# Parametric Behaviors of Sugar Palm (Arenga Pinnata Wumbb Merr.) Sap Crystallization Process

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# Parametric Behaviors of Sugar Palm (*Arenga Pinnata Wumbb Merr.)* Sap Crystallization Process

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**Abstract:** *This study was conducted to determine the parametric behaviors of sugar palm sap as it undergoes evaporation and crystallization processes into sugar palm sweetener. These parametric behaviors are temperature profile, pH profile, and Brix profile. The unit operations for the sugar processing were done at an ambient temperature range of 20-25°C. The temperature profile has an increasing trend until the heat will be reduced when the sap already turned into a heavy syrup. It is observed that the highest temperature occurred during crystallization process ranging from 105-110°C. Most of the moisture migration, on the other hand, occurred during boiling at a temperature ranging from 98 - 101°C. The pH level of the sap reached its maximum during evaporation process at a range of 7.6-8.1. The Brix profile has an increasing trend over process time starting from 12° to 87°.*

**Keywords:** sugar palm; Arenga pinnata; crystallization parameters; sap crystallization process; sugar palm sap

## 1. INTRODUCTION

Sugar palm, locally known as *kaong* (*Arenga pinnata Wumbb. Merr.*), is considered as high-value but an underutilized crop. This crop is abundant in one of the provinces of the Philippines, the province of Cavite specifically in the Municipality of Indang. The presence of many river systems in the area makes it suitable for the crop growth and sustainability. They thrive mostly in riparian areas, or places along the banks of the riverways. This kind of location has a significant effect to the quality of sap produced. However, future studies are needed to verify this claim.

Fig. 1. Sugar Palm or *Kaong* Tree

The processing of fruit into *kaong* gels has been the most common utilization known by the residents. Though the returns have been promising, especially that the product is presently known and commercialized in local markets; the crop has a lot to offer. The other parts of the tree like the fiber (also known as cabonegro) can be utilized into brooms and rope. The leaves can be made into brooms, baskets, and decorations. The innermost trunk of the tree is also a source of starch and flour.

The sap is harvested from male inflorescence of the tree through tapping method for *kaong* vinegar. According to studies, the sap yield of each tree varies depending on its age, its environmental climatic conditions, and the tapping time. It is determined that a tree can produce 20,000 liters of sap for 3 years or an equivalent of 12 tons in average for 20 years. Though the vinegar produced from sap can easily be processed, the product has low in commercial value.

With the goal of getting the maximized potential of kaong in terms of product development and economics, it is encouraged to process the sap into granulated brown sweetener. With this product development, the commercial value of the processed sap will have a ten-times increase compared to vinegar. Aside from this, the product was tested by the Department of Science and Technology – Food and Nutrition Research Institute (DOST-FNRI) to have a low glycemic index compared to table sugar [8]. This means that the sugar can be consumed by diabetic patients as food sweetener. Sweet taste receptors act as energy sensors by detecting carbohydrates, which are a source of calories [5].

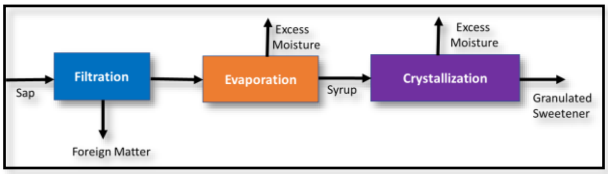


Fig. 2. Process Flow of Kaong Sap Crystallization

To convert the sap into sweetener, the sap undergoes different unit operations as shown in Figure 2. Firstly, the sap moisture is reduced through evaporation process converting the whitish or pale brownish water-like liquid into a brown viscous syrup. Once the large bubbles appear, heat will be lowered as the syrup is starting to undergo crystallization process. During crystallization, solid brown granules appear. These granules need to be air-dried until the temperature and humidity equilibrate with the storage environment. After air-drying, the produced granulated brown sweetener will be packed and sealed to prevent exposure from high-humid air. This sap to sugar processing is still manual; thus, there are variabilities in process parameters to respective unit operation and process. Consecutively, this affects the quality parameters of the product and the overall market acceptability. These variabilities are also due to limited studies about the process and quality parameters mentioned.

Thus, the main objective of this study is to determine the parametric profiles of kaong sap as it is processed into granulated brown sweetener. These profiles are very important consideration given that processors are skeptical especially on the economic potential of the product. Currently, the kaong granulated sweetener is sold in the market at PhP 200.00 ($4.00) per kilogram. These process and quality parameters can help in optimizing the product yield of the input materials and consequently the price of the commodity in the market.

The process parameter to be measured is temperature while the quality parameters are pH and Total Soluble Solids.

Figure 3. Processed Granulated *Kaong* Sweetener

## 2. MATERIALS AND METHODS

This presents the test materials and the instruments used in the study. This also discusses the methodologies used during data collection for process and quality evaluation. The conceptual framework for process parameters and quality parameters are shown in Figure 4 and Figure 5, respectively.

### 2.1 Test Materials

The test materials were freshly harvested kaong sap and processed granulated brown sweetener as input and output materials, respectively. The kaong sap was harvested in the plantation of Cavite State University, Indang, Cavite, Philippines. This sap was randomly collected from mature trees ready to be tapped during the duration of the study. On the other hand, the granulated kaong brown sweetener was processed manually using an open pan exposed to an ambient temperature. The fuel used during the process is wood.

### 2.2 Instruments

The process and quality parameters, as well as the environmental conditions, were measured and evaluated using standard instruments. A food thermometer was used for test material temperature determination. The Total Soluble Solids or Brix was measured using the handheld refractometer while the pH was determined using the pH meter.

### 2.3 Methodology

The process and quality parameters were measured and evaluated using standard instruments. A food thermometer was used for temperature determination. A pH meter and refractometer were used for pH level determination and Brix level determination, respectively.

#### 2.3.1 Sap Collection

The kaong sap was collected twice a day. It is obtained by tapping the unopened spadix (male inflorescence) of the sugar palm tree. The apex of the stalk is sliced about 1 – 5 mm during tapping process [2]. Then, a plastic bottle is inserted into the base to collect the sap. The sap initial temperature, pH, and Brix was measured. The collected and measured sap are then processed to the processing area of the research facility to avoid pH drop; thus, affecting the sap quality. Sap must have a pH value within 6-7 to produce high-grade sugar [1].

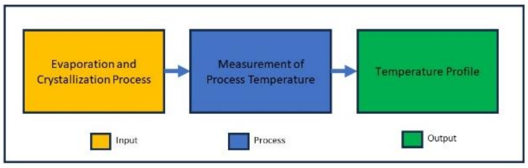


Fig. 4. Conceptual Framework for Process Parameters

#### 2.3.2 Temperature Measurement

Upon the arrival of the sap in the processing area, the fuel was prepared so that it will be processed immediately. A 10-liter sap was put in the clean pan and allowed to be heated. During the process, the temperatures at the center, at the midpoint of the center and the pan diameter, and along the pan diameter were measured. However, only the average of these three points were used for data interpretation. The temperatures were measured and recorded every 10 minutes from the start of the cooking process to the end of crystallization using food thermometers.

#### 2.3.3 pH level measurement

The pH level measures the acidity or basicity of the test material. As mentioned above, the pH of the sap plays a major contribution to the quality of the sugar produced. Thus, before processing, the initial sap pH was measured using the pen-type pH meter. It was made sure that the sap collected was processed immediately to avoid pH drop before the sugar processing. Once the sap is processed, the test material was measured every 10 minutes from the start of cooking up to the end of crystallization. This was done by taking a sample every 10 minutes to represent the pH level of the processed sap.

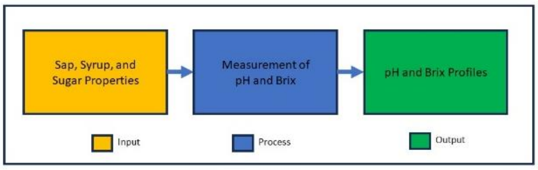

Fig. 5. Conceptual Framework for Quality Parameters

#### 2.3.4 Brix Measurement

Brix is the measure of sucrose to the total soluble solids. The same with pH, the Brix of the sap highly influence the quality of the sugar produced. The Total Soluble Solids content of coconut sap and sugar palm juice was reported in a range of 12-14 °Brix [3] and 14-16 °Brix [6]. With these ranges, with the right process parameters used, the yield will be high quality sugar.

In this study, the same with pH level, Brix of the sap was measured at the start of the process. Then, a sample was taken and was analyzed using the handheld refractometer every 10 minutes to represent the Total Soluble Solids of the test material.

## 3. RESULTS AND DISCUSSION

This section presents the results of the parametric behaviors of kaong sap crystallization process from the data gathered through experimental method. The parameters analyzed are temperature, pH, and Brix.

### 3.1 Temperature Profile

In evaporation and crystallization processes, temperature is a very important parameter as it will dictate the energy requirement of each unit operation, as well as the overall process.

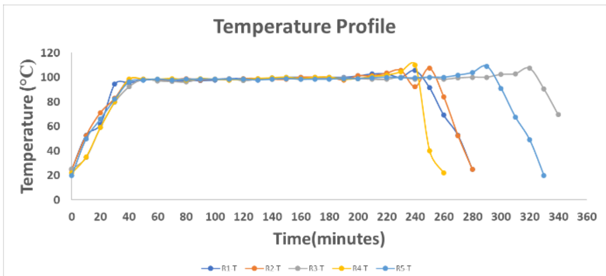

Fig. 6. Temperature Profile of Sap Crystallization

At a room temperature of 20°C, there is an immediate temperature rise to the 20th minute of the process. During this period up to the 30th minute, scum forms. This scum was removed as it is considered a foreign manner in sugar processing. The steam's saturation temperature of 100°C was attained at the 40th minute. The evaporation process took 130-140 minutes until the sap transformed into its glassy state. The glass transition temperature of the palm sugar sap was attained at 100°C during the 170th to 180th minute of the process. This is manifested by the formation of large bubbles indicating the presence of sugar in the sap. On the 190th minute of the process, the sap finally turned into a brownish viscous light syrup called the *Maillard reaction* or non-enzymatic browning. Since more water has evaporated and the material turned into semi-solid, its specific heat has decreased. Thus, increasing the temperature of material beyond the steam saturation point. The temperature has registered from 103-110°C. At this point, heat is reduced to avoid the material from burning.

Then, the medium brown heavy syrup was removed from heat at 220th minute; yet continuous stirring was done for crystallization. During this period, the temperature is still rising due to the specific heat change that happened to the material. After continues stirring (air-drying) for 20 minutes, granulated brown sugar was produced.

### 3.2 pH Profile

The pH level of the sap is a very important quality parameter as it defines the quality of the sugar produced. When the sap is left unprocessed at ambient temperature, the pH behavior naturally decreases by time; this acidification makes it suitable for vinegar production. However, the pH behavior has not been observed when the sap is processed into sugar.

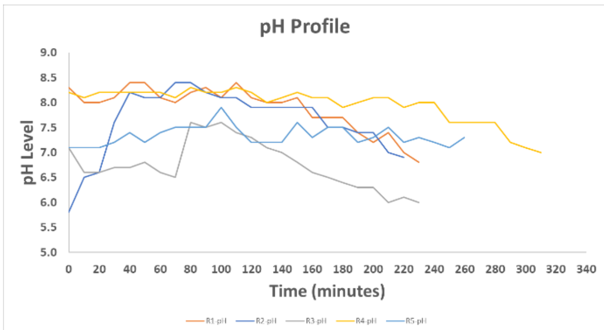

Fig. 7. pH Profile of Sap Crystallization

Based on the profile shown in Figure 6, three behaviors were observed. First behavior is for the sap with an initial pH at neutral level (measured at 7). For R5-pH, it shows that the pH level during the process is higher compared to the 7.1 initial pH with the highest pH obtained at 7.9 during the midst of evaporation process at 100th minute. The processing time from sap to sugar was 330 minutes. However, for the same initial pH level at R3-pH, different behavior occurred. At the start of the process, the pH suddenly dropped by 0.1 pH level per minute yet spiked to 7.6 during the midst of evaporation process at 100th minute. However, this process only took 270 minutes to convert the sap into sugar. This is an hour earlier than the process of R5-pH.

The second behavior is for the sap having an initial pH above the neutral level. R1-pH has an initial sap pH of 8.3. At the start of the process, its pH level to 8 and has sustained during the evaporation process at the pH level of 8.1. The whole process took 300 minutes. The R4-pH, on the other hand, has an initial pH of 8.2. The pH level sustained up to boiling. During evaporation process, the pH level dropped to 8.1. The whole process took place 320 minutes. This is 20 minutes late compared to R1-pH.

Lastly, the behavior for the sap having an initial pH below the neutral level (less than 7). This sap is considered slightly acidic. At R2-pH, the sap initial pH started at 5.8. Then it abruptly increases to 6.5 during the $10^{th}$ minute then 7.6 during the $20^{th}$ minute, and to 8.1 when boiling happened. This level was sustained during the evaporation process. The whole process took place in 270 minutes.

Based on the pH profile, regardless of the initial sap pH, during evaporation process, the pH level converges at a range of 7.6 - 8.1. This means that the sap becomes basic during evaporation process and approaches to neutrality once viscosity for the syrup is attained.

### 3.3 Brix Profile

The same with pH, Brix or the Total Soluble Solids of the sap is a very important quality parameter. The initial Brix will define the quality, as well as the yield, of the sugar produced. Brix level measures only the amount of sugar but not the intensity of sweetness [7]. In a separate research study of the author, Brix has a huge weighing factor to the yield of the sugar. Yet, on this study, the focus is the behavior of the Brix content of sap during sugar production process.

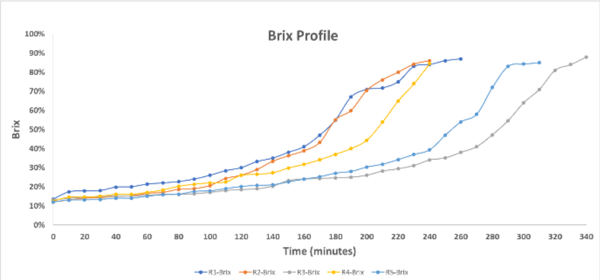


Figure 8. Brix Profile of Sap Crystallization

Based on the profile shown in Figure 7, the measured initial Brix of the sap is 13°. Once evaporation starts, the sap Brix eventually rises to 20° and continue to increase up to 41° at the end of boiling. The Brix level during glass transition temperature is 55°. The syrup is crystallized at 67° and ended the process at 86°.

The Brix level after crystallization was determined in a separate research study.

## 4. CONCLUSION

This research study has a main objective of determining the parametric profiles of *kaong* sap as it is processed into granulated brown sweetener. These profiles are vital information for the energy and material analyses of the process. The process parameter measured is temperature while the quality parameters are pH and Total Soluble Solids. It is determined that the glass transition temperature of the kaong sap is at 100°C. During the conversion of sap to syrup, the specific heat is reduced making the temperature of the syrup increase up to 110°C. At glass transition temperature, the pH of the syrup converges at a range of 7.6-8.1 while the Brix level rises to 55°.

## 5. FUTURE RESEARCH

In line with this research study, the author is currently studying the modeling and optimization of the process. One of the future research projects, which will be a collaboration with agricultural economics will be the value chain analysis of *kaong* sweetener production. This will also cover the market potential of the commodity.

## 6. ACKNOWLEDGMENT


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