SIMULTANEOUS PRODUCTION OF SUGAR AND ALCOHOL FROM SUGARCANE

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Abstract

This paper describes the current production of sugar and alcohol from sugarcane in Brazil, with emphasis in pointing out the advantages of simultaneous production of both products. The idea of the study is to provide a basis for convincing people in other sugar countries to begin making ethanol as a feasible and profitable activity. The data presented were collected in the factories that belong to the Cooperative (Copersucar). It can be concluded that the Brazilian way for making sugar and alcohol simultaneously has some advantages compared to other sugar countries because less energy is used, the quality of the products is better, and the yields attained are greater (stoichiometric ethanol yield 91%), with lower costs (about $US 0.20/litre ethanol).

Introduction

Sugar production is a very old industry in Brazil, beginning in the XVIIth century. Although drinking alcohol has also been a common product of sugarcane for centuries, fuel alcohol began being produced and used here only in the XXth century. A big national alcohol program was launched in the mid 1970s as a means for replacing imported petroleum and also taking advantage of existing production capacity and low sugar prices. Figure 1 shows the evolution of sugar, ethanol and sugarcane production.

Evolution of Brazilian Production of Cane, Sugar and Ethanol

Fig. 1—Brazilian production.
It can be seen that, before 1976, the ethanol production was about 0.6 billion litres per year, made exclusively from molasses. From 1977 until 1985, ethanol production grew very quickly together with sugarcane production, but sugar production increased just a little. This means that more and more ethanol was made using sugarcane juice, together with molasses since, besides independent ethanol plants that appeared at that time, the existing sugar plants also began increasing their ethanol production sending to the distillery not only molasses but sugarcane juice as well.

The variations in the proportion of sugar and alcohol production that happened later points to one big advantage of the simultaneous production of two products, that is the flexibility, i.e. milling capacity could be fully maintained, but the proportion of sugar and alcohol could be regulated, depending on market requirements.

**Production process**

Figure 2 shows a typical simplified production flow sheet for the Brazilian conditions.

![Diagram](attachment:image.png)

It can be seen that having the distillery annexed to the sugar factory allows a series of manoeuvres that are virtually impossible if the distillery is separated:

1. All low quality sugar containing streams such as secondary juice (from the 2\textsuperscript{nd} to the last mill), filter juice and others can be sent to the distillery with no losses, allowing also the full use of the reducing sugars (glucose and fructose, that amounts to nearly 6% of the total sugars).
2. There is no need to extract so much sugar from the syrups, since richer molasses can be sent to the distillery again with no sugar losses. Final molasses purities are between 55% and 75%, using two massecuites, compared with less that 50% for a typical sugar mill.
3. Low pressure vapours from the evaporators can be efficiently used in the heat treatment of the juices sent to the distilleries and also in the distillation of the fermented mashes.
4. All problems that occur in the sugar factory can be solved much more easily by sending sugar containing materials to the distillery.
5. The necessity for evaporation of juice sent to the distillery is minimised since it can be mixed with molasses, in order to reach the right sugar concentration for the fermentation (18–24\degree Brix).
6. The same facilities used for sugar production can be shared with ethanol production such as steam and electricity generation, water, waste disposal, laboratories, maintenance workshops, management, safety, commercialisation, etc.

The results of this integration are:
1. Lower production costs of sugar and ethanol (due to the high stoichiometric ethanol yield around 91% for the past seven years, compared with values from 80% to 87% for conventional distilleries).
2. Better quality of both products, especially the sugar quality that can be kept almost constant, even with low quality sugarcane.
3. Surplus energy that can be sold as electricity to the grid or as fuel bagasse for other industries.
4. Optimisation of critical agronomical operations such as harvesting, enhancing industry stabilisation, and optimisation of milling.
5. Profitability even with low sugar prices.

Making fuel ethanol also brings relevant environmental and social benefits due to:
1. Replacement of fossil fuels by a renewable one that has almost zero net CO₂ emissions
2. Abatement of air pollution in big cities.
3. New jobs creation and collection of more taxes in the countryside.

Evolution of the integration of sugar and alcohol production

Thousands of performance data were collected from associated mills during the extended period that began with the large-scale ethanol production until today.

Most important are the data from the fermentation process that evolved as a function of the varying proportion of ethanol to sugar.

Analysing these data, it is possible to say that molasses as a raw material for ethanol production is definitely a more complicated substrate than sugarcane juice, but also this material is not optimal since it has not enough sugar to make cheap ethanol. Increasing the sugar content by means of evaporation only is not enough since, for fermentation until a high alcoholic content is obtained, a greater nutrient concentration is needed, so using molasses mixed with sugarcane juice is a better solution.

Typical sugarcane juice has only 13° Brix and, mixing it with our rich molasses, one can have 24° Brix (enough for more than 9% v/v final ethanol content) with an almost optimum balance of nitrogen, phosphorus, salts (K⁺, Ca²⁺, etc.) and micronutrients.

Figure 3 shows the historical profile of an important parameter of the fermentation process, the final alcoholic content of the fermented mash.

**Final ethanol content (% vol.)**

![Fig. 3—Final ethanol content.](image-url)
It can be seen clearly (compare with Figure 1) that, working only with molasses (1974–1977), the final ethanol content was around 7% (v/v). With an increasing proportion of alcohol production (more sugarcane juice mixed with molasses), it could reach ca. 9.5%. The clear tendency of lowering this parameter after 1992 is due to the large increase in sugar production, reinforcing the lower molasses fermentability.

Several other similar profiles are available for several parameters, all them showing relevant improvements in ethanol production. The stoichiometric ethanol yield, a most important cost parameter, also evolved very favourably, from 82–85% for molasses to more than 91% for juice plus molasses.

The poorer molasses fermentability when compared to sugarcane juice, in our Brazilian conditions, where we use the fed-batch or continuous multistage processes with total cell recycle and acid treatment of the recycled yeast, is due to several reasons. It is mainly related to its high buffering capacity which puts limits to the efficiency of the yeast acid treatment (see Figure 2). It is also due to the higher salts content (e.g. calcium, potassium, etc.) and, with corresponding increases in the osmotic pressure, there is a shift in cell metabolism, with a significant increase in glycerol production (Petrovska et al., 1999), and a decrease in cell viability, due to the higher level of stress.

Also in the Brazilian conditions, molasses can have some sulfite, which also leads to more glycerol and less ethanol production. Finally, due to the limited efficiency of the acid treatment and increased nutrient availability, there is an increased growth of undesirable microorganisms such as lactic acid bacteria and ‘wild’ yeasts, some of them inducing a co-flocculation phenomenon with the fermenting yeast which leads to severe losses.

Treating the molasses is not an economical and feasible option, as it is much easier to mix it with sugarcane juice, and there is then an optimum synergy.

For example, when only molasses is used, the consumption of sulfuric acid for the yeast treatment can be as high as 25–30 g/L of ethanol and, using sugarcane juice and molasses, it can be as low as 5–8 g/L. The high use of sulfuric acid increases the yeast death rate considerably, and it is a clear sign of buffering.

Conclusions

It is shown that producing sugar and ethanol simultaneously lead to a great optimisation of the whole sugar business, with benefits for the sugar and alcohol production. The fermentation process that is used here is very efficient and evolved very favourably as a function of using increasing proportions of sugarcane juice, mixed with molasses. Using only sugarcane juice, even if concentrated by evaporation to obtain a high final ethanol content, is not a better option than using sugarcane juice mixed with rich molasses.

The final results are low cost and high quality of the sugar and ethanol products.

REFERENCE