31. MOLASSES QUALITY AND ETHANOL YIELD IN BRAZILIAN FACTORIES

N. V. Amorim and H. Campos
Escuela Superior de Agricultura "Luiz de Queiroz",
University of Sao Paulo,
Piracicaba, S.P., Brazil, CEP 13.400

ABSTRACT

Correlation studies between several parameters and ethanol yield in three ethanol fermentation plants were carried out. Sulfite, phosphoric acid, sodium phosphate used for juice clarification affects molasses quality and ethanol yield when used for ethanol production. Brix, purity, as well as reducing sugar in the molasses, also are associated with ethanol production. Suggestions to improve molasses quality for ethanol production will be given.

KEYWORDS

Molasses quality; ethanol yield; yield fermentation; ethanol from molasses; sugar cane molasses; molasses fermentation.

INTRODUCTION

In Brazil, the ethanol production from sugar was mainly from sugar cane molasses. Because of the fact that ethanol from oil was cheaper than the ethanol from molasses, the fermentation plants in Brazil did not improve in the last 30 years. After 1973, the situation changed, and the ethanol price increased in the world market and Brazil increased its production, first by fermentation only with molasses, and now with molasses and cane juice. It is known in the literature that ethanol yield as well as Baker's yeast production from molasses fermentation depend upon molasses origin, i.e. molasses quality (Bergander, 1979; Hodge and Hildebrandt, 1954; Olrich, 1969). Although most of the ethanol produced today in Brazil comes from juice and not from molasses, it is interesting to note that most of the ethanol produced today comes from sugar factories which produce sugar and ethanol. Because of the fact that the price of alcohol and sugar in Brazil are linked for political reasons, it is important to optimize the sugar production, sugar quality and also the ethanol yield. Knowing the process of sugar production and the factors which affect molasses quality, one may improve the ethanol yield when molasses is used, by improving some steps of the process.
MATERIALS AND METHODS

The data presented in this paper came from three sugar mills which also produce ethanol and they are the following: Usina Santa Elisa S.A. (Sertãozinho, S.P.), data from four years; Cia. Açucareira Vale do Rosário (Morro Aguda, S.P.), data from six years and Iráianos Biagi S.A. Açúcar e Alcool - Usina da Pedra (Serrana, S.P.), data from two years. Chemical and physical methods used in the analysis of sugar and alcohol were from INCUASA (mentioned in Meade and Chen, 1977). The last year, however, total reducing sugar and reducing sugars procedure (Amorim, Zago and Mores, 1979). Ethanol was measured by distillation in an adapted micro-Kjeldahl apparatus and the density measured in an Anton Paar digital densimeter (DMA-45) (Amorim, Zago, Gutierrez, 1979). Statistical analyses were made following the suggestions of Pimentel Gomes (1963).

RESULTS AND DISCUSSION

It seems that the main aspect of differing molasses quality for ethanol production is due to the different treatments to which the juice is submitted in order to remove interfering compounds or salts (this process is called clarification or defecation) which affect sugar crystallization, centrifugation, exhaustibiility and filterability. Depending upon the type of sugar to be produced, the clarification process may differ. In general, to achieve high sugar purity, more chemicals, flocculants, polymers, etc. have to be added in the juice to remove impurities. On the other hand, when more sucrose is crystallized and removed from the massecycle, the lower is the purity of the molasses. Even producing the same type of sugar, clarification process may vary depending upon the quality of the cane and the juice. The lower the quality, the harsher is the treatment. As it is shown, later, the clarification process may affect the sugar composition of the molasses, as well as the ethanol production.

In Brazil, the clarification process to produce white sugar uses lime and sulfite. Figure 1 shows that an inverse correlation exists between Pol and reducing sugar in molasses. The more sulfur that is burned for clarification, the more reducing sugar is found in molasses, and the less is the polarization. Sulfite decreases the pH, and more sucrose might be hydrolyzed in the process.

It is interesting to note that there is a negative correlation between reducing sugar in molasses and ethanol yield (Fig. 2). Similar results were found by Dalmaux, (W.B.) with Cuban molasses. However, Dalmaux used the ratio sucrose/reducing sugar to correlate with the capacity of the molasses to produce alcohol. The higher the ratio, the higher the ethanol produced by fermentation, based on total reducing sugars.

The purity of molasses (Pol/Brix) also affects the ethanol yield (Fig. 3). This result agrees with the data shown in Fig. 2, because the higher the reducing sugar, the lower the purity.

The amount of sulfur used for juice clarification affects the ethanol yield drastically, chiefly if the sulfur exceeds 400 g/ton of cane (Fig. 4). It is believed that not only does sulfite inhibit fermentation, but also the calcium that should be added to neutralize the sulfite. Calcium precipitates Zn^{2+}; Mn^{2+} and PO_{4}^{3-}, and these three elements are important in fermentation.

Even if juice is used as the main substrate, the molasses content of the must in combination with the amount of sulfur used affects significantly the ethanol yield (Figs. 5 and 6). Besides, the effect on ethanol yield, sulfite complexes with acetaldehyde, avoiding the reduction to ethanol. Acetaldehyde builds up in the fermentation must and when it is distilled (column A), the acetaldehyde is oxidized to acetic acid, increasing the acidity of the alcohol produced (Fig. 7). It is possible to
control the alcohol quality, although it takes some time.

The Brix of molasses also was negatively correlated with ethanol yield (Fig. 8) and two reasons might explain what was found: one of them is that, in winter time, people used to apply steam in the molasses in order to pump it. Caramelization always occurred and the higher the Brix, the more steam should be applied to overcome the problem. Another reason might be that reactions of caramelization (Maillard type) increase with solids concentration (Olbrich, 1969; Bergander, 1969; Hodge and Hildebrandt, 1954).

Phosphate is known to be important in fermentation, and a positive correlation was found between phosphoric acid used in juice clarification and ethanol yield in molasses fermentation (Fig. 9). It is important to say that the cane of most of the sugar plants in this region had a low level of phosphorus in the juice; for this reason, the addition of phosphorus in the form of phosphoric acid helped clarification. However, while several forms of phosphate helped clarification, the tri-sodium phosphate used for juice clarification affected negatively the ethanol yield (Fig. 10). The reason for this result might be related to the solubility of sodium. This cation does not precipitate in the clarification process and builds up in the molasses. Due to high concentration of another cation, the potassium found in molasses, the competition with Mg²⁺, Zn²⁺ and Mn²⁺, might have depressed the uptake of these other cations, affecting negatively the ethanol production.

It is well-known in the sugar industry that cane of poor quality is difficult to purify and also to exhaust the massecuite; for this reason, the amount of molasses per ton of cane increases. Figure 11 shows that a negative correlation exists between molasses production and ethanol yield. Because of the fact that sugar was measured by copper reduction methods, it is possible that part of the measured sugar is not fermentable sugar (Satter and Zerban, 1945). However, these reducing non-fermentable compounds were produced by destruction of fermentable sugars.

In Brazil today, since most of the alcohol is produced in annexes distilleries (plants which produce sugar and alcohol), an improvement in the ethanol yield may be achieved by controlling the sulfur and calcium applied in the clarification process. Because of the fact that it is not necessary to exhaust the massecuite, one may produce molasses of higher purity, lower Brix and chiefly do not use steam to pump the molasses in the cold weather. Several of these suggestions will automatically improve the sugar quality.

![Graph showing correlation between sulfur used for juice clarification and reducing sugar in molasses](image-url)

**Fig. 1. Sulfur burned vs. POL and RS in molasses**
Fig. 2. RS in molasses vs. ethanol yield (molasses fermentation)

Fig. 3. Molasses purity vs. ethanol yield (molasses fermentation)

Fig. 4. Sulfur burned vs. ethanol yield (molasses fermentation)

Fig. 5. Relative amount of sulfur burned in sugar percent of the must vs. ethanol yield (molasses and juice fermentation)
Fig. 6. Mixture of molasses and cane juice affecting ethanol yield (molasses and juice fermentation)

Fig. 7. Effect of sulfur burned in the alcoholic quality

Fig. 8. Brix of molasses vs. ethanol yield

Fig. 9. Phosphoric acid added in juice vs. ethanol yield (molasses fermentation)
Fig. 10. Tri-sodium phosphate added in juice vs. ethanol yield (molasses fermentation)

Fig. 11. Molasses production vs. ethanol yield

REFERENCES