Assessment of rotary drum and aerated in-vessel for composting of garden waste

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Abstract

For in-vessel composting of garden waste, the selection of reactor is an important factor for efficient degradation. The present study evaluates working performance of rotary drum reactor (RDR) and aerated in-vessel (AIV) for composting of garden waste. 100 kg garden waste was mixed with 10 kg cow-dung slurry and 5 kg compost and feed into both the reactors for 45 days composting period. The reactors vary in their system configuration, shape and orientation, blade design, rate of aeration, odour control, leachate production and energy requirements. Rotary drum was rotated daily six times in clockwise and anti-clockwise direction and AIV was rotated daily for 3–5 minutes using motor. Rise in temperature started within 24 hours of composting and reached 65°C and 59°C on second day itself and thermophilic phase continued for 7 and 5 days for RDR and AIV respectively. Moisture content reduction after composting period was 15.25 and 18.45 %, C/N ratio was 16.14 and 13.33, TVS reduction was 23.74 and 29.78 % and CO_2 evolution rate was 6.18 and 4.14 mg/g VS/day in RDR and AIV respectively. Reduction of hemicellulose, cellulose, and lignin was more in AIV. The percentage reduction of acid insoluble lignin was 36.10 and 29.01 % and the percentage reduction of acid soluble lignin was 48.85 and 43.3% in in AIV and RDR respectively after 45 days. AIV gave better performance for composting of garden waste.

1. Introduction

In developing and developed nations, growth in urban green areas has led to tremendous increase in garden waste (GW) generation. GW is a low density (50–75 kg/m^3), heterogeneous mixture with low decomposition rate (Reyes-Torres et al., 2018a). GW comprises of 15–18% fraction of total municipal solid waste generated (Kumar et al., 2010; Manu et al., 2013; Wei et al., 2017). GW can be utilized as a feedstock for composting or co-composting methods (Vandecasteele et al., 2016) and even for the production of energy (Shi et al., 2013).

The selection of method, substrate, microbial inoculant, rate of aeration and type of reactor needs to be given upmost importance for GW composting (Sangamithirai et al., 2015). In-vessel composting has numerous benefits when compared with other types of composting methods. It can process huge amount of waste along with different types of organic waste (Kalamdhad et al., 2009). It occupies less space for installation and operation and produces minimum odour (Iyengar and Bhave, 2006). Also, problem of fly breeding and rodents are eradicated because of close and intact design (Chang et al., 2006). Similarly, it has better control of environment factors such as temperature, moisture and airflow. Also, it can be used year-round in any type of place and climate (Hogland and Marques, 2003).

Finstein et al., (1983), in their study classified laboratory scale reactors as self-heating reactors and fixed temperature reactors, however (Ashbolt and Line, 1982) grouped laboratory scale reactors based upon the method of periodic mixing or method of agitation incorporated. Self-heating reactor solely depend upon the heat generated by microbial degradation for rise in temperature (Kalamdhad and Kazmi, 2009). Many researchers have studied self-heating reactors and investigated their effect on variations in temperature, moisture content, rate of aeration, and maturity parameters (Campbell et al., 1990).

Extensive literature is available on various types of reactors in varying shape and size. Also, volume of various type of reactors range from 0.4 to 1780 L (Coss et al., 2010). In terms of shape, both cylindrical and rectangular shapes have been studied extensively for composting of various types of organic waste. VanderGheynst and Lei, (2003) used 30 litre self-heating cylindrical reactor having SA/V ratio 18 $m^2\ m^{-3}$. Similarly, Mason and Milke (2005) used another cylindrical reactor with SA/V ratio of 17.6 $m^2\ m^{-3}$ for organic waste composting. Also, other researchers have used self-heating reactors of 119 litre capacity with SA/V ratio of 12.1 $m^2\ m^{-3}$ and 33.3-L self- with a SA/V ratio of 17.6 $m^2\ m^{-3}$ (Taylor et al., 2013). As per Petiot and De Guardia, (2004), cylindrical shaped reactors are most common and recommended laboratory scale reactors as they have minimal SA/V ratio which decreases excess heat loss from the surface of reactor. VanderGheynst et al., 1997 proposed that as SA/V ratio increases, heat loss potential from the reactors also increases. Hence, SA/V is considered as an important criterion for designing of reactors to achieve thermophilic phase for longer duration which will help in sanitation of whole feedstock (Reyes-Torres et al., 2018b). Also, Taylor et al., (2013) proposed in his study that reactor with small size (less than 30 litres) are incapable in maintaining thermophilic phase due to excess loss of heat through external surface.

In any reactor, the amount of heat generated depends upon the quantity of biodegradable matter in the feedstock, volume of the substrate and heat losses from the surface of reactor (Petiot and De Guardia, 2004). Also, the material of the reactor plays equally important role in confining the heat to remain inside the reactor (Campbell et al., 1990). Various different types of insulation materials like glass, wool, polyurethane, polystyrene, and proprietary materials with their thicknesses varying from 12.7 to 120 mm have also been utilised for increasing the heat on reactor (Reyes-Torres et al., 2018a). Aeration is another important factor for efficiency of any reactor. Rate of aeration affects the rate of degradation, activity of microbes, temperature and moisture variations and maturity parameters (Puyuelo et al., 2010).

Among various reactors available, rotary drum rector is an efficient and proven reactor for the effective degradation of organic waste (Varma and Kalamdhad, 2015). Rotary drum facilitates adequate agitation, sufficient aeration, and proper mixing of the waste, and time of degradation is reduced to 2–3 weeks (Kalamdhad and Kazmi, 2009). Rotary drum can be designed as per the requirement of total waste generation. Also, rotary drums can be upgraded to manage continuous flow of waste for diverse type of organic waste such as chicken litter, vegetable waste, food waste, municipal biosolids, swine manure and cattle manure (Smith et al., 2006; Aboulam et al., 2006; Kalamdhad and Kazmi, 2008; Tolvanen et al., 2005; Varma and Kalamdhad, 2015).

Aerated in-vessel (AIV) is another in-vessel reactor that offers faster degradation in least duration. Unlike RDR, AIV is designed in a specific way to speed up the degradation at maximum using specifically designed blades that churn and mix the waste during rotation. AIV is in a U shape and can be designed as per the requirement and compost output desired. The present study evaluates and compares the performance of RDR and AIV using GW as the main feedstock along with cow-dung and slurry for a period of 45 days.

2. Material And Methods

2.1. Study Site:

The experiment was performed at Solid waste laboratory, Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, Gujarat, India. The site is located at 21.17 °N latitude and 72.83 °E longitude. Surat has a tropical savanna climate, and the average temperature varies between 27°C to 31°C.

2.2. Raw materials

The experiment was performed using garden waste, cow dung, and fresh flower compost. In the present study, garden waste was collected from Jawahar Lal Nehru garden, Athwa gate, Surat, Gujarat. The waste represented the homogenous mixture of varieties of tree species but the majority of them include fallen leaves (brown and green), grass, small branches, sticks, and others. The garden waste brought was thoroughly mixed and unwanted materials (papers, plastics, cans, and sticks) were removed. For composting, small branches and twigs that contained the majority of the woody part were also removed. The garden waste was shredded 1.5-3 cm diameter particle size range using leafcutter/pulverizer before using as feedstock material.

Fresh cow-dung was collected from Umra village, near SVNIT, Surat. 5 kg cow-dung was mixed with 5 litres of water and converted into slurry. Fresh compost was prepared in the SVNIT laboratory by using flower waste as feedstock. Cow-dung and compost used acted as a source of microbial biomass to enhance degradation of GW. The physico-chemical characteristics of all raw materials are given in Table 1.

2.2. Reactor Configuration and design- Rotary drum

Figure 1 shows a rotary drum reactor with 0.6 m^3 capacity. The drum measurements were the following: length- 1.20 m, diameter- 0.80 m and thickness of metal sheet as 0.3 mm. To keep the drum rust-free, inner parts were painted with anti-corrosive paint (red oxide). The angles were welded longitudinally for an enhanced mixture of waste inside. Two holes of 10 cm were given at the bottom of the rotary drum to drain off any leachate production. A metallic stand was fabricated for the proper installation of the drum. Roller and chain were used for the rotation of the drum. Air enters naturally from half side open of the drum and is mixed with the waste as it tumbles. The waste gets mixed, aerated and agitated during the rotation of drum. The drum can be open or partitioned. An open drum moves all the material through continuously in the same sequence as it enters.

2.3. Reactor Configuration and design- Aerated in-vessel (AIV)

Figure 1 shows the AIV developed at SVNIT, laboratory with around 400 kg capacity (Patent number: 300468). The reactor is one-third rectangular shape, and remaining portion is in circular shape reactor. The circular shape below the reactor gives the proper space to the waste mixture and helps in the proper up and down and for proper mixing inside the digestion chamber. The reactor was made up of 10-gauge iron sheet. In reactor 50 mm circular iron shaft was attached. The blade was attached at the distance of 15 cm at top and bottom of the shaft. The length of the shaft was 1.5 m. The blade was attached with the shaft of 15 cm distance from the upper and lower portion of the shaft with the angle of 35°.

2.4. Methodologyb

RDR and AIV were used for composting of garden waste (100 kg), cow-dung slurry (5 kg cow-dung mixed with 5 litres of water) and fresh flower compost (2.5 kg) in (10:1:0.5) ratio for 45 days with particle size 1-2.5 cm. The ratio and particle size were selected as per information available in the literature for maximum degradation. Materials were feed into both drums and the experiment was run for 45 days. In both RDR and AIV, temperature was observed on a daily basis using digital thermometer (Mextech ST9283B Multi Stem Thermometer) and all other parameters were recorded at three days interval. Temperature was monitored at six different locations of the reactors and its average value was recorded. Moisture content was monitored for 45 days during which maximum degradation took place and moisture subsided gradually, however, after 30 days, addition of water was done on dry weight basis to maintain the moisture level between 50–60% for maximum survival of microbes. Rotary drum was rotated daily three times in clockwise and anti-clockwise direction and AIV was rotated daily for 5 minutes using motor. All parameters were analysed immediately after collection of sample or store in the deep freezer for further analysis.

2.5. Analysis of physico-chemical parameter

Moisture content was calculated in a hot air oven by drying the sample at 70 ± 2 ºC for 24–72 hours. Ten grams of oven-dried powdered sample, diluted with 100 ml distilled water (1:10 w/v), and then rotated in a rotary shaker for 120 minutes and kept for 60 minutes to let it settle down and subsequently filtered using Whatman filter paper no. 42 to find pH and electrical conductivity. Kjeldahl approach was used to determine total nitrogen. KCl extraction procedure led by the phenate method (APHA, 2005) was used to determine ammoniacal nitrogen. Total volatile solids were`calculatedby burning the oven-dried sieved samples at 550 ± 5 ºC. Also, as per Adhikari et al., (2009), TOC (Total Organic Carbon) was calculated by dividing the volatile solids by 1.83. CO_2 evolution rate was found using the lime-soda method as per Singh and Kalamdhad, (2014). For phosphorous analysis, 0.2-gram sample was digested using a heating digester (Velp Scientifica DK 20) with 10 ml H_2SO_4 and $HClO_4$ for 2 hours at 300°C in 5:1 ratio and then stannous chloride was used to find phosphorous concentration. Potassium concentrations were found using a flame-photometer (Systronics 128l) by digesting 0.2 gram oven-dried sieved sample with 10 ml $HClO_4$ and H_2SO_4 for 2 hours at 300°C in the ratio 5:1 (Jain et al., 2019).

3. Results And Discussions

3.1 Temperature, Moisture content, pH and Electrical conductivity

Temperature is an important factor and decides the rate at which all processes take places inside the reactor and even influences microbial growth (Hassen et al., 2001). An efficient reactor will sustain higher temperature for proper degradation of organic waste within short period of time (Angeles and Gmbh, 1998). Rise in temperature started within 24 hours of composting and reached towards 65°C and 59°C on second day itself and thermophilic phase continued up-to 7th day 5th day for RDR and AIV respectively as shown in Fig. 2. The temperature rises rapidly at the start due to rapid microbial breakdown of organic matter (Ogunwande et al., 2008). The rise in temperature was more in RDR as more heat is conserved due to its compact design and only two half doors open. In AIV, the upper part is completely open and loss of heat is more. It has been stated that the temperatures from 52°C to 60°C during the composting cycle is considered to sustain the greatest thermophilic activity (Ramdani et al., 2015). Both reactors were efficient in sustaining higher temperature for a longer time. VanderGheynst and Lei, (2003) observed similar results for rectangular and cylindrical reactors used for composting of organic waste.

Moisture content plays critical role during the degradation of organic waste. A higher reduction in moisture content was observed in both reactors for first week during which thermophilic phase was predominant and temperature reached 65ºC. Also, loss of moisture and the rise of temperature is an index of the rate of decomposition since microbes generate heat as they decompose (Singh and Kalamdhad, 2016). Figure 2 gives the initial moisture content in RDR and AIV as 71.24 and 71.56% which reduced to 56.12 and 53.55% respectively after 30 days. Higher moisture loss shows higher degradation which occurred in AIV, maybe due to its blade configuration which allowed adequate recirculation of organic matter. Also, as per Kalamdhad and Kazmi, (2009b), due to higher aeration rate, moisture content reduction was more when compared with low aeration rate during mixed organic mixture composting in rotary drum reactor.

pH of the feed material is one of the indicators for the rate of degradation. The initial pH was 6.27 and 6.75 which increased to 7.62 and 7.87 in RDR and AIV respectively and then lowered towards neutrality after end of composting period as shown in Fig. 2. pH in both reactors first decreased initially due to release of organic acids (Awasthi et al., 2015). The rotation of garden waste in the AIV reactor and tumbling action in RDR provides adequate aeration accountable for the rise in pH value and increased degradation of garden waste due to hydrogen ions released during aeration. Similar in change in pH results were observed by (Kalamdhad and Kazmi, 2009b) during cylindrical reactor composting of different organic waste.

Electrical conductivity (EC) is an important indicator of compost maturity and reflects salinity of substrates present, and is important because plant growth does not desire high salinity (Vaverková et al., 2017). EC > 12 mS /cm or higher in compost will adversely affect the growth of plants such as low germination and withering (Varma and Kalamdhad, 2015). The initial EC was 2.72 and 2.47 mS/cm which increased up to 2.71 and 2.73 mS/cm in RDR and AIV respectively after end of composting period as shown in Fig. 2. EC values within 3–12 indicate an index of compost maturity (Zhao et al., 2012). The release of mineral salts (phosphate, ammonium ions) in both reactors led to the decomposition of organic matter which led to an initial increase in EC. Mineral salt precipitation could be a reason for a decrease in EC in all combinations (Krishna and Kalamdhad, 2014). A similar result in EC was observed by (Zhao et al., 2012) and (Sharifi and Renella, 2015) during composting with organic waste.

3.2. Total organic carbon (TOC), Total volatile solids (TVS), ash content, and ammoniacal nitrogen

TOC is an important parameter and indirect indicator of the degree of compost maturity (Awasthi et al., 2015). The initial TOC was 45.72 and 45.09 % which dropped to 29.45 and 31.95 % after 45 days in RDR and AIV respectively as shown in Fig. 3. Because of higher microbial activity at higher temperature in both the reactors; the rate of degradation of garden waste was high, resulting in a high reduction. The higher degradation of TOC because of active microbial metabolism at thermophilic stage is supported by (Kalamdhad and Kazmi, 2009). Thus, TOC concentration of composting garden waste decreased with mass reduction (Gabhane et al., 2012). A similar reduction in TOC was observed by Elango et al., (2009) and Adhikari et al., (2009) during composting of municipal solid waste and food waste.

The initial total volatile solids were 83.67 and 82.51 % which reduced to 53.89 and 58.77 % in RDR and AIV respectively after 45 days of composting process as shown in Fig. 3. TVS reduction of RDR an AIV wea 29.78 and 23.74 % respectively. The high volatile solids reduction in the first 15–20 days was more in AIV as compared to RDR. It may be due to the adequate availability of substrate to the microbes. The result is supported by Jain et al., (2019) where TVS decreased during composting of vegetable waste, saw-dust and cow-dung at thermophilic phase.

The ash content in all reactors increased when the reduction of TOC started. The initial ash content in RDR and AIV was 16.33 and 17.49% which increased to 46.11 and 41.53 % respectively after 45 days as shown in Fig. 3. Percentage of ash content increased as performance of reactor increased. Also, similar rates of ash content were observed during GW composting with 500 litre cylindrical reactor (Hannon and Mason, 2003) and during mixed organic waste mixtures in large-scale reactor (Francou et al., 2008).

Ammoniacal nitrogen acts as an indicator of the maturity of compost. For the compost maturity, the concentration of ammonia nitrogen < 400 mg/kg is appropriate (Bohacz, 2017). The initial value was 157.45 and 159.13 mg/kg which decreased to 129.61 and 137.41 mg/kg in RDR an AIV respectively as shown in Fig. 3. Similar result of decreasing ammoniacal nitrogen was observed by Rekha et al., (2005) when organic waste was composted in different reactors. During day 2–12, highest ammonia volatilization rates were observed, however after thermophilic phase, loss of ammonia was very low. It was observed during the study that ammonia volatilization increases with increase in temperature and rate of aeration. Similar results were reported by Sharma et al., (2017) during which increased aeration was responsible for increase in ammonia emissions. Zhang and Sun, (2016) reported a similar observation during treatment of organic waste in different reactors.

3.3 CO_2 evolution rate, C/N ratio and NPK (Total Nitrogen, Potassium and Phosphorous)

CO_2 evolution rate is one of the most important indicators to check the maturity of compost. The rate of CO_2 evolution is related with volatile compost material degradation and indicates the readily degradable composting material present in the compost sample (Gupta et al., 2018). Initially the CO_2 evolution rat was 20.12 and 18.67 mg/g VS/day which decreased to 4.11 and 6.18 mg/g VS/day in RDR and AIV respectively as shown in Fig. 4. No significant differences were observed in carbon dioxide volatilization for both the reactors during first week days. However, differences were observed during thermophilic phase and after maturity phase which is in sync with decreasing trends of CO_2 evolution rate as observed by Kalamdhad et al., (2009) during composting of vegetable waste in rotary drum.

The C/N ratio is the compost maturity indicator affecting the composting process and end product properties of compost (Kumar et al., 2010). Carbon is utilized as source of energy by microbes and nitrogen is used for building cell structure (Sharma and Yadav, 2017). In present study, the C/N ratio was 30.68 and 31.10 which dropped to 13.33 and 16.14 after 45 days in RDR and AIV respectively. The C/N ratio is a significant factor determining the maturity rate, microbial growth speed, compost quality and nutrient presence in the final compost. Similar values were observed by Kumar et al., (2010) during composting of food waste and GW in different reactors.

The concentration of nitrogen is generally increased after the composting process due to the loss of organic matter content and the activity of nitrogen-fixing bacteria (Varma and Kalamdhad, 2015b). The initial concentration of TN was 1.49 and 1.45 % which increased to 2.21 and 1.98 % in RDR and AIV respectively as show in Fig. 4 after 45 days. During reactor composting of organic waste, Varma & Kalamdhad, (2015b) reported a percentage increase in total nitrogen from 1.6-2.0% to 2.8-3.0%. The increase in total nitrogen can be due to net loss of dry weight as CO_2 evolution and loss of moisture from heat generation by microbial activity on organic matter. In addition, at the later composting stage, nitrogen-fixing bacteria may also contribute to an increase in total nitrogen (Varma and Kalamdhad, 2015b) In this study, the increasing trends in total nitrogen were similar to (Jolanun and Towprayoon, 2010) results. The increase in TN was due to net loss of dry weight (Kalamdhad and Kazmi, 2009). The result is supported by (Sharma and Yadav, 2017) during composting of flower waste using dry leaves as bulking material in rotary drum.

Phosphorous is essential for plant growth and used by the microorganism for body metabolism during the composting process (Shi et al., 2013). The initial concentration of phosphorous was 1.42 and 1.71 g/kg which increased to 5.07 and 4.57 g/kg in RDR and AIV respectively as shown in Fig. 4. The increase in phosphorus concentration may be attributed to the loss of organic matter during composting. (Li et al., 2014) and (Zhang et al., 2013) found a similar increase in phosphorous content during composting of dairy waste, kitchen and garden waste, food waste. Also, a similar increase in phosphorous content was observed by Singh and Kalamdhad, (2012) during the composting of water hyacinth and vegetable waste in rotary drum reactor.

In plants, potassium primarily assists in photosynthesis and also regulates the absorption of CO_2. Potassium helps in enzyme activation and is important in adenosine triphosphate (ATP) production (Takahashi, 2014). The initial concentration of potassium increases from 5.27 and 5.23 to 9.48 and 8.79 g/kg in RDR and AIV respectively after composting period as shown in Fig. 4. The reason for increment of nutrients from initial to final day was loss of weight and organic matter degradation and no loss of leachate into both reactor system. Also, concentration of potassium increased in all rotary drums due to the potassium assimilation and immobilization by microbes (Singh and Kalamdhad, 2016). Also, similar increase in potassium and phosphorous concentration were observed during the composting of GW on full-scale plants (Hannon and Mason, 2003).

3.4 Cellulose, hemicellulose and lignin

The degradation of lignocellulose compound depends on the microbes (Hubbe, Nazhad, & Sánchez, 2010). During the process of composting the microbes first utilized the hemicellulose as the source of energy than the microbes utilize the cellulose. The microbes degrade the hemicellulose more easily as compared to the cellulose (Yu et al., 2019). The initial presence of hemicellulose in combination in AIV and RDR was 17.21 and 17.45% which was reduced to 2.93 and 4.17% at the end of 45 days It was observed that the reduction of hemicellulose was more as compared to cellulose as shown in Fig. 5. The similar higher reduction of hemicellulose was reported by (Sarika et al., 2014).

The percentage reduction of cellulose was 49.21 and 41.20 % respectively in combinations in AIV and RDR after 45 days. It was observed that in RDR, the degradation rate was slow due to the formation of lump and reduction of cellulose was low as compared to AIV. Figure 5 shows the variation of acid insoluble lignin and acid soluble lignin during the composting process. Lignin is very complicated or tough structure which is highly resistant to microbial degradation (Tuomela, Vikman, Hatakka, & Itävaara, 2000). The percentage reduction of acid insoluble lignin was 36, and 29 % and the percentage reduction of acid soluble lignin was 48.85 and 43.39 % in AIV and RDR after 45 days. The degradation of lignin mainly occurs at the thermophilic phase of the composting process. The degradation of lignin by most of the fungi produces humus, water, and carbon dioxide (Wan & Li, 2012). During the degradation of lignin, the release of energy was less which cannot be utilized by the microorganism, but the degradation of lignin produce adequate carbohydrate for the utilization of microbes, so the microbes which degrade polysaccharides also secret ligninolytic enzymes (Tuomela et al., 2000).

3.4. Other miscellaneous parameters

Volume reduction, leachate formation, heat generation and effect of blade configuration have direct impact on overall degradation of garden waste. The volume reduction was more in AIV (69.50%) as compared to RDR (55.50%) which shows higher degradation in AIV. No leachate was formed in any of the reactors as garden waste was mostly dry. Also, many studies have proven that maintaining proper C/N ratio with adequate aeration leads to elimination of leachate (Reyes-Torres et al., 2018b).

AIV released more heat due to its design and configuration. Being open and in a U-reactor shaped, majority of its heat dissipated. However, it was covered for the first 7 days to prevent maximum dissipation of heat. For RDR, loss of heat was lower compare to AIV due to its design. It was covered from above and only its half sides were open. One of the major reasons for higher degradation in AIV was due to the design of its blades. At every rotation, the whole compost would rise and fall in its own place with the help of longitudinal blades that led to higher aeration and adequate availability of oxygen by microbes to perform higher degradation. No blades were designed in RDR. It would only do the tumbling action and rotated the whole compost from its place where the bottom part would come at the top and vice-versa. Due to its design and configuration AIV is more expensive as compared to RDR, however, the price of both reactors may vary depending upon the feedstock quality, material of reactor, and compost quality required.

4. Conclusions

The present study was conducted to evaluate working performance of RDR and AIV using GW as main feedstock along with cow dung slurry and flower waste compost. The reduction in TOC by 16.27 %, TVS reduction by 29.78%, CO_2 evolution rate of 4.14 mg/gVS/d, and C/N ratio of 13.33 within 45 days of composting gave optimum conditions for efficient working performance by AIV. Among both the reactors, aerated in-vessel proved to be more efficient. Type of reactor is playing a critical role on compost maturity, time and quality.

Declarations

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Declaration of interests:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Tables

Table 1

Initial physico-chemical characteristics of feedstock material.

Parameters	Unit	Garden waste	Cow dung	Compost
Moisture content	(%)	46 ± 2.44	90.82 ± 2.52	46.02 ± 1.63
Total organic carbon (TOC)	(%)	38.02 ± 0.83	32.11 ± 0.67	23.4 ± 0.92
Total volatile solids (TVS)	(%)	80.35 ± 0.24	58.76 ± 0.37	42.39 ± 0.21
Ash content	(%)	19.21 ± 0.43	40.22 ± 0.67	55.0 ± 0.84
Potassium (K)	(g/kg)	0.25 ± 0.51	10.0 ± 0.22	28.52 ± 0.42
Phosphorous (P)	(g/kg)	0.13 ± 0.21	2.78 ± 0.18	22.21 ± 0.75
pH	-	6.93 ± 0.23	6.87 ± 0.32	7.43 ± 0.12
Electrical conductivity (EC)	(mS/cm)	1.52 ± 0.12	3.44 ± 0.18	2.87 ± 0.13
Total nitrogen (TN)	(%)	1.64 ± 0.12	1.41 ± 0.14	2.01 ± 0.18
Ammoniacal Nitrogen	(mg/kg)	181.14 ± 1.72	0.34 ± 0.03	75.67 ± 1.36
C/N ratio	-	28.43 ± 0.67	23.29 ± 0.41	14.56 ± 0.22

where number of samples (n) = 3

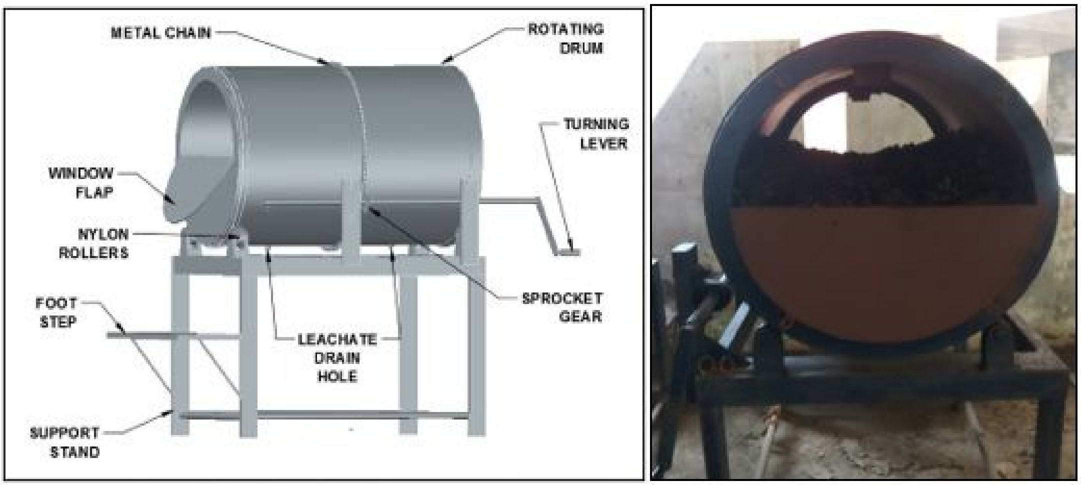
Table 2

Physico-chemical characteristics of feedstock and compost material

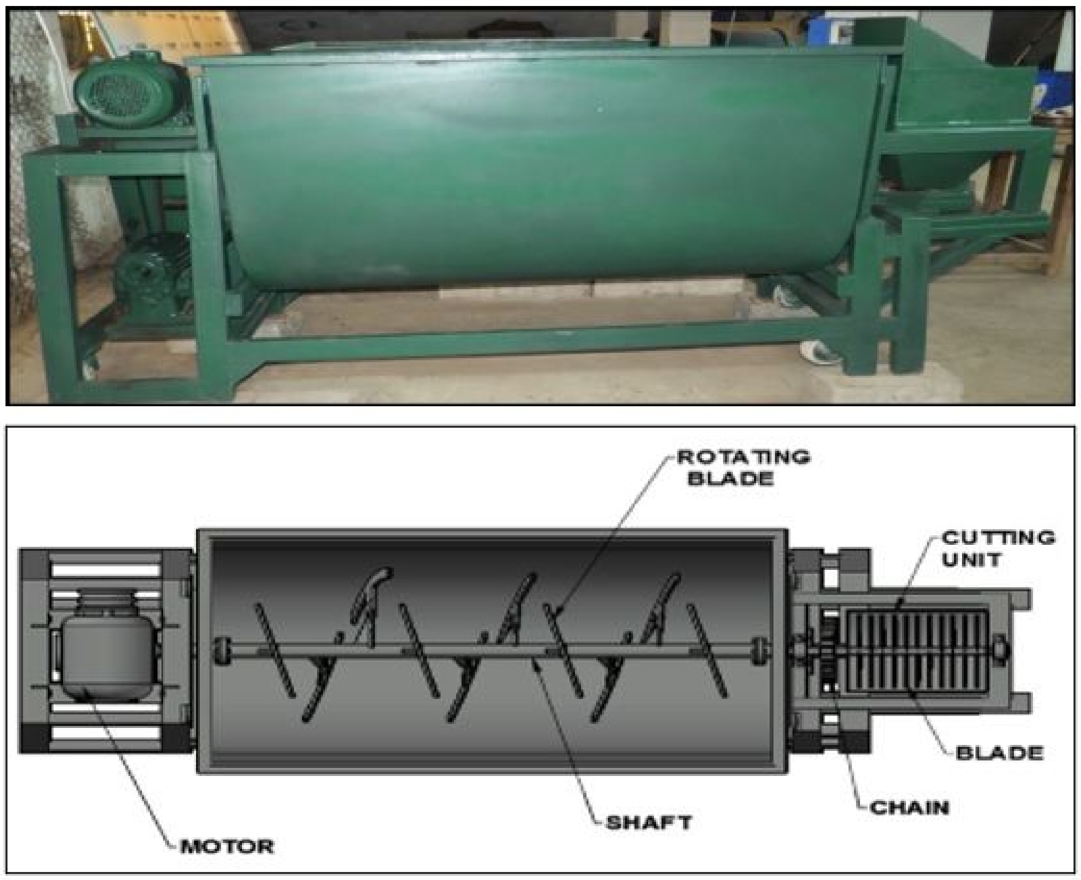
Parameters	Unit	Aerated in-vessel (Feedstock)	Aerated in-vessel (Compost)	Rotary drum (Feedstock)	Rotary drum (Compost)	Compost standards FAI (2007)	TMECC (2002)
Moisture content	(%)	71.24	55.12	71.56	56.25	35-55	35-45
Total organic carbon	(%)	45.72	29.45	45.09	31.95	≥16	-
Total Volatile Solids	(%)	83.67	53.89	82.51	58.47	-	-
Ash content	(%)	16.33	46.11	17.49	41.53	-	-
CO_2 evolution rate	(mg/gVS/d)	20.12	4.14	18.67	6.18	<2-3	-
Potassium (K)	(g/kg)	5.27	9.48	5.23	8.79	0.6-1.7 (%)	≥4
Phosphorous (P)	(g/kg)	1.42	5.07	1.71	4.57	0.4-1.1 (%)	-
pH	-	6.27	7.30	6.75	7.23	6.5-8.5	5.5-8.5
Electrical conductivity	(mS/cm)	2.72	2.71	2.47	2.73	-	≥ 4
Total nitrogen	(%)	1.49	2.21	1.45	1.98	1.0-3.0	-
Ammoniacal Nitrogen	(mg/kg)	157.45	129.61	159.13	137.31	-	75-500
C/N ratio	-	30.68	13.33	31.1	16.14	<25	<25

where, TMECC: Test Method for the Examination of Composting and Compost, FAI: The Fertilizer Association of India

Figures



1(a): Rotary drum reactor



1(b): Aerated in-vessel

Figure 1

Actual photograph and pictorial view of in-vessel reactor (a) Rotary drum reactor, (b) Aerated in-vessel

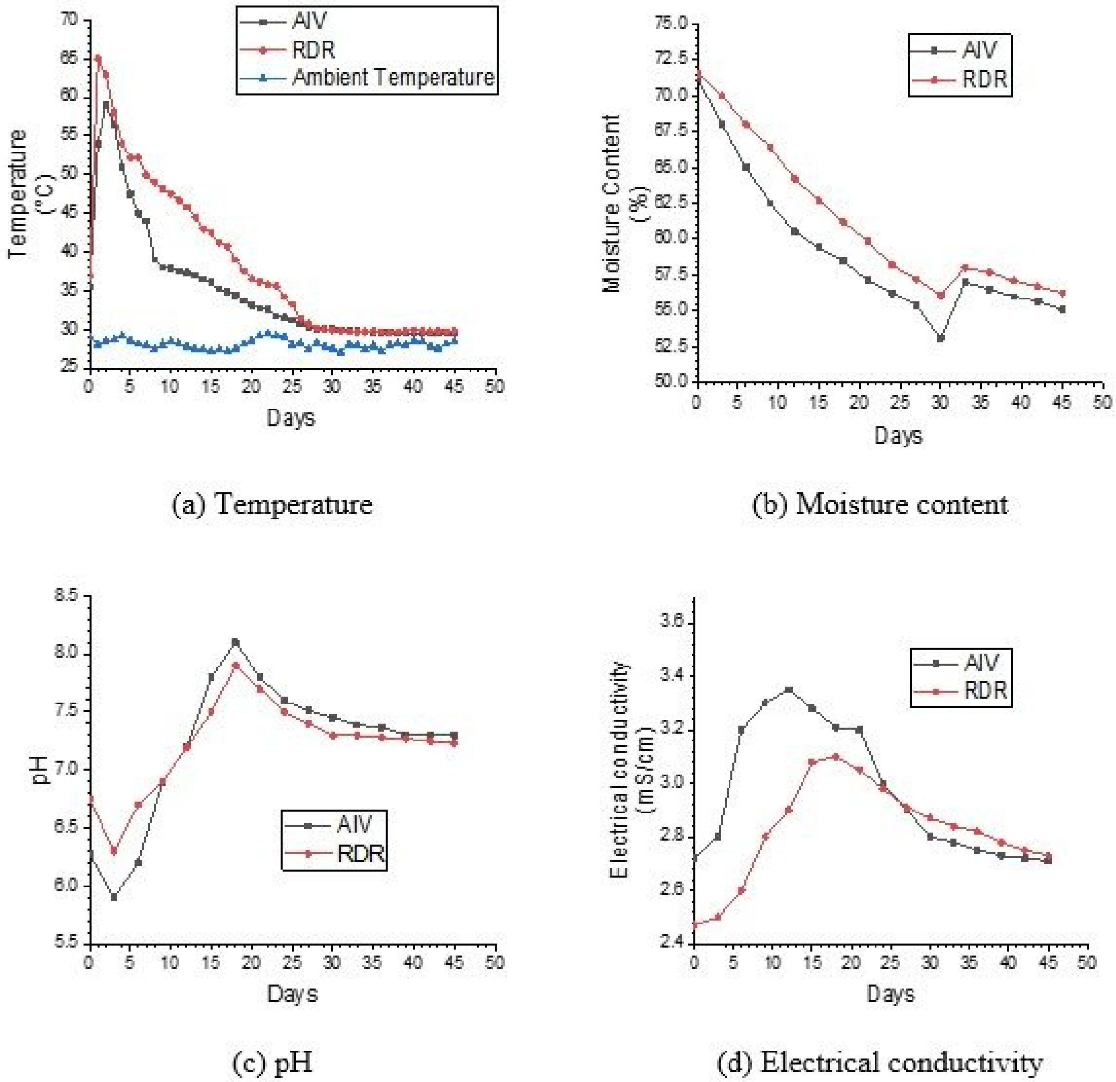


Figure 2

Temporal variations of (a) temperature, (b) moisture content, (c) pH and (d) electrical conductivity during garden waste composting

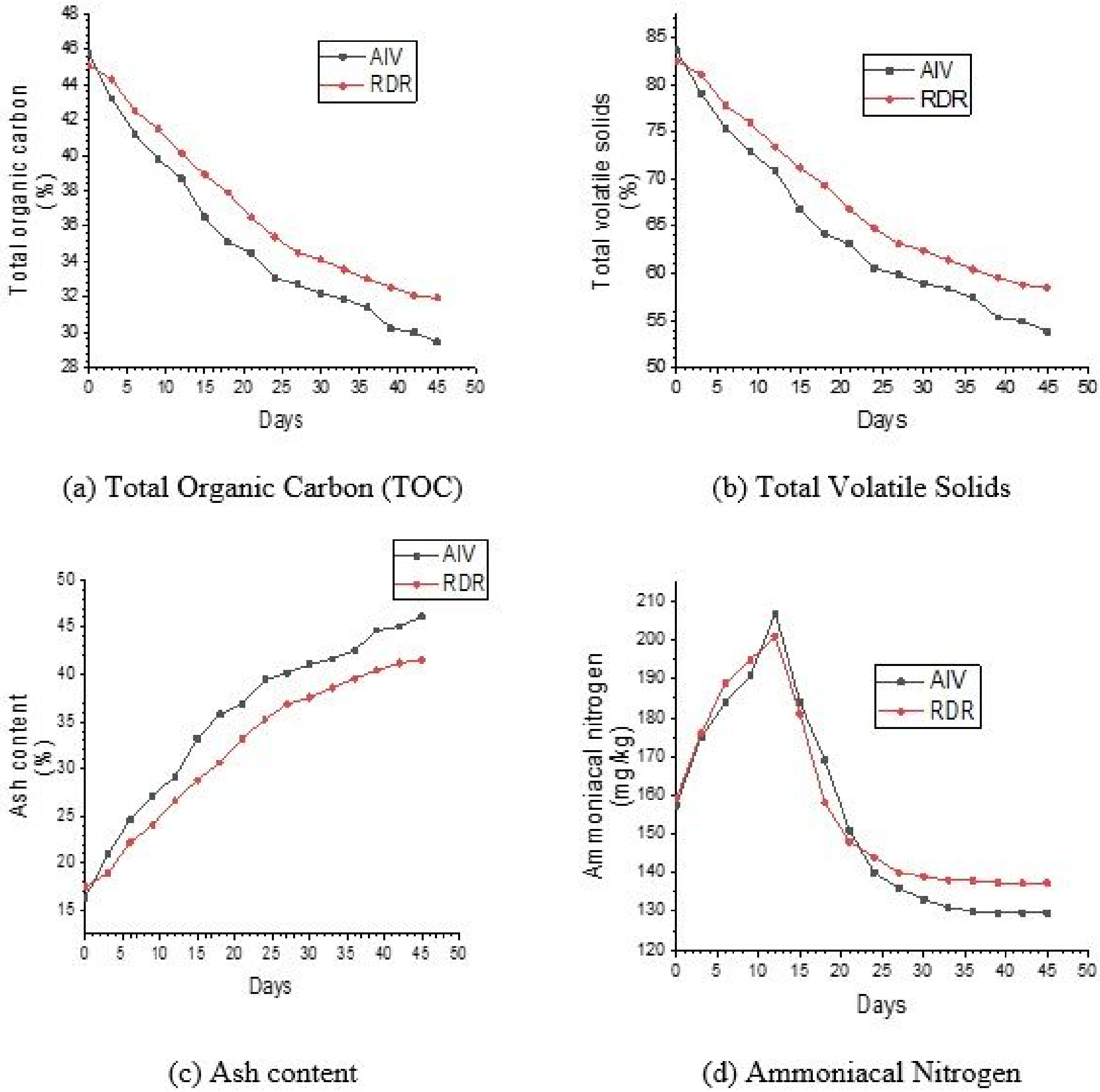


Figure 3

Temporal variations of (a) Total Organic Carbon (TOC), (b) Total Volatile Solids (c) Ash content, and (d) Ammoniacal Nitrogen

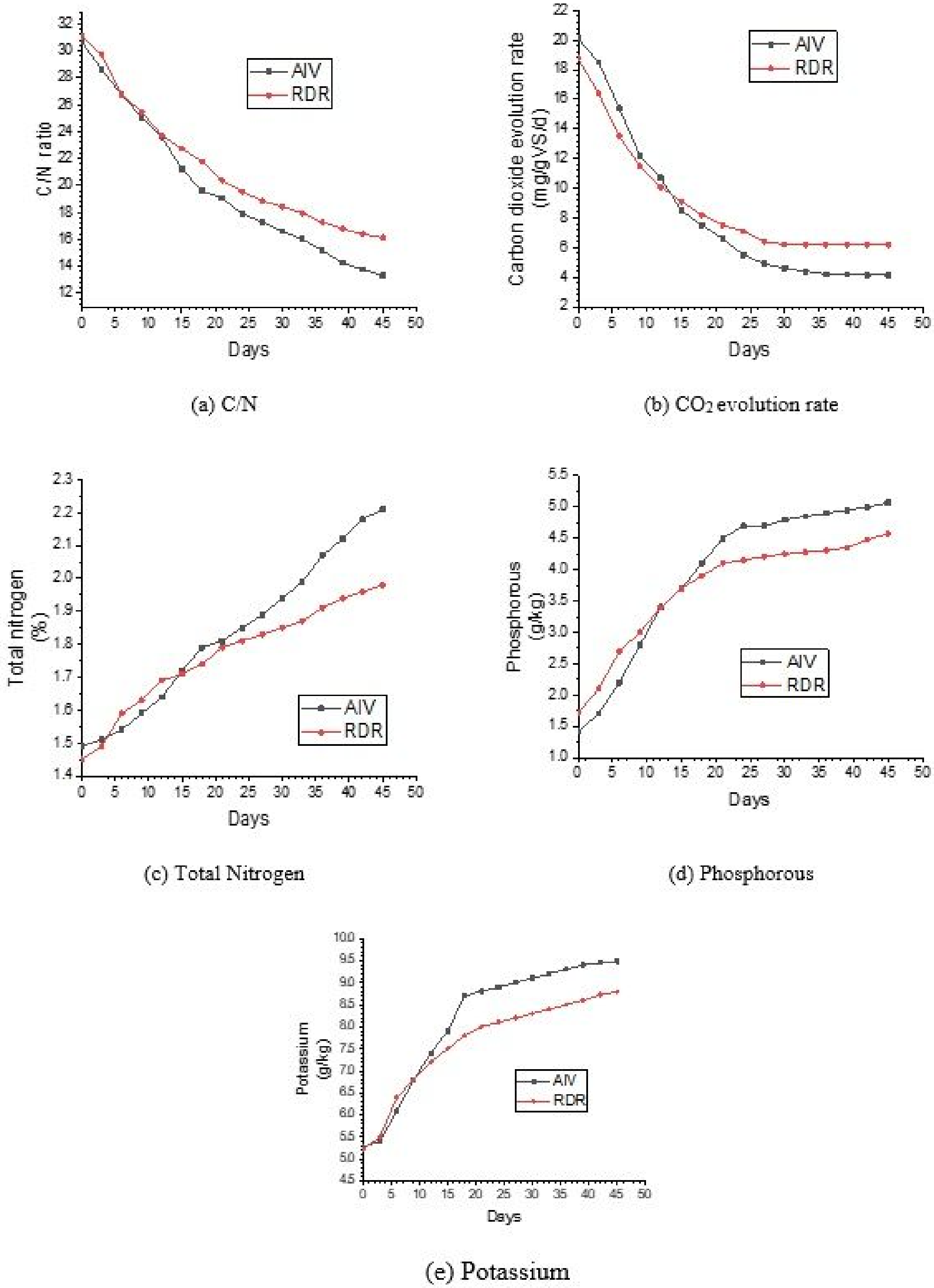


Figure 4

Temporal variations of (a) C/N, (b) CO2 evolution rate (c) Total Nitrogen, (d) Phosphorous and (e) Potassium during garden waste composting

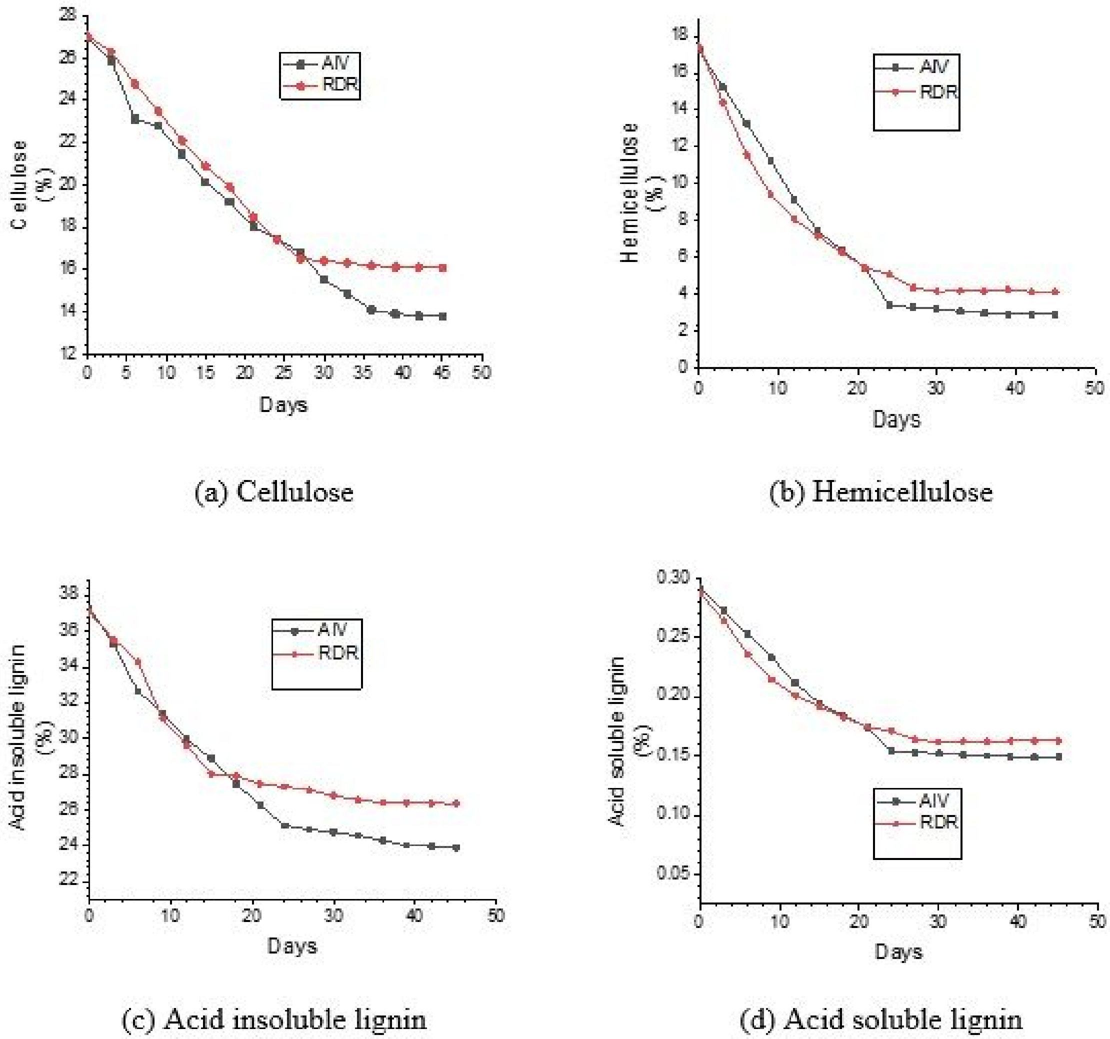


Figure 5

Temporal variations of (a) Cellulose and (b) Hemicellulose (c) Acid insoluble lignin and (d) Acid soluble lignin during garden waste composting

Supplementary Files

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