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PRODUCTION OF CRYSTAL SUGAR AND ALCOHOL FROM SWEET SORGHUM

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ABSTRACT

In the semi-arid tropics worldwide, Sweet sorghum is cultivated by farmers on a subsistence level, and consumed as food by humanity. In the context of China, we examine the economic and environmental advantages that transformation of sorghum to ethanol, can give to China. Reducing the use of non-renewable fossil energy reserves together with improving the environment are two important reasons that drive interest in the use of bioethanol as an automotive fuel.

Keywords: Sweet Sorghum, Sugar, Alcohol and Environment

INTRODUCTION

Sorghum is a cultivated tropical cereal grass. It is generally, although not universally, considered as having been first domesticated in North Africa, possibly in the Nile or Ethiopian regions as recently as 1000 BC. Today, sorghum is cultivated across the world in the warmer climatic areas. It is quantitatively the world’s fifth largest most important cereal grain, after wheat, maize, rice and barley. Sorghum is an important food cereal in many parts of Africa, Asia and the semi-arid tropics worldwide.

It out-performs other cereals under various environmental stresses and is thus generally more economical to produce. More than 35% of sorghum is grown directly for human consumption. The rest is used primarily for animal feed, alcohol and industrial products. The United States is the largest producer and exporter of sorghum, accounting for 20% of world production, and almost 80% of world sorghum exports in 2001-2002 (USDA-FAS, 2003).

In general terms, the production of ethanol from sorghum was more favorable than burning it to make power. However, the relative merits of making ethanol or sugar from sorghum’s juice was very sensitive to the price of sugar in China. Increasing petroleum oil prices are forcing the chemical industry to find alternative raw materials for the production of ethanol. On the other hand, burning petroleum for power contributes to a major portion of carbon dioxide emissions to the atmosphere, raising concerns about global climate change. Ultimately, petroleum use is not sustainable, and new sources of energy are needed to address a range of important economic, environmental, and strategic issues and insure a perpetual energy supply.

What benefits can China obtains from sorghum?

Sorghum is one of the increasing number of crops that can be used to produce Bioethanol at practical scales for rural communities and industries. The sugars obtained from the sugar-rich stems can be extracted and fermented to produce ethanol for uses such as a liquid fuel.
Sorghum can be grown successfully on a wide range of soil types. It tolerates a range of soil pH from 5.0 - 8.5 and is saline. Traditionally, the sorghum has been used as grain in the hot subtropics where the conditions of precipitation are limited (300 - 1100mm a year).

A large portion of petroleum is used for transportation, and the transportation sector is almost totally dependent on petroleum, particularly for powering personal vehicles and trucks (US DOE, 2002). Furthermore, the transportation sector is rapidly expanding in developing countries such as China, straining the supply of petroleum even more. Extensive experience has been accumulated with using ethanol as pure fuel and for blending with gasoline (Wyman, 2004). In Brazil, ethanol, mostly from cane sugar, is produced as either anhydrous ethanol that contains 99.6% (Vol.) ethanol and 4.5% water for use in 20 - 24% blends, with gasoline that is burned directly as a pure fuel in dedicated ethanol-fueled vehicles.

In this study, production of ethanol from sweet sorghum was investigated as a pathway to couple use of new and established technologies for possible application to the growing market in China.

**The potential use of sorghum as a non-polluting source of energy.**

Any energy should be evaluated with consideration to its environment impacts. World energy consumption has increased by 17 times in the last century, and emissions of CO2, SO2 and NOx from fossil-fuel combustion are primary causes of atmospheric pollution. At present, some 85% of the world’s energy demand is met by fossil fuels. In the last two decades, the CO2 content has increased by 27% and, as a result of the greenhouse effect, an average global temperature increase of 0.5°C has been suggested. If use of fossil fuels is not restricted, a further 2 – 5 °C temperature increase and perhaps a 1.8 - 2.4m increase of sea level may occur.

Lester R. Brown, an American economist said, if the Chinese use oil at the same rate as Americans now do, by 2031, China would need 99 million barrels of oil a day. The world currently produces 79 millions barrels per day and can not produce much more than that. Apart from unbeatable air that such coal burning would create, carbon emission from fossil fuel burning in China alone would rival those of the entire world today. Climate change could spiral out of control, undermining food security and inundating coastal cities.

Currently, approximately 26 billion tones of CO2 are estimated to be emitted annually into the atmosphere. Approximately 80% of this amount originates from combustion of fossil fuels such as coal, petrol and natural gas. It has been found that CO2 emissions from fossil-fuel sources have increased 4 times in the last 40 years. In addition, averages of six billion tones of CO2 are emitted yearly into the atmosphere as a result of the
destruction of rain and other forests. The production of energy from sweet sorghum has been the primary form of energy for millions of years and has regained importance.

PROCESSING OF SWEET SORGHUM TO SUGAR VERSUS ETHANOL

Juice conversion to sugar

In addition to sugar, the juice contains other compounds and impurities, which have to be eliminated before crystalline white sugar, can be made. Furthermore, sweet sorghum sugar consist of 85% sucrose, 9% glucose and 6% fructose - on average - and only sucrose may readily be converted to white sugar (Woods, 2000). The first stage in juice purification is the addition of lime milk (liming) followed by saturation with carbonation gas (mainly carbon dioxide) to precipitate the lime milk in a clarifier and capture the impurities in the raw juice. The settled solids (mainly calcium carbonate and non-sugars) from the clarifier are filtered in membrane presses and sent to the spent lime storage area, while the clear portion is again saturated in a second carbonation station. The purified juice obtained after the consequent filtration is called thin juice and is thickened in a multi-effect evaporator into thick juice. High-pressure steam produced in the boiler house provides the energy for evaporation, and the condensed steam is returned to the boiler house or used as technical water. The thin juice that has been diluted with water during extraction and purification enters the evaporating station with an average sugar content of 15% while the thick juice leaving the evaporator contains approximately 70% sugar.

White sugar in its crystalline form is eventually obtained from the thick juice by crystallization in vacuum pans at reduced temperature and pressure. The mixture of crystals (sucrose only) and mother liquor (green syrup) are separated in centrifuges, where the sugar is washed with hot water. The wet sugar is dried in a drum drier, screened, and finally stored in silos after cooling, while the syrup from the centrifuges is passed through an additional boiling stage to extract most of the remaining sugar. The syrup left over is known as molasses. Although molasses is about 50% sugars, the concentration of non-sugar is so high.

A simplified flow diagram of the overall process is given in (Figure1).

The sugar yield is 109 kg per ton of sweet juice processed.

Juice conversion to ethanol

The production of ethanol from the sweet juice is a well-understood process. It has long been used in Brazil with sweet sugar as raw material. The fermentation process envisaged is a continuous cascade using a train of fermentors and buffer tank. The alcohol concentration rises from 6 - 7% (vol.) in the last one. Fermentation temperature is kept between 33 °C and 35 °C.
The growth of yeast is controlled by oxygen supply to the first and second fermentor. Phosphorous (in the form of phosphoric acid) and nitrogen are also needed for yeast growth. Yeast cream is separated by centrifuges into holding tanks, and clarified beer from the separators is fed into the fermentation buffer tank. Ethanol is then recovered from the fermentation broth by distillation and dehydration (Figure 2) for the production of anhydrous ethanol. This is accomplished in two columns, namely a distillation column and a rectification column, coupled with vapor-phase molecular sieves in which a mixture of nearly azeotropic water and ethanol is purified to pure ethanol. The ethanol yield is 87L per ton of the sweet juice process.

ENVIRONMENTAL IMPACTS OF ETHANOL VERSUS GASOLINE

Ethanol generally burns cleaner than petroleum fuel because it is made-up of organic compounds, which are less complex chemically than gasoline and diesel fuels. Because they are less complex and burn more completely, they do not leave as many residues that cause polluting emissions. The Renewable Fuels Association recently wrote that, “ethanol is one of the best tools we have to fight urban air pollution” because it burns much cleaner than gasoline and reduces most exhaust emission. (RFA, 2001).

CONCLUSIONS AND RECOMMENDATIONS

An important asset of sweet sorghum is its multipurpose use, and the results from this study suggest that the best way to take advantage of this flexibility is through a flexible conversion facility capable of serving both sugar and ethanol markets.

It is important to note that, at reasonable yields, making ethanol from sorghum bagasse should bring in more revenue per quantity of feedstock processed than making electricity now. From a strategic point of view, indeed, producing fuel-ethanol from sorghum is more valuable than generating electricity because there are cheaper ways to generate electricity from renewable and non-food fuels. From a sustainability point of view, ethanol has a higher strategic value as a motor fuel due to scarcity of high quality renewable liquid vehicle fuels while many options can be used to produce electricity in a sustainable way.

Sweet sorghum, which can be grown under various climatic conditions, have been identified as a promising crop with the potential to provide for a wide spectrum of energy uses.
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REFERENCES


