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Recent Research Progress of *Miscanthus* as an Energy Crop

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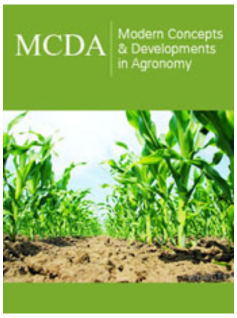

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Abstract

Miscanthus is a perennial C4 crop of Poaceae with a major impact on biomass production. It can be harvested annually for about 20 years. Because of several outstanding traits like drought and cold resistance, wide adaptability and low cost, it has become a raw biomass material for energy production. It can be large scale planted on marginal land to alleviate energy pressure, improve soil properties, protect environment and promote sustainable economic development. As an energy crop, *Miscanthus* has two main forms of utilization, one is to produce solid biofuel for combustion, and the other one is to convert it into fuel like biomass ethanol and biogas through thermochemical or biochemical methods such as biomass gasification, pyrolysis, etc. This editorial discusses the recent research progress of *Miscanthus* as an energy crop, and prospected research focus in the future.

Keywords: *Miscanthus*; Biomass; Energy crops

Introduction

The energy shortage and environmental deterioration demand for more attention to renewable biomass. Therefore, the utilization technology of bioenergy has made rapid development in recent years. Technologies such as biomass coupled power generation, biomass pyrolysis and gasification and bioenergy with carbon capture and storage have made great contributions to the full utilization of biomass and zero carbon emission. As one of the most potential energy crops, *Miscanthus* has also been applied to all links of bioenergy development and utilization.

Used as solid biofuel

Coal for traditional energy supply is non-renewable in a short time, and the waste gas from coal combustion seriously pollutes the environment. Therefore, energy crops with high calorific value and less pollution are undoubtedly one of the best choices to replace fossil energy. At present, the bioenergy supply of combustion has formed an industrial chain from raw material collection, storage, transportation, pretreatment, to efficient transformation. The solid biofuel production in Finland, Canada, Germany, the United States have reached more than 20 million tons/year. The latest research on *Miscanthus* also involved into those processes.

Miscanthus harvest operations include mowing, conditioning and baling, etc. However, the low natural bulk density leads to an increase in costs. To solve this problem, Fasick et al. [1] examined the effects of a mechanical conditioning system for *Miscanthus* on bale density, the compressive force during small square bale compression as well as the energy consumed during the compression process through lab scale studies. Compared with untreated *Miscanthus*, the regulation system reduces 37% energy consumption and 37% peak compressive force.

Some quality parameters of *Miscanthus* such as bulk density, ash content, durability and calorific value, are worse when compared with wood biofuel [2]. However, considered deforestation and low cost, *Miscanthus* has more advantages than woody crops [3], they have lower energy consumption in the granulation process [4], and process improvement has also narrowed the gap with wood biofuel. A recent study [5] tested the processes of drying, compacting, and torrefaction of *Miscanthus* through laboratory scale experiments and determined the optimum process temperature for solid biofuel production from a mass loss ratio and economical perspective. Moreover, wet torrefaction for *Miscanthus* reduced the NOx emissions, ash content and low melting point K_2O content of ash after combustion when compared with untreated *Miscanthus* [6]. In addition, converted *Miscanthus* into high energy solid fuel through hydrothermal carbonization improved combustion characteristics and greatly reduced gaseous pollutants when co-fired with lignite [7].

Used as liquid or gaseous fuel

Biomass pyrolysis and gasification technology is a comprehensive technology to decompose polymer organic biomass into small molecule and high-quality fuel under certain temperature conditions. The co-pyrolysis study of *Miscanthus* and three ranks of coal, namely lignite, bituminous coal, and anthracite showed that the optimum positive synergistic effect was obtained on *Miscanthus*-lignite blend with a biomass blend ratio of 1:1 [8]. Gasification of biomass with steam had strong advantage to converted low-grade solid fuels into high economical value and clean products [9]. The gasification reactivity of *Miscanthus* chars mostly determined by the microcrystalline structure and the inherent alkali and alkaline earth metals, *Miscanthus* chars prepared at low temperature (i.e., 600 °C) was relatively high in reactivity [10].

Cellulose ethanol is a promising biofuel produced by biotransformation, which can reduce the net carbon release effectively. Research [11] evaluated the greenhouse gas reduction potential of *Miscanthus* ethanol production which combined with carbon capture and storage technology. It is described that reduction potentials between 104% and 138% relative to the fossil comparator are likely. The conversion of cellulosic bioethanol requires three main steps: preliminary physical and chemical pretreatments to destroy the cross-linking structure of lignocellulose, sequential enzymatic hydrolysis to release soluble sugar, and final yeast fermentation for bioethanol production [12]. A one-step mild alkali pretreatment achieved high cellulosic ethanol yield and obtained large solid residues as active bio sorbent for Pb adsorption [13]. Another scheme found that delignification using trifluoroacetic acid followed with a microorganism consortium leads to 3.1% to 3.4% bioethanol yield in terms of the initial amount of biomass when converting *Miscanthus* biomass into bioethanol [14].

Biogas is a mixed methane-rich gas produced by microbial fermentation of organic biomass in anaerobic environment, which can be used for energy supply. With a large amount of fermentable sugar, *Miscanthus* is expected to be used as a seasonal raw material or a co-substrate [15] in biogas production. However, the application in biogas or methane production partly limited due to high lignin, low moisture content and high cellulose crystallinity during the winter/spring harvest. Therefore, for use as a biogas substrate, a green harvest is conducted in late autumn [16]. Another limitation is biomass yield, under 11t DM/ha can render *Miscanthus* cultivation on marginal land uneconomic [17]. Breeding and process improvement is effective for *Miscanthus* methane yield. The potential methane yield of GNT-14 (a new *Miscanthus* hybrid) was only 70% that of *Zea mays* (maize), but the energy input (GJ ha^{-1}) required for cultivation was 26% that of maize for biogas generation [18]. A process improvement study [19] utilized photocatalytic pretreatments with TiO_2 to break down the lignin component of *Miscanthus* and increased methane yield up to 46% compared to the untreated.

Prospect

Despite that *Miscanthus* has been developed for large-scale energy production in some European countries, some barriers should be noted, and more efforts should be made. Breeding works need to be done to cultivate varieties suitable for wide areas and with excellent biomass characteristics. Then, *Miscanthus* should be planted close to the biotransformation factory to deal with the transportation and harvesting costs caused by land dispersion. Moreover, co-utilizate with other biomass to solve the problem of harvest concentration is necessary. Finally, improving the production process and increasing the utilization rate of each component are conducive to the biomass utilization of *Miscanthus*.

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