Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Biotechnology

Toward the lowest energy consumption and emission in biofuel production: combination of ideal reactors and robust hosts

Ke Xu[1], Bo Lv[1], Yi-Xin Huo and Chun Li

Rising feedstock costs, low crude oil prices, and other macroeconomic factors have threatened biofuel fermentation industries. Energy-efficient reactors, which provide controllable and stable biological environment, are important for the large-scale production of renewable and sustainable biofuels, and their optimization focus on the reduction of energy consumption and waste gas emission. The bioreactors could either be aerobic or anaerobic, and photobioreactors were developed for the culture of algae or microalgae. Due to the cost of producing large-volume bioreactors, various modeling strategies were developed for bioreactor design. The achievement of ideal biofuel reactor relies on not only the breakthrough of reactor design, but also the creation of super microbial factories with highest productivity and metabolic pathway flux.

Address
Institute for Biotransformation and Synthetic Biosystem, Department of Biological Engineering, Beijing Institute of Technology, Beijing 100081, PR China

Corresponding authors: Huo, Yi-Xin (huoyixin@bit.edu.cn),
Li, Chun (lichun@bit.edu.cn)
[1] These authors contributed equally to this work.

Current Opinion in Biotechnology 2018, **50**:19–24

This review comes from a themed issue on **Energy biotechnology**

Edited by **Akihiko Kondo** and **Hal Alper**

http://dx.doi.org/10.1016/j.copbio.2017.08.011

Introduction

Environmental concerns and an increasing global energy demand that exceeds the finite supply of fossil fuel have spurred scientific research and political action to deliver alternative fuels. Large-scale production of biofuel by native or engineered microbial organisms, is a promising approach to solving energy and environmental problems [1•]. Biofuels covers approximately 10% of the total world energy demand [2], and are listed as 'top priority' in the development of alternative transportation fuel. Microbial fermentation, advanced and efficient conversion technologies now allow the extraction of biofuels from biomass, such as wood, crops and waste material [3,4••].

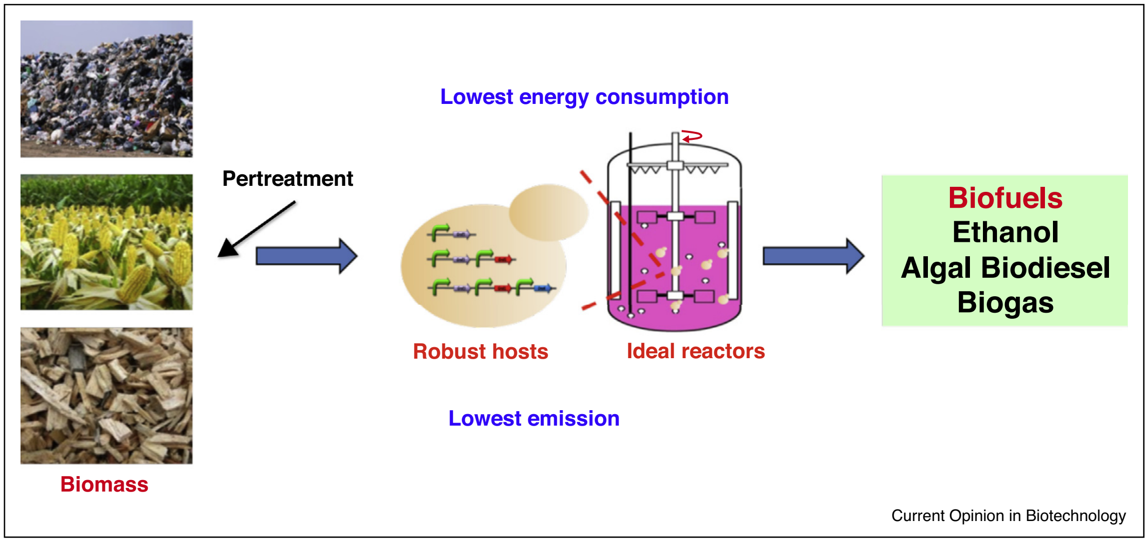
However, current biorefinery schemes are suboptimal and the profit margin is limited by the rising feedstock costs, low crude oil prices, and other macroeconomic factors [5]. One of the most critical issues that limit efficient and economical biomass conversion is the high operating costs of biofuels reactors [6], which is caused by the low degree of integration and automation, high energy consumption and poor stability [7,8•]. Using the production of bioethanol, algal biodiesel and biogas as examples in this review, we summarized the energy-density stages of major biofuel production processes, and analyzed the potential of process optimization. New microbial hosts capable of performing under high temperature, acid or alkaline conditions, high-osmosis environments also provide new challenges and opportunities for the bioreactor designers. The achievement of ideal biofuel reactor relies on not only the breakthrough of reactor design, but also the creation of super microbial factories with highest productivity and metabolic pathway flux (Figure 1).

The energy-efficient bio-alcohol production in anaerobic bioreactor

Supplies of ethanol have increased tremendously in the last decade [9], and is expected to continue rising rapidly in both developed and developing countries. Most ethanol (approximately 70% of global production) is converted from the fermentation of a carbohydrate (starch, sugar or cellulose) derived from sugar crops, including sugarcane, sugar beets or molasses [10]. Although the ideal raw material for the industry is cellulose [11], the high energy and capital cost of its pretreatment limited its utilization as the major resource [12]. In United States, ethanol yields have risen from 8.3 l of ethanol per bushel of corn to more than 10.2 l per bushel, capital costs have decreased from $0.95 per liter to approximately $0.26 per liter [13].

Bio-ethanol production has seven main processes: grain handling; starch conversion; fermentation; distillation; dehydration; separation and drying (Figure 2a) [14]. The thermal and electrical energy consumption of each process in a typical modern 40 MGY (million gallons per year) facility [15] were shown in Table 1. Although the amount of energy consumed by fermentation is less than the ones of several other processes, a lot of energy saving potential exists. The cooling of bioreactors is the major

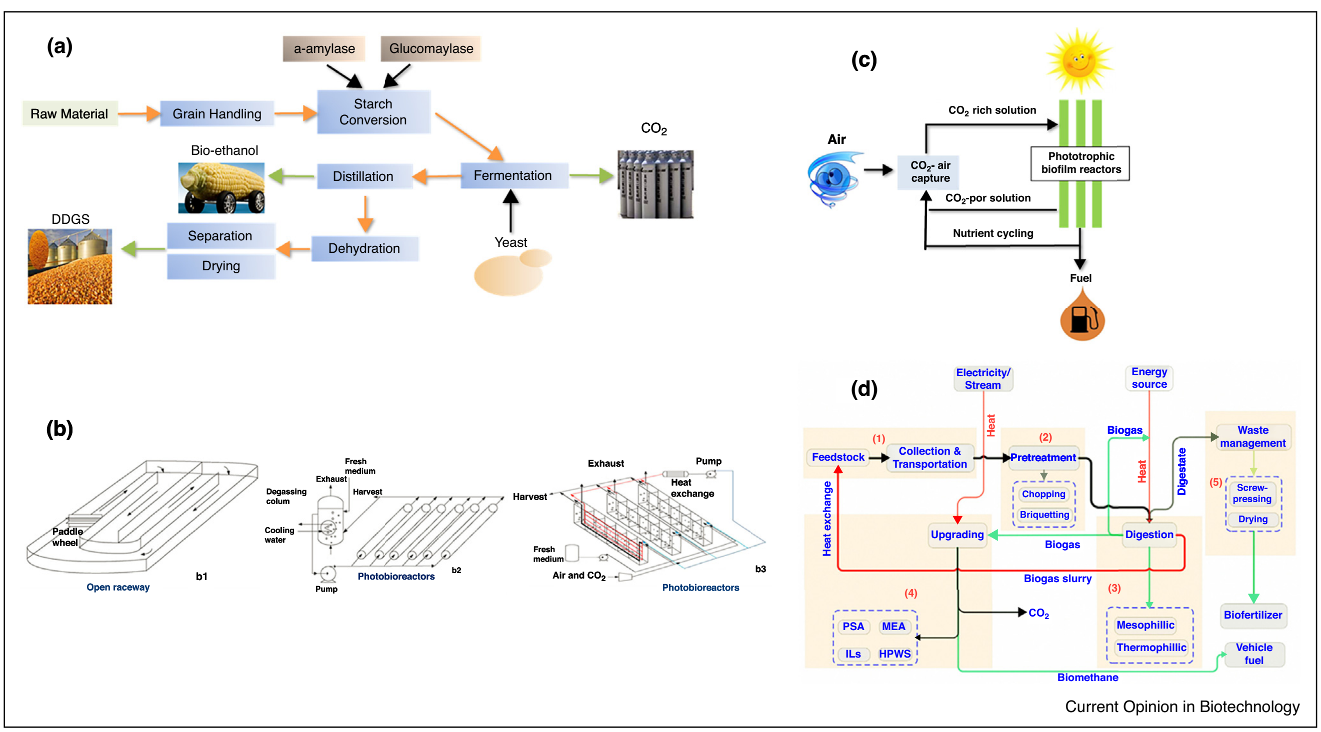
Figure 1



Combination of ideal reactors and robust hosts in biofuel production.

energy consumption step because the metabolism of yeast releases a large amount of heat and the temperature of the liquefied mash could rise rapidly without cooling. The cooling water load is significant for the fermentation process and is approximately 30% of the total water flow [16]. The energy consumption can be effectively reduced by reforming the reactor. Using Variable Frequency Drives (VFD) [16] and optimized control systems can

Figure 2



(a) Production flow chart of the first generation bio-ethanol; **(b)** schematic drawing of the three different cultivation systems for mass production of Algal biodiesel: **(b1)** raceway ponds; **(b2)** tubular horizontal photobioreactors; **(b3)** flat-plate photobioreactors [29]; **(c)** the cultivation of phototrophic microorganisms in highly alkaline conditions with biofilm reactors; **(d)** biomethane production and utilization system.