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FORMULATION AND QUALITY EVALUATION OF READY-TO-DRINK COFFEE BREW FROM DATE SEED POWDER

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ABSTRACT. The aim of this research was to prepare ready-to-drink coffee from date seed powder and to evaluate the coffee drink during storage at 40 °C. The proximate composition, physicochemical properties, total phenolic content, total flavonoid content, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity of the powder were determined. The total suspended solids (TSS) and pH of the ready to coffee drink decreased by increased the ADSP during 10 days of storage. Total phenolic content (TPC) ranged from 678.99-203.79 GE/100 g dry weight in different ready to coffee drink. The half-maximal inhibitory concentration (IC_{50}) at the beginning was (23.67 - 42.12 µg/mL) indicating that ready-to-drink coffee has a very strong antioxidant activity. Increasing the storage periods decreased the TSS. The lightness values (L*-value) increased with time values whereas a* (red/green value) and b*- (blue/yellow value) values decreased. Microbial studies revealed that the total viable count for coffee ranged from 8.84×10^1 to 5.07×10^6 CFU/mL on the 8th day of storage. The sensory analysis indicated that the ready-to-drink coffee incorporated with 15% coffee brew was more acceptable than the others. This study suggests that date seeds can be considered a potential raw material for ready-to-drink coffee.

KEY WORDS: Agglomeration, Cold brewing, Solubility, Ready-to-drink coffee, Antioxidant activity

INTRODUCTION

Throughout the world, dates (*Phoenix dactylifera*) are a popular food, especially in arid and semi-arid regions [1]. Dates are composed of two structural components: a consumable edible pericarp and a pit or seed that is thrown away as waste or a by-product [2]. However, date seed as by-product has several valuable applications, including the extraction of seed oil for various industrial uses [3]. Substantial amounts of date waste are generated during fruit consumption and industrial processing, including the production of date confectionery, syrup, juice concentrates, jams, jellies, pastes, vinegar, and alcohol [4]. Additionally, ground date seeds are commonly used as animal feed [5]. Dates are becoming more and more popular in Bangladesh since they are an excellent dietary supplement. Depending on the species, variety, and quality, a date may contain 10–18% of its weight in seeds [6]. The seed's composition varies according to the type, but it typically comprises 8-10% moisture, 6.0-8.5% fat, 4.0-5.6% protein, 1% ash, and 75-81% carbohydrates, mostly from dietary fibers and soluble sugars. Date seeds have been shown to contain many useful components, including dietary fiber, minerals, vitamins, fatty acids, and amino acids [7]. It also

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includes a high concentration of bioactive substances such as carotenoids, polyphenols, flavonoids, and tocopherols [3, 8, 9]. According to [10], date seeds contain around 51.1 g/kg of polyphenolic compounds, which is more than that of flaxseed, tea, and grapes. Date seeds contain 60-80% of the recommended daily amount of fiber [11, 12]. However, researchers are attempting to develop methods for boosting the amount of dietary fiber in seed [11]. Due to the nutritional composition, date seeds are being used in pharmaceuticals, nutraceuticals and food industries [13]. Date seeds can be used as functional ingredients to process bread, pasta, noodles, drinks, soups, chocolates [1, 14]. It is also used in bakery products, meat products, dairy products, and date seed brew [3, 14]. Typically, these seeds are utilized to incorporate a variety of nutrient-rich foods to increase their variety [14]. A by-product of date processing, date seed is frequently thrown away as environmentally beneficial agricultural waste, which presents a few problems for the quality of the air, land, and water [15, 16]. Methane emissions from the anaerobic breakdown of organic matter in landfills are one significant worry. Implementing sustainable waste management techniques is therefore necessary to reduce the amount of garbage produced, optimize resource recovery, and encourage recycling and reuse programs. Utilizing and recovering resources are crucial components of sustainable waste management techniques. Processing date-seed coffee as ready-to-drink could be one of the vital options to reduce the date waste.

Coffee consumption is the most popular trend on the globe, since it is one of the drinks which is taken the most and has evolved into a supplement to support our everyday activities. Additionally, coffee can help with restoring mental alertness or wakefulness in times of fatigue or drowsiness [17]. Caffeine is the major compound in coffee [18]. Caffeine abuse can occasionally lead to a variety of health problems. Researchers discovered that consuming too much caffeine can cause hypertension and heart disease [19]. Calcium levels in the body are lowered by caffeine and reduce iron and zinc in the body too [20]. Date seed powder, which offers consumers caffeine-free coffee, may be the approach to overcoming these health problems [21]. Caffeine free coffee from roasted date seeds provides a distinctive flavor and taste to the consumer without for negative effects [22].

Nowadays, ready-to-drink coffee (RTD) is replaced by carbonated soft drinks. RTD coffee is gaining popularity all over the world due to its distinctive flavors. RTD coffee promotes relaxation and provides antioxidants, among other benefits. Foremost, ready-to-drink coffee enthusiasts favor this product primarily for its convenience, seamlessly fitting into their hectic schedules. Therefore, the primary objectives of this research are to develop ready-to-drink coffee from instant date seed powder and to evaluate the physic-chemical parameters, antioxidant, sensory properties and storage stability of RTD.

EXPERIMENTAL

Chemical and reagents

Ajwa date seeds were collected as a by-product from different households of on the Bangladesh Agricultural University campus in April and May, at the time of Ramadan. Other ingredients such as milk powder (23% fat) and sugar (Brand: Fresh) were bought from a local market in Mymensingh, Bangladesh.

Preparation of date seed powder

After collecting date seed, it was kept in icebox and brought into the laboratory. The collected Ajwa date seeds were washed using drinking water to remove adhering dirt and soaked in the water at 25 ℃ for 24 h. After removing water, seeds are kept in a strainer for 30 min to remove extra water. The seeds were dried at 60 ℃ for 10 h using a cabinet tray dryer ((BP-80, Kluay Nam Tai, Bangkok, Thailand). The dried seeds were roasted by drum roaster at 200 ℃ for 15 min to darken the date seed with a coffee-like aroma [14]. The roasted seeds were crushed using the

hammer mill (CMC-20) and sieved at a mesh size of 170 (0.088 mm) to get the fine powder. The DSP was packed in a high-density polyethylene zipper (Ziploc®, San Diego, CA, USA) and stored at -20 ºC for further analysis [1].

Agglomeration of date seed powder

Date seed powder (DSP), 100 g, was wet by adding the required quality of water. The DSP was properly mixed with water and agglomeration was formed. The wet mixture was sprayed in trays. The DSP was dried in a cabinet try dryer (CT-C-0, Jiangsu Shuntong Drying Tech., China) for 6 h at 60 ºC. The sample was cooled at room temperature (28±2 ºC). The solubility of the sample was measured. The heating and cooling were repeated until the solubility of the powder reached more than 90%. The agglomerated date seed powder (ADSP) was vacuum-packed and kept at -18 ºC until further use.

Apparatus and instruments

Chemical analysis of roasted date seed powder and agglomerated date seed powder

Proximate composition. The proximate composition of DSP and ADSP was analyzed according to AOAC methods including ash [23], fat [24], moisture [25], and crude protein [26] using muffle furnace, soxhelt, hot air oven, and kjeldhal apparatus. The dietary fiber was analyzed according to the enzymatic-gravimetric method [27] described by [28].

Total phenolic content. Folin-Ciocalteu (FC) reagent technique was used to measure the concentration of total polyphenol in date seed powder [29]. Briefly, 1 mL extract solution (100 mg instant date seed powder/100 mL of ethanol volume) was mixed and filtered through a solvent resistant filter paper. The filtrate was mixed thoroughly with 5 mL Folin-Ciocalteu reagent (1:10 v/v in distilled water) for 2 min followed by the addition of 4 mL of 7.5% (w/v) sodium carbonate. The mixture was vortexed for 15 sec and allowed to stand for 30 min at room temperature for color development. The absorbance was measured at 765 nm with a spectrophotometer (Photolab 7600, UV-VIS, EU). For the calibration curve, gallic acid was used as a standard and results were expressed as mg GAE /100 g dry weight.

Total flavonoid content. The TFC of instant date seed powder extracts were spectrophotometrically determined by the aluminum chloride method using rutin as a standard [29] with minor modifications. 1 mL aliquots (100 µg/mL) of date seed powder extract were mixed with 0.2 mL 10% $AlCl_3$ solution in 3 mL ethanol, 0.2 mL 1 M potassium acetate, and 5.6 mL distilled water. The mixture was incubated for 10 min at room temperature, and absorbance was measured at 420 nm. Flavonoid content was determined using a calibration curve of rutin and expressed as rutin equivalents per 100 g of dry weight.

1,1-Diphenyl-2-picrylhydrazyl) radical scavenging activity. Antioxidant activity was estimated using DPPH *in vitro* method [30]. 2 mL of date powder was added to 3 mL of 1 M DPPH solution was added to 1 mL extract solution at different concentrations and made the volume up to 10 mL by ethanol. The mixture was stirred vigorously for 15 s and left in a dark place at room temperature for 30 min to allow for reaction. Absorbance was then measured at 517 nm using a single beam spectrophotometer (Photolab 7600, UV-VIS, EU), against a blank. 20-80 µg/mL of Trolox was used as standard. The calibration curve was plotted based on trolox concentration (µg/mL) and % inhibition. The quantity of Troxol equivalent antioxidant capacity (TEAC) per gram of dried extract (mg TEAC/g) was used to measure DPPH radical scavenging activity.

Functional properties of roasted date seed powder and instant date seed powder

Solubility. A 1 g sample was mixed with 100 mL of distilled water (40 ºC), agitated for 5 min at 700 rpm and centrifuged at 3000 × 1 g for 5 min [31]. The supernatant was dried for 5 h at 103 °C. Solubility percentage (g of sample per 100 g water) was calculated from the weight difference.

Bulk density and tapped density. The bulk density was measured by pouring a sample of 1 g weight into a 10 mL graduated measuring glass cylinder and the cylinder was jerked and tapped gently 5 times to level the topmost surface of powder in the cylinder [32]. Then the bulk density was estimated from the ratio of mass of sample to volume occupied by the sample in the measuring cylinder as equation (1).

$$\text{Bulk density} = \frac{\text{Mass of sample (g)}}{\text{Volume occupied by sample (mL)}} \quad (1)$$

For the tapped density, the cylinder was vigorously tapped by hand until no more volume change occurred [28]. Then the tapped density was estimated by dividing the weight of powder by the tapped volume as equation (2).

$$\text{Tapped density} = \frac{\text{Mass of sample (g)}}{\text{Volume occupied by sample after tapping (mL)}} \quad (2)$$

Flow-ability. Flow-ability of powder is categorized by the Carr's Index which is a ratio of the difference between tapped density and bulk density to the tapped density. The Carr's index also represents the compressibility of powder, higher the value of the Car index is the indicator of poor flow ability and high compressibility. The Carr's index (CI) is calculated as equation (3).

$$\text{CI} = \frac{\text{Tapped density} - \text{bulk density}}{\text{Tapped density}} \quad (3)$$

Cohesiveness. The Hauser ratio is used to classify powder cohesiveness, which is also a decent measure of powder consistency and flow ability. There is an inverse relationship between cohesiveness and flow ability. Lower the Hauser ratio results in higher cohesiveness. Hauser ratio (HR) is calculated by the following equation (4).

$$\text{HR} = \frac{\text{Tapped density}}{\text{Bulk density}} \quad (4)$$

Hygroscopicity. Approximately, 2 g of date seed powder sample was placed in a container with saturated NaCl solution (75.29% RH) at 25 °C. Hygroscopicity was measured by the quantity of moisture acquired by the samples daily until consistency was achieved [33] and expressed as g of adsorbed moisture per 100 g solid (g/100 g) equation (5).

$$\text{Hygroscopocity}\left(\frac{\text{g}}{100\text{g}}\right) = \frac{\text{Wf} - \text{Wi}}{\text{Wi} \times \left(100 - \frac{\text{moisture}}{100}\right)} \times 100 \quad (5)$$

where, Wf = final weight, Wi = Initial weight

Determination of color. Color of DSP and ADSP was studied using a colorimeter (Chroma Meter CR400, Konica Minolta, Japan) under conditions (Illuminant: *C, D65; space: LAB). Prior to measurement, the equipment was calibrated for color analysis using a white reference tile. Ten

randomly selected samples were measured for CIE L*, a*, and b* values. The CIE-L*a*b* system, in which L* denotes lightness (100: white, 0: black). The values of a* and b*, respectively, stand for the redness (+)/greenness (-) and the yellowness (+)/blueness (-) of an image. The total color difference (ΔE) was also determined by the equation (6).

$$\Delta E = \sqrt{[(L)^2 + (\Delta a)^2 + (\Delta b)^2]} \quad (6)$$

Characteristics of final products

Brewing of ready-to-drink date seed brew

The date seed powder, 5, 10, and 15 g were weighed and mixed with 100 mL of water (25 °C). The mixture was kept in a refrigerator for 18-24 hours. After refrigeration, the extract was filtered through Whatman No. 4 paper and the brew was collected. Three types of brews are collected from this process, S_1 (5% w/w brewed solution, S_2 (10% w/w brewed solution), and S_3 (15% w/w brewed solution).

Measurement of the browning index of the brew

50 µL of date seed was diluted to 2 mL with demineralized water. Browning index was measured by reading absorbance at 420 nm after 2 min in a 3 mL cuvette with a UV-Vis spectrophotometer (Photolab 7600, UV-VIS, EU), indicating caramelization and Maillard reaction products, including melanoidins [14].

Preparation of ready-to-drink date seed brew

100 mL brew was taken, and milk powder and powdered sugar was heated and added to the brew. Three types of ready-to-drink date seed brew were prepared by adding a certain amount of sugar (8 g) and milk powder (5 g) to different levels (5, 10, and 15%) of instant date seed brew as shown in Table 1. The mixture was homogenized (1st stage 2500 psi and 2nd stage 500 psi) with a two-stage homogenizer (15 MR-8TA, SR. 109713623, APV Gualin, Inc. West Sussex, UK) and filled into a glass bottle and a plastic bottle. The mixture was then cooled at room temperature and stored in the refrigerator at 4 °C. The mixture was analyzed for storage (4 °C) stability and sensory evaluation.

Table 1. Basic formulation for preparation of ready-to-drink coffee (on 100 mL basis).

Sample	Coffee brew (mL)	Powdered sugar (g)	Milk powder (g)
C_1 (5% date seed brewed coffee)	100	8	5
C_2 (10% date seed brewed coffee)	100	8	5
C_3 (15% date seed brewed coffee)	100	8	5

Analysis of ready-to-drink date seed brew

The color parameter, TPC, antioxidant activity, pH, TSS, heating effect, microbial analysis and sensory analysis was conducted during the storage at 4 °C for 10 days of ready-to-drink date seed brew.

Microbial analysis

Nine test tubes were filled with 900 µL of Peptone Buffered Saline (PBS) each. A 1 mL sample was mixed with 9 mL sterile PBS in a falcon tube, following ISO recommendations. 1000 µL

from the mixture was transferred to the first test tube, resulting in a 1:100 dilution. Subsequently, 100 µL from each tube was serially transferred to the next. This process was repeated for each sample. For TVC determination, 9 µL of each dilution was spread on triplicate PCA plates, followed by incubation at 35 °C for 12 hours. Colonies were counted, and results were expressed as CFU/mL [21].

Sensory evaluation for overall acceptability

Samples were assessed by 50 untrained panelists (25 females and 25 males). The untrained panelists ranged in age from 18 to 75 from Mymensingh City Corporation, Bangladesh. Panelists were picked from among frequent coffee drinkers. Before testing, the coffee brews were prepared as per the usual method of coffee preparation and kept in a thermos to maintain the temperature. In short, 10 g of samples were added to 100 mL of boiled water and heated at 80 ºC for 2 min [14]. Sensory quality coffee drink was evaluated at 25 ºC in individual cabins under regulated environmental conditions, including white light (300 lx) and 54% relative humidity [34]. Furthermore, to reduce the impact of shock, all panelists were notified in advance that new products were being manufactured to replace the original coffee brew.

Statistical analysis

Each data was measured in triplicate except for color parameter. Results were statistically analyzed by ANOVA-single factor and t test (two samples assuming equal variance) using Microsoft excel software and the differences at $p < 0.05$ were considered as significant.

RESULTS AND DISCUSSION

Physicochemical and functional properties of date seed powder and agglomerated date seed powder

The powder of date seed powder (DSP) and agglomerated date seed powder (ADSP) was analyzed for moisture, ash, fat, protein and carbohydrate content (% dry basis). Moisture content of date seed powder is very important regarding its shelf life and better storage stability. The seed composition of different date varieties depends on variety, origin, harvesting time, fertilizer, maturity, region, weather conditions and so on. The moisture content of DSP and ADSP was found to be 6.73±0.62 and 2.62±0.33 %, respectively (Table 1). However, Niazi *et al.* [35] and El Sheikh *et al.* [22] found that roasted date seeds powder contained 5.65±0.17% and 5.59% moisture, respectively. On the other hand, Hamada *et al.* [12] and Rehman *et al.* [36] found 9.9% and 1.6% moisture content, respectively. The ash content of DSP and ADSP was found to be 1.32±0.34 and 1.84±0.11 %, respectively (Table 1). Al-Farsi *et al.* [8] and El Sheikh *et al.* [22] suggested 1.12% and 1.21% ash, respectively. But Rahman *et al.* [36] reported only 0.97% ash in the roasted date seed powder. The protein content of DSP and ADSP was found to be 4.82±0.56 and 6.70±0.36%, respectively (Table 2). Amir Azodi *et al.* [37] and Niazi *et al.* [35] suggest 5.56 and 5.85% protein content in date seed powder, respectively. The fat content of DSP and ADSP was found to be 8.86±0.22 and 8.78±0.64%, respectively (Table 2). Rahman *et al.* [36] and Akasha *et al.* [38] indicated 8.08 and 8.14%, respectively, in the date seeds powder. The dietary fiber content of DSP and ADSP was 63.59±1.15 and 57.49±1.12%, respectively (Table 2). Amany *et al.* [39] and Elleuch *et al.* [15] reported that date seed powder contained 22.50–80.20% and 68.7% dietary fiber, respectively. The difference in ash, moisture, fat, protein and dietary fiber content may be linked to differences in horticultural practices, geographical location, seasons and cultivar. The seed composition of different date varieties differ may be due to the variability of the studied cultivars and climatic conditions [40].

The color attributes of roasted powders might also influence consumer acceptability. It is seen that, in ADSP, L*-values reduced while a* and b*-values rose (Table 2). Therefore, it can be proposed that more pyrolysis and non-enzymatic browning reactions occur during the roasting process, which increased the development of brown pigments, and gave the date seed powder a darker color. Besides, the reddish color increased as a*-value increased as well as the yellowish color increased in instant date seed powder as the b*-value increased. But there is a slight difference in the total color difference (ΔE). Bouaziz *et al.* [41] reported that color parameters vary with different varieties of date seed and found L* from 36.97 to 51.28, a* from 3.07 to 13.09 and b* from 8.19 to 17.42 in four date varieties.

The functional properties of the DSP and ADSP were shown in Table 2. The values obtained for bulk density are 0.518±0.025 g/mL and 0.375±0.010 g/mL. The values for tapped density are 0.630±0.017g/mL and 0.438±0.005 g/mL, respectively. Shokrollahi and Taghizadeh [42] reported that the values obtained for bulk density, tapped density were 0.48 g/mL, 0.75 g/mL, respectively. Flowability in DSP and ADSP were 17.76 and 15.35 according to Carr's index. Cohesiveness is noted by Hausner ratio as 1.22 and 1.18 in DSP and ADSP, respectively. Carr's index in light roasted and dark roasted coffee was found 12.28 ± 0.01 and 18.48 ± 1.63 and Hausner ratio was found 1.23 ± 0.024 1.14 ±0.00 for light roasted and dark roasted coffee by Nakilcioglu-Taş and Otles [43]. Hygroscopicity for DSP and ADSP was found 6.67±0.303% and 8.47±0.095% respectively. There was significant difference ($p < 0.05$) between the bulk density, tapped density and hygroscopicity of DSP and ADSP. Nakilcioglu-Taş and Otles [43] found 8.64 ± 0.60 10.52 ± 0.10% hygroscopicity for light roasted and dark roasted coffee.

Table 2. Physico-chemical and functional properties of date seed powder (DSP) and instant date seed powder (ADSP).

Components/Functional properties	Date seed powder	Agglomerated date seed powder
Nutritional composition		
Moisture (%)	6.73±0.62^{a}	2.62±0.33^{b}
Protein (%)	4.82±0.56^{b}	9.70±0.36^{a}
Fat (%)	8.86±0.22^{a}	8.78±0.64^{a}
Ash (%)	1.32±0.34^{a}	1.84±0.11^{a}
Carbohydrate (%)	78.27±0.29^{a}	77.06±0.55^{a}
Dietary fiber (%)	63.59±1.15^{a}	57.49±1.12^{b}
Color parameter		
L*	53.28±1.25^{a}	51.78±1.55^{a}
a*	0.52±0.04^{a}	0.67±0.07^{a}
b*	8.89±1.05^{a}	9.10±1.15^{a}
ΔE	48.46	48.46
Functional properties		
Bulk density (g/mL)	0.518±0.02^{a}	0.375±0.010^{b}
Tapped density (g/mL)	0.630±0.017 ^{a}	0.438±0.005 ^{b}
Hygroscopicity (%)	6.670±0.303 ^{a}	8.47±0.095 ^{b}
Solubility (%)	65.86±2.22^{b}	85.55±1.13^{a}
Carr's index for flowability	17.76	15.35
Hausner ratio for cohesiveness	1.22	1.18

Data were represented as mean ± standard deviation (n = 3). Different super scripts with small letters indicate significant differences ($p \leq 0.05$) within the row.

Solubility of DSP and ADSP were found to be 65.86±2.22% and 85.55±1.13%, respectively (Table 2). The solubility of date seed powder varied from 85.5 to 97.4% with the effect of ascorbic acid reported by Benjakul [44]. The solubility percentage of DSP was quite low for the preparation of coffee. The solubility of ADSP was near to the desired solubility.

Phenolic compounds, flavonoid compounds, and antioxidant activity of ADSP

The TPC of ADSP was found to be 2553 mg GE/100 g dry weight. The TPC range between 2058–2983 mg GE/100 g was stated by Mistrello *et al.* [45]. Ardekani *et al.* [9] estimated the polyphenol contents in date seed powder was 1260 – 3541 mg/100 g, depending on the variety of date seeds. Whereas Besbes *et al.* [2] determined the TPC in date seed powder was 2548±75.71 - 3284±10.14 mg/100 g. The TFC was found at 1058 mg RE/100 g dry weight. Ardekani *et al.* [9] found flavonoids (1224 mg RE/100 g DW). Mistrello *et al.* [45] reported the flavonoid content is 1271–1932 mg CE/100 g FW. The value of total flavonoids of date seed measured during a current study through solvent extraction was 29.5 mg/g dry weight, and it was reported by Besbes *et al.* [2]. The maximum antioxidant activity of date seed powder was found to be 70.02% and the calculated IC_{50} of the instant date seed powder was 31.02 µg/mL. IC_{50} values imply the concentration of the sample which is necessary to scavenge 50% DPPH free radicals [2, 45]. Amany *et al.* [39] found that the IC_{50} value of date seed coffee is 23.81 µg/mL, which means that date seed coffee has high antioxidant activity.

The roasting procedure controls the phenolic compounds that improve the antioxidant activity and flavor of coffee beverages [2, 9, 39, 45]. Depletion of polyphenols was attributed to the degradation of these compounds by oxidative enzymes that are linked to the cell wall by convective airflow (Hajji *et al.*, 2020). Some investigations assumed that the polyphenol losses during the thawing phase due to hydrolytic degradation [9, 39, 45]. Textural deterioration is really the source of water exudation and improved lixiviation of hydrolyzable compounds [46].

Browning Index of the ready-to-drink date seed brew

Three ready-to-drink date seed brews were prepared by incorporating different levels (5, 10, and 15%) of DSP in water which was labeled as C_1, C_2 and C_3, respectively. BI was found to be 0.134±0.006, 0.156±0.003 and 0.184±0.003 for 5, 10, and 15% date seed ready-to-drink coffee brew, respectively. Fikry *et al.* [47] found that the highest BI value of the date seed coffee brews at the point of a roasting temperature of 200 °C, 30 min was found at 0.181 and lower BI was found at 160 °C for 10 min. The roasting time is 0.124. The highest BI value of the brew was identified in C3 containing 15% (w/w) cold brew extraction.

Analysis of ready-to-drink date seed brew

Sensory evaluation of ready-to-drink date seed brew

Ready-to-drink date seed brew samples C1, C2 and C3 were exposed to sensory evaluation. Sensory analysis indicates that the color of sample C3 was most acceptable ($p < 0.05$) by the panelists as it achieved a better color acceptability score than other samples (Table 3). The sample with 15% date seed brew was moderately liked (score 7.87) by the consumer whereas, the sample with 10% date seed brew was liked slightly (score 6.73). In the case of flavor and taste, the two-tail t test at 0.05% significance demonstrated that the flavor and taste of sample C3 was most preferred and the sample C1 (score 6.41) and C2 (score 7.33) were least preferred by the consumer. In the case of overall acceptability, sample C3 was liked very much (score 8.4) whereas C3 was liked slightly (score 6.73) and was significantly different from sample C1 (6.27) and C2 (7.67) (Table 2). Fikry *et al.* [47] prepared a brew of date seed coffee at 1:50 (w/v) ratio by using hot extraction and got the highest color score of the brew was 6.67 at a roasting condition of 200 °C and 20 min. The highest taste score of the brew was 7.33 obtained at a roasting condition of 200 °C and 10 min. The highest color score of the brew was 6.53 at a roasting condition of 180 °C and 20 min and the highest overall acceptability scores of the brew were 6.67 obtained at roasting condition of 200 °C and 20 min.

Table 3. Sensory analysis of ready-to-drink date seed brew.

Sample	Sensory attributes			
	Color	Flavor	Taste	Overall acceptability
C_1	6.73[a]	6.40[a]	6.53[a]	6.27[a]
C_2	7.27[a]	7.33[a]	7.07[a]	7.67[b]
C_3	7.87[b]	8.27[b]	8.13[b]	8.40[c]

Data were represented as mean ±standard deviation (n = 3). Different super scripts with small letters indicate significant differences ($p \leq 0.05$) within the column. C_1 = 5% ready-to-drink date seed brew; C_2 = 10% ready-to-drink date seed brew; C_3 = 15% ready-to-drink date seed brew.

Determination of TSS and pH in the ready-to-drink date seed brew during storage

The maximum TSS was 15º Brix at zero (0) days of storage and the minimum TSS was 10º Brix after 10 days of storage periods (Figure 1). The TSS varied due to the various incorporations of date seed powder and differed during the storage period, but the difference varied from 0.7 for sample C1, 1.33 for sample C2 and C3 (Figure 1). Cempaka *et al.* [48] observed a decline in total sugar content during beverage product storage. This decrease is attributed to the conversion of polysaccharides soluble in reducing sugars, acid-induced hydrolysis of sugars causing disaccharide degradation into monosaccharides, and sucrose hydrolysis. Additionally, microbial fermentation contributes to the formation of reducing sugars [49].

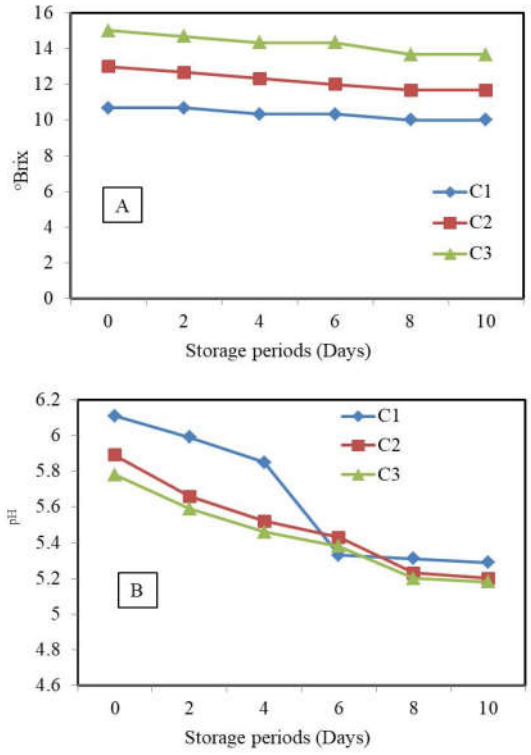

Figure 1. Changes of total soluble solid (TSS, A) and pH (B) during 10 days of storage periods. C_1 = 5% ready-to-drink date seed brew; C_2 = 10% ready-to-drink date seed brew; C_3 = 15% ready-to-drink date seed brew.

The maximum pH of C1 is 6.11 and the minimum pH is 5.31. The pH value of C2 ranged from 5.89 to 5.23 and for C3, it ranged from 5.78 to 5.20. For the entire sample, the pH is reduced over the storage time (Figure 1). Cempaka *et al.* [48] observed a decline in pH during product storage, indicating increased acidity likely due to microbial activity.

TPC and antioxidant activity (IC_{50}) of ready-to-drink date seed brew during storage

Ready-to-drink date seed brews were stored at 4 °C for 10 days to test the durability of TPC and antioxidant activity. TPC decreased with time for the samples during storage. The maximum TPC that was determined in the C3 on Day 0 is 702 mg/100 mL and the minimum TPC was 679 mg/100 mL. For C2, the maximum TPC is 439 and the minimum TPC is 409 mg/100 mL. For C1, the maximum TPC is 236 and the minimum TPC is 204 mg/100 mL (Figure 2).

The IC_{50} lies between 31.71 to 55.45% for C1. However, for C2 and C3, IC_{50} lies between 25.22 to 41.43% and 17.98 to 25.58%, respectively (Figure 2). The increasing IC_{50} denotes that the antioxidant activity is decreasing with the storage time.

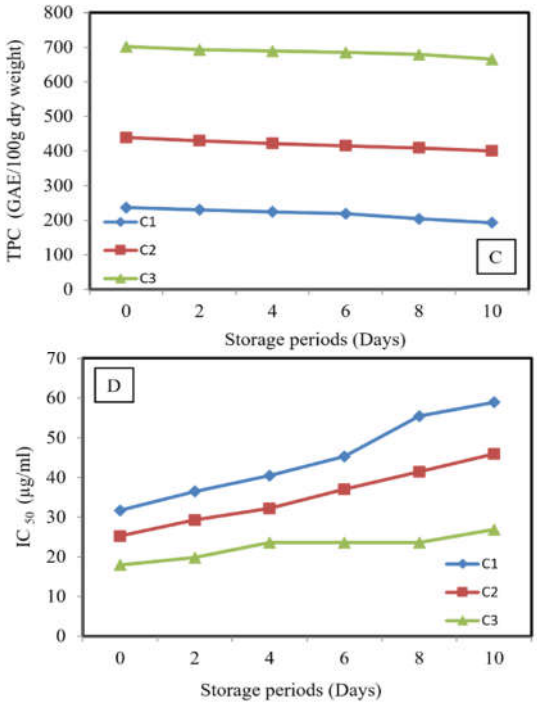

Figure 2. Change of total phenolic content (TPC, C) and antioxidant activity (IC50, D) during 10 days of storage periods. C_1 = 5% ready-to-drink date seed brew; C_2 = 10% ready-to-drink date seed brew; C_3 = 15% ready-to-drink date seed brew.

Color parameters of ready-to-drink date seed brew during storage

The L* value, an indicator of the brightness, increased from 52.71 to 56.22 for C1, from 51.47 to 54.43 for C2 and from 48.23 to 52.08 for C3 (Figure 3). This might be due to non-enzymatic browning reactions. The value of a* and b* is reduced during storage. Cempaka *et al.* [48]

observed an increase in L* value indicating brighter color over storage, while a* decreased, suggesting a yellowish hue in coffee drinks. Additionally, b* decreased, indicating a reddish tint. This color shift signifies potential quality deterioration, aligning with Culver's [50] assertion that color is pivotal in assessing food product quality.

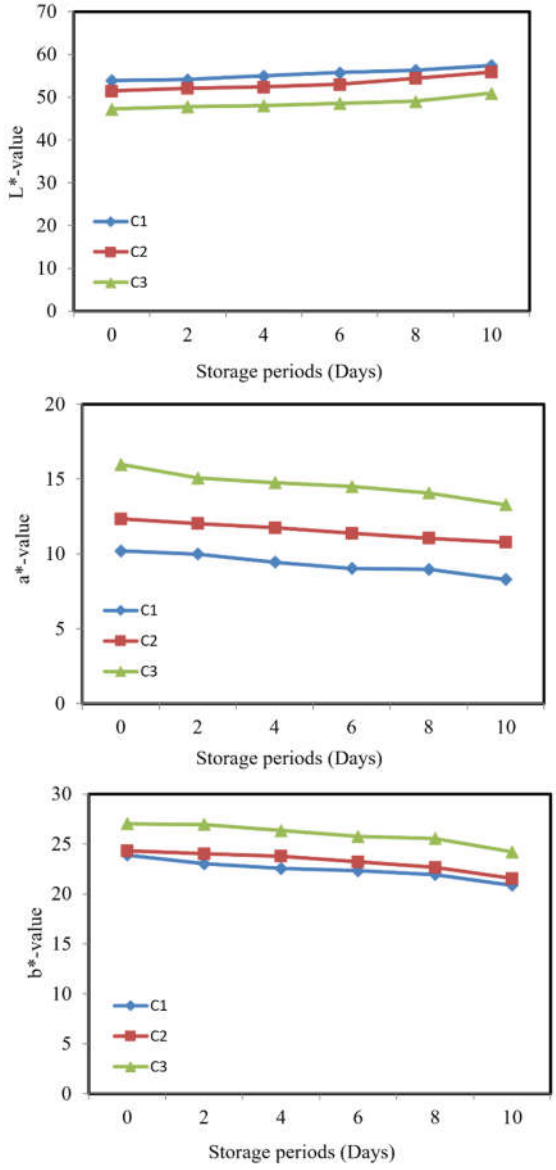

Figure 3. Changes of color parameters during 10 days of storage periods. C_1 = 5% ready-to-drink date seed brew; C_2 = 10% ready-to-drink date seed brew; C_3 = 15% ready-to-drink date seed brew.

Total microbial count of ready-to-drink date seed brew during storage

The results of TVC showed that C1 were 8.84 x 10^1, 9.86 x 10^2, 1.51 x 10^4, 3.01 x 10^5, 5.07 x 10^6 cfu/mL of samples at day 0, day 2, day 4, day 6 and day 8, respectively. The TVC values on day 0, day 2, day 4, day 6 and day 8, were 1.73 log, 2.67 log, 3.91 log, 5.003 log and 6.48 log cfu/mL, respectively, for samples with 10% coffee brew. The sample with 15% coffee brew showed TVC were 1.68 log, 2.63 log, 3.70 log, 4.78 log and 6.034 log cfu/mL of samples at day 0, day 2, day 4, day 6 and day 8, respectively (Figure 4). The cfu limit for human consumption is 100 cfu/100 mL.

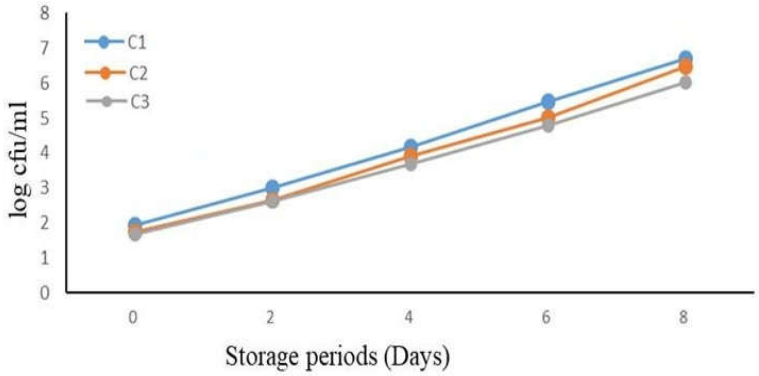

Figure 4. Total microbial load during 10 days of storage periods. C_1 = 5% ready-to-drink date seed brew; C_2 = 10% ready-to-drink date seed brew; C_3 = 15% ready-to-drink date seed brew.

Cempaka *et al.* [48] observed a significant increase in microbe count in Arabica coffee drinks over 12 days, indicating microbial activity. Cempaka *et al.* [48] noted that such activity impacts food quality and quantity. Decreases in pH and total sugar suggest microbial presence. Microbial growth, influenced by intrinsic (e.g., pH) and extrinsic factors (e.g., storage conditions), is assessed via total plate count (TPC). Higher TPC may result from factors like storage temperature, not just changes in pH or sugar content.

Effect of re-heating on overall acceptability

Some people prefer drinking hot ready-to-drink coffee. So, the ready-to-drink date seed brew drink was re-heated (80 °C) and the overall acceptability was noticed and no significant difference ($p > 0.05$) was seen between them according to two tail t tests at significant level 0.05 (Figure 5). The result suggests that ready-to-drink date seed brew could be used as an alternative to coffee a drink.

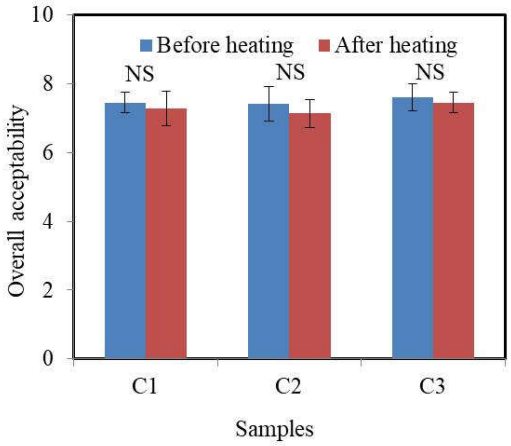

Figure 5. Overall acceptability of ready-to-drink date seed brew after heating. Bar represents standard deviations. C_1 = 5% ready-to-drink date seed brew; C_2 = 10% ready-to-drink date seed brew; C_3 = 15% ready-to-drink date seed brew.

CONCLUSION

The utilization of date seed powder in the formulation of ready-to-drink date seed brew presents an innovative approach towards sustainable utilization of by-products and enhancement of beverage diversity. In the present study, 15% of different date seed coffee brews showed better that was used with a certain amount of milk and powdered sugar to prepare the ready-to-drink date seed brew. Physico-chemical suggests that date seed powder and agglomerated date seed powder are better sources of dietary fiber. This research indicates that instantization increased solubility. DSP contains a significant number of phenolic compounds which show better antioxidant capacity. DSP showed fair cohesiveness, while ready-to-drink date seed powder had better cohesiveness. Chemical analysis revealed nutritional content. Sensory evaluation favored a 15% coffee brew. Storage analysis showed decreasing pH and TSS, with increasing phenolic content in C_3. Micronutrient content decreased during storage. Heating had no impact on ready-to-drink date seed brew acceptability. Glass jars were preferred for both cold and hot coffee packaging. Overall, the results suggest that date seed powder can be effectively utilized in the development of ready-to-drink date seed brews with enhanced nutritional profiles, contributing to sustainable utilization of date by-products and diversification of beverage options in the market. This research suggests that 15% coffee brew could be utilized to prepare ready-to-drink date seed brew. This study implies that date seed might be a good option to produce ready-to-drink date seed coffee. Further studies are suggested on phytochemical profiling and in vivo studies of the ready-to-drink coffee powder.

Ethical statement

This is to inform you that in this study, we have not been involved in any animal and human studies. The authors like to state that for the sensory analysis, a written consent form has been presented to the panelists including the procedures of analysis, ranking scale, potential risks, and permission to publish the research findings in future.

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