Version YELLOW

2. METHODOLOGY

2.1. Technical Assessment

The first generation ethanol process from sugarcane is well established in Brazil and it fundamentally consists on sugars fermentation, followed by the ethanol purification via distillation and dehydration.

There are some alternatives to produce second generation ethanol as described by Dias et al. (2012). In this evaluation is considered that surplus sugarcane trash and bagasse are converted to ethanol by steam explosion process, straight to alkaline delignification and enzymatic hydrolysis. In the steam explosion, most of the hemicellulose is hydrolyzed into pentoses, with small cellulose losses and no lignin solubilization. A filter is used to separate the pretreated solids from the pentose. Pentoses produced during pretreatment are fermented into ethanol. In alkaline delignification step, most of the lignin is removed from the pretreated material decreasing its inhibitory effects on the following enzymatic hydrolysis step.

The platform to produce the bio jet fuel, as described by Crawford (2013), consists in three steps. Bio jet fuel is composed mainly by a C-12 to C-16 hydrocarbons and can be produced by ethanol through alcohol to jet route. In the case of a sugarcane industry, the 1st and 2nd generation ethanol is dehydrated with a catalyst to form olefin ethylene. Later, compressed ethylene is dimerized to 1-butene that is sent to a reactor to polymerize into a C-12 hydrocarbon. This oligomer still have a carbon-carbon double bond, thus, the next step consists into hydrotreatment to synthesize a saturated end product. The bio jet fuel is water, sulfur and nitrogen free. The main parameters used in the simulations are shown in Table 01 and a block flow diagram of integrated first and second generation ethanol production with an ATJ platform are displayed in the Figure 01.
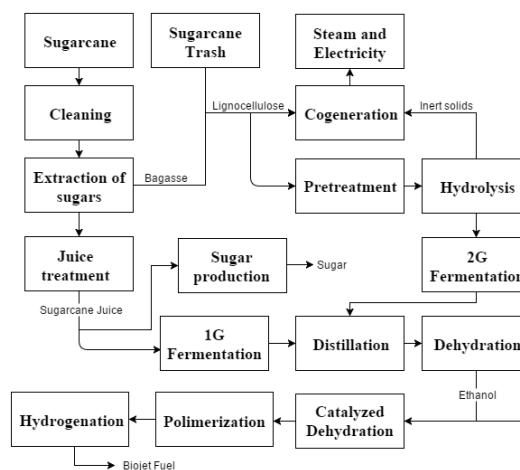

Figure 01 – block flow diagram of integrated first and second generation ethanol production with an ATJ platform

Table 01 – Main parameters adopted in the process simulation of bio jet fuel production form sugarcane

Parameter	Value	Parameter	Value
Sugarcane processed	3.000 kT/year	Boiler Pressure	65,0 bar
Days of operation	200 days/year	Boiler Temperature	510 °C
Sugarcane total reducing sugars content	13,6%	Ethanol to Bio Jet Fuel Ratio	1,8 kg/kg
Sugarcane fiber contents	13,0%	Hydrogen Specific Consumption	0,01 kg/L BJF
Straw productivity (dry basis)	140 kg/TC	Process Power Consumption	29,00 MW
Mix to sugar production	50,0%	Turbine Efficiency	81%
Straw kept in the field	40,0%	Generator Efficiency	98%
Straw moisture (mass fraction)	15,0%	Boiler Thermal Efficiency	88%
Sugarcane Bagasse LHV (50% moisture)	7,5 MJ/kg	Lignin content (dry Basis)	23%
Sugarcane Lignin LHV (50% moisture)	7,3 MJ/kg	Bagasse to sugarcane ratio	26%

Version BROWN

2. METHODOLOGY
2.1. Process Description and Simulation

To assess the economic viability of using sugarcane straw for the production of jet fuel, the base case scenario considers ethanol produced in a second-generation plant to be catalytically converted to jet fuel (ATJ). In the competing scenario, ethanol is supplied from a first-generation plant fed with sugarcane juice (sucrose). These configurations were studied considering either a pre-existing first-generation ethanol plant (retrofit design) or a greenfield project, leading to four design options having the ATJ plant annexed to (1) an existing 1G sugarcane mill; (2) a 2G ethanol plant integrated with an existing 1G mill; (3) a greenfield 1G mill, and (4) a 2G ethanol plant integrated with a greenfield 1G mill. Each of these options is associated with investments with different magnitudes and technology risks. Block flow diagrams representing the four scenarios are shown in Figure 01.

The sugarcane mill has a crushing capacity of 3 million tons per year, and 50% of the sugarcane juice feeds the sugar (food grade) production process. Electric drives are employed in sugarcane preparation and juice extraction systems. The other half of the juice is sent to the first-generation ethanol plant. Ethanol is dehydrated in distillation columns. Regarding the cogeneration system, in scenarios 1 and 3, steam and electricity are produced from the combustion of sugarcane bagasse only. In scenarios 2 and 4, on the other hand, lignin (a by-product from the second generation process) is used as a supplementary fuel to the boilers (operated at 65 bar). The process consumes all steam produced; therefore, boilers are connected to back-pressure turbines. Further information on the first generation plant (sugar + ethanol plants) and cogeneration unit may be found elsewhere (DIAS et al., 2012).
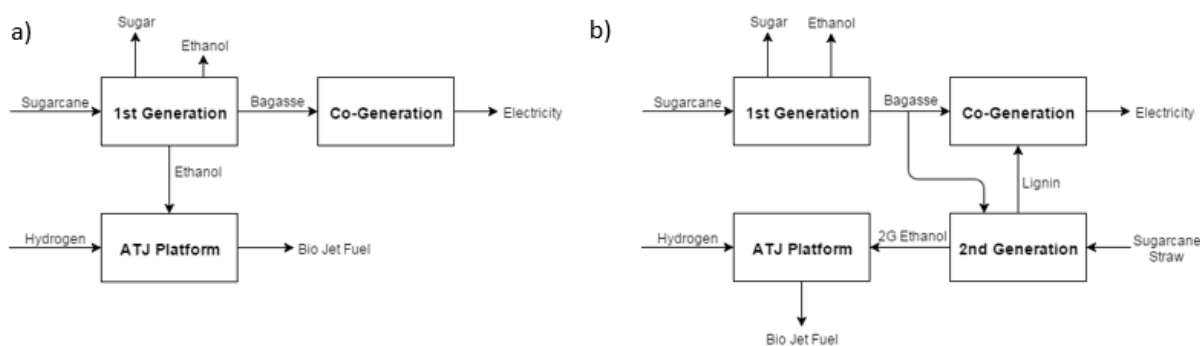

Figure 01 – Technical configuration of scenarios (a) 1 and 3; and (b) 2 and 4.

For the production of second-generation ethanol (scenarios 2 and 4), 60% of the sugarcane straw is collected and transported to the mill, which is mixed with surplus bagasse (bagasse accounts for 27% of the biomass mix, dry basis), leading to a production of 73,000 m^3 ethanol per year. Biomass is converted into fermentable sugars through pretreatment (steam explosion) and enzymatic hydrolysis. Upon pretreatment, most of the hemicellulose is hydrolyzed into pentoses, with small losses of cellulose and the absence of lignin solubilization. Sugars (glucose + xylose) are co-fermented into ethanol, and the fermentation beer is sent to the distillation/dehydration unit of the first generation mill.

The conversion of ethanol to jet fuel is conducted in three steps (CRAWFORD 2013). In the first, ethanol is catalytically dehydrated to ethylene. Afterward, compressed ethylene is dimerized to 1-butene that is sent to a reactor to polymerize into a C-12 hydrocarbon. This oligomer still has a carbon-carbon double bond, thus, the third step consists of hydrogenation to synthesize a saturated end product. The jet fuel is water-, sulfur-, and nitrogen-free. The main technical parameters used in the simulations are shown in Table 01 and a block flow diagram of the integrated first- and second-generation ethanol production with an ATJ platform is presented in Figure 02.

The energy and mass balances of the four scenarios were simulated in a Microsoft Excel® spreadsheet and calculations were solved iteratively by maximizing the production of ethanol while meeting the biomass and steam process requirements. Process stream values (ethanol, sugar, sugarcane, sugarcane straw, sugarcane bagasse, electricity, steam, jet fuel, and hydrogen) fed the economic analysis.
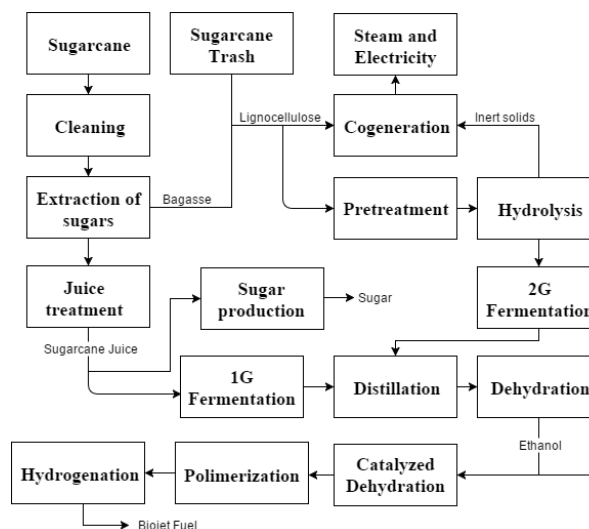

Figure 02 – Block flow diagram of integrated first and second-generation ethanol production with the ATJ platform

Table 01 – Main parameters adopted in the process simulation of jet fuel production from sugarcane straw

Parameter	Value	Parameter	Value
Processed sugarcane (t/y)	3,000,000	Steam boiler pressure (bar)	65.0
Operational days (days/y)	200	Steam boiler temperature (°C)	510.0
TRS content in sugarcane[1]	13.6%	Turbine efficiency	81%
Fiber content in sugarcane	13.0%	Generator efficiency	98%
Straw productivity (dry kg/ t of sugarcane)	140	Boiler thermal efficiency	88%
1st generation integrated plant configuration (ethanol:sugar)[2]	50:50	Lignin content in sugarcane trash	23%
Straw kept in the field	40.0%	Bagasse moisture content	50%
Straw moisture content	15.0%	Ethanol to jet fuel ratio (kg/kg)	1.8
Sugarcane bagasse LHV (MJ/kg)	7.5	Hydrogen consumption (kg/L jet fuel)	0.01
Sugarcane lignin LHV (MJ/kg)	7.3	Jet fuel plant capacity (ton/a)	30,000

[1]TRS: total reducing sugars; [2]based on the volume of sugarcane juice