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STUDY OF BIOLOGICAL PARAMETERS OF PAPER WASTE DEGRADED THROUGH VERMICOMPOSTING IN AN INSTITUTIONAL SETUP

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ABSTRACT

Paper is more than an industrial product. It is the cultural barometer of the nation and a significant discovery that turned around the history of the world.Consequently, production of large quantities of paper directly leads to the enormous production of this organic waste posing major environmental and disposal problems.Vermicomposting is identified as an innovative and alternative technology to convert it into a positive environmental impact by reducing the amount of organic waste that finds its way into landfills, incinerators, and sometimes the ocean.In the present study, the experiments were conducted in triplicates for each treatment taken, (T1) – newspaper waste and cow dung, (T2) – written paper and cow dung. The epigeic earthworm species, *Eisenia foetida* is used in the study. The earthworms were bred in both the treatments and their controls were devoid of worms.This setup was monitored over a period of 60 days. The study reveals that newspaper was degraded more efficiently than written paper via vermicomposting. The newspaper vermicompost had more of earthworm numbers, earthworm biomass and cocoon production while growth rate of worms was found to be higher in written paper vermicompost. pH near neutral is recommended for efficient degradation and for biological augmentation of earthworms. Thus, vermicomposting using *Eisenia foetida* is an effective method for the management and degradation of cellulosic paper waste in an educational institution.

KEYWORDS: Vermicompost, *Eisenia foetida*, Paper waste, Physico-chemical analysis, Biological analysis, Coliform estimation, Regression analysis.

INTRODUCTION

The enormous quantity of solid waste generation with its ever increasing trend is one of the growing problems of concern in both developed and developing countries. Inadequate and improper systems of waste disposal makes human life miserable in many parts of the world entailing huge costs and creating civil war like conflicts within the societies. The rapid increase in the volume of waste is one aspect of environmental crisis as a concomitant consequence of global industrial, consumption and economic developmental activities. Most common practices of waste disposal include the uncontrolled dumping which causes mainly water and soil pollution. Although various physical, chemical and microbiological methods of processing organic wastes are currently in use, these methods are time consuming and expensive. Vermicomposting is a very effective, eco-friendly, cheap and easy method of recycling biodegradable waste using selected species of earthworm. More than a mere means of waste disposal it could possibly turn out to be a source of good manure, as a collateral benefit, for best organic farming practices.

In any environment, recycling of the degradable waste is the natural way of replenishing it with the friendly ingredients from wastes. Because of the negligence and indifference, the damage to the environment has surpassed the replenishment. Paper is one such product in the modern life which is so obvious that no other manufactured product possess such diversity of use. After consumption it often makes its way to trash bins and thus comes to be termed as “waste paper”. Municipal Solid Waste (MSW) in India accounts approximately 40% of paper waste, making it the top material that we throw away. That means for every 100 kilogram of trash we throw away, about 40 kilograms of it is paper. This rise in demand of production, use and recycling of paper has also led to a number of adverse effects on the environment which are known collectively as paper pollution. Pulp mills contribute to air, water and land pollution; discarded paper (before recycling) forming a major component of many land-fill sites and its disposal as a major concern to the industry in the face of local environmental pressures; and even recycled paper due to the sludge produced during deinking can be a source of pollution.

Therefore, attention is being paid to evolve economically viable technologies for organic waste management. The importance of earthworms in waste management, environmental conservation, organic farming and sustainable agriculture has been highlighted by several workers (Senapati, 1992; Bhawalkar, 1993; Ghatnekar *et al.*, 1998; Talashikar and Powar, 1998).

Eisenia foetida, Eisenia andrei, Eudrilus euginae, Lumbricus rubellus and *Perionyx excavates* are the major waste eater and bio-degrader earthworm species. They are used worldwide for waste degradation and are found to be very successful functionaries for the ecological management of organic municipal wastes (Edwards, 1988). Sinha *et al*., (2008) had anticipated a vermiculture revolution through their study in which it was established as a low-cost and sustainable technology for management of municipal and industrial organic wastes (solid and liquid) by earthworms with significantly low greenhouse gas emissions. Gajalakshmi *et al*., (2002) had done a detailed investigation on the efficiency of vermicomposting of paper waste with an indigenous anecic earthworm, *Lampito mauritii* (Kinberg).

The present study highlights the possibility of vermicomposting different types of paper wastes generated in an educational institution and, in doing so, evaluating the potential of using *Eisenia foetida* to degrade the paper waste.

MATERIALS AND METHODS

Procurement of earthworm and organic wastes

The earthworm species, *Eisenia foetida* was obtained from the vermicompost pit of Nirmala College for Women (Autonomous), Coimbatore. The species was identified in the college by the Department of Zoology. The two different types of paper waste generated from the college campus were collected and segregated as newspaper waste and written paper waste. These papers were shredded manually. Cow dung was obtained from a local cowshed and was sun dried and flaked.

Experimental design

The experiment was conducted in square plastic pots measuring 17 x 17 x 17 cm of length, breadth and height respectively. Holes were drilled at the bottom of the pots so as to drain excess water. The pots were filled bottom up with successive layers of pebbles, coconut husk, cow dung flakes and shredded papers respectively. The paper waste was mixed with cow dung flakes in the ratio of 1:1. All pots were maintained in triplicates. Water was sprinkled daily on all pots to maintain the moisture content and turned at regular intervals for proper mixing and aeration. The experimental pots were kept under shade and covered with gunny bags to prevent moisture loss. This setup was maintained for 15 days for partial degradation and stabilization. After 15 days, 20 non-clitellated earthworms were introduced into each treatment pots containing newspaper waste (T1) and written paper waste (T2). The control pots of newspaper waste (C1) and written paper waste (C2) were devoid of earthworms. This setup was also sprinkled with water daily and was monitored for a period of 60 days. On the 15^{th}, 30^{th}, 45^{th} and 60^{th} day of the experimental period, the earthworms were carefully removed for biological study and the samples of compost and vermicompost from all experimental units were collected and used for analysis.

Physico-chemical parameters

A change in colour and texture of the substrate in each pot was observed periodically and noted until it turns dark brown-black colour and moist, homogenously dissipated, granulated form(Tahir and Hamid, 2012, Sonowal *et al*., 2014).The weight loss percentage of organic substrate during vermicomposting was estimated by finding the difference between the final weight of the organic substrate and the initial weight of the organic substrate (Tripathi and Bharadwaj, 2004). pH was estimated by the standard electrometric method using a digital pH meter (Sundberg*et al*., 2004).

Biological parameters

The total number of earthworms was counted after carefully removing the worms manually from the treatment pots. The earthworms removed were rinsed with distilled water to remove all extraneous material, briefly drained on a tissue paper and weighed on a scale (Manaf *et al*., 2009). All the worms in each pot were weighed as a unit.

The formula used to determine the growth rate is as follows (Suthar, 2006):

$$\text{Growth rate determination, } R = (N_2\text{-}N_1) / T$$

Where, R = Growth rate,N_1 = Initial earthworm biomass ,N_2 = Final earthworm biomass achieved, T = Time period of the experiment day.

The number of cocoons were counted by hand sorting method from the treatment pots (Manaf *et al*., 2009).

Microbiological estimation

Total coliforms were determined by the membrane filtration method (IS 15185: 2002).

Statistical analysis

All results reported are the means of three replicates. The statistical significance of difference ($P < 0.05$) was tested withTwo way ANOVA using SPSS 16.0 package for parameters analyzed on the composted and vermicomposted samples over a period of 60 days.

The pH and the biological parameters such as earthworm numbers, earthworm biomass and cocoon production were subjected to correlation analysis. Linear logistic regression was used for the dichotomous dependent variable and categorical independent variables to calculate the odds ratio to assess the causative factor. The correlation coefficient between each parameter was calculated.

RESULTS

Physico-chemical parameters

Colour

The colour of the samples drastically changed during the vermicomposting period. Initially, the pots C1 and T1 inoculated with newspaper waste were grey in colour, and in C2 and T2 containing written paper waste was white in colour. On the 60th day, the samples in T1 and T2 were rich black in colour while C1 and C2 showed some white lumps in-between the black mass.

Texture

Vermicomposting had a tremendous effect on the texture of the two different substrates. Initially, all experimental units contained shredded papers and flaked cow dung. On comparison of the substrates at the end of the experiment i.e., on the 60th day, both the treatment pots T1 and T2 contained more stabilized, homogenously dissipated, moist granulated manure whereas their control consisted of aggregated masses of partially degraded paper and completely composted cow dung.

Weight Loss of Organic Substrate

A significant difference (P < 0.05) in weight loss of the organic substrate had been observed on the 60th day of vermicomposting period. The maximum degree of degradation or weight loss in percentage was exhibited by T2 (46.25 ± 1.25), followed by T1 (40.00 ± 2.50). The least degradation or loss percentage in weight of the substrate was recorded by C2 (25.83 ± 3.82). Results obtained for weight loss of the organic substrate are depicted in Table 1 and Figure 1. Two way ANOVA revealed an overall significance of differences (P < 0.01) for all experimental units across the experimental period (Table 8).

Table 1: Weight loss of the organic substrate during composting and vermicomposting process of different paper waste (grams)

Sample	Weight of Organic Substrate		
	Initial	Final	Loss (%)
C1	400.00 ± 0.00*	280.00 ± 10.00*	30.00 ± 2.50
T1	400.00 ± 0.00*	215.00 ± 5.00*	46.25 ± 1.25
C2	400.00 ± 0.00*	297.67 ± 15.28*	25.83 ± 3.82
T2	400.00 ± 0.00*	240.00 ± 10.00*	40.00 ± 2.50
SEd	6.18017		
CD (P<0.05)	13.10154		

Values are Mean ± Standard Deviation of three samples in each group; **SEd**– Standard Error of the Difference; **CD** – Critical Difference; ***** - Significant at P < 0.05 level; **C1** – Newspaper waste, **T1** – Newspaper waste + Earthworm, **C2** – Written paper waste, **T2** – Written paper waste + Earthworm

pH

The shift in pH from initial alkaline range to a more neutral condition was observed for all experimental units as shown in Table 2. pH reduced in all pots during the vermicomposting period. Two factor ANOVA exhibited a significant pH change between the treatment pots with respect to their control on all days of analysis during the experimental period (Table 8). The best pH change was observed in the treatment pot T2, which was followed by T1 and then the control pots C1 and C2 respectively. During the experimental period, the 60th day had revealed a more neutral pH in the ascending order of values as T2 (7.37 ± 0.06), T1 (7.53 ± 0.06), C2 (7.57 ± 0.06) and C1 (7.71 ± 0.15).

Table 2: Changes in pH during composting and vermicomposting process of different paper waste

Sample	Days			
	15	30	45	60
C1	8.40 ± 0.10*	8.00 ± 0.20*	7.77 ± 0.06*	7.71 ± 0.15*
T1	8.13 ± 0.21*	7.70 ± 0.10*	7.40 ± 0.10*	7.53 ± 0.06*
C2	8.50 ± 0.10*	8.20 ± 0.10*	7.90 ± 0.10*	7.57 ± 0.06*
T2	8.03 ± 0.12*	7.77 ± 0.06*	7.50 ± 0.10*	7.37 ± 0.06*
SEd	0.09280			
CD (P<0.05)	0.18902			

Values are Mean ± Standard Deviation of three samples in each group; **SEd**– Standard Error of the Difference; **CD** – Critical Difference; ***** - Significant at P < 0.05 level; **C1** – Newspaper waste, **T1** – Newspaper waste + Earthworm, **C2** – Written paper waste, **T2** – Written paper waste + Earthworm

Biological parameters

Earthworm Numbers

The earthworms increased in numbers in both the treatment consisting of the newspaper waste (T1) and the written paper waste (T2) as the days progressed, whilst a decrease was noted on the 15th day (Table 3). A significant change in the number of earthworms between the treatment pots T1 (60.67 ± 15.53, 66.33 ± 15.50) and T2 (44.67 ± 9.87, 53.33 ± 7.77) was observed only on the

45th and the 60th day respectively. Among the treatments, the maximum increase in number of earthworms during the vermicomposting period was recorded in T1 (66.33 ± 15.50). Two way ANOVA revealed an overall significant differences (P < 0.01) for all treatments across the experimental period (Table 8).

Table: 3 Earthworm numbers during composting and vermicomposting process of different paper waste

Sample	Days				
	0	15	30	45	60
C1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
T1	20.00±0.00*	17.33 ± 2.52*	27.33 ± 2.08*	60.67±15.53*	66.33 ± 15.50*
C2	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
T2	20.00 ± 0.00*	17.67 ± 3.21*	26.00 ± 4.36*	44.67 ± 9.87*	53.33 ± 7.77*
SEd	4.75862				
CD(P<0.05)	9.61773				

Values are Mean ± Standard Deviation of three samples in each group; **SEd**– Standard Error of the Difference; **CD** – Critical Difference; ***** - Significant at P < 0.05 level; **C1** – Newspaper waste, **T1** – Newspaper waste + Earthworm, **C2** – Written paper waste, **T2** – Written paper waste + Earthworm

Earthworm Biomass

After 60 days of vermicomposting, the highest earthworm biomass gain was found in T1 (51.00 ± 6.56) followed by T2 (48.00 ± 7.94) without any significant difference at 95% confidence level. Also, the 45th and 60th day recorded the best gain in biomass (grams) during the experimental period. The change in earthworm biomass in all pots over the experimental period is illustrated in Table 4. Two way ANOVA revealed a significant difference (P < 0.01) between all treatments across the experimental period (Table 8).

Table 4: Earthworm biomass during composting and vermicomposting process of different paper waste (grams)

Sample	Days				
	0	15	30	45	60
C1	0.00 ±0.00	0.00 ±0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
T1	8.00 ±0.00*	31.00 ±3.61*	37.00± 1.00*	45.33 ± 3.51*	51.00 ± 6.56*
C2	0.00 ±0.00	0.00 ±0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
T2	8.00 ±0.00*	31.00 ±8.54*	37.67± 8.74*	41.00 ± 9.64*	48.00 ± 7.94*
SEd	3.53396				
CD(P<0.05)	7.14256				

Values are Mean ± Standard Deviation of three samples in each group; **SEd**– Standard Error of the Difference; **CD** – Critical Difference;***** - Significant at P < 0.05 level;**C1** – Newspaper waste, **T1** – Newspaper waste + Earthworm, **C2** – Written paper waste, **T2** – Written paper waste + Earthworm

Earthworm Growth Rate

The growth rate has been considered as a good comparative index to compare the growth of earthworms in different waste (Edwards *et al*., 1998). Although significant differences were not noted between the treatment pots across the entire experimental period, the written paper waste T2 (1.53 ± 0.57) exhibited the highest growth rate in comparison with newspaper waste T1 (1.53 ± 0.24) (Table 5). The difference could be due to the physical characteristics of the substrate. This maximum growth rate was observed to have been on the 15th day of analysis which is also considered as the best treatment period. It was observed that on the 60th day, there is a lower growth rate in newspaper waste (T1 – 0.37 ± 0.21) despite the attainment of more biomass gain than the written paper waste (T2 – 0.47 ± 0.12). This is due to the fact that the time taken to achieve the maximum biomass is longer for T1 than T2. Two way ANOVA revealed a significant difference (P < 0.01) between all treatments of the experimental period (Table 8).

Table 5: Growth rate in each sample unit of earthworms during composting and vermicomposting process of different paper waste (grams/unit worms/day)

Sample	Days			
	15	30	45	60
C1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
T1	1.53 ± 0.24*	0.40 ± 0.20*	0.55 ± 0.27*	0.37 ± 0.21*
C2	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
T2	1.53 ± 0.57*	0.44 ± 0.51*	0.22 ± 0.10*	0.47 ± 0.12*
SEd	0.18517			
CD(P<0.05)	0.37719			

Values are Mean ± Standard Deviation of three samples in each group; **SEd**– Standard Error of the Difference; **CD** – Critical Difference;***** - Significant at P < 0.05 level;**C1** – Newspaper waste, **T1** – Newspaper waste + Earthworm, **C2** – Written paper waste, **T2** – Written paper waste + Earthworm

Cocoon Production

Total number of cocoons produced was found to be highest in T1 which was significant (P < 0.05) on the 30th, 45th and 60th day of analysis (Table 6). Results obtained on 60th day exhibited the highest cocoon production (T1 – 40.67 ± 3.06 and T2 – 34.33 ± 3.79) while the poorest was recorded on 15th day (T1 – 5.00 ± 1.00 and T2 – 5.33 ± 1.15) of the experimental period. Two way ANOVA revealed a significant difference (P < 0.01) between all treatments of the experimental period (Table 8).

Table 6: Cocoon production during composting and vermicomposting process of different paper waste

Sample	Days			
	15	**30**	**45**	**60**
C1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
T1	5.00 ± 1.00*	24.33 ± 4.73*	38.67 ± 4.53*	40.67± 3.06*
C2	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
T2	5.33 ± 1.15*	18.33 ± 8.50*	25.00 ± 6.08*	34.33 ± 3.79*
SEd	2.58199			
CD (P<0.05)	5.25948			

Values are Mean ± Standard Deviation of three samples in each group; **SEd**– Standard Error of the Difference; **CD** – Critical Difference; ***** - Significant at P < 0.05 level; **C1** – Newspaper waste, **T1** – Newspaper waste + Earthworm, **C2** – Written paper waste, **T2** – Written paper waste + Earthworm

Microbiological estimation

The total coliforms in the present study was initially higher in all experimental units (C1 – 31.00 ± 2.00, T1 – 29.33 ± 1.53, C2 – 29.33 ± 0.58 and T2 - 28.00 ± 6.00) of the composting process and decreased considerably at the end of the experimental period with statistically significant differences (P < 0.05) observed between the days and the samples during the entire period (Table 7). Decline in total coliforms was found higher in T1 (23.00 ± 2.00) followed by T2 (24.33 ± 4.16) and these reductions were significant on the 60th day of the experimental period (Plate 5). Two way ANOVA revealed an overall significant difference (P < 0.01) between all treatments and a significance at 95% confidence level was observed across the experimental period (Table 8).

Table 7: Total coliforms present in the samples during the composting and vermicomposting process of different paper waste(cfu/g)

Sample	Days			
	15	**30**	**45**	**60**
C1	31.00 ± 2.00*	31.67 ± 1.53*	30.00 ± 1.00*	28.00 ± 2.00*
T1	29.33 ± 1.53*	25.33 ± 2.52*	25.33 ± 3.06*	23.00 ± 2.00*
C2	29.33 ± 0.58*	33.33 ± 1.53*	27.67 ± 0.58*	27.33 ± 0.58*
T2	28.00 ± 6.00*	28.00 ± 1.73*	26.00 ± 4.36*	24.33 ± 4.16*
SEd	2.16025			
CD (P<0.05)	4.40040			

Values are Mean ± Standard Deviation of three samples in each group; **SEd**– Standard Error of the Difference; **CD** – Critical Difference; ***** - Significant at P < 0.05 level; **C1** – Newspaper waste, **T1** – Newspaper waste + Earthworm, **C2** – Written paper waste, **T2** – Written paper waste + Earthworm

Table 8: Two Way ANOVA for various parameters analyzed during the experimental period for different paper waste

Parameter	Source of variation	df	SS	MS	F	P	CV%
Weight loss of organic substrate	Days	1	121126.041667	121126.041667	2114.2000	0.000**	1.99
	Samples	3	6228.125000	2076.041667	36.2364	0.007**	
pH	Days	3	4.915000	1.638333	126.8387	0.000**	1.42
	Samples	3	1.578333	0.526111	40.7312	0.000**	
Earthworm numbers	Days	4	4586.833333	1146.708333	33.7598	0.000**	35.06
	Samples	3	18996.666667	6332.222222	186.4246	0.000**	
Earthworm biomass	Days	4	3060.566667	765.141667	40.8439	0.000**	26.58

	Samples	3	17149.933333	5716.644444	305.1590	0.000**	
Growth rate	Days	3	2.832956	0.944319	18.3601	0.000**	61.29
	Samples	3	5.706056	1.902019	36.9803	0.000**	
Cocoon production	Days	3	1816.229167	605.409722	60.5410	0.000**	24.72
	Samples	3	7135.062500	2378.354167	237.8354	0.000**	
Total coliform	Days	3	126.229167	42.076389	6.0109	0.016*	9.39
	Samples	3	165.229167	55.076389	7.8681	0.007**	

df– degrees of freedom; **SS** – Sum of Squares; **MS** – Mean Square; **F** – F-test; **P –** Probability; **CV** – Coefficient of Variation; ****** - Significant at P < 0.01 level; ***** - Significant at P < 0.05 level

CORRELATION BETWEEN pH AND BIOLOGICAL PARAMETERS

The pH values, which were adopted as the markers of compost maturityand other biological parameters such as earthworm numbers (on 60^{th} day), earthworm biomass (on 60^{th} day), growth rate (on 15^{th} day) and cocoon production (on 60^{th} day), were correlated by using logistic linear regression analysis method for both the treatments T1 and T2 (Figure 1and 2).

The multiple linear regression showed that there is a significant difference (T < 0.01) between pH and earthworm numbers with the value of probability of T as 8.142 for T1. The R-square value (Coefficient of determination) strongly indicates that 0.9431 % of the variation in earthworm number can be explained by regression. In contrast, the multiple linear regression showed that the value of probability of T is -8.226 with no significant difference between pH and earthworm biomass in T1. The R-square value indicates that 0.9442 % of the variation indicating an increase in pH value is negatively correlated with earthworm biomass. Weak correlation between pH and growth rate with no significant difference was observed with T value of 0.540 for T1 with R-square value at 0.068 % of variation. A high positive correlation between pH and cocoon production was estimated with R – square value as 0.9628 % of variation and T value as high as 10.179 (T < 0.01).

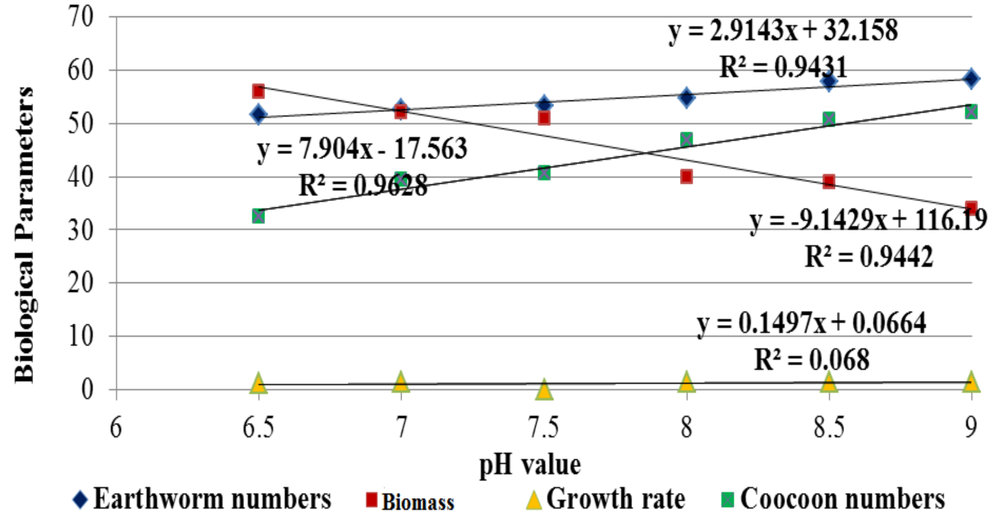
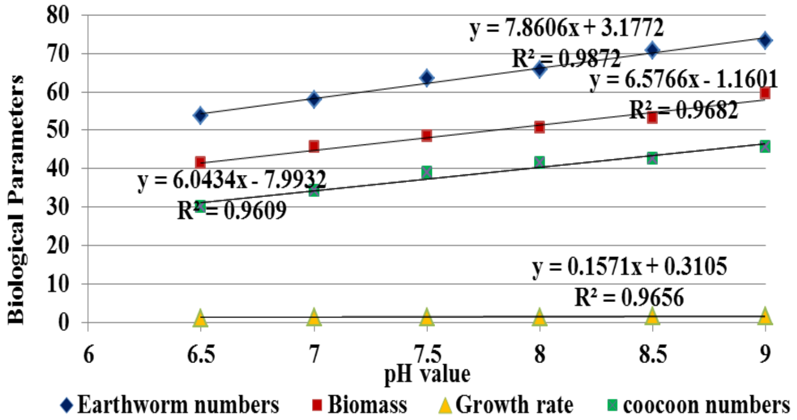


Figure 1: Correlation between pH and biological parameters of T1 containing newspaper waste

The multiple linear regression for T2 showed a T value of 17.550 which is highly significant (T < 0.01) between the pH and earthworm numbers. The R-square value strongly indicates that 0.9872 % of the variation in earthworm number shows positive correlation between the analyzed parameters. Similarly, the value of probability of T is 11.033 with significant difference (T < 0.01) between pH and earthworm biomass in T2. The R-square value indicates that 0.9682 % of the variation indicating that pH value could be positively correlated with earthworm biomass. Strong correlation between pH and growth rate with significant difference (T < 0.01) was observed with T value of 10.598 for T2 and with R-square value at 0.9656 % of variation showing positive correlation. A high positive correlation between pH and cocoon production was estimated with R – square values as 0.9609 % of variation and T value as high as 9.912 which is significantly different (T < 0.01).

Figure 2: Correlation between pH and biological parameters of T2 containing written paper waste



DISCUSSION

The colour of the vermicomposted material depends on the initial substrate. Natarajan and Gajendran, (2014) reported that the vermicomposted end material was more stabilized, odour free and dark brown in colour.

The changes in texture of the substrate could be related to an earlier study of SEM (Scanning Electron Microscopy) analysis where the pre-vermicomposted samples of bagasse were found to be as aggregates of biomass arranged into cellulose fibers and the protein matrix being strongly bound. However, in the post-vermicomposted samples the protein and lignin was disaggregated by earthworms (Bhat *et al.*, 2015). The activities of earthworms that have greatest influence on texture difference are: the ingestion of the substrate, partial breakdown of organic matter, intimate mixing of these fractions and ejection of this material as surface and sub-surface casts; and burrowing through the substrate (Ghabbour, 1973).

The distinct weight losses between these experimental units were possibly due to the presence of cow dung which could catalyze the microbial degradation of wastes. Such activities encourage the release of CO_2 via mineralization process of organic matter. The weight losses in treatment pots with earthworms were higher than those in the control (without worms). This indicates that the presence of earthworms in the system demonstrated the enhancement of a biological process, leading to higher weight loss compared to the setups without worms. Also, the worms' physical activities like blending and mixing of waste increased the surface area exposed to microorganisms, hence creating more favourable conditions for microbial activities and faster degradation (Rupani *et al.*, 2013). Swift *et al.*, (1979) stated that the variations in degree of decomposition and mineralization can be attributed to the substrate quality and the composition of the decomposer community. Nair *et al.*, (2006) reported that the pre-composting process because of its thermophilic nature prior to vermicomposting had also helped in mass reduction and pathogen reduction.

The pH reduction may be due to the mineralization of nitrogen into nitrates /nitrites and phosphorus into orthophosphates as well as bioconversion of organic waste to organic acids as observed by Ndegwa *et al.*, (2000). This was also in agreement to the studies conducted by Fares *et al.*, (2005) who opined that changes in pH are attributable to sequential and continuous utilization of organic acids and persistent increase in mineral constituents of waste. Haimi and Huhta, (1987) stated that the decrease of pH towards neutral is an important factor to be considered influencing retention of nitrogen and that the lower pH recorded in the final products might have been due to the production of CO_2 and organic acids by microbial activity during the bioconversion of the different substrates in the beds. Also, this breakdown of organic matter during vermicomposting releases carbon dioxide and volatile fatty acids that tend to decrease pH (Kaushik and Garg, 2004). The decreased trend of pH in the compost and vermicomposted samples in all experimental potsis also in accordance with the findings of Suthar, (2009).

The factor that influences the number of worms is directly related to the cocoon production. So, a relationship between cocoon production and number of earthworms is that, as the number of cocoons increases it will also increase the number of worms due to the hatchlings from the cocoons (Manaf *et al.*, 2009). A favourable environment will also increase the number of worms with less or no mortality. The present results corroborate with the findings of Bhat *et al.*, (2015) that an ideal ratio of bagasse with cattle dung was 50: 50, as final vermicompost started granulating on its surface earliest and this ratio was also found to be suitable for growth and population buildup of *E. foetida*.

The earthworm biomass gain is directly related to the feeding rate, palatability of feed stuff and particle size of feed stock; however, there is a close relationship between feed stock quality and microbial richness of bedding substrates which directly or indirectly affects the earthworm feeding rate, as microbes are the important component of earthworm diet (Gomez-Brandon *et al*., 2011). Additionally, the earthworms may have utilized microorganisms present in their substrates as food source and could digest them selectively (Suthar, 2009; Singh and Sharma, 2002). The readily available nutrients in the substrate would also enhance the feeding activity of the worms, showing their increase in biomass (Suthar and Singh, 2008).Also, the earthworm density, earthworm life-stage, change in pH of the substrate are all influential factors with respect to change in biomass of the earthworms.

Manaf *et al*., (2009) stated that the growth rate of worm increases gradually with time compared to pH where it decreases propotional to time and suggested that the best pH condition for the growth of the worm is pH near to neutral. Also, Suthar and Singh, (2008) reported that the worms when introduced into wastes showed an increased growth rate and reproduction activities, which could be reasoned out for the increased growth rate on the 15^{th} day in the present findings. Similar observations have been reported by Chaudhuri and Bhattacharjee, (2002) for vermicomposting of cow dung and kitchen waste by *Perionyx excavatus*.

The difference between rates of cocoon production could be related to the biochemical quality of the feeds, which is an important factor in determining the time taken to reach sexual maturity and onset of reproduction (Flack and Hartenstein, 1985). Feeds which provide earthworms with sufficient amount of easily metabolizing organic matter and non-assimilated carbohydrates favour growth and reproduction of earthworms. Edwards *et al*., (1998) concluded that the important difference between the rates of cocoon production in the two organic wastes must be related to the quality of the waste material, which is one of the important factors in determining onset of cocoon production. Suthar, (2005) summarized the chemical nature of feeding stock may be of primary importance for rearing of earthworms on organic waste resources. So, the difference in cocoon production could be due to variation in quality of the substrate. It has also been reported that along with feed quality the microbial biomass and decomposition activities are also important. It has to be taken note that the stage at which the earthworms were introduced into the substrate was the non-clitellated stage which attained the clitellated form at a later time period to lay cocoons and reproduce effectively.

Coliforms are the indicators for the presence of pathogens. Use of such an indicator as opposed to the actual disease-causing organisms is advantageous, as the indicators generally occur at higher frequencies than the pathogens and are simpler and safe to detect (Khwairakpam and Bhargava, 2010). The increased reduction in the vermicomposted samples presumably is because of the elimination of coliforms as they enter the food chain of the earthworm.

Manaf *et al*., (2009) suggested that the best pH condition for the growth of the worm is pH near to neutral. Munroe, (2004) 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. Different pH value largely affected the activity 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. Most experts feel that the worms prefer a pH of 7 or slightly higher. According to Hou *et al*., (2005) the optimum pH value was in the range of 6.5-8.6. There was a decrease in pH of all the vermicomposter including the control vermicomposter during vermicomposting. In general, the pH of worm beds tends to drop over time. Most of other reports on vermicomposting (Mitchell, 1997; Gunadi and Edwards, 2003; Garg and Kaushik, 2005) have also reported similar results. But pH decrease in all of the vermicomposter does not exceed below 6.5. The alteration of pH in the bedding is due to the fragmentation of the organic matter under series of chemical reaction. It has been recorded by Edward *et al.*, (1998) that different species of earthworms have their own pH sensitivity and generally most of them can survive at the pH range 4.5 to 9. They have also reported that different substrates could result in production of different intermediate species and different feed substrates show a different behavior in pH shift.

CONCLUSION

The present study concludes that the two types of paper wastes utilized namely newspaper and written paper, can be degraded efficiently through vermicomposting using *Eisenia foetida* than normal composting process. It is also interesting to note that newspaper was degraded more efficiently than written paper and that the written paper had exhibited a good growth rate of worms with commensurate shift to neutrality of pH value. The vermicompost thus obtained was rich black and homogenous in nature. The newspaper vermicompost had high levels of earthworm numbers, earthworm biomass and cocoon production while growth rate of worms was found to be higher in written paper vermicompost. A significant reduction of coliforms was noted as the substrate enters the food chain of the earthworm. pH near neutral is suggested for efficient degradation and for biological augmentation of earthworms. Thus, vermicomposting turns out to be an efficient strategy to manage and degrade cellulosic paper waste using *Eisenia foetida* in an educational institution.

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