Biochemical Engineering Journal 116 (2016) 3–16

Contents lists available at ScienceDirect

Biochemical Engineering Journal

journal homepage: www.elsevier.com/locate/bej

Review

Valorization of organic residues for the production of added value chemicals: A contribution to the bio-based economy

Daniel Pleissner[a], Qingsheng Qi[b], Cuijuan Gao[b,c,d], Cristina Perez Rivero[e], Colin Webb[e], Carol Sze Ki Lin[d], Joachim Venus[a,*]

[a] Department of Bioengineering, Leibniz Institute for Agricultural Engineering Potsdam-Bornim, Potsdam, Germany
[b] State Key Laboratory of Microbial Technology, Shandong University, Shanda Nanlu, Jinan 250100, People's Republic of China
[c] School of Life Science, Linyi University, Linyi 276005, People's Republic of China
[d] School of Energy and Environment, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong
[e] Satake Centre for Grain Process Engineering, School of Chemical Engineering and Analytical Science, The University of Manchester, PO Box 88, M60 1QD Manchester, United Kingdom

ARTICLE INFO

Article history:
Received 30 July 2015
Received in revised form
16 December 2015
Accepted 20 December 2015
Available online 24 December 2015

Keywords:
Succinic acid
Lactic acid
Fatty acids
Bio-plasticizer
Agricultural residues
Food residues
Vegetable residues

ABSTRACT

Establishing of a bio-based and green society depends on the availability of inexpensive organic carbon compounds, which can be converted by microbes into various valuable products. Around 3.7×10^9 t of agricultural residues and 1.3×10^9 t of food residues occur annually worldwide. This enormous amount of organic material is basically considered as waste and incinerated, anaerobically digested or composted for the production of heat, power or fertilizers. However, organic residues can be used as nutrient sources in biotechnological processes. For example, organic residues can be hydrolyzed to glucose, amino acids and phosphate by chemical and/or biological methods, which are utilizable as nutrients by many microbes. This approach paves the way toward the establishment of a bio-based economy and an effective organic residues valorization for the formation of bio-based chemicals and materials. In this review, valorization of organic residues in biotechnological processes is presented. The focus is on the production of three industrially important added value chemicals, namely succinic acid, lactic acid and fatty acid-based plasticizer, which have been used for the synthesis of environmentally benign materials and food supplements. Furthermore, utilization strategies of residues coming from fruit and vegetable processing are introduced.

Contents

1. Introduction

Due to the finiteness and environmental impacts of fossil oil, bio-based chemicals have been considered as sustainable alternatives to petroleum-based chemicals in chemical reactions. It is particularly the diversity of biochemical pathways of microbes that allows the biotechnological production of a wide range of industri-

* Corresponding author. Fax: +49 331 5699 849.
E-mail address: jvenus@atb-potsdam.de (J. Venus).

http://dx.doi.org/10.1016/j.bej.2015.12.016
1369-703X/

ally relevant bio-based chemicals [1]. The cost-efficient realization of biotechnological processes depends on the presence of inexpensive nutrients, to be used as carbon, nitrogen and phosphate sources for microbes [2]. Pure nutrients (e.g., glucose, amino acids and phosphate), however, are expensive and make most of the developed biotechnological processes economically unfeasible.

It was estimated that 3.7×10^9 t of agricultural residues is produced annually as by-products by agricultural industries worldwide [3]. Agricultural residues consist of around 40% cellulose, 30% hemicellulose, 20% lignin, 5% proteins and 5% minerals [4]. In total, it was estimated that 1376×10^6 t cellulose and 848×10^6 t hemicellulose occur globally every year [3]. Due to the recalcitrant structure of agricultural residues, tough processes, such as hydrothermal treatment or chemical hydrolysis in combination with the use of enzymes are needed for depolymerization and sugar recovery. The released C5- and C6-sugars can then be used as carbon sources in biotechnological processes [5–9]. Furthermore, it was estimated that one third of the food produced globally for human consumption is wasted every year. The overall amount of food wasted corresponds to around 1.3×10^9 t [10,11]. A composition of 30–60% starch, 5–10% proteins and 10–40% (w/w) lipids constitutes food residues a promising feedstock in biotechnological processes [12–14]. Recovery of nutrients from food residues in the form of carbon, nitrogen and phosphorous compounds can be performed by chemical and biological/enzymatic methods after solubilization of the waste matter [15–19]. Even though the technologies for organic residues valorization are known, the potential of organic residues as nutrient sources in biotechnological process for the establishment of a bio-based economy has not been fully exploited.

The concept of circular economy considers the reuse and recycling of any types of waste. In this aspect, the utilization of organic residues in biotechnological process for the production of value added chemicals would enable an application of the circular economy concept on organic waste management and contribute to the development of a bio-based economy. Within the circular economy, the cascading use of biomass is particularly important, as it considers the production of food and feed prior to material and energetic usage [20].

The current options for the valorization of waste organic residues are shown in Table 1. The options range from the production of antioxidants, flavonoids, enzymes and proteins, fatty acid methyl esters, glycerol and erucic acid from fruits and vegetables, animal waste, meat and derivatives, waste oil and dairy products [21–23]. Lignocellulosic biomass has also been used for the production of various compounds, such as phytosterols, polypropylene, acrylic acid and esters [23]. Furthermore, lignin has been used as substrate for the production of polyhydroxyalkonates and adipic acid [24,25]. It should be indicated here that the metabolic versatility of microbes enables the fermentative production of a wide range of products. Fig. 1 shows relevant industrial metabolites obtainable via fermentative processes [1]. The products range from amino acids, such as aspartate and lysine, carboxylic and dicarboxylic acids, such as lactic acid and succinic acid, and polyhydroxyalkanoates. Furthermore, microorganisms are able to synthesize long carbon chains in form of fatty acids. It should be admitted that the metabolic versatility of microbes opens not only the door to the development of biotechnological processes for the production of value-added chemicals, but also to innovative treatment strategies of organic residues.

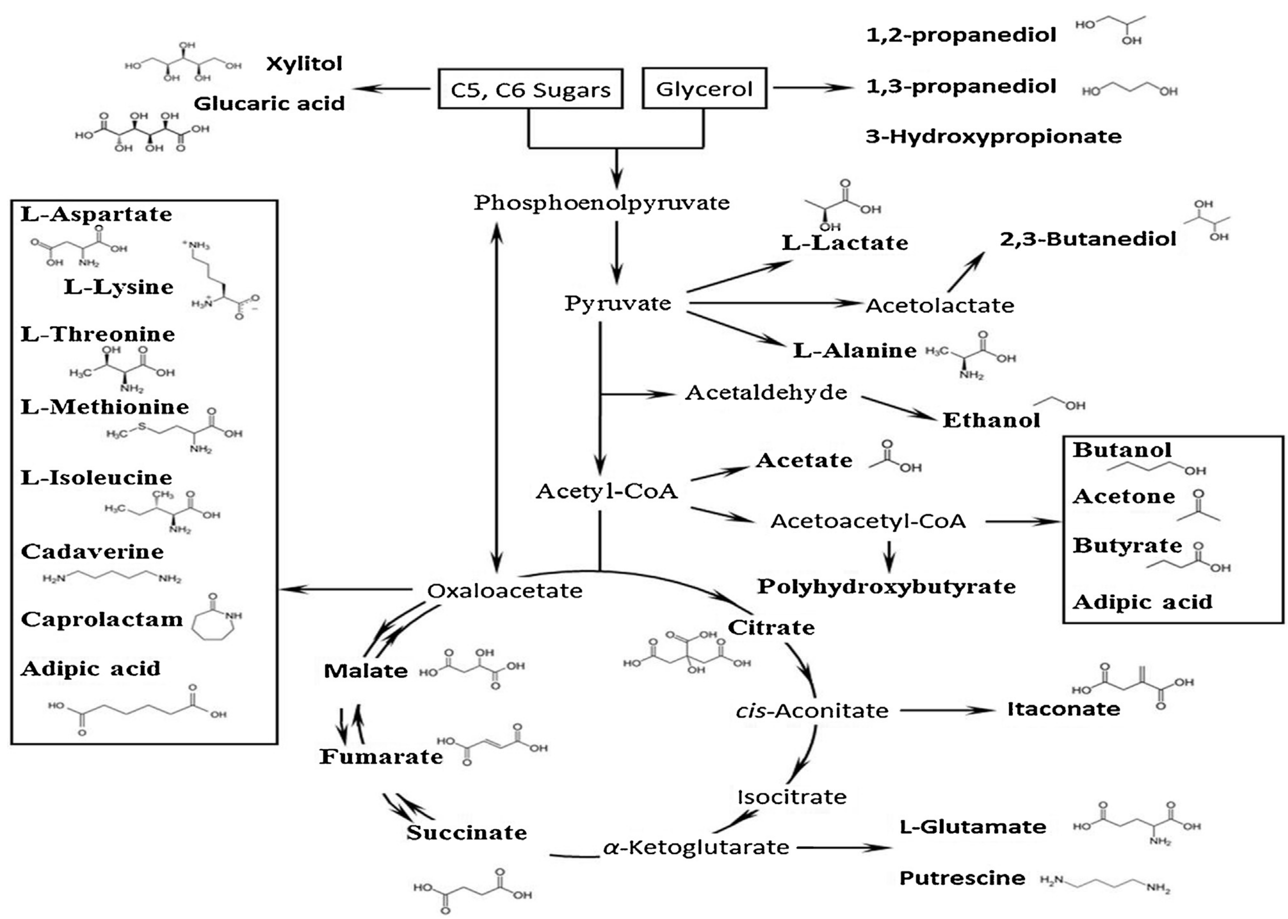

Fig. 1. Industrially relevant metabolites obtainable via fermentative processes [1].