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ORIGINAL RESEARCH

Influence of composting conditions on gaseous emission and compost quality during composting of cow manure and wheat straw

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Abstract

Purpose The composting of manure is the common practice for the feedlots of cattle, but emission of gasses during composting was poorly understood. So, there is need to enhance nutrient contents in composting material, reduce odor and other impurities by various amendment in composting material. This study was planned to find best composting condition for quality compost production.

Method Experiment was performed under completely randomized design (CRD) with three factors. First factor (treatment) comprised of three levels e.g: T1: CM + WS (25% + 75%), T2: CM+WS (50%+50%) and T3: CM +WS (75% +25%). Second factor was composting conditions consisted of two levels e.g., aerobic and anaerobic conditions. Third factor was duration of composting (days).

Results Composting conditions significantly influenced emission of greenhouse gasses and compost quality. Maximum gas volume (658 ml) and methane production (58.89%) were produced under anaerobic decomposition of cow manure and wheat straw 3:1, respectively. Maximum carbon dioxide (18.56%) was produced under the aerobic decomposition of cow manure and wheat straw mixed in 1:3 ratio. Nutrient analysis of compost revealed that high-quality compost with maximum total organic carbon (20.1%), total nitrogen (2.47%), phosphorus (0.76%) and potassium (1.49%) was observed from compost produced from anaerobic decomposition of cow manure and wheat straw mixture @ 3:1.

Conclusion This work highlights that the anaerobic composting of cow manure and wheat straw has potential to produce the biogas as well as best quality compost.

Keywords Composting, Greenhouse gasses, Organic matter, Compost quality, Anaerobic composting, Waste management

Introduction

Composting is the widely used practice in the farms for the management and development of various fertilizers rich in nutrients. The composting process uses many methods eg windrows, in-vessel and static pile composting. The pile composting can be done in different intensity levels, by turning, forced aeration and addition of water within open or closed containers. Furthermore, some farms amend the compost with other organic matter sources or use solid manure for composting (Peigné

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et al. 2004). The main objective of the researchers is to enhance the nutrient availability in the soil by the application of compost and reduce the odor of compost. Composting rate and transformation extent mainly depends on composting conditions and the nature of feedstock (composting material). Different researchers in last 15 years worked to define the physical, chemical and microbial activities during the composting process (Baeta-Hall et al. 2005; Alburquerque et al. 2006; Canet, et al. 2008), and use of compost as a fertilizer, but little work was carried out to find the suitable composting conditions to enhance the biogas production and get high quality compost (Altieri et al. 2010; García-Ruiz et al. 2012). It was observed that the production of biogase and nutrient enhancement in the compost are mainly associated with the nature of composting substrate, composting conditions, ratio of carbon to nitrogen (C:N), moisture content, temperature, pH and aeration. An efficient composting process primarily depends on the ratioof feed stock mixture, carbon to nitrogen (C:N) ratio, moisture content, temperature, pH and aeration (Gao et al. 2010). The ideal ratio of carbon to nitrogen (C:N) is 20 -40, moisture content (40 to 60%), temperature (55 to 60°C) and pH (5.0 to 8.0) (Nekliudov et al. 2008). But international technical standards recommendthe ratio of carbon to nitrogen about 20-30 for the production of high-quality compost (Vochozka et al. 2017). The high C:N ratio slow the process of composting as the microorganism has to degrade the excess amount of carbon, but low ratio of C:N indicate an excess of nitrogen which may be lost from the process (Antil et al. 2014). Therefore, low ratio of C/N needs addition of more composting material for balancing of both elements. The carbon amendments and manure proportion in the compost effects the microflora of compost which may disturbs the zoonotic pathogen survival (Erickson et al. 2009). The balancing of C/N ratio is also essential in composting for optimization of bulking material. So, there is immense need to enhance the nutrient content in the composting material, reduce the odor and other impurities by various amendment in the composting material. This study was planned to find the best condition of composting for quality compost production.

Materials and methods

For decomposition of biomass, wheat straw (WS) and cow manure (CM) were collected and subjected to decomposition process through oxidative CC1 (aerobic) and fast decomposition and fermentative and CC2 (anaerobic), slow decompositionmethod. This experiment was laid under completely randomized design (CRD) with three factors i.e., the first factor (treatment) comprised of three levels e.g: T_1: CM + WS (25% + 75%), T_2: CM+WS (50%+50%) and T_3: CM +WS (75% +25%). While the second factor consisted of two levels of composting conditions e.g., aerobic and anaerobic conditions and the third factor is duration of composting (days). The composting materials are mixed thoroughly to homogenize the material (Fig. 1)

Fig. 1 Mixing of wheat straw and cow manure to homogenize the mixture

The decomposition was carried out in the controlled container of (20 L) which was filled one third with the mixed ratio of composting material, and then 10-liter water was added to fill the container. The compositing was carried out for 48 days (Fig. 2)

Fig. 2 Filling of homogenized composting material in the drums (20 L size) and completely sealing the drums for the composting and production of biogas

The data was recorded for the emission of greenhouse gasses (CH_4 and O_2) on daily basis up to 48 days with the help of BH-4S Portable Multi-Gas Detector Bosean Electronic Technology Co., Ltd., Zhengzhou, China (Fig. 3).

Fig. 3 Data recording for daily temperature, gas volume and greenhouse gasses emission

The gas volume was also recorded from the gas storage bags. The daily outside and inside drum temperature was also recorded with the help of portable thermometer. When the compositing process was completed, the compost was air dried in the shade and then used for the analysis of organic matter, nitrogen (N), phosphorus (P) and potassium (K) in the sample. The detailed procedure is given below.

Organic matter (%)

Organic matter was estimated by the weight loss on ignition (LOI), or “volatile solids,” method, which estimates the portion of sample weight lost during combustion at 550°C (1,022°F). Because organic matter content is not determined directly by the LOI method, the reported value is only an approximation. Weight can also be lost during combustion from other sources, including rubber, plastic, and "mineral-bound" water. Often, low organic matter values in compost (below 25 percent) result from soil or sand being mixed into the compost during turning. This is common when compost is prepared on bare ground. Composts with high levels of organic matter (more than 65 percent) may not have been thoroughly composted. These materials may contain considerable unstable organic matter that will be lost (as carbon dioxide gas) via rapid decomposition after field application.

Nitrogen (%)

After grinding of compost, one gram sample was added into 50 ml digestion flask by adding 12 ml H_2SO_4 for each sample and digested on heating plate. When the color changes from black to green or white, the flask was cooled at room temperature and volume was made up to 100 ml and sample was used for distillation. The nitrogen in the form of ammonia was collected in 4% boric acid solution and then titrated with 0.1 normal H_2SO_4 as described by (Jones et al. 1991).

$$N(\%)=\frac{1.4V \times N}{W}$$

Where, V is the acid volume used during titration, N is the normality of standard acid and W is the weight of sample.

Phosphorus (ppm)

Dicarboxylic acid mixture was used for digestion of compost sample. After digestion, color developing reagents were prepared by using ammonium molybdate and nitric acid. Then sample were run in spectrophotometer after calibration with 'P' standards as method described by (Jones et al. 1991).

$$P\ (\%) = \text{ppm P (From calibration curve)} \times \frac{V1}{W} \times \frac{100}{V2} \times \frac{1}{1000}$$

Where P is the value obtained from spectrophotometer after calibration, V_1 is the initial volume of the sample after digestion, V_2 is the final volume and W is the weight of sample.

Potassium

Flame photometer was calibrated with standard solution. One-gram dried sample was dissolved in (distilled) water and then filtered through filter paper. Emission reading was taken at 767 nm wavelength. The potassium was determined by using flame photometer as described by (Jones et al. 1991). Potassium concentration was calculated according to callibration curve. Soluble K (ppm) = ppm K (from calibration curve). The collected data was subjected to the analysis of variance (Steel et al. 1997) and the mean comparison were estimated by the least significant difference (LSD) test.

Results and discussion

During composting, the greenhouse gasses produced were measured with the portable gas detector (BH 4S, Bonsean Technologies China) from each treatment separately. The obtained data was statistically analyzed to find differences among treatments. The results showed significant differences among days (D), conditions (C), and treatments (T). The results also showed significant differences among days × condition (D × C), days × treatments (D × T), and condition × treatments (C × T). There are also the significant differences from days × condition × treatments (D × C × T). These treatments have significantly impacted to methane (CH_4), hydrogen sulfide (H_2S), carbon dioxide (CO_2), volume and inside temperature. However, these treatments have not significantly impacted to oxygen (O_2) (Table 1).

Table 1 Mean sum of square for the Oxygen (O_2), Methane (CH_4), Carbon Dioxide (CO_2), volume and inside temperature under different composting conditions, treatments and duration of composting

Source	DF	Oxygen (O_2)	Methane (CH_4)	Hydrogen Sulfide (H_2S)	Carbon Dioxide (CO_2)	Volume	Inside temperature
Days (D)	9	119.01**	2340.5**	11990.0**	4580.08**	202300**	1582.93**
Condition (C)	1	313.00**	8530.5**	27.4**	1566.57**	316446**	96.18**
Treatments (T)	2	0.001^{NS}	186.1**	2247.7**	642.41**	1254965**	197.55**
D×C	9	23.08**	675.5**	269.9**	192.02**	57505**	16.66**
D×T	18	9.20**	23767.4**	441.6**	54.89**	35947**	22.31**
C×T	2	2.45**	1532.2**	6753.8**	56.67**	2500443**	297.79**
D×C×T	18	29.36**	27579.0**	917.1**	4.98*	92930**	21.40**
Error	120	0.07	3.5	3.6	55	45	0.74
Total	179						

where the * = significant at $p \leq 0.05$, ** = highly significant at $p \leq 0.01$ and the NS = non-significant at $p > 0.05$

The gas volume varied significantly among the conditions, composting treatments and composting duration. In case of **conditions x treatments (C × T)** the more gas volume was produced under anaerobic conditions than the aerobic composting conditions. Among the treatments the maximum gas volume (658 ml) was recorded under cow manure: wheat straw (3:1) under anaerobic conditions, followed by cow manure: wheat straw (3:1) under anaerobic conditions (378 ml). The lowest gas volume (285 ml) was recorded under cow manure: wheat straw (1:3) (Fig. 4). It was observed that the composting condition has the significant effect on the gas volume, and more gas was produced under anaerobic composting.

In case of **days x conditions (D × C)**, the more gas production was observed under anaerobic conditions compared to aerobic composting. The maximum gas volume (469 ml) was recorded under anaerobic composting after 15 days of composting, followed by anerobic composting under 20 and 25 days of composting (362 and 367 ml). The lowest gas volume was observed (30 and 0 ml) and recorded under aerobic conditions at 45^{th} and 50^{th} day of composting (Fig. 5).

In case of **days × treatments (D × T)**, the cow manure: wheat straw (3:1) produced more gas volume compared to other treatments. The maximum gas volume (539 ml) was observed under cow manure: wheat straw (3:1) at 15^{th} day of composting, followed by 451 ml, recorded under cow manure: wheat straw (3:1) at 10^{th} day of composting. The minimum gas volume (24 ml) was recorded under cow manure: wheat straw (1:3) at 50^{th} day of composting (Fig. 6).

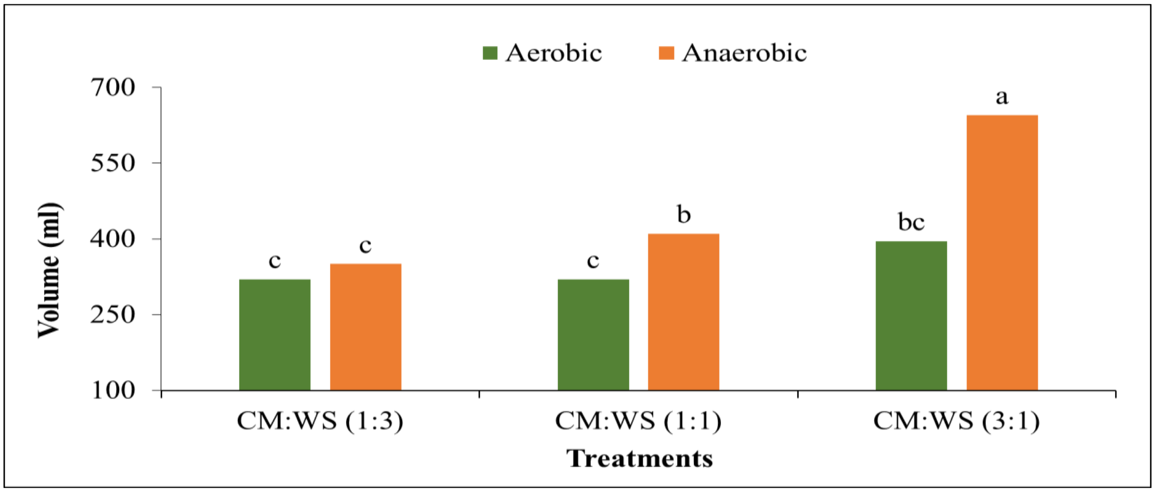

Fig. 4 Interactive effect of composting condition and substrate ratios on volume of biogas

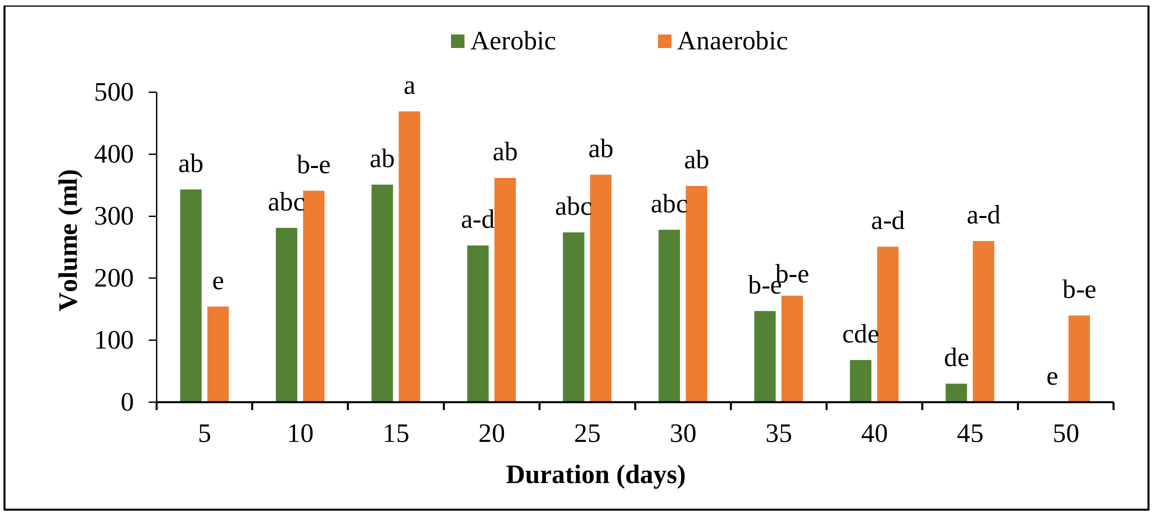

Fig. 5 Interactive effects of composting conditions × duration on the volume of biogas

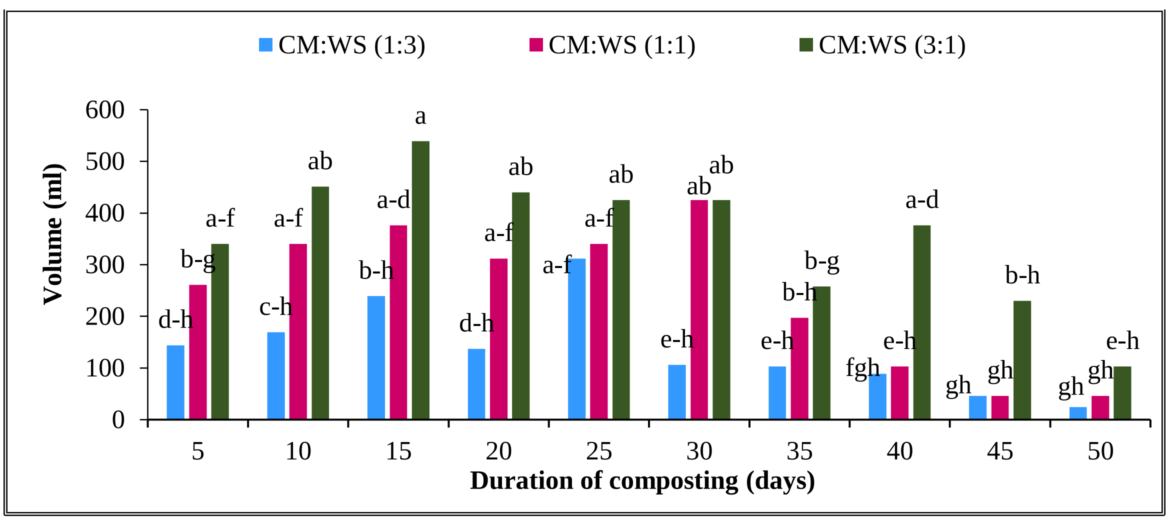

Fig. 6 Interactive effects of composting treatments × duration on the volume of biogas

The methane production is the most important during the composting process because the methane is used to fulfil the energy demand in the commercial composting. It was observed that the methane production was more in the anaerobic composting than the aerobic composting. The results showed that among the **conditions x treatments (C × T)**, the composting under anerobic conditions produced more methane than the aerobic composting. The maximum methane (58.89%) was produced under anaerobic condition from the treatment manure: wheat straw (3:1), followed by 47.41% produced under anerobic condition from the treatment manure: wheat straw (1:1). The lowest methane (18.83%) was produced under aerobic composting of the treatment manure: wheat straw (1:3) (Fig. 7).

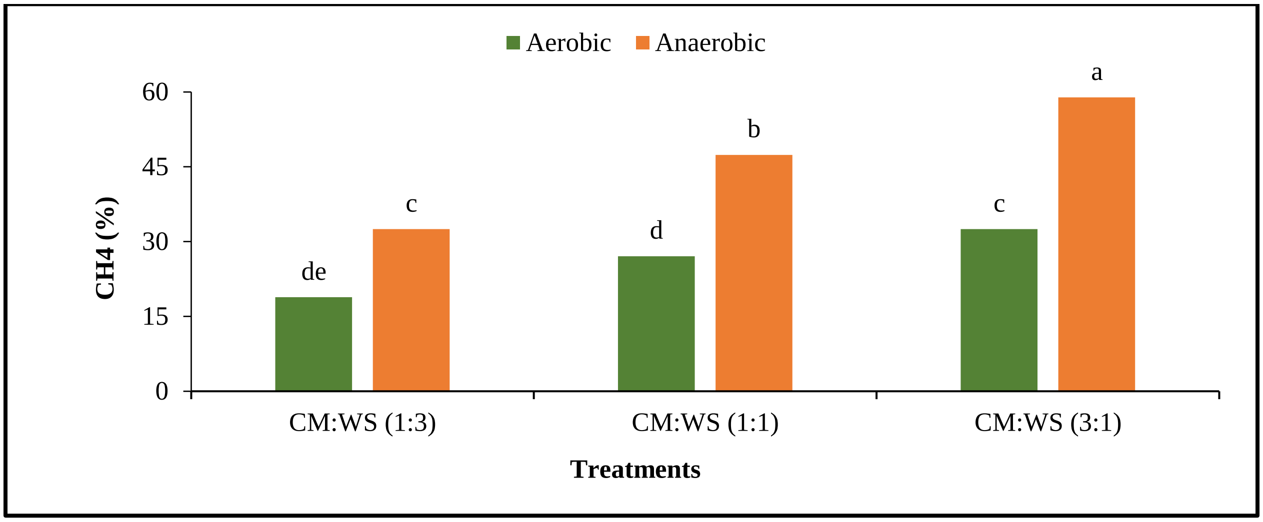

Fig. 7 Interactive effect of composting condition and substrate ratios on methane

The interactive effect of **conditions x days (C × D)**, also influenced the methane production. It was observed that the maximum methane (57.29%) was recorded under anaerobic condition at 30th day of composting, followed by 40.77% recorded under anaerobic condition at 25th day of composting. The lowest 10.96% and 0% was recorded under anaerobic and aerobic conditions at 50th day of composting (Fig. 8).

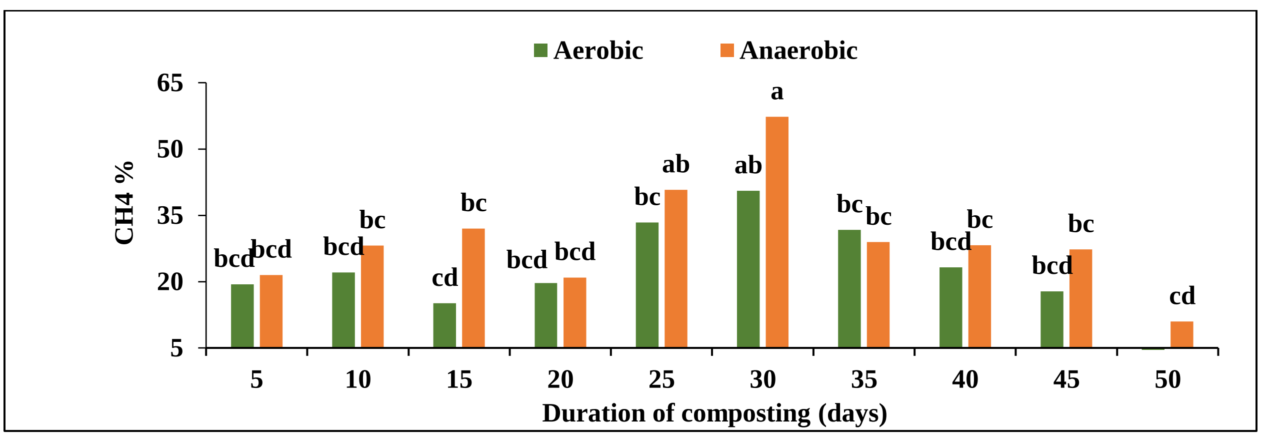

Fig. 8 Interactive effects of composting conditions × duration on the methane

In case of **days × treatments (D × T)**, maximum methane was produced under cow manure: wheat straw (3:1) compared to other treatments. The maximum methane (63%) was observed under cow manure: wheat straw (3:1) at 30th day of composting, followed by 49.57%, recorded under cow manure: wheat straw (3:1) at 25th day of composting. The minimum methane (15.36 %) was recorded under cow manure: wheat straw (3:1) and (1:1) at 50th day of composting (Fig. 9). According to (Beck-Friis et al. 2003), the emission of methane, occurs only during the thermophile phase, representing less than 2% of the initial TOC in the case of a poorly ventilated compost pile. Volatile fatty acids, found in young composts can also be released during composting. These results demonstrated that the anaerobic decomposition produced more gases compared to aerobic decomposition of the organic waste.

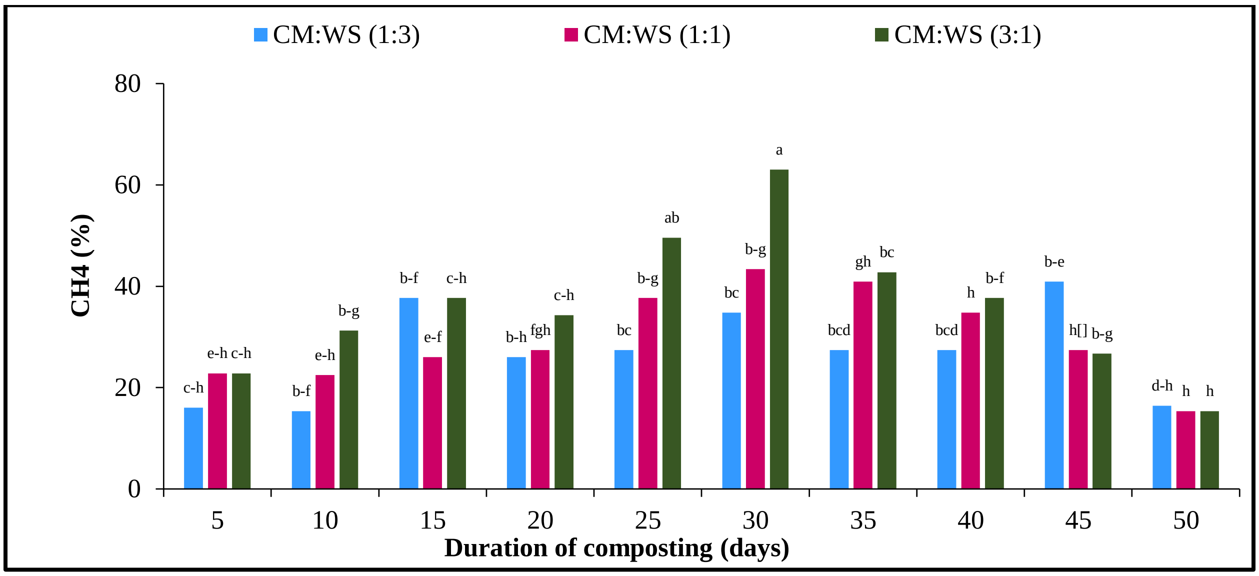

Fig. 9 Interactive effects of composting treatments × duration on the Methane

Our results showed that aerobic composting produced more carbon dioxide compared to anaerobic composting, as in the aerobic composting more oxygen is present so, more production of carbon dioxide. The results revealed that among **conditions x treatments (C × T)**, aerobic composting produced more carbon dioxide compared to anaerobic conditions. The maximum carbon dioxide (18.56%) was produced under aerobic condition from the treatment manure: wheat straw (1:3), followed by 15.64% recorded under aerobic conditions from the treatment manure: wheat straw (1:1). The lowest carbon dioxide (11.34 and 12.05%) was recorded under anaerobic conditions from the treatment manure: wheat straw (1:1 and 3:1), respectively (Fig. 10).

In case of **conditions x days (C × D)**, maximum carbon dioxide (46.9%) was produced under aerobic condition at 5th day of composting, followed by 43.4% under aerobic condition at 15th day of composting. The lowest carbon dioxide 0 and 0.2% was recorded under aerobic and anaerobic conditions at 50th day of composting (Fig. 11). In case of **days × treatments (D × T)**, maximum carbon dioxide was produced under cow manure: wheat straw (3:1) compared to other treatments. The maximum carbon dioxide (49.8%) was observed under cow manure: wheat straw (3:1) at 15th day of composting, followed by 49.35%, recorded under cow manure: wheat straw (1:3) at 5th day of composting. The minimum carbon dioxide (0, 0 and 0.3%) was recorded under cow manure: wheat straw (1:3, 1:1 and 3:1) at 50th day of composting, respectively (Fig. 12).

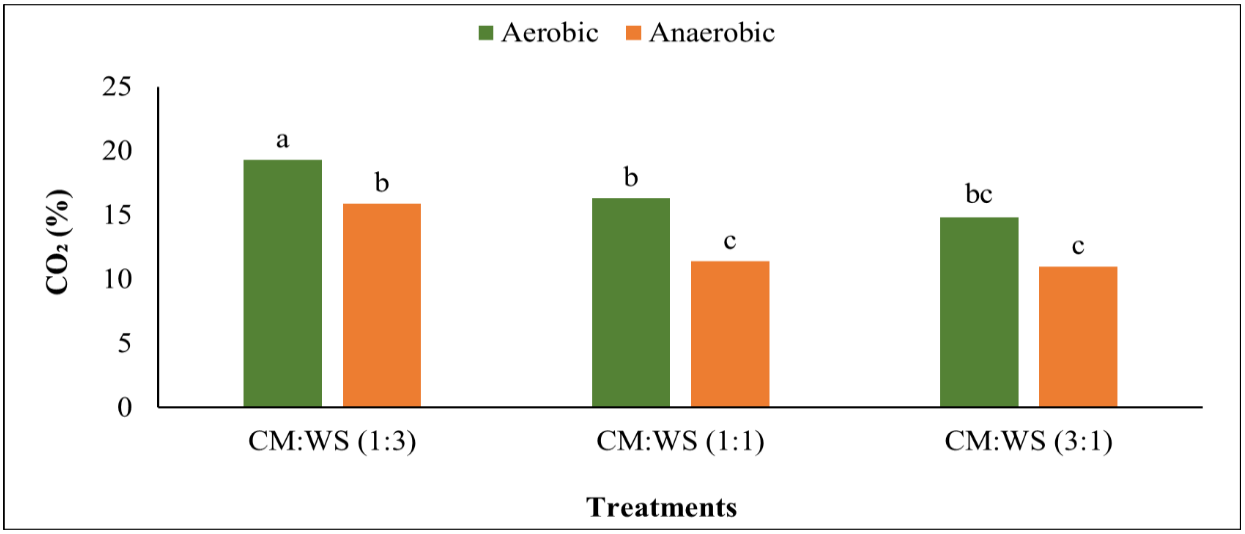

Fig. 10 Interactive effect of composting condition and substrate ratios on Carbon dioxide

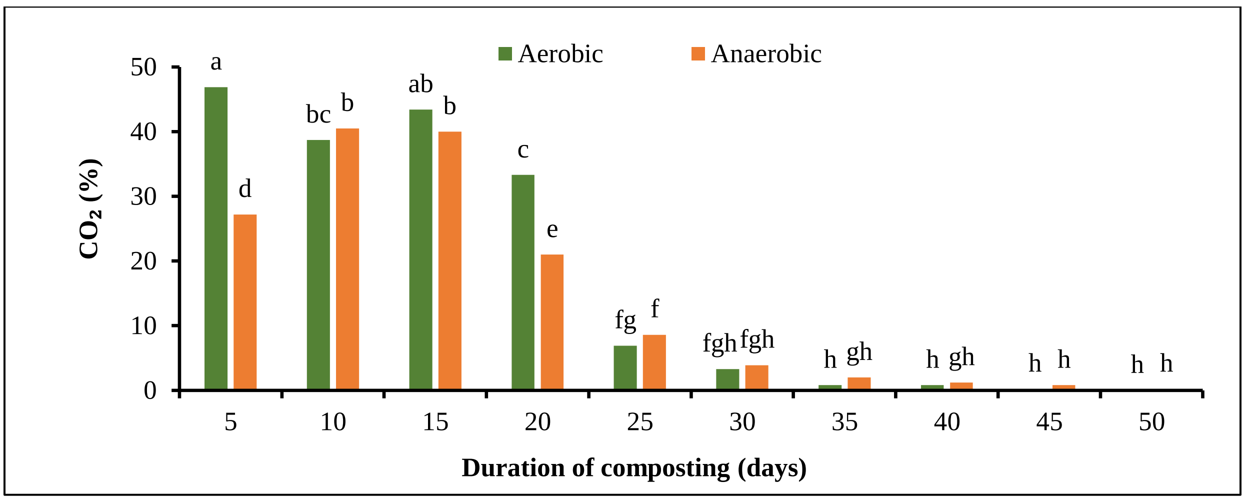

Fig. 11 Interactive effects of composting conditions × duration on the Carbon dioxide

To maintain the aerobic condition inside the compost pile, a minimum rate of 5% O_2 in pore space is required, while anaerobic condition occurs with less than 1% of O_2 (Mustin 1987). During the active phases of aerobic fermentation, the microorganisms consume 15 to 30 times more carbon than nitrogen (Mustin 1987). Thus, resulting in more oxygen production in the aerobic composting compared to anaerobic composting. The production of methane is the main event during the anaerobic composting. The possible presence of anaerobic sites in the compost pile may result in methane (CH_4) emissions associated with fermentative metabolism (He et al. 2000).

Nutrient analysis of compost

The compost produced from both aerobic and anaerobic composting were analyzed for the nutrient composition. The results showed significant differences for the total organic carbon among the treatments (T), conditions (C) and interaction treatment × conditions (T × C), while the nitrogen differed significantly among the treatments and non-significantly among conditions and interaction (T × C). The phosphorus showed non-significant differences among the treatments, conditions and interaction (T × C). The potassium differed significantly among treatments and conditions, but non-significantly differed among the interaction (T × C) (Table 2).

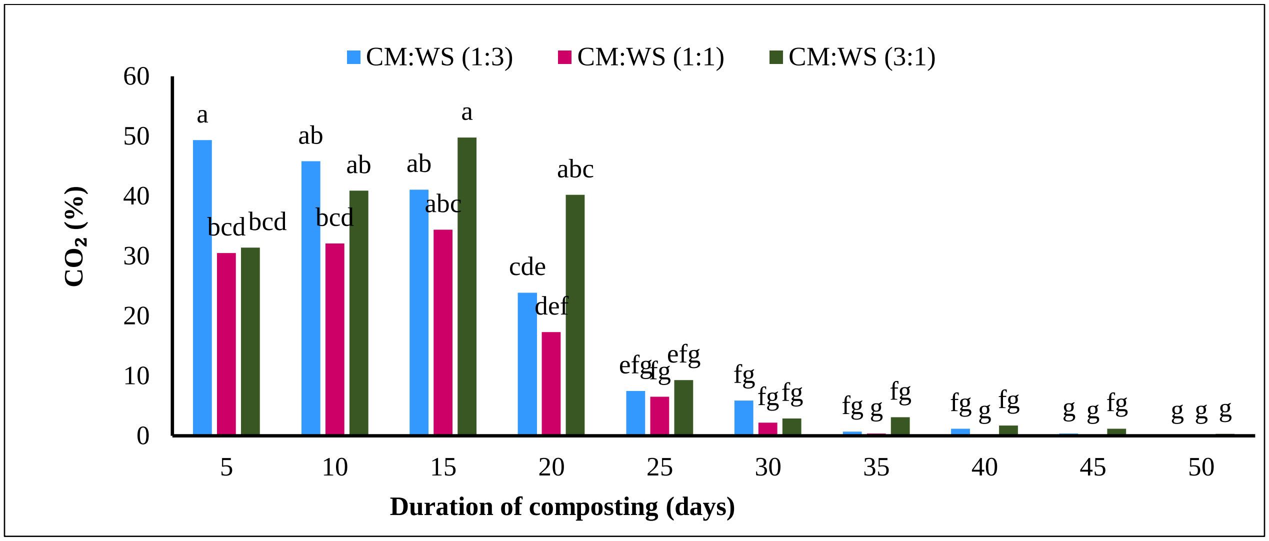

Fig. 12 Interactive effects of composting treatments × duration on the Carbon dioxide

Table 2 Mean sum of square for the Total organic carbon (TOC), Nitrogen (N), Phosphorus (P) and Potassium (K) in compost under different composting conditions and treatments

Source	DF	TOC	N	P	K
Treatments (T)	2	90.50**	0.46**	0.011^{NS}	0.026**
Condition (C)	1	186.89**	0.04^{NS}	0.003^{NS}	0.005*
T×C	2	18.39*	0.01^{NS}	0.000^{NS}	0.000^{NS}
Error	12	4.14	0.02	0.003^{NS}	0.001^{NS}
Total	17				

where DF = degree of freedom, * = significant at p≤0.05, ** = highly significant at p≤0.01 and the NS = non-significant at p>0.05

The compost quality is determined by the micronutrients produced during the composting process. Our results showed that the maximum nitrogen, total organic carbon, phosphorus and potassium were produced by the decomposition of cow manure and wheat straw under anaerobic condition. During the active phases of aerobic fermentation, the microorganisms consume 15 to 30 times more carbon than nitrogen (Mustin 1987).

In case of total organic carbon, the maximum value (20.1%) was observed under anaerobic composting of cow manure: wheat straw (3:1), followed by 15.1%, recorded under anaerobic composting of manure: wheat straw (1:1). The lowest value of total organic carbon (11.98%) was observed under aerobic composting of manure: wheat straw (1:3) (Fig. 13). So, it is concluded that the composting of cow manure under anaerobic conditions produces more total organic carbon compared with anaerobic composting. Thus, suggesting that the organic carbon is less in the aerobic composting than anaerobic composting. During composting, organic nitrogen of waste is mineralized mainly into ammonium (NH_4^+) and nitrate (NO_3^-) when nitrification is achieved. A portion of this mineral nitrogen is reincorporated into the active microbial metabolism during composting. Some is incorporated into organic matter during humification, and a part is released in the form of inorganic nitrogen matrix (Larsen et al. 2000).

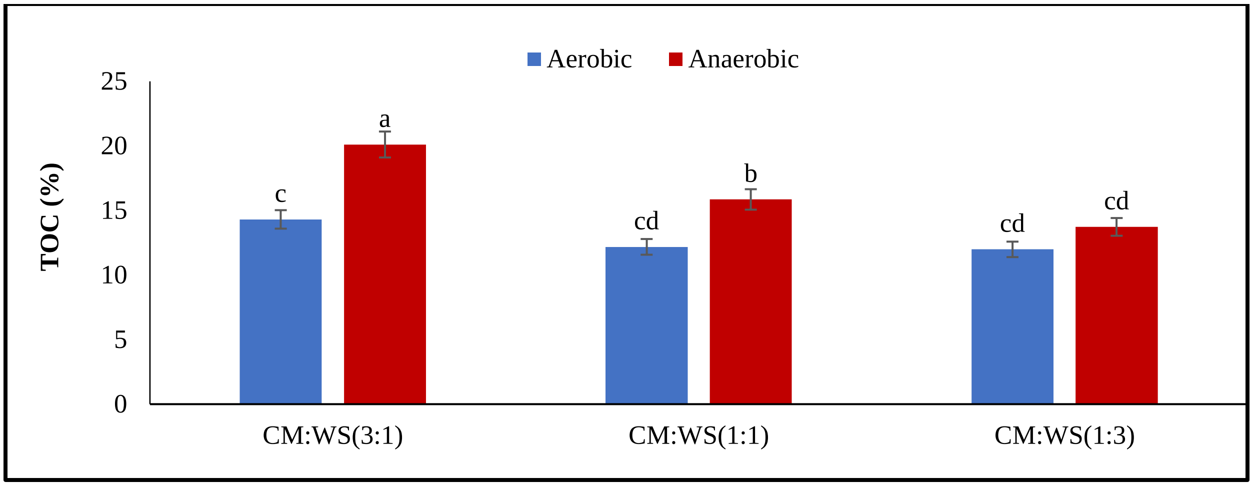

Fig. 13 Total organic carbon in compost under aerobic and anaerobic composting

The maximum value (2.47%) of total nitrogen was observed under anaerobic composting of cow manure: wheat straw (3:1), followed by 1.93%, recorded under anaerobic composting of manure: wheat straw (1:1). The lowest nitrogen (1.56%) was observed under aerobic composting of manure: wheat straw (1:3) (Fig. 14). At the end of composting, mineralization process become predominant, and an increase in the content of NO_3^- is frequently observed (Sánchez-Monedero et al. 2001). Under the optimal aeration condition, the pH rise causes transformation of NH_4^+ into a volatile nitrogen (NH_3). On the other hand, the limited ventilation causes an increase in the content of volatile fatty acids, resulting in a decrease of the pH, and locking of nitrogen as NH_4^+ (Michel et al. 1998). These results showed that the anaerobic composting reduces the nitrogen losses thus more nitrogen is produced in the anaerobic composting. Finally, these results showed that the anaerobic composting produced more gas volume and best quality compost compared to aerobic composting.

The composting conditions also significantly influenced the phosphorus and potassium contents. The maximum phosphorus (0.76%) and potassium (1.49%) was observed under anaerobic composting of cow manure: wheat straw (3:1), followed by 0.71 % and 1.42 % of phosphorus and potassium was recorded under anaerobic composting of manure: wheat straw (1:1). The lowest values of phosphorus (0.63%) and potassium (1.26%) were observed under aerobic composting of manure: wheat straw (1:3) (Fig. 15 and Fig. 16, respectively).

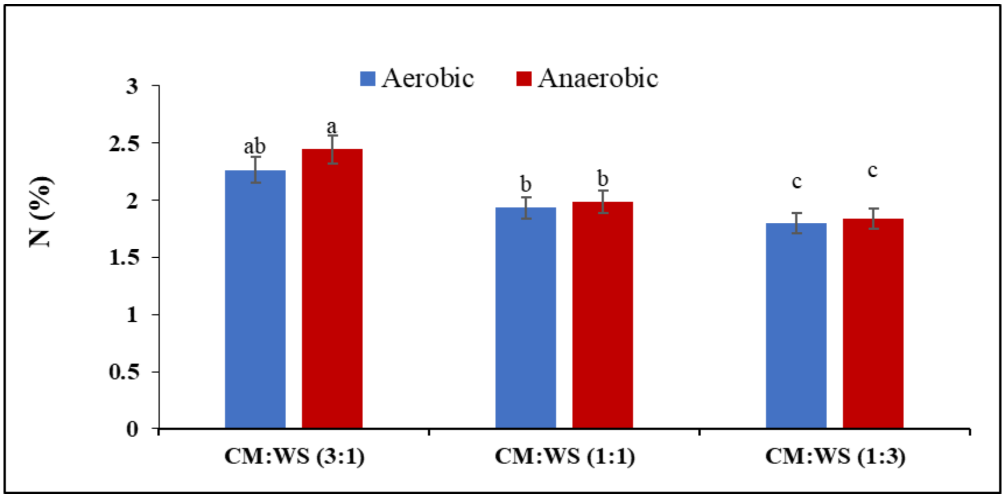

Fig. 14 Nitrogen (%) in compost under aerobic and anaerobic composting

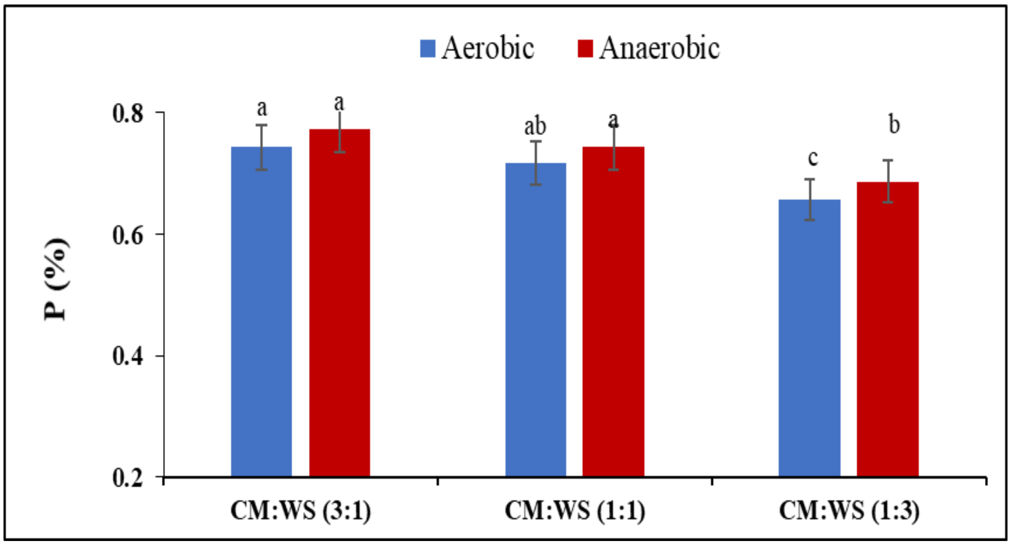

Fig. 15 Phosphorus (%) in compost under aerobic and anaerobic composting

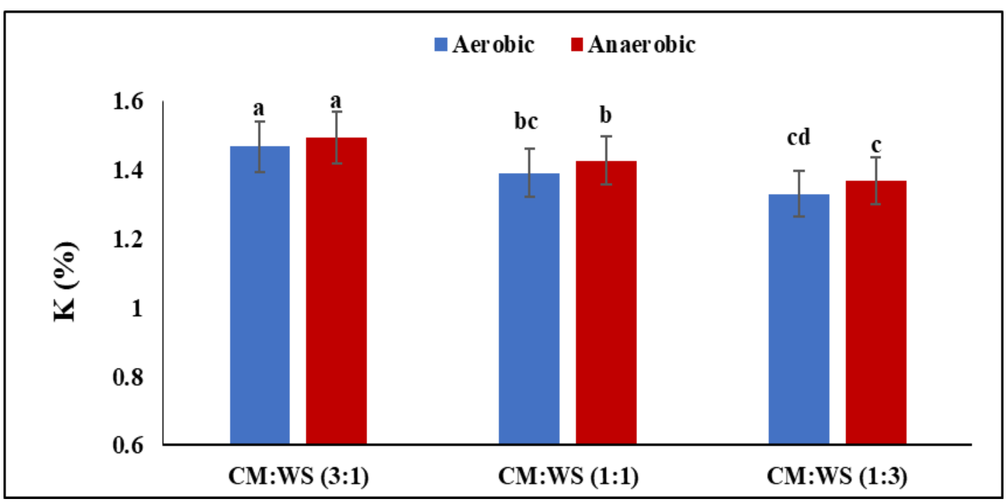

Fig. 16 Potassium (%) in compost under aerobic and anaerobic composting

Conclusion

There are many parameters that can be considered for start-up, monitoring and quality of compost. However, it becomes challenging when extrapolating the process into field and industrial level. We conclude that anaerobic composting of cow manure: wheat straw (3:1) produced maximum methane and low carbon dioxide. It also produces high compost quality with containing organic matter, nitrogen, phosphorus and potassium. Thus, composting has the potential to reduce the environmental pollution by reducing the extensive inorganic fertilizer use and it also enhance the soil organic profile.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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