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Status of availability of lignocellulosic feed stocks in India: Biotechnological strategies involved in the production of Bioethanol

Gentela Jahnavi, Govumoni Sai Prashanthi, Koti Sravanthi, Linga Venkateswar Rao*

Department of Microbiology, Osmania University, Hyderabad, Telangana State 500 007, India

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ABSTRACT

Bioethanol, as a biofuel has got an exceptionally noticeable role in the world. It is a solution to the overwhelming reliance on petroleum based products, in terms of energy security, impact on environment and climatic change caused by vehicular pollution. There are many setbacks associated with the usage of petrol based resources. India, being agriculturally enriched, produces bountiful amounts of residues after harvest of the crop. Taking this into consideration, the review manly explains about the availability of agroresidues in India and emphasizing the requirement for pretreatment and saccharification methods like acidic and enzymatic techniques. The mode of action of these treatment methods on lignocellulosic wastes were also discussed. We also focused on the role of microorganisms in fermentation and the need for genetic engineering approach, with a detailed discussion on CBP and SSF of lignocellulosic material to ethanol. Finally, this article concludes with a brief investigation on biofuels from algae, an emerging technology for third generation biofuels.

1. Introduction

Bioethanol is the cutting-edge technology to petroleum since it is produced from renewable and sustainable biomass, generates less emissions than fossil fuels, produces no net CO_2 and is compatible with current fuel distribution infrastructure. India is a nation with an impetus in uplifting view point towards renewable energy innovations and focusing on the utilization of renewable sources to supplement its energy necessities. For the last 20 years, Governments all over the world are involved and have been participating actively in identifying, developing and commercializing the technology to produce a substitute to transportation fuels [1], since vehicular pollution is evaluated to have amplified eight times over the last two decades. Most of the air pollution is contributed specially by automobiles. So, it is indeed a very emergent need for the countries to substitute fossil fuels with the bio based fuels using feed stocks. India along with other nations is very keen to develop bio fuel technology because of the ascent in oil costs and fuel emissions have become a great threat to the nations while the country also has an aspiration to diminish the green house gas emissions. In April 2003, the planning commission released a report on bio fuels, where India further strengthened its bioethanol program [2], the report analyzed various blending targets, price and feedstock availability scenarios and issued the recommendations to expand the industry to meet 5–10% blends of bio ethanol. Later the 11th five-year plan (2007–2012) suggested to increase the mandatory bioethanol blending to 10% once E5 blends were put in place across the country [3] The E10 blending target remains in effect and will be scaled up to E20 by 2017, as proposed by the country's recently enacted National Policy on Biofuels. India's energy security would remain vulnerable until alternative fuels produced from renewable feedstock are developed to substitute petro-based fuels [4]. India is one among other nations with a separate ministry which is involved in the development of renewable energy resources [5]. The Ministry of Petroleum & Natural Gas (MoPNG), Government of India mandated 5% ethanol blend in gasoline by the oil marketing companies (OMCs). The 5% blending was initiated after consulting with the key stakeholders at the state and central government levels, including the society for Indian automobile and major sugar manufacturers [6]. This was put up in nine Indian states and four union territories with effect from January 2003, through its ambitious 'Ethanol Blending Program' (EBP). A Committee was constituted in July 2002 by the planning commission and the final report was released in July 2003. The report encouraged India to develop and gradually move towards the use of biofuels [7]. In a nation-wide survey conducted by IMRB employed by NIIST, sponsored

Abbreviations: GHG, Green house gases; IMRB, Indian Market Research Bureau; NIIST, National Institute of Inter Disciplinary Science and Technology; TIFAC, Technology Information, Forecasting and Assessment Council; IIT, Indian Institute of Technology; TERI, Tata Energy Research Institute; ICRISAT, International Crops Research Institute for the Semi-Arid Tropics

* Corresponding author.
E-mail address: vrlinga@gmail.com (L.V. Rao).

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by TIFAC, Government of India has reported the availability of biomass residues which account for about 80% generated mostly by crops [8]. India has long been into lignocellulosic to ethanol research with the innovative efforts of Biochemical Engineering Research Centre, IIT, Delhi. In 1980, they instituted a demonstration for production of 50 L bioethanol/day. Rice straw was used as feed stock for this process with an ethanol yield of 230 L/ton. [9]. In a study conducted by Arvind Lali (DBT-ICT Centre for Energy Biosciences, Institute of Chemical Technology, India) the current situation in India is that the land per capita is less than Canada, USA, Brazil and Australia and to resolve few intricacies involved in the production, marginal lands must be used to develop suitable crop varieties. The agroresidues can be used completely and judiciously. In response to the Government's initiatives on Make in India and Swachh Bharat Abhiyan, the Department of Biotechnology, Ministry of Science and Technology supported DBT-ICT Centre for energy biosciences at ICT Mumbai, and has successfully demonstrated for the first time the production of ethanol from lignocellulosic biomass. India's first 2G or Cellulosic Ethanol (alcohol) demonstration plant with a capacity of 10 t/day was set up on 22nd of April 2016 at India Glycols Ltd., Kashipur, Uttarakhand. Using this technology and plant, any biomass feedstock like wheat straw, rice straw, bagasse, cotton stalk, bamboo, etc. will be converted to alcohol in less than 24 h, and if effectively operated and scaled-up will make India a global technology provider in the field of renewable resources and results in the reduction of carbon-emissions other than affecting significant savings in import of unrefined petroleum. The DBT-ICT Centre has developed designs of plants which can convert 250 t/day and 500 t/day of biomass. The Department of Biotechnology is confident that this technology with the lowest capital and operating costs would allow 2G-Alcohol to be produced and sold at competitive price. http://www.dbtindia.nic.in/india%E2%80%99 s-first-cellulosic-alcohol-technology-demonstration-plant-inaugurated/.

In our earlier review by Chandel et al. [10] have tried to explain the availability of agrowastes in Andhra Pradesh since it is agriculturally enriched state. The current review focuses on the availability of the agricultural residues in India, the strategies involved in the bioconversion of these wastes to bioethanol and engineering the genetic makeup in yeasts and a note on fermentation methodologies like consolidated bioprocessing and simultaneous saccharification and fermentation.

1.1. Molasses to ethanol in India

The question posed to us is that why country needs to make use of lignocellulosic feed stocks. In India bioethanol is primarily produced from molasses, a by-product of sugar production. Total quantity of molasses produced in India enables about 11.6% bio ethanol blending. Molasses alone is not adequate for achieving the target of 20% blending in 2017 [11]. To meet this target there is a need for the use of other lignocellulosic based feed stocks. In 2003-04, India faced drought that finally lowered the production of sugar cane crop which consequently lead to the decrease in using molasses to 6.75 Mt (usually 10 Mt) and therefore the manufacturing of ethanol declined to 1518 million liters [12], this eventually resulted in the shoot up in the price of molasses. These circumstances made India to import ethanol and molasses in 2003-04. According to Kaushik Ranjan Bandyopadhyay [7], there was revitalization in cane production in 2005–07 and this has driven the government to resuscitate the 5% blending in November 2006. In October 2008, the government moved towards the target of 10% blending which did not emerge out to be successful. In the study conducted by Joseph B Gonsalves [13], on the assessment of biofuel industry in India, it was stated that one ton of sugarcane yields about 100 kg sugar and 40 kg molasses from which 10 L of ethanol could be recovered and the use of sugarcane juice results in the yield of 70 L of ethanol from 1ton of sugar cane. Because of the increasing population, there will be higher dependence on sugar and for which million hectares of land is required for cultivation of sugarcane crops for higher yields. It becomes even more difficult to increase the area because of other competing crops. Thus, there will be a burden on sugar industry to meet this demand.

Table 1
World fuel ethanol production (2014).
Source: RFA analysis of public and private estimates, http://ethanolrfa.org/pages/World-Fuel-Ethanol-Production#sthash.gzTnTMl1.dpuf

Country	Ethanol (Millions of Gallons)
United States	14,300
Brazil	6190
Europe	1445
China	635
Canada	510
Thailand	310
Argentina	160
India	155
Rest of the world	865

1.2. Production of ethanol: International scenario

Brazil, China and the US are the leading bioethanol producers in the world. The production of ethanol in the US was 39×10^9 L using corn as the major substrate and Brazil produced 30×10^9 L of ethanol using sugarcane [14]. As per the report given by GAIN [15], Brazil is the largest producer of sugarcane and ethanol. Nearly 590 million tons of sugarcane was harvested in 2015, and a large part of this harvest produced 2.34 billion liters of ethanol approximately. By 2016, an increase in 5% ethanol production is predicted compared with that in 2015, with the exportation of >1.3 billion liters. The Government of Canada has consented to diminish the GHG's by 6% between 2008 and 2012 in its Kyoto convention [16]. The production of ethanol in countries in 2014 is given in Table 1.

1.3. Fossil fuels: a serious threat to the environment

The use of fossil fuels continuously to meet most the world's energy demand is threatened by increasing the amount of carbon dioxide (CO_2) and carbon monoxide (CO) in the atmosphere released by burning of fossil fuels. As a concern for global warming, a search for renewable energy sources that reduce CO_2 emissions becomes a matter of widespread attention. Global warming causes harmful and devastating effects on earth. Over the last 150 years, there is more than 25% increment in the amount of CO_2 released due to burning of fossil fuels (http://opinion.bdnews24.com/2016/10/09/why-fossil-fuel-companies-shouldnt-be-allowed-in-cop-22/). There is an emergent need to replace the fossil fuels with lignocellulosic biofuels. These major pollutants like CO, CO_2, sulfur oxide (SO), nitrogen oxide (NO), hydrocarbon compounds, lead (Pb) and suspended particulate matter (SPM) emitted from vehicles cause harmful effects on health and environment. The organic lead emitted from cars, gets easily absorbed and results in serious health hazards. For this reason, use of leaded petrol in the developed countries has been banned [17]. In metropolitan cities 95% of all CO emissions are from automobiles. It is very much lethal to humans if the concentration of CO exceeds approximately 750 ppm. (http://www.pollutionissues.com/A-Bo/Air-Pollution.html#ixzz3eXIBaAsL). In one of his talks, former Indian president Dr. A.P.J. Abdul Kalam has suggested to substitute the use of fossil fuels with biodiesel and bioethanol, where India ought to reduce the dependency on fossil fuel usage and imports and must adopt alternative methods such as mandatory ethanol usage in the future http://www.psgtech.edu/ Abdulkalamvisit.php.

2. Availability of agro residues in India: an overview

India, being agriculturally enriched, has copious amounts of agro