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REVIEW ARTICLE

Transformation of agro-biomass into vanillin through novel membrane integrated value-addition process: a state-of-art review

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Abstract

Bio-based feedstock utilization for the green manufacturing of valuable organic compounds is reckoned as a crucial goal to be achieved by the global scientific communities in this century to encourage sustainable business while saving the fixed stock of fossil fuels. Vanillin is a key aromatic flavoring compound extensively used in the food and cosmetic industries. Around 12,000 tons of vanillin are widely consumed in a year, and less than 1% of it is obtained from vanilla beans through the costly extraction process. Extensive scrutiny of the existing literature shows that vanillin can be produced bio-technologically from several sources. Currently, the production of vanillin from lignin is enticing because it caters to the supply of renewable aromatics in nature. However, the scaled-up applications of the biological routes are limited owing to the slow process, the requirement for precise process control, the risk of product inhibition and degradation, bacterial strain selection, and a complex downstream purification. These challenges highlight the need for vanillin synthesis through an alternate eco-friendly combined biological–chemical route. This review gives an insight into the development of a novel membrane-integrated photo-microreactor system for converting lignocellulosic biomass to vanillin and downstream purification, which appears to be the most promising bio-chemical, environmentally friendly, and cost-effective choice. The status quo of lignin extraction, purification, recovery, and techno-economic assessment for scale-up are also discussed thoroughly, enabling researchers to comprehend the possible lignocellulosic agro-biomass material conversion methodologies for the production of valuable aromatic compounds.

Keywords Vanillin · Waste biomass · Lignin · Biosynthesis · Photocatalysis · Recovery · Membrane integration

1 Introduction

Vanillin (4-hydroxy-3-methoxybenzaldehyde) stands out as a highly sought-after food flavorant with a global annual demand of approximately 12,000 tonnes [1]. According to an industry estimate, the global demand for vanillin was 18,653.9 tonnes in 2016 and was expected to grow at 6.2% compounded rate annually (CAGR), from 2017 to 2025. Food and beverage items were identified as the largest end-use sector. It was expected to generate income worth US$724.4 m by 2025, at 7% compounded annual growth rate [2]. It is used in an array of end-use products and is considered a high-value product globally. A fine white needle-like crystal with a sweet vanilla flavor, antimicrobial, antioxidant, and antimutagenic properties, it has wide use as a taste and fragrance enhancer or a convenient constituent in edibles, cosmetics, and pharmaceutical and nutraceutical products

Jayato Nayak and Aradhana Basu have equal contribution.

Highlights
- Various biomass treatments for vanillin synthesis have been reviewed.
- Membrane distillation allows product recovery with high purity.
- Membrane-based integrated system enables production and facilitates catalyst recovery.
- The cost analysis for sustainable industrialization enhance the scale-up confidence.

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