# The future of biorefineries: a strategic vision, challenges and opportunities of biorefining in Brazil

José Vitor Bomtempo*[1,2], Flávia Alves[3], Fábio Oroski[3], and Carlos Correa[3]

[1]Escola de Química da Universidade Federal do Rio de Janeiro – Brazil
[2]GEBio, Bioeconomy Study Group, School of Chemistry, Federal University of Rio de Janeiro – Brazil
[3]School of Chemistry, Federal University of Rio de Janeiro – Brazil

**Abstract**

This article's main contribution is the proposal of an analytical framework to guide the study of biomass from a perspective that considers the future of biorefineries. The article is the result of a study carried out in 2024 on biorefining in Brazil. In addition, it presents illustrations of the situation and challenges of biorefining in Brazil.
Over the last twenty years, interest in biorefineries and biorefining has grown significantly. According to the Scopus database, to date, 18,025 documents have included the terms biorefinery or biorefining in their titles, abstracts, or keywords. Of this total, only 3 were registered in 2000. In 2010, 338 documents were published; in 2023, the annual number of documents reached 2,084.

However, except for biofuels in a few countries, generally restricted to first-generation biofuels, the sustainable valorization of biomass has made little progress. If we consider the ambition of 25 years ago, the results of new bioproducts and biomaterials launched are certainly not exciting (1, 2).

However, this scenario is set to change. The intensification of climate change pressures in the last 10 years could open up a new space for biorefining as a contribution to reducing the use of fossil resources and valorizing renewable carbon. In addition, a new way of producing and using biomass can be seen as an opportunity for sustainable development in many regions.

How should biorefining be viewed when building biorefineries in the future? What conceptual vision of biorefining should be constructed to develop sustainable businesses that effectively meet the economic, environmental, and social dimensions? What attributes should biorefineries strive for? These are the questions the article aims to address.

In the study of biomass, in addition to bibliographical research, interviews were conducted with 46 players (industry, government, and research centers), and case studies were drawn up exploring selected biomass with experience or potential for exploitation in Brazil.

A systemic view of biorefining is proposed as a starting point. This vision considers that biorefining involves not only the industrial units for treating and converting biomass, i.e., the biorefineries themselves but also the production chains and the production and innovation

*Speaker

ecosystem. The production chain includes the supply of biomass, processing, industrialization, and marketing.

The importance of a systemic view of biorefining was emphatically emphasized in the study Innovation Ecosystems in the Bioeconomy (3). The construction of industrial units - biorefineries - is seen as the most straightforward element in developing new businesses in the bioeconomy. The most critical challenges lie in creating ecosystems of companies and organizations and value chains capable of supporting the activities of biorefineries.

In addition to a systemic vision, the ideal of biorefining is to look for a set of strategic attributes for achieving biomass's sustainable valorization. Based on the literature, mainly reports and strategic plans for the bioeconomy, four main attributes stand out: product diversification, full biomass utilization, circularity, and regional/territorial insertion.

Based on the systemic vision of biorefining and its strategic attributes, an analytical framework is proposed that can be used to diagnose the current situation of biorefineries. The analytical framework can be presented in a matrix on two axes considering the structuring of supply and biomass valorization. The horizontal axis positions the resource in terms of the supply model and structure, considering supply derived from extraction or cultivation, mastery of cultivation and harvesting technologies, and levels of utilization of the waste generated (low, high, full). The vertical axis considers the different levels of product diversification (lack of diversification with the extraction of only one main product, diversification of products with low added value, and diversification of products with high added value).

Each biomass of interest can be positioned in the diagnostic matrix. This diagnosis guides the study of a given biomass and makes it possible to identify the challenges for the development of biorefining in each case.

In addition to the systemic level, policies and programs must be able to consider the challenge of structuring businesses. Biorefining businesses are often emerging without a defined structure and require innovation. The different levels of structuring can be identified and characterized in an analytical framework that considers four key dimensions in co-evolution: raw materials/resources, technologies, products, and business models (4, 5).

The study of these dimensions and how they are articulated allows for a characterization of biorefineries, distinguishing the different levels of structuring. The policies and strategies implemented for the development of biorefining must consider the challenges involved in each of the dimensions.

As an illustration of the proposed methodology, a brief discussion of the Brazilian case is presented. Six biomasses representative of the variety of resources available in Brazil are explored, including biomasses from Brazilian biodiversity (açaí, macaúba, babassu) and from agro-industrial chains (sugarcane, planted forests, coffee). The analysis allows us to identify the challenges these biomasses face in their evolution from the perspective of the future of biorefining. Policy and strategy recommendations can be derived from the analysis of these challenges.

References

1 - de Jong et al., **Bio-based Chemicals, Value Added Products from Biorefineries,** IEA Bioenergy Task 42, available at www.ieabioenergy.com, 2020.

2 - Teixeira, L.V.; Bomtempo, J.V.; Oroski, F.d.A.; Coutinho, P.L.d.A., **The Diffusion of Bioplastics: What Can We Learn from Poly(Lactic Acid)?** Sustainability, 2023, 15, 4699.https://doi.org/10.3390/su15064699

3 - OECD. Innovation Ecosystems in The Bioeconomy. OECD Science, Technology and Industry Policy Papers. No. 76, september 2019.

4 - BOMTEMPO, J. V., *Nota técnica do sistema produtivo Química e foco setorial Bioeconomia*, para o projeto Indústria 2027 – Riscos e Oportunidades para o Brasil diante de Inovações Disruptivas, CNI/IEL, 2017.

5 - BOMTEMPO, J. V., ALVES F., Innovation Dynamics in the Biobased Industry, **Chemical and Biological Technologies in Agriculture**, **1**:19 doi:10.1186/s40538-014-0019-8, 2014.

**Keywords:** biorefining, biomass, Brazil