Production of Fuels and Chemicals by upgrading short-chain fermentation products

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Introduction

This abstract describes the production of chemicals i.e. alcohols for surfactant synthesis and fuels such as kerosene and diesel from bio-based short-chain alcohols and ketones. This pathway provides alternatives to the synthesis of these products from oleochemical sources like palm kernel or coconut oil and petrochemicals sources.

Background

The production of bio-based chemicals and fuels needs short-chain alcohols and ketones as educts. Nowadays several short-chain alcohols and ketones can be derived from fermentations with various microorganisms. As it has often been written, many of these fermentations convert sugars from renewable feedstocks but also some of them use carbon dioxide or carbon monoxide in combination with hydrogen (synthesis gas) as feed. The synthesis gas can be produced by gasification of plant materials. Whereas the fermentation of ethanol is already quite technologically advanced, the fermentation of other alcohols and ketones like propanols, butanols and acetone are focused in actual research topics.

Fraunhofer UMSICHT developed a heterogeneous catalytic process in which fermented alcohols can be converted to value-added products such as specialist chemicals or fuels. The reaction takes place at 350 to 400 °C and at a pressure range from atmospheric pressure up to 30 bars. The setup allows high throughputs at high conversion rates. Process runtimes for several weeks and sample production up to 100 L have been tested. The alcohols react with acetone in a condensation reaction with elimination of water and form long chain secondary alcohols and ketones as it is shown in Fig. 1. The ongoing reaction can be identified as the Guerbet reaction or aldol condensation. The reaction is catalyzed by a modified activated carbon which contains no noble metals. Another benefit of this catalyst is the resistance to water. This property allows it to handle fermentation products with higher water content. The lower purity in regard to the water content compared to commercial chemicals simplifies the downstreamprocessing after fermentations.

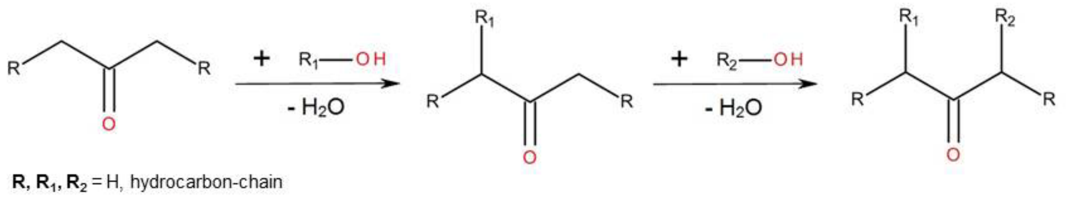

Fig. 1: Main condensation reaction for acetone and primary alcohols.

Results

One example is the condensation of acetone and i-butanol. The main reaction has two steps which are illustrated in Fig. 1. In the first step one i-butanol molecule reacts with one acetone molecule to form an intermediate. In the second step the intermediate reacts with another alcohol molecule. In this reaction the conversion of acetone is larger than 90 %. The analysis shows that a negligible amount of i-butanol form byproducts. Additionally, the selectivity to the product after the second reaction step is much higher than to the intermediate. For these reasons the yield of the condensation product derived from one acetone and two i-butanol molecules is approximately ten times higher than the yield of the intermediate. The branched symmetric C11-molecule appears in the product mixture as alcohol and ketone. The ratio of alcohols to ketones is 1:5. In combination these process conditions lead to a product mixture with only small amounts of byproduct and only one educt remaining. Compared to other separation processes the downstreamprocessing in this case is easy to handle.

The unique symmetric C11-structure opens a wide range of applications. The further processing of the product mixture depends on the desired functional group in the molecule. Hydrogenation and hydrodeoxygenation are possibilities for next downstreamprocessing steps. The hydrogenation product 2,8-Diethyl-5-nonanol can be used as a substitute for fatty alcohols in the detergent production. The hydrodeoxygenation product 2,8-Diethylnonane has the physical and chemical properties which hit nearly the diesel specifications (EN 590). Another benefit is the ability to use also educts from conventional petrochemical sources or mixtures of bio-based and petrochemical educts. One example is the condensation reaction of acetone and 2-ethyl-1-hexanol which also produces branched, symmetric products.

First calculations show profitability for these products because of their value-added application and the simple and cheap production. Also the purification can be carried out with well described thermal separation processes.