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Production of Bioethanol from Sweet Sorghum

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ABSTRACT*:The consumption of bioethanol as biofule may reduce greenhouse gases, gasoline imports. Also it can be replaced with lead or MTBE (Methyl tert-butyl ether) that are air and underground water pollutants, respectively. Plants are the best choice for meeting the projected bioethanol demands. For this scope, a comparative analysis of the technological options using different feedstocks should be performed. Our research and other studies indicate that sweet sorghum can be used as a feedstock for ethanol production under hot and dry climatic conditions. Because, it has higher tolerance to salt and drought comparing to sugarcane and corn that are currently used for biofuel production in the world. In addition, high carbohydrates content of sweet sorghum stalk are similar to sugarcane but its water and fertilizer requirements are much lower than sugarcane. Also, sugarcane is not a salt tolerant plant. On the other hand, high fermentable sugar content in sweet sorghum stalk makes it to be more suitable for fermentation to ethanol. Therefore, it is suggested to plant sweet sorghum for biofule production in hot and dry countries to solve problems such as increasing the octane of gasoline and to reduce greenhouse gases and gasoline imports.*

Key words: Sweet sorghum, Carbohydrate, Bioethanol, Biofuel.

INTRODUCTION

Each year, fossil energy resource is reducing in the world. Therefore, a substitute should be found. There are many crops available for producing energy such as sweet sorghum which not only produce food, but also energy, feed and fiber. Sorghum can be classified as sweet, grain and forage types. Sweet sorghum like grain sorghum produces grain 3 - 7 t/ha. But the essence of sweet sorghum is not from its seed, but from its stalk, which contains high sugar content .In general, it can produce stalk 54 - 69 t/ha. The sugar content in the juice of sweet sorghum varies in different varieties. The Brix range in different varieties of sweet sorghum is 14.32 -22.85% . Besides having rapid growth, high sugar accumulation, and biomass production potential sweet sorghum has wider adaptability. Also it is well adapted to sub-tropical and temperate regions of the world and it is water efficient. Sweet sorghum has many good characteristics such as a drought resistance, waterlodging tolerance, salinity resistance and with a high yield of biomass etc.
In addition, sweet sorghum is a C4 crop with high photosynthetic efficiency. Thus development of sweet sorghum will play an important role in promoting the development of agricultural production, livestock husbandry energy sources (biofule) refining sugar, paper making etc. Carbohydrates, which are present in sweet sorghum, can be nonstructural such as sugars and

starch, or structural such as cellulose, hemicellulose, and pectic substances. The chief sugars present in sorghum kernels are the monosaccharides glucose and fructose, the disaccharides sucrose and maltose and the trisaccharide raffinose. According to the kind of sugar in the stalk, it can be divided into saccharin- type sweet sorghum and syrup-type sweet sorghum. Saccharin-type sweet sorghum, which mainly contains sucrose, can be used for refining crystal sugar. Syrup-type sweet sorghum, which mainly contains glucose, can be used for producing syrup. Sugars content in sweet sorghum stalk juice mostly were sucrose and invert sugars which invert sugars are included glucose, fructose, maltose and xylose. Also, they reported that mannose, galactose and arabinose were not detected in sweet sorghum juice. Therefore, it seems that using carbohydrates in the stalk (sucrose and invert sugar) is suitable for ethanol production for biofuel because these carbohydrates are easily converted to ethanol. Although, ethanol can be produced from sweet sorghum grain but it needs more process for converting it's starch to glucose that later will be converted to ethanol.
In addition, the produced baggas after juice extraction can be used for ethanol production or animal feed. However, presently it is not economically feasible to produce ethanol from sweet sorghum baggas. The aim of this review is to summarize the information available on sorghum carbohydrates for biofule production.

Sweet sorghum agronomy

Sweet sorghum cultivation and practices are simple and readily adoptable. It is a short day plant and most varieties require fairly high temperature to make their best growth. The cereals and tolerate a wide range of soil conditions. Sorghum tole-rates compacted subsoil and can stand high press wheel pressure at planting. It tolerates a pH range of 5.0 to 8.5 and some degree of salinity alkalinity and poor drainage. It also will grow on heavy, deep cracking vertisols and light sands. The seed of sweet sorghum should be planted deep enough to give it moisture to germinate and allow its roots to grow down through moist soil into subsoil moisture, ahead of the drying front. Planting time usually start when the air temperature is above 12°C. Late planting reduces the length of the growing season, yield and carbohydrate content. Also, it may cause late and troublesome harvest and may expose the crop to pests and diseases and other hazards which are dominant at the end of the crop season. Balanced fertilization can increase yield. Nitrogen fertilizer and its application time promotes sucrose content and growth rate in sweet sorghum. Application of adequate amounts of K fertilizer increase yield res-ponses than increasing levels of nitrogen fertilizer alone. Sweet sorghum is harvested at milk stage. Experiment crop can with-stand periods of drought better than mostpotential for sweet sorghum production can be increased through selection and development of adapted cultivars. The aim of agronomy in sweet sorghum is to increase productivity with focus on biofuel and improved feedstock supply duration as follows. Water and fertilizer (macro- and micronutrients) ef-fects and their interaction on sugar, grain and bagasse yield and quality.

Effect of day length, temperature and their interac-tion, on sugar, grain and bagasse yield and quality (and help identify suitable cultivars for season/location).

Crop rotation experiments to identify the most pro-ductive and sustainable cropping systems for different ecosystems.

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The important of ethanol in biofule

One method to reduce air pollution is to oxygenated fuel for vehicles. MTBE (Methyl tert-butyl ether) is a member of a group of chemicals commonly known as fuel oxygenates. It is a fuel additive to raise the octane number. But it is very soluble in water and it is a possible human carcinogenic. Thereby, it should be substituted for other oxygenated substances to increase the octane number of the fuel. Presently, ethanol as an oxygenous biomass fuel is considered as a predominant alternative to MTBE for its biodegradable, low toxicity, persistence and regenerative characteristics. The United States gasoline supply is an ethanol blend and the importance of ethanol use is expected to increase as more health issues are related to air quality. Ethanol may be produced from many high energy crops such as sweet sorghum, corn, wheat, barely, sugar cane, sugar beet, cassava, sweet potato and etc. Like most biofuel crops, sweet sorghum has the potential to reduce carbon emissions. It is an efficient converter of solar energy, as it requires low inputs and yet, a high carbohydrate producer.

As a drought-tolerant crop with multiple uses. It has a concentration of sugar which normally varies between 12 - 21%, directly fermentable (that is, no starch to convert).

It can be cultivated in temperate, subtropical and tropical climates. All components of the plant have economic value - the grain from sweet sorghum can be used as food or feed, the leaves for forage, the stalk (along with the grain) for fuel, the fiber (cellulose) either as mulch or animal feed and with second generation technologies even for fuel. Its bagasse, after sugar extraction, has a higher biological value than the bagasse from sugarcane, when used as feed for animals.

Its growing period is shorter (3 - 5 months) than that of sugarcane (10 - 12 months), and the quantity of water required is 1/3 of sugarcane. In tropical irrigated areas sweet sorghum can be harvested twice each year (by ratooning) and its pro-duction can be completely mechanized.

1. It has some tolerance to salinity.
2. It can produce large quantities of both readily fermentable carbohydrate and fiber per unit land area.

Therefore, based on the above characteristics, it seems that sweet sorghum is the most suitable plant for biofuel production than other crops under hot and dry climatic conditions. In addition, possible use of bagasse as a by-product of sweet sorghum include: burning to provide heat energy, paper or fiber board manufacturing, silage for animal feed or fiber for ethanol production. However, since sweet sorghum is at a relatively early stage of its development, continued research was needed to obtain better genetic material and match local agro-economic conditions. The challenge is to harvest the crop, sepa-rate it into juice and fiber and utilize each constituent for year-round production of ethanol.
Sweet sorghum juice is assumed to be converted to ethanol at 85% theoretical, or 54.4 L ethanol per 100 kg fresh stalk yield. Potential ethanol yield from the fiber is more difficult to predict. The emer-ging enzymatic hydrolysis technology has not been proven on a commercial scale. One ton of corn grain produces 387 L of 182 proof alcohol while the same amount of sorghum grain produces 372 L. Sorghum is used extensively for alcohol production, where it is significantly lower in price than corn or wheat. The commercial technology required to ferment sweet sorghum biomass into alcohol has been reported in china. One ton of sweet sorghum stalks has

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the potential to yield 74 L of 200- proof alcohol. Therefore, it seems that because ethanol can be produced from both stalk and grain of sweet sorghum, so it is the most suitable crop for ethanol production using for biofuel comparing to other crops such as corn or sugarcane.

Sweet sorghum stalk processing for ethanol production

Juice extraction

Juice is extracted by series of mills. The juice coming out of milling section is first screened, sterilized by heating up to 100°C and then clarified. The muddy juice is then sent to rotary vacuum filter and the filtrate juice is sent to evaporation section for concentration (syrup to etha-nol). The juice can also be directly sent to fermentation section (juice to ethanol). Depending on the scheme selected the juice can be concentrated using evaporators to attend various brix. In case of juice to ethanol (no syrup), it is advisable to partially increase the concentration of juice to 16 - 18 brix. The syrup which needs storage for using during off season needs to concentrate to minimum 65 brix (normally 85 brix).

Fermentation

Fermentation is a multidisciplinary process based on the chemistry, biochemistry and microbiology of the raw materials. Juice or syrup is converted into ethanol by the yeast *Saccharomyces cerevisiae*. Sugar is con-verted to ethanol, carbon dioxide and yeast biomass as well as much smaller quantities of minor end products such as glycerol, fusel oils, aldehydes and ketone

Conclusion

It is clear that fuel ethanol from sweet sorghum is the best choice to be implement under hot and dry climatic conditions regarding both economic and environmental considerations. Because, sweet sorghum has higher tolerance to drought, water logging and salt, alkali and aluminum soils; It may be harvested 3 - 4 months after planting (Table 1) and planted 1 - 2 times a year (in tropical areas); Its energy output / fossil energy input is higher than sugarcane, sugar beet, corn, wheat and etc… specially in temperate areas; It is more water use efficient (1/3 of water used by sugarcane at equal sugar production); Its production can be completely mechanized and Its bagasse has higher nutritional value than the bagasse from sugarcane, when used for animal feeding.

Also, by implementing agricultural practices such as adequate water and fertilizers, suitable cultivars or hybrids, crop rotation, pest management and etc… can increase productivity with focus on biofuel production. In addition, sweet sorghum has high amount of sucrose and invert sugar which are easily converted to ethanol. Therefore, it seems that sweet sor-ghum is the most suitable crop for biofuel production in arid regions of the world. This awareness should push government of the countries with such climatic condi-tions to promote the development of projects for fuel ethanol production from sweet sorghum.

However, social aspects (including environmental concerns) should play a more significant role in the selection of the most suitable feedstocks for the alcohol industry. In this way, financial indicators would not be necessarily the decisive factors when new large-impact projects for biofuels production are studied and implemented in developing countries.

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