**Table S1.** Chemical indicators for compost maturity from different sources.

|  |  |  |
| --- | --- | --- |
| **Chemical indicators** | **Value** | **References** |
| CHA/CFA | ≥1 | (Ji et al., 2023) |
| T values (Final C/N ratio / Initial C/N ratio) | <0.6 | (Gao et al., 2021) |
| C/N ratio | <12 | (Beesigamukama et al., 2022) |
| Dissolved organic carbon | ≤4 g kg−1 | (Wang et al., 2021) |
| CHA/CFA | >2.5 | (Ko et al., 2008) |
| C/N ratio | ≤23 for mature and highly mature | (Ji et al., 2023) |
| T values (Final C/N ratio / Initial C/N ratio) | ≤0.8 for highly mature | (Ji et al., 2023) |
| pH | 5.5-8.5 | (Kong et al., 2024) |
| EC | <4 mS/cm | (Dhanker et al., 2021) |
| Cation exchange capacity (CEC) | ≥ 60 cmol/kg | (Jamroz et al., 2020) |
| NH4+/ NO3– ratio | <0.16 | (Kong et al., 2024) |
| NH3 | / | / |
| N2O | / | / |
| CH4 | / | / |
| CO2 | / | / |

Note: HA = humic acid; FA = fulvic acid, CHA and CFA are their respective concentrations.

**Table S2.** Keywords used for literature review.

|  |  |
| --- | --- |
| **No.** | **Key words for literature search** |
| 1 | Biochar or Black carbon or Char |
| 2 | Maturity or Mature |
| 3 | Composting or Compost |
| 4 | Not review |
| 5 | Not meta-analysis |

**Table S3.** Main physicochemical parameters of the compost materials (mean ± standard deviation of three measurement results) used in the three experiments.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | PM | WS | WSB |
| Moisture content (%) | 54.3 ± 1.24 | 7.2 ± 0.3 | 2.63 ± 0.13 |
| pH | 8.41 ± 0.06 | 6.33 ± 0.12 | 8.67 ± 0.10 |
| C/N | 11.97 ± 0.23 | 236.25 ± 7.79 | 106 ± 24.18 |
| Surface area (m2/g) | / | / | 297.92 ± 1.3 |
| pore volume (cm3/g) | / | / | 0.132 ± 0.01 |

Note: PM, pig manure; WS, wheat straw; WSB: wheat straw biochar

**Table S4.** Determination of ADs for multiple models in predicting compost maturity based on different levels of cosine similarity from 0 to 1. The kept data % is the amount of data kept from the original test set.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Maturity indicators | Cosine similarity | R2 of discarded data | RMSE of discarded data | Amount of discarded data | R2 of  kept data | RMSE of kept data | Amount of kept data % |
| C/N ratio | 0-0.61 | None | | 0% | 0.80 | 3.53 | 100% |
| 0.62-0.73 | 0.58 | 2.75 | 1.88% | 0.82 | 3.52 | 98.12% |
| 0.74-0.80 | 0.88 | 2.47 | 2.35% | 0.80 | 3.53 | 97.65% |
| 0.81-0.82 | 0.93 | 1.67 | 5.63% | 0.80 | 3.59 | 94.37% |
| 0.83 | 0.92 | 1.89 | 13.15% | 0.79 | 3.69 | 86.85% |
| 0.84 | 0.92 | 1.68 | 13.62% | 0.79 | 3.70 | 86.38% |
| 0.85-0.86 | 0.91 | 1.88 | 15.49% | 0.79 | 3.73 | 84.51% |
| 0.87-0.88 | 0.91 | 1.85 | 15.96% | 0.79 | 3.74 | 84.04% |
| 0.89 | 0.91 | 1.75 | 21.60% | 0.79 | 3.86 | 78.40% |
| 0.90 | 0.90 | 2.09 | 33.80% | 0.78 | 4.05 | 66.20% |
| 0.91 | 0.78 | 3.06 | 39.44% | 0.81 | 3.78 | 60.56% |
| 0.92 | 0.79 | 2.91 | 50.23% | 0.81 | 4.03 | 49.77% |
| 0.93 | 0.79 | 3.24 | 65.26% | 0.81 | 3.96 | 34.74% |
| 0.94 | 0.84 | 3.08 | 92.02% | 0.57 | 6.71 | 7.98% |
| 0.95-1 | 0.81 | 3.51 | 100% | None | None | 0% |
| GI | 0-0.59 | None | | 0% | 0.63 | 18.42 | 100% |
| 0.60-0.80 | 0.50 | 16.04 | 5.84% | 0.65 | 18.28 | 94.16% |
| 0.81-0.85 | 0.69 | 16.27 | 6.49% | 0.63 | 18.41 | 93.51% |
| 0.86-0.87 | 0.51 | 17.54 | 16.88% | 0.63 | 18.43 | 83.12% |
| 0.88 | 0.52 | 17.42 | 22.08% | 0.63 | 18.52 | 77.92% |
| 0.89 | 0.55 | 18.41 | 35.06% | 0.67 | 18.22 | 64.94% |
| 0.90 | 0.57 | 19.27 | 42.21% | 0.69 | 17.53 | 57.79% |
| 0.91 | 0.65 | 18.57 | 68.18% | 0.63 | 17.66 | 31.82% |
| 0.92 | 0.67 | 18.57 | 81.82% | 0.40 | 16.95 | 18.18% |
| 0.93 | 0.65 | 18.25 | 92.21% | 0.51 | 18.64 | 7.79% |
| 0.94-1 | 0.64 | 18.28 | 100% | None | None | 0% |
| NO3--N | 0-0.78 | None | | 0% | 0.75 | 0.10 | 100% |
| 0.79-0.84 | None | | 11.07% | 0.76 | 0.10 | 88.93% |
| 0.85 | 0.63 | 0.06 | 12.98% | 0.77 | 0.10 | 87.02% |
| 0.86-0.88 | 0.66 | 0.06 | 22.14% | 0.77 | 0.10 | 77.86% |
| 0.89 | 0.84 | 0.06 | 25.19% | 0.75 | 0.11 | 74.81% |
| 0.90 | 0.80 | 0.09 | 40.08% | 0.75 | 0.11 | 59.92% |
| 0.91 | 0.76 | 0.91 | 68.32% | 0.78 | 0.12 | 31.68% |
| 0.92 | 0.75 | 0.94 | 77.10% | 0.79 | 0.12 | 22.90% |
| 0.93 | 0.77 | 0.97 | 88.55% | 0.73 | 0.12 | 11.45% |
| 0.94-1 | 0.77 | 0.10 | 100% | None | None | 0% |
| NH4+-N | 0-0.79 | None | | 0% | 0.73 | 0.64 | 100% |
| 0.80-0.86 | 0.01 | 0.95 | 13.86% | 0.75 | 0.62 | 86.14% |
| 0.87 | 0.72 | 0.30 | 20.22% | 0.74 | 0.63 | 79.78% |
| 0.88 | 0.82 | 0.53 | 28.09% | 0.74 | 0.60 | 71.91% |
| 0.89 | 0.85 | 0.50 | 37.83% | 0.67 | 0.62 | 62.17% |
| 0.90 | 0.80 | 0.54 | 66.67% | 0.68 | 0.65 | 33.33% |
| 0.91 | 0.79 | 0.53 | 76.03% | 0.69 | 0.71 | 23.97% |
| 0.91 | 0.74 | 0.60 | 89.14% | 0.93 | 0.30 | 10.86% |
| 0.93-1 | 0.76 | 0.58 | 100% | None | None | 0% |
| CO2 | 0-0.71 | None | | 0% | 0.48 | 0.34 | 100% |
| 0.72 | None | | 0.55% | 0.48 | 0.33 | 99.45% |
| 0.73-0.82 | 0.12 | 0.57 | 1.65% | 0.48 | 0.33 | 98.35% |
| 0.83-0.84 | 0.52 | 0.36 | 4.40% | 0.48 | 0.34 | 95.60% |
| 0.85-0.91 | 0.03 | 0.50 | 10.44% | 0.53 | 0.32 | 89.56% |
| 0.92 | 0.36 | 0.48 | 16.48% | 0.44 | 0.30 | 83.52% |
| 0.93 | 0.45 | 0.44 | 19.78% | 0.44 | 0.31 | 80.22% |
| 0.94 | 0.47 | 0.28 | 81.87% | 0.44 | 0.54 | 18.13% |
| 0.95 | 0.48 | 0.34 | 95.6% | 0.49 | 0.21 | 4.40% |
| 0.96-1 | 0.48 | 0.34 | 100% | None | None | 0% |
| CH4 | 0-0.72 | None | | 0% | 0.52 | 0.03 | 100% |
| 0.73-0.92 | 0.44 | 0.04 | 15.31% | 0.55 | 0.03 | 84.69% |
| 0.93 | 0.71 | 0.03 | 33.67% | 0.26 | 0.03 | 66.33% |
| 0.94-0.95 | 0.55 | 0.03 | 90.82% | 0.28 | 0.04 | 9.18% |
| 0.96-1 | 0.52 | 0.03 | 100% | None | None | 0% |
| N2O | 0-0.94 | None | | 0% | 0.30 | 0.02 | 100% |
| 0.95 | None | | 2.15% | 0.33 | 0.02 | 97.85% |
| 0.96 | 0.30 | 0.02 | 78.49% | 0.51 | 0.01 | 21.51% |
| 0.97 | 0.31 | 0.01 | 93.55% | 0.16 | 0.02 | 6.45% |
| 0.98-1 | 0.33 | 0.02 | 100% | None | None | 0% |
| NH3 | 0-0.72 | None | | 0% | 0.58 | 0.13 | 100% |
| 0.73-0.82 | None | | 9.02% | 0.84 | 0.07 | 90.98% |
| 0.83-0.91 | 0.21 | 0.28 | 18.05% | 0.83 | 0.07 | 81.95% |
| 0.92 | 0.22 | 0.25 | 23.31% | 0.83 | 0.07 | 76.69% |
| 0.93 | 0.34 | 0.18 | 42.86% | 0.84 | 0.07 | 57.14% |
| 0.94 | 0.34 | 0.18 | 48.12% | 0.88 | 0.07 | 51.88% |
| 0.95 | 0.37 | 0.14 | 84.96% | 0.91 | 0.08 | 15.04% |
| 0.96-1 | 0.59 | 0.13 | 100% | None | None | 0% |

**Table S5.** Assessment of the importance evaluation matrix using the Analytic Hierarchy Process (AHP).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Importance evaluation matrix** α | | | | | **Weight** | **Assess** |
| **Indicator** | **GI** | **C/N ratio** | **NO3--N** | **NH4+-N** | **Wi0** | **Test indicators** β |
| **GI** | 1 | 2 | 3 | 6 | 0.4762 | C.I.=0.0839  R.I.=0.90  C.R.=0.0933 |
| **C/N ratio** | 1/2 | 1 | 2 | 5 | 0.2888 |
| **NO3--N** | 1/3 | 1/2 | 1 | 4 | 0.1759 |
| **NH4+-N** | 1/6 | 1/5 | 1/4 | 1 | 0.0591 |

α Importance evaluation matrix: A pairwise comparison matrix was constructed based on the hierarchical ranking of each indicator, thereby facilitating the determination of indicator weights.

β C.I., consistency index; R.I., average random consistency index, C.R.= C.I./R.I. (test coefficient). According to AHP standards, a conformance test is considered passed when C.R. is ≤ 0.1.

**Table S6.** IMS analysis of the four internal maturity indicators with 8% biochar amendment.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Compost time (day)** | **C/N** | **GI** | **NH4+-N** | **NO3--N** | **IMS** |
| 0 | 24.82 | 14.63 | 1.028 | 0.046 | -0.39 |
| 4 | 23.94 | 35.87 | 1.011 | 0.025 | -0.29 |
| 9 | 23.07 | 35.05 | 0.951 | 0.027 | -0.29 |
| 16 | 22.1 | 62.15 | 0.918 | 0.027 | -0.15 |
| 23 | 21.51 | 75.37 | 0.767 | 0.068 | -0.08 |
| **37** | **19.54** | **102.98** | **0.047** | **0.283** | **0.11** |
| **51** | **13.1** | **114.55** | **0.027** | **0.388** | **0.22** |

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