SWEET SORGHUM - A GOOD SOLUTION FOR BIOETHANOL

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Abstract. *The paper presents an overview of the potential of sweet sorghum to be used as raw materials in the bioethanol industry. The stem juice of sweet sorghum is rich in fermentative sugar and is a desirable alcoholic fermentation material. The oil crisis of 1973 and 1976 renewed interest in the commercial production of sweet sorghum for biological transformation into ethyl alcohol - bioethanol for use as fuel or fuel additive.*

Keywords: biofuels, bioethanol, renewable energy, renewable resources

INTRODUCTION

The "Proposal for a Directive of European Parliament and of the Council on the promotion of the use energy from renewable sources" (COM {2008} 30 final – SEC {2008} 57 - SEC {2008} 85) introduces an innovative point of view, such as the environmental sustainability of the biofuel production. The main sustainability criteria introduced for biofuels are: the greenhouse gas emissions saving from their use shall be at least 35 % and they shall not be made from raw material obtained from land with recognized high biodiversity value (forest undisturbed by significant human activity, areas designated for nature protection purposes, highly biodiverse grassland).

Policies to blend petrol with up to 10% ethanol are widely adopted globally, which led to additional ethanol requirement. Existing feed stocks, such as sugarcane/sugarcane molasses, are unlikely to meet actual demand. Therefore other options have to be sought, and it was found that sweet sorghum has very good potential as a feedstock for ethanol production (Bennett and Anex, 2008). In recent years, there is an increased interest in the utilization of sweet sorghum for ethanol production (Christakopoulos et al., 1993). Ethanol from sweet-stem sorghum (*Sorghum bicolor (L.) Moench*) appears to be a viable alternative to fossil fuels, especially for petroleum products as a cooking, lighting and automotive fuel.

Its growing period and water requirement are 4 times lower than that of sugarcane. Sweet sorghum is best suited for ethanol production because of its higher reducing sugar content as compared to other sources. These important traits, along with its suitability for mechanized crop production and seed propagation makes it the best alternative source of raw material for ethanol production. Sweet sorghum

represents an important opportunity to improve the economic and environmental sustainability of the bioethanol pathway (Gnansounou et al., 2005).

Traditionally, ethanol has been produced mainly from sugarcane and molasses. Molasses, a byproduct of sugarcane processing, is available relatively cheaply, but sweet-stem sorghum can compete economically due to its high-value grain production. Also, it has several advantages over sugarcane, such as the ability to withstand dry conditions, require less fertilizer, rapid growth rate, ease of planting, and lower cost of total fermentable sugars.

MATERIAL AND METHOD

Sweet sorghum is an annual crop, can be grown in the South EU regions, as well as tropical, subtropical and temperate areas. This variety of areas is possible because the total accumulated daily temperature during the growing cycle, with minimum germination temperature of 8-10 °C, is from 2,600 °C up to 4,600 °C (Shinners, 2007). These characteristics suggest that in the EU climate conditions the optimal yield for sorghum can be obtained in the South regions. Concerning the requirements of its cultivation, sweet sorghum is suitable also for poor soils, which are characterised by different kind of texture (heavy clay or high sand content), pH range (4.5-8.5) and salinity. Considering its sugar yield (7.5 tons/ha), the attended bioethanol production is in the range 3.9-4.7, based on the used variety (availability of 4,600 varieties). This crop is promising for many reasons: technological simplicity, energetic, economic and socio-economic sustainability.

- *The technology is simple enough,* because the biomass contains fermentable sugar. The extraction of the sugar juice can be carried out crushing the stalks into an horizontal power mill, where an high pressure (about 50-100 tons) is applied through some rollers (3-5 generally). The sugar juice obtained can be fermented, distilled and dried until 99 % v/v, using the traditional technology applied in the traditional pathways.
- *Sweet sorghum permits an higher CO_2 adsorption and then a positive GHG balance.* Including into the account the combustion GHG emissions, sweet sorghum is estimated neutral (sweet sorghum: emissions 93 gCO_2/MJ, comparable with the traditional crops: 14 gCO_{2eq}/MJ for the growing cycle, 79 gCO_{2eq}/MJ for the conversion into bioethanol; adsorption 45 tCO_2/ha, higher than corn, 22 tCO_2/ha, and sugar beet, 5 tCO_2/ha).
- *The sweet sorghum water demand is low*: 200 m^3/t with an average rainfall of 500-600 mm; if the rainfall is 750-800 mm, the irrigation is not necessary to obtain a normal yield (about 30 t/ha as dry matter).
- *Sweet sorghum fertilizer requirements are lower than those of corn and sugar beet*: nitrogen (as N) 119 kg/ha (corn 200-250 kg/ha, sugar beet 120 kg/ha), phosphorous (as P_2O_5) 24 kg/ha (corn 120 kg/ha, sugar beet 50 kg/ha) and potassium (as K_2O) 10.8 kg/ha (corn 100 kg/ha, sugar beet 50-100 kg/ha).
- *The by-products exploitation (bagasse, about 25 tons/ha, vinasse, 16 l/l of bioethanol) increases the energy balance.* The bagasse can be dried and direct

burned in order to produce heat (for distillation phase) or electric power (with an ORC turbine); the vinasse and bagasse can be used as substrates for anaerobic digestion to produce biogas. The estimated energy balance (output/input) increases from 1.4 (without by-products) to 7.3 (with by-products).

- *Lower bioethanol production costs*. If all the by-products are exploited the EU production cost is estimated in 300 €/ton. In the EU bioethanol market feedstock cost is the major limiting factor with prices ranging from US$ 0.74 per litre (i.e. nearly 600 €/ton) from wheat to US$ 0.85 per litre (i.e. nearly 700 €/ton) from sugar beet compared to US$ 0.21 litre in Brazil. Ethanol production from food crops (e.g. maize and cereals) is far from competitive when compared to gasoline and diesel prices. Therefore in the short run the tendency is avoiding any strategy of large scale implementation until feedstock costs can be reduced significantly (IEA Bioenergy, "Market evaluation: fuel ethanol", January 2007).
- *Increased decentralisation of the bioethanol pathway due to the short distance (max 50 km) between biomass suppliers and processing site*. The biomass reach in water (65-80 %w/w) and sugar (10-20 %w/w) has to be produced near to the plants, whose capacity therefore can not be higher than 10,000-50,000 tons/year. Instead at the current time the EU bioethanol market is controlled by big industrial groups and large agricultural cooperatives of the sugar and alcohol industries, so that sugar and alcohol production industries are the principal actors of the bioethanol sector ("Biofuel Barometer - 5.38 MTOE consumed in 2006 in the EU", EurObervEr, 2007).
- *Increased participation of farmers to the pathway, as biomass suppliers or biomass transformers.* They can increase the added value of the agricultural products and, finally, the improvement of the life style in rural areas. The proposal can modify significantly the current situation for the EU bioethanol market. At the moment the EU market is controlled by some big industrial groups and large agricultural cooperatives of the sugar and alcohol industries, so that sugar and alcohol production industries are the principal actors of the EU bioethanol sector ("Biofuel Barometer - 5.38 MTOE consumed in 2006 in the EU", EurObervEr, 2007).
- The current EU market concentration depends on several reasons among these information barrier occurs. In particular benefits of sustainable biomass energy, new crops technologies, e.g. sugar crops, and by-products market are still largely unknown to many stakeholders such as small-medium enterprises, farmers, policy makers, NGOs and the general public. On the contrary experiences carried out in other regions (Asia and United States) are demonstrating that bioethanol production from sweet sorghum is highly promising particularly in small-medium pathways.

RESULTS AND DISCUSSION

Conventionally, bioethanol has been produced from sugar bearing feedstocks like cane/beet juice and molasses or from starch based feedstocks like wheat, corn or even tubers like cassava (Reddy et al., 2008).

Application of alcohol as transport fuel has created a need for newer energy feedstocks having in view: relatively low water requirement for cultivation and processing; wider adaptability; high yields and co-product possibility.

Sweet sorghum can be an answer to the all above mentioned requirements because:

- sweet sorghum can be uniformly grown in warm, sunny weather;
- harvesting & cultivation practices are easier and are identical to sugar cane;
- sweet sorghum requires less water and fertilizers compared to sugarcane;
- crop cycle is short- 3.5 to 4 months. Usually, two cycles are possible from same piece of land annually, provided irrigation is possible;
- sweet sorghum, on crushing to extract juice, gives bagasse as co-product which can be a principal source of energy for operation of distillery in the form of boiler fuel. This practically makes alcohol production free of energy cost and improves possibility of operation in remote areas.

The Table 1 presents a comparison of sweet sorghum with sugarcane (Kobayashi and Nakamura, 2004).

Table 1

Comparison of sweet sorghum with sugarcane

Parameters	Sugar cane	Sweet Sorghum
Harvesting cycle	9 -14 Months	4 months
No of cycle in a year	One	Two
Water resources	100%	65-70%
Fertilizer requirement	100%	35-40%
Stalks productions, MT/hectare/cycle	65 … 80	45 … 55 for one cycle/year 84 … 110 for two cycles/year
Fermentable sugars concentration in stalk (% w/w)	10.0 … 14.0	9.0 … 12.0
Yield of fermentable sugar, MT/hectare/cycle	6.0 … 10.5	3.6 … 6.2 for one cycle/year 7.2 … 12.4 for two cycles/year
Ethanol (100% basis) yield lits/hectare/cycle	3400 … 6000	2020 … 3500 for one cycle/year 4000 … 7000 for two cycles/year
Bagasse MT/hectare/cycle 50% w/w moisture	19 … 24 (30% on cane weight)	10 … 14 for one cycle/year (25% on stalk) 20 … 28 for two cycles/year

CONCLUSIONS

Sweet sorghum has benefits over sugarcane and maize as feedstock for ethanol production. It requires only one half of the water required to grow maize and around one eighth of the water required to grow sugarcane; and has the least cost of cultivation which is around one fifth of the cost for growing sugarcane.

Sweet sorghum is also a carbon neutral crop, according to the Latin American Thematic Network on Bioenergy (LAMNET). This means that the amount of carbon dioxide that sweet sorghum fixes during its growing period is equal to the amount it emits during crop growth, conversion to ethanol and combustion of ethanol.

Sweet Sorghum is a new feedstock for bioethanol and it represents an opportunity for facilitating the possibility of becoming large high value energy producers, with significant impact on rural development.

Projects about bioethanol chain from sweet sorghum must be supported at European level especially by founds of the European Commission, because the process has not yet been explored at lower levels. It should be highlighted that, the scarcity of previous initiatives does not mean that there is no interest about the topic but the topic has not been deeply explored and the idea is innovative in the European context.

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