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The Effects of various enrichment treatments on the chemical characteristics of maturated vermicompost

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One of the primary constraints of vermicompost (VC) applications in the field is the requirement for relatively large quantities of VC to achieve a noticeable yield improvement. Thus, one method of increasing VC efficiency is via nutrient enrichment. In this research, we investigated variations in the chemical characteristics of VC in response to several enrichment treatments, including chemical fertilizers. The results indicated that after enrichment, all additional elements except S declined significantly. Increased pH-induced introduction of N as urea has a detrimental impact on VC quality, decreasing available P. Concurrent addition of urea, S, and P improves the quality of VC by increasing the amount of accessible P. Humic acid levels increased significantly across all enhanced treatments, whereas fulvic acid levels dropped. The analysis of the extracted humic acid revealed that enrichment increased the number of functional groups and the O/C ratio while decreasing the C/N and H/C ratios. In general, the findings indicated that supplementing VC with chemical fertilizer may be a viable option for increasing VC efficiency.

Keywords: vermicompost, nutrient enrichment, chemical fertilizers, Humic acid

INTRODUCTION

Recently, global attention is being paid to the sustainability of agricultural systems. The rising cost of chemical fertilizers, the incapability of soil nutrition to be sustainable, the deterioration of environmental health, the adverse effects on physical and chemical soil properties, and the deterioration of soil biological characteristics, such as a reduction in N_2-fixation, as a result of recurrent and extreme use of chemical fertilizers, have compelled us to reduce our reliance on chemical fertilizers and substitute them with organic and biological fertilizers (Gholamin and Khayatnezhad 2020, Karasakal, Khayatnezhad et al. 2020, Bi, Dan et al. 2021, Huang, Wang et al. 2021, Li, Mu et al. 2021)

Vermicompost is a biofertilizer that promotes plant development, is redundant, non-biased, and environmentally beneficial (Khayatnezhad and Gholamin 2020, Sun and Khayatnezhad 2021, Xu, Ouyang et al. 2021, Zhang, Khayatnezhad et al. 2021). One of the primary constraints of vermicomposting in the environment is the requirement for relatively large quantities of VC to achieve a meaningful increase in yield. Enrichment with plant nutrients is one method of increasing VC effectiveness (Aletor 2021, Barth 2021, Hewitt 2021). Numerous studies have shown that enriching organic wastes may be beneficial in establishing sustainable agriculture (Si, Gao et al. 2020, Hou, Li et al. 2021, Khayatnezhad and Gholamin 2021). Enrichment of compost with ammonium sulfate and urea as nitrogen sources was performed and increased overall nitrogen and compost efficacy (Gholamin and Khayatnezhad 2020, Jia, Khayatnezhad et al. 2020, Khayatnezhad and Gholamin 2020, Guo, She et al. 2021, Ren and Khayatnezhad 2021).

This research aimed to determine the feasibility of nutrient enrichment of VC and the impact of nutrients on VC quality parameters such as humification. The primary idea is that the chemical enrichment of VC with nutrients may enhance its quality and suitability for field applications (Gholamin and Khayatnezhad 2020, Sun, Lin et al. 2021, Zhu, Saadati et al. 2021). By determining many chemical characteristics and evaluating several of the primary and significant features of humic acid (as the primary component of humic matter), the ability of enhanced VC to be applied efficiently was assessed.

MATERIALS AND METHODS

2.1. Vermicompost production

VC was produced in the presence of the composter worm Eisenia fetida from cow dung during a four-month timeframe in Mazrae Nemuneh, Humand Absard, Iran. For this reason, cow manure was first put in plastic containers (0.2 m W, 0.15 cm H, and 30cm L) and left in the laboratory for four months. After extensive watering and leachate treatment, each plastic container was introduced with fifty adult E. fetida. The moisture level of the containers was about 50%-60% during the vermicomposting phase, and daily irrigation was used to sustain the moisture levels. After the procedure, earthworms were removed from the finished product (VC), and the resulting VC was tested for the properties described before (Ma, Khayatnezhad et al. 2021). Table 1 summarizes the properties of vermicompost.

2.2. Experimental design

A 60-day investigation was performed using a fully randomized design with three replications to determine the impact of enrichment on the quality of VC. In this research, we tried to utilize the most critical necessary nutrients that are most often used in agriculture. Five treatments were chosen for this purpose:

VA: VC without enriching (control)

VN: VC + 1% nitrogen (as urea)

VS: VC + 1% elemental sulfur (elemental sulfur)

VP: VC + 1% phosphorous (as superphosphate triple)

VE: VC + 1% nitrogen + 1% elemental sulfur + 1% phosphorous

All procedures were moistened with distilled water to a retention capacity of 60%. After 60 days of incubation at 28 ° c temperature, samples were examined for chemical features of enhanced VC treatments at 0, 20, 40, and 60 days.

2.3. Chemical analyses

Chemical characteristics of treatments were determined in three replications using the following techniques: soluble sulfate according to Bardsley and Lancaster (1960), total N according to Kjeldahl, available p according to Olsen, organic carbon according to Walkley-Black, and pH according to a pH meter in saturated extract.

The HA was extracted using 0.5 M NaOH as reported in (Qi, Aldrich et al. 2004); in short, 20g of air-dried vermicompost samples were combined with 200 ml of 0.5 M NaOH under N_2 at a ratio of 1/10 (w/v) vermicompost/solution. Prior to centrifugation, samples were shaken at 150 rpm for 18 hours. After allowing the treated slurry to remain for 1, 7, and 9 days at room temperature in the dark, the supernatant was extracted using centrifugation at 10,000 rpm. The supernatant was acidified with HCI for 6 minutes at a pH of 1.17–1.50 to isolate the humic acids from an alkaline suspension comprising humic and fulvic acids. The precipitated humic acids were then filtered with HCl/HF 0.1/0.3 M, rinsed with distilled water until the pH of the H+-exchanged soil was 4–5, and lastly dried at temperatures less than 50 C°. As per Carter and Gregorich, fulvic acid was measured using the alkali technique (2006). The following values were used to calculate the humification ratio (HR) and humification index (HI) (Amir, Benlboukht et al. 2008):

$$HR = [(HA + FA)/TOC] \times 100.$$
$$HI = (HA/TOC) \times 100.$$
$$Degree\ of\ polymerization = HA/FA.$$

The current research investigated the major chemical characteristics of humic acid, the most abundant component of humic matter, in enhanced VC and reported the findings.

C, H, N, and S were used to determine the elemental composition using a piece of analyzer equipment (Elementar Analysen System GmbH Vario EL). Oxygen was estimated using the following formula:

$$O\% = 100 - (\%C + \%H + \%N + \%S)$$

The ash content was calculated as a proportion of dry solid weight after six hours of burning in the air at 660 C°.

The total acidity and carboxylic groups (COOH) content were determined using the standard techniques given by (Huma, Lin et al. 2021, Kabir, Arefin et al. 2021). The phenolic-OH group content was estimated using the difference between the two results. All of these analyses were carried out in three replicates.

2.4. Statistical analysis

To determine the significance of the difference between treatments, Tow way analysis of variance (ANOVA) was performed, followed by Tukey's posthoc testing. $P<0.05$ was chosen as the threshold of statistical significance.

RESULTS AND DISCUSSION

During incubation, enriched nutrients undergo significant modifications. When VS and VE were incubated with elemental sulfur, the amount of accessible sulfur rose with the length of the incubation (Table 2). To make sulfur accessible via sulfate conversion, the following conditions must exist moisture, organic matter, and sulfur-oxidizing bacteria (Power and Prasad 1997, Gholamin and Khayatnezhad 2020, Ma, Ji et al. 2021). These conditions were maintained throughout incubation, and available S was increased. Still, the rise in VE was greater than that of other procedures, which may be ascribed to an increase in biological activities (Table 2).

During incubation, the total amount of organic carbon dropped in all treatments. VE has the greatest reduction in organic carbon content, whereas VA has the least (Fig. 1). The decrease in organic carbon throughout the enrichment process was due to increased bacterial activity and respiration, suggesting that organic matter is humified and stabilized when incubation time is extended (Huang, Wang et al. 2021, Radmanesh 2021, Rodríguez 2021). Organic carbon concentration dropped quickly as incubation time rose, which may be attributed to an increase in the microbial population.

VS had the lowest pH value, which may be ascribed to the reduction and oxidation of S throughout incubation (formation of H_2S and SO_4^{2-}), which culminated in the formation of H+ and a decreased pH value in this treatment (Druschel, Hamers et al. 2003, Gholamin and Khayatnezhad 2021). VN's greatest pH was found, indicating that urea was transformed to ammonium carbonate during incubation, then hydrolyzed and changed into ammonium bicarbonate, ammonium, and ammonium hydroxide in an increase in pH in this treatment (Adamtey, Cofie et al. 2009). Additionally, pH dropped in VP throughout incubation, perhaps due to increased microbial population and organic acid generation. VE supplemented with S and urea exhibits minimal change in pH; it is possible that urea and elemental S counteracted each other's effects during incubation. In all cases, increasing the temperature lowered the pH. (Fig 2).

The current research found that increasing the incubation time increased the quantity of humic acid while decreasing the amount of fulvic acid. The highest and lowest concentrations of humic and fulvic acid were found in VE and VA (control). Since VE had lost a larger proportion of organic matter and, according to Veeken, Nierop et al. (2000), potentially transformed to more stable matter, this treatment had the greatest concentration of humic acid and the lowest concentration of fulvic acid (Table 3). Fulvic acid's greater degradability than humic acid may account for the decline in fulvic acid over the last weeks (Khayatnezhad and Nasehi 2021, Tao, Cui et al. 2021). Increased temperature has a negligible effect on the quantity of humic acid in treatments, whereas it has a negligible effect on the amount of fulvic acid (Table 3).

The polymerization ratio denotes how more complex molecules (HA) are formed from simpler ones (FA). This statistic is sometimes referred to as the maturity index (Sánchez–Monedero, Roig et al. 1999). The results indicated that this ratio increased throughout the vermicomposting process, with VE having the highest values and VA (control) having the lowest. The other indices (HR and HI) reflect the VC maturity ratio, and as shown in Table 3, VE has the greatest values during vermicomposting, whereas VA (control) has the lowest values.

Elemental examination of humic acid, a proxy for humic matter, revealed that VE produces more alterations than other treatments. Carbon and hydrogen concentrations were reduced by about 6% and 14% in all treatments, respectively, as seen in Table 4. Nitrogen and sulfur concentrations rose by 3 and 13% in all treatments, respectively, which may be attributed to increased these nutrients during vermicomposting (Amir, Jouraiphy et al. 2010, Khayatnezhad and Gholamin 2021). It is stated that as the length of vermicomposting grew, certain chemicals formed in the humic matter, increasing the nitrogen content of the humic matter structure (Amir, Jouraiphy et al. 2010). The C/N ratio of humic matter decreased significantly after vermicomposting, and the reduction was much higher for VE. After vermicomposting, oxygen levels rose significantly, and the O/C ratio increased by 15%. This may result from the active breakdown of aliphatic molecules and peptide structures and the production of oxidized humic structures (Peng, Khayatnezhad et al. 2021, Yin, Khayatnezhad et al. 2021). The H/C ratio dropped during vermicomposting, suggesting that aromatic chemicals increased and aliphatic compounds decreased (Karasakal, Khayatnezhad et al. 2020). As time passed, humification intensified; carbon levels dropped significantly, while other metrics remained rather stable.

Table 5 summarizes the results of the analysis of extracted humic acid samples. Enriched VC substantially enhanced the functional groups in humic acid, which may be attributed to the resulting humic acid's improved activity, stability, and efficiency (Tan 2003, Cheng, Hong et al. 2021, Wang, Shang et al. 2021, Zheng, Zhao et al. 2021, Zhu, Liu et al. 2021). In the current research, raising the temperature had no discernible impact on the changes in functional groups.

Table 1: Initial vermicompost (VC) properties

pH	EC (dSm^{-1})	Total N (%)	OC (%)	P (%)	K (%)	Na (%)	Fe (%)	Ca (%)	C/N
7.63	2.14	1.2	24.37	0.82	6.52	1.10	0.57	8.5	20.3

Table 2: Nitrogen and phosphorous and sulfur content (%) of VC across experimental treatments

Treatments ^{a}	**N**	**S**	**P**			
	Start	End	Start	End	Start	End
VA	1.20^{b}	1.23^{b}	1.94^{b}	1.942^{c}	0.82^{b}	0.81^{c}
VN	2.20^{a}	2.10^{a}	1.94^{b}	1.933^{c}	0.82^{b}	0.77^{d}
VS	1.20^{b}	1.15^{c}	2.12^{a}	2.557^{b}	0.82^{b}	0.88^{b}
VP	1.20^{b}	1.17^{c}	1.94^{b}	1.942^{c}	1.25^{a}	1.16^{a}
VE	2.20^{a}	2.09^{a}	2.12^{a}	2.652^{a}	1.25^{a}	1.14^{a}
C.V.	1.62	1.302	0.76	0.32	1.15	1.71
SEM±	0.015	0.012	0.009	0.004	0.006	0.010

Means differ if they have a different letter at: lower case superscript (a, b, c…) for comparison of treatments (ANOVA; Tukey's test, P<0.05)
a for treatment description see text.

Table 3: HA, FA contents and HA/FA, HR and HI values of the VC across treatments through time

Treatments ^{a}	HA (%)		FA (%)		HA/FA		HR		HI	
	Start	End	Start	End	Start	End	Start	End	Start	End
VA	5.17^{c}	5.53^{e}	3.59^{b}	3.35^{b}	1.44^{c}	1.65^{e}	35.93^{c}	39.38^{e}	21.21^{c}	24.52^{e}
VN	5.78^{a}	7.30^{b}	3.89^{a}	3.51^{a}	1.48^{a}	2.08^{c}	39.68^{a}	48.65^{b}	23.71^{a}	32.84^{b}
VS	5.04^{d}	5.77^{d}	3.52^{b}	2.80^{cd}	1.43^{d}	2.06^{d}	35.13^{d}	38.95^{d}	20.68^{d}	26.21^{d}
VP	5.17^{c}	6.40^{c}	3.59^{b}	2.92^{c}	1.44^{c}	2.20^{b}	35.93^{c}	42.24^{c}	21.21^{c}	29.02^{c}
VE	5.23^{b}	8.41^{a}	3.62^{b}	2.74^{d}	1.45^{b}	3.07^{a}	36.29^{b}	51.23^{a}	21.46^{b}	39.50^{a}
C.V.	0.32	0.87	1.64	2.77	0.09	0.98	0.29	1.30	0.67	1.49
SEM±	0.010	0.034	0.035	0.05	0.001	0.013	0.06	0.34	0.08	0.27

Means differ if they have a different letter at: lower case superscript (a, b, c…) for comparison of treatments (ANOVA; Tukey's test, P<0.05)
a for treatment description see text.

Table 4: elemental analysis of HA across treatments through time

Treatments[a]	C	H	N	S	O	Atomic ratios		
						C/N	H/C	O/C
Initial								
VA	50.6[a]	6.3[b]	4.8[c]	0.3[b]	37.9[b]	12.34[b]	1.50[a]	0.56[b]
VN	50.2[c]	6.4[a]	6.3[b]	0.3[b]	36.8[d]	9.39[c]	1.54[a]	0.55[c]
VS	50.5[a]	6.3[b]	4.8[c]	0.6[a]	37.7[c]	12.37[ab]	1.51[a]	0.56[b]
VP	50.3[bc]	6.4[a]	4.8[c]	0.6[b]	38.1[a]	12.40[a]	1.52[a]	0.57[a]
VE	50.4[b]	6.3[b]	6.5[a]	0.3[a]	36.1[e]	9.15[d]	1.51[a]	0.54[d]
C.V.	0.16	0.89	0.14	3.47	0.07	0.28	3.22	0.25
SEM±	0.047	0.033	0.004	0.009	0.015	0.018	0.028	0.001
Final								
VA	49.1[a]	5.7[a]	4.9[d]	0.4[b]	39.9[d]	11.73[a]	1.41[a]	0.61[c]
VN	48.2[b]	5.7[a]	6.4[b]	0.4[b]	39.2[e]	8.85[c]	1.42[a]	0.61[c]
VS	47.2[d]	5.4[b]	5.0[cd]	0.7[a]	41.7[a]	11.21[b]	1.38[a]	0.66[b]
VP	47.9[c]	5.4[b]	5.1[c]	0.4[b]	41.1[c]	11.10[b]	1.37[a]	0.64[b]
VE	45.9[e]	5.2[c]	6.8[a]	0.7[a]	41.4[b]	7.91[d]	1.36[a]	0.68[a]
C.V.	0.21	0.78	1.43	1.90	0.11	0.53	2.50	1.98
SEM±	0.058	0.025	0.046	0.006	0.027	0.031	0.021	0.007

Means differ if they have a different letter at: lower case superscript (a, b, c…) for comparison of treatments (ANOVA; Tukey's test, P<0.05)
a for treatment description see text.

Table 5: Acidic functional groups (total acidity, carboxylic and phenolic-OH groups) contents of the studied HA (mmol g−1)

Treatments [a]	Total acidity		carboxylic groups		phenolic-OH group	
	Start	End	Start	End	Start	End
VA	4.53[c]	5.67[e]	2.73[b]	3.41[c]	1.80[c]	2.25[d]
VN	4.86[a]	6.32[c]	2.92[a]	3.22[d]	1.93[a]	3.09[a]
VS	4.65[b]	6.51[b]	2.80[b]	3.92[b]	1.85[b]	2.59[c]
VP	4.56[c]	6.11[d]	2.75[b]	3.94[b]	1.81[c]	2.17[e]
VE	4.54[c]	6.81[a]	2.73[b]	4.10[a]	1.81[c]	2.71[b]
C.V.	0.54	0.93	1.77	1.29	0.82	0.58
SEM±	0.015	0.034	0.028	0.028	0.009	0.009

Means differ if they have a different letter at: lower case superscript (a, b, c…) for comparison of treatments (ANOVA; Tukey's test, P<0.05)
a for treatment description see text.

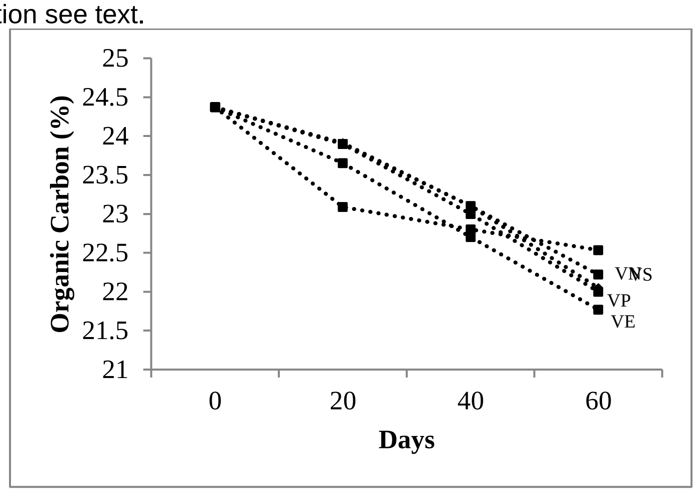

Figure 1: Organic carbon content in VC in different enriching treatments through time

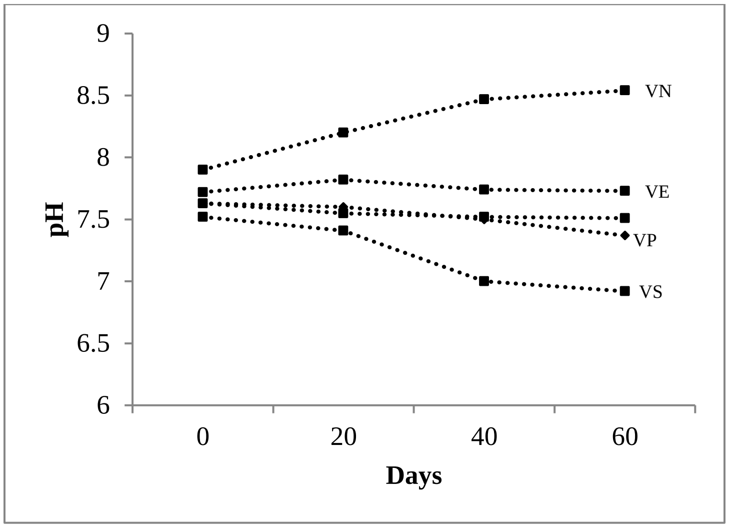

Figure 2: pH of VC in different enriching treatments through time

CONCLUSION

The length of incubation is a critical factor in VC enrichment. Our and other studies have shown that 45 to 60 days at 28 ° c. is adequate to produce biased chemical characteristics in VC. Chemical fertilizer enrichment enhanced the grade of VC. The enrichment procedure has shown that VC is an ideal carrier and bed for improving additional nutrients' bioavailability and absorption capacity. This implies that supplementing VC with chemical fertilizer may increase VC efficiency while decreasing VC application rates in soils.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Masoud Radmanesh conducted, planned, Analyzed the data, wrote manuscript and interpreted the results and involved in manuscript preparation. All authors read and approved the final version.

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