BIOTECHNOLOGY RESEARCH FOR A COMPLEX WORLD
20th anniversary of the EC-US Task Force on Biotechnology Research
2 june 2010
UNIVERSITAT POMPEU FABRA BARCELONA

FINDING ALTERNATIVES TO FOSSIL FUELS; THINKING OUTSIDE OF THE LUNCH BOX FOR SOLUTIONS FROM PLANTS

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In 2008 the world produced over 60 billion litres of ethanol biofuel from crops. Production is expected to increase 20 – 30% over just the next 4 years. Sugar derived either by crushing cane or hydrolyzing maize starch is fermented by yeast (as in making wine), and then the ethanol distilled (as in the making spirits). Although there is considerable potential to expand sugar cane production without impacting food production, this is not true in the case of maize, where there is direct competition between food, feed, and fuel. Use of maize and other grains or starch crops for fuel, and oil seeds, has also been criticized on environmental grounds. These crops require large inputs of energy, nitrogen and other environmental resources, in their production. In addition, expansion of annual grain crops onto marginal lands for biofuel production could hasten soil erosion and degradation. Sustainable non-food crops and wastes could provide all of the sugars required for ethanol production, although realization of this possibility would be greatly accelerated via GMOs.

Like starch, celluloses are polymers of sugars. Celluloses are arguably the most abundant biological substance on the Earth's surface. Celluloses, together with lignin, constitute the cell walls of plants; collectively this material is called lingo-cellulose. Wood, straw and plant material in general is typically more than two-thirds celluloses by mass. So if celluloses are so abundant, why are starches and not celluloses being used today? Celluloses are of two types: cellulose (a polymer of the 6-carbon sugar glucose) and hemicellulose (a polymer of a range of sugars, mainly sugars made up of five carbon atoms). Starch is also a polymer of glucose, but is far more easily degraded to release its glucose than celluloses. Although ethanol has been made from celluloses for over a century, this has involved an inefficient acid hydrolysis to release the sugars. In nature, micro-organisms in the digestive systems of some termites, wood boring worms and insects, and grazing animals are able to efficiently digest ligno-celluloses to sugars. Discovery of genes coding for the enzymes that allow this breakdown and, in turn, transgenic commercial production of these enzymes, is facilitating increasingly cheaper and more efficient enzyme cocktails for the release of sugars from lingo-cellulose for fermentation to ethanol. This technology has opened up the opportunity for the efficient and economic use of urban, crop and forestry wastes and the vast array of sustainable perennial plants that can be grown on abandoned agricultural, saline and semi-arid land. Analysis of available land suggests that for many countries, demand for liquid fuels could be met entirely from these sources without any impact on food and feed production. It would also benefit the economies of regions where salination, erosion or otherwise poor or semi-arid soils cannot support food crops or any other currently productive use of the land. Further, the low value of this land, coupled with the low inputs required for perennial lingo-cellulosic crops, promises to make the use of food crops on high-quality arable land economically uncompetitive – thus avoiding a food vs fuel conflict. However, GM technologies are critical to accelerating and perhaps ever realizing this transition, in particular in accelerating the development of these new perennial crops.

Not only are GM technologies currently essential for efficient digestion of ligno-cellulose, but they also provide additional benefits. Currently yeasts are only effective in fermenting six carbon sugars, but GMO yeasts have been developed that can ferment five carbon sugars and so opening the potential to almost double the amount of ethanol produced per gram of lignocellulose. GM is facilitating rapid improvement of the new largely under-developed perennial feedstocks, for example in quickly improving pest resistance. Finally, GM is allowing the engineering of micro-organisms to ferment sugars to oils, rather than ethanol. This latter development avoids the high water and energy use needed in ethanol fermentation and distillation. GM technologies promise to replace our unsustainable and socially unacceptable use of food crops for ethanol production with use of wastes and sustainable perennial systems grown on land which cannot support food crops. Particular emphasis will be given to the potential and experience of Miscanthus as an emergent crop system for sustainable alternative energy.