Effects of Varieties, Heat Pretreatment and UHT Conditions on the Sugarcane Juice Quality
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Received: 6 November 2009
Accepted: 7 May 2010

ABSTRACT
In this work, the effects of sugarcane varieties, heat pretreatment methods and UHT conditions on the quality of sugarcane juice were investigated. The aim was to attain the background information that is useful for the production of high quality UHT sugarcane juice. The experimental results indicated that the sugarcane Suphan Buri 50 variety is more suitable for juice production than Singapore variety in aspects of total solid and consumer preference. Furthermore, it appeared that both the microwave heating for 5 minutes by frequency 2,450 MHz at 850 W and the blanching sugarcane in hot water at 80°C for 5 minutes could inactivate the peroxidase enzyme at the comparable level. Nevertheless, the blanching was preferred due to its ease of control, lower energy and equipment cost. In addition, if $F_0 \geq 4$ is demanded, the UHT sterilization at 140°C and holding for 4 seconds could maintain the sugarcane flavors and provide the more favorable juice than those of 135°C for 10 seconds.

Keywords: sugarcane juice, blanching, microwave, UHT, sterilization.

1. INTRODUCTION
Sugarcane (Saccharum officinarum L.) is one of the most important crops in the world especially for the tropical countries. Most of them are used for the sugar and alcohol production. Fresh sugarcane juice is a popular beverage in many countries such as China, Malaysia and Thailand due to its taste and cheap price. Apart from that in the Indian systems of medicine, it has been used to cure jaundice and liver-related disorders [1]. Nevertheless, the marketing of sugarcane juice is limited because of its rapid quality deterioration [2-4].

The Ultra-High Temperature (UHT) processing is an attractive technique to extend the shelf-life and raise the consumer safety while maintaining the fresh quality of sugarcane juice. In the UHT juice production, the selections of sugarcane variety and the pretreatment are vital. Tangpremsri et al. [5] pointed out that the sugarcane variety Suphan Buri 50 provided the mean juice yield 1.3
times higher than the widely grown variety, Singapore. Besides, the juice from Suphan Buri 50 was fine color (green yellow), tasty and 10% higher in Brix than those of Singapore variety. To stabilize the fruit juice quality during processing and storage, the pretreatments like blanching in hot water and/or addition of antioxidant agents are commonly applied [6,7]. These pretreatments aim to inactivate the enzymes that cause the color, sensorial and nutritional changes in the fruit and vegetable products during processing and storage [8-13]. Qudsieh et al. [14] pointed out that the key enzyme related to the browning of sugarcane juice was the polyphenol oxidase that reacted with phenolic compounds. Mao et al. [4] showed that the blanching of sugarcane stems in boiling water for 5 minutes before squeezing and addition of 0.1% ascorbic acid could effectively prevent the browning and reduce the enzyme activities in the fresh sugarcane juice. Although the thermal resistance of polyphenol oxidase is dependent on its origin or the product types, some researchers claimed that in most cases solely short exposures of fruit or vegetable products to the temperatures between 70 and 90°C were adequate for partial or complete inactivation of the polyphenol oxidase [10, 15].

Owing to the lacking of research in the area of sugarcane juice processing, the effects of 3 parameters comprising with sugarcane varieties, heat pretreatment methods and UHT conditions on the quality of sugarcane juice were investigated. The aim was to obtain some useful information for the UHT sugarcane juice production.

2. MATERIALS AND METHODS

2.1 Comparison between Sugarcane Varieties

Samples of freshly harvested sugarcane of the “Suphan Buri 50” and “Singapore” varieties grown in the central region of Thailand were used in this study. The samples were weighed, manually peeled, cut, cleaned and then blanched in hot water at 80°C for 5 minutes. After that, the samples were squeezed by the “NHY” rolling squeezer motor 0.25 HP 220 V 50 Hz and screened the solid particles by the filter bag. The juices from both varieties were compared in terms of total solid, pH, color and consumer acceptance. The descriptions of the juice quality determination and the evaluation of consumer acceptance are presented in Section 2.4. The result of varieties comparison would justify the sugarcane variety used in the following steps.

2.2 Heat Pretreatments

After the variety determination, the chosen sugarcane variety was exposed to the comparison between the two heat pretreatment options, (1) blanching in hot water at 80°C for 5 minutes and (2) microwave heating for 5 minutes using “SHARP” microwave oven model R-7A56 at frequency 2,450 MHz, 850 W and setting convective air temperature at 250°C. These two pretreatments were compared because the hot water blanching is a conventional method that has the advantages in aspects of controllability, low energy and equipment cost [16] while the microwave heating is a new approach that was proposed to reduce enzyme activities in many studies due to its penetration depth and fast heating rate [8, 13, 17]. The main function of the heat pretreatments in this work was to diminish the enzyme activities that normally cause quality deteriorations of sugarcane juice such as degreening and/or browning during processing and storage. The experiments for each pretreatment were carried out at least 2 replications. The juices squeezed from the samples pretreated by these two options were exposed to the peroxidase activity test and sensory evaluation. Also, they were measured
the total solid, pH and color. Moreover, the fresh juice squeezed from the non-pretreated sugarcane stems was exposed to the peroxidase activity test. However, the pH, color and total solids measurement and the sensory test were not conducted for this sample because its quality attributes were unstable and rapidly changed along the time due to the enzyme activities and high microbial growth rate.

2.3 UHT Sterilization

After realizing the proper variety and heat pretreatment for sugarcane juice preparation, the UHT sterilization was carried out using the lab-scale “MicroThermics” UHT/HTST machine model “Lab 25 EHV Hybrid”. The schematic diagram of the UHT process is illustrated in Figure 1. In the UHT machine, there were Type-T thermocouples installed at various positions for measuring the juice temperatures. Prior to the UHT experiments, the total solid of sugarcane juice was adjusted to 12°Brix by adding the distilled water so that the raw samples for all experimental runs were in the same condition. The fresh juice preparation and the UHT sterilization were conducted on the same day for each experiment. As generally recognized, the process lethality ($F_0$) is the most important parameter that can indicate the level of the sterilization process and consequently the microbiological risk of sterilized food [18-22]. $F_0$ is defined as the time (seconds) at a reference temperature (121.1°C) to which the process is equivalent [19]. It was calculated from the temperature history of the sterilization process by integration of the following equation over time (t) [20-22]:

$$F_0 = \int_0^{t_{(121.1)}} \frac{10^z}{t} \, dt$$

Similar to the common sterilization of food, the target microorganism of the UHT sterilization in this work was Clostridium botulinum; hence, the z value of 10°C was applied in eq. (1) [21,22]. The $F_0 \geq 4$ was specified for the UHT sterilization in this study in order to slightly beyond a minimum requirement ($F_0 \geq 3$) for the low-acid food that was recommended by Lewis [18]. There were 4 conditions for the UHT experiments as detailed in Table 1. The UHT experiments were conducted without replication.

![Figure 1. A schematic diagram of the UHT process.](image-url)
The UHT processed juices were aseptically filled in the clean fill hood and kept in the sterilized glass containers for sensory evaluation and the determination of total solid, pH and color. The sensory evaluation and the quality determination were conducted within one week after the production of UHT samples.

2.4 Quality Determination

The total solid content, pH and color of the sugarcane juice were measured by “ATAGO” hand refractometer, “JENCO” pH meter and “Minolta” color meter model CM-3500D respectively. The sensory was evaluated using Hedonic scale test by at least 20 panelists who were the students in the department of Food Science and Technology, Kasetsart University. The peroxidase activity test was conducted by putting the 5 drops of the juice sample into the enzyme test hole and then 2 drops of both the solutions of guaiacal 0.5% and hydrogen peroxide 0.3% respectively [23]. After 30 s, the sample color would change and be recorded. The peroxidase enzyme is more heat stable than polyphenol oxidase [11]. Therefore, if the peroxidase is inactivated, the polyphenol oxidase that is the key enzyme related to the browning of sugarcane juice [14] would be ceased as well.

The determination of the total solid content, pH, color and peroxidase activity test were done in three replications. The software package Statistica 5.5 StatSoft™ (supplied by StatSoft, Inc. Tulsa, OK 74104 USA) was used for the analysis of variance (ANOVA) and a Duncan’s multiple range test in the statistical analysis.

3. RESULTS AND DISCUSSION

The results of comparing the total solid, pH, color and sensory evaluation (by 26 panelists) between Singapore and Suphan Buri 50 varieties in aspect of flavor are presented in Table 2. It appeared that the mean total solid of juice from Suphan Buri 50 was 19.6 °Brix, which was significantly higher than that of the Singapore variety (12.1 °Brix). However, the average pH value of juices from both varieties were insignificant different (average pH = 5.0 and 5.3 for Suphan Buri 50 and Singapore respectively). This went along with the result of Tangpremsri et al. [5] who claimed that the total solid of juice from Suphan Buri 50 was higher than Singapore. Furthermore, the colors of the two varieties were significantly different. The color of juice from Suphan Buri 50 was darker (lower L*) and more saturated (higher C*) than those of Singapore. However, the juice from Singapore variety was greener (higher h) than Suphan Buri 50. These results indicate the color features of juice from each sugarcane variety.

Table 1. The conditions of UHT experiments.

<table>
<thead>
<tr>
<th>Run no.</th>
<th>Raw sample</th>
<th>UHT condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sterilization temperature (°C)</td>
</tr>
<tr>
<td>1</td>
<td>Fresh sugarcane juice</td>
<td>140</td>
</tr>
<tr>
<td>2</td>
<td>Fresh sugarcane juice added with a sugar flavor</td>
<td>140</td>
</tr>
<tr>
<td>3</td>
<td>Fresh sugarcane juice</td>
<td>135</td>
</tr>
<tr>
<td>4</td>
<td>Fresh sugarcane juice added with a sugar flavor</td>
<td>135</td>
</tr>
</tbody>
</table>
Importantly, the sensory test disclosed that the flavor of juice from Suphan Buri 50 was significantly preferred. As a result, the Suphan Buri 50 variety was chosen for the following experiments.

After the varieties comparison, the results of two pretreatment methods, blanching in hot water and microwave heating are shown in Table 3. There were 30 panelists for this sensory evaluation. The peroxidase activity test revealed that the color change happening in fresh juice from non-pretreated sugarcane faster and more intense than those of pretreated samples. It means that the peroxidase activities in the sugarcane were partially reduced by either blanching in hot water or microwave heating. Furthermore, the color change for the peroxidase activity test in case of blanching the cane in hot water was in the comparable rate and intense to the microwave heating. This result is similar to the Moreno et al. [13] who found that the enzyme activities of strawberries after steam blanching and microwave heating were decreased to the similar levels. In terms of the total solid, pH and sensory, there was insignificant difference between juices squeezed from samples pretreated by these two methods. Nonetheless, the color of juice from microwave-heated sugarcane was slightly darker (lower L*) and greener (higher h) than those of hot-water blanched sugarcane. Likewise, Moreno et al. [13] stated that merely small differences of L*, C*, and h values could be observed among the samples pretreated by the steam blanching and microwave heating. The darker color of the juice from microwave-heated sugarcane can be explained by the fast heating rate inside the sugarcane stem occurring during the microwave treatment. This heat expedited the maitlaid reaction between the reducing sugar and amino acid in the stem leading to the browning or darker color [19]. For the juice preparation in the UHT experiments, the pretreatment by blanching sugarcane in hot water at 80°C for 5 minutes was selected due to its ease of control, lower energy and equipment cost [16] but providing comparable enzyme inactivation level and juice quality to the microwave pretreatment.

The experimental results of the four UHT runs are presented in Table 4. The sensory evaluation in this part was performed by 20 panelists. It was clear that the juice sterilized at 140°C for 4 seconds was preferred to those of 135°C for 10 seconds. Moreover, the juice without sugar flavor additive acquired the higher rating than the flavor-added juice. In addition, the color of UHT processed juice significantly differed from the fresh

### Table 2. The properties of sugarcane juice from Singapore and Suphan Buri 50 varieties.

<table>
<thead>
<tr>
<th>Sugarcane variety</th>
<th>Total solid (°Brix)</th>
<th>pH</th>
<th>Color</th>
<th>Sensory test result in aspect of flavor (7 = maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>12.1 ± 0.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.3 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>55.8 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.1 ± 0.11&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Suphan Buri 50</td>
<td>19.6 ± 0.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.0 ± 0.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>44.2 ± 0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>23.8 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: The color was measured in L* (lightness), C* (chroma) and h (hue).
Total solid, pH, L*, C*, h and sensory test results are means ± standard deviation.
Means with the same superscript within same column are insignificant different (P < 0.05).
Table 3. The properties of sugarcane juice from different heat pretreatments.

<table>
<thead>
<tr>
<th>Pretreatment</th>
<th>Peroxidase activity test results</th>
<th>Total solid (°Brix)</th>
<th>pH</th>
<th>Color</th>
<th>Sensory test result in aspect of flavor (7 = maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The time duration to change color (s)</td>
<td>Intensity level of color change (5 = maximum)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-pretreatment</td>
<td>10</td>
<td>5</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>(1) Blanching in hot water 80°C for 5 minutes</td>
<td>25</td>
<td>4</td>
<td>19.6±0.2a</td>
<td>5.0±0.1a</td>
<td>44.2±0.03a</td>
</tr>
<tr>
<td>(2) Microwave heating for 5 minutes</td>
<td>25</td>
<td>4</td>
<td>18.5±0.09a</td>
<td>5.2±0.1a</td>
<td>39.5±0.09a</td>
</tr>
</tbody>
</table>

Note: N/A = Not applicable
The color was measured in L* (lightness), C* (chroma) and h (hue).
Total solid, pH, L*, C*, h and sensory test results are mean ± standard deviation.
Means with the same superscript within same column are insignificant different (P < 0.05).
Table 4. The properties of sugarcane juice from different UHT conditions.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>UHT condition</th>
<th>Sterilization Temperature (°C)</th>
<th>Holding time (s)</th>
<th>Adding flavor</th>
<th>Total solid (°Brix)</th>
<th>pH</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>Appearance</th>
<th>Aroma</th>
<th>Color</th>
<th>Taste</th>
<th>Texture</th>
<th>Overall liking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>140</td>
<td>No</td>
<td>4</td>
<td></td>
<td>12.1±0.4</td>
<td>5.0±0.04</td>
<td>32.8±2.7</td>
<td>4.2±0.4</td>
<td>19.2±0.5</td>
<td>6.7±1.6</td>
<td>6.9±1.7</td>
<td>6.7±1.7</td>
<td>6.9±1.7</td>
<td>6.4±1.1</td>
<td>7.1±1.4</td>
</tr>
<tr>
<td>2</td>
<td>140</td>
<td>Yes</td>
<td>4</td>
<td></td>
<td>11.9±0.5</td>
<td>4.5±0.01</td>
<td>32.1±0.8</td>
<td>4.5±0.1</td>
<td>18.2±0.1</td>
<td>5.9±1.8</td>
<td>5.4±1.8</td>
<td>5.9±1.8</td>
<td>5.9±2.1</td>
<td>6.3±1.3</td>
<td>6.1±1.4</td>
</tr>
<tr>
<td>3</td>
<td>135</td>
<td>No</td>
<td>10</td>
<td></td>
<td>11.0±1.1</td>
<td>5.0±0.10</td>
<td>30.6±1.5</td>
<td>4.2±0.2</td>
<td>18.6±0.5</td>
<td>4.9±1.3</td>
<td>4.9±2.1</td>
<td>5.0±1.6</td>
<td>4.5±2.2</td>
<td>5.8±1.3</td>
<td>4.9±1.5</td>
</tr>
<tr>
<td>4</td>
<td>135</td>
<td>Yes</td>
<td>10</td>
<td></td>
<td>11.8±0.4</td>
<td>4.5±0.01</td>
<td>30.6±2.3</td>
<td>4.4±0.3</td>
<td>17.6±0.5</td>
<td>5.1±1.6</td>
<td>5.4±2.3</td>
<td>5.2±1.4</td>
<td>5.3±2.1</td>
<td>5.6±1.2</td>
<td>5.6±1.5</td>
</tr>
<tr>
<td>5</td>
<td>Fresh juice</td>
<td>No</td>
<td></td>
<td></td>
<td>11.8±0.5</td>
<td>5.2±0.05</td>
<td>34.6±0.3</td>
<td>2.9±0.1</td>
<td>18.4±0.1</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: N/A = Not applicable
The color was measured in L* (lightness), a* (redness) and b* (yellowness).
Total solid, pH, L*, a*, b* and sensory test results are mean ± standard deviation.
Means with the same superscript within same column are insignificant different (P < 0.05).
counterpart especially the redness \((a^*, +)\). The redness of UHT processed juice was higher than the fresh juice while the lightness \((L^*, +)\) was lower. The explanation was that the heat during sterilization expedited the maillard reaction between the reducing sugar and amino acid in the juice leading to the browning and degreening [19]. Moreover the degreening of UHT juice could be occurred by the decrease in chlorophyll content [2] during the sterilization. Also, it appeared that the yellowness values \((b^*, +)\) were significantly different between flavor-added and no flavor-added samples. If deeming the total solid, there was insignificant difference between samples. On the other hand, the average pH of juice decreased from 5.2 to the range between 4.5-5.0 after UHT process. This pH reduction went along with the findings of Venkatachalam et al. [24] and Rustom et al. [25]. The decrease of pH was occurred due to the protein unfolding, through denaturation by heat and release of protons [25].

4. CONCLUSIONS

According to the results, it appeared that the sugarcane varieties, heat pretreatment methods and UHT conditions have significant effects on the sugarcane juice quality. This work illustrated that the sugarcane Suphan Buri 50 variety is more appropriate for juice production than Singapore variety. Also, the heat pretreatment by blanching sugarcane in hot water at 80°C for 5 minutes should be performed to diminish the enzyme activities occurring during the juice processing and storage. The higher sterilization temperature but shorter holding time seemed to provide the better quality juice. If requiring \(F_0 \geq 4\), the UHT sterilization at 140°C for 4 seconds could keep the sugarcane flavors in the product and provide the more favorable juice than those of 135°C for 10 seconds. Therefore, the flavor additive was deemed unnecessary in this case.

ACKNOWLEDGEMENTS

The authors would like to convey special thank to the Commercial Research and Development Project Cooperated Between Government and Private Sector, the Office of the Higher Education Commission, Thailand and the T.N. Sugar Industry Co.Ltd. for the project grant.

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