STUDY OF THE SUGAR CANE JUICE CONCENTRATION DURING PRODUCTION OF GRANULATED PANELA BY DIRECT BOILING IN OPEN SYSTEMS AT ENVIRONMENT CONDITIONS

Nelly Lara¹ and Alejandra Clavijo²

¹Quality and Nutrition Department, Santa Catalina Experimental Station, Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP), P.O. Box 1701340, Quito, Ecuador
²Faculty of Chemical and Agro-industry Engineering, Escuela Politécnica Nacional, P.O. Box 17012759, Quito, Ecuador

Introduction

Around the world, sugar cane is one of the important commercial crops used to manufacture several types of sweetener such as white, refined, brown and raw sugar (Harish Nayaka et al., 2009). The manufacture of these sugars generally comprise two different way of processing which are often carried out in separate location. While, processing sugar cane for industrialized sugar include juice concentrating in sugar mills well-equipped with multi-effect evaporators, raw sugar typically takes place in or near sugar cane fields in rural areas with technological limitations, using open pans at environment conditions to concentrate sugar cane juice (Donovan and Williams, 2001). Closely-related to raw sugar, granulated panela is another presentation of a traditionally sweetener produced all over the word under different names, such as gur, desi, jaggery, hakuru, htayet, panocha, or naam taan oi in Asian and African countries (Rao et al., 2009; Kumar & Tiwari, 2006), and piloncillo, papelón, panela, chancaca or raspadura in Latin American countries (Mujica et al., 2008). Granulated panela has a long cultural heritage in Central and South America. Most artisan farmers in these countries use a simple crusher consisting of two or three metal roller, operated by diesel power, to compress the sugar cane and extract the juice. The extracted juice is then filtered through cloths or sieves and removed from it, macro solid particles by sedimentation in a pre-cleaner tank. After that, the juice is collected and heated in a first open pan at 60-70 °C, in which the clarification of juice is carried out using natural mucilage extracted from endemic bushes of the region (Gonzales, 2001). In order to boil and concentrate the clarified juice, it is sequentially transferred to a second and third, open pans. Boiling temperature is between 89 to 92 °C, and the juice is boiled until soluble solid contents near to 70 Brix. The concentration of soluble solids in the juice increases the temperature, exceeding 100 °C. Just before of the syrup solidification, the temperature is ranging between 118 to 125 °C, and the soluble solid content of syrup is higher than 88 Brix. In this point, the resulting syrup is poured into in
other pan and strongly mixed to obtain the granulated panela (Lara and Clavijo, 2004). This study shows the increasing of temperature during the boiling-concentration time of juice batches and its effect on the soluble solids (Brix), water activity, titratable acidity and color.

Materials and methods

Juice extraction

Two genotypes of sugarcane (POJ 28-78 and POJ 27-14), cultivated for production of granulated panela by artisans, were used in this study to characterize the concentration process of sugarcane juice in open pans. The sugarcane stems were washed, peeled in an electrical metal brusher with circular movement (Magtron), and then crushed in a sugar cane extractor (Magtron, serial B-720) to obtain the juice. The juice was filtrated through a laboratory test sieve of 100 microns. A hold house open pan (Cuisinart) with temperature control was used at 149 and 177 °C to concentrate the sugarcane juice by boiling at environment condition. Three liters of juice was used each time. The temperature and time were monitored during the boiling-concentration process while small samples of juice and syrup, by duplicate, were taken out to determine the behavior of soluble solids (Brix), water activity, titratable acidity and optical density. The experiment was carried out by triplicate.

Analysis of samples

Digital and hand refractometer (Atago) of 0-53, 28-62 and 58-90 Brix were used to measure soluble solids in juice and syrup. Values of water activity were measured with a digital water activity meter (AQUALAB) calibrated with standard solution from 0.2 to 0.9. Titratable acidity was determined by titration with standardized solution of NaOH 0.01 N, and expressed as ml of NaOH 0.01 N used to rise the pH value to 8.3 in 10 ml of sample (Mao et al., 2007). Color (brown pigment formation) was determined measuring the absorbance of diluted samples at 420 nm (Turkment et al., 2005).

Statistical analysis

Plotting temperature, Brix, aw, titratable and color versus time; and Brix, aw, titratable acidity and color versus temperature, the experimental data were analyzed by simple and polynomial regression using the software Statgraphics plus version 5.1. Statgraphics centurion, version 16.1.03, was used to fit temperature and color versus time by more sophisticated models.

Result and discussion

Models and their parameters were computed for the treatments resulting from the experimental combination between two genotypes (a0: POJ 28-78 and a1: POJ 27-14) and two temperature, used to heat the open pan (b0: 149 °C and b1: 177 °C). All relationship were predicted by simple regression, excepting water activity versus temperature which was fitted by polynomial regression with values of
5.36944, -0.0754317, 0.000297624 for \(a\), \(b\) and \(b^2\), respectively (Table 1). Plotting boiling temperature, Brix, water activity, acidity and color again time, the models selected for the most relevant treatments were: inverse-Y square-X, exponential, logistic, exponential and square root-Y square-X, respectively. In the same way, plotting Brix, acidity and color again temperature, the models with mayor resolution were: inverse-X, lineal and lineal, respectively. The goodness of the models were checked according to the values of correlation coefficient \((r)\), determination of coefficient \((R^2)\), standard error \((\% SE)\) and provability value \((P-value)\). Therefore, graphically, the influence of time and temperature on soluble solids, water activity, acidity and color during sugar cane juice concentration may be used to control the process. As example, Figures 1 exhibits the increasing change of color from juice to syrup which was quantified by measuring the absorbance at 420 nm.

**Conclusion:**
The main correlations evaluated in this study showed that both time and temperature may be monitored to control Brix, water activity, acidity and color during the sugar cane juice concentration, and thus improve the standard quality of granulated panela traditionally produced in open pans at environmental conditions. However more investigation is required considering that at artisan scale, three or more open pans are used in sequential line to produce granulated panela. Consequently, the knowledge generated about the behavior of these processing factors is an important base to attempt the quality standardization of granulated panela at the artisanal scale.

**References**

Table 1. Models and parameters for temperature versus time and their relationship with Brix, water activity ($a_w$), titratable acidity and color during concentration of sugar cane juice

<table>
<thead>
<tr>
<th>Models parameters</th>
<th>Treatments $a_i/b_i$ / Time as independent variable</th>
<th>Treatments $a_i/b_i$ / Temperature as independent variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Temperature $a_i/b_0$</td>
<td>Brix $a_i/b_1$</td>
</tr>
<tr>
<td>$a$</td>
<td>0.0111775</td>
<td>2.87644</td>
</tr>
<tr>
<td>$b$</td>
<td>-5.60E-07</td>
<td>0.0257347</td>
</tr>
<tr>
<td>$r$</td>
<td>-0.95161</td>
<td>0.98562</td>
</tr>
<tr>
<td>$R^2$</td>
<td>90.5561</td>
<td>97.14</td>
</tr>
<tr>
<td>$% SE$</td>
<td>0.00033114</td>
<td>0.106</td>
</tr>
<tr>
<td>$P$-value</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Figure 1. Experimental and predicted values of color during sugar cane juice concentration: a) versus time and b) versus temperature.