MINIMISATION OF SUGAR LOSS DURING EVAPORATION

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Abstract

At elevated temperatures and long residence times, losses of sucrose due to hydrolysis is a major problem. Thus, it is essential to reduce these parameters as much as possible during evaporation. By replacing the Robert type evaporators by the more efficient, compact Alfa Laval plate evaporator, the residence time during evaporation would decrease by 50 minutes and the sugar loss by 70-80% compared to a Robert quadruple. This would represent annual savings of US$200 000 worth of sugar for a 5000 tcd factory.

Introduction

All process steps in sugar production are subject to sugar loss to a greater or smaller extent. Sucrose is lost either physically, chemically, or by microbial reactions. All these losses add up to a significant amount, and they are impossible to avoid completely. Nevertheless, there is an incentive to minimize them as much as possible. This paper focuses on how to minimize sucrose hydrolysis in the evaporation station without coming into conflict with other concerns such as keeping energy consumption to a reasonable level.

Sugar loss during evaporation

It is well known, both in the beet sugar industry as well as in the cane sugar industry, that sucrose will hydrolyse into glucose and fructose when subjected to elevated temperatures. The effect is more pronounced in the cane sugar industry since the juice is thermally less stable than beet juice. Apart from high temperature, also low \( \text{pH} \) and long residence time increase the level of hydrolysis. The glucose and fructose molecules produced continue to react through Maillard reactions with amines or amino acids to produce melanoidins which affect the white sugar quality by increasing its colour. In fact, the colour increase is more or less directly proportional to the sugar hydrolysis when the glucose and fructose molecules are the rate limiting factor.

The section of the mill where sugar is subject to the highest temperatures during a long period of time is, of course, the evaporation station where losses of sugar in the range of 1.39% on sucrose have been estimated (Edye and Clarke, 1995). For a 5000 tcd mill and a raw sugar price of US$225/t, the economic loss represents no less than US$1720/day, assuming an 11% yield. This amounts to a loss of US$258 000/campaign for a 5 month crushing season. Thus, by minimizing sugar hydrolysis in the evaporators, a lot of money is saved while also resulting in sugar of higher quality, as the colour would also decrease. How could this be achieved?

Sugar hydrolysis increases exponentially with increasing temperatures and residence time. Juice \( \text{pH} \) higher or lower than 7-9 also promotes hydrolysis. Thus, in order to reduce the sugar loss hydrolysis to a minimum, evaporation should preferably take place at:
- low \( \text{pH} \) values, preferably below 100°C;
- \( \text{pH} \) around 8.5;
- short residence time.

Clearly, this mode of operation comes into conflict with other concerns since evaporation at pressures below atmospheric gives room for only 3 effects leading to a very high energy consumption. Therefore, compromises between different aims must be made and there is room for optimising the mode of evaporation. Such compromises have led to different layouts of the evaporation station in beet and cane sugar mills.

In the beet sugar industry, much focus has been on energy savings and the standard today is to use a 6 effect evaporator train with the first effect evaporating at 125-130°C and only the last below atmospheric pressure, so called pressure evaporation. The high temperature in the first effects and the longer residence times due to more effects lead to increased sugar degradation and colour formation in the evaporation station. However, that negative effect of energy savings has in some respects been counteracted by shifting from inefficient Robert type evaporators with long residence times to more efficient evaporators with shorter residence times. Examples of these are the tubular falling film evaporator and the AlfaVap, a rising film plate type evaporator developed by Alfa Laval in co-operation with Sudzucker and British sugar in 1989-90.

It is only recently that energy savings have been a big issue in the cane sugar industry. Thus, focus has been to minimize sugar degradation and color formation by keeping temperatures down. A quadruple evaporation train with Robert type evaporators has become the standard with the first effect operating typically at 110-115°C and the remaining effects operating below atmospheric, so called vacuum evaporation. With an average residence time of 10-15 minutes per effect, the juice is subject to elevated temperatures for roughly one hour taking into account also preheaters and piping.

KEYWORDS: Plate Evaporator, Residence Time, Sugar Hydrolysis, Sugar Losses.
The corresponding average residence time in the AlfaVap is in the range 10–50 sec. (Licha et al., 1989; Schiweck, 1991; Gilatt and Thompson, 1996; Wilhelmsson, 1999). Taking into account separator vessels and pipings etc., the total residence time in an AlfaVap quadruple is substantially less than 10 minutes. Bearing in mind the strong impact of residence time on sugar hydrolysis the substantially shorter residence time has a great impact on reducing the sugar loss in the evaporation station.

When comparing the two evaporator types under the same process conditions, Shiweck (1991) found the sugar inversion to be decreased by 70–80% in the AlfaVap compared to the Robert type evaporator.

As a theoretical example, combining the findings of Edye and Clarke (1995) and Shiweck (1991), an AlfaVap quadruple would decrease the sugar loss from 1.39% to 0.35% of sucrose. This corresponds to a decreased sugar loss in a 5000 tcd plant of 5.72 t/d sugar assuming an 11% yield. During a 5-month crushing season, it adds up to 860 t which represents a value of almost US$200 000 annually at a raw sugar price of US$225/t.

In South America, with Brazil as a front runner, the concept of highly efficient short residence time evaporators have been readily adopted with some factories this year installing their fourth generation of AlfaVaps. Following the success of AlfaVap in South America, many cane sugar customers requested an AlfaVap plate pattern designed specifically for the cane sugar industry. Alfa Laval have answered these requests by developing a new, larger AlfaVap with a low fouling plate pattern. The new unit will be launched during the second quarter of 2001.

REFERENCES