Eco. Env. & Cons. 27 (February Suppl. Issue) : 2021; pp. (S315-S321)

ISSN 0971–765X

Vermicomposting process parameter optimization for feed of biomethanation sludge, fruits and vegetable waste (FVW) using *Eisenia fetida* species

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(Received 15 June, 2020; Accepted 25 July, 2020)

ABSTRACT

The present research work was carried out with an objective to optimize important parameters viz., incubation period, pH and moisture percent for vermicomposting using biomethanation sludge, fruits and vegetable waste (FVW) and earthworm species *Eisenia fetida.* The biomethanation digester running on FVW was used for the sludge collection. The FVW was collected from Gultekadi Market Yard, Pune and used for experiments after its processing. The dewatered sludge was admixed with partially decomposed fruits and vegetable waste (PDFVW). The plastic trays of 1kg working capacity were used for optimization of parameters. The results showed that incubation period of six weeks, pH 7.0 and moisture content of 80-90% were optimum condition for vermicomposting using *Eisenia fetida*. The average growth rate mg/worm /day for optimized incubation period, pH and moisture % was 4.9±0.18, 5.7±0.06 and 7.3±0.3, respectively and at all the three optimized conditions, it was 8±0.04.

Key words : *Biomethanation, Eisenia fetida, Fruits and vegetable waste, Moisture, pH, Vermicomposting*

Introduction

The waste of all kinds and their management is raising global concerns. The agricultural productivity has increased in India from last few decades (Welfare, 2018 and Neeraj *et al.*, 2017). The fruit and vegetables contribute as major part of waste at vegetable markets all over the world. The use of ecofriendly and sustainable treatment methods are required as permanent solution for waste related problems. The FVW can be scientifically managed by various methods viz. biomethanation, composting, vermicomposting etc. The biomethanation of FVW generates revenue in the form of methane gas and generates manurial sludge (Kenasa and Kena, 2019; Azouma *et al*., 2018 and Budiyono *et al*., 2018). The sludge generated from biomethanation plant has potential to be used as feed for vermicomposting process (Hank and Vasak, 2015 and Rajeshkumar and Ravichandran, 2015). The FVW generated from vegetable market places also has potential for vermicomposting (Chatterjee *et al*., 2014 and Kosamkar *et al*., 2017). The use of variety of earthworm species has been practiced for process of conversion of organic waste into vermicompost (Kale *et al*., 1982; Devi *et al*., 2012; Wani *et al*., 2013 and Dandotiya and Agrawal, 2014). The earthworms have potential to consume biomass equal to their bodyweight (Gurav and Pathade, 2011). The present work has an objective to optimize the process parameters of vermicomposting viz. incubation period, pH and moisture content of feed using popular earthworm species *Eisenia fetida.*

Materials and Methods

The vermicomposting process was studied in present study for optimization of process parameters. The material and methods used for experiments are discussed here in details.

Experimental earthworm species used: The experiment species was *Eisenia fetida.* The earthworms were collected from Vasantdada Sugar Institute (VSI) Pune (Plate 1).

Plate 1. *Eisenia fetida*

Biomethanation plant sludge and FVW as feed

The biomethanation of FVW was performed in biogas digester. The biogas digester sludge (BDS) was obtained and dewatered before its use. The FVW collected from Gultekadi Market Yard, Pune was processed and Partially Decomposed Fruits and Vegetable Waste (PDFVW) were used for experiment. The BDS and PDFVW was admixed together and then used as substrate to feed earthworms.

Vermicompost pots

The plastic trays of 5Kg capacity with working volume 1Kg (25cmX17cmX7cm) with reference to Mane and Raskar, (2012) were used for vermicomposting experiments. All the trays were provided facility for aeration and removal of vermiwash by making 1mm sized holes at the base and all sides of walls of trays for ventilation. All the trays were covered with cotton fabric and kept in the rack. The rack was covered with wet empty jute bags during experiment to prevent infestation of insects and rodents and to maintain dark conditions to avoid direct exposure of sunlight during experiment. The same trays were used for process parameters optimization e.g. incubation period, pH and moisture with reference to Kadam (2004) while ambient temperature was used as incubation temperature and was around 25-30 ^{0}C.

Optimization studies for vermicomposting of FVW

Acclimatization of earthworms to feed: The optimization of pH and moisture were important part of the study. The initially pH of the feed was maintained around 7.0 and moisture around 60-80%. The earthworms were acclimatized to experimental conditions for 15 days with selected pH-7.0 and moisture (60-80%). Then acclimatized earthworms were used for optimization studies.

Optimization of incubation period for vermicomposting using above substrate (feed)

The experiment was performed in triplicates. The feed mentioned in (2.2) was used for experiments. The 70 to 80% moisture was maintained by manually spraying specific quantity of water regularly throughout the experiment. The feed pH value was maintained to 7.0. The ambient temperature during the experiment was around 25-30 °C. The ten juvenile earthworms were released in each respective trays containing 1kg of feed/tray. The trays were incubated for 8 weeks of incubation period. The weight gain/tray/week and mortality of earthworms for all experimental sets were recorded. The earthworms were removed from trays and washed with tap water for recording of weights. The excess water was blotted/absorbed using blotting paper. The weight of earthworms recorded and earthworms were released back in respective trays. The optimized condition was considered where maximum average weight gain for earthworms and maximum vermicompost amount was obtained.

The average growth rate (mg/tray/day) of earthworm was calculated by method of Manaf *et al.*, (2009) and Suthar (2009). The formula used for the same was as below:

$$\text{Earthworm growth rate (mg/tray/day)} = \frac{\text{(Maximum biomass) - (Initial biomass)}}{\text{(Total number of days in which biomass is obtained)}}$$

The average growth rate (mg/earthworm/day) of earthworm was calculated by method of Manyuchi and Phir, (2013).

The formula used for the same was as below:

$$\text{Earthworm growth rate (mg/earthworm/day)} = \frac{\text{(Maximum biomass) – (Initial biomass)}}{\text{(Total number of days in which biomass is obtained)} \times \text{(Number of earthworms inoculated)}}$$

Optimization of pH of feed for vermicomposting

The experiments were performed in triplicates with feed pH range of 5.0, 6.0, 7.0, 8.0 and 9.0. The 1N HCl /1N NaOH were used for adjustment of respected pH values. The 70-80% moisture was maintained by manually spraying water. The ambient temperature during experiment was around 25-30°C. The ten juvenile earthworms were released in each respective trays containing 1 kg of feed/tray. The experiment was performed for six weeks (as optimized condition of experiment 2.4.1). The weight gain/tray/week and mortality of earthworms for all experimental sets were recorded. The weight measurement was done as per 2.4.1. The pH value of feed at which maximum average weight gain for earthworms and maximum vermicompost amount was obtained was taken as optimum pH.

Optimization of moisture content of feed for vermicomposting

The experiments were run in triplicates with feed moisture range of 50-60, 60-70, 70-80, 80-90 and 90-95%. The optimized condition six weeks incubation period and pH 7.0 of feed were maintained during all experiments. The ambient temperature was around 25-30 °C.

The ten juvenile earthworms were released in each respective trays containing 1 kg of feed/tray. The experiment was performed for six weeks (as optimized condition of experiment 2.4.1). The weight gain/tray/week and mortality of earthworms for all experimental sets were recorded. The weight measurement was done as per 2.4.1. The moisture percent at which maximum average weight gain for earthworms and maximum vermicompost amount obtained was taken as optimum condition for vermicomposting.

Vermicomposting using optimized conditions

The experiment was performed in triplicates with optimized conditions (6 weeks incubation period, pH 7.0 and 80-90% moisture) obtained in experiment 2.4.1, 2.4.2 and 2.4.3. The feed was used as per 2.2. The ten juvenile earthworms were released in each respective trays containing 1kg of feed/tray. The weight gain/tray/week and mortality of earthworms for all experimental sets were recorded. The weight measurement was done as per 2.4.1. The weekly maximum average weight gain for earthworms and maximum vermicompost amount was recorded during experimental period.

Results and Discussion

Optimization studies for vermicomposting of BDS and PDFVW

Optimization of incubation period

It is evident from Table 1 and Fig. 1 that gradual weight gain for earthworm increased from week one (186.25±21.50) to week six (2153.27±82.17) and average maximum weight gain recorded at 6th week. The further incubation on 7th week onwards resulted in weight loss. The average maximum weight gain for three sets was 2153.27±82.17 mg/tray. The weight loss in 7th and 8th week may be attributed to nutrient deficiency thus the optimum incubation period was taken as six weeks. The average growth rate (mg/worm/day) and vermicompost obtained (g/Kg of feed) was found as 3.7±0.1 and 557.3±22.8 respectively.

Table 1. Optimization of incubation period for *Eisenia fetida* (mg/tray)

Incubation period : average weight of *Eisenia fetida* in (mg/tray)	
Week	Average weight gain
0	95.47±7.27
1	186.25±21.50
2	330.01±33.82
3	619.17±23.18
4	995.91±53.10
5	1452.50±79.22
6	2153.27±82.17
7	2080±66.5
8	1994.5±19.4
Weight gain/ tray	2057.8±74.9
Average growth rate (mg/tray/day)	36.7±1.3
Average growth rate (mg/worm/day)	3.7±0.1
Vermicompost (g/Kg of feed)	557.3±22.8

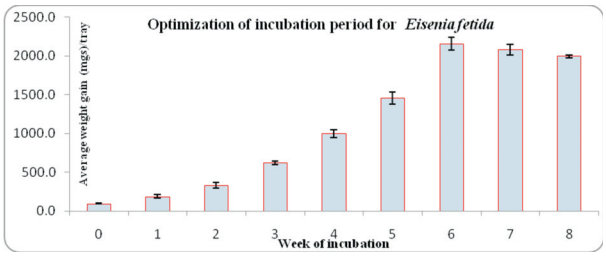

Fig. 1. Optimization of incubation period for *Eisenia fetida*

The previous study by Pandit and Maheshwari (2012) for sugar cane bagasse and press mud as substrate reported growth of *Eisenia fetida* with optimum of 6th week with pH 7.0, particle size 1-2mm, temperature 25^{0}C, and moisture level of 80% and obtained 175 to 3363mg with 1999% gain in biomass. The present study also reported 6th week period as optimum incubation period for *Eisenia fetida*. Kadam (2004) used tendu leaves as substrate and reported weight loss on 7th and 8th week of incubation for *Eudrilus eugeniae* which is similar to present results.

Optimization of pH of feed for *Eisenia fetida*

It was evident from Table 2 and Fig 2 that pH 6.0 and below and at pH 8.0 and above of feed, the average maximum weight gain for earthworm was less as compared to weight gain at pH 7.0 and hence pH 7.0 was taken as optimum for vermicomposting of BDS and PDFVW. In this experiment incubation period of six weeks and 70-80% moisture were used (as optimized in 3.1). The average maximum weight gain was found at pH 7.0. The average maximum weight gain for three sets on 6th week was 2497.6±28.2. The average growth rate has maximum value at pH 7.0 as 5.7±0.06. The average growth (mg/worm/day) rate was reported as 5.7±0.06. The vermicompost obtained at pH 7.0 was 594.4±11.6/g /kg of feed. Hence pH 7.0 was considered as optimum.

The result of the present study is similar with previous studies by Gajlakshmi and Abbasi (2004) who in review paper reported for aquatic weeds and agro based substrates pH 7.0 as optimum and migration of earthworms if pH value decreased below six. The research by other authors (Kadam, 2004 ; Gurav and Pathade, 2011 and Utekar and Deshmukh, 2016) have also reported pH 7.0 as optimum for other species of earthworm *Eudrilus eugeniae*

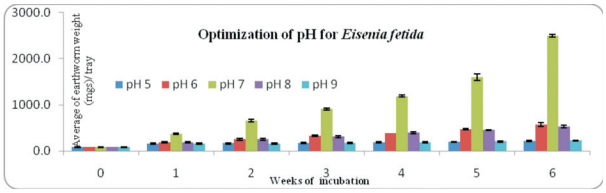

Fig. 2. Optimization of pH of feed for *Eisenia fetida*

Optimization of moisture content of feed for *Eisenia fetida*

Table 3 and Fig 3 indicate that there was gradual increase in weight of earthworm up to 80-90% moisture. The average maximum weight gain and growth rate of earthworm was reported on 6th week at 80-90% moisture was 3189.4±151.4 and 7.3±0.3 mg/worm/day. The average total vermicompost obtained at moisture 80-90% and was 627.7±12.6 g/Kg of feed

The average maximum weight gain was found at 80-90% moisture at optimized conditions of six weeks incubation period, pH 7.0 and feed ambient temperature of 25-30 ^{o}C. At 50-60%, 60-70% and 70-80% moisture level the average growth rate (mg/worm/day) was 1.5±0.04, 1.7±0.2 and 3.9±0.5 respectively, which was less as compared at 80-90% moisture as 7.3±0.3. Hence 80-90% moisture was taken as optimum moisture.

The result of the present study seems to at par with previous reports. The survival of *Eisenia fetida*

Table 2. Optimization of pH of feed for *Eisenia fetida*

pH values of feed and average weight gain/tray for *Eisenia fetida*					
Week/pH of feed of incubation	pH 5	pH 6	pH 7	pH 8	pH 9
0	85.13±8.19	92.63±3.8	86.50±7.35	90.1±4.94	81.6±9.57
1	162±15.5	191±14.1	368.9±13.39	189.8±19.9	157±13.9
2	167.4±13.7	253.7±22.9	657.1±28.32	254.0±24.0	160.4±13.8
3	174.7±14.3	328.4±13	908.70±19.8	315±24.1	172.9±13.5
4	184.8±12.4	390.1±4.6	1192.33±20.8	395.7±19.7	189.2±13.3
5	197.2±12.4	474.4±17.1	1601.3±67.3	457.3±4.4	207.2±13.6
6	213.4±14.1	576.2±39.5	**2497.6±28.2**	533.6±30	224.9±14.6
Weight gain/tray	128.3±6.7	483.6±42.1	2411.0±25.6	443.4±34.8	143.3±4.4
Average growth rate (mg/tray/day)	3.05±0.16	11.5±1	57.4±0.6	10.5±0.8	3.4±0.11
Average growth rate (mg/worm/day)	0.3±0.02	1.1±0.10	5.7±0.06	1.0±0.08	0.34±0.01
Vermicompost (g/Kg of feed)	187±16.7	318.4±13.9	**594.4±11.6**	334.2±12.2	164.3±13.8

with moisture 50-90% and optimum growth at 80-90% moisture was reported by Domfnguez (2004). Wani *et al.* (2013) used substrate as kitchen waste, garden waste and cow dung and reported optimum humidity range of 80 to 90% for growth of *Eisenia fetida.* While the results by Rostami *et al.* (2009) for food wastes as substrate using *Eisenia fetida* indicated 65-75% moisture as optimum range.

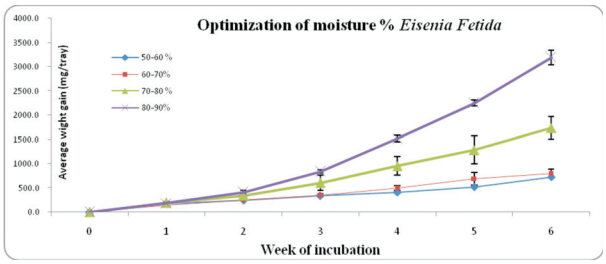

Fig. 3. Optimization of moisture content of feed for *Eisenia fetida* (mg/tray)

As optimum average weight gain and vermicompost amount was obtained at 80-90% moisture content it seemed that further fining is required to find out exact % moisture content which may be between 80-90%.

The optimized conditions for vermicomposting at 1-Kg tray level studies

The experiments conducted for optimization of pH and % moisture of substrate/feed and optimized sets of conditions for vermicomposting of BDS and PDFVW were as below: (Table 4).

Vermicomposting using optimized set of conditions at 1 kg tray level study

The experiment was performed in triplicate at 1 kg tray level using optimized incubation period of 6 weeks, feed pH 7.0 and % moisture of feed to 80-90%. The average maximum weight gain was found on 6th week was 3426±17.7 mg and vermicompost produced was 668.3±34.1g/kg of feed. The growth rate was 79.9±0.4 mg /tray/day (Table 5 and Fig. 3.5).

Table 4. Optimized conditions for vermicomposting *of Eisenia fetida*

Parameter	
pH	7
Moisture %	80-90
Temperature (ambient ^{0}C)	25-30
Incubation period (weeks)	6

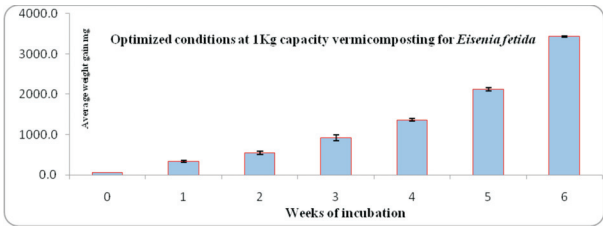

Fig. 4. Vermicomposting using optimized set of conditions using *Eisenia fetida* (1Kg tray level study)

It was further found that average weight gain and growth rates increased when all optimized conditions were used as compared to results at the time of optimization of individual conditions.

Conclusion

- The BDS and PDFVW were amenable to vermicomposting using *Eisenia fetida*.

Table 3. Optimization of moisture content of feed for *Eisenia fetida*

	% moisture content of feed and average weight gain/tray				
Week of incubation/% Moisture of feed	50-60%	60-70%	70-80%	80-90%	90-95%
0	85.2±6.9	76.8±3.2	86.1±5.3	87.9±4.9	The earthworms
1	172.5±7.5	144.9±8.7	192.6±28.9	190.6±12.9	very unstable and
2	244.4±8.9	257.6±29	347.7±65.5	413.9±34.9	left the trays
3	339.4±14	348±37.6	605.7±160.8	839.1±30.6	and there was
4	415.3±9	500.9±49.7	955.8±193.1	1519±67.2	mortality
5	523.9±17	689.9±133.5	1281.5±287	2247.6±61	as well
6	724.5±13.1	801.4±91.5	1735.1±229	3189.4±151.4	
Weight gain/ tray	639.3±18.4	724.7±89.2	1649±226.2	3101.5±146.8	
Average growth rate mg/tray/day	15.2±0.4	17.2±2.1	39.2±5.4	73.8±3.5	
Average growth rate mg/worm/day	1.5±0.04	1.7±0.2	3.9±0.5	7.3±0.3	
Vermicompost (g/Kg of feed)	542.2±18.7	563.4±16.8	587.9±9.6	627.7±12.6	

Table 5. Vermicomposting using optimized set of conditions using *Eisenia fetida* in (1 Kg tray level study)

Vermicomposting using optimized set of conditions using *Eisenia fetida*	
Week	Average weight gain
0	69.3 ± 2.2
1	338.4 ± 22
2	554.2 ± 42.8
3	925.6 ± 76
4	1368.2 ± 39.3
5	2125.9 ± 43.4
6	3426 ± 17.7
Weight gain/ tray	3356.7 ± 16.8
Average growth rate (mg/tray/day)	79.9 ± 0.4
Average growth rate (mg/worm/day)	8 ± 0.04
Vermicompost (g/kg of feed)	668.3 ± 34.1

- The earthworm *Ef* produced significant amount of vermicompost from substrate (feed)
- The optimized pH of feed for vermicomposting of BDS and PDFVW was pH 7.0.
- The optimized % moisture range of feed was 80-90%.
- The average growth rate at 1 kg feed with optimized conditions was found to be 8±0.04 mg/worm/day.
- The vermicompost obtained using all optimized conditions was **668.3±34.1** g/kg of feed

Acknowledgment

We express thanks to Dr. R. G. Pardeshi, Principal Fergusson College, Pune for their constant encouragement and support. We also express thanks to management of H.V. Desai Collge Pune for providing us facility to conduct experiments on terrace of college building.

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