OPTIMUM MOISTURE REQUIREMENT DURING VERMICOMPOSTING USING PERIONYX EXCAVATUS

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Abstract. A study was conducted to evaluate the ash content as a function of time of vermicomposting and the moisture content which plays a significant role in the process. The data revealed a linear relationship between the ash content and time in the effective range of the vermicomposting duration. The model parameters of this linear relationship also have linear correlation with the moisture content. Through substitutions, a generalized predictive model for the ash content has been evolved in terms of the duration of vermicomposting and the moistures contents. A plot of the predictive and experimentally observed values indicated a high robustness of predictive model. The study also showed that a moisture content of 80% is optimum for stabilization of waste in minimum processing time.
Keywords: *earthworm, ash content, moisture content, waste management, modeling*

Introduction

Vermiculture technology is emerging as a potential alternative for organic solid waste management. It is an attractive and economical recycling process for treatment of non-toxic organic solid wastes as little capital and energy is needed for the process. Moreover, the waste is converted into vermicasting (vermicompost), a manure rich in plant nutrient [2, 3, 13, 24, 25] to be used in agriculture and horticulture.

Advancement in vermiculture technology requires a detailed understanding of functioning of the system. There are still many fundamental aspects, which need to be studied for the success of vermicomposting process. There is abundant literature available on the response of earthworms in the stabilization of organic wastes but not much literature is available on the effect of moisture content on vermicomposting. In this paper, the effect of moisture content variation using epigeic (surface burrowing) earthworm (*Perionyx excavatus*, Perrier, 1872, family: Megascolecidae) to predict optimum moisture requirement during vermicomposting is investigated.

Review of Literature

Grant [8] reported that water constitutes 75-90% of the body weight of earthworms. Therefore, prevention of water loss is essentially required for survival of earthworms. Nevertheless, they have considerable ability to survive adverse moisture conditions; if they can not avoid dry soil they can survive with the loss of a large part of total water content of their bodies [5]. *Lumbricus terrestris* can lose 70% and *Allolobophora chlorotica* 75% of their total body water and survive [22]. Gerrard [7] reported that some species can withstand dry conditions better than others. Olson [20] reported that the largest numbers of earthworms occurred in soils containing moisture between 12% and 30%. Duweini and Ghabbour [4] reported that in soils with 5-85% gravel and sand, an increase in moisture content from 15% to 34% was usually associated with an increase in numbers, but above 34% extra moisture had no effect. Madge [16] reported that soil with a moisture content of about 23.3% appeared to be optimum for earthworms to produce casts.

Viljoen and Reinecke [26] reported that moisture level of 80% was most favorable for *Eisenia eugeuiae* in waste management. Edwards and Bater [6] reported that optimum moisture content for growth of *E. fetida*, *Dendrobaena veneta*, *E. eugeniae* and *P. excavatus* was 85% in organic waste management. Muyima et a1. [19] reported that optimum moisture content for growth and maturation of *D. veneta* in waste management was 75%.

Materials and Methods

All the experiments were performed out in truncated porous earthen pots of approximately 8-liter capacity. The pots were initially filled to a 2.5 cm height with 12.5 mm nominal size chips of stone (aggregates), which was then covered with 2.5 cm thick layer of 1-5 mm size gravel to ensure proper drainage of excess water. A layer of local soil mixed with cow dung humus in 1:1 ratio of 2.5 cm thickness was used above the gravel bed to provide natural habitat to the earthworms. The experimental pots were kept in the laboratory.

Mixed vegetable residues (organic waste) collected from hostel kitchen were vermicomposted with 40 local adult (clitellate) epigeic earthworms (*Perionyx excavatus*) for the purpose of vermicomposting. The earthworms were introduced to prepared pots one day prior to feeding of waste into the pots. This was done with a view that earthworms could acclimatize into the new environment and settle themselves in the new habitat. The organic waste (substrate) having initial moisture content 78% was then top feeded (10 cm thickness) into different experimental pots. The pots were maintained at varying moisture content of 40%, 50%, 60%, 70%, 80% and 90% respectively to ensure the effect of the moisture content variation. Assessment of maintaining stated moisture content was done by several trials before starting the actual experimentation. The amount and interval of water sprinkling required to maintain the desired moisture content were obtained thereby.

A control (of 10 cm waste thickness) was maintained without earthworms at 70% moisture level. The substrate thickness was restricted to 10 cm to ensure the maintenance of aerobic condition. All the experiments were performed in replicates. Regular water sprinkling was done in all the experimental pots including in the control pot in such a way as to ensuring the maintenance of approximately 40%, 50%, 60%, 70%, 80% and

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90% moisture level, to account for the loss of water due to evaporation and drainage. Water sprinkling in different pots, except for 80% and 90%, was started after they attained the said moisture level. The experiment was carried out till 45 days. The substrate samples were drawn on 3 days interval up to 30 days and thereafter 5 days interval up to 45 days from all the experimental pots. Moisture analysis was carried out by drying the samples in a hot air oven at 105 °C for 24 hours. Ash content was determined by heating the moisture-free samples in a muffle furnace at 550 °C for 4 hours. The percent ash content on dry basis was computed and sample mean was used for analysis.

Results

The observed values of ash content (dry basis) for control of the substrate having varying moisture contents of 70% in the control (i.e., without earthworms), and 40%, 50%, 60% 70%, 80% and 90% with 40 number of initial earthworms in each test run are presented in *Table 1.*

Table 1. *Variation of Ash content (% dry basis) with different moisture contents during Vermicomposting.*

Day	Moisture Content						
	Control (70%)	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**
0	13.2	13.2	13.2	13.2	13.2	13.2	13.2
3	14	13.8	13.8	13.9	14	14	14
6	14.7	14.7	14.7	14.9	15.1	15.2	14.8
9	16.8	16.2	16.8	17.6	17.7	17.8	17.4
12	18.9	18.5	18.7	19.4	19.8	20.2	19.4
15	22.1	19.8	20.3	22.1	22.7	23.2	21.6
18	24.8	21.3	22.4	24.9	26.2	27.2	24
21	26.1	23.2	24.6	27.8	29.8	30.7	26.2
24	29.2	25	25.8	30.6	33.5	34.6	28.6
27	31.9	26.8	27.3	33.8	36.7	38.9	33.4
30	34.2	28.2	29.7	34.9	40.2	42.8	37.2
35	36.7	30.1	31.9	38.4	44.1	46.7	40.1
40	39.6	33.1	34.9	43.6	49.6	50	43.6
45	41.8	37.1	39.2	48.7	51.2	51.6	46.7

Analysis

The ash content (α) variations with respect to time (T) of stabilization (9 to 35 days only) values are plotted as follows (*Fig. 1*).

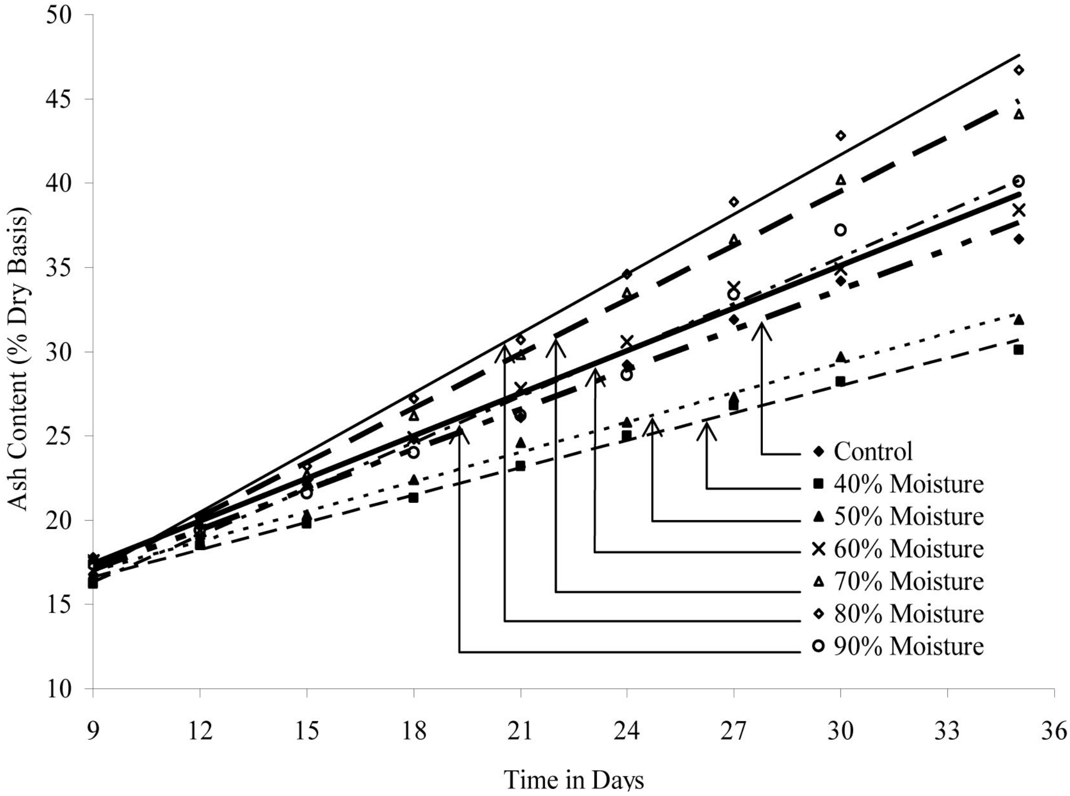

Figure 1. *Variation of ash content with different moisture contents during vermicomposting.*

It may be noted that the α values of initial phase of vermicomposting were left out as there was negligible increase in the ash content manifesting a lag phase and acclimatization stage. Similarly, α values beyond 35 days were left out as the ash content (the measure of degradation) tended to be stabilized depicting not so significant rate of increase. Therefore, data set corresponding to 9^{th} to 35^{th} day was used for modeling purposes, and to establish a possible correlation between α and T. The lines of best linear fits (using least square regression technique) in respect of each of the various moisture contents are also shown (*Fig. 1*). All the stated curves follow linear relationships shown in Eq. 1 having R^2 values of 0.993, 0.9946, 0.963, 0.9924, 0.9959, 0.9948 and 0.9841 respectively for the control (without earthworms at 70% moisture content), 40%, 50%, 60%, 70%, 80% and 90% moisture contents sets.

$$\alpha = mT + c \qquad \text{(Eq. 1)}$$

In Eq. 1, m and c are model parameters. The values of the model parameters m and c for all the treatments are presented in *Table 2.*

Table 2. Model parameters m and c variation with respect to different moisture contents.

Moisture content	Model parameter	
	m	c
Control (70%)	0.7918	9.9401
40%	0.5425	11.72
50%	0.5881	11.687
60%	0.8414	9.865
70%	1.0723	7.3205
80%	1.1788	6.3282
90%	0.9168	8.0889

The values of m and c (excluding the data for the control, 40% and 90% moisture content runs), when regressed (using least square regression technique) with respect to the moisture content (w as percentage) also followed linear trends as shown in following figures (*Fig. 2 and Fig. 3*).

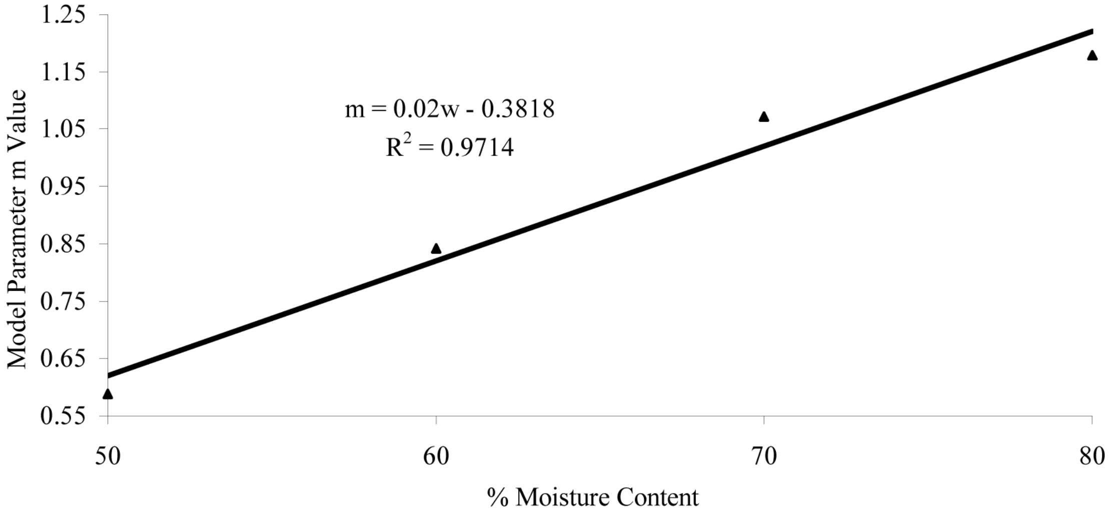

Figure 2. Model parameter m variation with respect to moisture content.

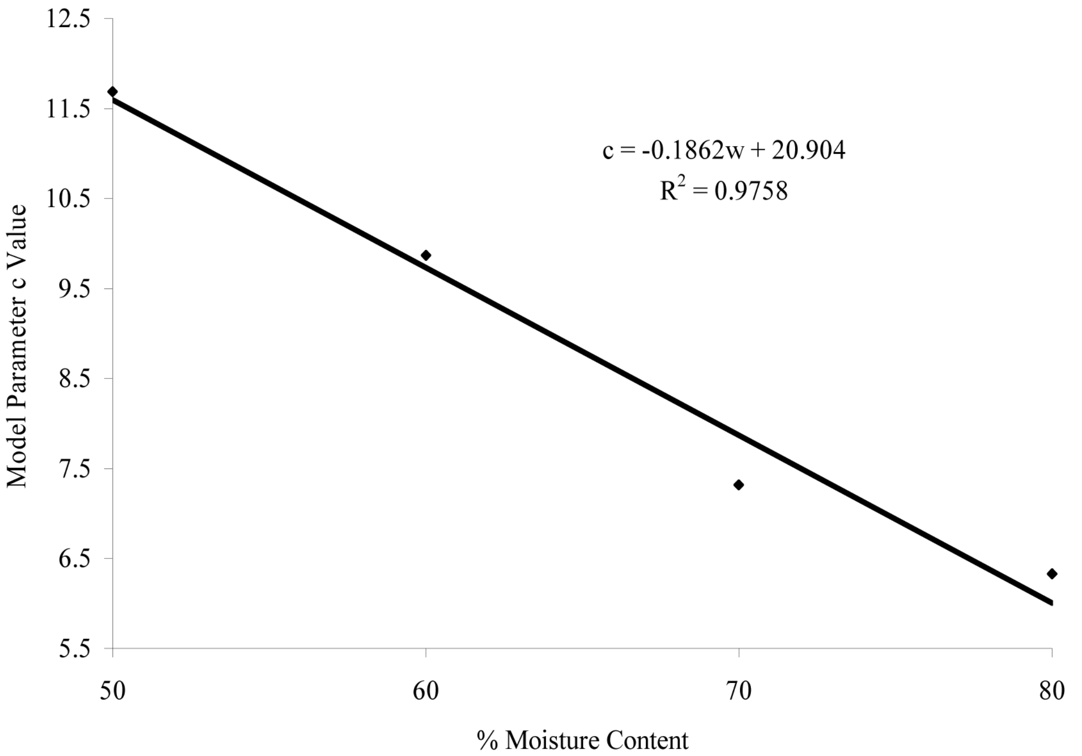

Figure 3. *Model parameter c variation with respect to moisture content.*

The reasons for excluding the control, 40% and 90% values were that the control run was without any earthworms and the 40% moisture content experimental set showed almost negligible earthworm activity while the substrate having 90% moisture content turned anaerobic. The respective expressions are shown in Eq. 2 and Eq. 3:

$$m = 0.02\ w - 0.3818\ (R^2 = 0.9714) \qquad \text{(Eq. 2)}$$

$$c = -\ 0.1862\ w + 20.904\ (R^2 = 0.9758) \qquad \text{(Eq. 3)}$$

By substitution of the m and c values shown respectively in Eq. 2 and 3 in Eq. 1, a generalized model for α as a function of time and moisture content is obtained as shown in Eq. 4:

$$\alpha = (0.02w - 0.3818)\ T - 0.1862w + 20.904 \qquad \text{(Eq. 4)}$$

The proposed model for predicting α (using Eq 4) at different times of vermicomposting and for various values of the moisture content can be useful in predicting the ash content or the degree of stabilization (at around 45% ash content, almost complete degradation was achieved).

On the basis of the above stated generalized and predictive model, the ash content values were computed for comparison with the observed experimental values. The α computed deviated by about 3% from the experimentally observed values. α (experimental) and α (computed) values are plotted as a scatter diagram (*Fig. 4*).

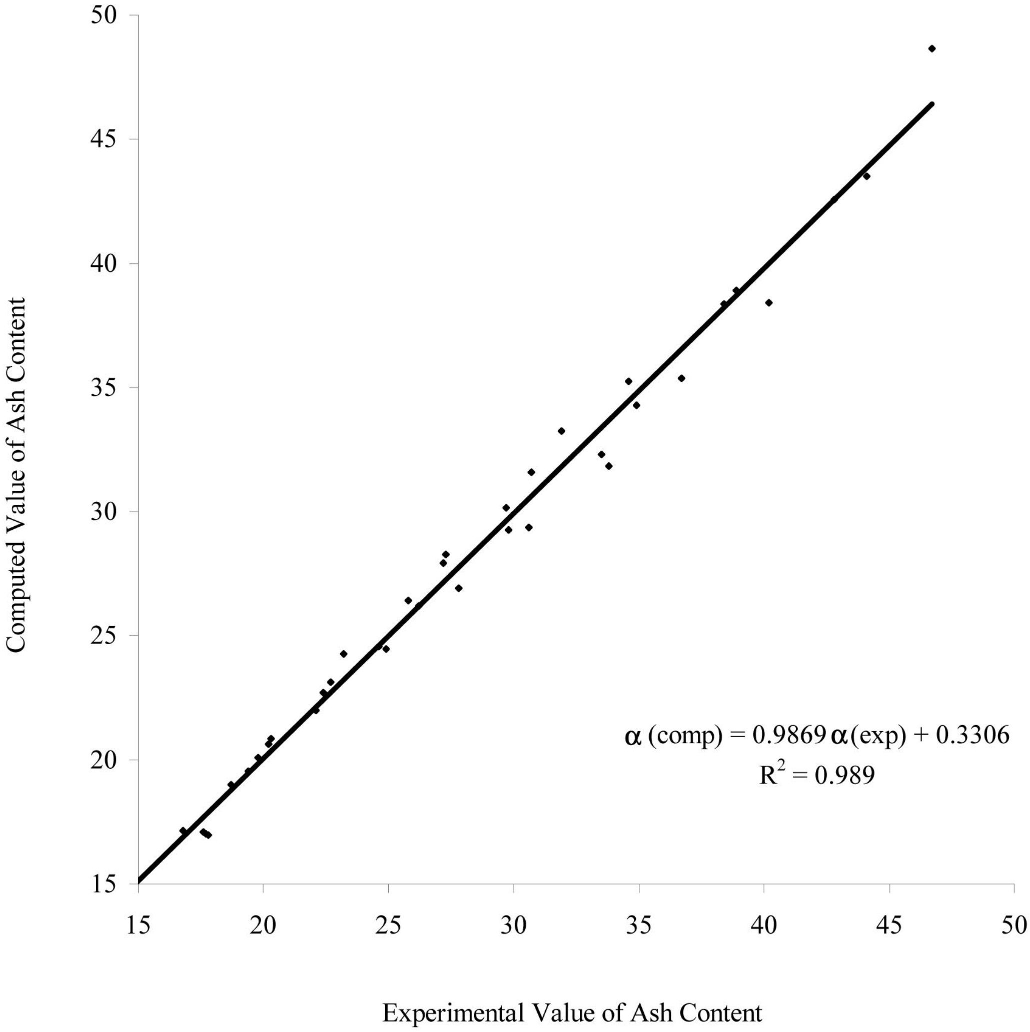

Figure 4. *Comparison of computed and observed data of ash content with different moisture contents.*

Using the least square regression technique, it yielded into a linear fit having a R^2 value of 0.989, which not only validated the proposed universalized model, but manifested the robustness of the presented predictive model shown in Eq. 4.

Discussion

The ash content of the substrate during vermicomposting was measured with a view to assess the degree of substrate stabilization as has been reported to be a good indicator of degradation and mineralization [12, 14, 17, 25]. Ash content increased slightly up to 6 days of vermicomposting in all the above stated runs. This is probably due to the acclimatizing effect. The increase in the ash content was observed to be faster thereafter, which can be ascribed to increased microbial activity after a lag phase (representing the acclimatizing phase) of the microbial growth [18]. The faster rate of increase in ash content can also be the result of faster consumption of substrate by earthworms due to an increased palatability of waste after initial decomposition [5]. Faster rate of increase in ash content indicated the higher rate of volatilization, which is a good measure of degradation of the organic waste. The experimental set having 90% moisture content turned anaerobic on 12th day of vermicomposting. The probable reason of anaerobicity can be the presence of excess water which restricted the air movement through the available pore spaces in the substrate. The development of anaerobic conditions [15, 23] and leachate production [11] in high moisture levels during aerobic composting have also been reported earlier. The ash content increased with the increasing moisture content (40% to 80% range). However, the rate of ashing in the substrate having 90% moisture was observed to be slower as compared to the substrates having 60%, 70% and 80% moisture contents. This lower rate of increase in ash content however, is attributed to negligible earthworm activity due to anaerobicity. The observation does not therefore match with the findings of Edwards and Bater [6] who have recommended moisture content up to 90% for use in waste management using *E. fetida.*

Similarly, the substrate having 40% moisture content showed minimum increase is ash content, which can be the result of less earthworm and microbial activity due to lesser moisture content as the earthworms also restricted their activity and kept themselves within the bedding. They were not seen inside the substrate, processing the waste during entire period of observations, while in other experimental sets they were seen inside the substrate, processing the waste during sampling and water sprinkling. The earthworms require sufficient level of moisture for normal activities as also, the water constitutes 75 to 90% of their body weight [8]. This may be the reason for keeping themselves in the bedding. Decreased microbial activity in lesser moisture content has also been reported during aerobic composting [11, 23].

The substrate having 40% and 50% moisture content showed very slow decomposition (as depicted from the values of ash content at different periods). Even after 45 days of vermicomposting, the degradation process of the waste continued in them. In contrast, the control (i.e. without earthworms at 70% moisture content) showed faster rate of mineralization (as manifested from the ash content) when compared to substrates having 40% and 50% moisture contents. The lesser increase in ash content and simultaneously, lesser decomposition can be ascribed to lesser assimilation by microbial population as well as due to lesser palatability of the substrate to earthworms.

The substrates having 70% and 80% moisture content showed faster increase in ash content and depicted the higher rate of volatilization/degradation. However, substrate having 80% moisture content showed fastest rate of volatilization and simultaneous four fold (approximately) increase in ash content from 13.2% to 51.6%. Six folds increase [10]; three and half folds increase [25]; two folds increase [14]; and two folds increase [1] have already been reported during vermicomposting. Further, almost complete degradation was observed in 35 days of vermicomposting resulting in 44.1% and 46.7% ash content in the substrates having 70% and 80% moisture contents respectively. This indicates the need of maintaining sufficient level of moisture content during vermicomposting. It is thus depicted that approximately 80% moisture is optimum for quicker stabilization of the organic solid wastes using *P. excavatus.* Similar results have been reported by different workers using different epigeic earthworm species in waste management [6, 9, 19, 21, 26, 27].

The study reveals that the ash content is greatly influenced by the moisture content of the substrate and varies with time. The predictive model expressing the ash content as a

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function of the moisture content and the time of vermicomposting can be used for determining the processing time to achieve the desired level of ash content at specific moisture content. The model's predictive values of the ash content are within about 3% of the observed values. The model thus fully justifies it robustness.

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