Prospect and Potentiality of Bio-fuel Production to revive the Sugar Industry of Bangladesh

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ABSTRACT

The present study was undertaken during the period 2005-2008 to asses the prospect and potentiality of bio-fuel production to revive the Sugar Industry of Bangladesh. Biofuel i.e., ethanol from molasses which is the by-product in huge quantities of sugar industry of Bangladesh was studied. The study reveals that there is a great potentiality of producing around 938 million proof litres of ethanol from sugarcane and 93.8 million proof litres of ethanol from molasses which can give maximum benefit to sugar industries of Bangladesh rather than producing sugar.

Key words: Bio-fuel, ethanol, molasses, sugar industry

INTRODUCTION

Ethanol represents an important, renewable liquid fuel for motor vehicles (Lewis, 1996). Most commercial production of ethanol is from sugarcane or sugar beet, as starches and cellulosic biomass usually requires expensive pre treatment. It is used as a renewable energy fuel source as well as to manufacture of cosmetics, pharmaceuticals and also for the production of alcoholic beverages. Due to continuously rising petroleum costs and dependence on fossil fuel resources, considerable attention has been focused on alternative energy resources. Production of ethanol or ethyl alcohol (CH_3 CH_2 OH) from biomass is one way to reduce both the consumption of crude oil and environmental pollution (Lang *et al.*, 2001 a). Primary consideration involves the production of ethyl alcohol from renewable resources and determination of the economic and technical feasibility of using alcohol as an automotive fuel blended with gasoline (Goldstein, 1981). The use of gasohol (ethanol and gasoline mixture) as an alternative motor fuel has been steadily increasing around the world for a number of reasons. Domestic production and use of ethanol for fuel can decrease dependence on foreign oil, reduce trade deficits, create jobs in rural areas, reduce air pollution, and reduce global climate change from carbon dioxide build up. Ethanol, unlike gasoline, is an oxygenated fuel that contains 35% oxygen, which reduces particulate and NO_x emissions from combustion.

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Ethanol derived from fermentation produces no net increase in atmospheric CO_2 when burned, is an octane enhancing additive and removes free water which can plug fuel lines in cold climates (Lang *et al.*, 2001b).The estimated world ethanol production in 1998 was 33.3 billion litres (Berg, 1998). Approximately 9% of ethanol is produced synthetically, and consequently, fermentation is responsible for 91% of global ethanol production (Wheeler *et al.*, 1991). Brazil is the dominant producer of alcohol with a production of 16.1 billion litres in 1998. Ethanol performs well as a fuel in cars, either in a neat form or in a mixture with gasoline (Table 1). In addition to ethanol/gasoline blend markets, ethanol has other motor fuel applications including:

i. use as E85, 85 per cent ethanol and 15 percent gasoline,
ii. use as E100, 100 percent ethanol with or without a fuel additive, and
iii. use in oxy-diesel, typically a blend of 80 per cent diesel fuel, 10 percent ethanol and 10 percent additives and blending agents.

Table 1. Potential and available motor fuels

Fuel Type	Available motor fuel
Traditional fuels	Diesel and Gasoline
Oxygenated fuels	Ethanol 10% (E10), Methanol, Methyl tertiary butyl ether (MTBE), Ethyl tertiary butyl ether (ETBE), Tertiary butyl alcohol (TBA) and Tertiary amyl methyl ether (TAME).
Alternative fuels	Liquefied petroleum gases (LPG), Ethanol 85% (E85), Ethanol 95% (E95), Methanol 85% (M85), Methanol neat (M100), Compressed natural gas (CNG), Liquefied natural gas (LNG), Bio-disel (BD), Hydrogen, and Electricity.

Source: AFDC, 1997

Greenhouse gas emission reductions should be estimated on an annual basis. Where the levels vary from year to year significantly, these should be specified on an annual basis. If bioethanol from biomass is used to drive a light-duty vehicle, the net CO_2 emission is less than 7% of that from the same car using reformulated gasoline (Bergeron, 1996).The worldwide desire to reduce greenhouse gas emission will lead to an increased interest in renewable resources for energy production. Ethanol has very good characteristics to be used as a fuel either in a neat form or in a mixture with gasoline. Ethanol is a potentially clean-burning fuel that reduces smog and emissions of carbon monoxide.

Ethanol yield scenario per hectare and per tone and cost per litre

Ethanol yield scenario of leading countries like USA, Brazil and France is reflected in the following figures 1 and 2.

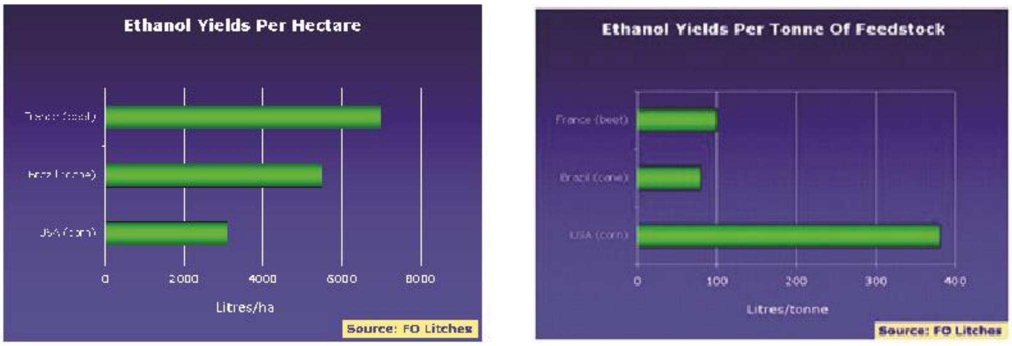


Figure 1. Ethanol yield per hectare and ethanol yields per tonne of feedstock

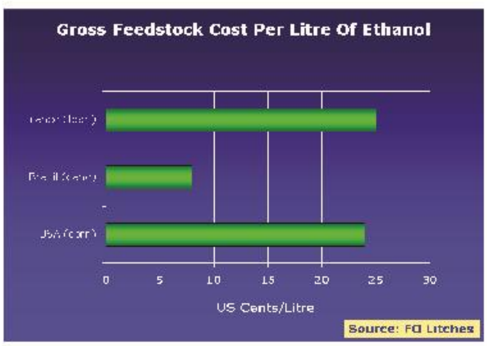


Figure 2. Gross feedstock cost per litre of ethanol

Thus considering the above facts, the present study was undertaken to achieve the following objectives:

i. To predict the potential of ethanol production from molasses

ii. Effectiveness of Ethanol as a bio-fuel.

MATERIALS AND METHODS

A new agriculturally-based bio-energy system has been developed that includes the perennial crop sugarcane, (12-18 months grown period) which has got the ability of production of ethanol. Research is continued for the development of novel technologies to produce bio-energy (ethanol, heat and electricity) from the sweet sorghum and sugarcane (C_4 sweet stemmed crop). The emergence of new, highly efficient biomass energy conversion technologies has now occurred aimed at bioenergy related issues, such as rural development, energy security, and climate change. 'Bioenergy' has begun to be perceived not as a historical energy source of last resort, but as a sustainable energy resource for the future. This re-assessment of bioenergy derives from four main factors:

i) Biomass is available virtually everywhere (i.e. anywhere plants grow)
ii) It has inherent, 'free', energy storage characteristics, unlike the other renewable energies.
iii) It can be converted into solid, liquid and gaseous energy carriers, and
iv) There are large quantities of agricultural residues produced globally which are generally under-used.

There are problems associated with the use of biomass. In natural state, the biomass is often dispersed, has considerably lower energy densities than comparable fossil fuels, and may have competing end uses. It is now better understood that badly managed use of biomass resources can have negative impacts on the environment e.g. de-vegetation, soil erosion, loss of bio diversity, etc. (Hall and Scrase, 1998; AFREPREN, 1997). Dedicated 'Energy Crops' (e.g. sweet sorghum for ethanol, short rotation coppice for electricity and heat, oil seed rape for biodiesel), sweet sorghum and sugarcane can be converted to produce liquid fuel (ethanol), heat, and electricity. However, the bioenergy derived will need to compete effectively with alternative energy sources and be produced in a sustainable, environmentally acceptable manner. If biofuels are to supply significant amounts of electricity, then bio-energy technologies must be able to generate base-load (continuous supply of) electricity. Biofuels must exploit their inherent advantage compared to other renewables, in that solar energy is stored in the structural components of plants, biomass energy can be stored at the conversion plant and therefore used for continuous generation. In this study the prospect of production of biofuels, i.e. ethanol and electricity, in a profitable and environmentally sustainable agro-industrial system was assessed. The in-built lack of energy efficiency found in most of the world's sugarcane mills and the unavoidable delivery of a large energy source to the mill (i.e. the bagasse) provides a second significant opportunity for increasing bioenergy production. A novel ethanol, heat, and electricity producing system could be regarded as acceptable if it demonstrates: Positive energy balance, Sustainability, Economic viability, Applicability, Complementary integration with existing processes, Demonstration of integrated gasification-gas turbine technology.

The important parameters are: the overall conversion efficiencies, electricity (bagasse-generated) production capacity, manpower requirements, and installation and O & M costs. In a bioenergy producing sugar-mill, there are three primary outputs. i.e. i.Crystalline Sugar, ii. Ethanol and iii. Electricity

The agronomic and processing parts of the biofuel production chain of the sugarcane systems and their impacts are described below through a process flow diagram in Fig. 3 (Woods, 2000).

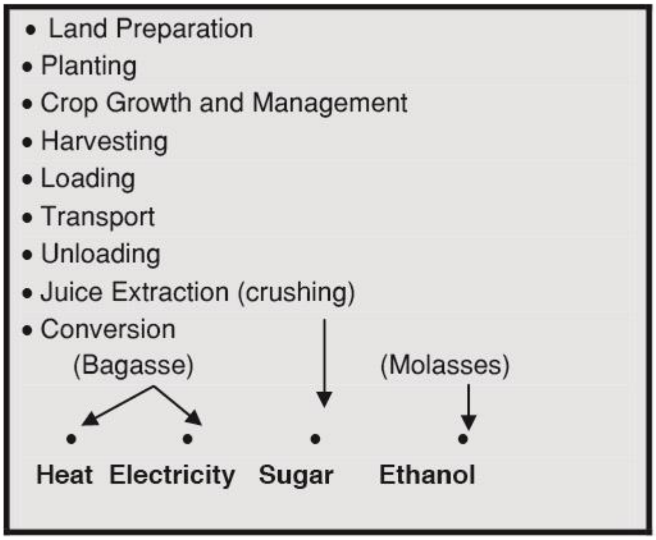


Figure 3. Process flow diagram of Sugar, Ethanol and Electricity Production

In the processing chain from the point of view of bioenergy production, there are two methods for the separation of the sugars from the fibre. (i) The older technology employs a mill tandem which effectively squeezes the sugar-rich juice from the fibre, (ii) The second method, called 'diffusion', extracts the sugars by washing them out of fibres. The diffuser employs a counter-current flow of hot water flowing against the fibres to achieve this. Two primary streams exit these processes, i.e. i) the sugar-rich juices and ii) the fibre-rich bagasse. In view of continuously rising petroleum costs and dependence upon fossil fuel resources, considerable attention has been focused upon alternative energy resources. Production of ethanol or ethyl alcohol (CH_3CH_2OH) from biomass is one way to reduce both the consumption of crude oil and environmental pollution (Lang *et al*, 2001a). Ethanol represents an important, renewable liquid fuel for motor vehicles (Lewis, 1996). Primary consideration involves the production of ethyl alcohol from renewable resources and determination of the economic and technical feasibility of using alcohol as an automotive fuel blended with gasoline (Goldstein, 1981).

In fact ethanol can be used as a liquid fuel in one of the following four ways: 1. Neat ethanol , 2. Blended with petrol, 3. Blended with diesel, 4. Octane enhancer. The demand for biologically derived ethanol for use as a biolfuel is expected to increase as industrialised countries in particular try to cut-carbon emissions associated with transport sector. It is worth pointing out that the production of ethanol is already a large –scale business and in 1998, world ethanol production was estimated at 32 billion litres up from 29.9 billion litres in 1995 (Berg, 1998b). According to Morrison and Boyd (1983) there are three principal methods to get the simple alcohols which are the backbone of aliphatic organic synthesis. There are-

a) by hydration of alkanes obtained from the cracking of petroleum,
b) by the hydrolysis of cellulosic materials, and
c) by fermentation of carbohydrates.

RESULTS AND DISCUSSION

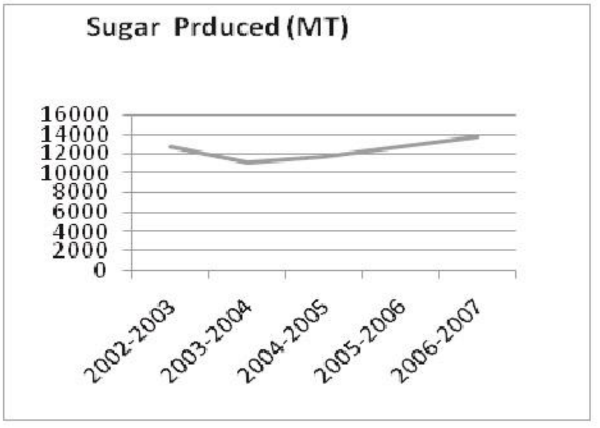
By-products produced from sugarcane in sugar industries are very important renewable source of energy. Hossain *et. al.* (1994) reported in their paper that they found by analysis of ten years data from 1981 to 1990 that the average annual production of sugarcane was 6.97 10^6 tons and the average annual net energy productivity of this sugarcane is 24.7764 10^9 MJ of which 22.82 10^9 MJ is from sugarcane biomass and 1.9537 10^9 MJ is from molasses. These energies obtainable from biomass and molasses may be used commercially for the production of electricity and motor fuel to minimize the energy crisis of the country and to reduce the dependence on foreign grants for energy production system. The heavy, dark, viscous liquid discharged by the centrifugals after no more sugar can be separated from the final low-grade massecuite by usual factory method is called final molasses, blackstrap molasses. Molasses contains (Table 2) particularly the whole of the soluble non-sugars found in the clarified juice, with sucrose, invert sugar and part of the chemicals used in the clarification process.

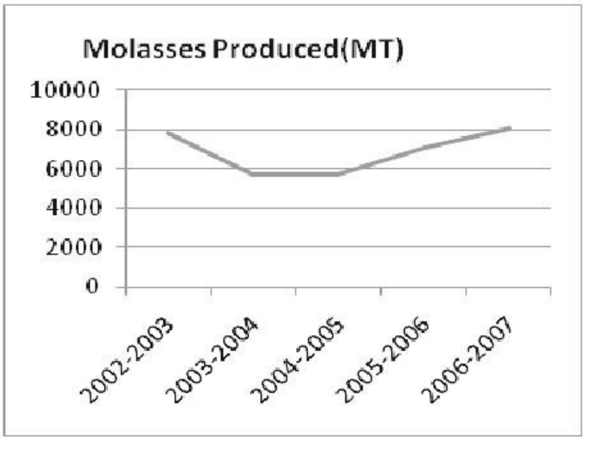
Table 2. Composition of molasses

The compositions of molasses are	Quantitative range
Sucrose	33.0% to 41.0%
Reducing sugar	13.0% to 17.0%
Total fermentable sugar as reducing sugars	48.0% to 53.0%
Ash	13.0% to 15.0%
Nitrogen	0.5% to 1.0%
Others	4.0% to 6.0%
Water	18.0% to 21.4%

Case studies of Thakurgaon sugar mills

Quantitative products and by-products (molasses) of Thakurgaon sugar mills (TSM) from 2002-03 to 2006-07 (which were collected from sugar mills annual reports by physical visits) are presented in Fig.4. It is observed from Fig.4 that sugarcane crushed in 2002-2003 was the highest (1,70,770.09 MT) among 5 crushing seasons of TSM. The trend was declining in the following years and increasing from 2005-06 crushing season. Sugar produced in 2006-07 crushing season was the highest (10,957.30 MT) and was the lowest (5,523.20 MT) in 2004-05 crushing season. The molasses produced in 2002-03 (6,251.20 MT) and in 2006-07 (6,165.70) seems very close to each other while the lowest (2,819.88 MT) was in 2004-05 crushing season. On an average of the five crushing seasons sugar and molasses produced in per cent basis were 6.82% and 3.662% respectively of total cane crushed. The by-products production scenario of TSM is reflected in the following graphs of Fig. 4





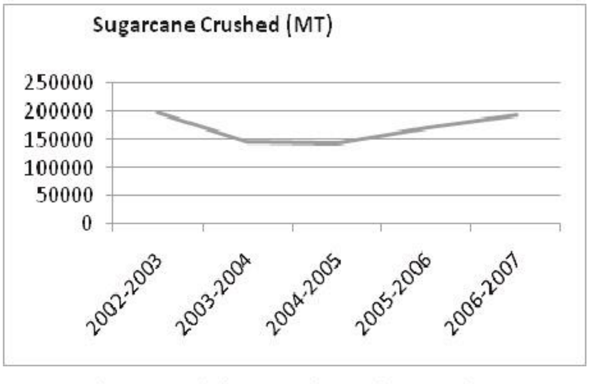


Figure 4. Sugarcane products and by products in metric ton (sugar and molasses) from 2002-2003 to 2006-2007 of TSM

Case studies of Carew & Company Sugar Mills and Distilleries

The distillery has made the Carew and Co. Sugar Mills profitable by selling its distillery products in home and abroad. The products and brands that are produced and marketed by Carew's distillery are shown in Fig 5. The quantitative products and by-products from sugarcane (Fig 6) as learnt from concerned experts and annual reports of Carew and Co. are shown in Fig 6. From Fig. 6 it is seen that from 2002-2003 to 2006-2007 crushing seasons at Carew and Co. the highest sugarcane crushed (19,9,041.00 MT) was observed in 2002-2003 crushing season and it was the lowest (14,4,442.91 MT) in the following year 2003-2004. Then an increasing trend in sugarcane crushed (MT) was observed. The highest sugar (13,719.00 MT) was obtained in 2006-2007 crushing season which was 7.09 % of total cane crushed in that season. However, the lowest sugar (11,118.05 MT) was obtained in 2004-2005 season. The highest amount of bagasse produced (73,317.00 MT) in 2002-2003 which was 36.83% of total cane crushed and the lowest 53,923 MT was in 2004-2005 which was 37.81% of total cane crushed. Molasses, the raw material of distillery products and ethanol was the highest (8,083.75 MT) in 2006-2007 followed by 7,859.00 MT in 2002-2003. The corresponding conversion percentages of molasses were 4.18% and 3.95% of total cane crushed in respective years. The lowest amount of molasses 5695.42 MT was produced in 2003-2004 which was 3.94% of total cane crushed. The distillery product ethanol expressed in lac proof litre (Lac PL) was the highest (33.93) in 2002-2003 followed by 33.15 in 2006-2007 and was the lowest (30.00) in 2004-2005 sugarcane crushing season at Carew and Co. For easy understanding the quantitative products and by-products scenario of sugarcane are furnished below in graphical presentation. Discussion was made regarding the production process and use of ethanol in the present context with the chemists of Carew's Distillery. They agreed that ethanol in a modern world is the most widely used liquid biofuel. It is an alcohol and is fermented from sugars, starches or from cellulosic biomass. But most commercial production of ethanol is from sugarcane or sugar beet, as starches and cellulosic biomass usually require expensive pretreatment.

Greenhouse gas emissions in the utilization of ethanol

The worldwide desire is to reduce greenhouse gas emission which leads to an increased interest in renewable resources for energy production. The greenhouse-gas emission produced from ethanol combustion (direct and indirect emissions) is of great importance and hence studied by researchers. The direct combustion of ethanol generates 1.51 Kg CO_2/l; however the emissions including the indirect plant-emissions are 4.8 kg CO_2/l. The cultivation, maintenance and harvesting of a crop generates about 490 kg CO_2/ha (Kramer *et al.*, 1999; Koga *et al.*, 2003) excluding fertilizer.

A value of 660 kg CO_2/ha is utilized to allow for the indirect emissions for diesel utilized in cultivation to harvesting. A value of 940 kg CO_2/ha is used for fertilizer manufacture (Kaltschmitt *et. al.,* 1997). Thus, the total greenhouse-gas production value for cultivation to harvest including fertilizer use and indirect emissions for diesel combustion is taken as 1600 kg CO_2/ha.

From the above table it is seen that the possible highest return in from ethanol production in the present context of prices of sugarcane and its by products.
1 ton sugarcane contains 40 kg molasses and 40 molasses yields 8 litre ethanol (13.4 proof litre).

Economic return from products and by products per tonne of sugarcane

i) 1 tonne sugarcane gives 72 kg sugar which costs (@ Tk. 55.00 per kg = Tk. 3960.00)
ii) 1 tonne sugarcane contains roughly 40 kg (4% of cane weight) molasses which costs (@ Tk. 20.00 per kg = 800.00) or 40 kg molasses gives 8 liter (13.4 proof liter) ethanol which cost (@ Tk. 190.00 per proof liter) = Tk. 2546.00
iii) 1 tonne sugarcane yields 360 kg (36% of cane weight) bagasse which costs (@ Tk. 0.50 per kg) = Tk. 180.00
iv) 1 ton sugarcane yields 40 kg filter cake / press mud (4% of cane weight) which costs (Tk. 0.50 per kg) = Tk. 20.00

Hence, without making ethanol, 1 ton sugarcane with its products and by-products gives return of Tk. (3960 + 800 + 180 + 20) = Tk. 4960.
If ethanol is made then 1 tonne sugarcane with its products and by products gives Tk. (3960 + 2546 + 180 + 20) = Tk. 6706.
From above calculations we get net benefit from products and by products (without making ethanol) per tonne sugarcane = Tk. (4960 – 1770) = Tk. 3190.
And net benefit from products and by products (by making ethanol) per ton sugarcane = Tk. (6706 – 1770) = Tk. 4936.
Hence, ethanol production may impart more benefit of Tk. 1746 (i.e. 98.46% more benefit) per tonne of sugarcane.

Potential of Ethanol production from sugarcane in Bangladesh

At present 15 public sugar mills of Bangladesh on an average produce 70 million tonne of sugarcane annually which can give 4% molasses i.e. 0.28 million tonne of molasses. On the basis of information gathered from DGM (Distillery), Carew and Co. Sugar Mills.

We came to know that 1 tonne molasses yields 335 proof litre (i.e. 200 litre or 160 kg) ethanol (Specific weight of ethanol has been taken as 0.80 kg/litre. Hence 0.28 million tons of molasses an yield 93.8 million proof litre ethanol. The present market value of 93.8 million proof litre ethanol is 17,822 million Taka.
If the total sugarcane is utilized in the production of only ethanol instead of sugar then 938 million PL ethanol can be obtained from 7.0 million tons of sugarcane. The market value of this ethanol is 178220 million Taka. Comparison of producing only ethanol from sugarcane with combined yield of sugar and ethanol from sugarcane is shown in the Table 6.

As fuel, ethanol is eco-friendly, cost effective, job creative, convenient for engine durability, imparts substitution for fossil fuel and helps to save foreign currency. Without affecting existing sugar production, ethanol can be produced from molasses which can be used as automotive fuel in Bangladesh as E-30 for petroleum and E-3 for diesel driven vehicles. At present 93.80 million proof litres of ethanol can be possible to produce annually from molasses of different sugar mills. Scopes of investor to establish private bio-ethanol plant which can reduce fuel dependency, increase job opportunity and contribute in our GDP. As ethanol is more valuable in respect of cost effectiveness than sugar, sugarcane price can be increased as incentives to the farmers to grow more sugarcane which can lead not only more sugar production but also higher ethanol (bio-fuel) production in the country.

Table 3. Probable cost for establishment of an Ethanol Plant in Bangladesh (Ethanol directly from sugarcane)

Tentative / targeted capacity : 30,000 litres / day

Sl. No.	Description of Items	Expense
1	Land	45,00,000
2	Building and Civil Structures	2,50,00,000
3	Plants and Machinery	10,00,00,000
4	Preliminary and pre-operatory expense	80,00,000
5	Contingencies	50,00,000
6	Margin money of working capital	1,00,00,000
7	Total (Indian Rs)	15,25,00,000
	(Bangladeshi Tk)	23,48,50,000

Table 4. Probable cost for establishment of an Ethanol Plant in Bangladesh (Ethanol directly from Molasses)

tentative/Targeted capacity = 30,000 litres/day

Sl. No.	Description of Items	Expense
1	Land	20,00,000
2	Building and civil structures	1,25,00,000
3	Plants and Machinery	5,50,30,000
4	Preliminary and Pre-operatory Expense	35,00,000
5	Margin Money of Working Capital	60,00,000
	Total (Indian Rs)	7,90,30,000
	(Bangladeshi Tk)	12,17,06,000

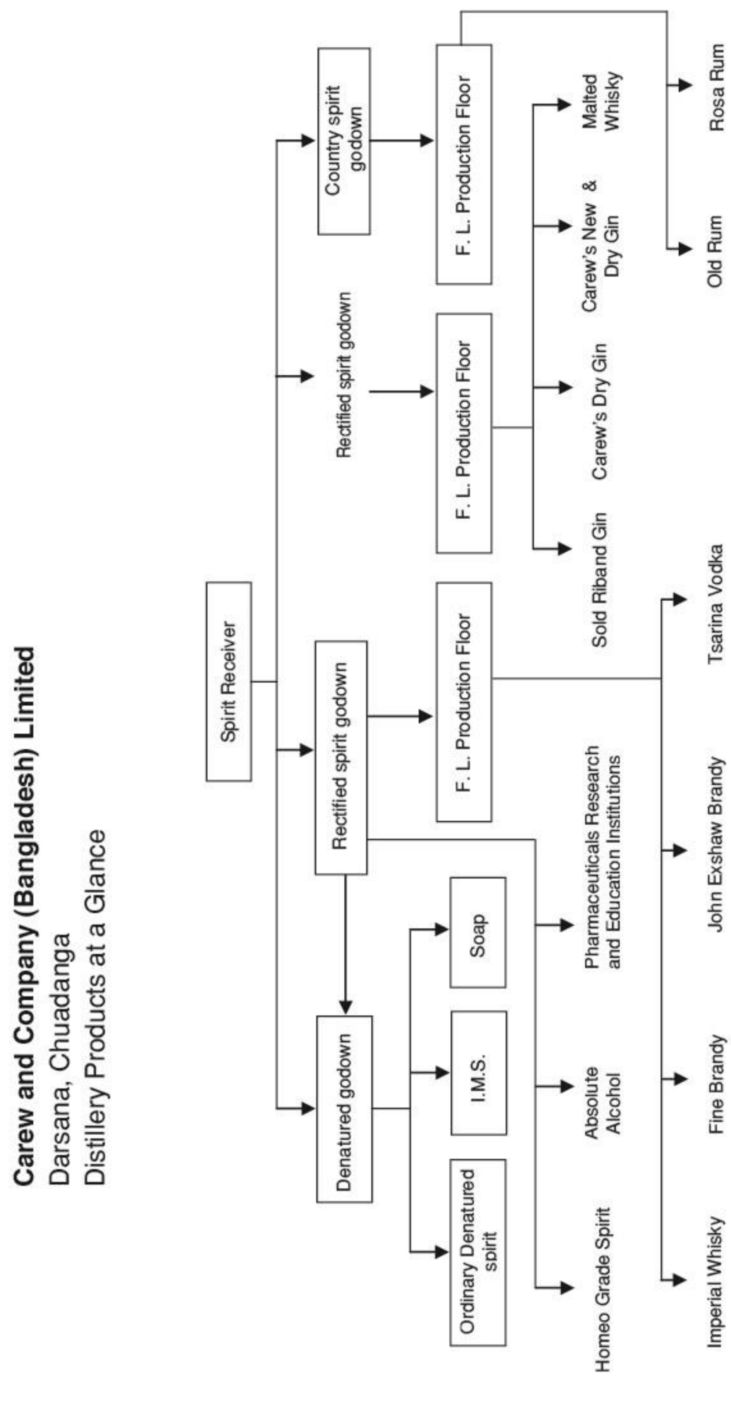


Figure5. Different Products and by products of Distillery at Carew and Co.

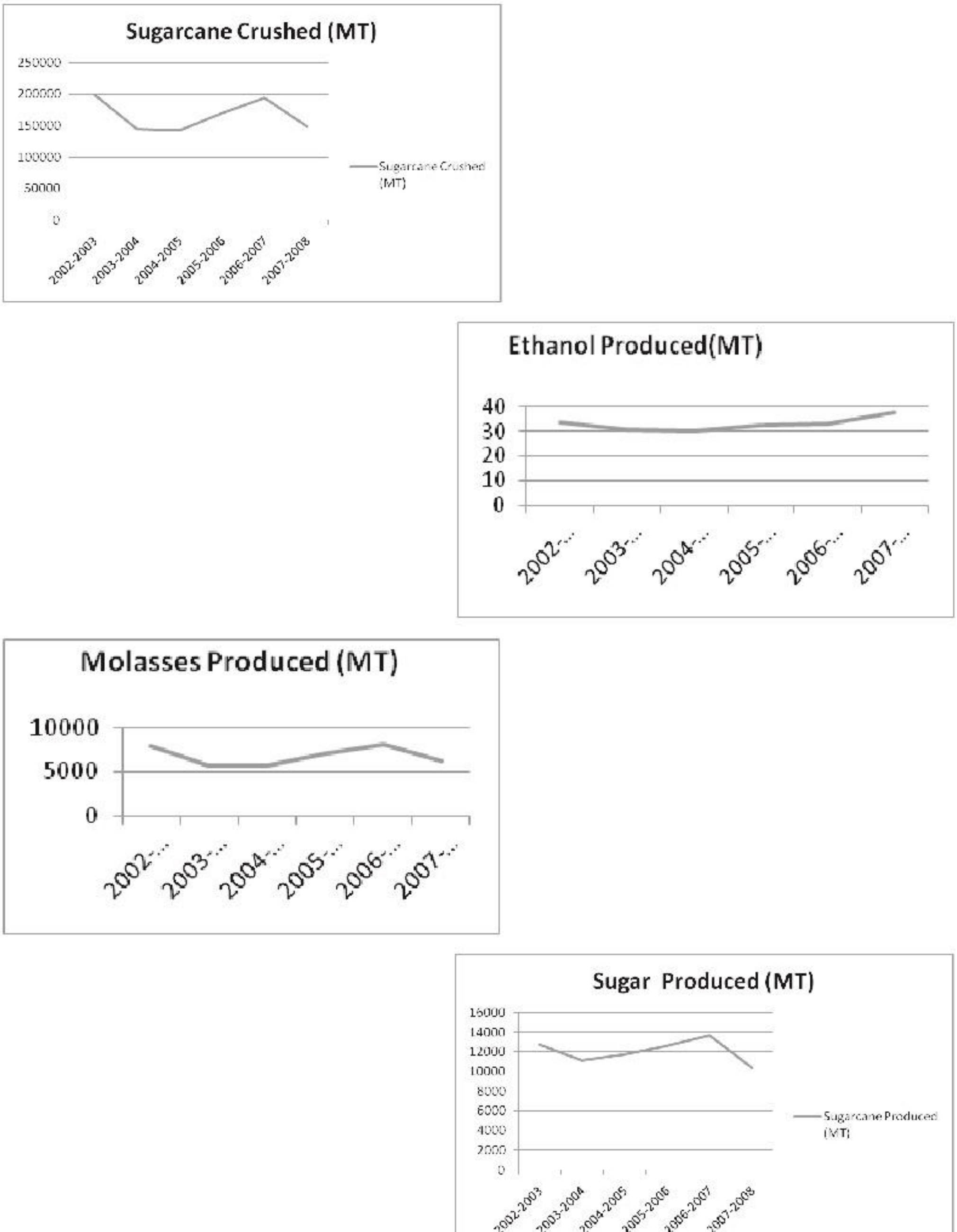


Figure 6. Products and by products from sugarcane (sugar, bagasse, molasses electricity etc) at Carew and Co. from 2002-2003 to 2007-2008.

Table 5. Obtainable benefits of sugar, Goor and ethanol from sugarcane (per ton)

Commodity	Production	Price per ton of sugarcane (Tk.)	Total cost of production (Tk.)	Market Price of Product (Tk.)	Net Benefit (Tk.)
Sugar	72.00 kg	1770.00	3235.00	3960.00	725.00
Molasses	40.00 kg	-	-	800.00	800.00
Ethanol from Molasses	8 Litres (13.4 proof liter)	-	840.00	2546.00	1706.00
Ethanol	80.00 Litres (134 proof liter)	1770.00	2570.00	25460.00	22890.00
Goor	100.00 kg	2680.00	2880.00	4800.00	1920.00

Table 6. Potentiality of sugar and ethanol from sugarcane

Sources	Production (million ton)	Product			Cost (million Tk)	Market price of product (million Tk)	Return (million Tk)
		Molasses (million ton)	Sugar (million ton)	Ethanol (million proof lire)			
Sugarcane	7.00	-	-	938	21770	178,220	156,450
Sugarcane	7.00	-	0.504	-	12,390	27720	15330
		0.28	-	93.8	469	17822	17353
					12,859	45542	32683

CONCLUSION

Sugarcane is a rich source of biomass and bio-energy. In Bangladesh, energy and bi-products from this industrial crop are still unexplored and underutilized. To impart more economic benefit from sugarcane to its growers and stakeholders we must come out from traditional practice of producing sugar only. We must think to harvest maximum from its products and by-products utilizing its potentiality. Ethanol/biofuel production may be a turning point of our losing sugar industry.

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