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Changes in quality of sugar-cane juice upon delayed extraction and storage

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Abstract

The quality of sugar-cane juice extracted from stored canes, as well as changes in quality of fresh juice stored at different temperatures, were studied. Cane stems were stored at 10±1°C, 85–88% relative humidity (RH) and 27±1°C, 55–85% RH, while fresh juice was stored at 5±1°C, 61–84% RH and 27±1°C, 55–85% RH. The physicochemical parameters evaluated were juice yield, juice colour, total soluble solids, sugar content (sucrose, fructose, glucose), titratable acidity, pH, chlorophyll content and sensory evaluation for colour and flavour. Viscosity and total microbial count on stored cane juice were also determined. Results showed that low temperature storage (10°C) of canes was able to maintain the quality of juice for up to 9 days while low temperature storage (5°C) of juice could last for only 4 days. During storage, sucrose contents decreased while fructose, glucose and titratable acidity increased in both types of samples. The colour changes in juice extracted from stored canes was inconspicuous until day 9. Deterioration of cane stored at 27±1°C occurred faster than that stored at 10±1°C. Fresh sugar-cane juice became spoiled after 4 days when stored at 5±1°C and 1 day when stored at 27±1°C. Microbial count, especially lactic acid bacteria count, increased during storage of cane juice.

Keywords: Cane storage; Delayed extraction; Juice quality

1. Introduction

Sugar-cane (*Saccharum officinarum*) has been grown in Malaysia since the 19th century (Tan, 1989) mainly for sugar production. The total area planted with sugar-cane was around 17,000 ha, confined mainly to areas in Kedah and Perlis where the climate was most suitable. Lately, the noble canes or chewing canes are also grown for fresh juice production and these occupy an even smaller land area, mainly in Negeri Sembilan and Selangor. Among the varieties grown, variety 'Tebu Kuning' or yellow cane is popular since it has a softer and less fibrous stem and produces abundant juice with a distinct flavour (Siti and Baharrudin, 1994).

Fresh sugar-cane juice is popular throughout Malaysia as a pleasing, sweet, thirst-quenching beverage. It is served fresh at many eateries from roadside stalls to high class hotel restaurants. Due to its commercial importance, and the crop's ability to thrive well in Malaysia, it is envisaged that sugar-cane juice production can become a profitable business provided efforts are made to preserve its fresh quality during storage.

As practised in the sugar-cane juice industry today, harvested canes are often stored in the shed at ambient temperature before they can be processed. Once extracted, the juice is immediately chilled and stored at chilling temperature before distribution. The delay in extraction of harvested sugar-canes is reported to cause some changes in the juice quality (Densay, Luthra, Senthiya & Dhawan, 1992). Low temperature storage has been observed to be able to prolong the shelf-life of the juice for a few days. However, no study has been conducted to detail these parameters. Knowledge of these aspects is important to the emerging industry. Thus, the objectives of this study are to determine effects of storing the canes on the quality of juice obtained, as well as to observe the physico-chemical and microbiological changes in fresh cane juice stored at different temperatures.

2. Materials and methods

2.1. Materials

Sugar-canes of 'Yellow variety' obtained from a plantation in Semenyih were used in this study. Mature

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canes (8–10 months old) were cut approximately 1 inch from the ground with about 12 inches of the shoot being retained. Harvested canes were immediately brought back to the laboratory.

2.2. Methods

The study was conducted in two parts. The objective of the first part was to monitor changes in the quality of juice extracted from canes that were stored at two different temperatures, 10 and 27°C. The second part of the study was to monitor the quality of juice stored at different temperatures.

2.3. Quality of juice from stored canes

Upon arrival at the laboratory, the canes were cleaned of mud and dirt and stored at 10 ± 1°C; 85–88% relative humidity (RH) and 27 ± 1°C; 55–85% RH for 15 days. Every day four canes were removed from storage for juice extraction. The physico-chemical tests carried out were yield of juice, colour of juice, sugar content (fructose, glucose, sucrose) (Hunt, Jackson, Mortlock & Kirte, 1977), total soluble solids (TSS), titratable acidity and pH (Ranganna, 1977), chlorophyll content (Nagata & Yamashita, 1992) and sensory evaluation for colour and flavour (Larmond, 1977).

The colour of sugar-cane juice was determined by using the Hunterlab Colorimeter Ultra-Scan, Model SN7877. The values were expressed as lightness '*L*', redness '*a*' and yellowness '*b*' (Ranganna, 1977). The changes in colour during storage were expressed as:

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

The total soluble solids was measured using an Otago hand refractometer (0–32° Brix) (Ranganna, 1977).

2.4. Extraction of sugar-cane juice

Stored canes were cut into uniform lengths about 1 m long (after removing two nodes from both ends of the cane). They were then washed with plain water to remove any dirt or foreign particles from the cane surfaces. After rinsing, a three-roller power crusher was used to extract the juice. The juice was filtered by passing through a four-layer muslin cloth. The extracted juice was collected in a chilled container and chilled immediately before being analysed. The chilling step was essential to retain the original colour and flavour of the juice.

2.5. Quality of stored sugar-cane juice

Freshly extracted cane juice was used. The chilled juice were then filled into glass bottles and stored at 5 ± 1°C, 61–84% RH; and 27 ± 1°C, 55–85% RH. The juices were analysed daily for similar physico-chemical parameters as above until they were considered no longer fit for consumption. Viscosity and microbiological analyses were also conducted. The viscosity of cane juice was measured using a digital rheometer, with spindle SC4-18 at 30 rpm (Ranganna, 1977).

2.6. Sampling

The experiments were carried out in two replicates using two samples per trial. Each reading was an average of four samples.

2.7. Sensory evaluation

Sensory evaluation of the juice extracted from stored canes was carried out by 25 panellists. The panellists rated the samples for colour and flavour using a hedonic scale of 1–9 (1 = dislike very much, 9 = like very much; Larmond, 1977). The evaluation on storage of fresh cane juice was carried out by 10 trained panellists using a triangle test. The panellists were asked to identify the odd sample in terms of colour, taste and flavour compared to a freshly extracted juice.

2.8. Microbiological analysis

Determination of total counts, on bacteria, mold and yeast for juice, were carried out at 0 h and every 24 h. One millilitre of juice from each storage temperature was transferred into a test tube containing 9 ml of peptone water. The mixture was homogenised. This homogenate represented a 10^{-1} dilution. From here, serial dilutions of 10^{-2} and 10^{-3} were prepared. One millilitre of each dilution was then spread over the surface of media plates. The plates were then incubated for a period of time and temperatures as indicated in Table 1.

Coliforms count was determined by using the most probable number (MPN) method. One millilitre of sample was pipetted into five tubes containing 9.0 ml MacConkey Broth. Three 10-fold serial dilutions were prepared (10^{-0}, 10^{-1}, 10^{-2}). The results were obtained after incubation for 24–48 h at 35°C.

Table 1
Type of media used with incubation temperature and time

Plate with media	Temperature (°C)	Incubation period (days)
PCA[a]	30	2
MRS[b]	35	2
MEA[c]	25	1–3

[a] PCA = Plate Count Agar (for total viable count).
[b] MRS = De Man , Rogosa, Sharpe Agar (for lactic acid bacteria).
[c] MEA = Malt Extract Agar (for yeast & mold).

2.9. Statistical analysis

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

3. Results and discussion

3.1. Analysis of stored sugar-cane stem

3.1.1. Yield

The yield of juice obtained from stored canes seemed to decrease with increase in time of storage. The decrease in juice yield was more noticeable in canes stored at ambient temperature (27°C) than in canes stored at 10°C (Fig. 1). The yield started to decrease from day 0 continuously until the end of the storage period. After 2 weeks, the yield decreased by 42.9% for canes that were stored at 27°C compared to only 9.5% for those stored at 10°C. In Malaysia, the small or part-time sugar-cane juice sellers get their supply of canes weekly. Before they are squeezed, the bundles of canes are stored by merely leaning the bundle against a tree. This study shows that storage at the normal ambient temperature would incur great losses in juice yield and is certainly not a wise practice to continue. Meanwhile canes that were stored at 10°C only started to fluctuate in yield after 3 days' storage.

3.1.2. Colour

The L, a and b readings were translated into colour values as shown in Fig. 2. Storage temperature and storage time slightly influenced the colour of juice extracted from stored canes. The rate of colour loss for the juices stored at 27 and 10°C seemed to be equal up to 4 days of storage. After 5 days, the colours of juices extracted from canes that were stored at 27°C were found to be darker or had decreased in colour. Visually, the juices extracted from canes that were stored at 27°C were darker in colour than canes stored at 10°C. This difference was observed immediately after juice extraction.

3.1.3. Sugar content

Storage of canes caused a decrease in sucrose content of the extracted juice (Fig. 3) and increase in fructose and glucose contents. The decrease in the sucrose content of stored canes at 27°C was faster than at 10°C. This might be due to the fact that, at lower temperature, cell respiration and invertase activities are inhibited or slowed down. Alexander (1973) also discovered the same results. The low sucrose and high fructose and glucose contents are due to the conversion of sucrose to reducing

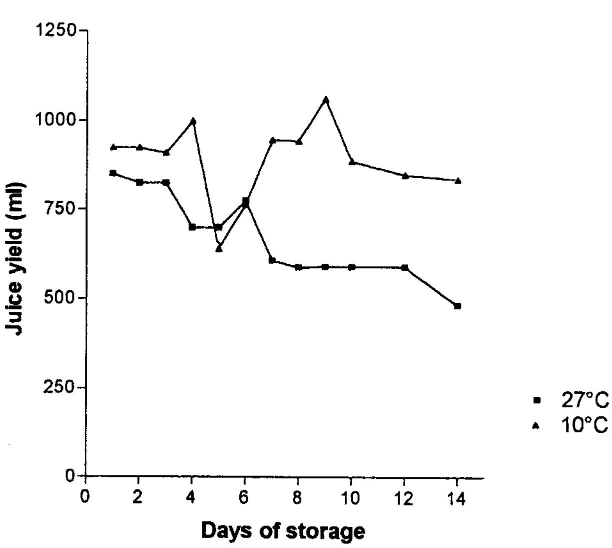

Fig. 1. Juice yield from sugar canes stored at 10 and 27°C.

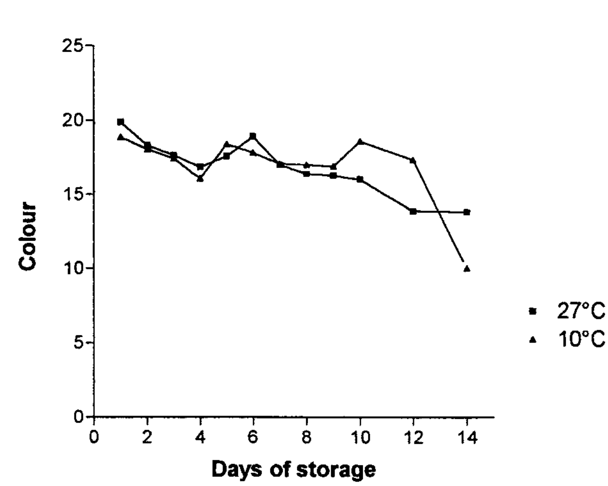

Fig. 2. Colour of juices extracted from sugar canes stored at 10 and 27°C.

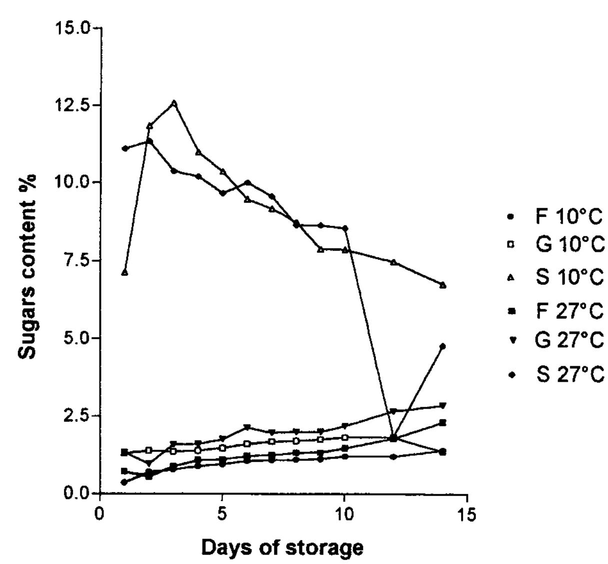

Fig. 3. Fructose (F), glucose (G) and sucrose (S) contents of juice extracted from sugar canes stored at 10 and 27°C.

sugar. Similarly, Densay et al. (1992) reported that delayed extraction of juice caused a loss in sucrose content.

3.1.4. TSS

There was an initial increase in the TSS content of juice extracted from canes stored at 27°C for the first 3 days of storage and after that it decreased (Fig. 4). This may indicate that, within the 3-day period, maturation of canes may have continued, resulting in an increase in sweetness. After 3 days, the TSS content decreased, probably due to the onset of senescence. For those canes stored at 10°C, there were irregular values for TSS until after 9 days, but when the canes became stabilized the value began to increase as in the initial stage of storage at 27°C.

3.1.5. Titratable acidity

The titratable acidity of extracted juice increased during storage (Fig. 5). The increase occurred on day 6 for both treatments. Sugar-cane stems stored at 27°C recorded higher acidity increases compared to those stored at 10°C. This was perhaps caused by the utilization of sugar during respiration of the cane stem itself. The acidity increase was, however, not detected by the panellists until day 9.

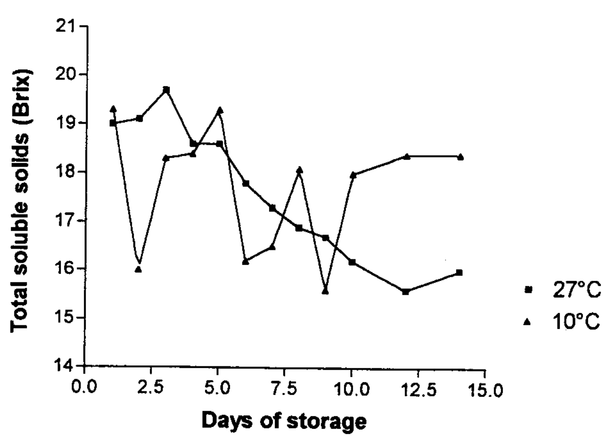

Fig. 4. Total soluble solids contents of juices extracted from sugar canes stored at 10 and 27°C.

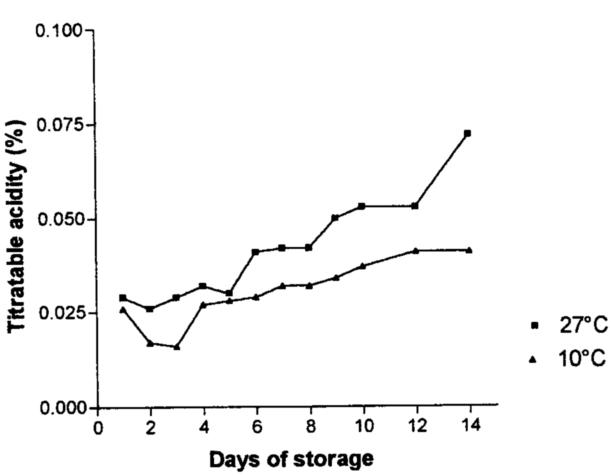

Fig. 5. Titratable acidity values of juices extracted from sugar canes stored at 10 and 27°C.

3.1.6. pH

The pH value of juices extracted from canes stored at 27 and 10°C both decreased at about equal rates until day 9 (Fig. 6). After that the juice of cane stem stored at 27°C had a faster drop compared to the juice of cane stems stored at 10°C.

3.1.7. Chlorophyll

Chlorophyll contributes to the attractive fresh greenish appearance of juice. The chlorophyll contents of juice extracted from stored canes decreased with increase in storage days. The juices of canes stored at 27°C showed a faster rate of chlorophyll degradation than those stored at 10°C (Fig. 7). The decrease in chlorophyll content resulted in the juice turning slightly yellowish in colour (less green) immediately after extraction.

3.2. Sensory evaluation

3.2.1. Colour

The panellists did not indicate any significant change ($p > 0.05$) in the colour of juices; that were extracted from canes stored for 3 and 6 days at either storage temperature (Table 2). However, on day 9 there was a significant difference ($p < 0.05$) in the colour among the juices from both types of canes. The canes that were stored at 10°C produced juices that were rated higher in colour (6.76 out of 9) than cane stems stored at 27°C (3.88 out of 9.0).

3.2.2. Flavour

The mean ratings for flavour of the juice samples stored under the two temperature treatments were found

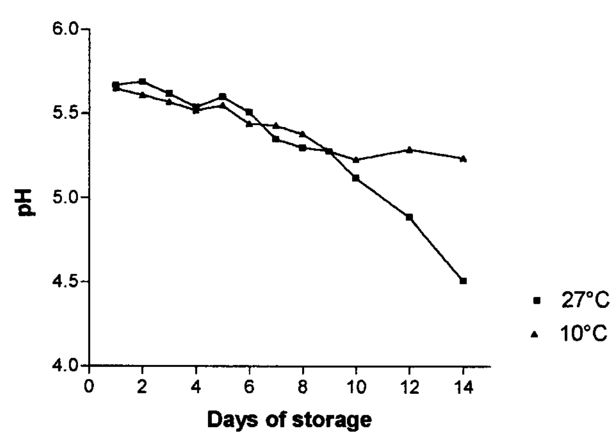

Fig. 6. pH values of juices extracted from sugar canes stored at 10 and 27°C.

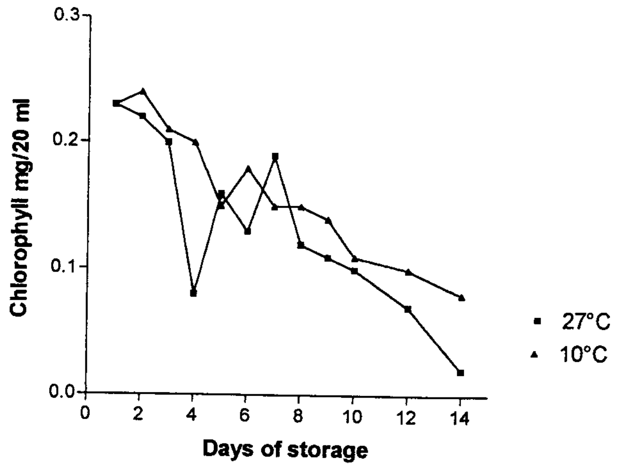

Fig. 7. Chlorophyll contents of juices extracted from sugar canes stored at 10 and 27°C.

Table 2
Mean values for the sensory evaluation juice of sugar-canes stored at different temperatures[a]

Storage duration (days)	Storage temperature (°C)	Colour	Flavour
3	10	5.18a	6.18a
	27	5.82a	6.06a
6	10	5.88a	6.71a
	27	5.41a	5.29a
9	10	6.76a	7.41a
	27	3.88b	4.53b

[a] Means for each storage duration followed by a similar letter are not significantly different $p > 0.05$.

to be significantly different also on day 9 ($p < 0.05$) (Table 2). The flavour of juice of cane stored at 10°C for 9 days was still high (7.41 out of 9). This means that sugar-canes may be stored at low temperature (10°C for 9 days) without affecting the flavour of the juice while storage of canes at ambient temperature for 9 days results in development of objectionable flavour.

3.3. Analysis of stored juice

3.3.1. Sugar contents

Results indicated that, as storage time increased, the sucrose content of samples stored at 5°C decreased gradually within the storage period of 15 days while the ones stored at 27°C decreased sharply within 3 days (Table 3). The decrease in sucrose content in both cases was due to the conversion of sucrose to reducing sugars as shown by the increase in fructose and glucose contents after 10 days of storage. The reducing sugars increased slightly towards the end of storage. The increase in reducing sugar was found to be linear and positively related to storage time, as reported by Ewaidah (1992). The sharp drop in sucrose that occurred in samples stored at 27°C was perhaps caused by microbes that utilised the sugars and in the end resulted in spoilage of juice.

3.3.2. Viscosity

The viscosity of juice stored at 5°C (Table 3) initially decreased within 4–10 days, after which period it increased. Meanwhile, the sample that was stored at 27°C recorded a decrease in viscosity. The increase in viscosity of juice stored at low temperature might be due to the development of dextran, i.e. a gummy substance produced by bacteria such as *Leuconostoc mesenteroides*. This phenomenon was found Lotha, Khurdiya and Maheshwawi (1994) who reported that the viscosity of mandarin juices increased during refrigerated storage and decreased when stored at ambient temperature.

3.3.3. TSS, titratable acidity and pH

There was an increase in the TSS content of juice stored at 5°C at the initial stage (up to 7 days) but the value decreased with time (Table 4). The juice sample stored at 27°C also showed an increase in TSS before it became spoilt. The increase was perhaps due to the breakdown of oligomers, such as sucrose, into simple sugars and acids. Acidity of juice increased with storage time. Bhupinder, Sharma and Harinder (1991) also found high acidity in juice during storage. The increase in acidity caused a concomitant decrease in pH value. High acid and low pH could be due to acetic acid and lactic acid production.

3.3.4. Chlorophyll

Chlorophyll content of cane juice decreased with storage time. This was perhaps brought about by the presence of oxygen, light and internal enzymes which converted chlorophyll to a more stable form, thus resulting in the colour of juice to change from greenish to yellowish. Degradation of chlorophyll pigment was faster in juice stored at 27°C than in juice stored at 5°C.

3.3.5. Microbiological analysis

There were significant differences ($p \geqslant 0.05$) in the mold and yeast counts of stored juice between storage duration and storage temperature (Table 5). There was an increase in total viable count and lactic acid bacteria count in juice stored at both temperature treatments. However, growth of mold could only be detected in juice stored at 5°C on day 6 while no yeast was detected during the storage period. The low temperature storage may have retarded the growth of the organism.

After 1 day at storage, the total viable count of juice stored at 27°C increased a $\log_{10}$/ml. High sugar content contributed to faster multiplication of bacteria. The growth of yeast and mold in juice stored at 27°C increased significantly ($p < 0.05$) after 6 days, but coliforms were found to decrease at the later stage of storage.

Table 3
Mean value for the sugar content and viscosity of sugar-cane juice stored at different temperatures[a]

Temperature (°C)	Storage duration (days)	Sucrose (%)	Fructose (%)	Glucose (%)	Viscosity (cps)
5	0	11.79a	0.77defg	1.45bcde	2.03ab
	1	11.64ab	0.87defg	1.59abcd	2.13ab
	2	11.64ab	0.77defg	1.37bcde	2.11ab
	3	11.13ab	0.59fg	1.10cde	2.18ab
	4	10.60ab	0.51g	1.21cde	1.75ab
	5	9.75abc	0.74efg	1.35cde	1.52b
	6	9.45abc	0.67fg	1.21cde	1.72ab
	7	9.44abc	1.35bc	1.01de	1.83ab
	8	9.43abc	0.99cdef	1.72abc	1.93ab
	9	9.04abc	0.47g	0.87e	1.98ab
	10	8.93abc	0.70efg	1.86ab	1.98ab
	11	8.73abc	1.49b	1.89ab	2.04ab
	12	8.15bc	0.52g	2.07a	2.13ab
	13	6.65cd	1.97a	1.53abcd	2.20ab
	14	6.49cd	1.15ab	1.50abcd	2.54a
	15	4.75d	1.08cde	1.04de	2.63a
27	0	11.79a	0.77ab	1.47a	2.03a
	1	7.89b	0.99a	1.24ab	2.12a
	2	8.16b	0.63ab	1.15ab	1.63ab
	3	7.99b	0.48	0.86b	1.30b

[a] Means for each storage duration followed by the same letter are not significantly different, $p > 0.05$.

Table 4
Mean values for the physico-chemical characteristic of sugar-cane juice stored at different temperatures[a]

Temperature (°C)	Storage duration (days)	TSS (°Brix)	TA (%)	pH (%)	Chlorophyll (mg/20 ml)
5	0	16.0g	0.045b	5.71a	0.22ab
	1	17.4de	0.035b	5.79a	0.25a
	2	17.0ef	0.042b	5.76ae	0.20abc
	3	17.7bcd	0.043b	5.76a	0.19abcd
	4	17.7bcd	0.043b	5.68ab	0.18bcd
	5	18.0abc	0.046b	5.69ab	0.18bcd
	6	18.4a	0.048b	5.67ab	0.17bcd
	7	18.5a	0.060b	5.66ab	0.17bcd
	8	18.2ab	0.053b	5.63ab	0.15cd
	9	17.5cd	0.069b	5.61ab	0.14d
	10	16.1g	0.078b	5.61ab	0.15bcd
	11	18.2ab	0.084b	5.49abc	0.16bcd
	12	18.0abc	0.098b	5.37abc	0.16bcd
	13	18.1ab	0.049b	5.15bcd	0.14d
	14	17.4de	0.045b	5.05cd	0.13d
	15	16.8g	0.14a	4.67d	0.13d
27	0	16.0b	0.045d	5.71a	0.22a
	1	16.6ab	0.16c	3.76bc	0.13b
	2	16.2b	0.19b	3.79b	0.11b
	3	17.3a	0.21a	3.66c	0.04c

[a] Means for each storage duration followed by the same letter are not significantly different, $p > 0.05$. TSS, total soluble solid; TTA, titratable acidity.

Table 5
Mean values for the microbial count of sugar-cane juice stored at different temperatures[a]

Storage duration (days)	Temperature (°C)	Coliform count	TVC	Mold count	Yeast count	LABC
1	5	2.99a	6.11b	0b	0b	5.48b
	27	3.04b	6.48a	2.00a	3.11a	7.16a
3	5	3.66b	6.67b	0a	0a	6.08b
	27	4.28a	8.05a	2.0b	3.23b	7.46a
6	5	3.66a	6.20	2.30b	0a	5.80a
	27	0.88b	TNTC	6.00a	6.00b	6.88b
9	5	4.99a	6.00	0a	0a	6.79a
	27	0.36b	TNTC	4.45b	4.30b	6.33b
12	5	2.18a	8.45a	–	0a	6.87b
	27	0.30b	8.40b	–	5.60b	7.10a
15	5	1.38a	TNTC	–	0a	6.06
	27	0.20b	TNTC	–	5.70b	TNTC

[a] Means for each storage duration followed by the same letter are not significantly different, $p > 0.05$. TVC, total viable count; LABC, lactic acid bacteria count; TNTC, too numerous to count.

Reduction of coliform count may have been caused by the development of undesirable growth conditions, such as low pH, high acid and presence of competitors in the stored juice after a certain time (3 days).

3.3.6. Sensory evaluation

Results of triangle tests showed that 70% of panellists were able to differentiate the colour of juice stored at 5°C from freshly extracted juice. Only 40% of the panellists were able to detect off-flavour from stored juice after 5 day's storage and 100% for juice after 7 day's storage. The flavour of cane juice stored at 5°C became sourish and off-flavoured after 7 day's storage. For juice stored at 27°C, spoilage ocurred during 24 h. One hundred percent of the panellists were able to identify and differentiate the spoiled juice from the freshly extracted juice in terms of colour and flavour. Objectionable flavour developed after 1 day's storage.

4. Conclusion

The yield and quality of juice obtained are important economic criteria in the sugar-cane juice business. Results of the study indicate that it is advisable to store sugar-canes at low temperature to maintain the juice yield. The canes may be stored at 10°C for 9 days and still produce good quality juice, to a maximum of 11 days. Beyond that, the canes suffer chilling injury. The sucrose content of juice decreased after 3 days storage; however, the glucose and fructose contents increased, resulting in the TSS content above 16°C, which was sweet enough and common for sugar-cane juice. The colour and flavour of juices obtained were also superior to canes stored at higher temperature. Storage of canes at 27°C, for more than 4 days, reduced the juice yield drastically. The colours of juice obtained were darker (more brown and less green) than the juices obtained from canes stored at 10°C and the flavour was also different.

In the second part of the experiment, it was found that freshly extracted, unpasteurised juice could be kept at 5°C for only 4 days. Beyond that, the quality deteriorated, which could be observed by the colour and flavour change followed by increase in viscosity. The juice became spoilt within a day when kept at 27°C.

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