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Perspective

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Nanobiotechnology at the biorefinery facility

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DESCRIPTION

The scope and definition of "Nanobiotechnology" itself is undergoing expansion to include the voluminous breakthrough happening at the upcoming biorefinery facility that is replacing the conventional fossil based refinery at a rapid pace. All the chemicals, fuels and materials that were conventionally produced at the fossil based refinery facility can, in principle, be produced from the biorefinery where in the biomass is used as the feedstock. Nanobiotechnology encompasses the use of nanocatalysts that memic the classical enzymes and act as selective agents for the transformation of biomass to biofuels without themselves being altered. Some unconventional catalysts of such nature include Zn doped CuO, polyoxometalates and SrO/silica beads. The use of such unconventional catalysts with wonderful activity and selectivity for the reactions as simple as dehydration, transesterification and hydrolysis will be exemplified with emphasis on catalytic reactions that serve as economic drivers at the upcoming biorefinery. Unconventional feedstock like CO2 and marine macro algae and freshwater micro algae will be dealt. Nanobiotechnology is increasingly playing a pivotal role in the advancement of biorefineries, which are emerging as sustainable alternatives to traditional fossil-based refineries. These modern facilities leverage renewable biomass to generate a wide spectrum of value-added products, including fuels, chemicals, and advanced materials. A key component of this transformation lies in the deployment of nanostructured catalysts that emulate the efficiency and specificity of biological enzymes. Unlike conventional catalysts, these nanoengineered materials—such as zinc-doped copper oxide (Zn-CuO), polyoxometalates, and strontium oxide immobilized on silica beads (SrO/SiO_2)—offer enhanced selectivity and reusability across a variety of biomass conversion processes. These nanocatalysts have demonstrated remarkable performance in fundamental reactions including hydrolysis, dehydration, and transesterification—reactions that underpin the production of biofuels and bio-based chemicals. Their integration not only improves the overall efficiency of biomass processing but also contributes to the economic viability of the biorefinery model. Moreover, the scope of feedstocks is expanding beyond traditional lignocellulosic biomass to include unconventional sources such as carbon dioxide, freshwater microalgae, and marine macroalgae. These feedstocks represent a promising avenue for sustainable production, reducing the dependency on arable land and freshwater resources.

CONCLUSION

The convergence of nanobiotechnology and biorefinery technology represents a transformative shift in the production of sustainable fuels, chemicals, and materials. By mimicking enzymatic action, nanocatalysts offer unprecedented efficiency, selectivity, and durability in key biomass conversion reactions. Their role in enhancing reaction pathways—especially hydrolysis, dehydration, and transesterification—positions them as critical enablers in the transition toward a circular, bio-based economy. Furthermore, the exploration of unconventional feedstocks such as CO_2 and algal biomass broadens the resource base while minimizing environmental impact. As biorefineries continue to evolve, nanobiotechnology will remain central to optimizing process economics, improving environmental performance, and achieving scalable, sustainable alternatives to fossil-based systems.