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The Future Crops for Biofuels

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1. Introduction

The Sun is sending around 174 peta watts of light energy to the Earth where only about 120 peta watts can reach the Earth surface after energy losses during penetrating of light through the Earth's atmosphere. In fact, the truly used solar energy for production of biomass on land is only 74 tera watts after counting arable land and photosynthesis efficiency, which is ca. 6% (the arable land area / the Earth area) and ca. 1%, respectively. Presently, the total human consumption requires about 15 tera watts, therefore it still makes the total bioenergy production on land 5 times more than what the human being consumes. Thus, the major question now and in the near future is how to efficiently transfer bioenergy from biomass to biofuels. This chapter will describe the current production of the four forms of biomass ie sucrose, starch, ligno-cellulose and plant oil by different bioenergy crops. It will also briefly describe how to convert the biomass to biofuels by different methods. An analysis of energy conversion efficiency during converting biomass to biofuels and an economic evaluation on using the different biomass will be carried out. A suggestion and discussion will be brought up on how to change biomass from one form to another *in viv*o and how to increase biomass production in the future crops for efficient use of bioenergy and economic production of biofuels.

2. Why biofuels?

2.1 Depletion of the fossil oil and development of the oil price

Since 1870s when Julius Hock in Vienna invented the world's first oil machine, and Etienne Lenoirand and Alphonse Bear de Rochas created the first car running on petroleum based fuel (Bryan and Hellemans, 1993), the human needs of all modes of transport gradually increased, resulting in a large number of production of the modern transportation such as automobiles, ships, trains and aircrafts. These modern means of transport led to the human increased demand for oil, in consequence exacerbating the exploitation of oil. Almost everyone knows that, the worldwide surge in oil extraction will deplete the oil out of the Earth sooner or later as the Earth has a certain amount of oil stored. Figure 1 shows the last

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forty five years of global oil consumption and exploitation (BP, 2010). According to this trend and according to most of the statistical predictions (Duncan RC, 2000), the Earth's stored oil will run out in the coming five decades despite the projected more or less inconsistent. In Figure 1 the gap between the future demand and production and the future form of energy to supplement the gap will be the challenges placed in front of the human focus. As this gap enlarges, the attendant thought-provoking side effects increase, such as the impact on the economy. The potential side effects on the global economy can be seen in the development of crude oil price in the last thirty years with an increase of triple and even four times on crude fossil oil price (data from BP, 2010). It is estimated that the gap between the demand and production in Figure 1 can bright the world price of crude oil to sky-high in the future (see also Duncan RC, 2000). Oil consumption and depletion shake the world economy not only directly through the soaring oil prices, but also by increasing the atmospheric greenhouse effect and the indirect damage to the environment and human health to generate greater economic losses, and a threat on human survival.

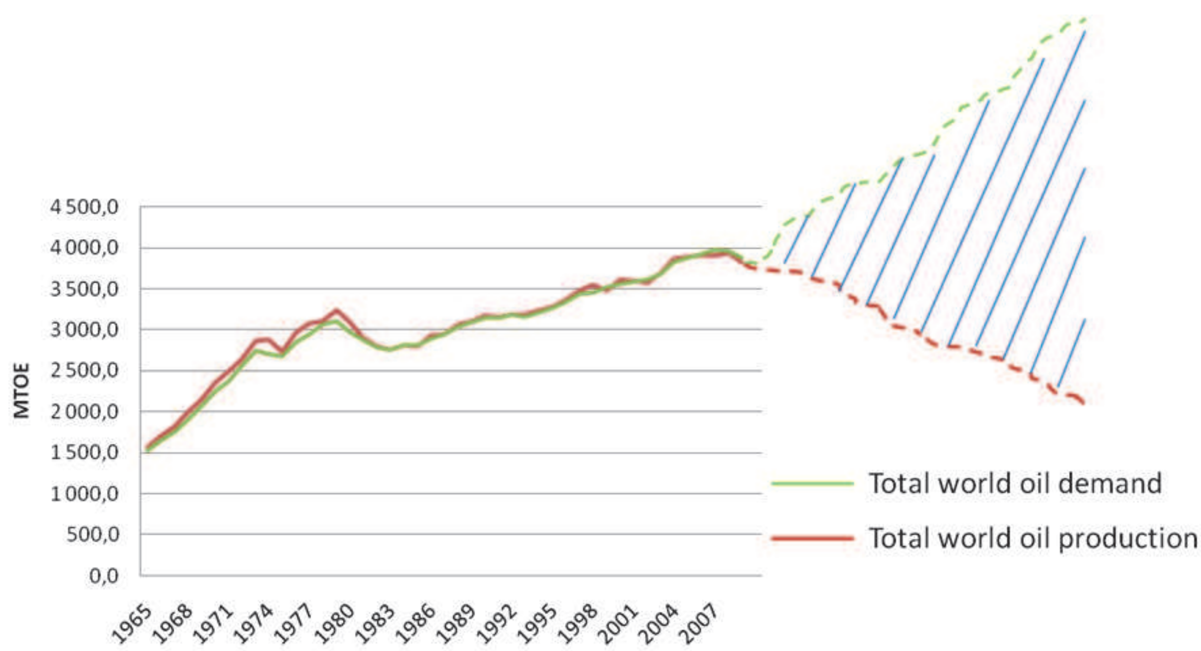

Fig. 1. The world fossil oil consumption and production from 1965 to 2009 (BP, 2010) and possible demand and production in the future. The gap with slashes indicates that additional energy supplies are needed to meet the global oil energy demand. MTOE (Million Tonnes of Oil Equivalent).

2.2 Increased concentrations of the most important greenhouse gases in the last decades

Green house effect is that the atmosphere can capture the radiation to keep temperature in different parts of the Earth relatively stable. Human activities can enhance the greenhouse effect on Earth, and may cause global warming which makes the temperature in different parts of the Earth unstable (Leaf et al, 2003). Specific meteorological data show that from 1980 to 2002, the earth's average temperature increased 0.3 degrees per year (Environment News Service, 2007). It is estimated that this upward trend will continue, by 2100 the Earth's average temperature will be 6 °C higher than the current (Barker et al, 2007). Global warming is largely caused by increased concentrations of some green-house gases. According to the content in the atmosphere, the ranked top five gases are, water vapor, carbon dioxide, methane, nitrous oxide and ozone. They increase the impact of global warming, respectively, 60% (water vapor), 26% (carbon dioxide), 6% (methane and nitrous oxide), 8% (ozone) (Kiehl and Trenberth, 1997). The exhaust emissions from vehicles contain at least two of them, namely carbon dioxide and nitrous oxide. We first look at the most recent decades of atmospheric carbon dioxide and nitrous oxide concentration and then, briefly discuss about methane and water vapor on the impact of global warming. Concentration of carbon dioxide in the atmosphere far from the industrial revolution some 150 years ago, has been increased from 280 ppm (parts per million) to today's 380 ppm (Barker et al, 2007). Following the trend, in 2100 the concentration of carbon dioxide in the atmosphere will reach more than 550 ppm. The increases of atmospheric carbon dioxide concentration can be directly linked to human activities that have employed energy materials such as oil, coal and natural gas in the high intake of energy and release of carbon to the atmosphere. The release of carbon has significantly increased since humans used a variety of fuels after the industrial revolution, particularly in the last four decades (Yu et al, 2008). The rapid increase of the concentration of carbon dioxide in the atmosphere in the last four decades may be due to the human consumption of large quantities of fuels, especially the oil consumption. Atmospheric nitrous oxide concentration in the similar period of years (nearly 150 years), from 270 ppb (parts per billion) increased to 310 ppb (Prather and Hsu, 2010; Aneja et al, 2009). One major reason for this increase may be the use of chemical fertilizers in agriculture and the global fuel consumption, especially oil use.

The content of methane in the atmosphere 200 times smaller than that of carbon dioxide and today's concentration is about 1.8 ppm (Sass and Cicerone, 2002; Bousquet, P. et al, 2006). However, due to its greater molecular volume than carbon dioxide, easy to absorb long wavelength radiation, the molecules absorb the energy unit (relative absorption power per molecule) is much higher than carbon dioxide (Bousquet, P. et al, 2006). It creates the greenhouse effect almost one-fifth of carbon dioxide. The lead to elevated concentrations of methane in the atmosphere is mainly (2 / 3) caused by a variety of human activities. The release of methane from human activities is of the three most important sources, fuel and gas mining, rice paddies and enteric fermentation from animals (Sass and Cicerone, 2002).

Water vapor is the most important component of the greenhouse effects. However, the production of main water vapor is naturally occurring. And human exploitation and utilization of the fuel may not be immediately linked to the content of water vapor in the atmosphere. But it is worth noting that with the warming of the earth, atmospheric water vapor will be more and more, so that warming of the Earth may have a snowball effect. To reduce global water evaporation or reduce water content in the atmosphere, one of the ways may be to increase the green coverage on the Earth's land area, that is, the development of bioenergy, the two fold purposes.

2.3 Economic losses due to the climate changes

Earth's climate change or global warming has brought the threats on human health and survival. These threats are mainly for instance in the following aspects, such as melting glaciers and rising sea levels, rampant diseases, extreme weather, food crisis, the extinction of species. It is extremely difficult to use the data to accurately estimate the damage by global warming. It might be more intuitive to examine the direct economic losses in recent years and in the future, in a number of countries in the world, caused by global warming. It is estimated that over the past five years (2006-2010) the global warming has caused direct economic losses of about 350 billion USD in the world (Akomo B, 2011). Table 1 is a rough estimate, predicting that the average temperature of the Earth increased 2.5 °C, different countries in the world would meet the economic loss (loss accounts for a percentage of GDP). In 2010, for example, the world's GDP was 74,000 billion USD (World Bank, 2011), if the surge in the world average temperature was 2.5 °C, it is estimated that the global economic losses could be 74,000 x 1.9% = 1,400 billion USD.

Country	Loss (+) and Gain (-) relative to GDP (%)
India	4.9
Africa	3.9
OECD Europe	2.8
Eastern Europe	0.7
Japan	0.5
United States	0.5
China	0.2
Russia	-0.7
The world average	1.9

Table 1. An assessment of putative impacts on the world economy of possible climate changes with an increase of 2.5 °C on average temperature (data source: Unions for Jobs and the Environment, 2002).

A detailed assessment was released by Natural Resources Defense Council (Natural Resources Defense Council, 2008) on impacts of the global warming in the future years on the US economy in four sections. These four aspects are, the hurricane hit, the real estate industry, energy and flood. By 2100 (possibly an increase of 6 °C on the world average temperature, see also above), the United States in these four aspects will get the economic loss of nearly 1.9% of the GDP, similar to the average loss of the world with an increase of 2.5 °C on the world average temperature (Table 1). Some tropical or subtropical countries, such as Africa, India, Southeast Asia, South America, South Europe and other regions may get affects even more.

2.4 Biofuels are two fold, the best and maybe only resolution on the dual problems

The data from all of the above sees that the world faces two major serious energy fuel related problems. 1, Depletion of the fossil fuels is getting close. Finding of new energy fuels is imminent. 2, Air pollution and global warming caused by the consumption of fossil fuels, must be improved. New energy fuels must be beneficial to the global environment, so to ease or stop global warming. What kind of new energy fuels can simultaneously solve these two problems or meet the above two conditions? It was a period of time human beings have a great affinity for nuclear energy as it is effective, together with small occupation of land areas. But recently on March 11, 2011 the earthquake in Japan caused leakage of radioactive materials from a nuclear power plant, illustrating once again that nuclear energy may not be the best choice.

The biomass and biomass derived fuels can be the perfect solution to the two challenging problems brought to mankind by fossil fuels. Biomass of plants on Earth uses photosynthesis to transform solar energy into chemical energy stored in biomass or carbohydrates, while consuming atmospheric carbon dioxide and water on the planet. Biofuels require solar energy, atmospheric carbon dioxide and water on the planet, therefore lifelong with the Sun and the Earth. Unlike fossil fuels, they are not subject to geographical location (such as oil zone), and human factors (such as war). Their producers are the green plants that cover the land surface of the Earth. The green plants play a direct role in mitigation of the two largest greenhouse effect gases i.e. water vapor and carbon dioxide. When biofuels are consumed, they release carbon dioxide and water. This is a perfect balance for the environment on the entire planet. Use of plants (known as the crops in agriculture) to produce bioenergy and biofuels is nearly perfect for the Earth. However, most of the concerns are whether the biomass and biofuels can produce enough energy to replace fossil fuels today, that is, to fill in the gap in Figure 1.

3. Can biofuels meet the global energy requirements?

One of the most critical issues when using biofuels to replace fossil fuels is, whether bio-energy can meet the human energy consumption. One way to answer this question may be to comprehensively analyze the energy budget on the Earth and the human energy demand. In Figure 2, we do a calculation on how much energy the crops can make from the solar energy. The Sun to the Earth (using the Earth disc for the calculation) is sending the energy of about 174,000 Tera Watts (TW, 1W = J / sec) (Rhodes, 2010). After the Earth's atmosphere (the atmospheric reflection and absorption) the energy reaches the Earth surface of about 120,000 TW. In the surface of the Earth, the land accounts for about 30% and available in the land to farming (growing crops) land area for about 20%. The average crop photosynthetic efficiency (conversion of light energy to bioenergy) is about 1%. Thus, humans use crops to produce bioenergy in total: 120,000 x 30% x 20% x 1% = 72 TW. And human needs of total energy at present are about 15 TW (Rhodes, 2010). It would appear that the crop bioenergy produced is five times more than what is needed for the total energy required for human activities including food, enough to meet the needs of mankind. It must be noted that the present average efficiency of changing bioenergy into the energy of biofuels is less than 20% (Tan et al, 2010; Octave and Thomas, 2009). This means that the human production of biofuels at the current situation is difficult to meet the energy needs of mankind. Moreover, the human must reserve parts of the crops to produce food. Accelerating the increase in world population is, the demand for energy and food growing. This has given human production and use of biofuels a challenging problem at the moment. The problem is how to improve conversion efficiency from the solar energy to biofuel energy. In the long term, each step in Figure 2 should be considered as for an improvement. But for the present situation, it might be mainly to solve the bottleneck problem, i.e. converting biomass to biofuels more efficiently.

4. Targeting the bottlenecks in biofuel production

It is quite obvious from Figure 2, there are three bottlenecks in the flow chart, 1, Land limitation. As much as possible the bioenergy crops should be cultivable aquatic plants, and easy to grow on low quality of land and adverse environmental areas, such as desert, barren mountains and marsh. 2, Photosynthesis. It is extremely important to improve the photosynthetic efficiency of plants or crops. 3, Energy conversion efficiency from biomass to biofuels. The points of 1, 2 and 3 above should be all strategic bottlenecks. However, from

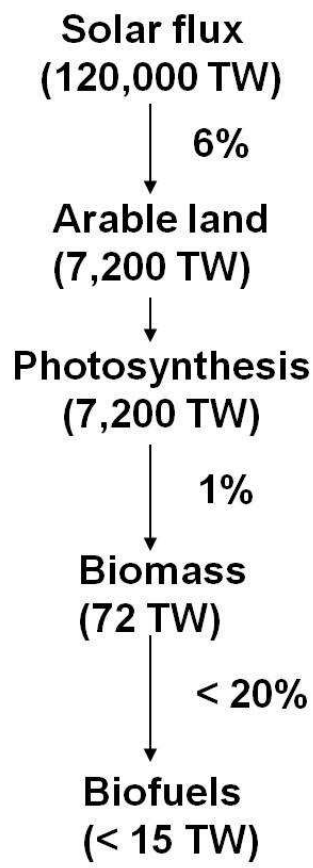

Fig. 2. A flow chart of the solar energy to the energy in biofuels based on the energy conversion efficiency of current biofuel production.

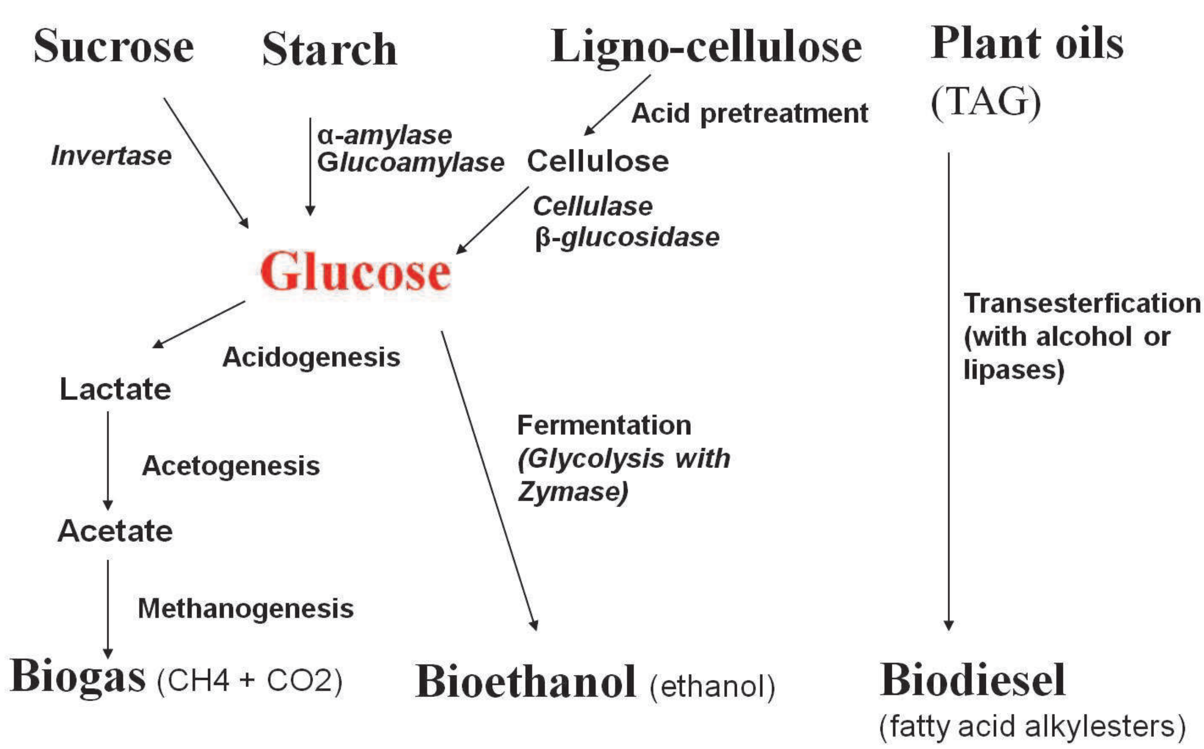

Fig. 3. A road map of biofuel production.

the current tactical point of view and existing biotechnology, the third point is an area worthy of a tremendously large effort. A basic reason is that in the coming years the production of bioenergy by crops far exceeds the total demand of mankind. How to make full and effective use of crop biological materials and turn them into biofuels, is the challenge before mankind, and it is also a very practical and realistic question. The current use of biomass to produce biofuels means that the use of sugar, starch, cellulose and plant oil to produce biogas, bioethanol and biodiesel (Figure 3; Tan et al, 2010; Octave and Thomas, 2009). Figure 3 is one of the typical presentations on production of biogas, bioethanol and biodiesel.
The chart from a technical point of view indicates that using of the sugar, starch, cellulose to produce biogas and bioethanol requires expensive enzymes. In addition, loss of energy in the fermentation process is large (Ohlrogge et al, 2009; Tan et al, 2010). In contrast, using vegetable oils to produce biodiesel is relatively simple, without the expensive enzymes and much energy loss. It might be one direction for the future development of biofuels (Ohlrogge et al, 2009).

Current crops for production of biomass and biofuels

Currently, the world's major bioenergy crops are few and listed in Table 2 according to their major production of the used biomass. Sometimes it is difficult to categorize a certain type of crop. Such as sugar cane, presently, the major biological materials being used are Syrup (Sucrose). And it can also be used as straw bagasse (cellulose) to produce bioethanol. Another example is maize, which contains the seeds for both production of a large number of endosperm starch, and the rich embryo oil. And it also contains a lot of straws (cellulose) for bioethanol production.

Biomass	Crop
Sucrose	Sugarcane, sugar beet and sweet sorghum
Starch	Maize, other cereals and cassava
Cellulose	Trees, switch grass, miscanthus and cereal straws
Plant oil	Oil palm, soy bean, rape seed, sun flower and cereals

Table 2. The currently major crops for biofuel production (data source: FAO, 2009)

4.1 Sucrose based bioethanol production

Using sugar to produce bioethanol is a rather ideal way based on the energy conversion efficiency, especially after the discovery of the bacteria *Zymonas mobilis* used for fermentation (Rogers et al, 2007). The bacteria can use both glucose and sucrose as subtracts with the energy conversion efficiency, 100% and 70%, respectively, higher than yeast. In addition, through genetic engineering, some of the bacterial strains can be improved for a higher conversion rate of sucrose. The bacterial fermentation is an ideal tool. Currently, the world's major crops for the production of sugar are sugar cane, sugar beet, and some crops, including sweet sorghum (FAO, 2009). In 2009, the world's total output of sugar from the three crops were, respectively, 1,683 M tonnes, 229 M tonnes and 0.9 M tonnes (FAO, 2009). Purely theoretical calculation according to ($H_20 + C_{12}H_{22}O_{11} \rightarrow 4C_2H_60 + 4\ CO_2$), gives that each kilogram of sucrose can yield about 538.4 grams of ethanol or 681.5 mL alcohol (using a basis of 0.790 grams of alcohol per mL). Thus, the only sugar produced from sugar cane, the total 1,683 M tonnes, can produce about 1,147 billion liters of bioethanol. According to the statistical data from the International Organization of Motor Vehicle Manufacturers (Worldometers, 2011), by 2009 around the world, there were around 600 Million passenger cars. We assume that the cars were all over the world bioethanol cars, with alcohol consumption per vehicle on average about 8.5 km / liter, the average exercise of 15,000 km per year. This is about 1,765 liters per year per vehicle bioethanol. Total worldwide cars of 600 M would consume 600 M x 1,765 L = 1,059 billion L bioethanol. That means that, by purely theoretical calculations, the only production of sugarcane bioethanol is enough for car use around the world. But, in fact, the production of sugar cane ethanol is far less from the theoretical calculation. In 2009, the total world's bioethanol production (including sugar cane), was about 76.6 billion L (RFA, 2011). One of the most important reasons is the production of ethanol from sugar cane in all aspects of technology is still not perfect (needs much improvement). In addition, sugar cane is limited to tropical and subtropical countries, notably Brazil, India, China and Thailand. Other sugar crops are also very important, such as sugar beet and sweet sorghum. Currently, the development of sweet sorghum seems to be particularly attractive. With the basic advantages of sugar cane, however, sweet sorghum has much wider planting areas on earth than sugar cane. In addition, it also has many other advantages. 1, Sorghum is a diploid plant, its genome is relatively small (approximately 730 Mbp), some variety genome have been sequenced or are being sequenced. This leads to a larger advantage of genetic breeding than sugar cane. 2, Sorghum has high resistance (biotic and abiotic). 3, And, like sugar cane, sorghum is a C4 plant with high efficiency of photosynthesis. From the current situation, sweet sorghum is a very promising sugar crop.

4.2 Starch based bioethanol production

Production of bioethanol is currently with the world's top five regions and countries, the United States, Brazil, EU, China and Canada (RFA, 2011). Among them, the United States and Brazil account for the world nearly 90% of total ethanol production. At present the main crops used in the regions are corn in the U.S.; sugar cane in Brazil; sugar beet, wheat and barley in the EU; maize and cassava in China; and corn in Canada. It is quite easy to see that in the world, currently the main crops used for starch based bioethanol production are corn, wheat, barley and cassava. Among them, corn is the main crop for production of bioethanol. Currently, the existence of important and debated issues of using starch crops to produce bioethanol is, 1, Starch crops are food crops. Using food crops to produce biofuels is the concern of most of the countries in the world. In fact, the use of food crops to produce bioethanol has directly or indirectly caused soaring food prices. 2, An economic issue with the important food crops to produce bioethanol. Corn, for example, according to a number of data produces biothanol with energy output and input ratio of about 1.3 to 1.6, much lower than that of sugar cane with 8.3 to 10.2 (Goettemoeller and Goettemoeller, 2007; Baligar et al, 2001; Gaur and Reed, 1998; Rooney, 1998; Tan et al, 2010). 3, A number of food crops such as corn, wheat and barley crops are annual crops and need a large amount of fertilizers for agricultural production, and certain amount of agricultural management of inconvenience. Large increase in fertilizers will produce greenhouse gases such as N_2O. At present, in order to solve the three problems, people are looking for a variety of ways, for example, i) Using of food crop straws to produce bioethanol, such as corn stalks, wheat and barley straws. ii) Going for some starchy crops such as cassava, which are economic, cost-effective, stress resistant, easy-managing, and none or little-fertilizing. iii) Using cellulose based bioethanol production to completely replace starch based bioethanol production, such as the use of forests, switch grass and miscanthus.

4.3 Cellulose based bioethanol production

The world's cellulose based bioethanol production is still in the very early stage, maybe in the research and development (RD) stage. The reason why this area is being prefered, may be, 1, Cellulose is the world's largest biomass. Only forests account for 80% of the biomass on earth. The use of cellulose as raw materials for biofuels may be the cheapest. 2, Most of the cellulose productions do not create any competition in land and starch production with food crops. 3, All food crops contain large amounts of straw cellulose. The use of food crop straws to produce bioethanol may add more economic value to food crops. However, the main problem of production of bioethanol with cellulose is the economic issue, in most of cases not economic at present based the current tactical situations. The main reason is that, cellulose in nature, mainly in plant cell walls with lignin and hemicellulose together. To effectively enable enzymatic degradation of cellulose, the cell wall structures should be deconstructed, the lignin has to be removed and hemicellulose should also be degraded simultaneously. To destroy the structure and to remove the lignin some harsh physical or chemical treatment processes are required (Tan et al, 2010; Octave and Thomas, 2009). In addition, fermentation of 5-carbon sugar from hemicelluloses is not effective at present (Tan et al, 2010; Octave and Thomas, 2009). These factors limit the current large-scale cellulose based bioethanol production. Prediction from the current situation indicates that in the future the main raw materials for the cellulose based bioethanol production may be, 1, Forest (the main Earth´s biomass). 2, Some fast growing plants such as switch grass, miscanthus, hybrid aspen and willow. 3, Crop residues such as corn stover; rice, wheat and barley straws and cassava stems.

4.4 Plant oil based biodiesel production

In the above, we made the assumption that if the world 600 M cars were bioethanol driven, then a total of about 1,059 billion L bioethanol per year would be of necessity. We can make a calculation on, if the similar vehicles of 600 M around the world were biodiesel cars, how much biodiesel would be required for the whole world per year. We assume that our average consumption of biodiesel per vehicle is about 17 km / L and the average requires the exercise of 15,000 kilometers per year. The total of such vehicles of 600 M worldwide would consume 530 billion L of biodiesel yearly. Currently the world every year (data from 2008) (EMO, 2011) produces about 13 billion L of biodiesel, far from the human needs. We can see from Table 3 that, in 2009 the world's total output of vegetable oil was about 136 M tonnes or 160 billion L (roughly, 1.176 L/kg). Even if all production of vegetable oil would be used for biodiesel, it would not be enough to run the total cars around the world. Among the vegetative oil production, palm oil, soy bean, rape seed and sunflower accounted for 86% of the total world´s production. Only palm oil accounted for about 35%, while palm oil is limited to the tropical cultivation. This indicates a problem that the human needs to develop oil crops, and breed new oil crops.

Oil crop	Production (M Tonnes)
Palm and kernel oil	47.1
Soy bean	36.1
Rape seed	21.2
Sun flower	13.1
World Total	136

Table 3. The major oil crops and their oil production in 2009 (data source: FAO, 2009)

5. The future crops for biofuels

5.1 What is required for the future bioenergy crops

From the analyses above and bottleneck targeting on the current situation of biofuel production, we suggest that the future crops for biofuels may need the following requirements (see also Figure 4).

1. high yielding
2. easy to grow, there is a strong resistance capacity
3. does not occupy a lot of high-quality land
4. multiple purposes
5. easy breeding in order to get more performance traits

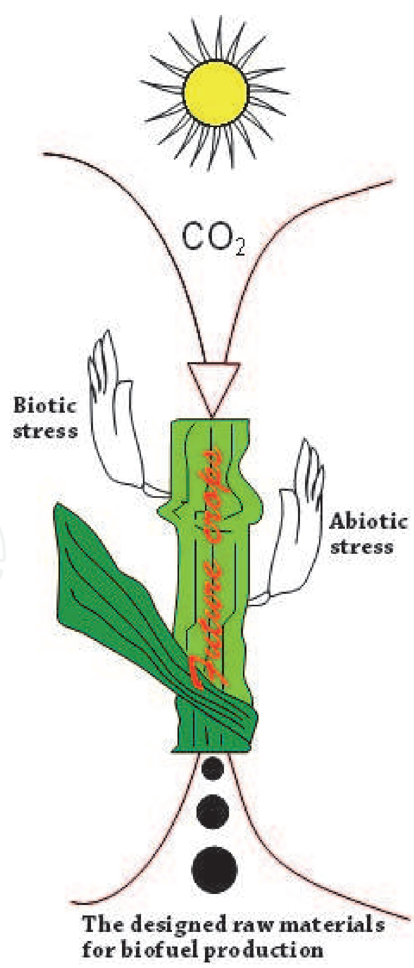

Fig. 4. The future crops with the designed raw materials for biofuel production.

1. High yielding

Many factors influence and determine the trait of high yielding. To the special nature of bioenergy crops, as a bioenergy crop its photosynthetic efficiency must be high, such as the C4 crops, sugarcane, sorghum, maize, or the crops like cassava and rice with high photosynthetic efficiency. They should be able to effectively convert the product (sucrose or carbohydrates) of photosynthesis and deposit them for production of biofuels-needed biomass, i.e. sucrose, starch, cellulose or oil. From the point of energy conversion efficiency of view, sucrose and oil based biofuel production is preferable in a short run, as the total bioenergy in the current crops exceeds the human needs.

2. Easy to grow, there is a strong resistance capacity

The future bioenergy crops should be easy to grow, including no needs for a lot of manpower, management and fertilizers. Also should have high resistance to both biotic and abiotic stresses. Switch grass, miscanthus, some cereals and cassava have shown such characters.

3. Does not occupy a lot of high-quality land

As elucidated in Figure 2, the future bioenergy crops should not occupy a lot of high-quality land. These high-quality land should be served as much as possible for the production of food crops to meet the rapidly growing human population and demands for food. This may be one of the reasons why switch grass, miscanthus, algae, trees and cassava have recently been as favorites.

4. Multiple purposes

The next generation crops should have multiple uses, especially for food and oil crops. They should produce digestible and easy-digesting straws. One can even breed a two fold crop. For example, the seeds of such crops would produce starch for food and their vegetative tissues produce vegetable oil. For multiple purpose crops, a good example is the cassava plant as reviewed recently (Westerbergh et al, 2011; Jansson et al, 2009).

5. Easy breeding in order to get more performance traits

With the development of modern biotechnology, especially in the recent systems biology and the genome sequencing of various plants, molecular breeding has been greatly facilitated. The future bioenergy crops should be very easy to change through modern breeding techniques to produce the crops needed by the human demands of the various products.

5.2 Breeding bioenergy crops in the future - some prospects

1. Starch to oil

Why starch into oil? First, we use corn as an example. Corn produces all four forms of biomass, sucrose, starch, cellulose and oil. The major production is corn starch (endosperm), cellulose (straw) and oil (embryo). From the current process data, energy conversion efficiency from corn starch, cellulose and oil into bioethanol and biodiesel are 46%, 43% and > 90%, respectively (Baligar et al, 2001; Gaur and Reed, 1998; Rooney, 1998; Tan et al, 2010). It is easy to see that if the corn could *in vivo* produce more oil, corn would no doubt increase the energy conversion efficiency. Second, in the above section we have already mentioned, there are very few world oil crops at present, namely palm oil, soy bean, rape seed and sun flower. While confined to tropical palm oil, soy bean and sun flower can occupy a very large area of high-quality land in addition to their other important uses such as soy bean as main protein recourses. Rape seed can not grow without mid-crop rotation. Thus, the development of more oil crops is imminent. Some cereals are ideal candidates, such as barley, oats. First of all, they are high yielding. They have strong resistance and they can grow in many places where the growth of rape seed is limited, such as very north of Northern Europe and North America.

1.a Converting some of the food crops to oil crops

The issue is to change storage starch into oil. With the development of system biology, a new technology known as transcription factor based technology in the field of molecular biology has just come (Century et al, 2008). The core of the technology is through up regulating or down-regulating the expression of transcription factors to enhance cell metabolism to a particular direction. The technology has been staged in animals, plants and has shown its influence and potential (Shen et al, 2010; Leaner et al, 2007; Broun, 2004). The method has become an important component in the field of molecular breeding. Currently, transcription factors controlling oil and starch synthesis have been reported (Cernac and Benning, 2004; Sun et al, 2003, 2005). We can employ transcription factor based technology to change cereal starch to oil.

1.b Production of plant oil in vegetative tissues

In some plant species, transient starch in leaves after photosynthesis during the day can be accumulated to 10% of the biomass (Stettler et al, 2009). If some of the starch could be converted into oil, those plants would produce a huge amount of vegetable oil. This goal may be through the transcription factor based technology to achieve.

2. More carbon deposition to the plant's storage organization

Some transcription factors are not only involved in the synthesis of some components, but also in source-sink communication and distribution of carbon in the source and sink tissues. An example is the transcription factor SUSIBA2 (Sun et al, 2003, 2005). We can use transcription factor based technology to increase carbon deposition to the plant storage tissue.

3. Use of plant cells as bioreactors for production of the expensive enzymes in degradation of starch and cellulose

According to the literature, some scientists have succeeded in over-production of cellulose-degrading enzyme in plants´ chloroplasts (Petersen and Bock, 2011). After harvesting, the enzymes can be used for cellulose based bioethanol production. We suggest a similar method here that one could produce starch-degrading enzymes in cellulose tissues and cellulose degrading enzymes in starchy tissues. The bioenergy plants after harvesting, smashing and mixing can accelerate the decomposition of starch and cellulose by the over-expressed enzyme mixture.

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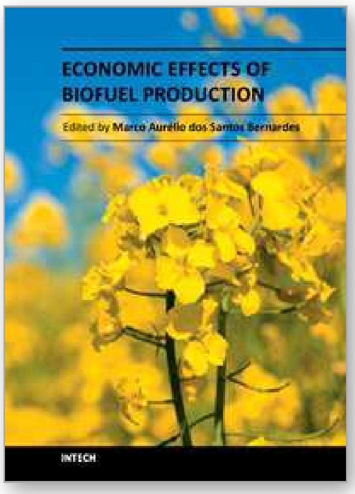

Economic Effects of Biofuel Production

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This book aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Readers will find themes including biofuels development efforts, their implications for the food industry, current and future biofuels crops, the successful Brazilian ethanol program, insights of the first, second, third and fourth biofuel generations, advanced biofuel production techniques, related waste treatment, emissions and environmental impacts, water consumption, produced allergens and toxins. Additionally, the biofuel policy discussion is expected to be continuing in the foreseeable future and the reading of the biofuels features dealt with in this book, are recommended for anyone interested in understanding this diverse and developing theme.

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