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Assessment of compost maturity using germination index in biochar amended caged layer manure compost

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Abstract
The present study was conducted to evaluate the effect of biochar incorporation and passive aeration techniques on the maturity of compost prepared from caged layer manure (CLM) using germination index (GI) as a biological indicator. Composting experiments were carried out at the Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, Tamil Nadu, India during summer and monsoon seasons. Nine treatments comprising different combinations of caged layer manure, biochar and coconut coir pith (CCP) waste under passive aeration and static composting systems were evaluated. The C:N ratio (20:1) and moisture content (50–60%) were maintained uniformly in all treatments. Compost maturity was assessed through seed germination and root elongation tests using cowpea and sorghum seeds. The germination index values ranged from 85.40 to 152.88 per cent during summer and 81.63 to 133.72 per cent during monsoon season. Among the treatments, compost amended with 50 per cent biochar and 50 per cent coconut coir pith waste under passive aeration with a V-shaped pipe system (T_5) recorded the highest pooled germination index value (137.32 ± 13.86%), whereas the static composting control without carbonaceous amendment (T_9) recorded the lowest value (83.30 ± 4.56%). The germination index values obtained in all treatments were above the minimum maturity threshold of 70 per cent, indicating satisfactory compost maturity. Biochar-amended treatments exhibited significantly higher germination index values than the control groups, suggesting enhanced degradation of phytotoxic compounds and improved compost quality. The study concluded that incorporation of biochar, particularly under passive aeration with a V-shaped pipe system, improved compost maturity and produced superior quality compost suitable for agricultural application.

Keywords: Caged layer manure, Biochar, Compost maturity, Germination index, Phytotoxicity

Introduction
Compost stability and maturity are important indicators of compost quality. Compost stability is primarily influenced by the presence of labile organic compounds and the oxygen demand required for aerobic decomposition. Compost maturity, however, refers to the ability of compost to support plant growth and is associated with the reduction of phytotoxic compounds, oxygen demand and the evolution of organic matter (Iannotti, 1994) [7]. The composting industry lacks universally accepted standards for accurately determining compost stability and maturity. Consequently, researchers have investigated several physicochemical and biological parameters to predict compost quality. The United States Composting Council (Thompson *et al.*, 2002) [12] recommended parameters such as pH, salinity, nutrient content, organic matter, moisture, particle size, inert materials, pathogen load and weed seed presence for evaluating compost suitability for agricultural use. Among the biological indicators, the germination index (GI) is widely used to assess compost maturity and phytotoxicity. Seed germination assays evaluate the decomposition of phytotoxic substances and organic acids generated during the initial stages of composting (Wu *et al.*, 2000) [15]. The GI integrates relative seed germination and root elongation, thereby providing a sensitive measure of compost maturity. Das *et al.* (2003) [.] suggested that mature compost should possess a GI above 70 per cent, whereas the Woods End Research Laboratory (Anon, 2005) [1] recommended values exceeding 90 per cent for high-quality compost.

The carbon-to-nitrogen (C:N) ratio is another commonly used maturity indicator. A final C:N ratio below 20 is generally considered satisfactory when the initial ratio ranges between 25 and 30 (Hirai *et al.*, 1983)[5]. However, Huang *et al*. (2004)[6] emphasized that the C:N ratio alone may not reliably indicate compost maturity.

Recent studies have demonstrated the beneficial effects of biochar incorporation during composting. Chen *et al.* (2010) [1] reported that biochar addition increased the GI value, indicating accelerated detoxification of phytotoxic substances. Similarly, Rombola *et al.* (2015) [9] observed that cornstalk biochar exhibited minimal phytotoxicity, whereas poultry litter biochar inhibited seed germination at high concentrations due to feedstock-specific chemical constituents. Sanchez-Garcia *et al.* (2015) [10] reported GI values exceeding 50 per cent in poultry manure composts amended with biochar, indicating acceptable compost quality. Glazunov *et al.* (2018) [4] further demonstrated that chicken manure biochar produced a GI of 97 per cent without adversely affecting wheat germination. Qasim *et al.* (2018) [8] also reported a significant negative correlation between electrical conductivity and GI, suggesting that lower salinity enhances seed germination. Considering these observations, the present study evaluated the germination index of compost prepared from caged layer manure (CLM) with biochar and coir pith compost (CCP) waste under different passive aeration systems.

Materials and Methods

Study Area

The study was conducted at the Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, Tamil Nadu, India. Namakkal is located at 11°09′42.1″ N latitude and 78°09′39.7″ E longitude at an altitude of 192 m above mean sea level. The district is characterized by non-calcareous red and brown soils and calcareous black soils. Owing to its extensive poultry production, Namakkal is popularly known as the “Egg City” of Tamil Nadu.

Composting Treatments

Static and passive aeration composting experiments were conducted using different combinations of caged layer manure, biochar, and coir pith compost waste. The C:N ratio was maintained at 20:1 and moisture content between 50 and 60 per cent in all treatments. Composting trials were replicated during both summer and monsoon seasons. Caged layer manure biochar and coir pith compost waste served as carbonaceous co-composting materials. The treatments are presented below:

Treatments	**Composition**	**Method of composting**
T_1	CLM+25% biochar+ 50 % CCP	Passive aeration (vertical ‘T’ shape pipe)
T_2	CLM+ 25% biochar+ 50 % CCP	Passive aeration (‘V’ shape pipe)
T_3	CLM+25% biochar+ 50 % CCP	Static compost
T_4	CLM+50% biochar+50% CCP	Passive aeration (vertical ‘T’ shape pipe)
T_5	CLM+50% biochar+50% CCP	Passive aeration (‘V’ shape pipe)
T_6	CLM+50% biochar+50% CCP	Static compost
T_7	CLM	Passive aeration (vertical ‘T’ shape pipe)
T_8	CLM	Passive aeration (‘V’ shape pipe)
T_9	CLM	As such

Germination Index Test

The germination index was determined following the procedures described by Zucconi *et al*. (1981) [16], Tiquia *et al.* (1996) [13], Tiquia, and Tam (1998) [14]. Compost samples were mixed with distilled water in a 1:10 (w/v) ratio and shaken for one hour to prepare aqueous extracts. Approximately 5 ml of each extract was transferred into sterile Petri dishes lined with Whatman No. 2 filter paper. Ten to fifteen seeds of cowpea and sorghum were placed evenly on the filter paper and incubated at 25°C in darkness for 48 hours. Distilled water served as the control. Each treatment was tested in triplicate.

The relative seed germination (RSG), relative root growth (RRG) and germination index (GI) were calculated using the following equations:

Number of seeds germinated in the extract

$$\text{Relative seed germination (RSG \%)} = \frac{\text{Number of seeds germinated in the extract}}{\text{Number of seeds germinated in the control}} \times 100$$

$$\text{Relative root growth (RRG)} = \frac{\text{Mean root length in extract}}{\text{Mean root length in control}} \times 100$$

$$\text{Germination index (GI \%)} = \frac{\text{RSG X RRG}}{100}$$

Statistical Analysis

The data were analyzed using least squares analysis as described by Snedecor and Cochran (1996) [11] using SPSS software package.

Results

The germination index values obtained during summer and monsoon seasons were presented in Table 1.

Table 1: Mean (± SE) Germination Index (%) of Compost Samples During Different Seasons

Treatment (n=6)	**Germination Index (%)**		
	Summer	**Monsoon**	**Pooled**
T_1	$122.99^{abc} \pm 15.26$	$111.29^{abc} \pm 7.50$	$117.14^{abc} \pm 8.30$
T_2	$152.88^{a} \pm 19.77$	$133.72^{abc} \pm 9.76$	$143.30^{a} \pm 10.90$
T_3	$118.22^{abc} \pm 8.83$	$107.57^{abc} \pm 10.67$	$112.9^{abc} \pm 6.80$
T_4	$130.71^{abc} \pm 11.38$	$114.70^{abc} \pm 6.46$	$122.71^{ab} \pm 6.69$
T_5	$143.61^{bc} \pm 27.05$	$131.04^{abc} \pm 9.89$	$137.32^{ab} \pm 13.86$

T_6	$123.11^{abc} \pm 7.72$	$110.42^{abc} \pm 3.59$	$116.76^{abc} \pm 4.49$
T_7	$88.21^{bc} \pm 11.59$	$81.63^{c} \pm 2.80$	$84.91^{c} \pm 5.77$
T_8	$101.71^{abc} \pm 12.02$	$107.22^{abc} \pm 8.62$	$104.47^{bc} \pm 7.10$
T_9	$85.40^{bc} \pm 8.33$	$83.30^{c} \pm 4.63$	$83.30^{c} \pm 4.56$

Means bearing different superscripts within a column differ significantly ($P < 0.01$)

During the summer season, GI values ranged from 85.40 ± 8.33 to 152.88 ± 19.77 per cent. Significant differences ($P < 0.01$) were observed among treatments, particularly between the passive aeration V-shaped pipe treatment (T_2 and T_5) and the static compost control (T_9). During the monsoon season, GI values ranged from 81.63 ± 2.80 to 133.72 ± 9.76 per cent. No significant differences were observed among treatments within the season; however, the pooled analysis showed significant differences ($P < 0.01$) between biochar-amended treatments and control groups.

Among all treatments, T_5 (CLM + 50% biochar + 50% CCP waste with V-shaped passive aeration) recorded the highest pooled GI value (137.32 ± 13.86%), whereas T_9 (CLM alone under static composting) recorded the lowest pooled GI value (83.30 ± 4.56%). No significant seasonal variation was observed.

Discussion

Seed germination index (GI) is widely recognized as a reliable biological indicator for assessing compost maturity and phytotoxicity in composted materials (Wu *et al.*, 2000; Chen *et al.*, 2010) [15, 2]. In the present study, the GI values recorded during the summer and monsoon seasons ranged from 85.40 to 152.88 per cent and 81.63 to 133.72 per cent, respectively, indicating satisfactory maturity of the compost produced under all treatment conditions. Among the treatments, compost amended with biochar and coconut coir pith (CCP) waste under passive aeration using a V-shaped pipe system exhibited the highest GI values (131.02 - 152.88%), followed by the T-shaped passive aeration system (111.29 - 130.71%). In contrast, the control treatments without carbonaceous amendments recorded comparatively lower GI values (81.63 - 107.22 per cent). The higher GI values observed in biochar-amended treatments suggest improved compost maturity and reduced phytotoxicity compared to the control groups.

The GI values obtained in the present investigation were considerably higher than the minimum threshold value of 70 per cent suggested by Das *et al.* (2003) [3] for mature compost, confirming that the compost products attained acceptable maturity levels. The enhanced GI values in biochar-treated composts may be attributed to the adsorption of phytotoxic compounds, improved aeration and enhanced microbial activity facilitated by the porous structure of biochar. These conditions likely accelerated the degradation of organic acids and other inhibitory substances formed during the early stages of composting. Furthermore, the present findings are in agreement with the observations of Chen *et al.* (2010) [2] who reported that biochar incorporation during composting significantly increased the GI by accelerating the detoxification process. Similar results were also reported by Rombola *et al.* (2015) [9] and Sanchez-Garcia *et al.* (2015) [10], who concluded that biochar amendment improves compost quality by reducing phytotoxic effects and enhancing seed germination. Therefore, the results of the present study demonstrate that the incorporation of biochar, particularly under passive aeration with a V-shaped pipe system, enhances compost maturity and promotes the production of high-quality compost suitable for agricultural application.

Conclusion

The study revealed that incorporation of biochar and passive aeration significantly improved the maturity of compost prepared from caged layer manure, as indicated by higher germination index (GI) values. All treatments recorded GI values above the acceptable maturity threshold of 70 per cent, confirming the production of mature compost. Among the treatments, compost amended with 50 per cent biochar and 50 per cent coir pith compost waste under V-shaped passive aeration showed the highest GI value, indicating superior compost quality and reduced phytotoxicity. Therefore, biochar incorporation combined with passive aeration can be recommended for producing high-quality compost suitable for agricultural use.

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