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A CASE-STUDY VISION

Determination of the cane honey point of panela under open evaporation in Colombia

Determinación del punto de miel de caña de panela bajo evaporación abierta en Colombia

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ABSTRACT

The granulated cane honey point of panela is given when the cane honey begins to solidify, based on the crystallographic properties of the honeys. In Colombia, the solidification point of panela is usually determined in an empirical way by panela manufacturers. In this study, we evaluated an automated method to determine the point of the panela cane honeys to produce a granulated panela in the regions of Colombia, in comparison with five possible scenarios that were previously tested, but choosing experimentally the best solution. The best method for determining the level was the saturation measurement by delta of the temperatures based on the graduation of the supersaturation of the sucrose presented as a line whose slope, and the value of Tan (θ) indicate an index of the degree of supersaturation.

RESUMEN

El punto de miel de caña de panela granulada se da cuando la miel de caña comienza a solidificarse, con base en propiedades cristalográficas de las mieles. En Colombia, el punto de solidificación de la panela suele ser determinado empíricamente por los fabricantes de panela. En esta investigación se evaluó un método para determinar, de forma automática, el punto de las mieles de caña panelera necesario para producir una panela granulada en algunas regiones de Colombia, comparando cinco escenarios posibles probados previamente, y eligiendo de forma experimental la mejor solución. De acuerdo con lo anterior, el mejor método seguido para la determinación del nivel fue la medición de la saturación por delta de temperaturas que se basa en la graduación de la sobresaturación de la sacarosa presentada como una recta, cuya pendiente -y el valor de Tan (θ)- indican el grado de sobresaturación.

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1. Introduction

The sugar cane industry includes one of the most important economic activities in our country, with the panela as its main product. The economic losses in panela production activities are mainly due to oversupply and high production costs. For decades, the small and medium producers have manufactured in a traditional way the products resulting from the juice of cane honeys. The panela production is one of the most traditional rural agro-industrial in Latin America, the Caribbean and Asian, where Colombia ranks the second worldwide in production of panela, after India, but according to the Ministry of Environment and Rural Development, the first place in terms of consumption per capita since in the country an average of 24.7 Kg of panela is used per person per year [1]–[4].

In Colombia, the panela production has presented some limitations to update the manufacturing processes (productivity and quality) related to technological adaptations in each production stage [3], [5]. Thus, the generation of innovative solutions for optimizing the productivity but containing technical, economic and environment requirements are still a challenge [1], [6], [7].

The panela production process begins by obtaining the juice extracted from the sugar cane, free of impurities, such as dust and the bagasse. Then, the juice is heated to a specific temperature and it is adding a pH corrector or in some cases a clarifier or flavoring. During the previous process, and before the juice reach the boil point, some of the colloidal particles are crystallized, giving the panela unwanted characteristics that decreases the quality. In this part, a chemical substance is added to create a cream called cachaça that removes manually the crystals with a saucepan. The clarified juice obtained is heated to evaporate about 80% of the water and concentrate the sugars until it turns into a substance similar to the honey. When the juice reaches a temperature range between 92° and 96° called the Brix degree, the juice is removed from the burner and it is whipped for a short time until its solidification and granulation [8]–[11].

The process of evaporation of panela has traditionally been carried out in a burner composed of a combustion chamber, a gas pipeline, a concentration battery and a chimney. The juice of sugar cane is submitted to three stages with energy supply: clarification, evaporation and concentration. During these three stages, water is removed from the sugar cane juice until it is brought to the proper concentration to solidify it and turn it into panela [12], [13].

Within the manufacturing stages of the panela, the picking and the shake are used to set the ideal point to create a product with the highest quality. The first stage, it means to establish the ideal point to remove the honeys and turn them into the final product as liquid sweetener, block panela or granulated panela. This stage can be carried out considering the boiling temperature of the product, which is considered as an accurate method to obtain a homogeneous product, or through the consideration by expert or called in Spanish as "melero" [14], [15]; the present paper is focused to find an automatic, viable and low-cost way to determine the point where cane honeys are ready to produce panela.

The color parameters are a good tool to establish differences in production, which depends on the heating system used in the production, because it influences the Maillard reactions that occur during the evaporation of water into the cane juice [16]. On the other hand, in this study we consider the following parameters: the ease of construction, the use of commercial electronic elements and the minimal mechanical adaptations required. Thus, we created a design index to indicate of which must be adaptable to different places of production. The solution must be durable in different scenarios (hot and humid), and the design index have to generates the confidence in the panela industry.

2. Materials y Methods

The characteristics of sugar cane juice do not have data available by the panela industry. The data in the literature indicates that the boiling point is reaching in a range of temperature above the sea level. The range do not indicate a considerable value of increment, but this represent how the concentration increases in degrees Brix, in the same way the corresponding viscosity is limited to values close to 74 Brix as shown in Figure 1 [17].

Similarly, the viscosity values are limited to the corresponding values of about 74Brix of concentration (Figure 2) [17], at very low temperatures compared to those of the panela scoring process, i.e. about 125°C.

Figure 1. Behaviour of boiling point by Brix at 760 mm Hg [17].

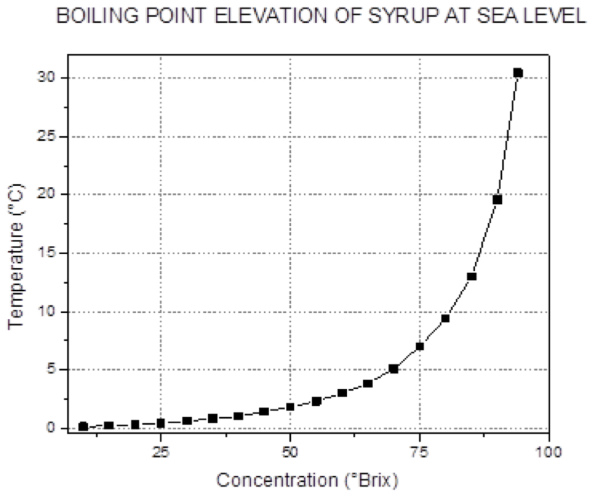
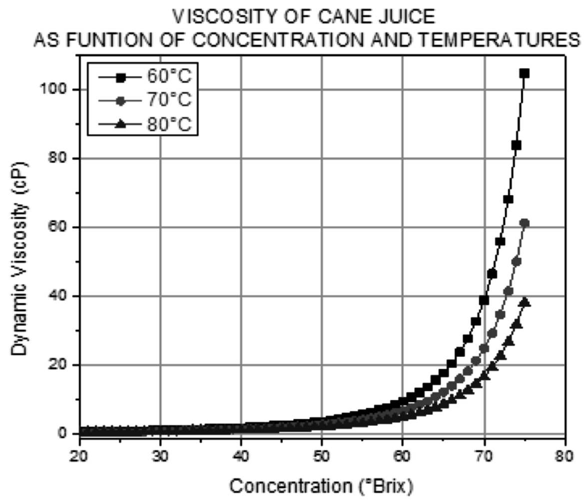


Figure 2. Dynamic viscosityof panela [17].



In order to find a viable solution for the "Determination of the cane honey point of panela under open evaporation", we tested five possible solutions: viscosity sensor by flow resistance, conductance sensor using a Wheatstone bridge, humidity sensor using a refractometer, shear viscosity sensor and supersaturation measurement by temperature delta. Moreover, the five variables associated with the efficiency of the solution were considered: Accepted temperature range, ease of construction or implementation, materials, viability of data collection and, the total cost related to production. Based on the above parameters, the analysis corresponding to the variables is presented in Table 1.

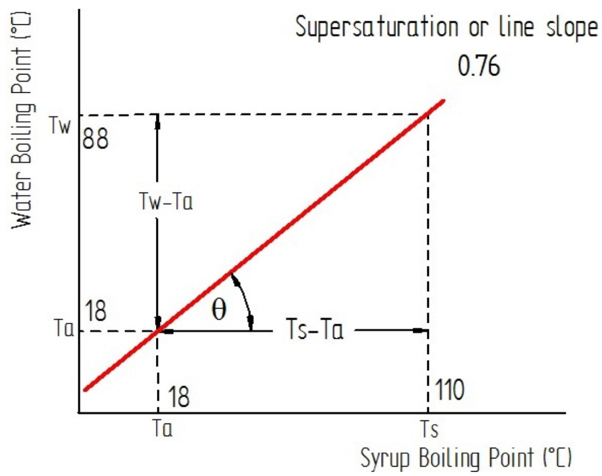
Table 1. Variables used in the proposed methods.

Variables / ***Method***	**Range of temperature**	**Ease of construction and/ or assembly**	**B P M (Materials, cleaning possibilities)**	**Feasibility of data acquisition**	**Production Costs**
Viscosity Sensor	The temperature range is not adequate (15 ºC to 120 ºC).	Standardized commercial models.	Commercial food sensor.	Easy transduction.	High, it would opérate out of range.
Conductance sensor (Wheatstone bridge).	It adapts to the room temperature.	It is necessary to use high frequency alternating voltage to avoid electrolysis.	It is not the most recommended as there are copper elements usually immersed in the juices.	Easy acquisition, the difficulty is its calibration and its assembly.	Low
Humidity meter (Refractometer).	Only works at room temperature.	It does not work for transducer.	It is suitable for food but the refractometer is damaged.	There is no transduction between the lights signal and the voltage or current.	High and short life by temperature.
Shear force viscosity meter.	The steam affects the power equipment.	Difficulty finding suitable springs and the possibility of contact between steam and electrical components.	Suitable according to the material of the disc, but requires periodic cleaning.	The voltage signal is variable by contacts with brushes.	Low, but the steam will decrease the useful life of the motor.
Oversaturation measurement by temperature delta	Suitable. It is no restriction for operating temperature.	It requires acquisition stage and signal conditioning.	Suitable for the material of the thermocouples.	The amplification with operational amplifiers is viable.	The initial cost decreases by quantity because the programming of the PIC is not equal, but only an in situ calibration.

Source: own.

Taking into account the above information, it became necessary to look for an independent alternative to the direct measurement of viscosity, and thus, the degree of supersaturation was determined. The proposed method consists that any degree of supersaturation of sucrose can be represented as a line whose slope value helps as an index of the degree of supersaturation (Figure 3) (equation 1).

Figure 3. Calculation of the index of the degree of oversaturation.



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We defined that:

$$\mathrm{Tan}\theta = \frac{Tw - T\alpha}{Ts - T\alpha} \quad (1)$$

where:

Tan θ: is the slope of the line that indicates the saturation state.

Tw: is the water evaporation temperature.

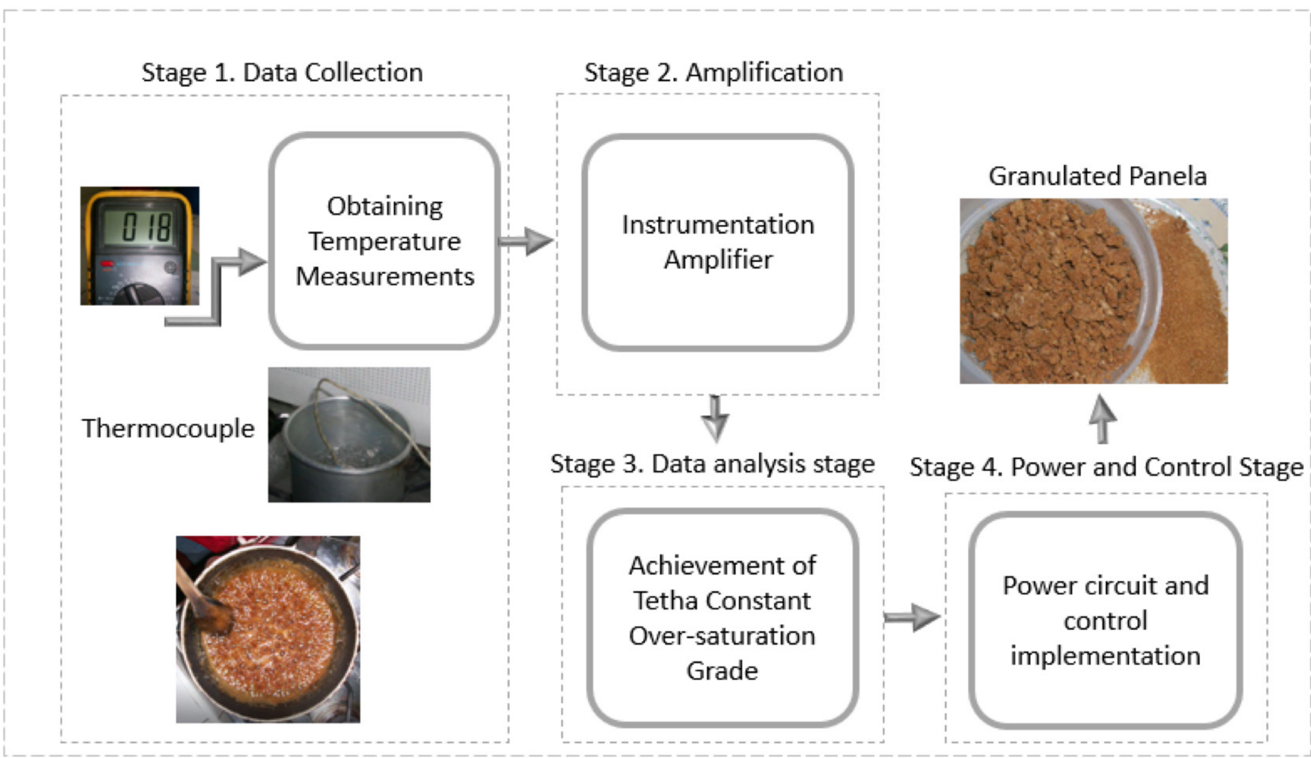
Tα: is the room temperature.

Ts: is the evaporation temperature of honey.

In this way, we designed an automated system for the drawing stage in order to calculate the temperature variables and a method to obtain the supersaturation.

The following 4 stages represent the method proposed as shown in Figure 4.

Figure 4. Design for the automated design in the panela production.



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The correction of the error was performed by measuring the temperature using thermocouples, and applying the Equation 2:

$$Vfe,c\,(T) = V + Vfe,c\,(Ta) \quad (2)$$

where:

V: Measurement by a Voltmeter in mV.

Vfe,c (Ta): It is the potential difference between the two metals of the thermocouple at room temperature in mV. It is obtained from the data table of thermocouple type *J*.

Vfe,c (T): It is the real potential difference between the two metals of the thermocouple at the process temperature in mV. This voltage is obtained from the table in ºC.

In the amplification stage, an instrumentation amplifier was designed with the main objective of being able to measure the input signals obtained from the sensors, then the PIC16F452 was chosen to be programmed and configured to read the input variables and obtain the oversaturation constant and finally, a power stage was designed to generate a visual and audible signal to the operator in charge of bringing the honey to the drawer to be beaten, and to dehydrate quickly and accelerate the crystallization of the granulated sugar as show in Figure 5.

Figure 5. Honeys knitting for the production of granulated panela.

Source: own.

3. Results

The temperature measurements are taken in an experimental way as input variables, obtaining Table 2.

Table 2. Measurement of temperature variables and obtaining the point.

Variable	Measurement	Calculating of $tan\theta$
Tw	88 ºC	$tan\theta = 0,76$
Ta	18 ºC	
Ts	110 ºC	

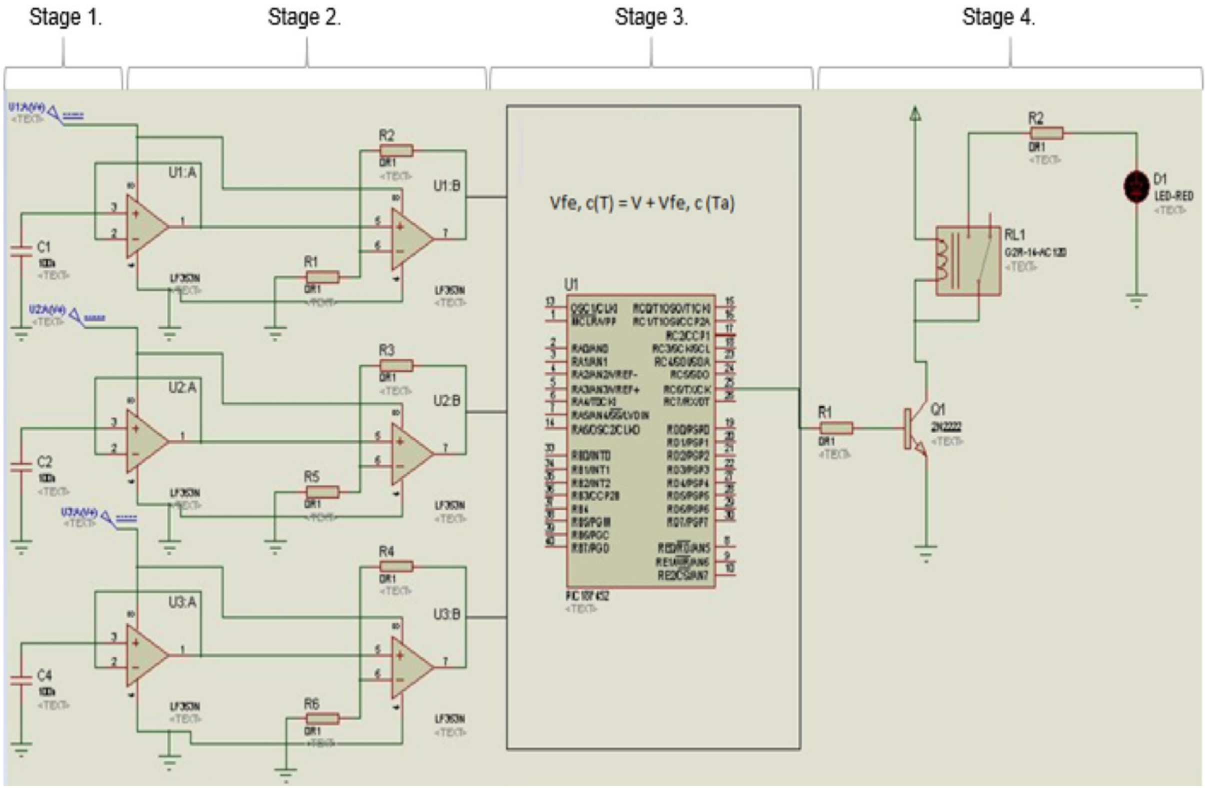
Source: own.

The automated system was implemented, and a pilot test was carried out in order to assess the determination of cane honey point of panela. The variables were measured in a controlled environment in an experimental way. The results were a good granulated panela compared to another panela manufactured by big companies.

Once the parameter for the determination of the point of the honeys for elaboration of granulated panela of Tan(θ) is equal to 0.76 or constant of supersaturation, we program the microcontroller with this parameter and the process was simulated. The tests were done in Bogotá because the value of tan (θ) is independent of the height above sea level where it is used because the method is not based on each of the measured temperatures but on the relationship between them.

At figure 6, the design of the circuit for the determination of the point by the supersaturation method is observed, providing the output with an on/off signal.

Figure 6. Electronic and electrical design of the automated system for the proposed method.



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4. Discussion and conclusions

The elevation of the boiling point of the honeys with respect to the evaporation temperature of the water and the environment can be represented as the slope of a straight line. Some tests carried out in Bogotá presented a mean value of $tan\theta = 0.76$ but with minimal dispersion. Additionally, the velocity during the changes *Ts* when it is reaching the point is considerably high, for this reason, we proposed in a future work consider the exchange rate through operational derivatives or other mathematical methods.

The previous test performed in other scenarios presented difference in evaporation temperature of water and honey with respect to room temperature. It indicates the degree of supersaturation due to the increase in sugar content in the final substance.

The proposed method will allow to the operator a greater precision to determine the right moment to bring honey to the drawer, providing better quality of the product. Finally, it should be noted that this work raised a low-cost solution to be implemented in a normal process of production of panela. The complete automation of the entire production of panela will be considered as a future work in order to strengthen the industry in Colombia.

References

[1] L. Gutiérrez, S. Arias, A. Ceballos, "Theoretical evaluation of the environmental impact of a traditional burner for panela production", vol. 34, pp. 477–480, 2016.

[2] D. A. Tenorio Dagua, "Proyecto, mejoramiento de la cadena de la agroindustria panelera, con 25 familias de productores del resguardo indígena de Munchique los Tigres, municipio de Santander de Quilichao, Cauca, Colombia", Universidad Santo Tomás, 2016.

[3] Delegatura de Protección de la Competencia, "Cadena productiva de la panela en Colombia: diagnóstico de libre competencia (2010-2012)", 2012.

[4] R. A. López Zaraza, "Evaluación técnica y económica de la implementación de un sistema de evaporación de múltiple efecto en los procesos productivos de la panela", 2016.

[5] G. Ramírez, "Characterization of traditional production systems of sugarcane for panela and some prospects for improving their sustainability", vol. 70, pp. 8045–8055, 2017. https://doi.org/10.15446/rfna.v70n1.61763

[6] Q. Moreno, M. Contreras, R. Domínguez, Q. Torres, A. M. Borja, O. Rojas, "Environmental Impact Evaluation of the Industry of Panela by Life Cycle Analysis", no. 1, 2017. https://doi.org/10.22161/ijeab/2.1.68

[7] L. F. Gutiérrez Mosquera, S. Arias Giraldo, A. M. Ceballos Peñaloza, "Advances in traditional production of panela in Colombia: analysis of technological improvements and alternatives", vol. 123, no. 1, pp. 107–123, 2018. https://doi.org/10.25100/iyc.v20i1.6190

[8] P. Forero, A. C. Guerrero, "Efecto de las variables de evaporación: presión y flujo calórico en la calidad de la panela", vol. 16, pp. 7–23, 2015. https://doi.org/10.21930/rcta.vol16_num1_art:376

[9] N. Lara, A. Clavijo, "Sugarcane juice properties as control parameters during the procurement process of granulated panela, process in open system Las propiedades del jugo de caña como parámetros de control durante el proceso de obtención de panela granulada proceso en sistema abierto", vol. 34, pp. 1363–1366, 2016.

[10] L. Lizandro, D. Montejo, "Manual de Producción de Caña de Azúcar (Saccharum officinarum L)", Manual de producción de caña de azúcar, 2002.

[11] J. F. Cárdenas Barbosa, "Diseño paramétrico de una planta de panela", Fundación Universidad de América, 2001.

[12] O. Andrés, M. Menjura, H. E. Hernández, "Análisis experimental de la evaporación del jugo de caña de azúcar en película sobre una placa plana Experimental analysis of the evaporation of sugar cane juice by film on a flat plate", vol. 14, pp. 113–127, 2013.

[13] A. Torregroza, L. Gomezcaceres, A. Vergara, L. Meneses, "Evaluación de variables asociadas al proceso de fabricación de miel de caña de azúcar y evaluación sensorial del producto Assessment of variables for the manufacturing process of sugar cane honey and sensory evaluation of the product", vol. 34, pp. 662–664, 2016.

[14] W. F. Quezada Moreno, "Guía Técnica de Agroindustria Panelera", Agroindustria Panelera, Ecuador, p. 159, 2007.

[15] G. A. García Moreno, "Proyecto de prefactibilidad para un plan de negocios en la diversificación de productos de la panela en una finca productora de caña de azúcar," Colegio Mayor de Nuestra Señora del Rosario, 2015.

[16] Á. Orjuela, C. Osorio, "Physicochemical and sensory (aroma and colour) characterisation of a non-centrifugal cane sugar ('panela') beverage", vol. 228, pp. 7–13, 2017. https://doi.org/10.1016/j.foodchem.2017.01.134

[17] P. Honig, "Principles of sugar technology", vol. 1. 1953. https://doi.org/10.1016/C2013-0-12499-3