TBP01x - Best Practice - Week 6a

Hello. My name is Joaquim Seabra and in this video I will show you the Brazilian case of first generation bioethanol production, using sugar cane as feedstock.

In the 2012/2013 harvest season, 590 million tons of sugarcane were processed in Brazil, yielding more than 38 million tons of sugar, 23 billion liters of ethanol and 12,200 GWh of surplus electricity. The mills in which this cane is processed are concentrated in three regions in Brazil: North-East, Central-West and South-East. More than 50% of the about 400 mills registered at the Brazilian Ministry of Agriculture, Livestock and Food Supply are mills with adjacent distilleries, followed by a growing number of autonomous distilleries (which produce only ethanol), and lastly by a small number of sugar mills. The mills with adjacent distilleries feature some flexibility, and the decision on how much of each product will be made varies according to the market conditions and technical aspects of the mill's design. In those distilleries, ethanol can be produced either from cane juice, molasses, or (more commonly) a mixture of both. Mills come in different sizes. The average sized mill in Brazil processes around 1.5 million metric tons of sugarcane per season, which usually lasts only 7 to 8 months per year.

At the mill, the production process starts with sugarcane reception. The loaded trucks are weighed, and cane samples are collected for laboratorial analysis. Sucrose content is evaluated for industrial control and for establishing the sugar cane price to be paid to cane growers. The trucks are unloaded, cane is transferred to the feed tables, and from there to the cleaning and milling system.

In the feed table, only the burned, manually harvested cane is washed for removal of impurities. Some mills feature a dry cleaning station to remove impurities from the unburned, mechanically harvested cane stalks. The feed table transfers the stalks to one or more conveyors that carry the cane to milling, via a preparation system.

The cane preparation system comprises sets of knifes and shredders that promote the increase of cane density and cane cells disruption, in order to facilitate the subsequent juice extraction. The juice extraction can be performed either by diffusion or milling (which is more common in Brazil). Milling consists of crusher rolls that separate the juice from the fiber by a volumetric process. To increase extraction, imbibition water is added in counter-flow with bagasse. A secondary, yet extremely important, aim of milling is to produce a final bagasse in suitable condition (at approximately 50% moisture content) for fast burning in the boilers.

In the mills with adjacent distilleries, after extraction, part of the juice is sent to sugar production, and part is diverted to ethanol production (which will be our focus today). The juice initially contains varying amounts of impurities. A primary treatment eliminates insoluble impurities, while the following chemical treatment promotes coagulation, flocculation and precipitation of other impurities, which are removed by sedimentation. The flocculated impurities are continuously removed in the clarifier, and the decanted juice is collected from the upper part of each compartment. The sedimented sludge is sent to a filter (for sugar recovery), whereby some juice is separated from the filter cake, and returned to the process.

After the clarification, the juice can be slightly concentrated in evaporators and/or mixed with molasses to produce the so-called must. Molasses is a by-product from sugar production, which contains the unrecovered sugars from the crystallization and centrifugation process. In the fermentation tanks, Saccharomyces cerevisiae yeasts convert the sugars mainly into ethanol and CO2, among other secondary products such as higher alcohols, glycerol and aldehydes.

The most common process in the Brazilian mills is the Melle-Boinot, which comprises a fed-batch fermentation with yeast recycling. The fermentation takes place in closed tanks, and the gas released during the process is washed for alcohol recovery. The fermentation time ranges from 8 hours to 12 hours, after which practically all the sugars are consumed. During this period, heat exchangers are used to keep the temperature at a suitable level. At the end of fermentation, the fermentation broth has an average alcohol content of 7-10%. In the fed-batch system, after the fermentation, the “wine” is centrifuged for yeast recovering. The recovered yeasts are then treated with acid to reduce contamination, before being recycled back to fermentation, while the centrifuged wine is submitted to distillation.

The distillation is performed in the following column sets: distillation, rectification, and dehydration. In the distillation columns, vinasse is removed at the bottom. At the rectification column, hydrous ethanol is produced, as well as flegmaça and fusel oil, which is stored for commercialization. Hydrous ethanol can be either commercialized in this form or submitted to a dehydration process to produce the anhydrous ethanol. Three methods are commonly used for ethanol dehydration: azeotropic distillation; adsorption dehydration by molecular sieves; or extractive distillation by mono ethylene glycol. The most common method still is the azeotropic distillation with cyclohexane, but molecular sieves are becoming much more common, especially in the new units.

The main outputs from the process, excluding electricity, are shown here. It must be mentioned that in the case of an autonomous distillery, no sugar is produced and the ethanol yield is around 85 liters per ton of cane. The main by-products produced in the process are vinasse, filter cake mud and bagasse boiler ash and soot. These by-products are completely recycled to the sugarcane fields: vinasse in liquid form for ferti-irrigation, and filter cake mud and boiler ash and soot to be used as fertilizers.

The entire energy requirements of the process are provided by a cogeneration system that uses only bagasse as fuel. The modern mills in Brazil feature completely electrified milling systems and are not only self-sufficient in energy, but are also able to export considerable amounts of electricity. These mills are equipped with high-pressure cogeneration systems, for instance 68 bar/480°C boilers, with condensing extraction steam turbines. As illustrated in the slide, part of the steam exhausted from the turbines is used to attend the heat requirements of the sugar and ethanol processes. Likewise, part of the power produced in the plant is used to attend the power requirements of the processes, and the excess electricity is exported to the grid. Using only bagasse as fuel, the electricity exports can reach around 60 kWh per ton of processed cane, but the use of sugarcane straw as supplementary fuel to bagasse can lead to much higher levels.

As for the economics, the slide shows, on the left side, the breakdown of the overall sugarcane agro-industrial costs estimated for the expansion regions in the 2011/2012 harvest season. It can be seen that sugarcane related costs represent approximately two-thirds of the total cost. In a different breakdown (shown on the right), one can see that the operational costs comprise the majority of the ethanol's cost, followed by similar contributions from land and capital costs.

Talking about technology trends for the future, in the short term, mills are expected to improve energy efficiency and expand the diversification of sugar-based products, including some production of value-added chemicals and hydrocarbon fuels. Electricity exports are projected to increase progressively, with significant contributions from the sugarcane straw collection, which will allow mills to export electricity beyond the sugarcane season. However, alternative bagasse uses should also be in place in the future, especially those aimed at the production of second-generation biofuels, which is a new and exciting new chapter in technology for biobased products.