Using Some Materials to Improve the Quality of Compost

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ABSTRACT

Compost is a double-edged sword, either it benefits the plant and increases the fertility of the soil with nutrients, or it causes severe harm to human and the soil by polluting the soil with heavy elements and transferring them to the plant and from there to human and animal. The search for more efficient additives has become a hotspot for improving composting humification process. Therefore, one of the main objectives of this review summarizes the recent literature on the enhancement of composting process in order to raise the efficiency and quality of the manufactured compost.

There are many modern mechanisms in the manufacture of compost, whether through the added materials to the compost, which organic, inorganic materials, clay minerals and biological organisms that increases the fertility and quality of the compost. For example, it was found that adding clay minerals (bentonite – zeolite) at rates of 90 gm reduces the severe damage of heavy elements in the compost.

Furthermore, adding some natural materials such as biochar at rates of 80 gm to the compost led to raising the quality of the compost. Finally, biological techniques, as scientific research has proven that treating compost with a biological solution containing Azotobacter bacteria has led to increased compost fertility. Therefore, modern techniques must be applied during the compost manufacturing process in order to achieve the highest quality of compost.

Keywords: compost, clay minerals, biochar, phosphor-gypsum, white-rot fungi.

INTRODUCTION

There are many methods, treatments and raw materials, whether natural or chemical, which improve and increase the quality of compost made from agricultural or animal waste or sewage, and thus reflect on the health of the plant and soil. Martins et al. (2023) indicated that the waste are containing high moisture, nutrients, and pathogens, poses significant environmental risks when applied directly to soil. Finally, it ultimately affects human health.

In this review article, we try in a few lines to list the latest methods and ways to improve the efficiency and quality of compost used in agriculture. chen et al. (2022a) demonstrated that the compost can inhibit the damage caused by heavy metals and reduce environmental risks from them by methylation, adsorption, co-precipitation and complex formation with them. Traditional organic fertilizer usually faces problems such as relatively low decomposition degree and maturity level as well as uncontrollable nitrogen loss. Therefore, there is increasing concern about the poor quality of organic fertilizer such as the compost products and serious secondary pollution in composting (He et al., 2022).

To overcome the limitations and improve the physical structure of manufactured compost, some recent studies have recommended the addition of certain materials. These include decomposing microbes, chemicals, biochar produced from biomass and natural minerals during compost fermentation (Manu et al., 2022). The inorganic materials, such as metal oxides, phosphate fertilizers, and soil minerals (montmorillonite), which are added to the compost during the compost manufacturing process, Chen et al. (2023) pointed out that inorganic materials enhance the process of decomposing organic materials and converting them into a form that is available for the plant. These materials are characterized by their low price and cost, their large specific surface area, and most importantly, they are environmentally friendly, producing ideal compost that can be applied in organic agriculture.

In recent times, used sludge bioleaching technology and natural materials such as phosphate, bentonite, diatomite, biochar and zeolite to improve compost quality. Su et al. (2024) studied the effect of using phosphate in the form of superphosphate (CP) and magnesium superphosphate (MP) on nitrogen conversion, humus fractions formation and bacterial community in food waste compost and emphasized that the addition of phosphate provides a new idea for regulating the retained nitrogen toward decomposition in composting, whereas the ratio of humic acid nitrogen in total nitrogen (HA-N/TN) in CP increased by 49 %. Ammonium nitrogen accumulation was increased by 75 % (CP) and 44 % (MP). In recent research to improve the quality of compost, it was found that adding phosphorus compounds during compost manufacturing increases the efficiency and quality of compost. Xiong et al. (2023) reported that the addition of superphosphate also reduced nitrogen-containing gas emissions during kitchen waste composting. In this point Kong et al. (2022) pointed out, phosphorus-rich additives are of great importance due to their beneficial effect on nitrogen conservation and increasing phosphorus nutrients in the fertilizer and added that the rock phosphate or superphosphate can be effective in increasing microbial load and functional cooperation by regulating pH and increasing the available nitrogen, thus improving the humification and compost maturity. For the manufacture of compost from pig manure, Li et al. (2018) reported that in pig manure and cornstalk composting phosphor-gypsum significantly decreased ammonia (NH_3) emission. This is because when calcium and magnesium phosphate fertilizer is added, struvite precipitates, which helps retain NH_4^+-N in the aqueous phase. Lei et al. (2021) confirmed that adding phosphate during pig manure has a positive effect on the richness and diversity of bacteria, and this is due to the introduction of biologically available phosphorus. Adding phosphate during the composting process can reduce emissions of gases such as ammonia and methane, and is greener than traditional composting (Yang et al., 2022). On the other hand, Wang et al. (2022) recommended adding 3% lime to compost made from pig waste to enhance the maturity of the compost and reduce the risks of heavy elements present in it.

Additionally, Kuypers et al. (2018) reported that the adding manganese oxide and carbon conditioner to compost during the composting process reduces nitrate volatilization and increases total nitrogen content due to the adsorbs of nitrate and ammonium moreover the positive effect on the activity of bacteria that convert nitrate and ammonium. Qi et al. (2024) confirmed that adding manganese dioxide-modified coal to the composting process stimulates microbial metabolic activity, thereby accelerating humic decomposition. Furthermore, its high capacity to absorb greenhouse gases and treat waste makes it environmentally friendly. Specifically, Qi et al. (2020) pointed out the essential role played by manganese oxides in the decomposition process during the compost manufacturing process, as catalysts, powerful oxidants, and regulators of functional group content. Catalytic manganese oxides play an important role in stimulating the activity of microorganisms that decompose organic materials added to the compost, thus accelerating the decomposition process and increasing the humic materials formed (Qi et al., 2020b). Along from that, (Zhang et al., 2020) stressed on, adding 5% manganese oxides to the compost during the manufacturing process increased the amount of humic acid formed by 37% compared to the control.

On the other hand, Liu et al. (2024) stated that the biochar or MnO_2 amendment is a common strategy to regulate humus formation during the composting process. For example, adding manganese oxide (0.5 % dw) in the corn straw composting process could increase humic substances concentration by 93.3 % (Wu et al., 2018).

Iron oxides are another inorganic material used to improve compost production. It is worth noting that iron oxides have the ability to improve the composting process, in addition to the fact that the mechanism of formation and decomposition of humic substances is completely similar to what happens with manganese oxides (Chen et al., 2023). In addition, iron oxide can react with the formed humic substances and form a thin layer on them that prevents microorganisms from decomposing it, Wei et al., 2021. Adding 3.75 % of $FeSO_4$ during the compost

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manufacturing process, the humic substances formed, which were 109.82–129.86 $g \cdot kg^{-1}$ were higher than the humic substances formed without addition, which were 106.31 $g \cdot kg^{-1}$ (Mei et al. 2021).

On the other hand, different natural materials and soil minerals such as montmorillonite, zeolite, illite, Ca-bentonite etc.…. can be used to improve the quality of compost. Dümenci et al. (2023) proved that the natural materials such as pumice, expanded perlite, and expanded vermiculite are used to reduce nitrogen losses and improve the compost quality for industrial sludge composting, the optimum conditions for minimum nitrogen loss by adding pumice of 40% amendment ratio. Chen et al. (2022b) reported that earth's minerals can be effective in promoting compost manufacturing process. In this point, Pan et al. (2021) recorded that montmorillonite and illite mineral can be improving the biological availability of nutrients elements and increase the efficiency of organic matter decomposition during the composting process as the humus content was increased by 11.5%, 39.3% consequently. In this field Song et al. (2021) found that the adding 10% of montmorillonite mineral to compost pile increased the humic acid to 20.93 and 23.86 g/ kg in the control and treatment groups, respectively. Previous studies of optimizing composting conditions established that adding ca-bentonite by 6-10% increased the humic acid and HA/FA ratio (Awasthi et al., 2018). On the other hand, when using diatomite mineral at a rate of 4% in the co-composting of pig manure and sawdust, the humic acid content increased by 82.19 % (Ren et al., 2021). The tourmaline mineral could promote the activities of microorganisms by optimizing composting conditions (such as moisture content, temperature and porosity) then improved the humification degree by 20.13–33.77 % when used it by 10% (Ren et al., 2020b). With respect to the effect of zeolite on compost fermentation process and the final product of compost, Gong et al. (2024) concluded that adding zeolite to compost produced from the decomposition of green residues and vermicomposting dried sludge reduces the risk of antibiotic resistance genes and led to passivate zinc and lead in the final compost product. Cui et al. (2021) confirmed that the clay minerals, zeolite and diatomite play a significant positive role in the compost manufacturing process, as they have the ability to remove heavy metals (HMs) and antibiotic resistance genes (ARGs) due to their unique properties, such as their large specific surface area, porous structure, and high water absorption and cation exchange capacity. All of this ultimately results in a high-quality compost product. At this point, Jiang et al. (2023) used a mixture of calcium phosphate, zeolite, and magnesium (ZCP) to slow down the activity of cadmium in compost. The result was an increase in inactivation of cadmium by 35.70–47.92% compared to the control treatment. On the other hand Chen et al. (2022) studied the effect of attapulgite mineral on compost fermentation process. They found the following: The attapulgite mineral raised the temperature of the pile with the length of the period and early entry into that stage compared to the control treatment, in addition to reducing the activity of some heavy elements according to the following order: Cd > Zn > Cr due to the conversion of heavy elements into less active fractions by Pseudomonas.

Cao et al. (2025) confirmed the effectiveness of Attapulgite mineral in composting humification, it increased the degree of humification in compost, leading to a more complex humus structure and reduced the loss of carbon, nitrogen, and phosphorus from soil. One of the beneficial properties of attapulgite when added to the pile compost is during aerobic composting, attapulgite provides the bacteria that decompose organic matter with sufficient amounts of oxygen, which increases the efficiency of the decomposition process and the quality of the production compost (Duan et al., 2023b). When attapulgite was compared to other clay minerals such as montmorillonite, it was found to be thermally stable and superior in its high capacity to buffer acids and bases, which promotes microbial growth and accelerates the compost maturation process (Xia et al., 2024). Explained the important role played by the attapulgite mineral in producing compost containing slow-decomposing nutrients, which rationalizes their use by absorbing humic/fulvic acids through the fine porous network and nanostructure that is unique to the attapulgite mine (Zhu et al. 2024c). Moreover, attapulgite is classified as a swelling mineral and a stable mineral, which gives it the ability to fixed the organic materials and prevent the loss of nutrients from them under leaching conditions (Zhang et al., 2024). On the other hand, Geng et al. (2024) noted that the attapulgite mineral plays an indirect biological role in the soil system during the compost manufacturing process, as attapulgite absorbs nitrogen and phosphorus, and bacteria begin to slowly decompose these two elements, which helps in raising the efficiency of the carbon and nitrogen cycle in the soil. Finally, Pan et al. (2021) confirmed that adding clay minerals is a positive way to promote the humification during the composting.

In recent years, biochar has gained the approval of a broad base of compost producers for its use as a good improver in compost manufacturing, thus improving the properties of the soil to which it is added (Das et al

.2020). Biochar can used to improve the quality of compost. He et al. (2024) reported that using the biochar and manganese dioxide co-conditioning during the aerobic composting of chicken manure can promote compost decomposition, improving the quality of organic fertilizers, substantially reducing NH_3 volatilization and enhanced nitrogen retention and total nutrients. In this field, Ebrahimi et al. (2024) conclusively shown that biochar plays an important role in improving the properties of compost through its ability to maintain the nitrogen content in the compost, reduce ammonia emissions from it, and achieve the appropriate acidity for microbial activity that decomposes organic matter. In addition, biochar is characterized by its high cation exchange capacity, which works to stabilize heavy metals and their low availability in compost. Biochar can improve the aromatization of humic substance and promote the stability of new humic substance molecules (Li et al., 2020a). On the other hand, Mustafa (2023) pointed out that adding biochar to the composting improves the physical and chemical properties of the compost, increases the total nutrients in the fertilizer, enhances microbial activity and thus enhances the decomposition of organic matter. Yin et al. (2023) noted that adding biochar to compost increased microbial metabolic activity which enabled the utilization of more readily available P fractions.

With respect to the effect of biochar on humification during the composting process, Li et al. (2021) illustrated this mechanism in Figure 1.

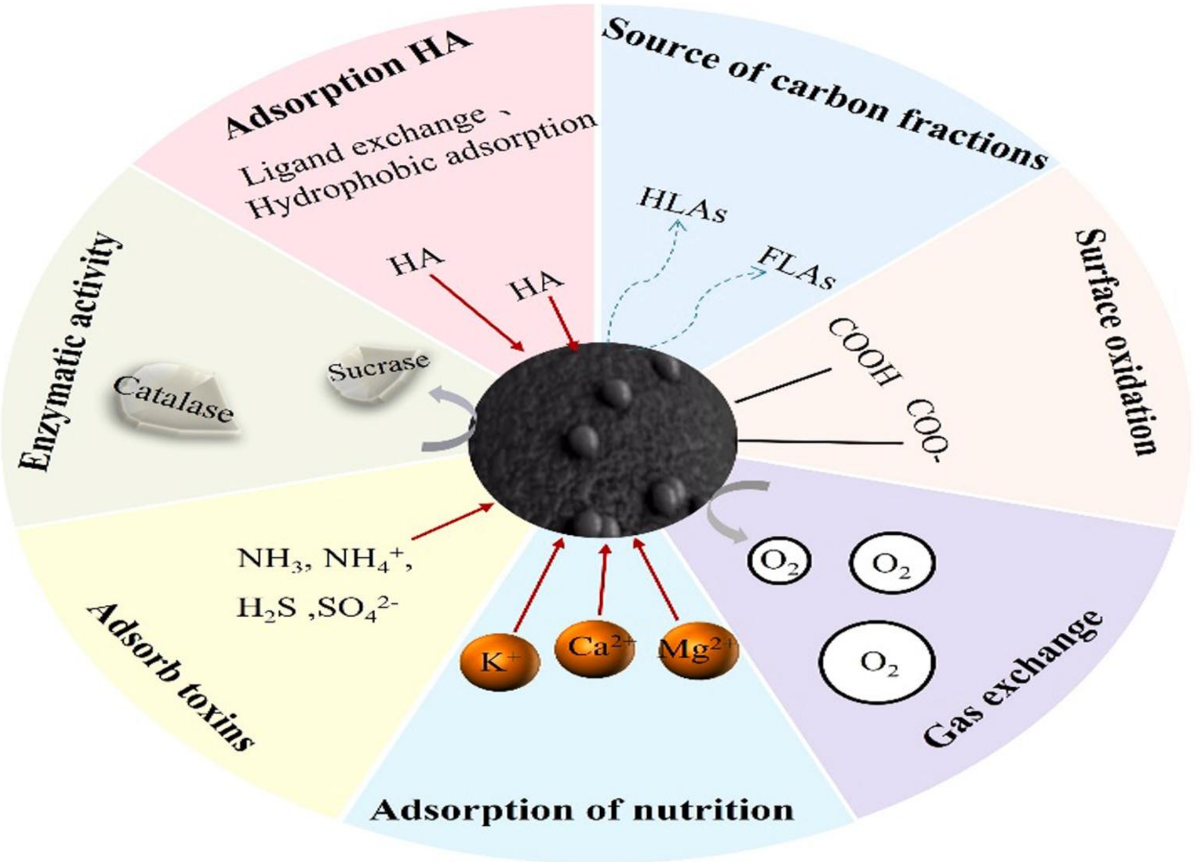

Fig.1.The role of biochar in composting humification process

Luo et al. (2024) argued that adding coal gangue during compost manufacturing creates a suitable and beneficial environment for microorganisms, which works to increase their numbers and activity, consequently leads to raising the quality of the product, adding confirms that the use of coal gangue as raw materials in compost manufacturing is one of the modern technologies for producing organic fertilizer and is also environmentally friendly. In this point, Zhu et al. (2022) confirmed that the coal gangue can act as a carrier for microorganisms, as they degrade it into carbon sources for their metabolic needs, enhancing the feasibility of producing organic fertilizers.

Ravindran et al. (2022) observed that the final pH increased from 8.0–8.5 in pig manure and farming west compos amended with rice husk biochar, compared to a final pH in the control group. The alkaline compost is useful to acidity soils. Qian et al. (2023) found that the addition of alkaline compost amended by biochar can help to neutralize acidic soils due to improve the nutrient availability and overall soil health.

The salinity value of compost product is very important point. Up to now, a number of studies have demonstrated that adding biochar to the pile the Ec value an initial decrease followed by an increase in the final product and Ravindran et al. (2022) reported lower EC values in biochar-amended compost compared to controls. On the other hand, adding biochar's derived from wood and paper waste typically to pile manure exhibiting lower EC compared to those from manure (Chaher et al., 2020).

Biochar affects the moisture content (MC) in composted food waste and wheat straw. Chaher et al. (2020) found a decrease in moisture content from 67.4 % to 43.7 % when adding biochar at a rate of 20% compared to the control, which was 56.3 %. Regarding the organic matter content in the compost product, Paul et al. (2020) established that adding biochar increases the decomposition of organic matter present in lignin and cellulose, and thus the amount of organic matter produced in the compost, because it increases the microbial activity responsible for decomposition due to its porosity and high cation exchange capacity. On the other hand, Fan et al. (2024) studied the effect of biochar on the composting process and found that adding biochar increased the relative abundance of dominant humus-reducing microorganisms (HRMs) by 20.3% and reduced redox potential (Eh) levels by 15.4%. HRMs also contributed to the dissolution of insoluble phosphorus through direct and indirect effects after biochar application.

Few studies have examined the consequences of positive effect of biochar on total Kjeldahl nitrogen (TKN) content during composting process, Voberkova et al. (2020) found an increase in the total Kjeldahl nitrogen content in compost with added biochar. This is due to the rapidity of microbial decomposition as a result of the catalytic properties of biochar. Biochar promotes humus formation, nitrogen retention, reduces carbon dioxide, ammonia and nitrous oxide emissions, and improves the quality of the compost product (Alarefee et al., 2023). In this field, Ravindran et al. (2022) studied the effect of biochar on compost produced from food waste, poultry waste and sawdust. The results showed a decrease in ammonium nitrogen (NH_4^+-N) and an increase in nitrate nitrogen (NO_3-N) concentration in the final product with increasing biochar content. This is due to the adsorption properties of biochar, rapid mineralization, increased nitrifying bacteria and volatilization of ammonium at high temperatures.

Previous studies have been show a link between the kindly of added materials to the compost and hazard of heavy metals. Current research has reported positive results for adding biochar to the compost pile, as biochar reduces the bioavailability of heavy metals (Chaher et al., 2020). Biochar has unique properties such as low density, high porosity and high adsorption capacity, which improves aeration and the microbial environment, thus reducing the movement of toxic metals in the compost (Ravindran et al., 2022). The compost added with 10 % and 19 % biochar improved the germination rate respectively compared to the control (Castro-Herrera et al. 2022). In conclusion, biochar can improve composting humification through their effects on microorganisms, extracellular enzymes and organic matter. Additionally, change the pH of compost material from slightly acidic to slightly alkaline and reduce the availability of heavy metals in compost.

Recently, a number of studies have been conducted on the subject and a variety of microbial groups have been used for this aim. Therefore, microorganisms play a vital role in the process of converting organic waste into compost. Zhang et al. (2024) used bio-trickling filter (BTF) and carbon-based microbial admixture (CBMA) in composting process and found that CBMA and (BTF) effectively changed the microbial community in the compost, protected ammonia-oxidizing microorganisms, and enhanced compost nitrate. Moreover, a significant amount of nitrogen was retained, while reducing odor emissions and improving compost quality. Studies have confirmed that ammonia is the main component of compost, and if left uncontrolled, the significant loss of nitrogen in the form of ammonia during fermentation will reduce the quality of the compost product (Wang et al., 2022). At present, several studies have confirmed the effect of carbon-based microorganism inoculations in improving nitrogen retention during composting. Koyama et al. (2022) used Neurospora sp bacteria to convert sludge into compost and found that the final decomposition of organic matter in the sludge treated with Neurospora sp. was higher than the control. Moreover, the amount of undissolved nitrogen decreased. In addition, the ammonia conversion rate improved significantly. The researchers also confirmed that Neurospora sp. bacteria decomposed organic nitrogen molecules, which require a long time for decomposition by the bacterial community during thermal composting

Zhu et al. (2021) pointed out; one of the most important problems facing the decomposition of organic waste in compost manufacturing is lignocellulose, as it is considered the most important component of organic waste and the most difficult and slowest to decompose with the formation of hydrogen sulfide compounds. Therefore, researchers have been recommended the use of microorganism's inoculants with lignocellulose decomposition properties to rapid composting process and improve the final product. Ji et al. (2023) mixed cellulose-degrading microbial sources and biochar to nitrogen metabolism and microbial community progression during pig manure composting, and all treatments with additives reduced nitrogen loss compared to the control treatment. In this field, studies have confirmed that inoculation of microorganisms with lignocellulosic degradation properties can enhance compost fermentation process and improve compost quality (Chen et al., 2021). It is worthy to mention that the humic acids content increased by 2.3-6.1% when Rastogi et al. (2019) used the bacillus bacteria in compost fermentation process. Regarding compost made from dairy manure and sugarcane leaves, Xu et al. (2019) indicated that adding compost born multifunctional thermophilic microbial consortium (CTMC) led to a significant increase in humic substances compared to un-inoculated compost. Some studies have shown that inoculation of ammonia-oxidizing bacteria (AOB) has a dual improvement on nitrogen fixation and humic substance production in the composting process (Xu et al., 2022).

Summarized, Wei et al. (2019) pointed out the essential role played by microorganisms in the process of converting organic waste into compost. They stressed that they are the driving force behind the composting process and the stability and increase of organic matter. Zhang et al. (2018a) vaccinated Phanerochaete chrysosporium into sewage sludge used in the manufacture of compost in the early stages, which led to a significant increase in the percentage of humic acid, reaching 40 percent. The combined activity of earthworms added to the compost and microorganisms during the composting process lowers the pH of the compost. This is due to the production of organic acids and the emission of carbon dioxide by these organisms (Biruntha et al., 2020). The overall picture, chen et al. (2023) stated that additives of inorganic, organic, biological, and compound during composting process lead to promote 5.58–82.19%, 30.61–50.92%, 2.3–40%, and 28.09–104.51% of humification respectively.

CONCLUSION

A recent systematic literature review concluded that a few recent years are many modern trends and techniques in the manufacture of compost. Each type of compost processing from animal waste, farming, or sewage sludge has its own technology to promote composting humification, whether by adding natural materials such as biochar or clay minerals such as zeolite or bentonite, and at rates which suitable suit each compost.

Finally, using the biological technology by adding or injecting or spraying the bacterial solutions to compost in order to increasing the fertility of the compost and raise its efficiency.

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