

Editorial

Integrated Production and Treatment Biotech-Process for Sustainable Management of Food Processing Waste Streams

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Food processing industry generates approximately 45% of the total organic pollution as wastewater and solid wastes. These organic pollutants pose increasing disposal and environmental challenges. The treatment and disposal of the organic wastes require many successive and costly treatment processes. These organic pollutants contribute high organic loading in organic carbon and nutrient sources. The processing effluents and solid wastes from food industries mainly contain carbohydrate organics such as sugars, starch and cellulose. They are biodegradable materials and naturally rich in nutrients, making them ideal substrates for microbial production [1,2]. Most of the existing treatment systems for the food processing wastes worldwide, however, are of old-fashioned processes and cause large losses of valuable nutrient and carbon resources. Considering increasing global concerns due to greenhouse gas emission and resource crisis, there is a general agreement that environmental protection can only be achieved by integrating a general environmental awareness into a company's business functions, making the carbohydrate wastes as renewable resources.

In recent decades, conversion of waste materials into bulk chemicals and clean energy has become an attractive topic for applied research and technology development around the world. Bioconversion of carbohydrate wastes to valuable products is receiving increased attention in view of the fact that these wastes represent possible and utilizable resources for producing market products [3]. Growing research and technology development activities have been offered towards sustainable utilization and value-addition of carbohydrate wastes, such as sugar cane bagasse and waste starch as useful carbon and nutrient sources. A number of biotechnological processes have been developed that utilise these waste materials for the production of bulk chemicals and fine products such as ethanol, single cell protein, mushroom, enzymes, organic acids, amino acids, biological active secondary metabolites [1–4], as summarised in Figure 1. This paves a promising way for recycling of resources to become an integral activity in industry to ensure economical and ecological sustainability.

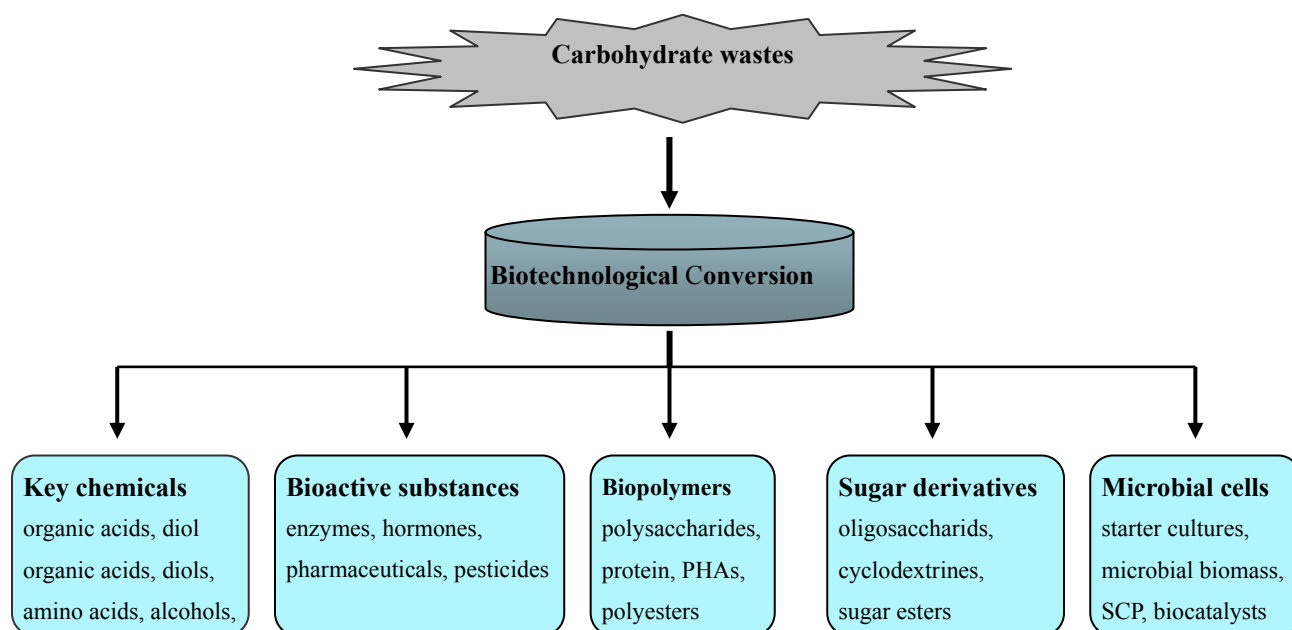


Figure 1. Target products from bioconversion of carbohydrate wastes to value-added products.

Biotechnological production from carbohydrate-wastes associated with their treatment requires an integrated engineering process strategy with concerns of utilization and treatment of the waste streams. Recent studies have given substantial R&D efforts to the development of an environmentally and economically sustainable integrated biotechnological process, so called “production treatment biotech-process” (PTB). The alternative PTB technology is to use the waste streams as bioconversion media to produce bulk products, while treating the carbohydrate waste streams [1,2,4]. The PTB engineering strategy is able to deliver an innovative “green cycle” technology, from which the value-added products, including those commonly used materials in food processing industries (organic acids and enzymes), can be produced from processing wastes, and can be served as feedstock for the industry, while reducing organic loadings. These advanced integrated technologies will give a significant contribution to update the traditional technologies of wastewater treatment and biological nutrient removal processes. Recent researches focused on developing and using technological tools of genetic and metabolic engineering and bioprocessing techniques in order to increase the production yield and the cost-efficacy of waste treatment [1,4,6]. There have been great advances in fundamental research into biochemical and chemical processing, biotechnological techniques and the genetic construction of high-performance industrial microorganisms with functional biochemical reaction capabilities in an industrial process [2,3,7].

The major limitations for the development towards application of the integrated PTB technologies with respect to economic and technique issues are (1) high costs for physical (steam expulsion) and chemical (alkali/acid hydrolysis, oxidation) processes employed for pretreatment of the raw materials, (2) long fermentation retention time, and (3) low efficiency for waste treatment [1,3]. The conventional industrial process for biological production from carbohydrate materials requires pretreatment by gelatinisation and liquefaction, which is carried out at high temperature of 90–130 °C for 15 min followed by enzymatic saccharisation to glucose and subsequent conversion of glucose to organic acids by fermentation [8,9]. However, this two steps

process involving consecutive enzymatic hydrolysis and microbial fermentation makes it economically unattractive. Alternatively, fermentation can be conducted simultaneously with the presence of enzymes known as ‘Simultaneous Saccharification and Fermentation’ (SSF) [4,7,10]. The SSF technology eliminates the need for complete hydrolysis step prior to the fermentation step. It is expected that the hydrolysis of polysaccharide and fermentation of glucose into bio-chemicals can be carried out simultaneously in the SSF process [10]. In the SSF process biochemical reactions in term of enzymatic hydrolysis, cell growth and metabolic production may occur simultaneously and or stepwise. The emerging tools of genetic engineering, however, have also stimulated the construction of microbial production strains for the direct synthesis of new metabolites within a SSF process model [9,10].

The enzymes as biocatalysts play key roles in the integrated biotech-process through substrate hydrolysis and metabolic formation. However, applications of these enzymes in an industrial process are limited by their instability and non-reusability. Enzyme immobilization represents the most promising approach to improving stability, loading, activity, and speciality of the enzymes. Nano-biocatalysis, in which enzymes are incorporated into nano-structured materials, has emerged as a rapidly growing area. Recent development in nanotechnology has provided a wealth of diverse nano-scale folds that could potentially support enzyme immobilisation. Nano-structures exhibit high specific surface areas and provide efficient manipulators, creating nano-scale microenvironment benefiting the immobilization of multienzymes and their interfacial reactions. They promise exciting advantages for improving enzyme stability and capability, and biochemical performances. The high specific surface area of the nano-immobilisers has been a principal driving force for studying and developing biocatalysts. Furthermore, enzyme immobilization using nano-structure carries allows for a significant increase in life cycles of the biocatalyst for its reuse, hence reducing the cost of the biocatalytic process [11]. The nanoscale-material provides a versatile new technology for enzyme immobilization with several inherent advantages, including low cost, rapid immobilization and reaction, similarity of nanosize, mild conversion condition, robust activities, mobility, high loading, minimum diffusional limitation, self-assembly and stability. The mobility, confining effects, solution behaviours and interfacial properties of nanoscale materials can introduce unique properties into nano-biocatalyst systems, making it possible to develop a revolutionary class of biocatalysts that differs from conventional immobilized enzymes in terms of preparation, catalytic efficiency and application potential [12].

Integrated production and treatment technology is an innovative and sustainable R&D practice. Incorporation and development of recent advances in metabolic production process and biological wastewater treatment technology will lead to improved genetic and biochemical engineering, and a deep practical insight of the integrated production treatment process. The development of integrated PTB technology will provide R&D opportunity to apply and develop processing technologies with integration of metabolic production, waste treatment and genetic engineering. The “green cycle” bioprocess will improve the old-fashioned waste treatment and recovery technologies, and take an important role for the cleaner production strategy in industries.

The integrated PTB engineering strategy is of today's important challenges for the sustainable production of renewable resources from waste organic materials. The advanced biotechnology and nanotechnology have significantly promoted the development of the biocatalysts and bioconversion technologies for the production of bioenergy and biomaterials from renewable sources, especially from industrial and agricultural organic waste streams.

AIMS Bioengineering has recently offered a special issue “Bioconversion for Renewable Energy and Biomaterials”. The Editorial Board has invited front-line researchers and authors to submit original research and comprehensive review articles for publication in the AIMS Bioengineering. Potential topics for this special issue include, but not limited to (1) Renewable energy, (2) Biomaterials, (3) Biocatalysts for bioconversion system, (4) Design and optimization of bioconversion process, (5) Compute and or mathematic modelling of bioreactor system, and (6) Life cycle assessment of bioconversion process.

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