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Research article

Development of value added drinks from date palm juice (*Phoenix sylvestris*)

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ABSTRACT

The high decaying tendency of date palm juice limited its manifold application. Here, we developed a preservation technique for concentrated juice and formulated ready to serve (RTS) drinks. The collected date palm juice was heated at 85 °C for 5 min; scum was removed and preserved in the sterilized glass bottle. After that, this pasteurized juice was concentrated to 9%, 12%, 15%, 18% and 21% total soluble solids (TSS) levels and treated with 200 ppm of potassium metabisulfite (KMS) and stored at refrigerated temperature (4 °C). Among them, 18% TSS showed overall acceptability to sensory evaluations for colour, flavour, sweetness, TSS, acidity and microbial load. In contrast, heat treated date palm juice (9% TSS) was used to formulate RTS drinks containing 10%, 20%, 30% and 40% date palm juice, were preserved in sterilized bottles and stored at 30 °C. Results showed that RTS drinks containing 30% date palm juice secured the best colour, flavour, sweetness, TSS, acidity, microbial load and overall acceptability. Furthermore, no significant change was observed in TSS, acidity, microbial load up to three and six months for concentrated juice and RTS drinks, respectively.

1. Introduction

From the onset of civilization, human beings have been habituated to extract their nourishments from various plants. Numerous staple foodstuffs like cereals, root crops, fruits, vegetables, and natural drinks are obtained from nature (Begum et al., 2015; Chandrasekara and Josheph Kumar, 2016; Rahman et al., 2021). Therefore, several natural sap and juice extracted from trees are inevitable for our thirst-quenching and providing necessary nutrients. Natural juice and drinks are prepared by pressing ripe fruits, tapping the tender inflorescences, fruits, and trunks of sap-yielding plants, or processed from other food grains (Gallo et al., 2019; Kamarubahrin and Haris, 2020). Among them, date palm counts as the oldest fruit crop enriched with numerous therapeutic bioactive and functional compounds like polyphenols, flavonoids, carotenoids, phytosterols, phytoestrogens, vitamins and minerals (Al-Alawi et al., 2017; Younas et al., 2020). Date palm juice (sap) has a high tendency of decaying in both original and concentrated form concerning the flavor, vitamins, color, and nutrients in open conditions due to its high reducing sugars and total sugars (Ahmad et al., 2021; Kulkarni et al., 2010). So it is a prerequisite to developing the technique related to the preservation of juice and derivatives with optimal storage stability for long-term utilization.

Date palm (*Phoenix dactylifera* L.) is monocotyledonous plants belongs to the family Arecaceae and is considered one of the ancient and main staple food in Southwest Asia and North Africa (Ahmad et al., 2021; Al-Alawi et al., 2017; Shehzad et al., 2021). Date palm, palmyra palm, and coconut palm are common types of palm trees in Bangladesh. In Bangladesh, wild date palm is found everywhere, especially in Jessore, Faridpur, Kustia, Khulna, and Rajshahi districts and it is very popularly known as *khejur* or *khajur*. Date palm juice (sap) is consumed as raw drinks or further processed for concentrated juice and jaggery manufacturing (Barreveld, 1993). In addition, date palm juice is the

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primary economic product of some marginal areas of Bangladesh that collects by tapping the tender trunk of the tree. During the tapping season (winter season), about 200–250 L of juice (containing 12–15% sucrose) is obtained per tree from which 25–30 kg molasses is prepared (Hussain, 2001; Rana et al., 2009). It was also reported that date palm juice contains 9–14% sugar, a tiny amount of organic acid, some trace elements, and some volatile components, which is very popular as thirst-quenching drinks (Dalibard, 1999) but is available only in the winter season. Thus, it may be utilized efficiently to prepare concentrated juice, and ready-to-serve (RTS) drinks to provide people with the taste of date palm juice yearly.

Ready to serve (RTS) drinks are refreshing beverages that can be consumed without dilution (Hemalatha et al., 2018). This type of fruit beverage contains at least 10% fruit juice and 10–15 % total soluble solids along with a trace amount of acid (Hemalatha et al., 2018; Nithiyananthan et al., 2018). Most of the juice is used for "gur" (jaggery) production by the farmers. Development of some alternative use of date palm juice such as formulation of RTS drinks and preparation of concentrated juice may pave the way for the commercial cultivation of date palm by the farmers. Thus, it can help to reinforce our economic growth by large-scale commercial production. However, despite having the research data on juice preparation and preservation from fresh dates, little or no information about date palm juice (sap) is available. Thus the objective of the present work was to develop concentrated date palm juice from raw juice, analyzing the storage stability and utilization for the preparation of ready-to-serve drinks.

2. Materials and methods

The study was conducted in the Department of Food Technology and Rural Industries laboratory, Bangladesh Agricultural University, Mymensingh.

2.1. Date palm juice

Freshly harvested date palm juice was collected from local farmers very early in the morning. After that, it was collected in a clean jar and then sieved through a clean cloth before further treatment.

2.2. Chemicals, solvents and ingredients

Chemicals and solvents used in the study were of AR grade, and water was glass distilled unless specified otherwise. Sugar and other raw materials were procured from the local market. Other essential ingredients were used from the laboratory stocks.

2.3. Treatment of date palm juice

Fresh and clean date palm juice was analyzed for various physical, chemical and microbiological properties. Then it was heated at 85 °C for 5 min (pasteurized) to inactivate enzymes and remove the scum. Heat-treated date palm juice (not concentrated) was treated with potassium metabisulfite (KMS) at 200 ppm and finally preserved in sterilized glass bottles. This heat-treated juice (not concentrated) was taken as a control sample for the study.

2.4. Proximate analysis of date palm juice

The fresh and heat-treated date palm juice was analyzed for total soluble solids (TSS), moisture, sugar, protein, crude fat content, acidity, pH, ascorbic acid and ash content. Titrable acidity, pH, total soluble solids and ascorbic acid content were determined as per the methods of Ranganna (1986). The analysis of moisture content, ash, fat and protein was performed according to AOAC (International and Horwitz, 2000).

2.5. Product development

Different types of products were prepared from date palm juice and assessed their acceptability. The developed products were concentrated juice and RTS drinks.

2.5.1. Preparation of concentrated juice

After removing scum, the date palm juice was heated at boiling temperature and concentrated on preparing five concentrated juice samples, S_1, S_2, S_3, S_4 and S_5, containing 9% 12%, 15%, 18% and 21% TSS. After that, potassium metabisulfite (KMS) was added at 0.02% level in each sample. Then the concentrated date palm juice samples were preserved in sterilized bottles following standard procedure. Concentrated date palm juice samples were taken for physical, chemical, and subjective analysis and the investigation of shelf-life.

2.5.2. Formulation of ready to serve (RTS) drinks

Four samples of ready to serve (RTS) beverages were formulated as shown in Table 1 from the heat-processed juice (not concentrated) with other ingredients. In the formulations, 10%, 20%, 30%, and 40% date palm juice were used to prepare four samples of RTS drinks D_1, D_2, D_3 and D_4, keeping the TSS of the RTS drinks constant (14%). According to the formulations, the corresponding quantity of water and sugar was used to achieve the required TSS.

2.5.3. Preparation of ready to serve (RTS) drinks from date palm juice

Various ingredients required to prepare ready-to-serve (RTS) drinks from date palm juice were weighed using an electric balance. Required quantities of date palm juice and water were measured using a measuring cylinder. The measured amount of sugar, citric acid, carboxymethylcellulose (CMC) and water figured from the formulation were mixed and boiled for about 3–5 min to prepare the syrup. Sugar syrup was then sieved through a clean cloth (sterilized). Then the measured quantity of date palm juice was added to the hot syrup and heated to boiling temperature. Then the prepared RTS drinks were cooled down to about 30–35 °C, and the calculated amount of potassium metabisulfite (KMS) was mixed thoroughly with each of the samples. Then prepared RTS drinks were filled into sterilized bottles keeping headspace about 0.75 inches, sealed airtight, and labeled. Finally, the bottles were stored in a dry place at room temperature (30 ± 2 °C) for shelf-life studies.

2.6. The standard plate count

The standard plate count was done according to the method described elsewhere (Sharf, 1966).

2.6.1. Preparation of dilution blanks

1 L distilled water was taken into a sterilized flask. The phosphate buffer solution was prepared as per the recommended methods (Sharf, 1966). Then the buffer solution was added to the distilled water at the

Table 1. Formulations of RTS drinks from date palm juice.

Ingredients (gm) (Based on 100 gm finished product)	Formulations			
	D_1	D_2	D_3	D_4
Date palm juice	10	20	30	40
Sugar	13	12	11	10
Citric acid	0.2	0.2	0.2	0.2
Carboxy methylcellulose (CMC)	0.03	0.03	0.03	0.03
Potassium metabisulfate (KMS)	0.02	0.02	0.02	0.02
Water	77	68	59	50

Where, D_1 = RTS drinks with 10 % date palm juice, D_2 = RTS drinks with 20 % date palm juice, D_3 = RTS drinks with 30 % date palm juice, D_4 = RTS drinks with 40 % date palm juice.

rate of 1.25 ml/1000 ml, and the pH was adjusted to 7.2. The dilution water was then dispensed into several dilution bottles at the rate of 100 ml each. Later, the dilution blanks were sterilized in an autoclave at 121 °C (6.795 kg pressure/sq. inch) for 15 min. The sterilized dilution blanks were kept in a refrigerator until use. Pipette, Petri dishes, and glassware were also sterilized at 121 °C for 15 min in an autoclave.

2.6.2. Dilution making and procedure of plating

1 ml of well shaked date palm juice was transferred in 99 ml portion of sterilized buffered distilled water dilution blank, and the sample was shaken vigorously 25 times up and down movement of about 30 cm in a time interval not exceeding 7 s. 1 ml portion was transferred to another 99 ml portion of the diluted sample from each dilution placed into sterile petri dishes aseptically to get the dilutions 1:10, $1:10^2$, $1:10^3$, and $1:10^4$. Each dilution was shaken as described earlier, just before transferring from the dilution bottles either into petri dishes or another dilution bottle. The pipette was allowed for 2–3 s to drain, then gently blown out the last and touched the tip of the pipette to a dry spot on the glass. As soon as the dilutions were poured into petri dishes, the mouth of the agar bottles was sterilized by flame and poured 12–15 of melted agar of 45 °C into the washed plate, slightly raising the lid of the petri dishes. Quickly the agar was then mixed with the dilution gently by rotating and tilting the dish. The agar was then allowed to solidify.

2.6.3. Incubation and colony count

After solidifying agar, the plates were inverted and placed in an incubator operated at 37 °C for 48 h. After incubation, the plates were taken out from the incubator, and the plates, those contained 30–300 colonies, were selected for counting. Colonies were counted with the aid of a GerbarColoney Counter. The numbers of colonies were multiplied by the dilution factor, and the total viable count per gram of sample was recorded.

2.7. Storages studies

Fresh and processed date palm juice samples were stored at room temperature and refrigerated temperature (4 °C). The different parameters for assessing deterioration and spoilage of processed date palm juice samples were observed at regular interval of time. The colour, flavour, acidity, TSS and microbial load (standard plate count) were observed initially at an interval of one up to two months and then at intervals of two months during the storage period of 6 months.

2.8. Sensory evaluation

Sensory evaluations of all the concentrated date palm juice and formulated RTS drinks prepared from date palm juice were done by a taste-testing panel of 10 panellists. At first, five concentrated date palm juice samples were presented to the panellist with a score sheet. They were asked to evaluate the concentrated date palm juice for colour, flavour, sweetness and overall acceptability by scoring with 9 points hedonic scale. Hedonic scale was as follows: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much; and 1 = Dislike extremely. Similarly, four samples of ready to serve (RTS) drinks prepared from date palm juice were presented to the panel of 10 panellists and asked to evaluate the RTS drinks for colour, flavour, sweetness and overall acceptability. The preference differences were evaluated by statistical analysis of data for variance and consequently quantified. The sensory evaluation tests were conducted according to established ethical guidelines. By maintaining all regulations, consent was obtained from all participants before experiment.

2.9. Statistical analysis

The data presented in the table were analyzed by SAS 9.4 (SAS Institute Inc., Cary, NC, USA) program following complete randomized design (CRD), and the mean differences were compared by the least significant (LSD) test. P values < 0.05 were considered to be significant.

3. Result and discussion

3.1. Composition of fresh date palm juice

Moisture content, acidity, TSS, ash content, ascorbic acid, total sugar, reducing sugar, non-reducing sugar present in date palm juice have been estimated, and the results of the analysis of the fresh date palm juice are presented in Table 2.

3.2. Analysis of concentrated date palm juice

The concentrated date palm juice samples were analyzed for their moisture, TSS, acidity and ash content. The result is presented in Table 3.

From Table 3, it is found that the acidity and ash content of the concentrated juice was increased with the increase of TSS, and subsequently, moisture content was decreased. This was due to the concentration effect on date palm juice. This variation of composition had an influence on the sensory properties and shelf-life of the concentrated date palm juice.

3.3. Sensory evaluation of concentrated date palm juice

Five concentrated juice samples containing 9%, 12%, 15%, 18%, and 21% of TSS were subjected to sensory evaluation. The colour, flavour, sweetness, and overall acceptability of these juice samples were evaluated by a panel of 10 panellists.

Table 4 revealed that the samples S_3 and S_4 Scored significantly ($P < 0.05$) better for colour than control and other samples. However, there were no significant ($P < 0.05$) differences in colour preference of samples S_1, S_2 and S_5. The control sample (S_1) scored highest for flavour acceptability, but there was no significant difference between the sample S_1 and S_4. Thus sample S_3 and S_5 (Table 4) scored the least for flavour acceptability. Concentrated date palm juice samples S_4 and S_5 scored better sweetness acceptability than other samples. Sample S_1 and S_5 scored the least sweetness acceptability following sample S_3. In case of overall acceptability, the sample S_4 scored significantly ($P < 0.05$) higher than other concentrated date palm juice. Sample S_5 scored second for overall acceptability following S_4. Acidity improves the palatability and nutritive value of food which influence the flavour, colour, stability and keeping quality of the products (Offia-Olua and Ekwunife, 2015). The higher TSS with higher acidity in S_4 and S_5 improved the sweetness, consistency and quality of the products that might influenced the overall acceptability.

3.4. Sensory evaluation of ready to serve (RTS) drinks

Four RTS drinks samples D_1, D_2, D_3, and D_4 containing 10%, 20%, 30%, and 40% pasteurized date palm juice (with 9% TSS) in formulations

Table 2. Composition of fresh date palm juice.

Compositions	Percentage (%)
Moisture content	90.46
Acidity	0.12
TSS	9.0
Reducing sugar	3.50
Non-reducing sugar	5.2
Total sugar	8.7
Fat	0.05
Protein	0.0148
Ash	0.347
Ascorbic acid	12.76 mg/100 gm

Table 3. Analysis of concentrated date palm juice.

Sample (%)	TSS (%)	Moisture (%)	Acidity (%)	Ash (%)
S_1 Control	9 ± 0.02^{e}	90.84 ± 0.9^{a}	0.064 ± 0.001^{e}	0.347 ± 0.017^{d}
S_2	12 ± 0.03^{d}	87.45 ± 1.1^{b}	0.067 ± 0.001^{d}	0.570 ± 0.025^{b}
S_3	15 ± 0.04^{c}	82.79 ± 1.1^{c}	0.078 ± 0.001^{c}	0.668 ± 0.025^{a}
S_4	18 ± 0.11^{b}	79.62 ± 1.1^{d}	0.102 ± 0.001^{d}	0.710 ± 0.025^{a}
S_5	21 ± 0.23^{a}	75.51 ± 1.2^{e}	0.121 ± 0.001^{e}	0.426 ± 0.019^{c}
$LSD_{0.05}$	0.21	1.82	0.002	0.04

Mean with the same superscript within a column are not significantly different at $p < 0.05$.

Table 4. Mean sensory scores for concentrated date palm juice.

Concentrated Juice Sample	Sensory attributes			
	Colour	Flavour	Sweetness	Overall acceptability
S_1 (Control)	6.3 ± 0.34^{b}	8.2 ± 0.4^{a}	6.2 ± 0.05^{c}	6.1 ± 0.01^{c}
S_2	6.6 ± 0.31^{b}	7.1 ± 0.12^{bc}	6.9 ± 0.02^{bc}	6.6 ± 0.02^{bc}
S_3	7 ± 0.41^{ab}	6.9 ± 0.05^{c}	7.2 ± 0.01^{ab}	6.7 ± 0.02^{bc}
S_4	7.8 ± 0.05^{a}	7.8 ± 0.3^{ab}	7.8 ± 0.01^{a}	8.0 ± 0.01^{a}
S_5	6.8 ± 0.26^{b}	6.6 ± 0.1^{c}	8.0 ± 0.01^{a}	7.2 ± 0.01^{b}
$LSD_{0.05}$	0.8223	0.7959	0.7595	0.6848

Mean with the same superscript within a column are not significantly different at $p < 0.05$.

were subjected to sensory evaluation. The colour, flavour, sweetness and overall acceptability of these RTS drinks samples were evaluated by a panel of 10 panellists.

Table 5 revealed that the samples D_3 and D_4 showed similar colour acceptability and were better than other samples. There was no significant difference between the colour acceptability of sample D_1 and D_2. Control sample D_1 was the least acceptable based on colour acceptability. The samples D_3 and D_4 were scored highest for flavour acceptability. There was a significant ($P < 0.05$) difference between sample D_1 and D_2. RTS drinks sample D_1 scored the least for flavour acceptability (Table 5). For sweetness, the RTS samples D_3 and D_4 were scored highest. There was no significant ($P < 0.05$) difference between the sample D_1 and D_2, and sample D_1 scored the least for sweetness (Table 5). The sensory evaluation is the basic criteria that demarcate the overall acceptability of any formulated drinks; among them, colour and taste were most preferred (Tiencheu et al., 2021). It was also depicted that colour has a significant effect on the other sensory characteristics; an attractive color and flavour will make unique and better drinks that ensure quality and overall

Table 5. Mean sensory scores for RTS drinks prepared from date palm juice.

Concentrated Juice Sample	Sensory attributes			
	Colour	Flavor	Sweetness	Overall acceptability
D_1 (Control)	5.2 ± 0.05^{c}	4.7 ± 0.01^{c}	5.8 ± 0.03^{c}	5.8 ± 0.01^{b}
D_2	5.4 ± 0.03^{bc}	5.6 ± 0.02^{bc}	6.5 ± 0.02^{bc}	6.6 ± 0.02^{ab}
D_3	6.1 ± 0.01^{a}	6.7 ± 0.01^{a}	7.6 ± 0.015^{a}	7.8 ± 0.02^{a}
D_4	5.8 ± 0.01^{ab}	6.5 ± 0.02^{ab}	7.4 ± 0.01^{ab}	6.7 ± 0.01^{b}
$LSD_{0.05}$	0.5686	0.9985	0.561	0.9990

Mean with the same superscript within a column are not significantly different at $p < 0.05$.
Where, D_1 = RTS drinks with 10 % date palm juice, D_2 = RTS drinks with 20 % date palm juice, D_3 = RTS drinks with 30 % date palm juice, D_4 = RTS drinks with 40 % date palm juice.

Table 6. Storage studies of concentrated date palm juice.

Storage period (months)	Sample	TSS (%)	Acidity (%)	Microbial load Log CFU/ml	Physical Observations
0	S_1	9 ± 0.02^{m}	0.064 ± 0.002^{r}	2.48 ± 0.31^{kl}	Good No gas formed
	S_2	12 ± 0.03^{k}	0.067 ± 0.002^{pqr}	$2.61 \pm 0.21^{i-l}$	
	S_3	15 ± 0.04^{h}	0.078 ± 0.002^{l}	$2.68 \pm 0.05^{h-l}$	
	S_4	18 ± 0.11^{e}	0.102 ± 0.002^{i}	$2.71 \pm 0.30^{h-l}$	
	S_5	21 ± 0.23^{b}	0.121 ± 0.002^{ef}	2.45 ± 0.20^{l}	
1	S_1	9 ± 0.01^{m}	0.065 ± 0.002^{qr}	$2.72 \pm 0.05^{h-l}$	Good No gas formed
	S_2	12 ± 0.02^{k}	0.067 ± 0.002^{pqr}	$2.83 \pm 0.31^{g-k}$	
	S_3	15 ± 0.03^{h}	0.079 ± 0.002^{l}	$2.82 \pm 0.21^{g-k}$	
	S_4	18 ± 0.09^{e}	0.103 ± 0.002^{i}	2.57 ± 0.05^{jkl}	
	S_5	21 ± 0.2^{b}	0.124 ± 0.002^{e}	$2.71 \pm 0.31^{h-l}$	
2	S_1	9.30 ± 0.02^{l}	0.065 ± 0.002^{qr}	$2.89 \pm 0.20^{g-j}$	Good No gas formed
	S_2	12.20 ± 0.03^{j}	0.0679 ± 0.002^{pq}	$2.96 \pm 0.05^{f-i}$	
	S_3	15.21 ± 0.03^{g}	0.080 ± 0.002^{l}	$3.03 \pm 0.31^{e-h}$	
	S_4	18.02 ± 0.10^{de}	0.107 ± 0.002^{h}	$2.94 \pm 0.21^{f-i}$	
	S_5	21.03 ± 0.19^{b}	0.129 ± 0.002^{d}	$2.87 \pm 0.05^{g-j}$	
3	S_1	9.37 ± 0.02^{l}	0.068 ± 0.002^{pq}	$3.16 \pm 0.3^{d-g}$	Good No gas formed
	S_2	12.35 ± 0.03^{ij}	0.069 ± 0.002^{op}	$3.27 \pm 0.23^{c-f}$	
	S_3	15.29 ± 0.05^{fg}	0.085 ± 0.002^{k}	$3.41 \pm 0.07^{a-d}$	
	S_4	18.20 ± 0.09^{cd}	0.112 ± 0.002^{g}	$3.39 \pm 0.28^{a-d}$	
	S_5	21.41 ± 0.22^{a}	0.137 ± 0.002^{c}	$3.45 \pm 0.21^{a-d}$	
4	S_1	9.46 ± 0.02^{l}	0.070 ± 0.002^{op}	$3.34 \pm 0.05^{b-e}$	Good No gas formed
	S_2	12.39 ± 0.03^{ij}	0.072 ± 0.002^{no}	$3.38 \pm 0.32^{a-e}$	
	S_3	15.37 ± 0.05^{fg}	0.087 ± 0.002^{k}	3.53 ± 0.23^{abc}	
	S_4	18.35 ± 0.13^{c}	0.115 ± 0.002^{g}	3.62 ± 0.04^{abc}	
	S_5	21.48 ± 0.22^{a}	0.141 ± 0.002^{b}	3.55 ± 0.30^{abc}	
6	S_1	9.48 ± 0.02^{l}	0.074 ± 0.002^{mn}	$3.47 \pm 0.21^{a-d}$	Slightly Spoiled
	S_2	12.43 ± 0.03^{i}	0.077 ± 0.002^{lm}	3.52 ± 0.06^{abc}	
	S_3	15.44 ± 0.04^{f}	0.091 ± 0.002^{j}	3.65 ± 0.33^{ab}	
	S_4	18.39 ± 0.12^{c}	0.119 ± 0.002^{f}	3.73 ± 0.20^{a}	
	S_5	21.53 ± 0.21^{a}	0.148 ± 0.002^{a}	3.68 ± 0.05^{ab}	
$LSD_{0.05}$		0.19	0.0034	0.36	

Mean with the same superscript within a column are not significantly different at $p < 0.05$.

Table 7. Storage studies of RTS drinks prepared from date palm juice.

Storage period (month)	Sample	TSS (%)	Acidity (%)	Microbial load Log CFU/ml	Physical Observations
0	D_1 (Control)	$14 \pm 0.12^{d-g}$	0.297 ± 0.009^{n}	2.15 ± 0.42^{ef}	Good No gas formed
	D_2	13.9 ± 0.11^{g}	0.302 ± 0.008^{lmn}	$2.52 \pm 0.41^{b-f}$	
	D_3	13.95 ± 0.12^{fg}	$0.311 \pm 0.009^{i-n}$	2.03 ± 0.42^{f}	
	D_4	$14 \pm 0.12^{d-g}$	$0.304 \pm 0.009^{k-n}$	2.34 ± 0.42^{def}	
1	D_1 (Control)	$14 \pm 0.12^{d-g}$	0.297 ± 0.009^{n}	2.22 ± 0.41^{def}	Good No gas formed
	D_2	13.9 ± 0.12^{g}	$0.304 \pm 0.009^{k-n}$	$2.58 \pm 0.41^{b-f}$	
	D_3	13.95 ± 0.12^{fg}	$0.311 \pm 0.009^{i-n}$	2.25 ± 0.42^{def}	
	D_4	$14.02 \pm 0.11^{d-g}$	0.301 ± 0.009^{lmn}	$2.43 \pm 0.42^{c-f}$	
2	D_1 (Control)	$14.02 \pm 0.13^{d-g}$	0.299 ± 0.009^{mn}	2.27 ± 0.41^{def}	Good No gas formed
	D_2	13.95 ± 0.11^{fg}	$0.312 \pm 0.009^{i-m}$	$2.67 \pm 0.41^{a-f}$	
	D_3	13.98 ± 0.12^{efg}	$0.310 \pm 0.01^{i-n}$	2.32 ± 0.42^{def}	
	D_4	$14.07 \pm 0.12^{b-g}$	$0.306 \pm 0.009^{j-n}$	$2.52 \pm 0.42^{b-f}$	
3	D_1 (Control)	$14.04 \pm 0.12^{d-g}$	$0.315 \pm 0.01^{h-l}$	2.36 ± 0.42^{def}	Good No gas formed
	D_2	13.98 ± 0.13^{efg}	$0.318 \pm 0.009^{h-k}$	$2.76 \pm 0.41^{a-e}$	
	D_3	$14.03 \pm 0.12^{d-g}$	$0.313 \pm 0.009^{h-m}$	$2.41 \pm 0.42^{c-f}$	
	D_4	$14.11 \pm 0.11^{a-f}$	$0.308 \pm 0.009^{j-n}$	$2.62 \pm 0.42^{b-f}$	
4	D_1 (Control)	$14.09 \pm 0.12^{b-g}$	0.319 ± 0.009^{hij}	$2.53 \pm 0.42^{b-f}$	Good No gas formed
	D_2	$14.05 \pm 0.12^{c-g}$	0.327 ± 0.008^{fgh}	$2.88 \pm 0.42^{a-d}$	
	D_3	$14.13 \pm 0.12^{a-f}$	0.324 ± 0.009^{ghi}	$2.63 \pm 0.41^{b-f}$	
	D_4	$14.18 \pm 0.11^{a-d}$	0.320 ± 0.008^{hij}	$2.82 \pm 0.42^{a-e}$	
6	D_1 (Control)	$14.15 \pm 0.11^{a-e}$	0.335 ± 0.009^{efg}	$2.62 \pm 0.41^{b-f}$	Slightly Spoiled
	D_2	$14.08 \pm 0.12^{b-g}$	0.347 ± 0.01^{cde}	3.20 ± 0.43^{ab}	
	D_3	$14.13 \pm 0.12^{a-f}$	0.339 ± 0.009^{def}	$2.74 \pm 0.42^{a-e}$	
	D_4	$14.18 \pm 0.12^{a-d}$	0.342 ± 0.009^{de}	3.07 ± 0.43^{abc}	
8	D_1 (Control)	14.24 ± 0.12^{abc}	0.352 ± 0.009^{bcd}	3.34 ± 0.44^{a}	Spoiled Gas formed
	D_2	$14.19 \pm 0.11^{a-d}$	0.373 ± 0.01^{a}	3.20 ± 0.42^{ab}	
	D_3	14.25 ± 0.12^{ab}	0.363 ± 0.01^{ab}	$2.74 \pm 0.42^{a-e}$	
	D_4	14.29 ± 0.13^{a}	0.359 ± 0.009^{abc}	3.07 ± 0.42^{abc}	
$LSD_{0.05}$		0.196	0.01	0.69	

Mean with the same superscript within a column are not significantly different at $p < 0.05$.

acceptability (Spence, 2015; Tiencheu et al., 2021). In the present study, sample D_3 was the best that secured the highest score for colour, flavour, sweetness and overall acceptability, and sample D_1 secured the lowest score for all sensory attributes among the four samples (Table 5).

3.5. Shelf life observation of concentrated date palm juice (at 4 ± 1 °C)

The concentrated form of juice is an important ingredient in soft drinks and has been used to develop various categories such as dilute-to-taste products that contain natural colour and flavour with minimum production cost (Ashurst, 2012). Sucrose itself is a good preservative, and its capacity in preservation is better than other monosaccharides like glucose and fructose, which are collectively known as reducing sugar (Begum et al., 2015). Date palm juice is a good source of reducing sugar (3.5%) regarding its total sugar content (8.7%); hence it is very prone to readily conversion of sugar to alcohol by yeast fermentation which presents naturally (Barh and Mazumdar, 2008). In the present study, heat-processed concentrated date palm juice samples were preserved at refrigerated temperature (4 ± 1 °C), and TSS, moisture, acidity, colour, and flavour were observed initially at one-month intervals up to four-month then at 2-month intervals until quality deteriorated. There were minor changes in the physical quality of the concentrated juice during the storage period (Table 6). The flavour was found unchanged up to 120 days then changed slightly. No gas formation was observed during the storage period; this was similar as reported by other studies (Hussain, 2001; Kulkarni et al., 2010).

Initially, the TSS of the juice was adjusted, remaining constant for the first four months, and then it was increased slightly with the increase of storage period. This range was similar to that reported by some other studies (Molla et al., 2007; Singh and Roy, 1984). TSS is denoted as a significant quality parameter that strongly correlates with texture and composition (Hossain et al., 2014). Increased TSS indicated the degradation of the juice as is primarily represented by sugar, with acid and minerals components (Touati et al., 2014). On the other hand, acidity is also a crucial physicochemical parameter that affects product quality by controlling the development of microorganisms (Kaddumukasa et al., 2017). In the present experiment, acidity for all the formulations at various storage periods was observed and determined. The observation showed that the acidity remained unchanged in the first four months then increased slightly (Table 6), which was also similar as reported by Hossain (Hussain, 2001). This phenomenon might be possible due to the oxidation of acid and change in TSS of the juice during storage (Islam et al., 2013; Touati et al., 2014).

Concentrated date palm juice samples stored at refrigerated temperature (4 ± 1 °C) were analyzed for microbial load during the storage period. As presented in Table 6, the microbial load was not changed significantly ($P < 0.05$) in the first three months of the storage period and then increased slightly. No gas formation was observed up to five months of storage period. Then gas formed slightly, and ultimately quality deteriorated.

3.6. Shelf life observation of RTS drinks prepared from date palm juice (30 ± 2° C)

Sterilized RTS drinks prepared from date palm juice were preserved at room temperature (30 ± 2 °C). After that, TSS, acidity, colour, and

microbial growth were observed initially at one-month intervals up to four months and then at two-month intervals until the quality deteriorated. Total soluble solids initially adjusted in formulations showed a negligible change throughout their 60 days storage period at room temperature. However, in the control sample TSS level remained the same during the storage period. From Table 7, it is found that the range of TSS increments was 3.9–14.29% in date palm juice, similar as reported by (Hussain, 2001; Molla et al., 2007).

The acidity was calculated based on titratable acidity. Acidity for all the formulations at various storage periods was determined, and results are shown in Table 7. It shows that the acidity of the formulations varied directly with their storage period. Nevertheless, in the control sample, there were minimal variations found after three months storage period. The acidity of various RTS drinks prepared from date palm juice was within the range of 0.297–0.359%. The increase of acidity was due to the fermentation of sugar present in RTS drinks, as acidity determines the susceptibility to microbial spoilage (Tasnim et al., 2010; Tiencheu et al., 2021).

Factors that influence the microbial colonization of the juices include relative humidity, temperature, pH, antimicrobial agents, and water activity (Aneja et al., 2014). The use of preservatives to extend the shelf life of juice is not a new practice, as it has little effect on the physicochemical properties of the juice (Tiencheu et al., 2021). RTS drinks samples prepared from date palm juice stored at room temperature (30 ± 2 °C) were analyzed for microbial load during the storage period. As presented in Table 7, the microbial load was not changed significantly ($P < 0.05$) in the first six months of the storage period and then increased slightly. No gas formation was observed up to six months of storage. Then gas formed slightly, and ultimately quality deteriorated. This is a much longer period compared to reports for the juice of natural fruits (Tiencheu et al., 2021).

4. Conclusion

The statistical analysis of data for sensory evaluation of concentrated juice revealed that the juice sample containing 18% TSS was the best, securing a higher score for colour, flavour, and overall acceptability. The physical and chemical properties of this sample were also better than the others. The RTS drinks containing 30% TSS were revealed as best securing the highest sensory properties. The shelf life of these RTS drinks was also observed, and no significant changes occurred in TSS, acidity, and microbial load up to six months. This study was a little attempt to find some alternative use of date palm sap for commercial utilization based on drinks processing to motivate the farmers for increasing commercial cultivation of date palm, as it is decreasing day by day. Further study can be conducted to prepare other juice-based products like jam, jelly, and squashes etc., with a detailed study on the feasibility of their commercial processing and physiochemical changes during the storage period.

Declarations

Author contribution statement

Faria Hossain Shanta, Barun Kumar Rahut, Md Jahirul Islam: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Md Obyedul Kalam Azad, Md. Abu Taher Sohel, Md Rashedur Rahman Rajib: Analyzed and interpreted the data.

Md Shams-Ud-Din, Md. Adnan: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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