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Emerging frontiers in microbial-mediated utilization of crop residues for economically valuable biomaterials

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ABSTRACT

Agricultural crop residues include leftover and unmarketable materials, such as crop stover, weeds, leaf litter, sawdust, forest litter, and livestock manure originating from crop cultivation, and post-harvest activities. Such residues are a storehouse of plant nutrients and several other resources and therefore need to be managed in an environment- friendly manner with minimum loss of plant nutrients and other resources that can be recovered. Microbial starter consortia are a key component in the rapid recycling of farm residue wastes and the production of other valuable products, such as biogas, bioethanol/biofuel, enzymes, molecules, and metabolites. Recent advances in microbial biotechnology can also facilitate the conversion of farm residues into economically valuable materials, *i.e.* soil additives, adsorbents, energy, and enzymes, thereby contributing to a circular economy. This special issue attempts to compile the latest advancements in the field of agricultural crop residue management for enhanced nutrient recycling and resource recovery by the use of compost starters and inoculant formulations.

The burning of agricultural crop residues is detrimental to the environment because of the release of greenhouse gases (GHGs), which exacerbate global climate change. This practice also leads to an increase in the levels of particulate matter and other harmful air pollutants, which can result in health issues, a decrease in cropped land diversity, and a decline in soil fertility (Pathak et al., 2012; Raza et al., 2022; Kumar et al., 2023). However, crop residues are a valuable source of plant nutrients, which can improve resource use efficiency and sustainability in agroecosystems (Dutta et al., 2022). Burning crop residues on farms is becoming increasingly problematic for various reasons. The shortwindow period for sowing of next crops, time, resources, finances, and farm mechanization are the reasons for crop residue burning (Liu et al., 2020). To address these negative impacts, alternative techniques, such as *in-situ* composting through microbial interventions, residue incorporation, and mulching can be employed (Bhuvaneshwari et al., 2019; Biswas et al., 2021; Semwal et al., 2023).

Managing crop residues also affects the microbial communities responsible for maintaining soil health. These microbes are responsible for breaking down organic matter and releasing essential nutrients into the soil thereby facilitating biogeochemical processes (Agrawal et al., 2023; Janeeshma et al., 2023). Engineered microbes can improve the bioconversion of lignocellulosic materials into valuable products, including biopolymer enzymes, bioethanol, biofuel, metabolites, and bioplastics (Blasi et al., 2023). This method aims to decrease the reliance on fossil-based plastics and promote the development of environmentally friendly packaging materials. By employing microbial fermentation techniques, bio-based chemicals and molecules can be produced from crop residues (Pramanik et al., 2021). These chemicals can serve as precursors for a broad range of industrial products (Ewing et al., 2022; Verardi et al., 2023).

The use of a microbial consortium or decomposing microorganisms, like *Aspergillus* spp., *Talaromyces* spp., *Penicillium* spp., *Sporotrichum* spp., *Fusarium* spp., *Trichoderma* spp., *Acremonium* spp., *Chaetomium* spp., *Phanerochaete* spp., *Bacillus* spp., *Pseudomonas* spp. and actinobacteria on crop residues can accelerate the decomposition process, increase the presence of beneficial microorganisms in the soil, and ultimately benefit agricultural ecosystems (Detain et al., 2022; Sagarika et al., 2022; Kumar et al., 2023). Researchers can utilize -OMICS technologies such as genomics, metagenomics, and metabolomics to better understand and optimize the microbial communities involved in the decomposition of crop residues.

Advanced process control strategies, including artificial intelligence and machine learning, can be employed to optimize microbial-mediated processes for the production of biomaterials from crop residues. Integrated systems that combine the microbial utilization of crop residues with other waste streams, such as agro-industrial by-products, can create a circular economy approach. Additionally, assessing the economic viability of microbial-mediated processes is crucial to ensure that the large-scale production of biomaterials from crop residues is financially feasible.

Utilization of crop residues by microorganisms for enhanced nutrient recycling and production of economically valuable biomaterials is an exciting and promising area of research in secondary agriculture and microbial biotechnology. Further research in this area has the potential to unlock new avenues for sustainable and circular agriculture while addressing the challenges associated with crop residue management.

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Therefore, this special issue aims to collect the most recent developments in microbial-mediated crop residue management.

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Declaration of competing interest

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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