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Biorenewable chemicals: Feedstocks, technologies and the conflict with food production

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ABSTRACT

Volatile petroleum product prices along with depleting resources of oil and increasing environmental concerns had prompted several government agencies to promote and subsidize the production of biofuels from edible crops. The alarming rate at which edible crops were being deviated to produce biofuels caused the price of food crops like corn to shoot by a margin of over 100% in the initial three years (2005–2007). The twenty-first century has so far witnessed an enormous growth in production of biorenewable chemicals. The economically more lucrative business of biorenewable chemicals is currently projected to grow at a compounded annual growth rate of 22.4% and account for 45% of the chemicals produced in the US by 2025. This calls for a thoughtful regulation of the parameters, which should be considered for the production of biorenewable chemicals, in order to avoid any direct conflict with food production. This study addresses the possible edible and non-edible feedstock sources, conversion technologies used, conflict with food production accessed in terms of market scenario, environmental concerns and availability of land area for the effective conversion of the individual generation of feedstocks to biorenewable chemicals.

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1. Introduction

Fossil fuels currently account for over 80% of the primary energy consumed in the world [1]. Rising concerns over diminishing fossil fuel reserves coupled with global warming effects caused due to alarming levels of CO_2 in atmosphere has driven the society towards the search for new renewable sources of energy, which have the potential of replacing petroleum for the production of valuable fuels and chemicals. In the recent years, biomass has shown promises as an alternative feedstock, which can serve the needs of the energy sector while keeping the CO_2 emissions under control [2]. Meanwhile, the production of numerous value added chemicals using multiple biological and chemical techniques on renewable biomass has also gained enormous momentum [3]. This trend of increasing demand of biomass calls for thoughtful regulations so as to eliminate the chances of any direct conflict with food or environment in the production of such biorenewable chemicals. A proposed biorefinery is suggested to have a variety of high value chemicals in its portfolio leading to greater profits, which further raises concerns over the use of edible biomass [4]. Inflation of corn prices in USA post 2005 has been reported to be partly due to the deviation of corn for biofuel production (Fig. 1a). Initial reports published by World Bank suggested that there was a serious need to reconsider all biofuel policies which subsidize its production in light of their impact on food prices [5]. The production of biofuel alone resulted in an estimated increase in corn prices by more than 100% in a span of just three years 2005–2007 (Fig. 1a) [6]. The rapidly growing production of biorenewable chemicals can further escalate prices of corn and other edible feedstock. The growing market for biorenewable chemicals (Fig. 1b), along with the potential for generating higher amounts of revenue compared with biofuels alone, has seen many companies like Blue Marble Energy (Seattle, Washington, USA) pivoting from producing biofuels to producing biorenewable chemicals [7]. The potential of biorenewable chemicals to generate higher revenue has been reaffirmed by reports generated by the US Department of Energy [8]. According to the reports published by the Iowa Energy Center, the revenue generated by deviating 70.6% of oil to fuel amounts to a gross total of $385 bn compared to a revenue of $375 bn generated by deviating only 3.4% of oil to petrochemicals [8]. The US department of agriculture (USDA) forecasts that by 2025 at least a 45% share of chemicals will be accounted by biorenewable chemicals. The biorenewable chemical market is likely to grow at a rate almost double to that of biofuel [9,10].

The growing market for biorenewable chemicals requires greater vigilance in order to ensure that the techniques used for their production do not increase food prices. Numerous research reports have been published in a short span of time regarding the production of biofuels using varying feedstocks along with its respective possible implications on food prices [11–14]. While several studies have stressed upon the importance of avoiding any conflict with food crops in biofuel production, to our knowledge no study has yet concentrated on the impact of biorenewable chemical production from edible biomass sources or non-edible biomass source grown on an arable land. In our current work, we address the challenges faced in dealing with issues related to feedstock selection for biomass conversion along with the energy efficiency, economic evaluation and environmental effects of technologies related to biorenewable chemical production.

2. Challenges faced in feedstock choices

Biofuels have earlier been classified broadly into three generations based on the kind of feedstock which is being used for its production (Fig. 2) [14]. The first generation of biofuels and biochemicals is produced from edible feedstock whereas the second and the third generations are produced from non-edible feedstock. All potential feedstocks which can be used for biomass conversion will be discussed in this study.

2.1. First generation feedstock

Biomass composed of primarily starch (including sugar) and edible triglycerides comprises this generation of feedstock. Triglyceride feedstock derived from plant or animal sources generally consists of fatty acids and glycerol. On the other hand, starchy feedstock composes of glucose polysaccharides. The easy production of sugar monomers by hydrolyzing glucose polysaccharides made starchy feedstock like corn [15] and sugarcane [16] as one of the most preferred choice. However, the use of edible food crops for the production of biofuels and biochemical raises concerns about food prices and quantity, leading to the search for alternative non-edible feedstocks [17].

2.2. Second generation feedstock

Lignocellulosic biomass qualifies to be an effective alternative to the previous generation of food crops primarily owing to its non-edible nature coupled with its abundant availability at a low price [18]. The main hurdle faced by researchers though is the cost involved in the conversion of lignocelluloses into simpler sugar

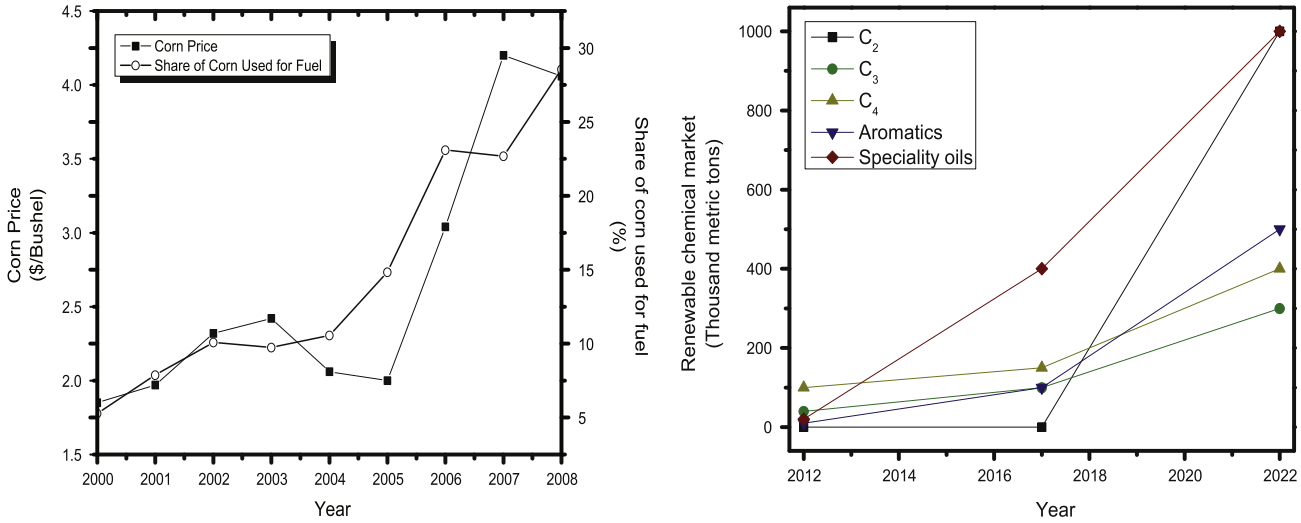

Fig. 1. (a) Corn price and share of corn used for fuel (2000–2008) [6,126] and (b) estimated renewable chemical market [127].