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Current states and prospects of organic waste utilization for biorefineries

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ABSTRACT

Energy demand is continuously increasing, due to rapid growth accompanying the development of population and industrialization. Because of the fossil sources are not keeping pace with the spiraling consumption, the over exploitation of nature resource results more environmental deterioration, which is not only in developing countries, but in some of the developed countries. Biomass, with its economic and environmentally-friendly properties, has been widely employed in biorefineries to recuperate from the scarcity of fossil fuels. Moreover, with the development of technology, recent research has upgraded the acceleration of biomass utilization. To date, the fourth generation of biomass, organic waste, has been widely applied, and multiple target products of biomass conversion are available. The present review article aims to highlight the various biochemical processes for the conversion of organic wastes into valuable products.

Contents

1. Introduction

The traditional definition of biomass refers to all organic materials that stem from plants. With the development of biomass utilization, waste biomass as a kind of organic substrates has become the top choice of bioconversion process. Agricultural residues, industrial residues, and even urban residues provide plenty of organic waste

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with useful composition, which can easily be converted to valuable products [1–3]. Compared with the traditional treatments of these organic wastes, which involves just being deposited and degraded by nature, bioconversion has been used to produce bio-products, with obvious significance. It is not only helping to solve environmental pollution, but has also increased the value of the organic wastes, evidently. With the rapid growth and development of population and industrialization, organic wastes have taken up a large portion of all waste quantity (Fig. 1). Nowadays, organic wastes account for around 46% of the global solid wastes, making up the largest proportion, which is one of reasons to develop direct utilization of these solid wastes. The large quantity of organic wastes also indicates the positive prospects of its utilization in the future. Biorefineries as environment-friendly technologies are one of top choices for the application of organic wastes in biomass utilization history.

Based on views of products, earlier studies of biomass conversion focused only on bioenergy, because of the scarcity of fossil energy. Bioethanol and biodiesel are typical bioenergy targets, which have been highly researched [4–6]. As a fuel suitable for direct use in spark ignition gas engines, some of these conversions have already been successfully applied in industry to solve problems from the lack of gasoline. Based on the major source from human beings, biomass is presently estimated to contribute to about 10–14% of the world's energy supply [1]. With the development of technology, it is reasonable to believe that organic wastes will play an important role in the future of bioenergy conversion. The production of bioethanol and biodiesel are still the top two on the list of target bio-products generation. Fig. 2 shows the worldwide biofuel production in the last decade.

Fig. 2 indicates that the quantity of biofuel production rapidly increased from 2005 to 2010, specially showing the highest growth in North America and Asia & Oceania. The trend of world renewable energy and its consumption is almost the same from 2002 to 2012, which is reasonable to estimate that the biofuel production from bioconversion has been directly used in society. This highly effective utilization makes large demands of substrate in bioenergy refinery, thus organic wastes has been paid high attention in these conversion processes. The top ten biofuel producers during that period have been shown in Table 1, in which the productivity has increased in all countries. While the United States had less production than Brazil before 2005, based on advanced biotechnologies, it became the champion of biofuel production in the next 6 years. The second biggest biofuel producer, Brazil, is famous for the industrialization of biofuel based on wildly planted corps, which could be understood as large quantity of biomass is the foundation of biorefinery. Although the large productivity of corps could be one of the supporters in

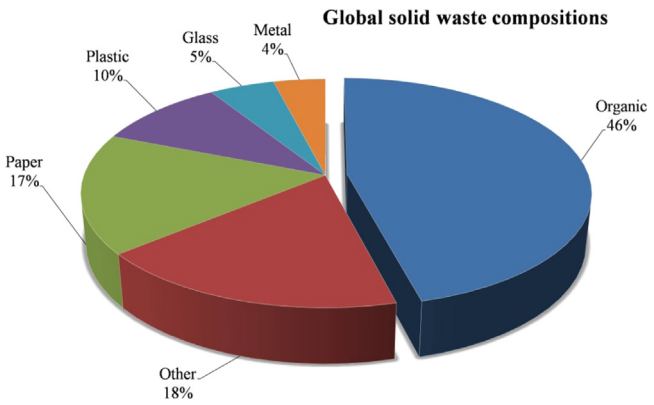

Fig. 1. Global solid waste compositions.
Source: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=79&pid=80&aid=1&cid=regions,&syid=2005&eyid=2011&unit=TBPD

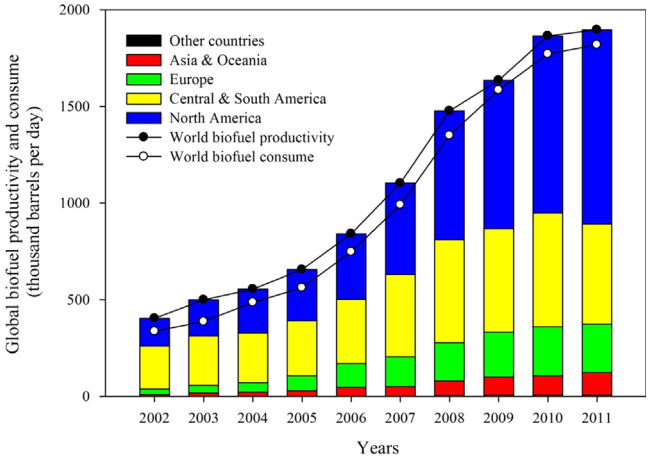

Fig. 2. Global renewable biofuel production.
Source: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=79&pid=80&aid=1&cid=regions,&syid=2005&eyid=2011&unit=TBPD

biorefinery, the development of organic wastes utilization is the sustainable prospective strategy.

With the development of genetic engineering, several target bio-products can be achieved in a number of bioconversions based on various kinds of organic wastes. The early stages of organic wastes conversion to the biochemical were based on microbial fermentation or metabolism. Ethanol fermentation by microorganism from sugar is a typical utilization model for organic wastes [1]. Engineered microorganism research was stared in the early 20th century; however, it was employed in waste conversion around 30 years ago. The breakthrough of genetic technologies in the late period of the last century was an important contributor to the increase in waste biomass conversion. The most tangible result could be concluded as bioenergy was not the only target of biomass conversion, and various chemicals or even enzymes have been successfully obtained as metabolic substances. Recently, many researchers have focused on the improvement of organic waste conversion to non-energy bio-products. These kinds of productions from waste biomass can be achieved by a number of technologies, each with individual characteristics, advantages and disadvantages. Not only the traditional ethanol fermentation process or recent enzyme production from fungal solid state fermentation, but also most conversions of organic waste to value added bio-products cannot avoid a microbial fermentation process. This kind of industrial application of fermentation can also be ranged as a typical “White biotechnology” which is based on microbial fermentation by organic wastes. Because it is closely related with the daily life of human beings, fermentation biotechnology has been rapidly developed in the past few decades. Both biomass development and genetic engineering skills have been improved, which allows to choose and design the target product, and to increase the product yield of conversion processes. For some specific white biotechnology cases, the efficiency of process depends on the characteristics of the organic waste biomass, the target product, and the microorganism used in conversion [7].

The whole conversion process can be separated into three parts. Firstly, selection of the organic waste biomass and microbial genetic engineering step are carried out. Exact analysis of the composition of the organic waste helps researchers to improve the efficacy of bioconversion by proper pretreatments. Metabolic engineering helps researchers to understand the metabolic pathways of the microorganism, which gives the possibility to increase productivity of the target by genetic engineering. Secondly, mid-stream control can improve the productivity. The optimization of fermentation is a typical process to increase the product concentration based on conversion from organic waste biomass. Design of