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Chapter 13: Alcohol Fuels: The biochemical route

***E. Tomás-Pejó** (IMDEA Energy, Biotechnological Processes Unit, Av. Ramón de la Sagra 3, 28934 Móstoles, Madrid, Spain) elia.tomas@imdea.org
A.D. Moreno (CIEMAT, Biofuels Unit, Av. Complutense 40 28040, Madrid Spain) david.moreno@ciemat.es

13.1 Introduction

The energy system of modern society is mainly based on fossil fuels. The extensive use of these fossil fuels contributes to climate change by emitting greenhouse gases into the atmosphere. Furthermore, as the energy demand increases, the duration of petroleum reserves is very controversial. The International Energy Agency (IEA, 2013) has foreseen that oil, natural gas and coal supplies will be depleted in about 45, 60 and 120 years, respectively unless important actions are taken. All these environmental concerns have stimulated the efforts in producing biofuels, which are interesting alternatives to prevent further CO_2 emissions and are sustainable options to replace current fuels in the transport sector.

In order to make the biofuel production process more economically viable and reduce competition with food-crops, it is essential to use abundant, low-cost raw materials. In this context, lignocellulosic sources, widely available as agricultural and forestry wastes, are considered a very promising choice. Lignocellulosic biomass, in addition to the well-known process of bioethanol production from carbohydrates, can be also employed to obtain other biofuels and a wide spectrum of chemicals.

Principal technologies to convert lignocellulose into biofuels are either thermochemical or biochemical. In biochemical conversion routes, enzymes and microorganisms are responsible for the production process. Although biochemical methods imply higher reaction times, they allow highly selective disruption of biomass and directed conversion into the desired biofuel. Furthermore, biochemical processes are performed at mild conditions and are less energy-intensive than thermochemical processes. Among all different types of biofuels (biogas, bioalcohol and biodiesel), alcohols are very attractive and promising alternatives for the transport sector. Biogas requires high pressure in automobile tanks and its leakage my cause big damages. With regards to biodiesel, the use of non-edible feedstocks for oil production requires large-scale cultivations that may compete with arable lands for food crops. In contrast, alcohol fuels are easily stored and handled when compared to biogas and biodiesel and can share current fuel distribution systems (Imran et al. 2013).

In the last years, big attention has been driven to the production of aliphatic alcohols such as methanol, ethanol, propanol, and butanol (Figure 13.1) with 1, 2, 3 and 4 carbons, respectively. These alcohols can be synthesized biologically and have characteristics that allow them to be used in current engines (Table 13.1). Furthermore, the high octane rating of all four alcohols tends to increase fuel efficiency and counterbalance their low energy density. Among all mentioned alcohol fuels, bioethanol is the most widespread biofuel. It is commonly produced from sugar, starchy or lignocellulosic biomass through fermentation processes. However, during the last years the production of non-ethanol alcohol fuels, as it is the case for butanol, has gained a lot of attention due to their interesting traits such as higher calorific value, higher hydrophobicity and lower flammability and corrosiveness (Baral et al. 2016).

When obtained from biological materials and/or biological processes, these alcohols can be so-called bioalcohols (e.g. bioethanol, biobutanol). Remarkably, there is no chemical difference between biologically-produced and chemically-produced alcohols. Thus, the scientific community is directing intense efforts to develop and optimize biochemical processes for the production of alcohol fuels by means of microorganisms. The important challenge resides in getting a biocatalyst that converts a given biomass into a product with high yields and productivities.

Due to the increased genomic information and the development of new tools and techniques, considerable progress has been made towards developing new microbes for the production of renewable biofuels. However, the complex physiology in non-traditional host-microorganisms has often slowed down the progress of strain development. The re-construction of a strange pathway in host organisms is very challenging since non-native pathways may interfere with the native metabolism. Furthermore, gene expression should be very well balanced in order to avoid bottlenecks in the biosynthesis pathway. Therefore, when constructing new microorganisms for a given chemical production it is of utmost importance to get the inserted pathways compatible with the host strain.

The main purpose of this chapter is to describe different biochemical routes for producing bioalcohols which can be potentially used as biofuels. Principal microorganisms and metabolic pathways involved in the production of such chemicals are described. Furthermore, recent advances in developing new microorganism are pointed out, which show the important progress made on this relevant area in the last years.

13.2 Alcohol fuel production through biochemical processes

13.2.1 Methanol

Methanol or methyl alcohol (CH_4O) is the simplest hydroxyl-containing molecule. At room temperature, this alcohol is a light, volatile, colorless and flammable liquid with a distinctive odor. Its physicochemical properties make methanol suitable to be used not only as antifreeze, solvent or fuel, but also as feedstock for electricity generation in fuel cells or as a versatile chemical building block to produce a whole range of polymer materials (including polyolefins, polyesters, polyurethanes, phenolic resins, and acrylic paints and adhesives) (Park and Lee 2013).