Pocket K

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Biotechnology for SUGARCANE

BIOFUELS ASSAY SUCROSE BIOFACTORY

Global Knowledge Center on Crop Biotechnology

More than Just a Sugar Crop

When we think of sugarcane, right away we associate it with table sugar, the most popular sweetener also chemically known as sucrose. In fact, this grass of the genus *Saccharum* accounts for 80% of sucrose produced worldwide, with the remaining 20% coming from sugarbeet. Each year around two billion metric tons of sugarcane stalks are crushed in sugar mills to get the sucrose juice. But there is certainly more to this crop than the sweet juice within.

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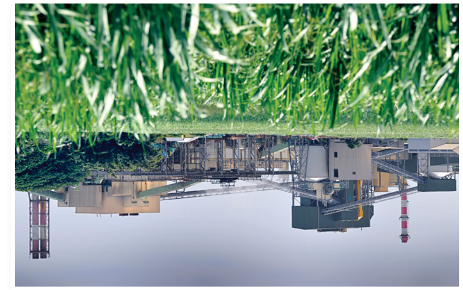

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With traditional technologies, sugarcane can yield a variety of products from fiber to chemicals. With the marvels of modern biotechnology, this crop can now be grown and used in more diverse ways. Plant genetic engineering, the process of inserting new genes and modifying existing ones, promises to turn sugarcane into a more efficient producer not only of sucrose but also of novel biofuels and compounds with medical and industrial uses.

Boosting the Sucrose Yield

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Genetic manipulation is being conducted to increase sucrose content of sugarcane. This work requires an understanding of the many interacting processes involved in accumulation of sucrose in sugar-storing stems. Scientists have identified the key enzymes that set in motion these processes, which can be hastened or slowed down by genetic engineering towards more efficient build-up of sucrose in stems[1].

In sugarcane, genetic modification is being carried out one step at a time to boost the sucrose yield. For example, as a first step, South African scientists genetically knocked down a particular enzyme[2]. This raised the amount of sucrose in young stems of the engineered sugarcane plants. Further tests in the field are being conducted. This and other recent developments[1] clearly indicate the potential for substantial improvement in sucrose yield of sugarcane through precise modification of underlying processes.

References

1 Patrick, J.W. et al. (2013). Metabolic engineering of sugars and simple sugar derivatives in plants. *Plant Biotech J.* 11: 142-156

2 Groenewald, J.H. and Botha, F.C. (2008) Down-regulation of pyrophosphate: fructose 6-phosphate 1-phosphotransferase (PFP) activity in sugarcane enhances sucrose accumulation in immature internodes. *Transgenic Res.* 17: 85-92

3 http://agencia.fapesp.br/en/16756

4 Harrison, M.D. et al. (2011) Accumulation of recombinant cellobiohydrolase and endoglucanase in the leaves of mature transgenic sugar cane. *Plant Biotech J.* 9: 884-896

5 Wang, M.L. et al. (2005) Production of biologically active GM-CSF in sugarcane: a secure biofactory. *Transgenic Res.* 14: 167-178

6 Petrasovits, L.A., et al. (2007) Production of polyhydroxybutyrate in sugarcane. *Plant Biotech J.* 5: 162-172

7 McQualter, R.B. et al. (2005) Initial evaluation of sugarcane as a production platform for a *p*-hydroxybenzoic acid. *Plant Biotech J.* 2: 1-13

8 Wu, L. and Birch, R.G. (2007) Doubled sugar content in sugarcane plant modified to produce a sucrose isomer. *Plant Biotech J.* 5:109–117

9 http://www.thejakartapost.com/news/2013/05/20/development-underway-first-transgenic-sugarcane-plantation.html

10 Arencibia, A. et al. (1997) Transgenic sugarcane plants resistant to stem-borer attack. *Molecular Breeding* 3: 247-255.

11 Gilbert, R.A. et al. (2009) Agronomic performance and genetic characterization of sugarcane transformed for resistance to sugarcane yellow leaf virus. *Field Crops Res.* 111:39-46.

12 Enríquez-Obregón, G. A. et al. (1998) Herbicide-resistant sugarcane (*Saccharum officinarum* L.) plants by *Agrobacterium*-mediated transformation. *Planta* 206: 20-27.

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September 2013 (No. 45)

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International Service for the Acquisition of Agri-biotech Applications

Making Cellulosic Biofuel

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Sucrose is widely used to make biofuel ethanol through fermentation. Ethanol provides an alternative to fossil fuels, which can reduce dependence on petroleum and curb greenhouse gas emission. Sugarcane breeders have focused on sucrose yield to boost ethanol production. However, the increasing use of sucrose to produce ethanol instead of food has raised ethical and economic concerns. These concerns have emphasized the need to produce ethanol without compromising the sucrose.

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Biotechnology seeks to tap the cellulose in sugarcane leaves and bagasse (the leftover residue from crushed stalks) for ethanol production. The complex chemical structure of cellulose can be degraded by enzymes into simple sugars which can be fermented into ethanol. However, it is heavily guarded by a tough material called lignin that needs to be removed using a harsh pre-treatment procedure, which is very costly.

Current genetic engineering efforts in Brazil aim to modify the chemical structure of lignin so that it can be easily separated from the bagasse, allowing a more efficient conversion of cellulose to ethanol[3]. In Australia, researchers have inserted microbial genes into sugarcane, creating transgenic plants that can make cellulose-degrading enzymes precisely engineered to operate in the leaves of mature plants[4]. Both initiatives could advance the cellulosic ethanol technology.

Biofactory for Niche Products

Sugarcane is the most efficient field crop in converting sunlight and water into biomass. For this reason, scientists find sugarcane as an ideal plant for the co-production of certain substances for medical and industrial applications. The genetic mechanisms within sugarcane cells can be tweaked to direct them to produce these substances, turning the whole plant into a biofactory. As proof, engineered sugarcane plants were shown to produce high-value chemicals like therapeutic proteins[5] and natural precursors of biopolymers[6,7]. This approach may turn out to be more efficient than current production methods.

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A remarkable achievement in this area is the production of an alternative sweetener called isomaltulose in transgenic sugarcane. This was achieved by inserting a bacterial gene for making an enzyme that transforms sucrose into isomaltulose[8]. If used as a sweetener, isomaltulose may bring certain health benefits because it is digested more slowly than sucrose, which is good for diabetics, and it does not support the growth of bacteria that cause tooth decay.

Enhancing Crop Productivity

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Transgenic technology may bring the productivity of sugarcane to an unprecedented level for the benefit of farmers and to complement the aforementioned objectives. Genes taken from other organisms can be inserted into sugarcane to protect it from harsh environmental conditions and pests. The first transgenic sugarcane commercially released in Indonesia is a drought tolerant variety[9]. This variety contains a bacterial gene responsible for the production of betaine, a compound which stabilizes the plant cells when there is lack of water in the field.

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Transgenic approaches have been developed to control insect pests, disease-causing microbes and noxious weeds that limit the productivity of sugarcane. For example, the introduction of a gene from a soil bacterium protects sugarcane from stemborer insects[10]. Infection of sugarcane by a harmful virus can be prevented by inserting a gene derived from the virus itself[11]. A bacterial gene responsible for detoxification of a certain class of herbicide has conferred an attractive trait for weed control[12].

Key Challenges

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The potential of sugarcane biofactory has drawn scientific and business interests, but its release for commercial use would be a huge regulatory challenge, especially if it is intended for open field cultivation. The risk of moving “unwanted” genes from plants designed for biomanufacturing to plants dedicated for food production is generally perceived as a drawback in biofactory approaches. Thus, the commercial viability of a sugarcane biofactory will depend on the efficiency of risk containment relative to non-food plant biofactory systems like tobacco. Proponents will have to determine the efficiency and profitability of sugarcane biofactory on a case-to-case basis both from socio-economic and biosafety perspectives.

The sugarcane research community is generally optimistic about the impact of planting transgenic sugarcane, arguing that potential benefits far outweigh the risks. This must be effectively communicated to address the growing negative perception of consumers and traders toward transgenic crops and products derived from them.