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Effect of Harvesting Stage on Physicochemical and Nutritional Properties of Coconut Water from the MATAG Variety (*Cocos nucifera* L.)

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ABSTRACT

Coconut water is popular as natural functional drink in health which contain stable composition of nutrition and minerals. It has been consumed worldwide due to its rich profile of electrolytes, vitamins and phytohormones. However, the quality and nutritional composition of coconut water are strongly influenced by the harvesting stage of the fruit. Although previous studies have examined variations in coconut water composition across different local varieties, information on hybrid cultivars remains limited, particularly for the MATAG variety, which is extensively cultivated in Malaysia for its high yield and superior quality traits. Therefore, this study evaluated the effect of harvesting stage on physicochemical and nutritional properties of coconut water from MATAG variety. The experiment was conducted using Randomized Complete Block Design (RCBD) with four replications. Four harvesting stages were designated as treatment; T1 (3 months), T2 (6 months), T3 (9 months) and T4 (12 months). The parameters assessed were total soluble solid (TSS), pH, sugar composition (fructose and glucose) and mineral elements, namely potassium (K), sodium (Na), magnesium (Mg), and calcium (Ca). The results indicated that harvesting stage significantly influenced most physicochemical and nutritional properties of coconut water, except for potassium content. This study identified that 9 month harvesting stage was identified as optimal for producing tender coconut water with desirable quality attributes in the MATAG variety.

Keywords: Coconut Water; Fructose Content; Glucose Content; Harvesting Stage; Hybrid; Liquid Endosperm; MATAG Variety; Maturity; Nutritional Properties; Physicochemical; Total Soluble Solid.

1.0. Introduction

Coconut (*Cocos nucifera* L.) is a monoecious, perennial crop that is widely cultivated in tropical and subtropical regions. It is grown in more than 90 countries, with Indonesia, India, Philippines and Sri Lanka being the largest areas of global coconut plantation [1]. Commonly referred as 'tree of life', the coconut palm is highly valued for its versatility, as nearly all parts of the tree provide economic and functional benefits. Increasing scientific evidence has highlighted the potential of coconut water in health and medicinal applications. Previously in Solomon Island, coconut water has been used as a short-term alternative for intravenous hydration during emergencies [2]. In addition of hydrating properties, coconut water is rich in sugar, minerals, vitamins, antioxidants, anti-inflammatory, anti-cancer and anti-microbial effects. This versatility has made it as an important source in practical uses and economic values of numerous products, both fresh consumption and value-added product.

Various components of the coconut palm, including the frond, husk, shell and trunk are utilized for building materials in construction, fuels, lubricants, veneer, handicrafts and agricultural inputs. However, the coconut fruit (nut) remains the primary focus for growers and stakeholders due to its role as a major source of food and nutritional beverage product. The fruit consists of both liquid and solid endosperm, where the coconut water represents the liquid endosperm, while the solid endosperm develops into edible kernel or flesh. The kernel of matured coconuts is processed into products such as coconut oil, desiccated coconut, coconut milk and copra, whereas, young coconuts (6 to 8 months old) are valued for the tender coconut water [3].

Coconut water is a liquid endosperm within the fruit, is widely recognized as a natural beverage with refreshing taste and nutritional benefits. It contains sugars, vitamins, minerals, growth promoting factors, proteins and amino acids, making it a popular functional drink [4]. It is also used as a growth supplement in plant tissue culture and micropropagation due to the presence of nutrients and phytohormones. However, the composition and quality of coconut water are dynamic and influenced by multiple factors, including variety, environmental conditions, soil properties, and particularly the stage of fruit maturity. Fruit maturity plays a critical role in determining the physicochemical and nutritional characteristics of coconut water. Coconut development is generally categorized into three stages: immature (up to 6–8 months), tender (9–11 months), and mature (11–12 months) [5]. These developmental stages strongly influence coconut water composition. Early harvesting may result in lower sugar content and less developed flavour, while overmature fruit often contain reduced water volume with a greasy or oily mouthfeel, associated with advanced kernel development and lipid accumulation in the solid endosperm. Therefore, appropriate harvesting timing is important for ensuring product quality, consumer acceptance and industrial suitability.

The MATAG coconut variety, a hybrid derived from Malaysian Tagnanan Tall and Malayan Yellow Dwarf, is widely cultivated due to its high yield and favourable fruit characteristics. Despite its increasing importance in Malaysia, limited information is available on the physicochemical and nutritional changes in coconut water from MATAG coconuts at different maturity stages. This knowledge gap presents challenges in optimizing harvesting time, postharvest utilization and potential industrial applications. By analysing parameters such as pH, total soluble solids, sugar content, and mineral properties across various developmental stages, this research seeks to provide a comprehensive understanding of the dynamic changes of coconut water. The findings are expected to support the identification of optimal harvesting stages for specific uses, improved product standardization and enhance the development of value-added of coconut water products in Malaysia and beyond.

1.1. Study Objectives

1) To evaluate the effects of different harvesting stages on the physicochemical characteristics of coconut water from the local MATAG variety.

2) To assess the influence of different harvesting stages on the sugar profiles of coconut water from the local MATAG variety.

3) To determine the effects of different harvesting stages on the nutritional properties of coconut water from the local MATAG variety.

4) To identify the optimum harvesting stage for producing as tender coconut water with desirable quality attributes.

2.0. Materials and Methods

2.1. Study Site and Samples Collection

A total of 32 coconut trees of the MATAG variety were selected from a research plot at Malaysian Agricultural Research and Development Institute (MARDI) Bagan Datuk Research Station, Perak. Tree selection was based on uniformity in physical characteristics including height, canopy architecture, trunk diameter and overall vigor to minimize inter-tree variability and ensure a consistent physiological baseline among experimental units. Selected frond which possessed with one-month aged of pollinated nut or 'button' were using colour-coded paint to identify or indicate different harvesting stages. Coconuts were harvested at three-months intervals, corresponding to the treatment of the study.

Four (4) harvesting stages coconut were defined: T1 (3 month), T2 (6 month), T3 (9 month) and T4 (12) months after pollination each with four (4) replications. These stages represent distinct physiological phases of fruit development, where 3-6-months reflecting the immature stage, 9 months represents the young stage and 12 months indicates full maturity. Harvesting was conducted using a harvesting pole and the total number of harvesting nuts was 128 nuts. All harvested samples were transported to MARDI Serdang for subsequent physicochemical and laboratory analysis.

2.2. Sample Preparation and Data Collection

The harvested coconuts were cleaned and washed with tap water, then labelled according to their respective fruit maturity treatments. The nuts were cut opened and the coconut water was filtered to remove debris and solid particles. The filtered coconut water was collected in clean containers and further subjected to laboratory analysis.

2.2.1. Total Soluble Solid (TSS) and pH

Total soluble solid (TSS) were measured using digital refractometer (ATAGO PAL-1) and expressed in °Brix. A few drops of coconut water were placed onto the prism of refractometer and the readings was recorded. The pH of fresh coconut water was measured using a digital pH meter (HI991001 Waterproof Portable pH Meter). The probe was placed directly into the coconut water samples and the readings were recorded.

2.2.2. Sugar Profiles and Mineral Content (K, Ca, Mg, Na)

A total of 250 ml of coconut water per samples was used to determine the sugar profiling (fructose and glucose), as well as nutritional quality based on mineral composition, including potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg). The samples were sent to MARDI Lab for further analysis of sugar profile and mineral content.

2.2.3. Experimental Design and Data Analysis

Data were subjected to analysis of variance (ANOVA) and mean comparison were performed using Duncan Multiple Range Test (DMRT) at $P<0.05$. Statistical analysis was conducted using the Statistical Analysis System (SAS).

3.0. Results and Discussion

3.1. Physicochemical Properties

Results revealed that different harvesting stages has significantly affected the physicochemical of MATAG coconut water at $P<0.001$ (Table 1). Total soluble solid (TSS) of coconut water significantly influenced by different harvesting stage. TSS in coconut water reached their peak at T3 (9 months), significantly exceeding levels found at all other harvesting periods. The sweetness in the coconut water was the highest at T3 (6.28°Brix) followed by T2(5.15 °Brix), T4 (4.93 °Brix) and T1 (3.55 °Brix). The TSS value peaked at T3 due to sugar accumulation, then slightly declined as these sugars converted into fatty acids for solid endosperm development. Visual observation, the hardening of the endosperm at T3 coincided with a reduction in TSS, as soluble solids were diverted from the coconut water to support kernel formation [4].

pH of coconut water was found to be significantly impacted by the harvesting stage. Statistical analysis revealed that the pH of coconut water at T3 was significantly higher compared to the other maturity stages. The pH of coconut water at T1, T2, T3 and T4 were 5.05, 4.75, 5.54 and 5.29 respectively. Organic acid content was highest during early development causing pH levels were slightly higher and as maturity progressed, the acid concentrations declined. Increased in coconut water pH during maturation is attributed to the utilization of fatty acids in coconut water for the development of solid endosperm [6]. Results indicated progressive reduction in acidity of the coconut water as the fruits approached maturity. According to Daa-Kpode, the pH of the liquid endosperm increased progressively from 3 to 9 months of nut maturity, corresponding to a reduction in acidity during the maturation process [13]. This can be related to the physiological changes of reduction of organic acids content in the coconut water and accumulation of sugars and minerals during the endosperm development. The increase in pH is attributed to the metabolic transformation of organic acids into sugars and structural carbohydrates during endosperm maturation [7]. This finding also aligns with the previous findings which reported that coconut water becomes less acidic as fruit progresses in age due to biochemical transformation in the nuts [8].

Table 1. Physicochemical characteristics of coconut water from MATAG variety affected by different harvesting stages.

Harvesting stage (month)	TSS (°Brix)	pH
T1	3.55^{c}	5.05^{c}
T2	5.15^{b}	4.75^{d}
T3	6.28^{a}	5.54^{a}
T4	4.93^{b}	5.29^{b}
P<0.05	***	***
Note: ns=Not significant, *Significant at *P*<0.05, **Significant at *P*<0.01, *** Significant at *P*<0.001		

3.2. Sugar Profiles

The results of the sugar profile analysis of MATAG coconut water identified only two type sugars namely fructose and glucose. These sugars have been reported previously as the main constituents in young coconut water [9]. The results in Table 2 revealed that both fructose and glucose content was significantly affected by the harvesting time. Fructose content at T3 was significantly higher compared to fructose content at T1 and T4, but was not significantly differed with T2. The highest fructose content was T3 (1.92 %), followed by T2 (1.54 %), T1 (1.33 %) and T4 (1.07 %). Glucose also plays an important role in giving the sweetness taste of the coconut water. Glucose content was significantly affected by different harvesting stage. Glucose content at both T2 and T3 was

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significantly higher compared to glucose content at pre-matured coconut water of T1, but not significantly different with T4. Sugar levels and TSS was fluctuate during maturity, starting with increasing pattern and then declining as it approached maturity [10]. Total sugar content in matured coconut water was observed to be lower than young coconut. However, total sugar content is highly influenced by coconut variety, geographic location, soil type, and seasonal precipitation [5].

Table 2. Sugar profiles of coconut water from MATAG variety influenced by different harvesting stages.

Harvesting stage (month)	Fructose content (%)	Glucose content (%)
T1	1.33^{b}	0.5^{b}
T2	1.54^{ab}	2.45^{a}
T3	1.92^{a}	1.99^{a}
T4	1.07^{b}	1.7^{ab}
$P<0.05$	*	*
Note: ns=Not significant, *Significant at $P<0.05$, **Significant at $P<0.01$, *** Significant at $P<0.001$		

3.3. Nutritional Properties

Based on the Table 3, there was no significant difference on potassium content at different harvesting stage of coconut. Across the stages T1-T4, the potassium content values were 276.39 %, 206.24 %, 209.20 % and 248.02 % respectively. Different harvesting stages does not impact on the potassium content in the coconut water of MATAG variety. Beyond the variations in palatability and sensory profiles of coconut water across different harvesting stages, these findings demonstrate that the consumption of both young and mature coconut water consistently provides an optimum supply of potassium for physiological requirements. It acts as an effective rehydration drink as the basic ion composition in the coconut water such as sodium, potassium, calcium and magnesium are able to replenish the electrolytes in the human body through [11]. Potash is the principal inorganic constituent of coconut water, and potassium constitutes more than half of the mineral content, with its concentration strongly influenced by potash manuring [12].

Sodium content in MATAG coconut water increased significantly over time. T4 has a significantly higher sodium content compared to T1 and T2, but no significant different with T3. The steady rise in sodium content towards T4, indicates cumulative absorption process in the nuts and possibly linked with the development of endosperm. It contributed to the overall osmolarity which helps the coconut water act as natural isotonic beverage. Sodium is an ion that is working with potassium to regulate hydration, support helps to regulate the osmotic in body.

As for calcium content, the result obtained significantly affected by harvesting stage. A significant decline in calcium levels was observed as the nuts matured, with T1 coconut water containing 78.70% more calcium than that of T4. Calcium content was decreased as the nuts matured as it focusing on developing tissues and to strengthen the cell walls. Coconut water functions as a nutrient reservoir, supplying essential minerals and metabolites required for cell division and growth during kernel formation.

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Similar pattern also showed in magnesium content of coconut water, where harvesting stage showed significantly reduced in magnesium content along the stages of coconut development. T1 obtained significantly higher content of magnesium in coconut water than the other stages of harvesting. The reduction of magnesium content from T1 to T2 was 49.27%. Concurrently, it was not statistically significant in magnesium content at the age of T2 until T4, even though the maturity of coconut progressed. Changes in magnesium concentrations may correspond to metabolic shifts associated with endosperm solidification. Overall, the mineral composition of coconut water, particularly sodium, magnesium, and calcium, changes with coconut maturity due to progressive endosperm development and nutrient redistribution during fruit growth.

Table 3. Nutritional properties of coconut water from MATAG variety affected by different harvesting stages.

Harvesting stage (month)	K content (mg/100g)	Na content (mg/100g)	Ca content (mg/100g)	Mg content (mg/100g)
T1	276.39^{a}	3.67^{c}	38.51^{a}	20.64^{a}
T2	206.24^{a}	5.44^{bc}	25.75^{b}	10.71^{b}
T3	209.20^{a}	10.79^{ab}	18.53^{b}	9.82^{b}
T4	248.02^{a}	15.15^{a}	21.55^{b}	10.47^{b}
P<0.05	Ns	**	***	***
Note: ns=Not significant, *Significant at P<0.05, **Significant at P<0.01, *** Significant at P<0.001				

4.0. Conclusion and Future Recommendations

These findings of local MATAG coconut water indicate that the harvesting stage significantly impacted the physicochemical and nutritional composition. Based on the results of this study, the optimum harvesting stage appears to be at 9 months of maturity, at which point the total soluble solids (TSS), pH, and sugar profile of the coconut water are suitable for fresh consumption and potential value-added beverage processing. This maturity stage ensures an optimal balance of sweetness and acidity, crucial for consumer preference and product stability. Furthermore, the enhanced nutritional profile at this stage supports its utility in functional food applications.

Based on the findings of this study, the following recommendations for future research are proposed to further establish and strengthen a comprehensive quality framework for coconut production and quality assessment:

1) Comparative studies among coconut varieties.

2) Environmental and seasonal effects on quality attributes on coconut water.

3) Integrated coconut water and kernel quality assessment.

4) Investigate the relationship between fruit yield, bunch load, and coconut water quality at different maturity stages.

5) Relationship between fruit development and nutrient uptake.

6) Predictive model for harvesting stage determination.

Declaration

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Competing Interest Statement

The author has declared that no competing financial, professional or personal interest exist.

Consent for Publication

All the authors contributed to the manuscript and consented to the publication of this research work.

Informed Consent

Not Applicable.

Availability of Data and Material

Supplementary of information is available from the authors upon reasonable request.

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Ethical Approval

Not Applicable.

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Declaration of Artificial Intelligence

Artificial intelligence (AI) tools were used to improve the language, grammar, and readability of the manuscript. The authors independently conducted all research activities, data analyses, interpretations, and conclusions and assume full responsibility for the content presented.

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