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Vermicomposting of Flower Waste: Optimization of Maturity Parameter by Response Surface Methodology

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ABSTRACT

In the present study, response surface methodology (RSM) was used to develop an approach for the optimization of quantity of flower waste and cow dung to determine maturity during the vermicomposting of flower waste. The effect of maturity parameters such as C:N ratio, Germination index and CO2 evolution rate were studied using central composite design (CCD). Eisenia foetida was used in different combination of flower waste and cow dung during the vermicomposting of flower waste. Results of study showed significant effect of both variables and their interactions with process parameters during vermicomposting process. The optimum results obtained from response surface methodology was nearly equal between predicted and experimental analysis. The optimum variation of process parameter was pH 7.07-7.12, electrical conductivity 3.28 -3.42 mS/cm, total organic carbon 33.72-34.06%, C: N ratio 14-15, phosphorous 4.95-5.21 g/kg and potassium 13.99-14.31 g/kg. The results suggest that compost obtained from the vermicomposting of flower waste and cow dung contains sodium, potassium and phosphorous which are beneficial for the plant growth. Flower waste compost is suitable for organic manure which reduces the quantity of waste by converting into valuable products.

1. INTRODUCTION

Reduce, recycle and reuse of the organic waste is big challenges for municipal authorities in developing countries. The generation of waste is increasing in faster rate due to urbanization, industrialization, rapid expansion of cities and migration of people from rural area to urban area and living standard of peoples. In India per capita waste generation is 0.17 to 0.8 per capita per day. Total waste generation in India is 1, 27,486 TPD in 34 states of municipality of this 89,334 TPD (70%) collected. Among these waste 48% are biodegradable waste and only 12.5% was used for processing such as composting and vermicomposting, production of gas etc [1]. Biodegradable waste contains fruits, flower, food waste etc. The quantity of flower waste in India is 300 MT/day [2]. Mostly flower waste mixed with municipal waste and used for landfilling. Flower waste contains useful micro and macronutrients which are beneficial for the growth of plants can be converted into nutrient enriched products.

Vermicomposting is a biotechnical process for the treatment of flower waste which adopts modern concept of ecological design by introducing earthworm [3]. It is a bio-oxidative process in which earthworm and microorganism play joint role to convert organic waste into matured and stabilized vermicompost. Although microbes are responsible for biochemical degradation of organic matter, earthworms are important driver of the process by conditioning the substrate and altering the biological activity [4]. However the quality and time required for the vermicomposting depends on the composition of initial waste mixture being processed. The various organic waste which have been vermicompost and turned into nutrient enriched manure include vegetable waste [5] (Suthar, 2009), cow dung [6] (Lazcano et al., 2008),water hyacinth [7] (Gajalakshmi et al., 2001), municipal waste [8] (Sharma, 2003).

The aim of present study was to study the effect of physicochemical and maturity parameters on the flower waste and cow dung during vermicomposting process and optimization using response surface methodology on the basis of maturity indices such as C:N ratio, CO2 evolution and germination index and physicochemical process.

2.0 Material and Methods

2.1 Feedstock

Flower waste was collected from temple in Surat city, India. Manual segregation of flower waste was carried to remove the debris (plastic, threads, incense sticks, coconut, etc.). Large quantity of marigold (Tagetus erecta) was observed along with rose (Rosa), lotus (Nelumbo nucifera), and siroi lily (Lilium macklinaie). Fresh Cattle dung was collected from dairy farm in nearby village, Surat, India. Table 1 shows the initial characteristics of feedstock

Table 1. Initial physicochemical characteristics of waste material

Parameters	Flowers waste	Cow dung
pH	5.28 ± 0.02	7.31 ± 0.02
Electrical conductivity (ms.cm^{-1})	4.20 ± 0.04	3.10±0.01
Total organic carbon (%)	45.58 ± 1.67	33.21±1.67
Total nitrogen (%)	2.08 ± 0.07	1.5 ± 0.14
NH_4-N (%)	1.69 ± 0.04	0.34 ± 0.03
C/N ratio	22.86 ± 0.34	22.84 ± 0.40
Total Phosphorous (g/kg)	3.28 ± 0.01	2.79 ± 0.03
Na (g/kg)	0.89 ± 0.07	2.55 ± 0.03

2.2 Vermireactor

Flower waste and cow dung with appropriate proportion were decomposed for seven days for semi-decomposition and stabilization to have optimum action of earthworms and microorganisms. The Precompost was transferred into Vermireactor after 07 days and matured earthworm of E. Fetida, randomly picked from stock culture, introduced into each Vermireactor. The size of Vermireactor was length, width and height. Each Vermireactor was prepared in duplicate and the average value was reported. All Vermireactor Waste was kept in dark at controlled laboratory temperature 22 ± 4oC. The mix proportions of each Vermireactor are shown in Table 3 as per design expert software. The biomass gain by the earthworms in each vermicomposting units was recorded weekly and only the data of optimum proportions of waste mixtures obtained from response surface methodology has shown. The waste in the container was turned out, then earthworms and cocoons were separated from the waste by hand sorting, counted and weighed after washing with water. Then all earthworms and the feed waste (but not cocoons) were returned to their respective container. Moisture content (60-80%) was maintained throughout the study period. About 100 g samples were collected from each 07 days interval. Number of earthworm has counted after adding the earthworm into reactor on 07 days dried samples were grinded into fine powder and sieved through 0.2 mm sieve and used for further analysis.

2.3 Analysis of physico-chemical parameters

For determining the pH and conductivity; 10 g dried sieved sample was diluted by 100 ml distilled water (1:10 w/v) and kept for shaking in rotary shaker for two hours. Then sample was kept for half an hour for settling, lastly filtered through whatman filter paper no 42 [9]. Pelican kelplus distyl ems instrument was used for total nitrogen determination. Sample was digested before analysis; by heating 0.2 gram sample with ratio of 1:5 Cupric sulphate and potassium sulphate, then 10 ml H2SO4 was added. Ammonical nitrogen was performed by KCl extraction methods followed by phenate methods [10]. Total organic carbon was calculated by dividing the volatile solids by 1.83 [9]. Sample was digested before analysis; by heating 0.2 gram sample with ratio of 5:1 of 10 ml H2SO4 and HClO4 at 300oC for two hours. The digested sample were used for determined the total phosphorous using Stannous chloride methods [15]. The concentration of Na and K were determined by using phlame photometer (Systronics 128µ). CO2 evolution rate was determined as described by (Singh et al., 2014). Germination index test was performed as described by (Zucconi et al., 1981).

2.4 Response surface methodology (RSM)

Two independent, controllable and important variables i.e., flower waste (gram) and cow dung (gram) were used to model maturity of the compost.

Thirteen different combinations of flower waste and cow dung were made using central composite designs (CCD) which consisted of 8 surface points and 5 centre points.

3.0 Results and Discussions

3.1 RSM modelling

RSM was used and second order polynomial model [as given in Eq. (2)] was developed using the experimental process the parameters data of which has been shown in Tables 3. The model was also developed for the process parameter and quality of compost such as pH, electrical conductivity, total organic carbon, total nitrogen, sodium, potassium and phosphorous (data not shown). The following model C:N ratio, germination index, CO2 evolution were involved for the maturity of the flower waste compost and is presented in terms of coded factors.

C:N ratio = +14.01+1.72x10-3*FW-3.66x10-3*CD ....(6)

G I = +52.17+0.002*FW+0.109*CD-1.50*10-5FW*CD-7.34*10-6*FW2 +1.71*10-5*CD2....... (7)

CO2 evolution = +0.93-5.65*FW-6.44*10-4*CD+2.15*10-7*FW*CD +2.42*10-7*FW2+1.71*CD2.... (8)

Multiple linear regressions were used to compute the regression coefficients of the quadratic model to minimize the sum of squares of the process parameter [11]. Tables 2 show the results of Anova analysis calculated from equation 6 to 8. It shows that the model was significant and can be used to traverse the design domain. The F value, P value (P>F) and adequate precision shows the efficiency and significance of the model.

Table 2. Anova for regression model and respective model terms for C:N ratio, germination index, CO2 evolution

Response	Source	Sum of squares	DF	Mean square	F-value	P-value prob>F	
C:N ratio	Model	16.58	2	8.29	31.23	<0.0001	significant
	Residual	2.65	10	0.24			
	Lack of fit	1.45	6	0.24	0.81	0.6126	Not significant
	Pure error	1.20	4	0.30			
Std. Dev = 0.52, C.V. % = 3.56 , R^2= 0.8620, $R^2_{adjusted}$= 0.8344, R^2 predicted= 0.7618 Adeq.Precision= 15.259							
Germination index	Model	258.93	5	51.79	134.62	<0.0001	significant
	Residual	2.69	7	0.38			
	Lack of fit	1.38	3	0.46	1.40	0.3652	Not significant
	Pure error	1.31	4	0.33			
Std. Dev = 0.62, C.V. % = 0.66 , R^2= 0.9897 , $R^2_{adjusted}$= 0.9824, R^2 predicted= 0.9547 Adeq.Precision= 30.604							
CO_2 evolution	Model	0.31	5	0.062	65.95	<0.0001	significant
	Residual	6.56E-003	7	9.382E-004			
	Lack of fit	2.84E-003	3	9.491E-004	1.02	0.4720	Not significant
	Pure error	3.72E-003	4	9.300E-004			
Std. Dev = 0.031, C.V. % = 5.42 , R^2= 0.9792 , $R^2_{adjusted}$= 0.9644, R^2 predicted= 0.9187 Adeq.Precision= 25.231							

A model will be significant at 95% confidence interval if F test having P value is less than 0.005. Table 4 shows the P value of all parameters which are less than 0.005. In the present study each parameter was statistically significant as per P value. Equation numbers 2 to 5 show the only statically significant model in terms of (P<0.005). In case of lack of fit (P>F) the P value greater than 0.005 is considered, it shows the failure of the model in representing data points in the experimental domain [11]. In this study the value of lack of fit was 1.45 for C:N ratio, 1.31 for germination index, 2.84E-003for CO2 evolution which indicate the lack of fit of the model is insignificant.

3.3 Maturity and quality of vermicompost produced from vermireactor units

The pH of the waste mixture significantly affects the process of vermicomposting. The changes in pH from initial to final compost are shown in table 5. Initially the pH in all reactors was acidic (5.1 to 5.89) and at the end of vermicomposting the pH was changed to basic (7.1 to 7.78). The electrical conductivity shows the salinity of the compost. Initially electrical conductivity was (2.01 to 3.8) into all vermireactor and it was increased to (3.3 to 4.11 mS/cm). The increase in EC was due to loss of organic matter and release of mineral salts in available forms such as phosphate, ammonium, potassium etc [4]. Decreasing trends of TOC was observed in each reactor during the vermicomposting process shows the stabilization of organic matter substrate due to combined actions of earthworms and microorganisms. It has been reported that earthworms modify substrate conditions, which subsequently enhance the carbon losses from the substrate through microbial respiration in the form of CO2 [4]. TOC reduction of 22% to 31% was observed in each vermireactor (refer table 3). The final total nitrogen depends on the initial content of nitrogen into waste mixture. Increase in total nitrogen contents was observed in each vermireactor. The total nitrogen contents in each reactor were varied from 1.7 to 2.85 (Table 3).

Table 3. Physicochemical changes during initial and final day into each reactor

S.NO	FW	CD	pH		EC		TOC		TN		NH4-N		Na		K		P	
			I	F	I	F	I	F	I	F	I	F	I	F	I	F	I	F
1	550	350	5.1	7.1	2.01	3.8	48.2	36.2	1.8	2.59	120.32	77.2	1.49	2.85	7.69	11.32	2.1	4.2
2	2100	350	5.7	7.5	2.07	4.5	49.09	38.09	1.7	2.38	130.32	84.21	1.82	3.52	9.23	13.52	2.4	4.9
3	550	650	5.8	7.7	3.01	4.09	48.19	34.19	1.8	2.85	145.21	90.21	1.62	3.18	9.52	14.62	2.8	5.2
4	2100	650	5.6	7.46	3.03	4.4	48.6	35.06	1.8	2.34	152.32	98.24	1.89	3.78	10.21	15.31	2.4	5.4
5	228	500	5.30	7.39	2.01	3.8	47.2	33.2	1.7	2.55	128.32	82.25	1.52	2.98	7.58	11.62	2.3	4.3
6	2400	500	5.81	7.78	2.09	4.6	51.52	37.52	1.8	2.21	128.21	92.32	1.81	3.64	9.89	14.89	2.3	5.1
7	1325	285	5.29	7.29	3.04	4.11	49.05	39.05	1.7	2.60	115.65	74.21	1.62	2.62	7.32	11.02	2.3	4.1
8	1325	712	5.59	7.39	3.08	4.4	49.2	35.6	1.8	2.54	151.21	94.25	1.72	3.56	10.32	15.02	2.8	5.09
9	1325	500	5.31	7.21	2.01	3.3	48.22	33.55	1.6	2.33	150.65	93.68	1.70	3.48	9.86	14.25	2.7	5.03

Total phosphorous was increased to (38 % to 50%) in each vermireactor (refer table 5). The available content of total phosphorous in each reactor was initially ranges from 2.1 to 2.8 g/kg which increased to 4.2 to 5.2 g/kg. The total available phosphorous was significantly higher in final day of vermicompost than the initial. The increase in phosphorous was due to the direct action of worms gut enzymes and indirectly by stimulation of the micro flora. Initial K contents in waste mixture were 7.32 to 10.32 g/kg while it was in the range of 11.02 to 15.02 into the vermicompost. The activities of earthworms lead to an increase in Na which ranged from 2.62 to 3.85 g/kg into vermicompost, whereas it was 1.49 to 1.89 g/kg in initial waste mixture. Sharma (2003) [8] have reported that higher Na concentration (30.53-92.80%) in the vermicompost prepered from municipal solid waste. Ammoniacal nitrogen was initially high in each vermireactor whereas it was decreased into the final vermicompost. The ammoniacal nitrogen concentration decreased due to the volatilization of NH4+-N by the microbes and the nitrification during the composting process [2]. Germination index shows the phytotoxicity of organic waste and it is good indicator of maturity of

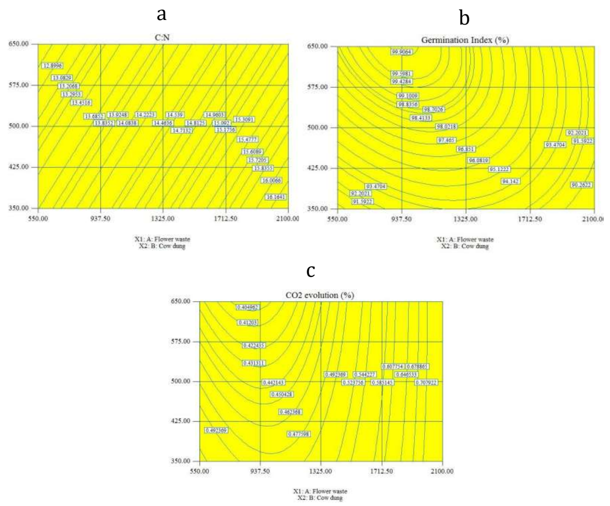

Figure 1. Contour plots of (a) C:N ratio (b) Germination index and (c) CO_2 evolution vermicompost.

Figure 1 (a) shows the contour plots of decreasing value of C:N ratio during the vermicomposting process mixed with flower waste and cow dung. Initial range of C:N ratio was 22 to 26 whereas at the final vermicompost was (15-12).

Figure 1 (b) shows the contour plots of germination index which indicate that flower waste is the organic in nature and good for the plant growth because in each vermireactor the germination index is more than 50% at the end of vermicomposting process. CO_2 evolution shows the maturity of the vermicompost and it is one of the best methods to determine the stability of the compost because it measures the carbon derived directly from decomposition or degradation of the organic matter.

3.4 Optimization and verification of model

The optimum proportionate weight of flower waste (FW) and cow dung (CD) for the vermicomposting was obtained from the various responses, using design Expert 8.0. Table 4 shows the experimental and predicted value for the optimum combinations of waste mixtures. The experimental and predicted values obtained from RSM model are nearly equal in optimum ratio (1280 g flower waste, 480 g cow dung). These results also confirm that RSM model was appropriate for optimizing the proportionate weight, maturity and quality of compost

Table 4. Analysis of final compost at optimum combinations (1280 g Flower waste: 480 g Cow dung)

Name of parameter	Predicted	Experimental	Name of parameter	predicted	Experimental
pH	7.07	7.12	C:N ratio	14.46	15
Electrical conductivity (mS/cm)	3.28	3.42	Phosphorous (g/kg)	4.95	5.21
Total organic carbon (%)	33.72	34.06	Potassium (g/kg)	13.99	14.31
Germination Index (%)	97.46	98.02	CO_2 evolution (%)	0.470	0.39
NH_4-N (mg/kg)	92.27	91.21	Na (%)	3.29	3.42

The variation of pH which was acidic (5.2) in initial day and it was increased to 7.12 at the end of vermicomposting process. Table 4 shows the predicted value of pH was 7.07 and experimental value was 7.12 in which the value of PH was slightly difference. The experimental and predicted value shows that the optimum combination of waste mixture was sufficient for the vermicomposting process. Electrical conductivity was 2.31 mS/cm at the initial day which was increased to 3.42 mS/cm into the final vermicompost. The total organic carbon was reduced 29.11% during the vermicomposting process which shows the degradation of organic matter and utilization of carbon as source of energy by microbes and earthworms. Total nitrogen was used by microbes for building the cell structure and nitrogen was increased from 1.83% to 2.27%. Due to decrement of total organic carbon and increment of total nitrogen C:N ratio was decreased. Initial C:N ratio into optimum mixture of waste was 26 whereas it was decreased to 15 into final vermicompost. The presence of ammoniacal nitrogen into initial vermicompost was 139.21 mg/kg which was decreased to 91.21 mg/kg. The experimental and predicted value was nearly equal into the optimum waste mixture.

Conclusions

This study concludes that flower waste mixed with cow dung into appropriate proportion then it can be vermicompost by E.fetida. Vermicompost obtained by flower waste was rich in sodium, potassium and phosphorus which is the essential for the plant growth and low electrical conductivity, higher reduction of total organic carbon, increase rate of total nitrogen, less C:N ratio, higher germination index and low CO_2 evolution shows the maturity and stability of vermicompost. The growth of earthworm biomass into flower waste was is in considerable amount. RSM technique used for optimizing the waste combinations validated the process efficacy and showed the fitness of the model. Among all the parameters value of R^2 was closer to 1. In the present study R^2 value was closer to R^2 adj representing the higher significance of the model. Therefore the coefficient of variance (CV) was not greater than 10% for all process efficacies which validated the fitness of the model. Hence, it can be concluded that RSM technique provided the appropriate combinations for performing composting with optimum ratio of 2.67:1 of flower waste and cow dung.

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