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Effective utilization of Forage crops for Bioenergy production

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Abstract

Globally fossil fuel consumption has put a major threat to sustainability. Adoption of renewable energy as a substitute will promote sustainable ways of energy usage in the future. One such best option is the use of biomass as a resource for energy production which can replace the solid fuels of coal and firewood, liquid fuels of petrol and diesel and gaseous fuels of natural gas. Among the biomass sources, lignocellulosic forage species is a promising feedstock to tap energy. In the recent years, the unexploited potential of forage is researched in the biofuel production perspective and the promising ways and feedstock are being found. The forage species of switch grass, miscanthus, cumbu napier, reed canary grass and buffalo grass are extensively researched and the possible energy conversion routes and suitability for deriving energy are discussed in this article.

Key words: Bioenergy, Biomass, Biofuel, Forage, Lignocellulose

Introduction

Unceasing depletion of fossil fuels, emission of greenhouse gases in the atmosphere and energy security are the major reasons for the extensive research on fuel production from sustainable resources. Lignocellulosic biomass is one of the most recognized sustainable resources for the production of renewable and clean energy due to its capability to control the number of toxic gases and carbon emission in the environment. In the world, the third-largest source of energy is biomass and its availability is about 220 billion tons per year (Giakoumatos and Kopsidas 2021). Forages, one among the lignocellulosic biomass can be used as a feedstock for conversion into liquid fuels, thermochemical products and other energy-related end products. Before World War II, forages fueled agriculture even in industrialized countries. With the appropriate technologies and processes for biomass production and conversion implemented economically, forages could once again fuel agriculture. In this chapter, the use of forage crops for the production of alternative fuels is addressed.

Bioenergy conversion routes

The lignocellulosic biomass can be converted to gaseous, liquid and solid products suitable for use either as fuel or as feedstock for producing other value-added products through several conversion routes. The physical/ mechanical conversion processes produce solid fuels such as briquettes and pellets. The cellulosic biochemical conversion process for bioethanol production requires biomass pretreatment and cellulose hydrolysis. During pretreatment, the hemicellulose part of the biomass is broken down into simple sugars and on cellulose hydrolysis, the cellulose part of the biomass is broken down into the simple sugars like glucose. Lignin and other byproducts of the biomass-to-ethanol process can be burned to produce electricity required for the bioethanol production process. Through thermo-chemical conversion processes biomass can be converted into three major products of bio-oil, syngas and char.

Forage Species for Biofuels

The lignocellulose in forage crops represents a renewable source of biomass feedstock for conversion into the second-generation biofuels. Some of the most extensively studied classes for cellulosic feedstock production include switch grass, miscanthus, cumbu napier, reed canary grass and buffalo grass.

Switch grass

Switchgrass is an immense biomass producer, and can reach heights of 10 feet or more in wetter areas of the country (Rinehart, 2006). It has excellent potential as a bioenergy feedstock for cellulosic ethanol productions and can yield sufficient biomass to produce approximately 1100 gallons of ethanol per acre. Switch grass pellets can be cofired with coal. Switch grass upon fermentation and anaerobic digestion may yield 0.329 l of ethanol per kg and 0.013 m^3 of biogas per kg respectively (Fuglestvedt, 2007).

Miscanthus

It is more amenable for thermochemical conversion process to produce biofuel than biochemical conversion, having good potential for the heat and power generation. Giant miscanthus yields are impressive of about 25 t DM/ha/yr (Anderson *et al.*, 2011). Upon subjecting to bioenergy conversion, it yields 150 g of ethanol per kg of DM (dry matter of miscanthus), 0.024 m^3 of biogas per kg and 57% of bio-oil (Lask *et al.*, 2018).

Cumbu napier

Cumbu Napier is an important plant for bioenergy because of relatively high biomass yields in the range of 65–80 t DM/ha/yr. This hybrid grass was developed at the Department of Forage Crops, Tamil

Nadu Agricultural University (TNAU), Coimbatore and the briquetting feasibility, biomethane potential and pyrolysis performance of Cumby Napier forage crop were studied in Department of Renewable Energy Engineering, TNAU. When briquetted, the bulk density of Cumbu napier increased from 118 to 1250 kg m^{-3}, while the heating value increased from 16.5 to 17.5 MJ kg^{-1}. The biogas production potential of the Cumbu napier was 0.02 m^3 kg^{-1} with 54 % methane content (Divyabharathi and Venkatachalam, 2014). The pyrolysis of Cumbu napier yielded 26 % of bio-oil and 28 % of char. The bio-oil obtained can be utilized for production of fuel and other value-added chemicals while the char produced can be used as an alternative fuel for coal, adsorbent and soil amendment. The crop when fermented, yields bio-ethanol of about 185 g/kg of DM.

Fig. 1 Briquettes production from Cumbu Napier

Reed canary grass

Reed canary grass yields are in the range of 5–10 t DM/ha/yr (*Sergej et al., 2019)* and is utilized for bioenergy production. RCG can be used for heating and electricity generation in form of pellets at good conversion efficiencies in modern power generation plants. The biogas yield from the crop is about 0.02 m^3/kg of raw biomass (Oleszek *et al.*, 2014). Other possible RCG bioenergy utilization is for bioethanol production.

Conclusion

Forages are sustainable feedstocks for energy and industrial products. Development of a significant national capacity to utilize forage crops as biofuels could benefit our agricultural economy by providing an important new source of income for farmers. Moreover, forages combine the important attributes of high yield, efficient use of water and nutrients, low agrochemical inputs and positive influences on soil and water conservation. In viewpoint of bioenergy, higher volatile matter, carbon content and lower moisture content proved the potential of forages as a feedstock for thermo-chemical conversion process. Higher cellulose content implied the feasibility of forages for biochemical conversion upon pretreatment. The bioenergy potential evaluation studies showed the versatility of forage biomass as renewable feedstock for energy generation.

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