

Biomass feedstock: diversity as a solution

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“ Overall, it is foreseeable that different biofuel production models will be established in different regions of the world based on the climate, soil property, social economic structure and nature resource constraints. ”

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Biomass-based biofuel production has emerged as a major approach to facilitate energy independence, reduce GHG emissions, revitalize rural communities and enhance sustainable economic development [1–3]. Despite the importance of biomass conversion improvement, feedstock development is also crucial in developing an economically viable and sustainable biofuel production system. Bioenergy feedstock development includes germplasm selection, molecular breeding and genetic modification of proper feedstock for biofuel production [1,4]. The development and implementation of lignocellulosic biofuel is hindered by several major challenges in feedstock development. The first challenge is feedstock availability, which translates into the need for increased use of marginal land and the development of a diverse range of feedstocks suitable for different niches. The second challenge is sustainability. We need biofuels that can ultimately reduce GHG emissions, that have a positive net energy balance

and that improve biodiversity and soil/water conservation. The third challenge is economic viability and profitability, especially among rural communities. Profitability is crucial for sustainable rural economic development and engagement of enough farmers to produce sufficient biomass for advanced biofuels. The diverse byproduct streams or traditional agriculture coproducts will increase economic viability. The fourth challenge is the inherent dilemma between the distributed feedstock production system with marginal land usage and the large-scale conversion in the traditionally vertically integrated operation for biofuel production. From the feedstock perspective, the solution is to both increase the yield of biomass and to maximize the land usage in order to reduce the transportation radius for the biorefineries.

These challenges require the scientific community to develop a diverse range of feedstocks together with the agricultural practices for feedstock production,

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which is the topic of several articles in this special focus issue. First, diverse feedstocks need to be developed for different climates in order to maximize the feedstock availability. In this special focus, one article has been focused particularly around addressing the issue of feedstock in extreme climates. Xue *et al.* present the biomass composition and yield for different perennial grasses in North Dakota, USA, a cold and relatively dry region [5]. The study highlighted that a traditional warm-season perennial feedstock such as switchgrass may not be the best fit for the region, owing to the lower yield. By contrast, the study indicated that tall wheatgrass could be a viable choice for regions such as North Dakota. The research suggested that there is no all-in-one solution for feedstock development, and various types of feedstock need to be developed and optimized for different climates.

Similarly, diverse feedstocks need to be developed to be tolerant to abiotic stresses toward better marginal land usage. Water usage itself is also a sustainable issue. Xin and Wang reviewed the potential of sorghum as a bioenergy feedstock, in particular, for abiotic stress resistance [6]. One of the major strengths of sorghum as a bioenergy feedstock is its drought and high temperature tolerance, which makes it a potential feedstock for the large semi-arid area in western China. In fact, sorghum is already a traditional food crop in western China, and the adaptation of high biomass or high sugar sorghum would provide the feedstock for biofuel production in western China and the southern USA [6]. Besides sorghum, many salt- and drought-tolerant grasses and other plant species have the potential to become bioenergy feedstocks to enable marginal land use.

Diverse feedstocks also need to be developed to address the sustainability issue. There are several issues relevant to sustainability including nutrition usage and perennial features. Among different feedstock options, perennial warm-season grasses such as switchgrass and *Miscanthus* stand out as having the qualities to meet the sustainability requirements [1,4,7,8]. If sorghum were to be exploited as a bioenergy feedstock, perennial hybrids may help to improve sustainability. However, such efforts will reduce the value of sorghum as a food crop and a balanced strategy needs to be developed for each region and country. In terms of nutrition usage, sorghum has significantly less nutrient requirements compared with corn and many other crops, which may help to promote the sustainability of biofuel production [6].

Byproduct and coproduct streams are additional important considerations for biomass feedstock development to promote profitability and economic viability, which is particularly important for developing countries such as China and India because the profit margin

for agriculture in these countries is very low, if any. The coproduct can be, for example, food, fiber or chemical products. Baxter *et al.* present the use of an intercropping strategy to maximize the utilization of wheat residues as feedstock for bioenergy without impeding the food yield [9]. Lignocellulosic biofuel can be produced complementary to traditional food and feed products to promote the farmers' income. In addition, feedstock with diverse end products can be developed as regional solutions. For example, *Amaranthus* spp. were recently proposed to be a bioenergy feedstock for both biomass-based ethanol production and seed-based biodiesel production. The diverse product streams can not only promote the economics, but can also help to provide the diesel for ethanol refineries.

Overall, bioenergy feedstocks have been a major focus of this special focus issue because of the tremendous challenges for regional solutions. Although optimized conversion is important for biofuel production, extensive research still needs to be carried out to identify, develop, optimize and evaluate a diverse range of bioenergy feedstocks, in order to deliver both global and regional solutions for better profitability and sustainability of the entire biofuel system. For example, we believe that sweet or grain sorghum cultivars will serve as a regional solution for Western China, northeast Africa and other dry and arid regions with a need for both fuel and food [6]. However, for the USA, with more abundant land, *Miscanthus* or switchgrass may serve as a better bioenergy feedstock in many areas owing to the lower cost for the large-scale production [4,8,10,11]. Overall, it is foreseeable that different biofuel production models will be established in different regions of the world based on the climate, soil property, social economic structure and nature resource constraints. Proper choice of feedstock will provide crucial enablement for these models, and eventually the sustainable economic growth in different parts of the world.

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