

COMPARISON OF PEELING, SQUEEZING AND CONCENTRATION METHODS FOR THE SUGARCANE JUICE PRODUCTION

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Abstract

In this research, various methods of sugarcane peeling, squeezing and juice concentration were compared. The objective was to determine the proper peeling, squeezing and juice concentration techniques for the sugarcane juice production. The experimental results indicated that the sugarcane should be peeled by the abrasive tool and squeezed by the roller in order to achieve high yields with shorter process time. It also appeared that the freeze concentration method applied in this work could not manufacture the high concentrated sugarcane juice. On the other hand, the vacuum evaporation operating at 70°C and vacuum pressure 70 cmHg could concentrate the juice to approximately 60°Brix. Nonetheless, the reconstituted sugarcane juice from the freeze-concentrated specimen was preferred to those from the vacuum evaporation.

Keywords: Sugarcane, sugarcane juice, concentrated juice, concentration

Introduction

Fresh sugarcane (*Saccharum officinarum* L.) juice is a popular beverage in many countries particularly in Asian region such as China, India, Malaysia and Thailand due to its taste and cheap price. It is served in many eateries from roadside stalls to five-star hotel dining halls. Additionally, sugarcane juice is used for the medication in some countries. For instance, the Indian systems of medicine have utilized it to cure jaundice and liver-related disorders (Kadam *et al.*, 2008). Hudson *et al.* (2000) and Hollman (2001) claimed that the flavonoids that can be

found in sugarcane juice have the abilities to protect cells from degenerative processes and to reduce the development of health problems such as cancer and cardiovascular diseases. Although the industrial production of sugarcane juice has a business potential, the selling of sugarcane juice cannot be expanded as expected owing to its rapid quality descent (Yusof *et al.*, 2000; Prasad and Nath, 2002; Mao *et al.*, 2007).

The juice concentration is deemed as a solution to lengthen the shelf-life, reduce the storage and shipping costs, and elevate the

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consumer safety while preserving the fresh quality of sugarcane juice. For the production of concentrated sugarcane juice, the preparation of raw sugarcane juice is a critical procedure. According to Tangpremsri *et al.* (1997), the sugarcane variety Suphanburi 50 should be chosen for the juice manufacture because of its high juice yield and total solid, taste, fine color and disease resistance. Furthermore, the stability of the concentrated sugarcane juice product during storage is normally required by the distributor and consumer. So, the pretreatments such as blanching raw materials in hot water and/or addition of antioxidant agents are commonly applied to the juice products (Ozoglu and Bayindirli, 2002; Margherita and Giussani, 2003). A pretreatment study for sugarcane juice conducted by Mao *et al.* (2007) indicated that the blanching of sugarcane stems in boiling water for 5 min before squeezing and/or addition of 0.1% ascorbic acid was an efficient method to prevent the browning and diminish the enzyme activities in the fresh sugarcane juice. Qudsieh *et al.* (2002) stated that the key enzyme related to the browning of sugarcane juice was the polyphenol oxidase (PPO) that reacted with phenolic compounds.

So far, there have been very little literature in the area of sugarcane juice concentration. One such work was the sugarcane juice concentration from 20 to 40°Brix for a jaggery making process using a heat pump based freeze concentration system proposed by Rane and Jabade (2005). However, this concentration scheme was inappropriate for making juice beyond 40°Brix due to the considerable increase in juice viscosity which led to the adverse effect on heat transfer and sucrose inclusion.

Due to the lack of background knowledge about the sugarcane juice preparation and processing in particular the concentration, the peeling, squeezing, and concentration techniques were studied in this work to enrich the existing knowledge. The objective was to determine the proper peeling, squeezing and juice concentration techniques for the sugarcane juice production.

Materials and Methods

The Comparison of Sugarcane Peeling and Squeezing Methods

The apt practice for peeling and squeezing the sugarcane was studied using the freshly harvested sugarcane of the “Suphanburi 50” variety. The sugarcane was grown in the central region of Thailand. Firstly, the juice yield comparison between peeling sugarcane stems manually by knives and mechanically by the abrasive peeler motor 0.5 HP manufactured by T.N. Sugar Industry Co. Ltd. as in Figure 1 was carried out. Then, the juice yield from squeezing peeled sugarcane stems by the “NHY” rolling squeezer motor 0.25 HP 220 V 50 Hz as in Figure 2 was compared with those of using the “SAKAYA” hydraulic pressing machine motor 1 HP 220 V 50 Hz as in Figure 3. The rolling squeezer and the hydraulic pressing machine were supplied by Ngow Huat Yoo MACHINERY Company Limited and Sakaya Automate Company Limited respectively. The sugarcane stems were cut to more or less 50 cm length before feeding them into the rolling squeezer whereas they were shortened to be 4-5 cm length, sliced to be thin pieces and put in the filtering



Figure 1. The abrasive peeler sugarcane

bag before loading them into the hydraulic pressing machine. After that, the appropriate peeling and squeezing methods were applied in the raw juice preparation for the juice concentration experiments.

The Comparison of Sugarcane Juice Concentration Methods

There were two methods for concentrating juice in this work. They consisted of

(1) *Vacuum evaporation*: The sugarcane juice was heated using hot water as a heating medium at temperature 70°C and evaporated in the chamber under vacuum pressure 70 cmHg. Under this condition, the outlet temperature of sugarcane juice at the heat exchanger was roughly 68°C. The hot juice was then fed into the evaporating chamber by the circulating pump and boiled because of the vacuum pressure in the chamber. The evaporated moisture would flow into the condenser, release heat to the cooling water and become condensed water at the bottom of condenser. The system was operated until the concentration of juice reached the maximum level which the evaporator could accomplish. The schematic diagram of this process is illustrated in Figure 4. The model of

the vacuum evaporator was “REV-T” and manufactured by Hisaka Works Company Limited in Japan.

(2) *Freeze concentration*: The sugarcane juice was initially frozen in the “KATOMO” batch-typed ice cream freezer model HA3505 motor 80 W 220 V 50 Hz at the freezing temperature approximately -9°C by applying the salted ice as the cooling agent. Then the frozen samples were put into the filter bag and separated the concentrated juice from the ice crystals using the “SAKAYA” hydraulic pressing machine.

The fresh juice preparation and the concentration process were conducted on the same day for each batch. After concentration, the juice was filled into the sterilized bottles and exposed to the determination of total solid, pH, color and viscosity. Moreover, they were reconstituted to the same total solid level as the fresh juice (19.6°Brix) for the color measurement and sensory evaluation.

Quality Determination

The total solid content, pH, color and viscosity of the sugarcane juice were measured by “ATAGO” hand refractometer, “JENCO” pH meter, “Minolta” color meter model CM-3500d



Figure 2. The rolling squeezer



Figure 3. The hydraulic pressing machine

and “BROOKFIELD” digital rheometer with spindle no.21 at 100 rpm respectively. The sensory evaluation was carried out for the fresh and reconstituted juices using 7-point Hedonic scale test by 26 panelists who were the students at the Department of Food Science and Technology, Kasetsart University. The total solid content, pH, color and viscosity determinations were performed in triplication. The software package Statistica 5.5 StatSoft™ (supplied by StatSoft, Inc. Tulsa, OK 74104 USA) was used for statistical analysis.

Results and Discussion

Peeling

The results of comparing the juice yields between peeling sugarcane manually by knives and mechanically by the abrasive peeler indicated that the latter was more efficient with the juice yields 76.4% and 94.6%, respectively. The reason was that peeling by the abrasive tool led to less sugarcane flesh loss in the peeled skins due to a constant depth of peeling

whereas the manual peeling by knives strongly relied on the skills and consistency of the worker. Furthermore, mechanical peeling was more convenient and much faster. Emadi *et al.* (2008) claimed that the abrasive peelers are common tools for fruits and vegetables such as apples, carrots and potatoes because this peeling method can keep edible portions of produce fresh and provide high peeling production rate. However, the main limitations of this peeling tool are the loading sensitivity and low flexibility.

Squeezing

For the squeezing method, it appeared that the rolling squeezer and hydraulic pressing machine resulted in the juice yields of 56.1% and 58.5%, respectively. It could be observed by the naked eyes that the squeezed sugarcane from the rolling machine was somewhat more humid than those from hydraulic pressing. It was because the sugarcane that were loaded into the hydraulic pressing machine were thinner and shorter size than those of rolling squeezer. Therefore, the intensity of the compression force on the sugarcane stem was higher resulting in

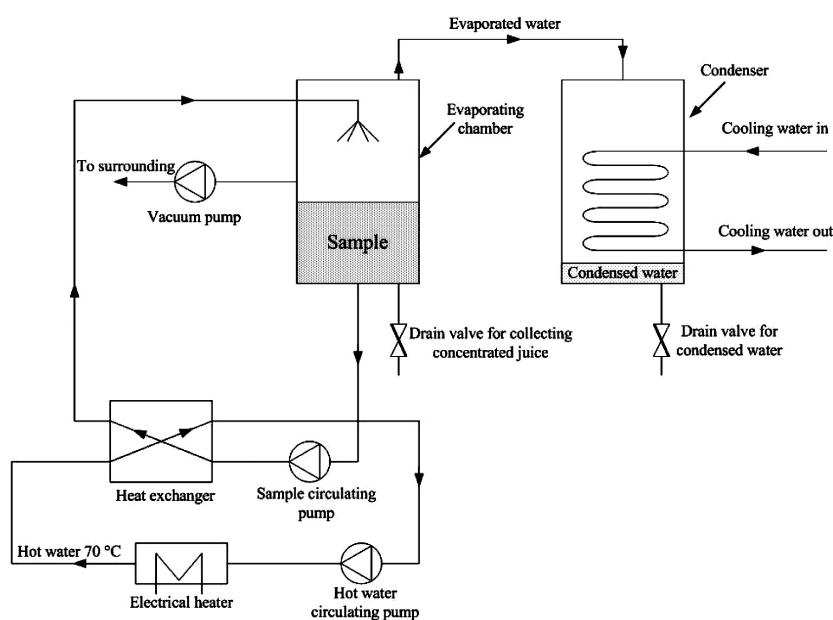


Figure 4. A schematic diagram of the vacuum evaporation process

the more amount of squeezed juice. Despite the higher yield from hydraulic pressing, the time consumed from the pressing method was 186 min while it was merely 20 min for the rolling squeezer at the same amount of sample (≈ 10 kg). It was mainly due to the limited amount and length of sample that could be loaded into the pressing machine for each batch. In contrast, for the rolling squeezer the 50 cm sugarcane stem could be fed into the machine continuously. The rolling squeezer was also applied for sugarcane squeezing in other studies as well such as Tangpremsri *et al.* (1997) and Mao *et al.* (2007). In the work of Mao *et al.* (2007), the sugarcane stem was cut into three portions with equal length about 50 cm before loaded into the three-roller squeezer same as the squeezing by the rolling machine in this research. Furthermore, Mao *et al.* (2007) found that the yield of extracted juice by this method was high especially for the unblanched stems.

Sugarcane Juice Concentration

The juice concentration experiments disclosed that the evaporation method using hot water as a heating medium at temperature 70°C under vacuum pressure 70 cmHg could produce the highly concentrated sugarcane juice ($\approx 60^\circ\text{Brix}$) but the freeze concentration method could not, even though the three continuous cycles of freezing and pressing were applied. It was due to the temperature of the freezer (using salted ice as the coolant) that was not low enough to freeze the water in the juice after reaching a certain concentration level (Bayindirli *et al.*, 1993). The concentration of freeze-

concentrated sugarcane juice in this work (31.5°Brix) is close to those of freeze-concentrated apple and pear juices obtained from the study of Hernandez *et al.* (2009) that ranged between $30.2\text{--}32.7^\circ\text{Brix}$. In order to manufacture the higher concentrated sugarcane juice by the method of freeze concentration, the lower temperature coolant such as liquid nitrogen or carbon dioxide must be applied. Nevertheless, Cassano *et al.* (2004) pointed out that a limitation of the commercial freeze concentration systems is that the achievable concentration is lower than the values obtained from the vacuum evaporator ($60\text{--}65^\circ\text{Brix}$). The total solid, pH, color and viscosity of the fresh and concentrated sugarcane juice are presented in Table 1, whereas the outcome of color measurement and sensory evaluation of reconstituted sugarcane juice from the vacuum-evaporated and freeze-concentrated samples are illustrated in Table 2. The result unsurprisingly indicated that the viscosity of highly-concentrated sample (59.8°Brix) was much higher than those of fresh juice (19.6°Brix) and freeze-concentrated juice (31.5°Brix). Although the juice viscosity elevated along the increasing juice concentration, the relationship was not linear but exponential pattern. The color measurement showed that the lightness (L^* , +) was lower for concentrated juice especially the vacuum-evaporated juice while the chroma (C^* , +) was higher. Moreover, the hue angle indicated that the freeze-concentrated sample was more yellow than the vacuum-evaporated specimen. The explanation was that the heat from circulated hot water during vacuum evaporation expedited the maillard

Table 1. The comparison between the properties of the fresh and concentrated sugarcane juices

Sample	Total solid ($^\circ\text{Brix}$)	pH	Viscosity (cP)	Color		
				L^*	C^*	h
Fresh juice	19.6 ± 0.2^a	5.0 ± 0.11^a	5.3 ± 0.2^a	44.2 ± 0.3^a	23.8 ± 0.2^a	93.3 ± 3.3^a
Freeze-concentrated juice	31.5 ± 0.1^b	5.4 ± 0.03^b	6.9 ± 0.2^a	43.4 ± 0.9^a	32.3 ± 0.2^a	90.7 ± 0.1^a
Vacuum-evaporated juice	59.8 ± 0.2^c	5.1 ± 0.02^c	33.9 ± 2.1^b	37.5 ± 0.1^b	40.9 ± 0.7^b	86.4 ± 0.4^b

Note: The color was measured in L^* (lightness), C^* (chroma) and h (hue).

Total solid, pH, viscosity, and colors (L^* , C^* , h) are mean $\pm$ standard deviation.

Means with the same superscript within same column are insignificant different ($P < 0.05$).

reaction between the reducing sugar and amino acid in the juice leading to the browning (Fennema, 1976). On the other hand, there was no heat contribution in freeze concentration. Also, the higher total solid and concentration of the vacuum-evaporated juice was another rationale for these color results.

For the colors of reconstituted samples, it appeared that their chroma and hue angles were insignificantly different from the fresh; however, their lightness slightly diverged. From the sensory evaluation, the reconstituted sugarcane juice from freeze-concentrated sample was preference to those from vacuum-evaporated specimen. It was because the freeze concentration is the method that does not apply heat during the process, as a result the aroma and taste of product were maintained and similar to the fresh (Cassano *et al.*, 2004). On the other hand, the vacuum-evaporated juice exposed to heat at approximately 68°C. As a result, a loss of fresh juice flavors, color degradation and a “cooked” taste occurred (Maccarone *et al.*, 1996; Jiao *et al.*, 2004). Nonetheless, the sensory scores of the reconstituted juice from the vacuum-evaporated product were not extremely far from those of the fresh and freeze-concentrated juice. In addition,

according to Cassano *et al.* (2004), the commercial freeze concentration systems (cryoconcentration) required remarkably more energy consumption than the vacuum evaporation system; hence, they are suitable for the high-value products. On the basis of these results, the vacuum evaporation method is proposed for the industrial production of concentrated-sugarcane juice.

Conclusions

The results illustrated that the sugarcane stem should be peeled by the abrasive machine and squeezed by the roller due to their high product yields and shorter process time. To produce the concentrated juice to approximately 60°Brix, the vacuum evaporator should be used at hot water temperature 70°C and vacuum pressure 70 cmHg. Although the freeze concentration provided the superior quality of juice, the freezer in this study could not concentrate juice to the required level. Lastly, the further investigation in the juice preparation technique and the physical change of juice during storage should be conducted in order to specify the complete procedure for producing the concentrated sugarcane juice with high quality.

Table 2. The comparison between the properties of the fresh and samples reconstituted from the concentrated sugarcane juices

Sample	Color			Sensory test result (7 = maximum)				
	L*	C*	h	Color	Aroma	Taste	Sweetness	Overall liking
Fresh juice	44.2 ± 0.3 ^a	23.8 ± 0.2 ^a	93.3 ± 3.3 ^a	5.2 ± 1.1 ^a	5.2 ± 1.3 ^a	5.3 ± 1.3 ^a	5.4 ± 1.3 ^a	5.4 ± 1.2 ^{ab}
Reconstituted sample from freeze-concentrated juice	47.4 ± 0.2 ^b	21.8 ± 0.02 ^a	95.5 ± 0.1 ^a	5.6 ± 1.3 ^b	4.9 ± 1.1 ^a	5.6 ± 1.2 ^a	5.6 ± 1.3 ^a	5.7 ± 0.9 ^b
Reconstituted sample from vacuum-evaporated juice	45.5 ± 0.2 ^c	25.2 ± 0.4 ^a	94.1 ± 0.1 ^a	5.3 ± 1.5 ^{ab}	4.4 ± 1.2 ^a	5.1 ± 1.5 ^a	4.9 ± 1.7 ^b	5.0 ± 1.3 ^a

Note: The color was measured in L* (lightness), C* (chroma) and h (hue).

The colors (L*, C*, h) and sensory test results are mean ± standard deviation.

Means with the same superscript within same column are insignificant different ($P < 0.05$).

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