

**PRODUCTION AND EVALUATION OF FREEZE-
CONCENTRATED SUGAR-CANE (*SACCHARUM OFFINARIUM*)
JUICE**

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Abstract

Sugar-cane (*Saccharum Offinarium*) juice with initial total soluble solid (TSS) of ~ 15 °Brix was extracted from blanched sugar-cane stalks and was used for the production of a double strength (~ 30 °Brix) sugar-cane juice using a freeze-concentration process. The freeze-concentrated juice was lower in pH and color values and higher in non-enzymic browning (NEB) index, chlorophyll content and relative viscosity as compared to the fresh juice, however its total viable microbial count was similar to the fresh juice. A sensory evaluation performed on the samples indicated that fresh sugar-cane juice had higher hedonic scores in sweetness, flavor, aftertaste and overall acceptability as compared to that of freeze-concentrated juice (30 °Brix). The sensory scores of concentrated juice however improved upon reconstitution with mineral water. Reconstituted juice with TSS of 15 and 20 °Brix had the highest hedonic scores for the flavor, sweetness, aftertaste and overall acceptability attributes as compared to other reconstituted juice. During storage, the TSS and pH values of freeze-concentrated juice stored at 10 and 25 °C decreased considerably with storage times, and the decrease was more pronounced in the juice stored at 25 °C. The TSS and pH values however were unchanged at storage temperatures of -18 and 4 °C. The color values and NEB index of all juice were not affected by the storage temperatures used.

Keywords: *Freeze-concentration; fresh sugar-cane juice; reconstituted juice*

Abstrak

Jus tebu (*Saccharum Offinarium*) dengan total pepejal terlarut (TSS) ~ 15 °Brix diperah dari batang tebu tercelur dan digunakan untuk penghasilan jus tebu terkonsentrat sejukbeku (~ 30 °Brix) menggunakan proses pemekatan sejukbeku. Jus terkonsentrat sejukbeku menunjukkan nilai pH dan warna yang lebih rendah dan indeks pemerangan bukan-enzimatik (indeks NEB), kandungan klorofil dan kelikatan relatif yang lebih tinggi berbanding jus tebu segar. Bagaimanapun, kiraan microbial total bagi ke dua-dua jus adalah sama. Penilaian sensori menunjukkan jus segar mempunyai skor Hedonik lebih tinggi bagi atribut kemanisan, perisa, “aftertaste” dan penerimaan keseluruhan berbanding jus yang dikonsentrat-sejukbekukan. Skor Hedonik sensori bagaimanapun meningkat setelah jus terkonsentrat dikonsitit-semula dengan air mineral. Jus terkonstitit dengan TSS 15 dan 20 °Brix menunjukkan skor Hedonik tertinggi bagi atribut perisa, kemanisan, “aftertaste” dan penerimaan keseluruhan berbanding jus terkonstitit lain. Semasa penstoran, nilai TSS dan pH jus terkonsentrat sejukbeku yang distor pada suhu 10 and 25 °C menurun dengan nyata dengan masa penstoran. Penurunan ini adalah lebih ketara pada jus yang distor pada suhu 25 °C. Nilai TSS dan pH bagaimanapun tidak berubah pada suhu penstoran -18 dan 4 °C. Nilai warna dan indeks NEB bagi semua jus tidak dipengaruhi oleh suhu dan masa penstoran.

Introduction

Fresh sugar-cane juice is a popular thirst-quenching drink in many South East Asia countries due probably to its refreshing sensation of cane's flavor and sweetness. The high sugar content of ~ 15 - 18 % (Tee *et al* 1997; Yusof *et al* 2000; Easa, 2000) of the juice suggests that sugar-cane juice can potentially be developed into a natural energy drink. Alternatively, the sugar composition of the juice can be modified in order to obtain the so called "functional sugar-cane juice"; a juice that is high in fructose-oligosaccharides and low in sucrose (Easa, 2000). By adding Pectinex Ultra SP-L enzyme followed by an incubation treatment, sugar modification was achieved, producing a potential health enhancing products. Another feature of the juice is the substantial content of chlorophyll of ~ 1 mg/100 ml (Yusof *et al*, 2000). This is important since chlorophyll has been suggested as one of the promising anticancer ingredients (Lin, 1999), an odor suppressor and wound healer (Humphrey, 2004). The similarity between the chemical structures of chlorophyll with blood pigment has also been suggested for correcting the effects of anemia (Humphrey, 2004). All these will be of significance if the juice can be properly preserved using a technology that is accessible by small operators. This however has not been sufficiently developed.

The main problem associated with fresh sugar-cane juice is its short shelf life and heat sensitivity of its flavor and components. Therefore, the juice is typically sold-fresh by the roadsides and small eateries throughout South East Asia countries. It is therefore not uncommon for the variation in the total solid content (TSS), flavor, color and other sensory attributes of the juice from eateries to eateries. The risk of contracting food

poisoning from drinking spoiled sugar-cane juice is also a concern since most of the sugar-cane juice operators are not trained in the area of food safety. The difficulty in preserving sugar-cane juice stems from the nature of the juice itself. In contrast to fruit juice, the pH of fresh sugar-cane juice is normally ~ 5.0 that is above 4.6 (Yusof *et al*, 2000), thus making the juice to be classified as a low acid product. This condition does not favor a long shelf life of pasteurized juice. In addition, the high sugar content of the juice makes it vulnerable to sugar degradation if heated at high temperatures such as during the processes of sterilization, evaporation and drying. Therefore, most of the attempts to preserve the sugar-cane juice have been focusing on the use of heat treatment with refrigeration, and inclusion of preservatives (Bhupinder *et al* 1991; Yusof *et al*, 2000). These treatments have not been commercially applied since the sensory attributes of the juice were altered. Amongst these treatments, the preservation using low temperatures has been the most effective method in maintaining the quality of sugar-cane juice (Yusof *et al*, 2000; Bhupinder *et al*, 1991) even though this may not be practical for many small scale sugar-cane juice vendors.

Since consumers are used to drinking fresh juice, the juice's authenticity becomes an important sensory attribute. Typically ice cubes are added in order to achieve the cool and freshness sensation of the fresh juice. In fact, in many road sides and "night-market" practices throughout Malaysia, freshly extracted juice is chilled by mixing it with a large quantity of crushed ice and left to stand for hours. This practice causes dilution of flavor and sweetness thus affecting the authenticity of the juice. The author could not find any

reference of attempts to standardize the flavor of sugar-cane juice by e.g. controlling the total solid content of the juice or by drying the juice to a powder form.

The objective of this study is to evaluate the use of a freeze-concentration process to produce concentrated sugar-cane juice with a standard solid content. This will be evaluated against fresh juice, and stored at a range of time and temperatures. Freeze-concentration is thought to be of benefit in conditions where heat is damaging to product quality (Despande *et al*, 1982; Braddock and Marcy, 1985). By controlling the freezing process, the total solid content (TSS) of ingredients occurring within the fresh juice can be increased without the use of excessive heat such as that applied during the process of evaporation. It is imperative that the development of methods for the preservation of sugar-cane juice such as the production of concentrate or powdered product is beneficial since the flavor and other important quality aspects of the juice can be standardized.

Materials and methods

Materials

Sugar-canes (*Saccharum officinarum*) of 'yellow variety' obtained from a plantation in Selangor (a state in Peninsular Malaysia) were used in this study. All canes were stored at 4 °C prior to extraction that was performed within 2-3 days of storage. All chemicals used for the project were of reagent grades.

Extraction of sugar- cane juice

Canes were cut into uniform lengths about 0.4 m long (after removing the nodes and outer skin from the cane). They were then washed with plain water to remove any dirt or foreign particles from the cane surfaces. Canes intended for freeze-concentration process were then blanched at 80 °C for 15 min using a steaming cabinet (MSM-2001, Malaysia). The stalk blanching method was not performed on the fresh juice. After rinsing, a three-roller power crusher (Mindong Electric, model CH-316, Taiwan) was used to extract the juice. The juice was filtered by passing through a layer of muslin cloth. The extracted juice was collected in a chilled container and chilled immediately before being analyzed.

Production of freeze-concentrated sugar cane juice

Extracted juice was filled into polypropylene plastic casings (30.5 cm x 21 cm) that was then sealed and subjected to a rapid chilling treatment to -18 °C using an air blast freezer (Irinnox, Italy). The process of rapid chilling from the ambience to -18 °C took between 30 to 35 min to complete. The juice was then transferred into a domestic freezer (Sharp, Malaysia) and stored for 24 h after which the hardening and completion of ice formation occurred. At this stage separation of ice and unfrozen phase consisted mainly of concentrated sugar-cane juice were evidenced. A small opening was made at one end of the plastic casing to allow the flow of the concentrated juice into a volumetric flask. This process of thawing was performed at room temperature and stopped once the total solid content of the juice reached ~ 30° Brix. The thawing process took between 50 to 70 min to complete.

Color, pH, microbiological and total soluble solid (TSS) analysis

The color of sugar-cane juice was determined by using the Minolta colorimeter (model CM-3500d, Japan) with spectra magic software and CIELAB color system. The values were expressed as lightness 'L*' (100 %, white; 0 %, black), redness 'a*' (+, red; -, green) and yellowness 'b*' (+, yellow; -, blue). The total color value of the juice was expressed as (Ranganna, 1977):

$$\text{Color} = (L^{*2} + a^{*2} + b^{*2})^{1/2}$$

The color of the juice was also expressed as;

$$\text{Chroma/Saturation} = (a^{*2} + b^{*2})^{1/2}$$

The total soluble solids was measured using an Otago refractometer (model HSR-500, Japan; 0-42° Brix) and pH was measured using a Horiba F series pH meter (model F 21).

Non-enzymic browning index, NEB index was estimated following the methods employed by Butchelli and Robinson (1994). Microbiological analysis was performed using the standard plate count method (Andrew, 1992).

Analysis of chlorophyll

Chlorophyll was measured according to the methods of Nagata and Yamashita (1992). Similar methods were used by Yusof *et al* (2000).

Estimation of relative viscosity

Juice was filtered through a 40 µ filter to separate the pulp and the viscosity of the juice measured using a graduated burette (50 ml. 1 mm orifice). Time required for 40 ml

freeze-concentrated juice to run out at 3-4 °C was measured and expressed relative to time found for fresh juice.

Sensory evaluation and reconstitution studies

To standardize the temperature of samples for sensory evaluation, freshly prepared samples were kept in paper cups and stored at 4 °C for 4 hr before serving. Sensory evaluation of the juice was carried out by 10 panelists. The panelists rated the samples for color, aroma, sweetness, aftertaste, flavor and overall acceptability using a Hedonic scale of 1-9 (1=dislike very much, 9=like very much). In the reconstitution studies, freeze-concentrated juice was reconstituted with a commercial mineral water to a TSS range of 15 to 25 °Brix and sensory evaluation performed.

Storage studies

Fresh or freeze-concentrated juice were filled into sterilized universal bottles and capped. Three bottles of each sample were stored at -18 °C (Control), 4 °C, 10 °C and 25 °C. Samples were removed at two days interval until eighth day of storage for the analysis of TSS, pH, NEB index and color.

Statistical analysis

Data were analysed by the analysis of variance and Duncan multiple range test using a Statistical Analysis System (SAS) program.

Results and discussion

Fruit juice concentrates with high soluble solids are normally produced through a high temperature short-time evaporative process under vacuum to minimize thermal damage to the juice. This high technology involving the use of sophisticated equipments is often too expensive for the small and medium industries to venture. The freeze-concentration process employed in this paper may be useful in controlling the soluble solids in the sugar-cane juice as these will vary with cane maturity, variety and growing conditions (Yusof *et al*, 2000).

The yield of fresh and concentrated juice can be estimated from the weight of canes used and the amount of juice obtained after extraction and freeze-concentration process. 4 kg of canes yielded approximately 2 L of fresh juice and this was later processed to produce approximately 500 ml of freeze-concentrated juice. The exact yield of the freeze-concentrated juice could not be established since the TSS of freeze-concentrated juice was controlled at ~ 30 °Brix. After the freeze-concentrated juice was obtained, a quantity of unthawed ice remaining was discarded. The TSS of this unthawed ice was ~ 2 °Brix. Despite differing in TSS value, the freeze- concentrated juice was visually similar to the fresh juice.

The physicochemical and microbiological data of the two types of juice are displayed in Table 1. The initial TSS of sugar-cane juice used was 15 °Brix. Typical juice or juice drinks are approximately 84 to 89 % water and 11 to 16 % solids and the soluble solids of these juices are primarily composed of sugars (Clydesdale *et al*, 1994). It can be seen

that the freeze-concentration process employed in this project was able to double the TSS of sugar-cane juice. The separation of concentrated juice from the frozen ice phase was performed manually by allowing the gravitational flow of concentrated juice into a beaker. This process was stopped when the level of TSS had reached ~ 30 °Brix (typically the range of TSS obtained was between 28 – 32 °Brix) and this took between 50 to 70 min. The increased solid content of the freeze-concentrated juice also increased its relative viscosity.

Changes in pH, NEB index and color values were apparent after the freeze- concentration process; freeze- concentrated juice was lower in pH and color values but higher in chroma value and NEB index. Thus the freeze-concentrated juice was higher in organic acid content, darker and more saturated in color and higher in the content of water soluble materials than the fresh juice. Despite the lower pH attained, the freeze-concentrated juice was still considered as a low acid product as its pH value was higher than 4.6. The slight darkening of the concentrated juice could have been attributed to some level of non-enzymic browning (Butchelli and Robinson, 1994) occurring during stalk blanching. The level of chlorophyll in the sugar-cane juice was ~ 0.1 mg/10 ml and this value increased to ~ 0.2 mg/10 ml following freeze-concentration. The ratio of chlorophyll *a* to chlorophyll *b* was 3:2, which was close to the typical ratio of most green plants, which is at a ratio of about 3:1 (Humphrey, 2004). Since chlorophyll is the main pigment responsible for the color of sugar-cane juice (Yusof *et al.*, 2000) it may have had accumulated in the concentrated juice and contributed to the color change. The shift of the *a** values towards a more negative value supports this explanation.

The freeze-concentrated juice had similar level of total viable microbial count as that of the fresh juice even though the freeze-concentration process took more than 24 hrs to complete. This could be contributed by the blanching treatment of cane stalks prior to extraction, rapid freezing rate employed during the early stage of the freeze-concentration juice production that was enhanced by a freezing storage of 24 hrs. Thus the treatment employed for the production of freeze-concentrated juice resulted in an acceptable microbial quality even though enzymic browning reactions could have proceeded at a higher rate due to the higher concentration of compounds.

One feature of the freeze-concentrated juice is its low acceptability of its sensory attributes (Fig. 1). Fresh juice scored higher in the attributes of flavor, sweetness, aftertaste and overall acceptability as compared to that of freeze-concentrated juice ($P < 0.05$). However, no difference in the score of color and aroma was detected between the two juices. This suggests that the freeze-concentration process had changed some of the sensory attributes of the sugar-cane juice and this could well be due to the concentrating, rather than freezing effect.

The reconstitution study of concentrated juice was performed with mineral water to a range of concentration between 15 to 25 °Brix before subjecting the diluted juice to a sensory evaluation (Table 2). The scores for color and aroma were unchanged upon reconstitution of the concentrated juice with water. On the other hand, the scores for sweetness, flavor, aftertaste and overall acceptability improved with reconstitution. This

trend is similar to that observed in Fig. 1. A similar sensory response of overall acceptance of reconstituted “Ya Pak King” juice with TSS has been shown by Suntornsuk *et al* (2004). Reconstituted juice with excessive level of sugars and flavor were least accepted, while those with similar TSS to the original juice were most preferred. The most acceptable TSS of the reconstituted freeze-concentrated juice was juices with the TSS of 15 and 20 ° Brix. As shown in Table 1, the TSS of these juices was similar to the freshly extracted juice. This indicates the possibility of reconstitution of the freeze-concentrated sugar-cane juice with water to achieve a similar sensory perception of the fresh juice. As many consumers would prefer drinking sugar-cane juice with ice cubes, the dilution of the freeze-concentrated juice with ice may yield sensory sensation similar to that of fresh juice.

The sensory attributes of fresh juice and reconstituted (15 ° Brix) juice were similar for all sensory attributes tested ($P < 0.05$; results not shown). Therefore water can be added into freeze-concentrated juice to bring it to the minimum single strength juice without affecting sensory appeals. This result suggests that most of the sensory attributes and overall acceptability of sugar-cane juice were governed by the TSS of the juice. The freeze-concentration process employed during the juice production had minimum effect on the freshness level of the juice. This could be explained partly to the fact that heat was not applied during juice production. The TSS of sugar-cane juice comprised mainly of sugars, natural flavorings, pigments and other nutrients (Tee *et al*, 1997). At this stage, the main contributing components of the juice responsible for the sensory scores and acceptance cannot be ruled out. It is thought however that a threshold level of TSS

could have existed for the sugar-cane juice that determines the sensory sensation and acceptability. This threshold is yet to be determined.

TSS and pH values have been used as chemical indicator of microbial growth of sugar-cane juice stored at low temperatures. During storage of freeze-concentrated juice, TSS and pH of juice stored at 10 and 25 °C decreased with storage time (Fig. 2 and 3), and the decrease was the fastest in the juice stored at 25 °C. This is not unexpected since a high storage temperature is known to promote microbial infestation of juice (Bhupinder *et al*, 1991) and caused a subsequent drop in pH. The decreased pH of the juice can be related to the development of acidity of sugar-cane juice during storage (Yusof *et al*, 2000; Bhupinder *et al*, 1991) that was thought to be due to acetic acid and lactic acid production. The slight decrease in TSS with storage might be due to the loss of sucrose that may have been consumed by microbes (Yusof *et al*, 2000). The sucrose loss could have been reduced if sugar cane juice is prepared with preservatives (Bhupinder *et al*, 1991). The TSS and pH values of juice stored at -18 and 4 °C remained almost unchanged throughout storage indicating the suitability of these storage temperatures for the juice preservation.

The NEB index and color values for all juice remained almost unchanged throughout storage for all temperatures used (results not shown). Similar patterns of response of TSS, pH, NEB index and color of fresh sugar-cane juice with storage time was observed (results not shown) and these were similar to the results shown by Yusof *et al* (2000). Therefore the pattern of change in most of the physical parameters of freeze-concentrated

juice was similar to those of the fresh juice. It is possible to suggest the incorporation of preservatives such as potassium metabisulphite (Bhupinder *et al*, 1991) to improve the keeping quality of the freeze-concentrated juice. Depectinization studies, i.e. the addition of pectinesterases on yield of sugar-cane juice are also suggested. Once concentrated, the concentrate can be prepared for retail or consumers by combining with other blends or water for juice standardization. Realizing this potential, a faster process for water removal of sugar-cane juice through the use of high temperature short-time evaporators, or microwave drying (Suntornsuk *et al*, 2004) which operate under vacuum should be initiated. Another innovative approach is to blend the juice with a fruit juice or product that will cause a decrease in pH without greatly affecting the sensory attributes. This new blend can be expected to have better shelf life following pasteurization and chilling.

Conclusion

A method to produce concentrated sugar-cane juice using freeze-concentration process is suggested. However the application of commercial freeze-concentration or membrane processing equipments could result in better yields.

Despite differing in most of the sensory attributes, the freeze-concentrated juice showed similar physicochemical changes during storage to that of the fresh juice. The concentrated juice can also be reconstituted with water to yield the sensory attributes similar to the fresh juice. The reconstituted juice was acceptable to taste panelists as its single-strength counterpart.

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Table and figure captions

Table 1. Physical properties of fresh and freeze-concentrated sugar-cane juice.

Table 2. Sensory attributes of freeze-concentrated sugar-cane juice after reconstitution with mineral water. Means in the same row with the different subscript are significantly different ($p < 0.05$).

Fig. 1 Comparison of sensory attributes of fresh sugar-cane juice (15 °Brix) with freeze-concentrated (30 °Brix) sugar cane juice. A bar with different letter as another bar is significantly different from the other ($p < 0.05$).

Fig. 2 Changes in pH of freeze-concentrated sugar-cane juice during storage at -18 (□), 4 (◆), 10 (○) and 25 °C (■) as a function of storage times.

Fig. 3 Changes in total soluble solid (TSS) of freeze-concentrated sugar-cane juice during storage at -18 (□), 4 (◆), 10 (◊) and 25 °C (■) as a function of storage times.

Table 1

Analysis	Fresh sugar-cane juice	Freeze-concentrated sugar cane juice
TSS (°Brix)	15.0	30.0
pH	5.1	4.8
NEB index	0.121	0.254
Color	97.8	93.7
Chroma/saturation	9.0	16.2
a*	-0.40	-0.70
Relative viscosity	1.00	1.10
Chlorophyll (mg/10 ml)	0.1	0.2
Microbiology (Total plate count; cfu/ml)		
i. PDA	i. 1.9×10^4	i. 3.8×10^3
ii. PCA	ii. 7.3×10^2	ii. 2.9×10^3