

The Influence of Temperature, pH and C/N Ratio on the Growth and Survival of Earthworms in Municipal Solid Waste

Hou Jicong¹, Qiao Yanyun², Liu Guangqing¹, Renjie Dong^{1*}

¹ College of Water Conservancy and Civil Engineering, China Agricultural University.
Address: 184#, 17 Qinghua Donglu Rd., Beijing, 100083, P.R.China. Email:
rjdong@cau.edu.cn

²Harbin University of Science and Technology

ABSTRACT

Earthworms can be used to treat solid organic waste. Many studies have reported the effect of temperature, moisture, and pH value on the growth, reproduction, and survival of earthworms in manure. A study of the influence of these parameters on the growth and survival of earthworms in municipal solid waste is presented in this paper.

The growth and mortality of earthworms in municipal solid waste with different temperatures (15, 20, 25 degrees C) was studied for 70 days, with different pH values (5.1, 5.4, 6.5, 7.2, 8.6) for one day, and with different C/N ratios (26, 24, 22, 20, 17, 15) for 15 days.

The following conclusions have been made:

1. The shortest growth period was 52 days at 25 degrees C, and the fastest growth rate was 0.0138 g per day.
2. A correlation between the growth rate and feed-conversion rate was determined. The largest weight-gain rate and feed-conversion rate at 19.7 and 21.9 degrees C was 0.0459 g/g ·day, 0.429 g/g ·day respectively.
3. The optimum pH value was in the range of 6.5~8.6. If the pH value was outside this range, the earthworm numbers decreased greatly (died).
4. The material conversion rate reached the peak value when the C/N ratio is 20 at 20degrees C.
5. The optimal fermentation period in municipal solid waste was 18 days.

Keywords: temperature, pH value, C/N ratio, municipal solid waste, Eisenia fetida(E.fetida)

1. INTRODUCTION

The temperature, pH value and C/N ratio of organic wastes used in vermicomposting are important factors influencing the growth and survival of earthworms (Qiao *et al.*, 2003, Hou *et al.*, 2004). The growth of *E. fetida* in organic matter substrates with different moisture contents and temperatures has been studied by various authors in the laboratory. This species gained weight maximally and survived best at temperatures between 20 °C and 29 °C and moisture contents

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between 70% and 85% in horse manure and activated sludge (Kaplan *et al.*, 1980). Edwards (1988) reported that the optimum growth of *E. fetida* in different animal and vegetable wastes occurred at 25-30°C and at a moisture content range of 75-90%, but these factors could vary in different substrates (Gunadi *et al.*, 2003).

Mangold in 1953 reported that earthworms absorb water and breathe through their skin. They are sensitive to pH value of the substrate. pH value is one of the most important factors affecting the survival of worms.

There is a certain range of pH value for earthworms to survive. The substrate is unsuitable for worms if it is too acidic or too alkaline. The appropriate pH value is between 6.0 and 8.0.

If the temperature and moisture values are optimal, the growth of earthworms is determined by the quality of substrate materials. C/N ratio plays an important role in determining the quality of substrates. Another important factor is whether materials have been fully fermented. Ndewa and Thompson (2000) found that when C/N ratio of material is 25 (Ndewa *et al.*, 2000), earthworm can grow better. Some other researchers reported that 20 is the suitable C/N ratio (Liu *et al.*, 2000). Temperature, pH value and C/N ration were studied in this article, in order to find the optimal factors for earthworms in municipal solid waste.

2. MATERIALS AND METHODS

2.1 Experiment 1: the Influence of Temperature

E. fetida from Dahuan earthworm cultivating plant was chosen as the experimental worms. The substrate material came mainly from China Agricultural University including leftover food, vegetables, leaves and other organic materials. The substrates were fully fermented. The containers were flowerpots with diameter of 20 cm were used as containers. Duncan's multiple-range test was used.

Water was added to the fully-fermented municipal solid waste to maintain the moisture content between 70% and 80%, and the pH value was adjusted between 6.0 and 8.0 by diluted acid or alkali. Then the waste was placed into nine numbered flowerpots. One hundred young earthworms were weighed and then placed in the waste in each of the nine flowerpots. The nine flowerpots were divided into 3 groups. Each group was maintained in a container with temperature controlled at 15°C, 20°C and 25°C. During the experiment, a layer of substrate (about 1cm) was added at 20:00 daily. All the experiments were conducted under dark conditions indoors and water was sprinkled every 7 days to maintain the desired moisture contents. The worms were weighed weekly. When the round-belt appeared on every group and worms began to lay eggs, the experiment was terminated.

Experiment 2: the Influence of pH Value

Municipal solid waste in different fermented stage was used as the substrate in this stage. Five 35cm-diameter and 26cm-height flowerpots were used as containers.

Ten grams of municipal solid waste which was fermented for 6, 8, 12, 15 and 18 days were taken, and the pH values were monitored by glass-electric (pH meter made in Shanhai Dapu instrument company) after being diluted by distilled water. The result is in table1.

Table 1. pH values of waste fermented.

Code of container	A ₁	A ₂	A ₃	A ₄	A ₅
Days fermented (d)	6	8	12	15	18
pH value	5.1	5.4	6.5	7.2	8.6

These 5 Samples of waste (Table 1) were used as substrate for the experiment 2. Their moisture contents were adjusted to 70%-80%, then put into the five flowerpots and identified as A₁, A₂, A₃, A₄, and A₅. The vitality of the earthworms were chosen from the cultivate pool (where experimental earthworms lived in), and then placed in the flowerpot. Twenty earthworms were placed into each pot. Because earthworms are afraid of sunshine, strong sunshine was used to let the worms under the substrate. The rest of earthworms were recorded after one day. Three replicates were used for each experiment.

Experiment 3: the Influence of C/N Ratio

The difference between experiment 2 and experiment 3 was the containers. In experiment 3, 20cm×20cm×20cm wooden boxes were used. The index of this experiment was the rate of material digestion or and the factor was C/N ratio. Substrates fermented for different period of time with C/N ratio of 26, 24, 22, 20, 17, and 15 were chosen. Two replicates were used for each experiment.

500g of substrate substrate was put into the containers only once. The temperature and moisture contents were controlled at 20°C (by constant temperature water area) and 65%, and pH value was adjusted between 6.0 and 8.0. 30g earthworms were put into each box. Water was sprinkled to the surface of substrate every day to maintain moisture content. The entire experiment lasted 15 days. At the end of the experiment, earthworms and the remaining substrate was separated and weighed.

3. RESULTS

The growth of *E. fetida* in municipal solid waste with moisture contents between 75% and 80%, different temperatures, pH values and C/N ratios followed a logistic growth pattern. The earthworm growth rate was fastest at a temperature 20°C with a maximum growth rate of 0.0379 g/(g-day). Earthworm growth rate at different temperature is given in Table 2.

Table 2. Growth rate of earthworm at different temperature.

Temperature ()	12	15	20	25	28
Number of worms	50	50	50	50	50
Growth rate (g/g-day)	0.0088	0.0258	0.0379	0.0356	0.0233

The relation between growth rate and temperature is shown in Figure 1. The highest growth rate 0.0459 g/g-day at temperature 19.7°C. The coefficient correlation of the curve is 0.9961; and it shows that this curve can be used with a high the relationship of growth rate and temperature.

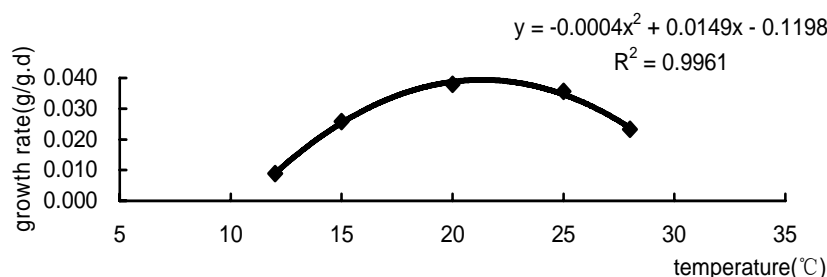


Figure 1. The relationship of growth rate and temperature for *Eisenia fetida* earthworms

There were most earthworms survived in the substrate with pH value 6.5, and the average number of worms which survived was 17.3. Earthworms could barely survive in the substrate with pH value 5.1. The relationship of the number of earthworm and pH value was obtained from these data, as show in Figure 2.

Different pH value largely affected the activity of worms. There were significant differences in the survival of earthworms at different pH values ($P < 0.05$). The optimal pH for earthworm growth was 6.5. This differed significantly from the survival of earthworms at pH value 5.1 and 5.4 but significantly with pH value of 7.2 and 8.4. When pH value was below 6.5, the number of earthworm decreased significantly, implying that worms were sensitive to acidic conditions. There was no significant difference in the survival. It can, therefore, be inferred that pH conditions between 6.5 and 8.6 are suitable for cultivation of earthworms.

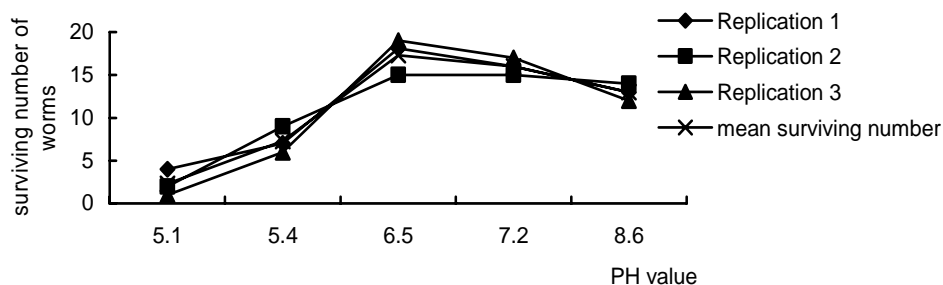


Figure 2. The relationship of number of surviving earthworms and temperature

The analysis of variance shows that the material conversion rate of earthworms was significantly affected by C/N ratio ($P < 0.05$). There were significant differences between A1 and A2, A3 ($p < 0.05$), but there were no significant difference between A1 and A4, A5, A6; A3 differed from A5 and much differed from A6, but it minimally differed from A2 and A4; A4 was greatly different from A6 and slight different between A2 and A5; A5 was greatly different from A6 and slightly different from A2.

C/N ratios had a distinct effect on conversion rate (Figure 3). At 20°C, the conversion rate was highest at C/N ratio 20. If C/N ratio was higher than 20, conversion rate increased with the decreasing of C/N ratio; if C/N ratio was lower than 20, conversion rate decreased with the decreasing of C/N ratio.

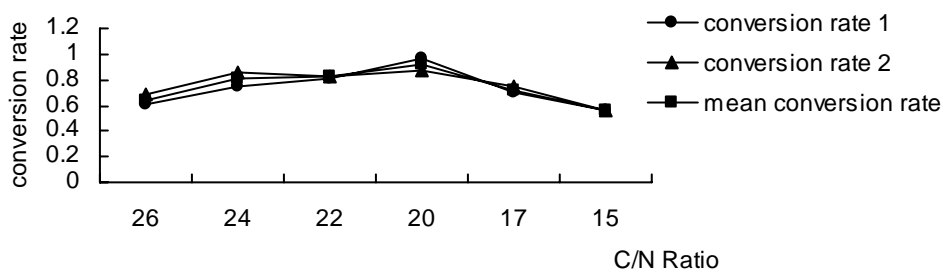


Figure 3. The relationship of C/N ratios and feed conversion rate for *Eisenia fetida* earthworms.

4. CONCLUSIONS

Earthworms attained the highest growth rate of 0.0459g / g-day at a temperature of 19.7°C. The shortest growth period was 52 days at 25°C, with the largest growth rate 0.0138 g /g-day. At 15 °C, 20°C and 25°C, the fastest growth rate appeared respectively in 53 days , 34 days and 27 days, with the growth rate 0.0068, 0.0123 and 0.0138 g /g-day.

pH value between 6.5 and 8.6 was the best condition for worms to survive. The earthworm number decreased dramatically when pH value fell out of this range. pH value is an important index of degree of fermentation of substrate. Completely-fermented substrate should be offered to earthworms. pH value was

affected largely by the substrate so it can be considered as a necessary condition for substrate fermentation, but not a sufficient one.

During the process of treating municipal solid waste with earthworms, the main purpose of fermentation is to stabilize the substrate so it could be easily used by worms. From experiment 3, the substrate conversion rate was highest when the C/N ratio was 20 at 20°C. As indicated by pH value and C/N ratio, the optimal fermentation period of municipal solid waste was 18 days, and earthworms could have good living conditions.

5. REFERENCES

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