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Cassava, a potential biofuel crop in (the) People's Republic of China

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ABSTRACT

Cassava ranks fifth among crops in global starch production. It is used as staple food in many tropical countries of Africa, Asia and Latin America. In (the) People's Republic of China, although not yet a staple food, cassava is of major economic importance for starch for a large area of southern (the) PRC, especially in the provinces of Guangdong, Guanxi, Yunnan and Hainan. Recently, cassava-derived bioethanol production has been increasing due to its economic benefits compared to other bioethanol-producing crops in the country. We discuss here the possible potentials of cassava for bioethanol production.

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1. Introduction

1.1. Cassava

Cassava (*Manihot esculenta* spp. *esculenta*) is a starch-containing root crop of worldwide importance as food, feed and non-food products (Fig. 1). More than 70% of this production is in the subtropical and tropical regions between 30° N and 30° S of Africa, Latin America and Asia by small-scale farmers. The crop is widely grown as staple food and animal feed in these regions with a total cultivated area over 18 million ha [1,2]. Cassava is a high starch producer with levels of up to 90% of its total storage root dry weight and is one of the most important sources of calories in the tropics. Starch is synthesized and deposited in the underground tuberous storage roots, which can measure up to 1 m in length and over 10 cm in diameter. The high starch production attributes together with the unique properties of its starch make cassava suitable for particular food and non-food applications [1,2]. It is consumed daily by more than 600 million people. It provides a cheap source of dietary carbohydrate energy (720×10^{12} kJ day^{-1}) ranking fourth after rice, sugarcane and maize, and fifth among starch crops in global production [http://faostat.fao.org]. It gives reasonable yields in dry and poor soils and does not require high management level and cost compared to other major food crops.

Cassava originates from South America and has been domesticated for more than 5000 years from its wild ancestor *M. esculenta* ssp. *flabellifolia* [3]. Selection during domestication has resulted in many morphological, physiological and biochemical differences between cassava and its wild ancestor. Some traits, such as increased size of tuberous roots, higher starch content in tuberous roots (Fig. 2), and vegetative propagation through stem cuttings are results of human selection. Interestingly, some progenies in the second (F_2) generation from a cross between cassava and *M. esculenta* ssp. *flabellifolia* showed considerably higher tuberous root weight than the cassava parent [4]. These interspecific hybrids may constitute important genotypes for improved root yield from which selection can be made in future cassava-breeding programs. In addition, high genetic diversity and morphology have been found within cassava [5,6], reflecting the genetic potential for plant modification. Here, we discuss the potentials of cassava in the biofuel sector and point to some research areas that need to be addressed to fully exploit cassava starch production for both food and non-food applications.

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Fig. 1. Field-grown cassava plants (*M. esculenta* spp. *esculenta*). Photo by Anna Westerbergh.

1.2. Cassava as a biofuel crop

Many characters of cassava such as high drought and heat tolerance, little requirement to agricultural fertilizers, and high starch content make it one of the most attractive plants for starch production in the future. With increasing population pressure and climate change it is predicted that the production of cassava will increase over the next few decades, and, as a result, cassava is now an international priority for crop improvement. Even though cassava is mainly grown by small-scale farmers, its use for agro-industrial processing in Asia is increasing [7]. Apart from its traditional role as a food crop, cassava is likely to increase its value by becoming an important biofuel crop. The high yields of starch and total dry matter in spite of drought conditions and poor soil, together with low agro-chemical requirements, result in an energy input that represents only 5–6% of the final energy content of the total cassava biomass. This translates to an energy profit of 95%, assuming complete utilization of the energy content in the total biomass. The energetic and economic aspects of using cassava as a biofuel crop are well documented. For instance, a direct comparison of bioethanol production from different energy crops was reviewed by Wang [8, Table 1]. A detailed study on the biofuel conversion performance and its related energy input in this crop compared to other energy crops has also been presented [9]. The conclusion was that cassava compared favorably to other crops such as maize [9], sugarcane and sweet sorghum [8, Table 1]. Indeed, the annual yield of bioethanol was found to be higher for cassava than for any other crops, including sugarcane.

Table 1
Comparison of bioethanol production from different energy crops.

Crops	Yield (tonne ha^{-1} $year^{-1}$)	Conversion rate to bioethanol (L $tonne^{-1}$)	Bioethanol yield (L ha^{-1} $year^{-1}$)
Sugarcane	70	70	4900
Cassava	40	150	6000
Sweet sorghum	35	80	2800
Maize	5	410	2050
Wheat	4	390	1560
Rice	5	450	2250

Source: [8].
tonne ha^{-1} $year^{-1}$, tones per hectare per year, L $tonne^{-1}$, litres per year, Lha^{-1} $year^{-1}$, litres per hectare per year.

Hence, the interest in production of cassava starch-derived bioethanol is progressively increasing in (the) PRC and the rest of world. In this review, we mainly address on biological issues of cassava as a biomass for biofuel production and some of its economic aspects in (the) PRC.

2. Cassava in (the) PRC

In (the) PRC, around 440,000 ha of cassava is cultivated, with annual yields of ca. 9110,000 tonnes of fresh weight of storage roots [10–12]. The harvested storage roots are mainly used for production of starch, including modified starch. Production of bioethanol from cassava is just at a beginning [13,14]. As a feedstock, cassava holds a top potential for bioethanol production in Asia. For maize-derived bioethanol in (the) PRC [15], production of 1 tonne of ethanol requires 3.2 tonnes of maize kernels. That corresponds to a cost of around 3456 CNY, based on a price of CNY1080 per tonne of maize. The same calculation for sugarcane-derived bioethanol shows that 13.5 tonnes of sugarcane stems are required for 1 tonne of bioethanol production at a cost of around CNY2295, assuming a price of CNY170 per tonne of sugarcane stems. As a comparison, cassava-derived bioethanol requires 6.6 tonnes of cassava storage roots for 1 tonne of ethanol. This corresponds to a cost of around CNY1716 using a price of CNY260 per tonne harvested cassava roots. Apart from the economic benefits, the environmental and geographic concerns should also be taken into account. The main arable land in (the) PRC is used for staple food production, such as rice, wheat, potato and maize. Thus high-quality land is in short

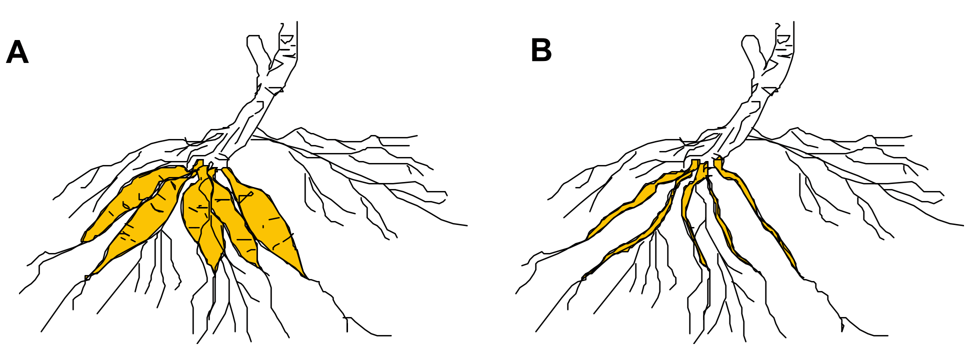

Fig. 2. Roots of cassava (A) and its wild ancestor *M. esculenta* ssp. *flabellifolia* (B).

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