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Lignocellulosic bioethanol: A review and design conceptualization study of production from cassava peels

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ABSTRACT

The importance of lignocellulosic biomass as important bioresources that can be utilized in many forms has increased in the last few decades. Cassava peels, a lignocellulosic biomass discarded during cassava processing, are commonly found in the tropics and several other countries around the world due to the popularity of cassava as an important calorie source. Interestingly however, a lot of energy deprived, oil dependent countries are also amongst the highest producer of this biomass. Hence, this review explores the suitability of cassava peels as a lignocellulosic biomass substrate for the production of bioethanol. Special consideration to the properties of the biomass drive the conceptualized plant design while conditions for optimal production and salient economic considerations are discussed. A cellulosic biorefinery of this type is expected to help in harnessing the presently improperly managed agricultural processing byproduct with a view to reducing dependence on fossil fuels, which are totally non-renewable and have damaging effects on the environment especially in developing countries.

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1. Introduction

The use of cheaply available fossil feedstock for cooking and heating, as well as in the production of many beneficial products was a turning point discovery for mankind. However, the realization that the supply of the fossil feedstock is limited, and the fact that the products are not environmentally, ecologically or economically sustainable, has led to a quest for renewable sources of energy globally in recent years [1]. The discovery of biofuels has helped a great deal in alleviating some of the problems identified with fossil fuels such as global warming as well as provide income and employment opportunities in rural areas.

First generation biofuels were produced from food crops and were usually blended with fossil-fuel-based fuels for use in existing internal combustion engines. However, the developments of new technologies adapted to biofuels are ongoing in several parts of the world. This generation of biofuel has been commercialized

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in several economies with an average of 859,000 barrels produced daily as of 2012 [2]. However, there are concerns amongst environmentalists, food technologists and other scientists regarding first generation biofuels [1]. The limitations identified for first generation biofuels include their competition for land and water that could have been used for food, their need for government subsidies without which competition with petroleum products would be impossible and the fact the net greenhouse gas emissions associated with their production approaches that of fossil fuels [3].

The reasons highlighted above have led to the use of waste biomass for fuel production, where residues of crop cultivation (stem, peels, leaves), crops which are generally not used for food as well as industrial wastes are employed in the production of biofuels. The fuels thus produced are termed second-generation biofuels and are produced by the release of the sugar locked in the lignin, hemicellulose and cellulose matrix of the feedstock. This sugar is then processed into bioethanol using the same methods used for first generation biofuel production. Examples of second-generation biofuels are cellulosic ethanol and Fischer–Tropsch fuels [4].

1.1. Current status

Generally speaking, bioethanol is a liquid biofuel, which can be produced from several feedstock and through several conversion methods. It is an attractive energy source because of its renewability, as well as its ability to reduce particulate emissions in compression-ignition engines [5]. The high octane number, broader flammability limits, higher flame speed and vaporization heats are particular characteristics of this liquid which enables it to compete with fossil fuels on an efficiency level [6]. However, bioethanol's disadvantages include its high corrosiveness, low flame luminosity and vapor pressure and miscibility with water. The total production of ethanol fuel surged to 84.6×10^9 L in 2011 with the United States accounting for 62.2% of the global production and followed by Brazil with 21.1×10^9 L [7]. Both countries exploit corn and sugar cane respectively for their bioethanol production. The top 10 nations producing bioethanol use them as a blend and as such cannot be referred to as totally oil independent, however the gains from bioethanol usage span the economic, environmental and energy nexus [8,9]. A typical case study can be seen in Brazil [10] where the production of bioethanol is with an energy balance of at least 9:3, there was no significant change in land use, a GDP increase by as much as 35% and a greenhouses gases reduction by as much as 86% [10] were recorded. In general, the reduction in importation dependency, increase in local jobs, agricultural developments have positive implications for the economic development of bioethanol producers. The environmental gains will also include proper sanitation and the reduction of wastes contamination (where agro-residues are used) while the security stemming from the renewability, reliability of this energy source are one of the many reasons for encouraging research into the production, commercialization and adoption of bioethanol production.

Second-generation bioethanol is produced from the treatment of lignocellulose biomass, which is comprised of lignin, cellulose and hemicellulose [3]. These polysaccharides are hydrolyzed into sugars — mostly pentose and hexoses — which are then fermented by the enzymes of specific organisms into ethanol. It can thus be inferred that the difference between the first-generation and second-generation biofuels is the hydrolysis of lignocellulosic plant material into sugars. Fig. 1 shows the different pathways for the production of the first-generation and second generation biofuels [11]. It is pertinent to note that not only is the cost profile for obtaining the feedstock for the second generation bioethanol less than that of the first generation bioethanol, it also does not require agricultural intensification as it is mainly supported through by-products. It has often been said that second generation biofuels are produced from biomass in a more sustainable fashion, which is truly carbon neutral or even carbon negative in terms of its impact on atmospheric carbon dioxide concentrations [12].

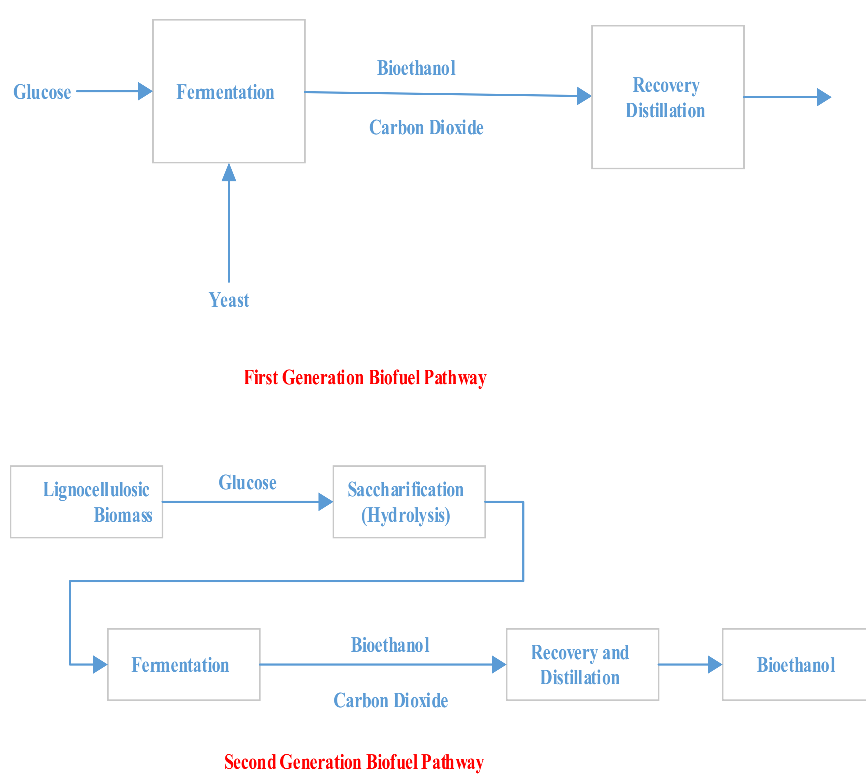

Fig. 1. First and second bioethanol processing steps.