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Editorial: Integrated waste biorefineries: achieving sustainable development goals

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Editorial on the Research Topic
Integrated waste biorefineries: achieving sustainable development goals

Introduction

The Sustainable Development Goals (SDGs) established by the United Nations provide a comprehensive framework for a brighter tomorrow, encompassing crucial aspects such as renewable energy, clean water and sanitation, and responsible consumption. However, accomplishing these goals requires dedicated efforts over an extended period. An innovative and effective solution to waste management and energy issues is the emergence of waste biorefineries. These advanced systems not only provide sustainable waste management and energy solutions, but they also have the potential to reduce poverty and hunger while supporting global economic growth initiatives.

As our world faces critical environmental concerns, such as climate change and serious health issues, a major shift in our production and consumption paradigms seems inevitable. One solution to achieve that would be extending waste-oriented biorefineries, converting waste into energy, power, and useful products in a circular economy context. In light of the

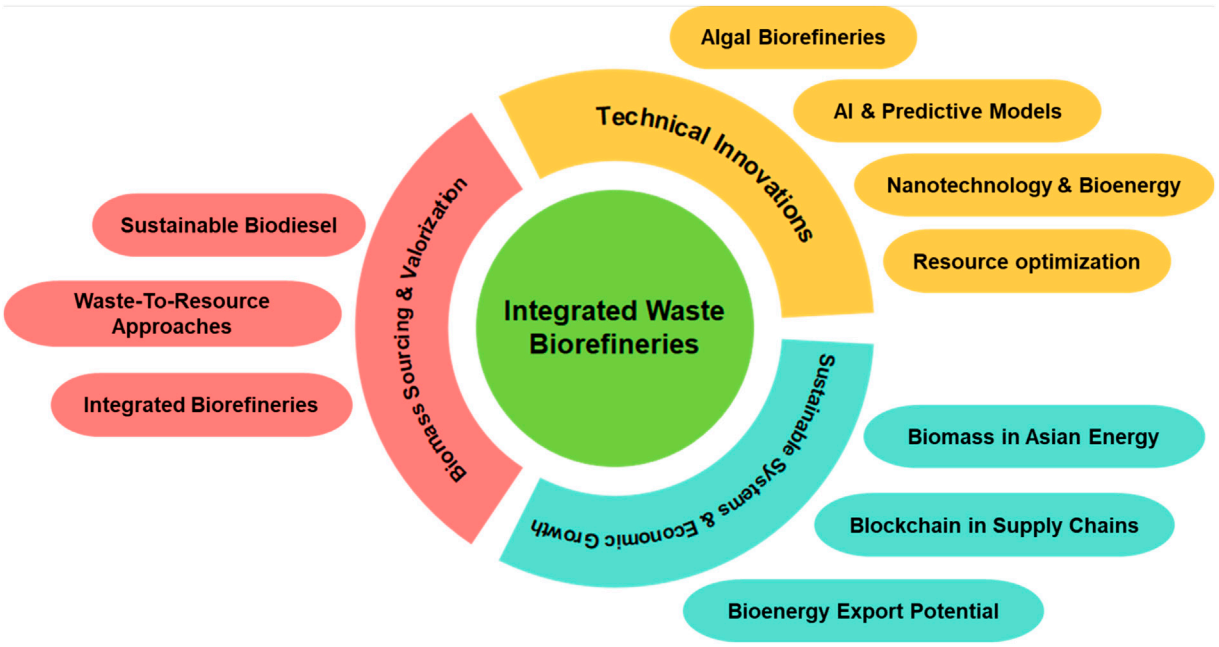

FIGURE 1
Categorization of articles in this Research Topic.

above, this Research Topic focuses on the role of waste biorefineries in meeting the SDGs, where respected scientists share their insights on waste biorefineries' status, advancements, and prospects. Through their contributions, readers can explore how these innovative systems can play a vital role in achieving SDGs, tackling pressing environmental and health issues, and creating a better future. The accepted articles in this Research Topic are categorized under the sections of (1) Technological innovations and advancements in biorefineries, (2) Biomass sourcing, characterization, and valorization, and (3) Sustainable systems, economic growth, and policy implications based on the relevancy of their Research Topic and aims (Figure 1).

Technological innovations and advancements in biorefineries

In today's world, technology has become essential in driving progress and achieving a sustainable future, especially in the biorefinery industry. Combining scientific research and innovation creates a more environmentally friendly and efficient energy landscape, which tackles current challenges and prepares for future requirements. Following are the 4 articles published under this subsection and their details.

The article by Nagi et al. highlights the untapped potential of microalgae as a platform for developing algae-based biorefineries. Microalgae present an environmentally friendly alternative to traditional fuels, but several challenges hinder their large-scale production, including nutrient requirements and water costs. The study emphasizes the necessity for coupling biofuel production with high-value or mid-value products, highlighting the industries' shift towards utilizing algae by-products in cosmetics, nutraceuticals, and animal feed. The review comprehensively analyses the status, challenges, and prospects of cost-effective microalgae biomass production. It also emphasizes the potential for valorizing high-value co-products to advance microalgal biofuel commercialization. This work aligns with "SDG 7: Affordable and Clean Energy", and "SDG 13: Climate Action", as the authors emphasize on the use of renewable energy sources and thereby reducing greenhouse gas emissions.

The research conducted by Ayub et al. emphasizes the high potential of alternative renewable fuels, particularly biomass, for electricity generation as a sustainable substitute for fossil fuels. It reveals an innovative Artificial Neural Network (ANN) model to forecast crucial process parameters for the integrated biomass gasification power plant: gasification temperature and air-to-fuel ratio. Using data from thermodynamic equilibrium model simulations across 86 different biomass feedstocks, this ANN model stands out for its impressive accuracy, reflected in an MSE score of 1,497 and a test R of 0.9976. Notably, this research offers a powerful tool for enhancing power generation efficiency and productivity of biomass gasification.

Khan et al. examined the role of nanotechnology in enhancing biogas yield from various wastes in bioenergy production. The study investigates the impact of diverse nano-additives on anaerobic digestion, from metal oxides to carbon-based nanomaterials. Based on a bibliometric analysis of 14,000 articles, it has been revealed that there has been a surge in biogas research over the last decade. Nanomaterials have revolutionized methane production and waste treatment. However, the environmental challenges of nanomaterial disposal post-process are also noted, emphasizing the need for further advancements before broad industrial application.

The potential to increase lactic acid (LA) yields from food waste fermentation was investigated by incorporating nitrogen as NH_4Cl

or digestate and augmenting with sucrose. The research by Bühlmann et al. demonstrates that while NH_4Cl and digestate boost LA formation rates, NH_4Cl also advances the final LA concentration. Crucially, introducing sucrose amplified the LA concentration and promoted desired *Lactobacillus* growth, suppressing undesired microbial communities. This shows that biorefineries can benefit by using digestate as a nutrient and sucrose as a carbon source, improving the feasibility of lactic acid-anaerobic digestion biorefinery models.

Biomass sourcing, characterization, and valorization

Biomass is a renewable resource that is crucial to our future energy needs. By improving our understanding of its sources, refining its characterization, and maximizing its value, we can move closer to a more sustainable energy paradigm that minimizes waste and prioritizes efficiency. Following are the 3 articles published under this subsection and their details.

Bukhari et al. delved into the potential of Dodonaea plant oil as a biodiesel source, a tropical shrub known for its high-fat content. Transesterification and esterification reactions were performed at 60°C for 70 min using a 1:6 M oil-to-alcohol ratio, resulting in a 90% biodiesel yield. The fuel characteristics of the derived biodiesel were promising when evaluated against the ASTM standards. Dodonaea presents an excellent non-edible source for biodiesel production. Its cultivation on marginal lands ensures a consistent feedstock for the bioenergy sector. Thoroughly monitoring its production quality highlights Dodonaea's potential for large-scale biodiesel commercialization.

Kopperi and Mohan examined a novel approach to an algal-biorefinery system that combines dairy wastewater treatment, hydrothermal liquefaction (HTL) of defatted algal biomass, and acidogenic processes in a closed-loop system. The study used Coelestrella sp SVMIICT5 microalgae and achieved 87% wastewater treatment, along with notable biomass growth of 3. 2 g/L of DCW. After extraction, the HTL process optimized the algal residue to produce an impressive 52% bio-crude yield, which holds potential for jet fuel production. Dark fermentation of the resulting HTL stream led to significant bio-hydrogen generation. This innovative research highlighted the potential of integrating biological and thermochemical processes in developing sustainable biorefineries. The work stresses the potential benefits of algal-biorefinery using the non-arable land and wastewater recycling, which contributes to the "SDG 6: Clean Water and Sanitation" as well as "SDG 15: Life on Land".

Qian et al. proposed blending alkaline black liquor, a biomass pretreatment by-product, directly with polyvinyl alcohol (PVA). This unique combination resulted in composite films that showcased outstanding UV-shielding and enhanced physical properties. Adding 3.0% of alkaline BL to the PVA reduced the film's UV transmittance to below 20%, boasting physical strengths surpassing films derived from commercial alkaline lignin. This method minimizes environmental impact and promotes biomass efficiency by eliminating costly lignin extraction, marking a step towards zero-waste biorefinery.

Sustainable systems, economic growth, and policy implications

Sustainability, economy, and policy are the major factors in global energy. Our energy future depends on understanding the connections between these different elements. Following are the 3 articles published under this subsection and their details.

Considering growing environmental concerns and resource depletion, researchers are delving into the transformative potential of blockchain technology for sustainable supply chain management. The study by Munir et al. systematically assesses blockchain's contribution to sustainability in supply chains across economic, environmental, and social dimensions, using 136 articles. The study highlighted blockchain's potential to improve economic sustainability through its traceability, transparency, and decentralization features. Blockchain can support sustainable supply chains, but its strategic significance is unclear. Developed nations have adopted it, but developing countries lag. Regulatory interventions are needed to promote green practices. Future studies should merge blockchain with big data IoT and consider the learnings from COVID-19. By the adoption of sustainable technologies and best practices, such as blockchain in the supply chain is crucial for achieving environmental and social sustainability aligns with SDGs such as "SDG 9: Industry, Innovation, and Infrastructure", "SDG 12: Responsible Consumption and Production", and "SDG 17: Partnerships for the Goals".

Biomass has historically been a primary source of cooking and heating in Asia, especially in countries like Bangladesh, China, India, Mongolia, Nepal, Pakistan, Sri Lanka, and Laos. However, traditional cookstoves (TCS) emit harmful substances like CO_2 and $PM_{2.5}$, leading to various health risks and showcasing low thermal efficiency. The review by Ahmad et al. synthesizes the fragmented information on biomass cookstoves in the mentioned Asian countries, highlighting the improved thermal efficiency and reduced emissions of improved biomass cookstoves (ICS). Although China leads to ICS adoption, financial constraints, lack of awareness, and infrastructural challenges are notable barriers across Asia. To address the issue, future interventions should prioritize the development of efficient and affordable stoves while promoting their use through targeted workshops, collaborations, and regular quality evaluations.

Ayub et al. explore bioenergy production and export potential in biomass-rich countries using the Product Space Model (PSM). Key findings highlight Pakistan's abundant biomass resources, with canola oil, leather flesh wastes, and poultry fattening showing the highest income potential. In contrast, goat manure and cashew nutshell presented lower income potential, suggesting their optimal use within local energy generation plants. According to a study, the U.S. is a major producer of sophisticated biowaste products. The study recommends that countries like Pakistan and Argentina broaden their export offerings by concentrating on underutilized products closely associated with their current exports. The potential for diversification is higher in the US, China, and India. The study demonstrates how biomass-rich nations can attain sustainable economic growth via optimized bioenergy production and export strategies.

Outlook

As we strive to overcome the global crises, the importance of integrated solutions like waste biorefineries for sustainability becomes clearer. These systems represent ideal opportunities within the circular economy by transforming waste into valuable resources. Moving forward, we must synchronize technological progress with evolving policies and changing economies. Need to raise public awareness about the potential benefits and applications to ensure the sustainability of biorefineries. Future research is required to explore the integration of biofuel systems with industrial commodities production to achieve economically sustainable outcomes. The application of blockchain technology in the supply chain should be further investigated to enhance environmental and social sustainability. Finally, emphasizing collaboration, informed decisions, and continual innovation will create a sustainable legacy for future generations.

Author contributions

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