Original Article

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The Efficiency of Compost and Vermicompost Reactors for Stabilizing Organic Waste and Municipal Sewage Sludge

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ABSTRACT

BACKGROUND AND OBJECTIVE: Unsystematic waste and sewage sludge disposal is a major public health threat. Today, the use of easy, inexpensive, and natural treatment such as compost is one of the main priorities for the treatment of these materials.

METHODS: In this experimental study, organic waste samples were prepared from household waste and sludge samples were prepared from municipal sewage treatment plant. Reactors R_1 and R_2 (for compost and vermicompost, waste), and R_3 and R_4 (for compost and vermicompost, waste and sewage sludge mixtures) were selected. Waste and sludge stabilization were evaluated by some indexes such as: (C/N), (VS), (TOC) and (TC), (FC) and (TP) and (TN).

FINDINGS: The level of VS in R_1, R_2, R_3 and R_4 decreased from 89.09, 89.09, 85.29 and 85.29 to 75.58, 64.04, 62.75 and 61.22, respectively. C/N values in R_1, R_2, R_3 and R_4 reached 28.08, 22.48, 21.31, and 18.60 during the process. Fecal coliforms in R_2, R_3 and R_4 decreased by 100, 93 and 99%, respectively. The vermicompost quality in R_2 and R_4 reactors was better than other reactors, but the R_4 reactor reached this condition one week earlier.

CONCLUSION: According to the results of this study, vermicompost reactor containing organic waste and sewage sludge is well-prepared for the high rate stage of composting process. In order to achieve optimal composting conditions in accordance with valid standards, the composting stage should be included in the work plans.

KEY WORDS: *Soil, Sewage, Waste*.

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Introduction

Population growth and consumerism are among the main causes of waste and sewage sludge production in the world. Today, the systematic management of these materials including the collection, treatment and processing, disposal and reuse is the most important environmental issue in urban areas (1, 2).

According to estimates, the costs of waste management in Tehran constitute about 33% of total urban services costs (3). On the other hand, according to the existing documentations, the initial investment costs and the management of sludge treatment and disposal facilities cover more than 50% of the costs of managing sewage treatment plants (4). Currently, in many developing countries, including our country, waste management and sludge disposal from wastewater treatment plants is not efficient. More than 80% of the municipal waste is buried in the country, which do not have proper sanitary conditions according to existing studies (5, 6).

Regarding the disposal of sludge from urban wastewater treatment plants, due to the lack of a specific standard for controlling the quality of the sludge, and considering the results of studies carried out in this regard, their quality is below the expected limit in most cases. The lack of systematic management of urban wastewater and sewage sludge in Iran has led to the entry of these materials into nature in the raw and untreated form and contamination of water, soil, air and agricultural products. The major environmental challenges of these materials include the production of toxic and hazardous leachate, greenhouse gas emission, entry of heavy metals, toxic substances and penetration of carcinogens into environmental resources and health hazards caused by direct or indirect contact with these materials (7–10).

In recent years, improvements in the management of municipal wastewater and sewage sludge in developed countries, while addressing the existing health and environmental challenges, have provided the context for treatment, stabilization and beneficial use of these materials.

Today, wastewater and sewage sludge are used as biological strategic economic resources to supply organic materials such as fertilizers, biomaterials, fuel and energy sources, and soil reformers in developed countries (11, 12). In the current situation, burial as the dominant option for waste disposal in urban areas of Iran not only did not fulfil the minimum health indicators, but also wasted the opportunity to recycle and reuse the fertilizer characteristics of these materials. Studies show that about 10% of urban waste from Iran is converted into compost in existing factories. The lack of full separation of impurities, such as plastic and glass, from fertilizers produced low quality products, and most farmers are not willing to use compost in the presence of abundant and cheap chemical fertilizers in the market (6, 13, 14).

In the past 30 years, the use of chemical fertilizers has decreased by 50%, because of the long-term effects of poisoning the soil, plant and humans and their carcinogens for living organisms. However, the figures show a twofold increase in the consumption of these fertilizers during this period in Iran (15, 16).

The experience of the European countries confirms that by utilizing waste management models based on separation from the beginning, upgrading the technological level of composting plants, producing vermicompost and producing waste compost and sewage sludge, the quality of fertilizer can be increased and farmers can be encouraged to use these fertilizers. Other contributing factors include the discontinuation of imports and the reduction of fertilizer production as the main competitor of compost fertilizer (17, 18). The purpose of this study was to evaluate the efficiency of compost and vermicompost reactors in stabilizing organic waste and municipal sewage sludge.

Methods

This experimental study was carried out after approval at the Ethics Committee of Iran University of Medical Sciences (Registration Code: IR.IUMS.REC. 1394.94.01.27.25745) in a laboratory scale on raw and residual sludge samples. Organic waste in this study was obtained from household wastes. Biodegradable wastes such as plastic materials, polyethylene bags, cans, wood, cardboard, newspapers and glass were isolated. Organic wastes were fragmented by a grinder into 2-3 cm pieces. The sludge was obtained from a wastewater treatment plant in Tehran.

The initial experiments of waste and sludge: First, the characteristics of waste and sewage sludge were studied in terms of several parameters including pH, volatile solids (VS), total organic carbon (TOC), total nitrogen (TKN), ash, carbon to nitrogen ratio (C / N), total phosphorus (TP), total coliform (TC) and fecal coliform (FC). The parameters in this research were measured based on the standard methods included in the book of standard measurement method (19).

Composite and Vermicompost Reactors: In order to produce compost and vermicompost from organic waste and mixture of waste and sludge, four R1, R2, R3 and R4 reactors were made from plastic in sizes (30cm×20 cm*20 cm). First, several 10 mm pores were created at the bottom of each reactor for aeration and drainage. Then, a layer of coolant was placed to allow easier flow of air from the reactor pores along with a cloth lining to prevent the exiting of worms (in reactors containing aquatic worms) and to avoid mixture of the coolant with compounds as the first layer inside the reactors.

Loading and storage conditions for reactors:

R_1: The second layer containing the compost bed was loaded onto the first layer (coolant and lace). Then, the third layer containing the processed and crushed waste was placed on the second layer.

R_2: In terms of loading, it was quite similar to the R_1 reactor, with the exception that the second layer contained a vermicompost bed. Finally, 40 eisenia fetida worms were added to the mixture.

R_3: The difference between this reactor and the R2 reactor is that in this reactor the mixture was prepared with chopped waste and raw sludge with a ratio of 2:1.

R_4: In terms of loading, it is quite similar to the R3 reactor, with the exception that in this reactor, 40 eisenia fetida worms were added to the mixture.

All reactors were kept in laboratory and at ambient temperature after loading for five weeks. The humidity of the reactor bed was kept constant throughout the process with the aid of distilled water spray in the range of 55 to 60%.

In order to investigate the conditions for the stabilization of waste and sludge in the reactors, the reactors were sampled once a week and all the parameters measured in the waste and sludge sewage were measured. The results were calculated using the Excel software and the corresponding graphs were plotted.

Results

PH: The initial value of pH in the reactors R_1 and R_2 is about 5.5, and in the reactors R_3 and R_4 is about 6.3, and then the value of pH increased after 21 days, followed by a decreasing trend (Fig 1). The pH value of the reactor R_4 during the process has increased slightly compared with the other reactors and remained at about 7.5 – 8 from the 14th day.

ASH, TOC and VS: The percentage of initial ash in R_1, R_2, R_3 and R_4 increased after 35 days from 15.35%, 15.35%, 20.89% and 20.89%, respectively, to 28.65, 35.94%, 37.25% and 38.78%, respectively (Fig 2a). VS percentage is one of the important factors that indicate the stabilization of sludge and waste. The percentage of VS in the reactor R_1 decreased from 89.09% to 75.58%, in R_2 decreased from 89.09% to 64.06%, in R_3 decreased from 85.29% to 62.75%, and in R_4 decreased from 85.29% to 61.22% (Fig 2b). The process of organic carbon changes in reactors in R_1 decreased from 33.95% to 29.6% (14.83% reduction rate), in R_2 decreased from 23.95% to 24.65% (33.04% reduction rate), in R_3 decreased from 37.02% to 27.2% (26.52% reduction rate) and in R_4 decreased from 37.002% to 24.011% (33.7% reduction rate) (Fig 3). The percentage of TOC in all reactors has declined faster in the first week, but the slope decreased after that.

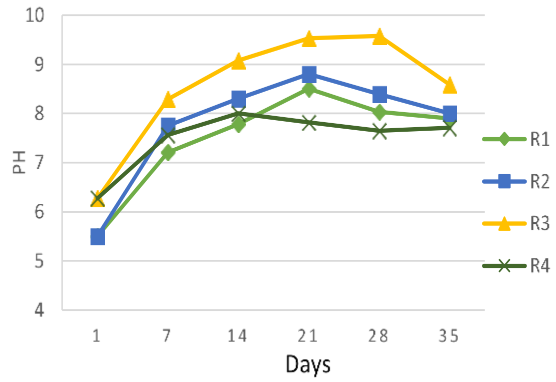

Figure 1. Percentage of pH changes during the composting and vermicomposting process in reactors R1, R2, R3 and R4

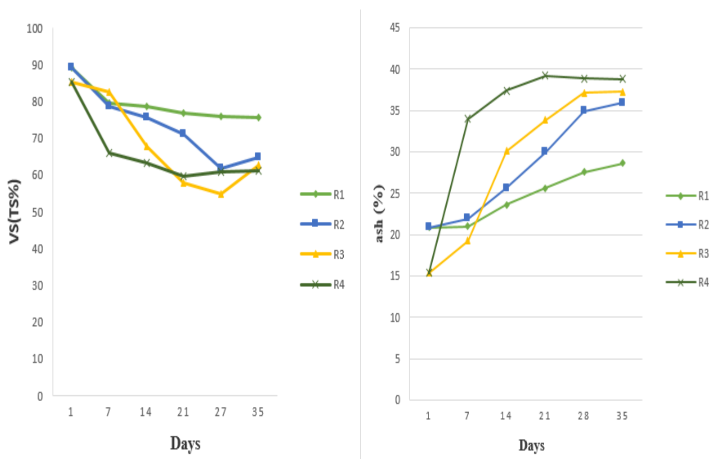

Figure 2. The percentage of changes in (a) ash and (b) volatile solids during the composting and vermicomposting process in reactors R1, R2, R3 and R4

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TN, C/N, and TP: Total nitrogen in all reactors shows an increasing trend (Fig 4a). In the present study, total nitrogen in reactors R_1, R_2, R_3, and R_4 increased respectively from 0.78% to 0.98%, from 0.605% to 1.2%, from 1.2% to 1.02%, and from 1.024% to 1.31%.

The initial value of C/N in the R_1 and R_2 was 43.53%, which was adjusted to about 30.75% by increasing the sludge to the R_3 and R_4 reactors. The initial values of C/N in the reactors R_1, R_2, R_3 and R_4 decreased to 28.08%, 22.48%, 21.31% and 18.60% during the process (Fig 4b). The initial value of TP in the reactors R_1, R_2, R_3 and R_4 was 4.8%, 4.7%, 4.6% and 3.5%, respectively, and increased to 6.1%, 8.1%, 8.5% and 8.8%, respectively, after five weeks (Fig 5).

TC, FC: Total coliform in the R_1 reactor decreased by 63%, in R_2 by 88%, in R_3 by 86%, and in R_4 by 91% (Fig 6a). Fecal coliform in the R_1, R_2, R_3, and R_4 reactors decreased by 88%, 86%, 89% and 91%, respectively (Fig 6b).

Table 1. Primary characteristics of organic sludge and waste and their mixture before composting

Parameter	Unit	Raw sludge	Waste	Mixture of waste and raw sludge
pH	-	7.59	5.5	6.27
TS	%	2.59	30.59	39.93
VS	%	89.18	79.11	30.85
TOC	%	39.55	33.95	37.03
TN	%	1.5	0.78	1.20
C/N	-	26.37	43.52	30.75
Ash	%	10.81	20.89	15.35
TP	%	9.5	8.5	8.76
MC	%	90.5	69.41	60.53
TC	MPN/g dw	1100	400	1100
FC	MPN/g dw	1100	50	1100

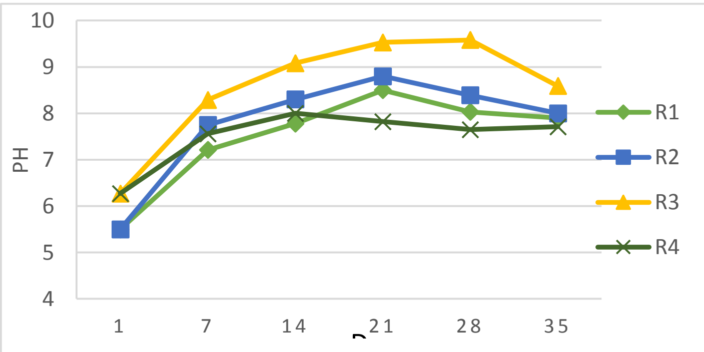

Figure 1. Percentage of pH changes during the composting and vermicomposting process in reactors R1, R2, R3 and R4

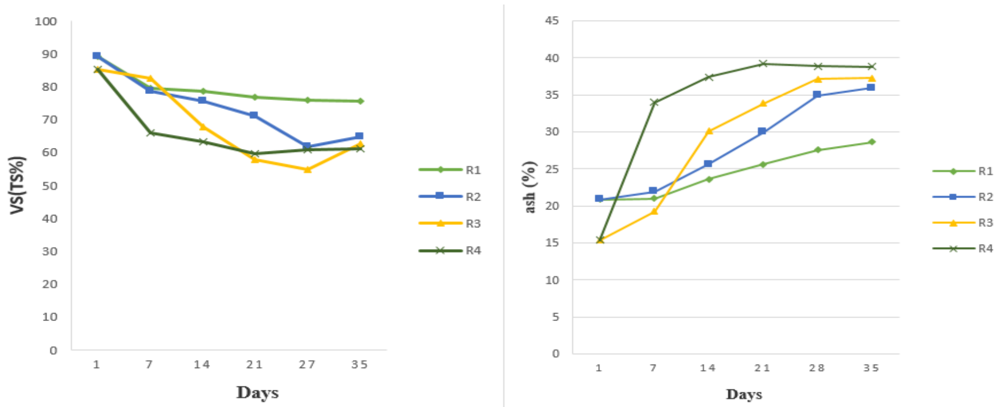

Figure 2. The percentage of changes in (a) ash and (b) volatile solids during the composting and vermicomposting process in reactors R1, R2, R3 and R4

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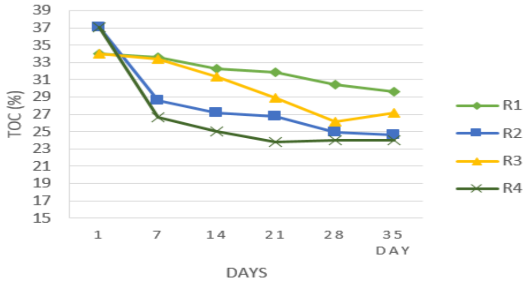

Figure 3. Percentage of total organic carbon changes during the composting and vermicomposting process in reactors R1, R2, R3 and R4

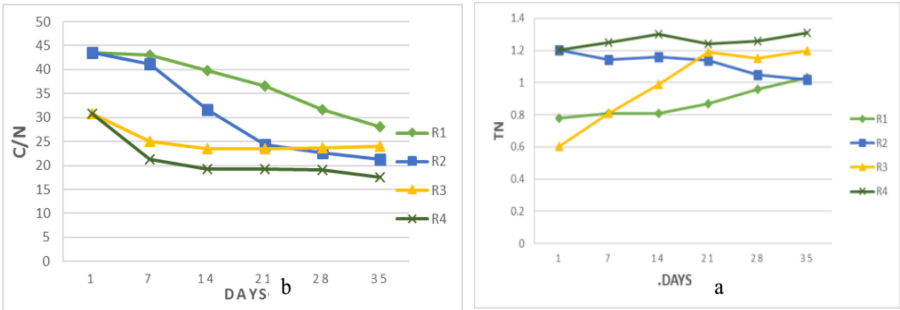

Figure 4. Percentage of changes in (a) total nitrogen and (b) carbon/nitrogen ratio during composting and vermicomposting process in reactors R1, R2, R3 and R4

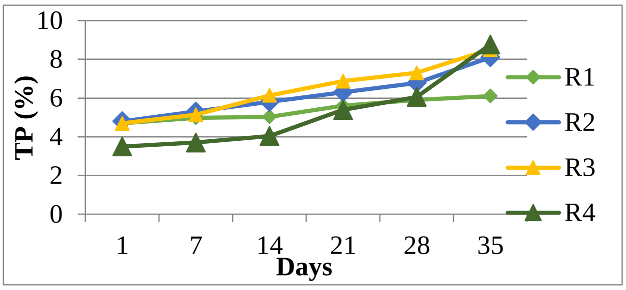

Figure 5. Percentage of total phosphorus changes during the composting and vermicomposting process in reactors R1, R2, R3 and R4

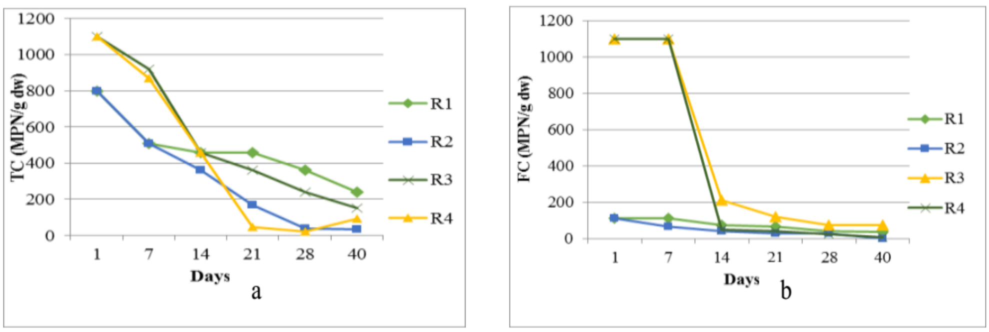

Figure 6. Percentage of changes in (a) total coliform and (b) fecal coliform during the composting and vermicomposting process in reactors R1, R2, R3 and R4

Discussion

In this study, the highest rate of VS reduction was observed in R_4 reactor (28.22%) and the lowest reduction was observed in R_1 reactor. Frederickson et al. achieved a 37% reduction in VS during the two-month vermicomposting process of garden waste, indicating desirable stabilization of garden waste. This indicates the effective activity of the eisenia fetida worms, which was exacerbated by the presence of

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germs in sewage sludge (20). Although the organic matter reduction in the reactors of this study did not reach 38% (optimal stabilization conditions), it should be noted that the reactor's residence time in this study was almost half the residence time in the study of Frederickson et al. Therefore, it can be expected that maintenance of the vermicompost reactor conditions for up to 60 days will provide optimal stabilization conditions in the R_4 reactor. The percentage of ash increase for the reactors was $R_4 > R_3 > R_2 > R_1$. These results indicate the activity of eisenia fetida worms and microbial activity in waste and sludge decomposition, which is in line with the results of Khwairakpam et al. on the recycling of sludge using vermicompost technology (21).

The results of this study showed that the percentage of TOC reduction in organic waste compost (R_1) is less than that of organic waste and active raw sludge (R_4) vermicompost. The results of a research by Suthar et al. regarding the production of compost from the urban wastewater and sewage sector by worms during two months were only 10% better than the results of this study during 35 days (22). The cause of reduced residence time in the reactor of this research (R_4) can be attributed to the optimization of the reactor driving conditions and the accumulation of germs in sewage sludge. In this study, TN is rising in R_4, indicating that the microbial population has a growing trend under appropriate growth conditions and substrate intake has been growing under the influence of metabolic activity of germs. Enrichment of excreta of worms' body with nitrogen is another way to increase nitrogen in the vermicompost reactor. The results of this study were consistent with the results of Khwairakpam, Hait, and Suthar in vermicompost waste reactors (21,23,24).

The C/N ratio is one of the important factors that indicates acceptable stabilization and maturity of compost and vermicompost. Senesi et al. showed that this ratio should be less than 20 (25). In this study, this factor reached optimal level (20>) in the R_4 reactor (vermicompost of waste and sewage sludge), 21 days after the beginning of the study, while the reactors R_1, R_2 and R_3 did not reach a satisfactory level during the 35 – day period. The difference in the ratio of C/N in the reactor R_4 compared with R_1, R_2 and R_3 confirms the role of eisenia fetida worms and the existing sludge microorganisms in the very rapid decomposition and mineralization of organic matter. The maximum increase in phosphorus is related to the reactor R_4 and the lowest reduction is related to R_1. The increasing trend of TP during the vermicomposting process was consistent with the results of Rajpal et al. on the compost of the organic part of urban solid waste and sewage by worms (1).

The reason for this is the mineralization of phosphorus content from organic matter and, to a lesser extent, the bacterial and phosphatase activity of eisenia fetida worms and the release of excess phosphorus due to the presence of phosphate – solubilizing microorganisms in the worm cyst (26). The pH value in the R_1, R_2, R_3 reactor increases until the 21st day, and decreases thereafter. While the R4 reactor has a slight increase compared to R_1, R_2 and R_3, it remains constant at pH 7.5 – 8 after 21 days. This increase may be due to the mineralization of protein substances and conversion to alkaline ammonia or loss of volatile acids (27). A study by Ndegwa et al. found results similar to the present study (28).

Reduced pH in vermicompost can be attributed to mineralization of nitrogen and phosphorus to nitrite or nitrate and phosphate. This study showed that vermicompost of a mixture of active waste and raw sludge is an effective process for stabilizing a wide range of organic matter. The results clearly show that vermicompost of the organic waste and active sludge mixture can increase the amount of plant requisites, such as nitrogen and phosphorus, and reduce the C/N ratio to acceptable levels in the shortest possible period. The vermicompost's arrival time (R_4) was one week earlier than other reactors. The results of this study clearly showed that the vermicompost waste and sewage sludge reactor is better than other reactors. However, considering the 35–day residence time in this reactor, its function to stabilize organic matter can be a rapid phase of composting process. In order to achieve optimal composting conditions in accordance with valid standards, we need more time and more steps in the process.

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