The GM crops for energy production

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EPROBIO
June 2010
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1. Introduction

The mineral and gas refinery is an important and strategic industry. Today, mineral oil provide the 42% of the EU energy requirements and the 95% of the required for transport (IPPC, 2003). In contrast, the limited availability of fossil fuel sources, worldwide rising energy demands and anticipated climate changes attributed to an increase of greenhouse gasses (GHG) are important driving forces for finding alternative energy sources (Bakker et al., 2007). Taking into account the aforementioned scenario, the EU commission approved the directive “Renewable Energy Roadmap – Renewable energies in the 21st century: building a more sustainable future” whereas 20 % target for the overall energy consumption have to be achieved in 2020, and a 10 % target for energy from renewable sources in transportation. In addition, this directive has stimulated much more the exploitation of alternative renewable energy sources for transportation such as biomass, better known as biofuels. The application of biofuels is very helpful to meet the global increasing energy demand and the reduction of CO₂ levels is the substitution of mineral oil derived transport fuels by CO₂-neutral biofuels (Directive 2009/28/EC).

1.1. What is a biofuel?

Biofuels are all those fuels which are in some way derived from biomass, at this moment around 65% of the renewable energy produced in the EU are due to the application of biomass (Eurobserv’ER, 2009). This concept includes a large amount of substrates: (1) solid biomass (e.g. residual wood, sawdust, charcoal, agricultural waste), (2) liquid fuels (mainly biodiesel and bioalcohols) and (3) gases (e.g. syngas, biogas, and hydrogen). Since many industrialized countries are pursuing the development and implementation of the biofuel industry for the transport sector, in order to reach one of the main goals of the European directive, from now on in this work more detail with be given to liquid biofuels. Liquid biofuels – biofuels- include the well knows bioalcohol or biodiesel and less familiar fuels such as dimethyl ether (DME) or Fischer-Tropsch liquids (FTL) made from lignocellulosic biomas (Unctad, 2008). Figure 1.1 shows how biofuels can be blended with common petroleum-derived fuels. As example, alcohol fuels can substitute gasoline in spark-ignition engines, while biodiesel and DME are suitable for use in compression ignition engines.
1.2. Actual scenario and application of biofuels

With almost 108 million tons of oil equivalent (Mtoe), biofuel consumption in 2008 represented a 3.3% share of the total consumption of fuels devoted to transport in the European Union (Eurobserv’ER, 2009). As shown in Figure 1.2 the consumption of biodiesel increases exponentially every year. However, more efforts in the following years will be needed by certain EU countries to come into line with the European biofuels directive which aims for an incorporation rate of 5.75% by 2010 and 10% by 2020. Paying attention to the consumed biofuels at EU level, it is clear that biodiesel is the predominant biofuel with more than 8 Mtoe consumed, while only 1.75 Mtoe of bioethanol is consumed. Moreover, other biofuels are used but they represent less than the 4% of the total (Eurobserv’ER, 2009).

1.3. Advantages and disadvantages of the biofuels exploitation

At present, biofuels are often considered to be a more environmentally responsible type of fuel compared to the conventional mineral oil. The use of these sources of energy has many advantages. However, some disadvantages in terms of social sustainability have been reported (Figure 1.3). Principally, the fact that the marketing of some food crops have created serious problems in many developing countries in supplying food at affordable prices to the poorer segments of the population due to the higher interest in biofuels in many developing countries.
Nowadays, the biofuel production is divided in “first-generation” and “second-generation” fuels. The main distinction between them is the feedstock used. First-generation, which are already being produced in significant quantities are generally made from the transformation of a specific - normally edible- part of the biomass produced by a plant, i.e. sugars, grains, or seeds, by a simple transformation process.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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</thead>
<tbody>
<tr>
<td>Simple and well-known production methods</td>
<td>Feedstocks compete directly with crops grown for food</td>
</tr>
<tr>
<td>Familiar feedstocks</td>
<td>Production by-products need markets</td>
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<tr>
<td>Scalable to smaller production capacities</td>
<td>High-cost feedstocks lead to high-cost production (except Brazilian sugar cane ethanol)</td>
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<tr>
<td>Fungibility with existing petroleum-derived fuels</td>
<td>Low land-use efficiency</td>
</tr>
<tr>
<td>Experience with commercial production and use in several countries</td>
<td>Modest net reductions in fossil fuel use and greenhouse gas emissions with current processing methods (except Brazilian sugar cane ethanol)</td>
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In the first-generation scenario, the use of renewable fuels in transportation is not enough to reach the goal expected by the European directive in 2010 or in 2020. The need to have access to clean liquid fuels, while helping to address energy costs, energy security and global warming concerns associated with petroleum fuels, raised the need for a second-generation biofuels, where the biofuels are made from non-edible feedstocks (i.e. non-edible lignocellullosic biomass, non-edible residues of food crop production or non-edible whole plant biomass) which limit the direct food versus fuel competition associated with first-generation biofuels.
Second-generation feedstocks, which are bred specifically for energy purposes, have a higher production per unit land area, and more plant material can be converted to biofuel. The main problem of the second-generation feedstock is the extraction of the sugars located inside the lignin and cellulose structure. To achieve these goals many technologies have been applied, enzymes, steam heating etc., in regard to this scope the generation of transgenic plants by biolistic transformation and direct gene transfer to protoplast have been applied with promising results (Wang et al., 2001).

1.4. Advantages of GM crops

The genetic modification of crops contribution to sustainable development in several significant ways listed and summarized below:

1. **Contributing to food security and more available food (lower prices)**
   Biotech crops can play an important role by contributing to food security and more available food through an increasing of productivity per hectare and a decreasing cost of production by a reduced need for inputs, less ploughing and fewer pesticide applications, which in turn also requires less fossil fuels for tractors, thus mitigating some of the negative aspects associated with climate change.

2. **Conserving biodiversity**
   Biotech crops are a land-saving technology, capable of higher productivity on the current 1.5 billion hectares of arable land, and thereby can help prevent deforestation and protect biodiversity in forests and in other in-situ biodiversity places.

3. **Contributing to the alleviation of poverty and hunger**
   The 50% of the world’s poorest people are small and resource-poor farmers, and another 20% are the rural landless completely dependent on agriculture for their livelihoods. Thus, increasing income of small and resource-poor farmers contributes directly to the poverty alleviation of a large majority, around the 70% of poorest people in the world.

4. **Reducing agriculture’s environmental footprint**
   The utilization of GMO implies a reduction in pesticides, saving on fossil fuels, and decreasing CO₂ emissions through less ploughing, and conserving soil and moisture by optimizing the practice of no till through application of herbicide tolerance. Also, the efficiency of water usage and availability of water globally increased. Seventy percent of fresh water is currently used by agriculture globally, and this is obviously not sustainable in the future as the population increases by almost 50% to 9.2 billion by 2050.
Another expectative is that the drought tolerance has a major impact on more sustainable cropping systems worldwide, particularly in developing countries where drought is more prevalent and severe than industrial countries.

5. Mitigating climate change and reducing greenhouse gases (GHG)
The most important contribution of GMO crops in the environmental is the reduction of greenhouse gases and help mitigate climate change in two ways. The first one is saving in carbon dioxide emissions through reduced use of fossil-based fuels, associated with fewer insecticide and herbicide sprays. Secondly, additional saving from conservation tillage (need for less or no ploughing facilitated by herbicide tolerant biotech crops) for biotech food, feed and fibre crops, led to an additional soil carbon sequestration.

6. Contributing to the cost-effective production of biofuels
Biotechnology can be used to cost-effectively optimize the productivity of biomass/hectare of first generation food/feed and fiber crops and also second-generation energy crops. This can be achieved by developing crops tolerant to abiotic stresses (drought/salinity/extreme temperatures) and biotic stresses (pests, weeds, diseases), and also to raise the ceiling of potential yield per hectare through modifying plant metabolism. There is also an opportunity to utilize biotechnology to develop more effective enzymes for the downstream processing of biofuels. In the USA, Ceres has just released biotech-based non-transgenic hybrids of switchgrass and sorghum with increased cellulose content for ethanol production and has transgenic varieties under development.

7. Contributing to sustainable economic benefits
It is estimated that the global net economic benefits to biotech crop farmers in 2007 alone was $10 billion ($6 billion for developing countries and $4 billion for industrial countries).

2. Biotechnology: GMO

2.1. What is GMO?

The definition of GMO is quite complicated. Different scientists and organizations have own way of explaining regarding GMOs. Generally GMOs are modified organisms, which modification is done by insertion or deletion of genes (pieces of DNA). In nature such kind of modification is happening but very slowly and almost unnoticeable. NCALRI (2000) defined regarding the GMO in which “the genetic make up of organisms and producing unique individuals or traits that are not easily obtained through conventional breeding techniques”. In other case, the genetically modified or genetically engineered or bioengineered crops have foreign genetic material. For instance,
producing higher sugar content sugarcanes, large size grapes, seedless citrus, etc. are some examples of GM crops. The first genetically modified crop was commercialized in USA in 1996 which was the maize crop in which a strain of bacteria, *Bacillus thuringiensis* (*Bt*) was inserted. These transgenic maize crops are able to produce toxin against the corn borers and other Lepidopteran insects (Benbrook, 2004). In case of biofuel production, the genetically modified poplars trees produce less lignin which facilitating on the biofuel production. This pilot project has been doing in Belgium in collaboration with The Netherlands under the framework of a European Interreg Project (anonymous, 2010).

2.2. How can we make GMO plants for biofuel?

Every living organism has certain number of chromosomes. Within chromosomes genes are presents. These genes are the pieces of Deoxyribonucleic Acid (DNA) codes which regulates all biological processes in living organisms. For instance, sugar content in sugarcane, disease resistance, oil contents in seed etc. The traits controlling gene can be easily detect in most of plants. After sequencing gene particular DNA sequences are responsible for governing these particular traits on plants. So that such piece of DNAs could be useful to transfer on desirable plants. This can be possible wide range of plant and animal species. From traditional breeding it is difficult to modify the plant species in those characters which are present in related plant species. In contrast, with the help of genetic engineering desirable gene can be transfer in plants even from animal.

For getting biofuels from plants numerous processes have to be complete. For instance, crops, bacteria, yeasts, catalysts etc. are major components of extracting biofuels from plants. Modification of above mentioned components are the main objectives of making GM plants. The modification of plants is depends upon the crop species, the objectives of improvement. Some plants species have more sugar whereas other plants have much oil contents. In general, obtaining fast growing crops, high sugar or starch content plants, plants contain more cellulose or less lignin, plants use less water and have greater degree of resistance to insects and disease and herbicides as well are considerable characteristics to make transgenic plants for biofuels. These GMOs can be made by two ways either by mutation (alteration of genes) or recombination (insertion of genes). Gene transfer can be done by two ways:

1) Vector mediated or indirect gene transfer: *Agrobacterium* or viral vector.
2) Vector less or direct gene transfer: chemical mediated gene transfer, microinjection, electroporation, particle gun or particle bombardment.
1) **Vector mediated gene transfer**

The vector mediated gene transfer also called recombinant DNA technology. Small pieces of DNA are transfer from one or more species into the crops plants in which DNA have desirable characters. In this method different types of viruses, bacteria etc have been using.

2) **Gene gun or micro-injection:**

Transformation of genes without help of biological vector is also called gene gun or micro injection. In this method, the modification is done simply by injecting the genetic material containing new gene into the recipient cell of desired plants. A fine-tipped glass needle is using for micro-injections.

![Figure 2.1. Process of creating a transgenic plant](image)

Some examples of improving efficiencies:

- **Reduced need for fertilizers**

Nutrients are most important factors for growth and development of plant. There are more than 16 nutrients have been identified for plant growth. Among them nitrogen, phosphorus, and potassium
are major elements. The element like nitrogen is the largest constituent of the atmosphere, about 80%. Nitrogen deficient plants couldn’t develop very well and ultimately the performance of plants goes down. So some plants like legumes trap the atmospheric free nitrogen for its own growth and development. Nitrogen fixation in legumes crops involved many bacterial strains. With application of genetic transformation non-legume crops are also able to fix the atmospheric nitrogen, so that it reduces the application of huge amount of fertilizers in fields to produce more biomass. Furthermore, scientists identified an enzyme called glucin dehydrogenase which involved in utilization of fertilizers in plants. The gene for glucin dehydrogenase is present in most of crops; however the expression level is varies with crop by crop (Rader, 2008). With the help of genetic transformation, we can increase the expression level of the gene on biofuel crops thereafter; ultimately increase the yield of crop from same field.

- **Improving solar energy use efficiency**

Plant produces sugar from water and CO₂. For this purpose solar energy is most important. The photosynthesis rate is varies from crop to crop. For instance, corn plants make more sugar per unit of sunlight than any of the other grains. So that could be possible to increase per unit sugar by improving the light energy efficiency, because the photosynthetic gene found in corn plant which is not present in rice plant (Rader, 2008).

Furthermore, carbohydrates are most important for growth and development of plants and always allocate toward the growing parts. To date the gene is identified responsible for partitioning for carbohydrate in corn plants. The gene is *Psychedelic* (*psc*) which controls the distribution of carbohydrates on growing parts like flowers (Slewinski and Braun, 2010), so that if we modify such gene only distributing on leaves and stem then we could able to get more biomass and obviously have more ethanol from corn plants.

Increasing cellulose contains and decreasing hemicellulose fraction on maize plants not only increases the bioethanol production but also improve the digestibility to livestock (Dhugga, 2007). Additionally, lignin is the most important part of plants for making rigid structures. The lignin is the one of lowest biofuel producing organs on plants. By means of genetic engineering we can remove the lignin from plant; however it does not make a sense. Without lignin very hard to get plant stand in earth surface. Thus, the objective for biotechnologists could be possible to make plant having easily degradable lignin. Furthermore, we can modify the biosynthesis of lignin molecules, structural rigidity, etc.

In contrast with benefits of GMO have some negative impacts of GMO have been a big issue.

- When farm lands are using for biofuel production ultimately reduce the farmland. That’s why increasing food prices and the world tend to hunger.
• The existing area for cultivation is not sufficient to fulfill the energy requirements so that more cultivation area should have increase. The only options for increasing farming land by reducing the forest land due to which cause net increase in greenhouse gases.
• Increase the dependency on eco-destructive pesticides to defense against the pest.
• Proliferation of dangerous genetically modified crops.
• Genetically modified crops are dangers in the sense that they have linked to organ damage and reproductive failure in mammals, sudden death and complete failure of crops.
• Social, religious and ethical issues.

3. Application of GMO in the world

3.1. Actual situation about GM crops in the world

As a result of the consistent and substantial economic, environmental and welfare benefits offered by biotech crops, millions of small and resource-poor farmers around the world continued to plant more hectares of biotech crops in 2008. Progress was made on several important fronts in 2008 with: significant increases in hectare of biotech crops; increases in both the number of countries and farmers planting biotech crops globally; substantial progress in Africa, where the challenges are greatest; increased adoption of stacked traits and the introduction of a new biotech crop. These are very important developments given that biotech crops can contribute to some of the major challenges facing global society, including: food security, high price of food, sustainability, alleviation of poverty and hunger, and help mitigate some of the challenges associated with climate change.

![Figure 3.1. Distribution of GM Crop Plantings in 2007 (ISAAA, 2007)]
Notably in 2008, accumulatively the second billionth acre (800 millionth hectares) of a biotech crop was planted – only 3 years after the first one-billionth acre of a biotech crop was planted in 2005. In 2008, developing countries out-numbered industrial countries by 15 to 10, and this trend is expected to continue in the future with 40 countries, or more, expected to adopt biotech crops by 2015, the final year of the second decade of commercialization.

The principal countries committed to biotech crops are India and China in Asia, Argentina and Brazil in Latin America and South Africa on the African continent – collectively they represent 2.6 billion people or 40% of the global population, with a combined population of 1.3 billion who are completely dependent on agriculture, including millions of small and resource-poor farmers and the rural landless, who represent the majority of the poor in the world.

3.2. The GM crops are not welcome in Europe

In Europe the perception of GM crops is negative generation for two reasons: that the foreign genes added to GM crops might escape into wild plants; and that food derived from GM crops could pose a health risk to consumers. Despite the fact that GM crops have been grown and consumed around
the world for more than 10 years now without causing any major environmental or health problems, some European environmental and consumer groups continue to assert that GM crops suppose an unacceptable risks. As a result, although the European Commission introduced a comprehensive regulatory regime for GM crops in 2003 and majority of trials of GM crops (grown by 8 EU member countries; Germany, Portugal, Spain, France, Czech Republic, Slovakia, Romania and Poland) still have not received regulatory approval in Europe.

This general belief on the negative health and environmental effects of GM crop is when producing ethanol meant for food grade and for other purposes other than as fuel. The fraternity between GM crop and biofuels in the US is banned in the whole of EU. So, in EU one reason is that the foreign gene added to GM crops might escape into wild plants and food derived from crops could suppose a serious health risk to the consumers. Both the environmental and consumer groups in the EU continue to assert that GM crops pose unacceptable risks.

3.3. The view of future of GM crops

The biotechnology as GMO crops increase efficiency of first generation food/feed crops and second-generation energy crops for biofuels presents both opportunities and challenges. Biofuel strategies must be developed on a country-by-country basis, food security should always be assigned the first priority and should never be jeopardized by a competing need to use food and feed crops for biofuel. Injudicious use of the food/feed crops, sugarcane, cassava and maize for biofuels in food insecure developing countries could jeopardize food security goals if the efficiency of these crops cannot be increased through biotechnology and other means, so that food, feed and fuel goals can all be adequately met. The key role of crop biotechnology in the production of biofuels is to cost-effectively optimize the yield of biomass/biofuel per hectare, which in turn will provide more affordable fuel. However, by far the most important potential contribution of biotech crops will be their contribution to the humanitarian Millennium Development Goals (MDG) of ensuring a secure supply of affordable food and the reduction of poverty and hunger by 50% by 2015.
4. Conclusions

The main conclusions extracted from this work are compiled in this section:

1. The limited availability of fossil fuel sources, rising energy demands and climate changes has stimulated the exploitation of alternative renewable energy sources.

2. Liquid biofuels can be blended with common petroleum-derived fuels. The application of biofuels, mainly bioalcohols and biodiesel, can be useful to reach the EU directive target by 2020.

3. First-generation biofuels technology is not enough to reach the goal expected by the EU directive, so that the need for a second-generation, in which feedstocks are bred specifically for energy purposes.

4. The genetic modification of crops contribute to sustainable development of biofuels in significant aspects, such as decreasing exploitation cost, reducing agriculture environmental footprint and reducing GHG emissions and making the process more cost-effective.

5. The genetic modification (GM) make up of organisms and producing unique individuals or traits that are not easily obtained through conventional breeding techniques. GMs can be made by two ways: mutation or recombination.

6. Using GM technology some modification have been performed such as plants with reduced need for fertilizers, better photosynthesis efficiency, higher content of carbohydrates or oil, fewer content of hemicellulose and lignin.

7. In spite of all these advantages, in Europe GM crops perception is negative for two reasons: (1) foreign genes added to GM crops might escape into wild plants and (2) food derived from GM crops could pose a health risk to consumers.
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