Biomass to Pharma: The Sustainable Catalytic Approach Towards Bio-based Amines

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Biomass valorization for the pharma industry

The depletion of fossil resources and their adverse environmental impact have prompted the modern research community to consider the comprehensive utilization of biomass as a renewable carbon feedstock for producing fine chemicals, bulk chemicals, polymer precursors, biofuels, and pharmaceutical precursors.[1–3] Efficient biomass valorization reduces our dependence on depleting fossil fuels and boosts carbon neutrality.

In this context, the necessity of using non-edible lignocellulosic biomass instead of edible biomass (starch and lipids) for the synthesis of chemicals and biofuels is crucial for a sustainable future. The non-edible lignocellulose consists of three polymeric components: cellulose (30-50 wt.%), hemicellulose (20-35 wt.%), and lignin (15-30 wt.%).[3,4] It is abundantly available from waste resources (e.g., sugarcane, bagasse, and corn stover) and forest residues. Catalysis provides industrial solutions for lignocellulose biorefinery.

The use of heterogeneous solid catalysts over homogeneous catalysts offers several advantages, including easy synthesis, high hydrothermal stability, and efficient reusability.

A large number of secondary amines are still produced from fossil-based resources, which may not be available in the near future due to the continuous depletion of fossil fuels.

Hence, it is crucial to develop sustainable catalytic strategies for producing secondary amines from non-edible lignocellulosic biomass and its derived platform molecules.

Sustainable Catalysis Research at SP HeteroCat Lab, IIT Hyderabad

Dr. Sudarsanam's group (SP HeteroCat Lab) at IIT Hyderabad is actively working on developing practically viable catalytic methods to valorize non-edible lignocellulosic biomass and its platform molecules into high-value fuels and chemicals.

Specifically, the SP HeteroCat Lab focuses on producing secondary amines from lignocellulose-based platform molecules, namely furfural (derived from hemicellulose) and vanillin (derived from lignin), through novel and sustainable catalytic methods (Figure 1).

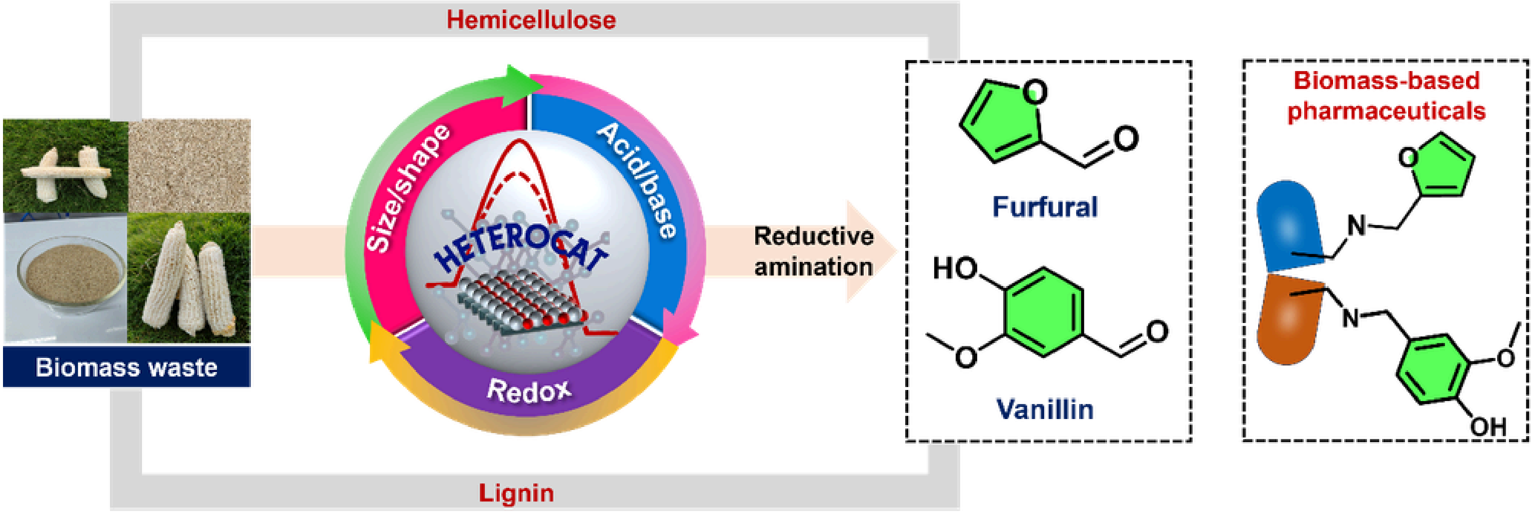

Figure 1. Overview of the research progress in Dr. Sudarsanam's Lab on the production of pharmaceuticals from biomass-based platform molecules.

Controlling the particle size and shape, as well as engineering the surface structure of heterogeneous solid catalysts, can optimize the active sites for target applications in lignocellulose valorization. Secondary amines hold significant importance in drug design and development, as they serve as versatile structural scaffolds in various pharmaceuticals, including anticancer, antiviral, and antibacterial agents.[5,6] Besides, they are potential monomers for the production of valuable polymers and vitrimers at a commercial level.

> *"The use of heterogeneous solid catalysts over homogeneous catalysts offers several advantages, including easy synthesis, high hydrothermal stability, and efficient reusability"*

The reductive amination strategy has received significant importance for producing biomass-derived secondary amines, as it is promising and can be extended to chemicals with versatile functionalities for the pharmaceutical industry.

The reductive amination involves carbon-nitrogen coupling and the subsequent hydrogenation using a hydrogen source (molecular hydrogen or hydrogen donors). For this, a suitable heterogeneous catalyst with an optimum amount of acid sites (for carbon-nitrogen coupling) and redox sites (for hydrogenation) is necessary.

With continuous efforts, Mr. Subha P, a PhD student in Dr. Sudarsanam's group, has developed a novel catalytic strategy to produce furfural-based secondary amines at room temperature using a PdNi-based nanoalloy catalyst with a mixture of triethylsilane and methanol as a hydrogen donor.[5] These amines hold significant importance in the pharmaceutical industry and serve as cost-effective precursors for several anticancer drugs.

The catalyst consists of alloyed ultrafine PdNi nanoparticles with optimal acid-redox synergy, which accelerates hydrogen generation from the triethylsilane-methanol couple, as well as the efficient hydrogenation of imine intermediates at ambient conditions.

Challenges and Prospects

Although we have developed an efficient catalytic strategy for producing furfural-based secondary amines using a mixture of triethylsilane and methanol as a hydrogen donor, the industrial viability of this process primarily relies on the number of byproducts formed during the reaction and how efficiently they can be separated from the targeted amines. To address these challenges, Dr. Sudarsanam Putla and

Mr. Subha P are currently working on the use of molecular hydrogen gas instead of hydrogen donors for the reductive amination of furfural and vanillin, aiming to produce pharmaceutical precursors at mild pressures (<10 bar) and near-room temperature.

On the other hand, we also focus on replacing precious metals (Pd and Ru) with earth-abundant metals (Ni, Cu, and Co) without compromising activity and mild reaction conditions.

Thus, we strongly believe that the strategies being explored in our lab will lead to a sustainable pathway for producing renewable secondary amines as next-generation pharmaceuticals with versatile applications, thereby boosting both the biorefinery and pharmaceutical industries.

References

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