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Towards molecules with low and high functionality: harnessing the carbon skeleton of sugars

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PURPOSE OF THE ABSTRACT

Our current high standard of living goes hand in hand with the exploitation of fossil resources. Nevertheless, the use of fossils is coming under increasing pressure because of its finite character and the environmental problems associated with the consumption of it. By consequence, great attention is currently paid to the transition from fossil feedstocks to renewable resources such as wind, solar and biomass. The biorefinery, which has certain similarities with a modern petrorefinery, plays an important role in this transition. Herein, biomass is fractionated, purified and subsequently converted into fuels, chemicals and materials.

Sugars, which are the main constituents of biomass, play an important role in the proposed transition towards renewables, but their full potential for the chemical industry is still underexploited. They have a unique carbon skeleton composed of 5 to 6 carbon atoms that are all connected in a linear way. Apart from the presence of oxygen atoms, these carbon chains are identical to the ones found in fossil light naphtha. This means that, providing a procedure for the selective removal of oxygen atoms, sugars potentially have an identical field of application as light naphtha [1]. If successful, these renewable drop-ins could immediately be used in the short term, while retaining the current technology and infrastructure. However, complete removal of all oxygen atoms is not always required. The production of new functionalised chemicals with unique properties can offer new opportunities in the long term. Promising platform molecules are for instance polyols (e.g. sorbitol) and (di)acids (e.g. lactic acid and FDCA) because of their high functionality, low toxicity, efficient synthesis routes from sugars and sustainable applications [2].

In this contribution, the direct hydrodeoxygenation of carbohydrate streams into light naphtha is presented. A one-pot biphasic catalytic system is used, yielding liquid C5-C6 hydrocarbons directly from (ligno)cellulosic feedstocks. The catalytic reaction proceeds at medium temperature and under H₂ pressure in presence of an acidic as well as a redox catalyst. The homogeneous acid is dissolved in the aqueous phase and is responsible for the cleavage of cellulose in glucose building blocks. The heterogeneous redox catalyst is present in the organic phase and enables the selective removal of all oxygen atoms, thus resulting in the formation of alkanes [3].

This contribution uncovers some essential insights concerning the catalysts, the substrate as well as the organic solvent of this Liquid Phase Cellulose-to-Naphtha (LPCtoN) technology [4-5]. Besides, two realistic process flow diagrams, with LPCtoN as central technology, are presented. First, naphtha-derived chemicals (e.g. benzene) and materials (e.g. short olefins) are synthesised in a stand-alone and decentralised biorefinery. The proposed concept is self-sufficient in the production of hydrogen and energy [4]. Second, this LPCtoN strategy is fully integrated into current petrorefinery processes. The key to success for this integration is the use of fossil light naphtha streams as organic phase, resulting in a direct enrichment with bio-naphtha. This bio-enriched stream can immediately be used as substrate in a conventional hydro-isomerisation unit, after which a valuable

(bio-)isomerase with a high octane number is obtained. This stream is extremely valuable for gasoline blends, especially taking into account the EU imposed directives of 10% green carbon in fuels by 2020 [5].

Although nearly all natural sugars are composed of a linear carbon skeleton, many functional chemical products have branched C-chains. Branching in saccharide valorisation can be introduced into the sugar feedstock. Therefore, also a new branching-first principle is presented, synthesising well-known drop-ins (short branched alkanes) in a different way or new functionalised molecules (branched C6 polyols) [6].

FIGURES

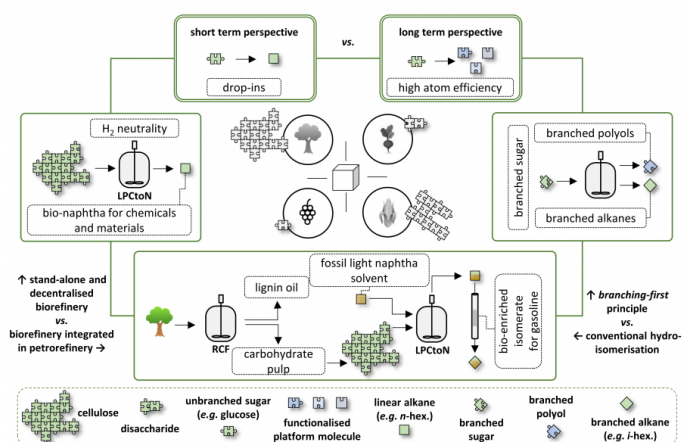


FIGURE 1

Towards molecules with low and high functionality
Harnessing the carbon skeleton of sugars

FIGURE 2

KEYWORDS

sugar valorisation | light naphtha | catalysis | short vs. long term

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