight. The container was opened and stirred 1-3 times daily. After a period of 5-7 days of sunshine or 21 days of rainy weather, the original IMO solution was obtained. The initial pH of IMO was 4.5, indicated for acidic environment.

To determine the successful production of IMO, several features were examined. The smell of the solution should be mild and sour, reminiscent of wine. When stirring the solution, foam should form on the surface. The taste of the IMO should be sweet and sour, similar to wine. Additionally, a deodorization test was performed by diluting the IMO at a ratio of 1:50 and spraying it directly on smelly areas such as garbage cans or manure piles. If the smell disappears within 5-10 minutes, it indicates that the IMO product has been successfully incubated.

Figure 1. *IMO after 7 incubated days*

2.2. Experimental set-up

This study utilized household organic waste as composting materials, including fruit peels, vegetable stalks, egg shells, fish bones, and leftovers. These materials were cut into 3-5 cm sizes and thoroughly mixed prior to composting as showed in Figure 2. The waste material was then placed into three compost containers, as outlined in Table 2. Container M1 received continuous aeration to ensure an adequate oxygen supply, while containers M2 and CT were manually stirred twice a day. Throughout the composting process, various parameters including temperature, pH, NO_3^-, NH_4^+, and organic carbon were continuously monitored and measured.

Figure 2. *Household organic waste*

The design of experiment is included three composting models with 20 liter containers, as following:

Table 2. *The design of experiment in the present study*

Treatment	Waste (kg)	IMO added (L)	Aeration	Stirring
M1	4	9	Yes	None
M2	4	9	None	2 times/day
CT	4	None	None	2 times/day

2.3. Parameters measurement

Temperature is measured using a mercury thermometer placed in the central region of the incubation model. The thermometer is inserted and left undisturbed for 10-15 minutes to allow for temperature equilibrium. The Mettler Toledo pH meter is utilized for pH measurement. The Hydrazine Reduction Method is employed to measure NO_3^- levels. In this method, nitrate is reduced to nitrite by hydrazine in the presence of copper. The Nitroprusside Method is utilized for NH_4^+ determination. This technique relies on the formation of a blue-colored inophenol complex during the nitroprusside reaction. The intensity of the blue color is measured at 655 nm, allowing for accurate quantification of NH_4^+ concentration. Organic carbon content (TOC) is determined following the TCVN 9294-2012 standard. This method relies on the oxidation of organic carbon using an excess potassium dichromate solution ($K_2Cr_2O_7$) in sulfuric acid. The remaining excess dichromate is then titrated with iron (II) ferric solution to derive the organic carbon content accurately.

2.4. Statistical analysis

Because the experiment is carried out according to the system and not repeated, therefore statistical processing is not performed. The correlation between the measured parameters (Pearson correlation) was processed on ver. 20 SPSS software, at the level of statistical significance $p < 0.05$ and $p < 0.01$.

3. Result and Discussion

3.1. Changes in temperature and pH during treating process

incubation, the temperature was not much difference

among treatments, fluctuated in the range of from 22.1˚C to 36˚C and reached the highest temperature at 35.9˚C on the 11th day of incubation of the M1 treatment. We find that the temperature of the treatments was not significantly lower than the air temperature. This can be explained because both treatments were liquid and incubated in an open aerobic environment. The temperatures continued to fluctuate over time, with varying degrees of stability observed among the treatments. M1 and M2 generally displayed higher temperature variability compared to the CT, which had more consistent temperature readings. As Figure 3 showed, the treatments entered the thermophilic phase on 7th day and lasted for 9th day with the temperature range of 27.3˚C to 35.9˚C. There was a higher temperature range of the M1 and M2 than that of the CT, which indicates that there was an increase in microbial activity in the M1 and M2 added IMO than that of CT added with water. In the M1 treatment, where aeration was provided but no stirring was conducted, the temperature initially started at a certain level and gradually increased over time. The presence of aeration likely promoted aerobic microbial activity, leading to increased heat generation through organic matter decomposition [14]. However, without stirring, the heat generated may not have been evenly distributed, resulting in temperature fluctuations throughout the study period.

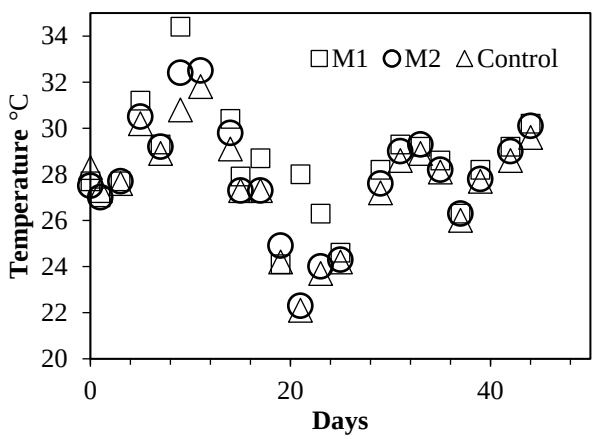

Figure 3. *Changes in temperature affected by IMO addition*

According to Figure 3 we can see that during in the M2 treatment, where aeration was not provided but stirring occurred twice a day, the temperature also exhibited fluctuations. The absence of aeration suggests that the decomposition process may have occurred under anaerobic conditions, with microbial activity producing heat through anaerobic digestion. The intermittent stirring likely helped distribute the heat generated and facilitate the breakdown of organic matter within the waste, contributing to temperature fluctuations observed throughout the experiment. In the CT treatment, where neither aeration nor IMO addition was present, the temperature remained relatively stable over the study period. Without the introduction of specific microbial cultures or aeration, the waste decomposition likely relied on the natural microbial community present in the waste and the surrounding environment. Stirring occurring twice a day may have contributed to slight temperature variations, but overall, the absence of additional factors such as aeration or specific microbial inoculation resulted in a more stable temperature profile [15].

From the results obtained in Figure 4, there was a difference in pH between the M1, M2 and CT treatments. Specifically, the pH of two M1 and M2 treatments was much lower than that of the CT during incubation. The reason for this difference is that both of M1 and M2 treatments were added IMO with a low pH value (3.8) while CT was only added water. After 3 days of incubation, the pH of all of them started to increase gradually and tended to stabilize after 35 days. Between the M1 and M2 treatments, we can see that the pH of the M1 tended to increase faster than that of the M2, that can be explained that by the M1 was aerated continuously which accelerated the decomposition.

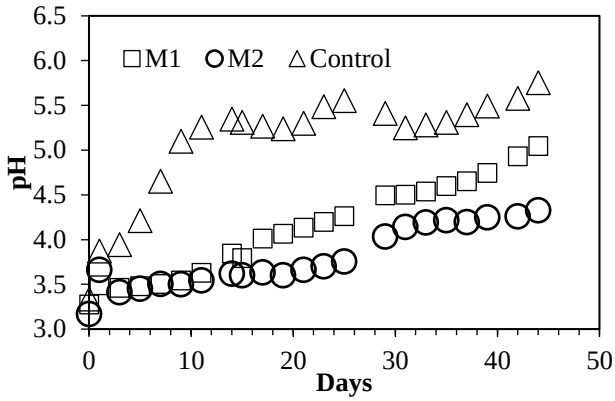

Figure 4. *Changes in pH affected by IMO addition*

There was also an organic acid formation in the early stage of aerobic decomposition which facilitates the growth of fungi and the breakdown of cellulose and lignin, and then, pH increases gradually due to the amount of ammonium produced by the breakdown of proteins. Interestingly, the M1 treatment shows the second-highest pH values across the study period, while the M2 treatment consistently maintains the lowest pH values [12, 16]. This suggests that the M1 treatment had a faster rate of pH increase compared to the M2 treatment, indicating a more rapid shift towards alkaline conditions. The differences in pH trends among the treatments can be attributed to the specific factors associated with each treatment. The addition of indigenous microorganisms (M1) and another treatment (M2) likely influenced the waste samples' pH by altering microbial activity, nutrient availability, and organic matter decomposition rates [17]. Furthermore, the CT treatment might have experienced less microbial activity or slower decomposition processes, resulting in a different pH trajectory.

3.2. Changes in total organic carbon

As Figure 5 revealed that the M1 treatment exhibited faster and more efficient carbon decomposition compared to M2. The use of IMO with continuous aeration significantly reduced decomposition time and mitigated unpleasant odors. Incorporating IMO, particularly through the M1 treatment, enhanced carbon decomposition

efficiency in kitchen organic waste, suggesting the potential of IMO as an organic additive coupled with continuous aeration for expedited and odor-reduced treatment of such waste. The decomposition or removal of organic carbon in waste samples can be influenced by various factors, with notable trends observed among the three treatments in this study. In the M1 treatment, the TOC percentages gradually decreased from 25.2% on day 0 to 10.3% on day 39, remaining stable at 10% on day 44. Similarly, the M2 treatment exhibited a decline in TOC percentages, decreasing from 25.2% on day 0 to 12.5% on day 44. The CT treatment also showed a decrease in TOC percentages, starting at 26% on day 0 and declining to 17.7% on day 44. These trends suggest that all three treatments had a significant impact on the decomposition or removal of organic carbon, resulting in decreased TOC percentages in the waste samples. However, it is important to note that the M1 treatment demonstrated a steeper decline in TOC percentages compared to the M2 and CT treatments, indicating a potentially more efficient organic carbon transformation or removal process in the M1 treatment. Additional factors such as temperature, moisture content, microbial community, composition pH, nutrient availability, waste characteristics and chemical factors may have interacted with the treatments and influenced the observed trends in TOC percentages among the three treatments [18-20].

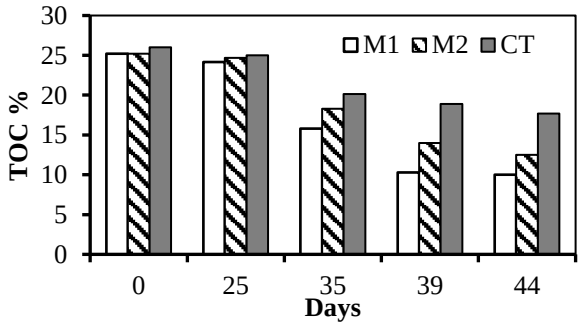

Figure 5. *Changes in TOC affected by IMO addition*

The rates of TOC degradation were compared among three treatments: M1, M2, and CT, which presented in Table 3. Treatment M1 exhibited the highest rate of TOC degradation, followed by treatment M2, and the control treatment had the lowest rate of TOC degradation.

Table 3. *The rate of TOC degradation over time*

Treatment	Degradation Rate (%TOC/day)	R	*p*
M1	-4.425	0.957	<0.001
M2	-3.610	0.969	<0.001
CT	-2.270	0.963	<0.001

The rate (a) were obtained from the linear equation of TOC degradation equation y= at + b with a and b are constant, t was time (days)

Statistical analysis revealed a strong correlation between the rates of TOC degradation and time for all three treatments. The correlation coefficients (R) were higher than 0.957 for all treatments, indicating a significant relationship between time and TOC degradation for each treatment ($p < 0.001$). These findings suggest that treatments M1 and M2 resulted in a more rapid degradation of TOC compared to the control treatment, highlighting their potential effectiveness in promoting TOC decomposition over time.

3.3. Changes in NH_4^+ and NO_3^- over treating period

According to results from Figure 6 and Figure 7, it can be seen that the amount of NH_4^+ was much higher than that of NO_3^-. During the incubation period, the amount of NO_3^- was gradually reduced because the denitrification takes place to form free nitrogen N_2. The amount of NO_3^- of all treatments on the first day ranged from 0.5 to 1.7 mg/kg of waste, but after 44 days, it reduced to 0.4 - 0.5 mg/ kg of waste. Opposite to NO_3^- parameter, the amount of NH_4^+ increased significantly in the M1 and CT treatments after 44th day. Specifically, the amount of NH_4^+ of the CT treatment increased the most from 7.2 to 120.7 mg/kg of waste, and from 5.1 to 23.6 mg/kg of waste in the M1. Besides, the amount of NH_4^+ of the M2 treatment tended to be stable during the incubation period.

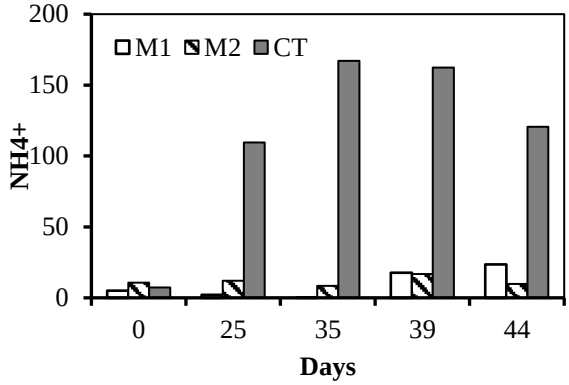

Figure 6. *Changes in NH_4^+ affected by IMO addition*

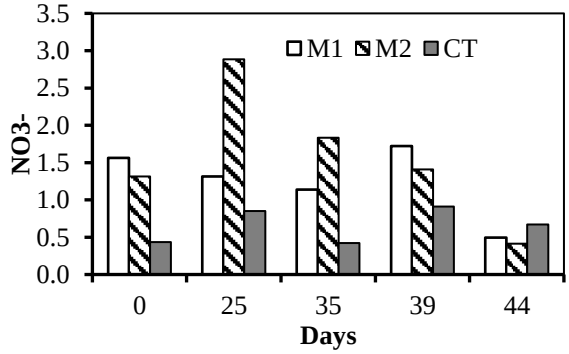

Figure 7. *Changes in NO_3^- affected by IMO addition*

NH_4^+ concentrations in the present study showed varied trends across the different treatments and time periods. In the M1 treatment, NH_4^+ levels initially decreased, then increased on day 39, and further increased on day 44. This observation aligns with previous studies that have demonstrated the influence of microbial processes and bioavailability of organic matter on NH_4^+ dynamics [21]. Conversely, in the M2 treatment, NH_4^+ concentrations showed fluctuations without a clear pattern. In contrast, the CT treatment exhibited a significant increase in NH_4^+ concentrations on day 25, followed by a gradual decrease towards the end of the study. These findings indicate that the addition of M1 and M2 treatments may have influenced

NH_4^+ dynamics differently compared to the CT treatment, suggesting the importance of these treatments in modulating NH_4^+ levels.

Regarding NO_3^-, the trends observed were less pronounced compared to NH_4^+. In the M1 and M2 treatments, NO_3^- concentrations did not show a clear pattern over time. However, in the CT treatment, NO_3^- levels displayed a slight increase on day 25, followed by relatively stable concentrations on days 35 and 39, and a slight increase again on day 44. These results align with previous studies that have reported the complex and dynamic nature of NO_3^- transformations influenced by factors such as microbial activity and nutrient availability [22, 23]. These findings suggest that the addition of M1 and M2 may have had minimal impact on NO_3^- dynamics, while the CT treatment exhibited slight fluctuations in NO_3^- concentrations throughout the study period. Overall, pH fluctuations play a crucial role in nitrogen transformations during composting, affecting NH_4^+ and NO_3^- levels, nitrogen loss processes, and the C/N balance of the composting material. Monitoring and managing pH levels within the suitable range can help promote efficient nitrogen transformation and maintain the desired compost quality.

3.4. The Pearson correlation between parameters

The correlation analysis revealed several significant relationships among the variables. TOC displayed weak negative correlations with pH (-0.23) and strong negative correlation with Temperature (-0.67**). NH_4^+ exhibited a weak positive correlation with TOC (0.05) and a strong positive correlation with pH (0.68**). NO_3^- showed a moderate positive correlation with TOC (0.21) and a moderate negative correlation with pH (-0.61*). Temperature showed weak positive correlations with NO_3^- (0.19) and pH (0.19). These findings indicate that pH has a notable influence on NH_4^+ and NO_3^- levels, while temperature has a strong negative association with TOC.

Table 4. *The Pearson correlation between parameters*

	TOC	**NH_4^+**	**NO_3^-**	**pH**	**Temp.**
TOC	1.00				
NH_4^+	0.05	1.00			
NO_3^-	0.21	−0.41	1.00		
pH	−0.23	0.68**	−0.61*	1.00	
Temp.	−0.67**	−0.01	−0.54*	0.19	1.00
** and ** present significant correlations at the 0.05 and 0.01 and level*					

The strong negative correlation between TOC and Temperature can be attributed to several factors supported by previous research. Studies such as Mikan, Schimel and Doyle [24] and Sinsabaugh, Carreiro and Repert [25] have indicated that temperature plays a critical role in influencing microbial activity and decomposition rates. Higher temperatures generally promote increased microbial activity, leading to enhanced decomposition and breakdown of organic carbon. This increased microbial activity at elevated temperatures results in a more efficient conversion of organic carbon into carbon dioxide (CO_2) or other forms of inorganic carbon, ultimately leading to a decrease in TOC. Additionally, [24, 26] have shown that temperature can directly impact carbon mineralization processes. The higher the temperature, the faster the reaction rates involved in the breakdown of organic matter. This accelerated mineralization process further contributes to a reduction in TOC levels. These studies collectively support the negative correlation observed between TOC and Temperature, highlighting the influence of temperature on microbial activity, decomposition rates, and carbon mineralization processes.

pH fluctuations can directly impact nitrification rates. If the pH becomes too high (alkaline), it can inhibit nitrification, as nitrifying bacteria tend to be more sensitive to alkaline conditions. Conversely, if the pH drops too low (acidic), it can also hinder nitrification, affecting the conversion of NH_4^+ to NO_2^- and NO_3^-. Therefore, maintaining a suitable pH range is essential for promoting optimal nitrification and preventing nitrogen loss. pH fluctuations can indirectly affect nitrogen loss processes such as ammonia (NH_3) volatilization and denitrification. NH_3 volatilization occurs when NH_4^+ is converted to gaseous ammonia and is lost to the atmosphere. Higher pH levels increase the likelihood of NH_3 volatilization, especially in the form of ammonium hydroxide (NH_4OH). On the other hand, denitrification, which converts NO_3^- back into gaseous forms of nitrogen (N_2, N_2O), is favored under anaerobic conditions and can be influenced by pH changes. The strong positive correlation between NH_4^+ and pH can be explained by several factors. Firstly, NH_4^+ formation is influenced by the availability of hydrogen ions (H^+) in the solution. In an acidic environment, there is a higher concentration of hydrogen ions, which leads to increased formation of NH_4^+. This relationship between NH_4^+ and pH has been observed in various studies. For example, [27] found a positive correlation between NH_4^+ and pH in anaerobic digestion processes. Similarly, in a study by [28, 29] investigating soil nitrogen transformation, they reported a strong positive correlation between NH_4^+ and pH. Furthermore, pH affects the balance of other chemical species, such as NH_3 (ammonia), which can be converted to NH_4^+ in the presence of hydrogen ions. The equilibrium between NH_3 and NH_4^+ is pH-dependent, and as pH increases, more NH_3 is converted to NH_4^+. This further supports the positive correlation between NH_4^+ and pH. These studies collectively provide evidence for the positive relationship observed between NH_4^+ and pH, highlighting the influence of pH on NH_4^+ formation and equilibrium.

4. Conclusion

The addition of IMO in the treatment of organic waste accelerated decomposition, as evidenced by significant reductions in TOC after 44 days in both M1 and M2 treatments: 60.3% in M1, 50.4% in M2. Additionally, the gradual decrease in NO_3^- levels in M1 and M2 indicated the release of nitrogen gas. Secondly, the combination of IMO addition and continuous aeration reduced the overall decomposition time, with substantial waste material decomposition observed in the M1 treatment after approximately 15 days of incubation. Thirdly, the use of IMO effectively reduced the stench associated with waste

decomposition during the incubation process. Lastly, the liquid product obtained from the incubation process showed potential as an organic fertilizer to enrich soil and supply nutrients for plants. Overall, these findings highlight the positive effects of IMO addition on waste decomposition, including accelerated decomposition, reduced decomposition time, odor mitigation, and the production of valuable liquid fertilizer. Further research is needed to explore the broader implications of these findings on waste management and resource recovery strategies.

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