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RESEARCH ARTICLE

Temporal Influences on Proximate Composition, Physicochemical Properties and Sensory Acceptability of Coconut Sap

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Abstract Coconut sap, locally known as neera, is a sweet, oyster-white liquid collected from the unblossomed spadix of the coconut tree (*Cocos nucifera*). Although the sap has economic importance and is well-known for its outstanding nutritional profile, studies on the influence of collection times and seasonal variation on its properties remain limited in Malaysia. It is important to know how the seasons and tapping time can affect its nutritional quality and consumer acceptance. Therefore, the objectives of this study were to evaluate the physicochemical characteristics, proximate composition and sensory attributes of the coconut sap collected at different sampling times (8 am, 5 pm and 12 am) from both wet Northeast Monsoon (NW) and dry Southwest Monsoon (ND) seasons. The physicochemical analyses (pH, total soluble solids (TSS) and colour), proximate composition (moisture, ash, crude protein, crude fat and carbohydrate) and food energy determination were conducted. The acceptance test was evaluated by 50 untrained panelists using a 9-point hedonic scale. The findings demonstrated that NWs (86.85%-88.10%) and NDs (85.93%-86.89%) did not significantly differ in terms of moisture content during both seasons. In contrast, NW8 has the lowest ash content (0.22±0.01%), crude protein (0.15±0.01%), and carbohydrates (11.51±0.05%) across the seasons and sampling times. The crude fat content is not significantly different across all samples. Meanwhile, the pH, TSS and colour of all samples are not significantly different by sampling times but vary across seasons. NWs have a higher pH (6.85±0.67) than NDs (5.94±0.18), and NDs possessed a higher value of TSS (15.89±4.21°Brix) than NWs (14.2±1.80°Brix). The colour determination was done using CIE Lab* colour system. NWs exhibited a lighter color as indicated by a higher L* value (37.21±0.72) than NDs (17.69±1.07). Sensory evaluation further indicated that NW samples were more acceptable, particularly in terms of color, sweetness and aftertaste, with NW12 (6.28 ± 1.80) having the “slightly like” score. Thus, this study highlights that the proximate and physicochemical values of coconut sap vary between seasons, but not by different sampling times.

Keywords: Coconut sap, nutritional content, tapping period, seasonal beverages.

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Introduction

Cocos nucifera L., known as the coconut palm, is a member of the Arecaceae family that is commonly grown in tropical areas [1]. In Malaysia, it is the fourth largest industrial crop, after oil palm, rubber and rice. The market value of coconut has an annual historical growth rate (CAGR) of 13.6% from 2011 to 2020. This is driven by rising demand for natural ingredients and plant-based diets for health benefits in cosmetics and healthcare [2]. The coconut-based products include coconut oil and coconut sap.

The coconut sap is economically important and consumed in the form of a non-fermented and fermented nourishing product, such as a beverage, vinegar and sugar [3,4,5]. Coconut sap has become more

popular as a natural beverage and as raw material products with added value, including honey, jaggery, palm syrup and coconut sugar [6]. Coconut sugar has also become a popular alternative sweetener to refined sugar [6,7], due to its low glycaemic index (GI) and high nutritional content, including vitamins and minerals [7,8]. Coconut sugar becomes a healthier sugar choice, with a lower GI value of 35 [4] as compared to palm sugar (*Borassus flabellifer*) and sugarcane sugars (*Saccharum officinarum* L.), which have GI values of 42 and 58-82, respectively [8,9]. According to previous research, the moisture content, ash content, crude protein, crude fat and carbohydrate of coconut sap were 85.93%, 0.27%, 0.26%, 0.01% and 13.53%, respectively [10].

In Malaysia, coconut sap production provides farmers with a steady income throughout the year, regardless of the seasons, from the sap sales. Its nutritional benefits and cultural significance also make the sap an integral part of the local diet. However, more scientific insights into the coconut sap have been reported from research in Indonesia and India, as compared to Malaysia. There is a notable gap in research on factors that would affect the composition and quality of coconut sap, including location, timing, season and tapping duration [9], especially in Malaysia.

Nutritional value may increase during the dry season (May to September) due to tree stress and decreased moisture. Meanwhile, the higher water levels and different physiological conditions of the tree during the wet season (November to March) can lead to changes in nutrient composition [10,11]. These seasonal conditions have been reported to influence the yield and quality of natural sweet exudates. For example, honey production varied across seasons, with the highest yield recorded in October (15.73 kg) compared with August (11.6 kg), September (9.80 kg), and November (8.37 kg). The highest yield was attributed to the maturation of nectar flow following the post-rainy flowering period that typically occurs in September [12,13]. Such findings suggest that seasonal variations in environmental conditions may similarly affect the physicochemical characteristics and yield of coconut sap.

Besides, previous studies have also demonstrated that tapping time has been reported as an important factor affecting coconut sap production. Sap collected during the evening-to-night period (from 2.00 pm onward) yielded a higher average volume (511.32 mL) than sap collected during the morning-to-noon period (6.00 am–2.00 pm), which produced an average volume of 466.34 mL [11,12]. This variation has been associated with differences in turgor pressure within the coconut tree, where greater turgor pressure triggers a higher rate of sap exudation, thus making nighttime tapping more productive. In addition, differences in physicochemical properties among tapping times may be influenced by microclimatic conditions. The sap collected during the morning-to-noon period is exposed to higher temperatures and humidity, creating favourable conditions for microbial activity that may accelerate fermentation and reduce pH compared with sap collected at night [11,12]. Similar effects of harvesting time on product quality have been reported in honey, where environmental conditions during collection influence physicochemical and nutritional characteristics [12,13].

The variability caused by seasonal changes and tapping times may contribute to inconsistencies in coconut sap quality and influence consumer acceptance and preferences. These inconsistencies also limit manufacturers' ability to provide accurate nutritional information and effectively market coconut sap-based products. Consequently, consumers may be unable to make well-informed decisions regarding the nutritional and health benefits of coconut sap. Therefore, a better understanding of the effects of season and tapping time on the physicochemical properties, nutritional composition, and sensory quality of coconut sap is essential. Addressing these knowledge gaps could support standardized practices, enhance product quality, potentially result in increased income for coconut farmers and promote the scientifically validated and resource-efficient commercialization of coconut sap products.

This study aimed to investigate the nutritional composition, physicochemical properties, and sensory acceptability of coconut sap collected at different sampling times and seasons, as local farmers have reported variations in taste and colour associated with seasonal changes and collection timing. Sampling times of 8.00 am, 5.00 pm, and 12.00 am were selected to represent morning, evening, and nighttime stages of sap collection, enabling the evaluation of temporal variations under different seasonal conditions. The findings provide a better understanding of how temporal factors influence the characteristics of coconut sap and help address existing knowledge gaps regarding its quality variability. Tackling these quality issues could greatly benefit the Malaysian coconut industry, particularly in Terengganu, by supporting the development of standardized production practices, improving product quality, increasing farmers' income, enhancing the livelihoods of coconut-growing communities, and promoting the scientifically validated and resource-efficient commercialization of coconut sap products.

Materials and Methods

Sample Collection

Fresh coconut sap was collected from a local farmer, ABEADI Group Sdn. Bhd. in Besut, Terengganu, Malaysia. The samples were tapped from different trees at 8 am, 5 pm, and 12 am, both during the Southwest Monsoon (dry season) from May to September, and the Northeast Monsoon (wet season) from November to March. The usage of natural preservative such as *laru* were used to reduce the fermentation time. The same trees were used for sampling during both seasons to minimize variations. After collection, the coconut sap samples were stored in the freezer at -20°C before collection to the Universiti Sultan Zainal Abidin laboratory. The coconut sap was stored in an ice box (4 °C) to prevent fermentation during transport to the laboratory.

Physicochemical Analysis

Physicochemical analyses included colour determination [8] , pH value [14] and total soluble solids (TSS) via °Brix [15]**.** The colour of coconut sap samples was evaluated using Konica Minolta V Chroma Meter CR-400, Japan. The colour parameters were measured based on CIE Lab* colour system, consisting of L* (lightness), scale from 0 (black) to 100 (white), while a* (redness/greenness), and b*(yellowness/blueness) values. The a* and b* values describe colour without specific numeric limits. Each value of the sample was triplicated, and the mean was calculated. In summary, L*=100 corresponds to white, L*=0 to black, +a* to red, -a* to green, +b* to yellow, and -b* to blue.

The pH of samples was measured using a pH meter (Thermo Fisher Scientific, Massachusetts, USA). A 20 ml of sample was measured into a beaker, and the electrode of the pH meter was inserted into the beaker. Each value of the sample was triplicated, and the mean was calculated.

The total soluble solids (TSS) content of the samples was determined using a digital refractometer (Easy R40, Mettler Toledo, China). A few drops of the undiluted sample were placed onto the refractometer prism at room temperature (25°C), and the TSS value was recorded in °Brix. The measurement was performed in triplicate, and the mean value was calculated and expressed as °Brix.

Proximate Analysis

Moisture, ash, crude protein, and crude fat content were analysed according to AOAC methods [16]. The moisture content of the sample was determined using the oven-drying method. Empty crucibles were dried in an oven at 105°C for 4 hours, cooled in a desiccator, and weighed (W1). Approximately 3 g of fresh sample was placed into each crucible, and the combined weight was recorded as W2. The samples were dried in an oven at 105°C for 24 hours, cooled in a desiccator, and reweighed to obtain W3. The moisture content (%) was calculated using the following equation.

$$\% \text{ moisture} = \frac{W2-W3}{W2-W1} \times 100$$

Where:
W1 = weight of empty crucible (g)
W2 = weight of sample + crucible (g)
W3 = weight of dried sample + crucible (g)

The ash content of the samples was determined using the dry ashing method. Empty crucibles were dried in an oven at 105°C for 4 hours, cooled in a desiccator, and weighed (W1). Approximately 3 g of the samples was transferred into each crucible, and the combined weight was recorded as W2. The samples were then incinerated in a muffle furnace at 550°C overnight. After cooling to room temperature in a desiccator, the crucibles containing the ash residue were weighed and recorded as W3. The ash content (%) was calculated using the following equation.

$$\% \text{ Ash} = \frac{W3-W1}{W2} \times 100$$

Where:
W1 = weight of empty crucible (g)
W2 = weight of sample
W3 = weight of ash + crucible (g)

The crude protein content was determined by the Kjeldahl method (KJEDATHERM system, Gerhardt). Briefly, 1 g of the sample was weighed into a digestion tube, followed by the addition of 3.5 g of catalyst mixture ($CuSO_4/K_2SO_4$) and 12 mL of concentrated sulfuric acid (H_2SO_4). The mixture was digested at 400°C for 60–90 min until a clear greenish-blue solution was obtained. After digestion, the sample was allowed to cool to room temperature for 10–20 min. The digested sample was then neutralized with 32% sodium hydroxide (NaOH) and distilled using a Gerhardt distillation unit. The liberated ammonia was captured in 25 mL of 2% boric acid solution containing five drops of mixed indicator. During distillation, 70 mL of distilled water and 50 mL of 32% NaOH were automatically added to the digestion tube, and the distillation process was completed within approximately 4 min. The collected distillate was titrated with 0.1 N hydrochloric acid (HCl) until the endpoint was reached, indicated by a colour change from green to pale pink. The nitrogen content was determined from the volume of HCl consumed, and the crude protein content (%) was calculated by multiplying the nitrogen content by a conversion factor of 6.25, according to the following equation.

$$\% \text{ crude protein} = \frac{0.1 \times (A-B) \times 14.007}{1\,(g) \times 1000} \times 100$$

$$\text{Crude protein} = N \times F$$

Where:
A = volume of HCl used for sample (mL)
B = volume of HCl used for blank (mL)
F = Protein factor, 6.25

The crude fat content was determined using the Soxhlet extraction method. The extraction cups were dried in an oven at 105°C for 6 hours, cooled in a desiccator, and weighed (W2). Approximately 3 g of sample (W1) was placed into an extraction thimble and loosely plugged with cotton wool. The thimble was then transferred into the extraction unit containing 150 mL of petroleum ether, and fat extraction was performed using an Automated Soxhlet Fat Extractor according to the manufacturer's protocol. After extraction, the extraction cups were dried in an oven at 105°C for 12 hours, cooled in a desiccator, and reweighed (W3). The crude fat content (%) was calculated using the following equation.

$$\% \text{ Fat} = \frac{W3-W2}{W1} \times 100$$

Where:
W1 = weight of sample (g)
W2 = weight of extraction cup (g)
W3 = weight of extraction cup + fat (g)

The carbohydrate content and food energy were determined using the following formulas:

$$\text{Carbohydrate (\%)} = 100\% - (\%\text{moisture} + \%\text{ash} + \%\text{crude protein} + \%\text{fat})$$

$$\text{Food energy} = (4 \times \text{crude protein}) + (4 \times \text{carbohydrates}) + (9 \times \text{crude fat})$$ [16]

Sensory Evaluation

The sensory evaluation was done using a 9-point hedonic acceptance test, and it was done separately for dry and wet season samples. The sensory analysis was approved by the UniSZA Human Research Ethics Committee (Approval code: UniSZA/UHREC/2024/649). The analysis involved 50 healthy, randomly chosen, untrained panelists aged 20 to 35 years, consisting of students and staffs from Universiti Sultan Zainal Abidin. The panelists were selected by strict criteria: non-smokers, no allergies to food, and healthy with no smell deficiencies. The evaluation prioritized attributes such as colour, aroma, consistency, sweetness, aftertaste and overall acceptance. The panel used the nine-point hedonic scale for ratings, where 1 means "Dislike extremely" and 9 means "Like extremely". Panellists received a cup of water to cleanse their palates.

Each sensory evaluation session consisted of three coconut sap samples from the same season, collected at different sampling times (8 am, 5 pm, 12 am). Following collection, coconut sap samples were immediately prepared for sensory evaluation to minimize changes in quality due to fermentation. Approximately 50 mL of each fresh sample was served in identical cups labelled with random three-digit sample codes. During the preparation, the remaining samples were stored in the chiller at 4°C to prevent fermentation. Three samples were presented in a random 3-digit order to minimize bias. Randomization and permutation methods were used throughout sample preparation [19][20]. The sensory evaluation was conducted in a sensory laboratory.

Statistical Analysis

All analyses were done in triplicate and presented as mean ± standard deviation (SD) except sensory evaluation. Two-way ANOVA ($p < 0.05$) was used to evaluate the effects of season and tapping time on physicochemical and sensory acceptability. For physicochemical characteristics, significant differences were determined using the Duncan method ($p < 0.05$). Meanwhile, for sensory evaluation, significant differences among samples were compared using Tukey's Honestly Significant Difference (HSD) test ($p < 0.05$). Relationships between physicochemical and sensory attributes were analysed using Principal Component Analysis (PCA), XLSTAT version 20.0, and Microsoft Excel, developed by Addinsoft in Paris, France [18].

Results and Discussion

The 8.00 am samples represented sap collected overnight, while the 5.00 pm and 12.00 am samples reflected daytime tapping, which may have influenced the concentration of soluble components, thus also affecting the physicochemical and sensory acceptability. The three collection times carried out in both dry and wet seasons have gathered respective samples, NDs and NWs.

Physicochemical Properties

Based on Table 1, colour profile analysis of coconut sap samples revealed significant variation with the seasons, as reflected by CIE Lab* colour parameters, but there are no significant differences between different sampling times in both seasons. The fresh coconut sap typically has a clear to slightly cloudy or oyster white colour, as described by previous research [10]. In this study, dry season samples (NDs) have significantly lower L* values (16.48 ± 0.88 to 17.69 ± 1.07) than wet season samples (NWs) (36.21 ± 1.96 to 37.21 ± 0.72), revealing a darker colour of NDs. In addition, NDs showed significantly higher values of a* (2.56 ± 0.29 to 2.82 ± 0.43), showing a greater redness intensity than NWs (0.59 ± 0.35 to 1.08 ± 0.04). The b* values of NDs were also significantly higher (2.67 ± 0.67 to 3.35 ± 0.28) than NWs (0.47 ± 0.35 to 0.74 ± 0.12), exhibiting a stronger intensity of yellow colour of NDs. Thus, NDs collected were found to be darker, redder and more yellowish than NWs. The colour was darker in samples collected during the dry season, likely due to more sunlight exposure [21]. Sunlight exposure can also influence the sap's microbiological stability. Even though sunlight has some antiseptic properties, it can also promote the growth of microorganisms in warm climates, leading to spoilage or fermentation and further changes in the colour of coconut sap. Additionally, enzymatic browning reactions may occur during sap collection [22]. Previous research showed that pigments from Kiam wood, which dissolve during collection, can also affect the colour of sap. This coloration indicates that the sap is unfermented and fresh. Any discoloration might suggest fermentation or contamination, which could affect how consumers perceive its quality and safety [23,24].

Coconut sap naturally undergoes fermentation shortly after collection due to the activity of microorganisms such as Lactobacillus, Leuconostoc, and yeasts, which convert sucrose into organic acids and alcohol, leading to a reduction in pH [25,26]. To slow this process and preserve sap quality, traditional preservatives such as chengal wood chips are often added to freshly collected sap. In this study, the pH of NDs ranges 5.94 ± 0.18 to 6.59 ± 0.99, while NWs ranged from 6.13 ± 0.52 to 6.85 ± 0.67. No significant differences were observed among different sampling times within the same season. When comparing the same sampling time (5.00 pm) across seasons, ND5 recorded a significantly lower pH value (5.94 ± 0.18) than NW5 (6.58 ± 0.49). The lower pH values of NDs of the dry season may be attributed to the enhanced microbial activity and faster fermentation under warmer conditions, resulting in greater organic acid production and thus having a lower pH [27]. In contrast, increased rainfall and moisture availability during the wet season may contribute to the higher pH values in soil [26].

Total soluble solids (TSS) represent the concentration of dissolved solids in a liquid, including sugars, salts, and other soluble compounds [4]. In the present study, TSS values did not differ among sampling times within a similar season. However, significant seasonal differences were observed, with NDs retaining TSS values ranging from 14.68 ± 1.05 to 15.89 ± 4.21 °Brix, which is higher than NWs, which ranged from 14.01 ± 1.05 to 14.20 ± 1.80 °Brix. These values are generally similar to those previously reported, which ranged from 15.2 to 19.7 °Brix [28]. The lower TSS values recorded in NWs may be attributed to higher humidity and moisture, which dilute the sugar concentration. In contrast, the higher TSS values observed in NDs correspond to the lower moisture content of the sap (Table 1), indicating a greater concentration of soluble sugars under drier sunny conditions [29]. Additionally, reduced sunlight intensity during the rainy season may limit photosynthetic activity, resulting in lower carbohydrate production and consequently reduced sugar accumulation in the sap [30].

Proximate Composition

Table 1 displays the proximate composition of coconut sap samples. The moisture content of NWs ranged from 86.85% to 88.10%, while NDs contained 85.93% to 86.89%. The slightly higher moisture of NWs is likely associated with increased soil and groundwater availability [26], which enhances water uptake by coconut trees and consequently produces sap with a more diluted composition during the wet season [23]. However, no significant differences were observed among samples collected at different sampling times within the same season.

The ash content, ranging from 0.22% to 0.32%, represents the overall mineral content in the samples. No significant differences were observed among the different sampling times within a similar season. However, there were significant differences between the same collection times across different seasons. The ash content of ND8 (0.26± 0.02%) was significantly higher than NW8 (0.22± 0.01%). Similarly, ND5 (0.31± 0.01%) and ND12 (0.32± 0.02%) also exhibited higher ash content when compared to NW5 (0.28± 0.04%) and NW12 (0.28± 0.04%), respectively. These values were consistent with previous findings (0.11-0.41%) [28], in which the wet, rainy climate may promote dilution, thus lowering mineral content in wet-season samples [29]. In addition, the crude fat content was found to range from 0.02% to 0.03%, showing a low value in all samples, with no significant difference among sampling times during the wet and dry seasons.

The protein content were also varied in this study, ranging from 0.15% to 0.26% during the wet season and 0.22% to 0.28% during the dry season. This content is consistently very low, corresponding to previous research reporting values of 0.01% [10] and 0.23%-0.32% [28]. A seasonal difference was observed at 8.00 am, where ND8 (0.22 ± 0.00%) had a higher crude protein content than NW8 (0.15 ± 0.01%). NW8 exhibited a significantly lower value of crude protein than NW5 (0.26 ± 0.04%) and NW12 (0.25 ± 0.02%). This finding suggests increased sap exudation, likely due to higher turgor pressure within the coconut tree during the night until sampling time at 8.00 am [11]. A similar trend has been reported previously, where coconut sap collected on rainy days contained lower concentrations of free amino acids than sap collected on sunny days [21], indicating that increased moisture may dilute nitrogenous compounds and other soluble components in the sap.

Besides, carbohydrate content in NWs and NDs was in range of 11.51% to 12.59% and 12.61% to 13.46, respectively, corresponding to a previous report of 15.00% [28]. No significant differences were observed among sampling at different times for both seasons. However, a significant difference was observed, with a higher carbohydrate content in ND8 (12.61 ± 0.01%) than NW8 (11.51± 0.05%). Furthermore, NW8 has a significantly lower carbohydrate content than NW5 (12.59 ± 2.20%) and NW12 (12.41 ± 2.22%). During the wet season, frequent rainfall and increased cloud cover can reduce light availability, which can limit photosynthesis and thus the replenishment of carbohydrate might be reduced the following morning [29]. Lastly, the food energy values is mainly contributed by the carbohydrate content and were found to range from 47.97 kCal to 55.23 kCal, with no significant difference among all samples.

Sensory Acceptability

The sensory acceptance test scores varied depending on sensory attributes, sampling times and seasons, as shown in Table 2. The colour attribute scores ranged from 4.76 to 5.72 for NDs and 5.54 to 6.86 for NWs. NW12 (6.86 ± 1.32) received the slightly liked score, followed by NW5 (6.56 ± 1.30). Meanwhile, ND8 (5.72 ± 1.68) recorded the “neither like nor dislike” score in the dry season, compared to NW8 (5.54 ± 1.82). These differences suggest that the colour intensity can significantly impact how panellists evaluate the hedonic score or the overall acceptability of coconut sap.

Besides, the aroma, consistency, and sweetness exhibited similar acceptability patterns among the panelists. Higher acceptability scores were attributed by NWs, as compared to NDs. This shows NW samples received a slightly like score (5 and above), while NDs received a slightly dislike score (under 5). In terms of aroma, there is no significant difference measured between sampling times within the same season, while a significant difference in aroma acceptability was found when comparing across the seasons. A higher acceptability score was related to NWs, with the highest score being NW8 (5.90 ± 1.87), and the lowest was ND8 (3.96 ± 1.89). For consistency acceptability, NW12 gained the highest score (6.38 ± 1.48), a slightly liked score, while the lowest was ND8 (5.30 ± 1.76). Meanwhile, NWs sweetness score ranged from 5.94 ± 1.89 to 6.36 ± 1.80, while NDs score ranges were from 4.86 ± 2.22 to 5.42 ± 1.95. NW12 gained the highest score and NW8 had the lowest score.

Table 1. Proximate composition, food energy, and physicochemical properties of coconut sap collected during different seasons at different sampling times.

Composition	Sample					
	ND8	ND5	ND12	NW8	NW5	NW12
Proximate Composition						
Moisture (%)	86.89 ± 0.02^{Aa}	85.93 ± 0.26^{Aa}	86.01 ± 0.02^{Aa}	88.10 ± 0.03^{Aa}	86.85 ± 2.29^{Aa}	87.04 ± 2.33^{Aa}
Ash (%)	0.26 ± 0.02^{Aab}	0.31 ± 0.01^{Aa}	0.32 ± 0.02^{Aa}	0.22 ± 0.01^{Bb}	0.28 ± 0.04^{Bab}	0.28 ± 0.04^{Bab}
Crude Fats (%)	0.02 ± 0.01^{Aa}	0.03 ± 0.02^{Aa}	0.03 ± 0.02^{Aa}	0.03 ± 0.02^{Aa}	0.02 ± 0.01^{Aa}	0.02 ± 0.02^{Aa}
Crude Proteins (%)	0.22 ± 0.00^{Aab}	0.28 ± 0.02^{Aa}	0.27 ± 0.06^{Aa}	0.15 ± 0.01^{Bb}	0.26 ± 0.04^{Aa}	0.25 ± 0.02^{Aa}
Carbohydrates (%)	12.61 ± 0.01^{Aa}	13.46 ± 0.29^{Aa}	13.38 ± 0.04^{Aa}	11.51± 0.05^{Ba}	12.59 ± 2.20^{Aa}	12.41 ± 2.22^{Aa}
Food Energy (kcal)	51.49 ± 0.15^{Aa}	55.23 ± 0.92^{Aa}	54.85 ± 0.21^{Aa}	47.97 ± 0.34^{Aa}	51.56 ± 9.04^{Aa}	50.83 ± 9.24^{Aa}
Physicochemical Properties						
pH	6.13 ± 0.43^{Aa}	5.94 ± 0.18^{Ba}	6.59 ± 0.99^{Aa}	6.13 ± 0.52^{Aa}	6.58 ± 0.49^{Aa}	6.85 ± 0.67^{Aa}
TSS (˚Brix)	14.68 ± 1.05^{Aa}	15.89 ± 4.21^{Aa}	15.31 ± 1.58^{Aa}	14.14 ± 3.23^{Ba}	14.2 ± 1.80^{Ba}	14.01 ± 1.05^{Ba}
Colour Analysis						
Lightness (L)*	16.48 ± 0.88^{Ba}	17.69 ± 1.07^{Ba}	17.34 ± 0.41^{Ba}	37.21 ± 0.72^{Aa}	36.21 ± 1.96^{Aa}	36.48 ± 1.74^{Aa}
*Redness (*a)*	2.82 ± 0.43^{Aa}	2.56 ± 0.29^{Aa}	2.70 ± 0.07^{Aa}	0.59 ± 0.35^{Ba}	1.08 ± 0.04^{Bb}	0.89 ± 0.13^{Bb}
*Yellowness (*b)*	3.35 ± 0.28^{Aa}	2.89 ± 0.38^{Aa}	2.67 ± 0.67^{Aa}	0.69 ± 0.55^{Ba}	0.74 ± 0.12^{Ba}	0.47 ± 0.35^{Ba}

*Data are expressed as means ± standard deviation of triplicate determinations. Data with capital letters (A, B) indicate significant differences (p< 0.05) between seasons at the same sampling time. Small letters (a, b) indicate significant differences among sampling times within same season ($p < 0.05$), ND: ND8, ND5, ND12 = samples collected during dry season at 8 am, 5 pm, and 12 am, respectively; NW: NW8, NW5, NW12 = samples collected during wet season at 8 am, 5 pm, and 12 am, respectively.

These differences may be related to seasonal climate, where there is less exposure of sap to the sun during the wet season and more humid conditions as compared to the dry season [12]. The stronger aroma detected in dry-season coconut sap may be attributed to the lower acceptability score of NDs. This aroma might be contributed by the higher concentration of volatile and flavour-active compounds [30,31] resulting from lower moisture content and higher soluble solids of NDs (Table 1). According to previous research, natural preservatives used to lower the rate of sap fermentation could also contribute to the unpleasant aroma [12,30]. Increased sunlight exposure during the dry season may also enhance photosynthetic activity and carbohydrate accumulation, providing additional precursors for aroma development [31,32]. The higher moisture, temperatures and humidity also exposed the plant metabolism to creating favourable conditions for microbial activity that may accelerate fermentation, producing off-flavour compounds [11,12]. The higher concentration of flavour-active compounds might be associated with less favourable consistency, sweetness and aftertaste of the panelists. Conversely, content during the wet season may dilute aroma compounds, resulting in a less intense aroma perception and a more consistent sample [31,32,33]. In terms of aftertaste, there was no significant different determines among all samples. As taste perception is highly personal, which makes small changes in coconut sap might be less noticeable to other consumers [24].

Lastly, the overall acceptance scores of NDs ranged from 4.12 ± 1.89 to 4.82 ± 1.85, and NWs had a score range from 5.38 ± 2.11 to 6.28 ± 1.80, indicating a significant seasonal effect on consumer acceptance. In contrast, sampling time within each season did not significantly influence overall acceptance. Among all samples, NW12 received the highest overall acceptance score (6.28 ± 1.80), corresponding to a rating of "slightly liked" on the 9-point hedonic scale, whereas ND8 received the lowest score (4.12 ± 1.89).

Table 2. Acceptance test of coconut sap collected at different sampling times during dry season and wet season.

Attributes	Sample					
	ND8	ND5	ND12	NW8	NW5	NW12
Colour	5.72 ± 1.68^{Aa}	4.94 ± 1.70^{Bb}	4.76 ± 1.55^{Bb}	5.54 ± 1.82^{Bb}	6.56 ± 1.30^{Ba}	6.86 ± 1.32^{Aa}
Aroma	3.96 ± 1.89^{Aa}	4.14 ± 1.99^{Ba}	4.10 ± 1.90^{Aa}	5.90 ± 1.87^{Aa}	4.82 ± 2.05^{Ab}	5.54 ± 1.70^{Aab}
Consistency	5.30 ± 1.76^{Ba}	5.52 ± 1.42^{Aa}	5.32 ± 1.49^{Bb}	5.98 ± 1.75^{Aa}	6.22 ± 1.57^{Aa}	6.38 ± 1.48^{Aa}
Sweetness	4.86 ± 2.22^{Ba}	5.16 ± 1.80^{Ba}	5.42 ± 1.95^{Ba}	5.94 ± 1.89^{Aa}	5.98 ± 1.66^{Aa}	6.36 ± 1.80^{Aa}
Aftertaste	3.68 ± 2.06^{Aa}	4.24 ± 2.20 ^{Aa}	4.36 ± 2.00^{Aa}	5.26 ± 2.15^{Aa}	5.34 ± 2.16^{Aa}	6.04 ± 1.80^{Aa}
Overall acceptance	4.12 ± 1.89^{Aa}	4.70 ± 1.87^{Ba}	4.82 ± 1.85^{Aa}	5.58 ± 2.05^{Aab}	5.38 ± 2.11^{Aa}	6.28 ± 1.80^{Aa}

*Data are expressed as means ± standard deviation of triplicate determinations. Data with capital letters (A, B) indicate significant differences (p< 0.05) between seasons at the same sampling time. Small letters (a, b) indicate significant differences among sampling times within same season (p < 0.05), ND: ND8, ND5, ND12 = samples collected during dry season at 8 am, 5 pm, and 12 am, respectively; NW: NW8, NW5, NW12 = samples collected during wet season at 8 am, 5 pm, and 12 am, respectively.

Since the sensory evaluation was conducted among panelists aged 20–35 years, many of whom were first-time consumers of coconut sap, the acceptability may differ compared to mature adult panelists [34]. This younger age group was selected because younger adults represent an important target market for natural and functional beverages and are generally more willing to try novel products. The higher acceptance of NW12 suggests that wet-season coconut sap may be more appealing to consumers with limited prior exposure to the beverage. In contrast, the lower acceptance of dry-season samples may reflect sensory characteristics that are less preferred by inexperienced consumers but potentially more familiar to regular coconut sap drinkers. Coconut sap is particularly popular on the East Coast of Peninsular Malaysia, especially in Kelantan and Terengganu, where consumers are accustomed to its traditional flavour profile.

Correlation between Seasonal Variation and Collection Time Influences on Coconut Sap Quality and Sensory Acceptability

A principal component analysis (PCA) biplot was plotted to discuss the correlation between sensory attributes and physicochemical properties of coconut sap samples collected at different seasons and times (Figure 1). Principal component analysis (PCA) explained 64.67% of the total variation, with F1 and F2 accounting for 44.72% and 19.95%, respectively. The PCA biplot revealed that sweetness, aftertaste, consistency, aroma, and overall acceptance were positively correlated and clustered together, indicating that these attributes were the main drivers of consumer preference. Samples collected during the wet season, particularly NW12, were positioned closest to these sensory attributes, supporting their higher acceptance scores. In contrast, dry-season samples were associated with higher Brix and L* values, suggesting greater soluble solids content and lighter colour.

However, these physicochemical characteristics showed an inverse relationship with overall acceptance, indicating that consumer preference was influenced more by sensory perception than by soluble solids content alone. The close association between a* and b* values further suggests that colour attributes varied together and contributed to sample differentiation across seasons [35]. Overall, the PCA demonstrates that seasonal variation exerted a stronger influence on coconut sap characteristics than collection time, with wet-season samples exhibiting more favourable sensory profiles including sweet taste [35,36,37]. This result suggests that consumer acceptance was influenced more by overall sensory attributes of the coconut sap than by physicochemical properties.

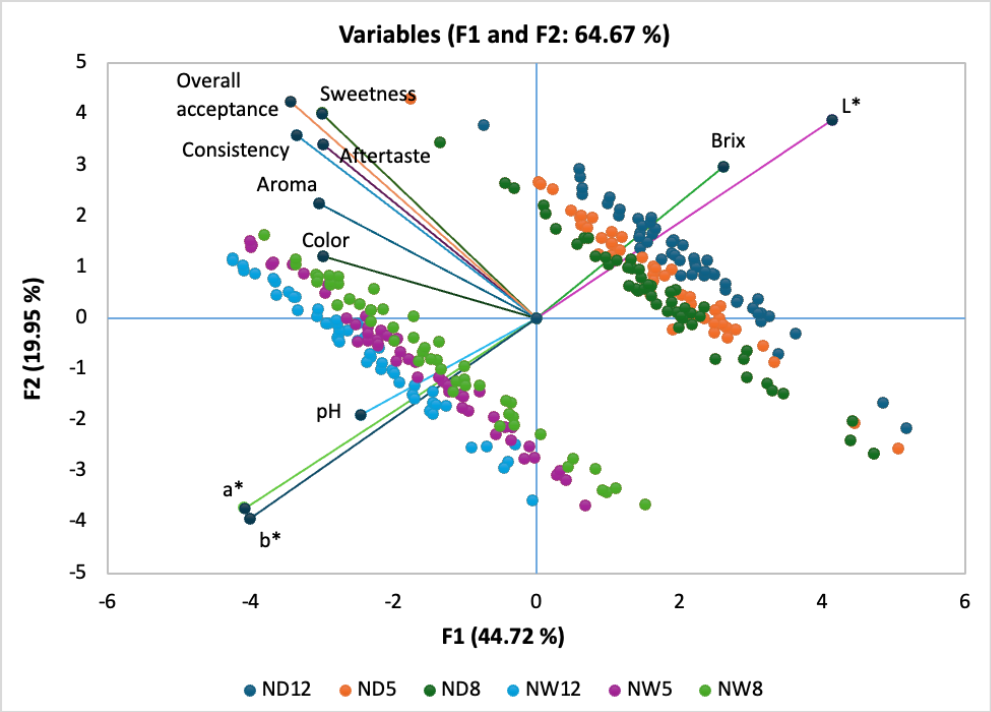


Figure 1. Principal component analysis (PCA) reveals the relationship between sensory attributes and physicochemical characteristics of all coconut sap samples of different seasons and collection times.

Conclusions

In conclusion, seasonal variation had a greater influence than collection time on the proximate composition and physicochemical properties of coconut sap. Total soluble solids, pH, colour, ash and crude protein differed between seasons, but these differences were not consistent across all sampling times. Crude fat content remained low across all samples (0.02–0.03%), with no significant differences between seasons or sampling times. Dry-season samples had significantly higher ash content than wet-season samples at the corresponding sampling times. Sensory evaluation showed that the wet-season sample collected at 12:00 midnight (NW12) achieved the highest ratings for sweetness, aftertaste, and overall acceptability. Overall, coconut sap exhibited a favourable nutritional profile and good consumer acceptance, highlighting its potential as a healthy natural beverage. However, the sensory evaluation was limited to panelists aged 20–35 years. Therefore, the acceptance results may not be fully generalizable to older consumers. Future studies should include a wider age range to represent potential target consumers better.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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References

[1] K.V. Reddy, D.P. Kumar, D.S. Rao, IOSR J. Bus. Manage. 19 (2017) 68–72.
[2] Agricultural Geospatial and Statistics Unit, Strategic Planning Division and Department of Agriculture Peninsular Malaysia, Crop Statistics Booklet (Food Crops Sub-sector), Department of Agriculture Malaysia, Kuala Lumpur, 2020.
[3] R.F.B. Maria, N. Malhija, M.T. Sherin, T. Kumaran, J. Basic Appl. Res. Biomed. 6 (2020) 50–52.

[4] Y. Kusumawaty, E. Maharani, S. Edwina, Agribusiness in Marketing 5 (2012) 1–13.
[5] K. Ysidor, K. Jean-Louis, K. Roger, A. Rachel, O. Joelle, I. Emmanuel, B. Marius, Am. J. Exp. Agric. 5 (2015) 352–365.
[6] D.-L. Ngo-Hoang, Qeios (2023) 1–5.
[7] J. Wrage, S. Burmester, J. Kuballa, S. Rohn, LWT 112 (2019) 108227.
[8] A.D. Saputro, D. Van De Walle, R.P. Aidoo, M.A. Mensah, C. Delbaere, N. De Clercq, J. Van Durme, K. Dewettinck, Eur. Food Res. Technol. 243 (2016) 177–191.
[9] P. Naknean, M. Meenune, G. Roudaut, Int. Food Res. J. 17 (2010) 977–986.
[10] M.T. Asghar, Y.A. Yusof, M.N. Mokhtar, M.E. Ya'acob, M.H. Ghazali, L.S. Chang, Y.N. Manaf, Food Sci. Nutr. 8 (2020) 1777–1787.
[11] K.B. Hebbar, R. Pandiselvam, M.R. Manikantan, M. Arivalagan, S. Beegum, P. Chowdappa, Sugar Tech 20 (2018) 621–634.
[12] Mustaufik, L. Sutiarso, S. Rahayoe, K.H. Widodo, IOP Conf. Ser.: Earth Environ. Sci. 653 (2021) 012015.
[13] S.A. Bariagabre, G. Tsegay, A. Berhe, D. Woldegebriel, Discov. Food 5 (2025) 430.
[14] D.C. Okafor, B.C. Ijioma, C.E. Ofoedu, J.C. Nwosu, E.U. Onyeka, N.C. Ihediohanma, T.I. Okafor, Asian J. Agric. Food Sci. 5 (2017) 1–10.
[15] L.S. Magwaza, U.L. Opara, Scientia Horticulturae 184 (2015) 179–192.
[16] H. William, W.L.G. George, AOAC International, Official Methods of Analysis of AOAC International, AOAC International, Gaithersburg, 2011.
[17] B. Walther, D. Guggisberg, R. Badertscher, L. Egger, R. Portmann, S. Dubois, M. Haldimann, K. Kopf-Bolanz, P. Rhyn, O. Zoller, R. Veraguth, S. Rezz, Front. Nutr. 9 (2022) 988707.
[18] A. Gámbaro, M.B. McSweeney, Advances in Food and Nutrition Research, Academic Press, Cambridge, 2020, p. 295–337.
[19] S. Muzzaffar, R. Jan, I.A. Wani, F.A. Masoodi, M.M. Bhat, T.A. Wani, G.R. Wani, Cogent Food Agric. 2 (2016) 1157920.
[20] Kemp, Hollowood, Hoart, Sensory Evaluation: A Practical Handbook, John Wiley & Sons, Chichester, 2009, p. 1–150.
[21] P. Haryanti, S. Supriyadi, D.W. Marseno, U. Santoso, Jurnal Agritech 38 (2019) 295–302.
[22] J. Chandrapala, C.M. Oliver, S. Kentish, M. Ashokkumar, Food Rev. Int. 29 (2012) 67–91.
[23] M. Chen, X. Wang, Y. Liu, P. Li, R. Wang, L. Jiang, Molecules 27 (2022) 7139.
[24] V.V. Priya, M. Balakrishnan, S. Karthikeyan, P. Rajkumar, M.R. Manikantan, K. Gurusamy, R. Pandiselvam, Sugar Tech 25 (2023) 906–915.
[25] N. Xia, Afr. J. Biotechnol. 10 (2011) 14999–15005.
[26] A.P. Okwukwe, S.E. Kakulu, M. Dauda, Int. J. Sci. Res. Publ. 12 (2022) 215–222.
[27] P. Haryanti, Supriyadi, M.D. Wiseso, U. Santoso, Int. J. Sci. Technol. 5 (2017) 52–57.
[28] A. Sharma, M. Meghwal, J. Nutr. Food Processing 8 (2021) 1–5.
[29] P. Shetty, A. D'Souza, S. Poojari, J. Narayana, P. Rajeeva, Int. J. Appl. Sci. Biotechnol. 5 (2017) 375–381.
[30] H. Lantemona, A.L. Abadi, A. Rachmansyah, J. Pontoh, IOSR J. Environ. Sci. Toxicol. Food Technol. 4 (2013) 42–48.
[31] Z. Liang, Z. Fang, A. Pai, J. Luo, R. Gan, Y. Gao, J. Lu, P. Zhang, Crit. Rev. Food Sci. Nutr. 62 (2022) 215–243.
[32] S. Louw, Anal. Sci. Adv. 2 (2021) 157–170.
[33] G. Wijonarko, I.S.M. Purbowati, T. Widjojoko, A. Maksum, Indonesian J. Food Technol. 1 (2022) 41–48.
[34] A.C. Hoffman, R.V. Salgado, C. Dresler, R.W. Faller, C. Bartlett, Tobacco Control 25 (2016) 32–39.
[35] K.B. Hebbar, M. Arivalagan, M.R. Manikantan, R. Pandiselvam, S. Beegum, P. Chowdappa, J. Food Sci. Technol. 52 (2015) 8142–8149.
[36] W. Ahrens, Flavour 4 (2015) 8.
[37] W. Liu, J. Su, S. Li, X. Lang, X. Huang, Sci. Rep. 8 (2018) 1083.