

RESEARCH ARTICLE

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Study on compositional changes of king coconut (*Cocos nucifera* var. *aurantiaca*) water and kernel during maturation and evaluation of optimum quality characteristics targeting commercial applications

MD Jayasinghe*, MMNP Gunasekara, MGDS Perera, KDSM Karunarathna, GU Chandrasiri and IGN Hewajulige

Industrial Technology Institute (ITI), 363, Bauddhaloka Mawatha, Colombo 07, Sri Lanka.

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Abstract: King coconut (*Cocos nucifera* var. *aurantiaca*) is a tropical nut with notable nutritional and medicinal values. King coconut water (KCW) and king coconut kernel (KCK) are sweet and refreshing. They undergo several changes during maturation. The objective of this study was to assess the physico-chemical changes of KCW and KCK with maturity. Three different maturity stages (6, 7, and 8 months) of the variety *aurantica*, known locally as 'Nawasi Thembili' were studied for several physico-chemical parameters. Whole nut weight (g), nut-circumference (cm), colour (water/kernel) (*L), nut-water volume (mL), kernel weight (g), and kernel thickness (mm) were assessed as physical parameters, while pH, total soluble solids (°Brix), titratable acidity (as % ascorbic acid), total sugars (g/100g; g/100mL), and minerals (mg/L; mg/kg) were analysed as chemical attributes. Sugars were estimated using Agilent 1260 HPLC and ICP-MS was used to measure the mineral profile. Results revealed that all the tested physical parameters of KCW and KCK increased significantly ($p < 0.05$) with maturity. The pH, TSS, total sugars, and acidity of KCW increased significantly ($p < 0.05$), while mineral content decreased significantly ($p < 0.05$) with maturity. However, the TSS and minerals of KCK decreased significantly ($p < 0.05$) with maturity and a higher sucrose content was reported in KCK compared to KCW at later maturity. The Ca^{+2} and Mg^{+2} were prominent in both KCW and KCK. The study concluded that the physico-chemical characteristics varied widely with the maturity of king coconuts. The selection of optimum harvest maturity to match the preferred attributes of intended applications is suggested.

Keywords: Harvest maturity, kernel, king coconut water, physico-chemical changes.

INTRODUCTION

King coconut (*Cocos nucifera* var. *aurantiaca*) is a tropical nut that belongs to the Family Arecaceae. It is endemic to Sri Lanka with unique flavour characteristics compared to green coconut. King coconut cultivation in Sri Lanka has been estimated as 2.20 million palms (Department of Census and Statistics, 2005), and has contributed Rs. 600 Mn of foreign exchange in 2020 (CDA, 2020). The nut consists of four distinct parts; exocarp (outermost skin), mesocarp (middle fibrous part), endocarp (hard-shell), and endosperm (water and kernel), where the endosperm is extensively used in industrial applications (Prades *et al.*, 2012a). The nut develops through the nuclear, cellular, and helobial stages; the endosperm is developed at the nuclear stage, while the embryo cavity is liquid-filled by the 'Cellularization Process' (Lopes & Larkins, 1993). Several compositional changes take place within the nut during maturation with distinct quality attributes at each harvesting stage (Yong *et al.*, 2009).

The king coconut water (liquid endosperm) and kernel are considered as the main edible parts, which possess a high economic value. King coconut water is a popular functional beverage with nutritional properties such as moderate concentrations of sugars, vitamins, minerals, and amino acids with therapeutic values (DebMandal & Mandal, 2011). The kernel is a delicate spongy material, which offers versatile market potential arising from claims on antioxidants and plant growth hormonal properties. However, it is evident that king coconut kernel is underutilized while king coconut water is extensively used for commercial scale productions such as bottled/packed king coconut water mainly for the export market (Perera *et al.*, 2015). Therefore, king coconut

* Corresponding author (maheshika@iti.lk.com;  <https://orcid.org/0000-0003-1162-6132>)



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kernel needs attention to identify potential opportunities for further commercialization (Kalina & Navaratne, 2018).

In terms of distribution, king coconut palms are mainly concentrated in the Gampaha, Kalutara, Kurunegala, and Galle districts, commonly in home gardens. King coconuts are mainly characterized by the orange-coloured pericarp compared with green coconuts. The major king coconut varieties are categorized as 'Typica' known locally as (*Ran Thembili*, *Gon Thembili*) and 'Aurantiaca' known locally as (*Nawasi Thembili*, *Rathran Thembili*, *Bothal Thembili*). The Aurantiaca varieties have been widely utilized as a beverage due to its higher nut water yield and sweet taste (Perera et al., 2014). '*Nawasi Thembili*' is the commonly grown king coconut variety in Sri Lanka and the availability of '*Rathran Thembili*' (characteristic pink coloured epicarp) and '*Bothal Thembili*' (bottle shaped nuts) are comparatively low (Ekanayake et al., 2010). Therefore, '*Nawasi Thembili*' is widely used for commercial scale productions due to its higher availability along with optimum quality characteristics (Perera et al., 2015).

A wide range of commercial applications such as fresh nut exports, bottled king coconut water, and kernel-incorporated functional beverages and confectionaries have raised a critical requirement of evaluating optimum quality characteristics of king coconuts based on maturity (EDB, 2019). It is demanded by the local industrialists with the aim of marketing the 'authentic' taste of Sri Lankan king coconuts as well as maintaining their product consistency within batches. Therefore, it is important to study the exact patterns of variations with maturity and to match optimum quality characteristics of edible king coconut components compatible with intended uses. Since, very limited research data is available on the nutritional and functional properties of king coconut water and kernel, it is vital to conduct comprehensive scientific research studies, for a better understanding. Therefore, this research study aimed to evaluate the compositional changes of king coconut water and kernel in relation to maturity as an effective approach to identify the optimum harvesting stage for specific industrial applications.

MATERIALS AND METHODS

Sample collection and preparation

A total of 60 nuts (n=20, 5 palms) were harvested of the variety '*Nawasi Thembili*' from a commercial king coconut cultivation in the Western Province, Sri Lanka at three maturity stages (6, 7, and 8 months after nut set) based on the 'Leaf Counting Method' recommended by the Coconut Research Institute (CRI), Sri Lanka. The three specific maturity stages were selected targeting industrial applications based on the preliminary research data and the 'Maturity Charts' developed by the Industrial Technology Institute (ITI), Sri Lanka. Based on the CRI guidelines, the 7 months old bunch was selected at the 14th leaf counted from the uppermost tender leaf of the tree, and bunches of 6 months and 8 months maturity were selected as bunches at the 13th leaf and 15th leaf, respectively (Ranasinghe & Wimalasekara, 2002). Bunches were immediately transported to the post-harvest technology laboratory of the ITI, Sri Lanka.

Each nut was split using a curved knife, in the laboratory to remove the king coconut water. The water was filtered through a muslin cloth into a clean plastic container. The soft, spongy coconut kernel was scooped out using a spoon from the nutshell avoiding excessive scraping. The mature kernel was cut into small pieces using a sharp stainless-steel knife and ground using mortar and pestle. The king coconut water and kernel samples at each maturity stage were composited separately into sealed containers, and stored at 4 ± 0.1 °C for further analysis.

Physico-chemical analyses

Physical parameters

Whole nut circumference, whole nut weight, nut water volume, kernel weight, kernel thickness, colour of king coconut water, and kernel were measured as physical parameters. The whole nut circumference was measured at the maximum girth of the individual nut using a measuring tape and all weights and water volumes were measured using a calibrated top loading balance and measuring cylinder, respectively. The thickness of the kernel was measured using a digital vernier caliper (MITUTOYO, 500-197-20, Japan). Colour was measured using the CIE Lab Space method (KONICA MINOLTA CR-410, Japan) and expressed as Lightness (*L value) (Brainard,

2003). As chemical parameters, pH was measured using a calibrated pH meter (EUTECH pH 510 Model, USA) at 25 °C, and TSS was measured using a hand-held refractometer (Atago, S-28, Japan). The pH of king coconut kernels was measured with a solution of 10 g of sample blended with 50 mL of distilled water. The TSS content was measured via extracting the juice out of the kernel by pressing using a cotton wool/cloth. Titratable acidity of the king coconut kernel estimated by the standard method using 0.1M NaOH with phenolphthalein indicator (ISO 750:998).

Analyses of total sugar content

Total sugar content was measured according to a modified method of ISO 10504 (2013); ‘Starch derivatives - Determination of the composition of glucose syrups, fructose syrups and hydrogenated glucose syrups’ using HPLC chromatographic system equipped with quaternary gradient pump and Refractive Index Detector (Agilent 1260 Infinity, USA). In this study, Hydrogen (H⁺) based cation exchange HPLC column was used as the modification, instead of using Calcium (Ca²⁺) column as depicted in the standard. The modified method was optimized by an in-house accredited laboratory at ITI, Sri Lanka, and validated for linearity, sensitivity, and selectivity parameters. Chromatographic separation was achieved on an analytical column/stationary phase (7.8 mm × 300 mm, 5 µm) (Phenomenex, Rezex ROA Organic Acid H⁺ 8%, USA), and a guard column (4.6 mm × 12.5 mm, 5 µm) (Phenomenex, Rezex, USA). The mobile phase was 0.005N H₂SO₄ with a flow rate of 0.4 mL/min for the analysis. Samples were micro-filtered (0.45 µm) and a volume of 10.0 µL was injected into an auto-sampler with a total run time of 30 min.

Analytical grade reagents (≥ 99% purity) of glucose, fructose, and sucrose (Sigma Aldrich, USA) were used to prepare the standard sugar solutions to generate a multi-point calibration curve for the quantification of sugars in the sample. Peaks were identified as Retention Time (R_T), as shown by the respective peaks of standard sugar solutions and quantified as area under the curve using a programmed software (OpenLab CDS, ChemStation Edition C.01.09) coupled with HPLC. The total sugar content of king coconut water and kernel was expressed as g/100 mL and g/100g on wet basis, respectively.

Analyses of mineral content

The mineral content (K⁺, Na⁺, Mg⁺², Ca⁺², and Fe⁺²) was measured using an Inductively Coupled Plasma Mass Spectrometer (ICP-MS) (Agilent 7900, Japan) based on the method described in Marasinghe *et al.* (2019). Approximately 10 mL of king coconut water and 1 g of king coconut kernel were digested separately at 180 °C for 30 min, using a microwave digester (MAS 5, CEM, USA) with added 10 mL of ultra-pure > 69% nitric acid. Digested king coconut water and kernel were filtered using Whatman No. 542 filter paper and diluted using deionized water up to 25 mL and 50 mL, respectively prior to mineral analysis. Mineral concentrations of digested and blank samples were analysed under standard operating conditions of ICP-MS.

Proximate analyses

King coconuts at 7 months of maturity, were used for proximate analysis covering both king coconut water and kernel according to standard AOAC analytical methods as follows. Moisture AOAC 2012 (934.01), Crude Protein AOAC 2012 (2001.11), Crude Fat AOAC 2012 (2003.05), Total Ash AOAC 2012 (942.05), Crude Fiber: AOAC 2012 (978.10). All reagents were analytical grade chemicals (Sigma Aldrich, USA).

Sensory analyses

The king coconut water and kernel samples at three different maturities were tested for quality attributes comprised of colour, flavour, taste (sweetness), texture (softness), and overall acceptance. Ten trained panellists from the ITI, Sri Lanka, scored the samples using a 7-point hedonic scale (1- Strongly Dislike, 7- Strongly Like) based on their preference (Gunathilake, 2012).

Statistical analysis

The experiment was conducted as a complete randomized design and the data were analysed at a 95% confidence interval using one-way ANOVA. The mean comparison was done by Tukey's family error rate test using SPSS 10 statistical package. The mean and standard deviations of data were calculated using EXCEL 2010.

RESULTS AND DISCUSSION

Physical parameters of whole king coconut

The general appearance of the whole nut and the pared nuts at each tested maturity stage of the variety '*Nawasi Thembili*' are given in Figure 1. The outer pericarp of the selected king coconuts was observed as bright orange in colour and poor kernel development was observed at the 6-month maturity stage.



Figure 1: The appearance of king coconut (whole nut) and pared nut at different maturity stages

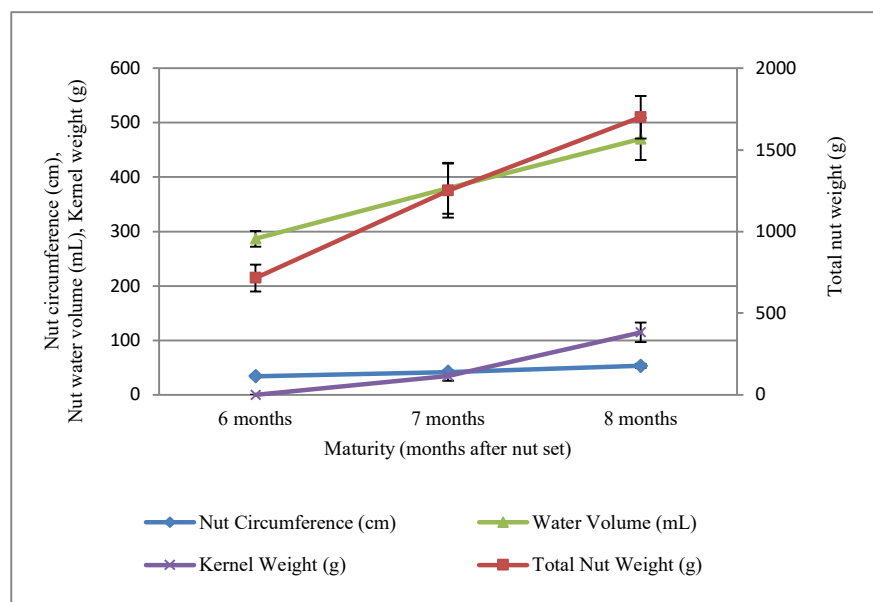


Figure 2: Changes in physical parameters of king coconuts (whole nut) at different maturity stages

As given in Figure 2, total nut weight, kernel weight, nut water volume, and the nut circumference of the whole nut increased significantly ($p < 0.05$) with maturity. The kernel thickness at the 7 month maturity was 2.97 ± 0.21 mm; this increased significantly ($p < 0.05$) to 5.34 ± 0.13 mm at the 8 month stage of maturity. The kernel at 7 month maturity was soft/smooth and became thick/hard at 8 month of maturity. The colour (*L) of king coconut water decreased significantly ($p < 0.05$) as 18.23 ± 0.07 , 18.08 ± 0.09 and 17.72 ± 0.07 at the stages of 6, 7, and

8 months of maturity, respectively. A significant turbidity development was observed at the 8 months of maturity in king coconut water. The colour (*L) of king coconut kernel increased significantly ($p < 0.05$) with maturity. The lightness value (*L) of the kernel varied from 51.86 ± 2.34 at 7 months of maturity to 75.20 ± 2.28 at 8 months of maturity.

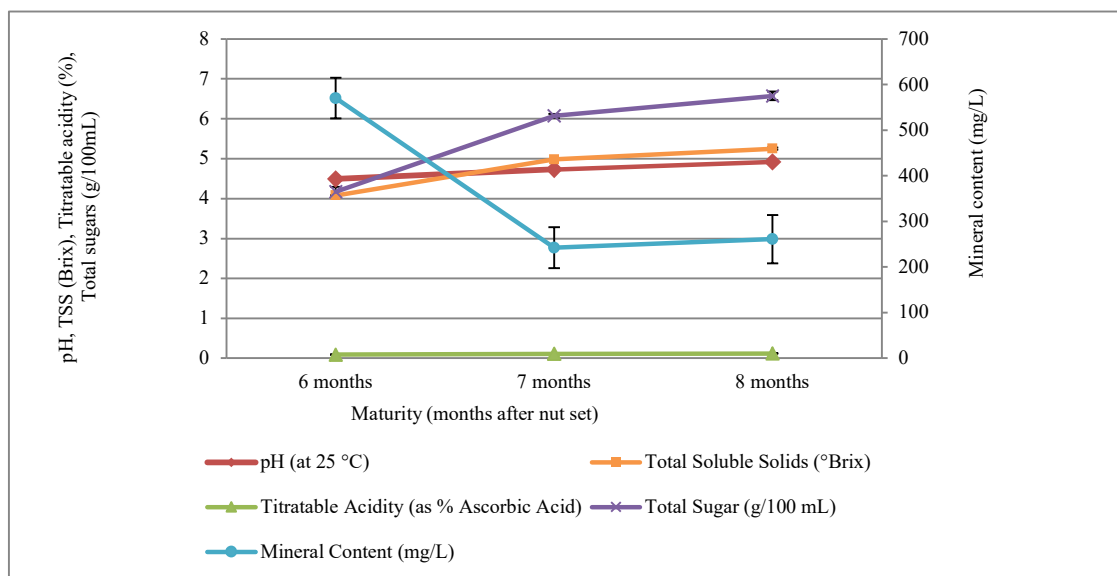


Figure 3: Changes in physico-chemical parameters of king coconut water at different maturity stages

The kernel weight was the highest at the 8 months maturity after fruit set; this is further supported by the significant increase ($p < 0.05$) in total nut weight from 7 to 8 months of maturity. The mean nut water volume at 6, 7, and 8 month stages of maturity varied as 287 ± 15 mL, 380 ± 47 mL, and 470 ± 39 mL, respectively; the nut water volume increased in a decreasing pattern along with a gradual increase of kernel development towards the later maturity stages. The nut circumference increased significantly ($p < 0.05$) as 34.2 ± 1.7 cm, 41.5 ± 2.7 cm, and 53.1 ± 3.8 cm at 6, 7 and 8 months of maturity, respectively. The chemical parameters of king coconut water and the kernel are given in Figure 3 and Figure 4, respectively.

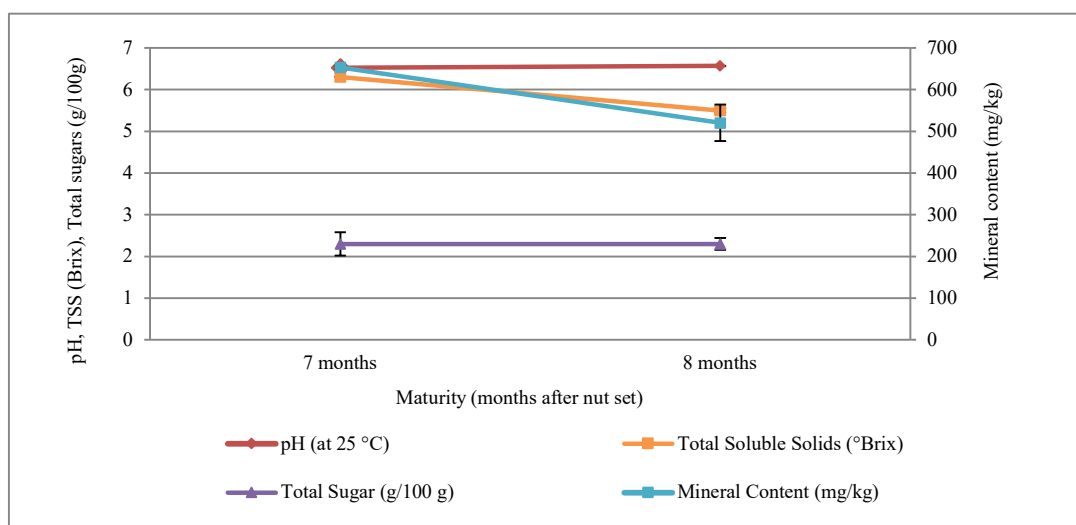


Figure 4: Changes in physico-chemical parameters of king coconut kernel at different maturity stages

According to statistical analysis, all the tested physico-chemical parameters of king coconut water were significantly varied ($p < 0.05$) with maturity, where pH, TSS, total sugars, and acidity increased significantly ($p < 0.05$) with maturity. However, mineral content and the TSS of the kernel decreased significantly ($p < 0.05$) during maturation, while changes in pH and total sugars were non-significant. Several researchers have found interesting relationships and patterns of physico-chemical variations (Tan *et al.*, 2014; Kannangara *et al.*, 2018) in king coconut water and kernel with maturity, similar to the findings reported in this study.

The low kernel content at 6 months of maturity and the gradual development at the of 7–8 months of maturity is in agreement with by Janick and Paull (2008), who reported that the king coconut shell initially contains clear sweet liquid and the tender young kernel begins to develop as a thin layer inside the endocarp/shell at the stage of 5 months of maturity. Furthermore, Jackson *et al.* (2004) and Chikkasubbanna *et al.* (1990) reported that the liquid endosperm exerts pressure inside the nut during maturation due to increased water holding capacity with the initiation of kernel development, and is partially replaced by the kernel to release the excess pressure.

Changes in total sugars

Total sugars play a vital role in the quality and sensory attributes of king coconut water and kernel, which directly affects its marketability. According to Figure 5, glucose and fructose were the most prominent sugar types present in immature king coconut water, and found to increase significantly ($p < 0.05$) during 7–8 months of maturity. HPLC peaks for trace sugars were not observed in the chromatograms in this study. However, the presence of trace sugars may not be detected in the present study due to low sensitivity. Therefore, it is suggested to follow LC-MS technology with enhanced sensitivity for better identification of trace sugars. Later initiation of sucrose at 8 months of maturity may influence the sweet taste of king coconut water. In contrast, king coconut kernel has shown a significant increase ($p < 0.05$) in sucrose compared to glucose and fructose throughout maturation. Therefore, young king coconut water at 7–8 months of maturity could be considered as a good source of invert sugars (glucose and fructose), while the mature kernel is rich in sucrose. The present work has shown that the sweet taste in both king coconut water and kernel could be achieved at 7 months of maturity.

The detection of individual sugar forms seems to be effective in selecting the optimum harvesting stage as given in Figure 5. However, the Aurantiaca (intermediate) varieties have shown the highest sugar contents of 5–7 % with a sweet taste for water and kernel, according to other research findings, (Kwiatkowski *et al.*, 2008). Therefore, it is important to select an intermediate maturity level of 7 months for optimum sweetness in king coconut water when it is used as a beverage, and the 7–8 months of maturity would be optimum when utilizing king coconut kernel for industrial uses such as kernel incorporated functional beverages, chewing confectionaries, table desserts, fruit leathers, and snacks.

Several research studies have shown that reducing sugars (glucose and fructose) predominate in young coconuts, and the mature kernel is rich in non-reducing sugars mainly as sucrose (Jackson *et al.*, 2004; Appaiah *et al.*, 2015). Furthermore, it was reported that the glucose and fructose concentrations steadily increase with the maturation of king coconut water and starts to decline with the increase of sucrose at later mature stages (Halim *et al.*, 2018).

The total sugars in king coconut water fluctuated, starting from a value of 4.18 ± 0.12 g/100 mL and increased gradually to 6.08 ± 0.05 g/100 mL, and 6.58 ± 0.11 g/100 mL at 7–8 months of maturity (Figure 5), followed by a value of 5.86 ± 0.14 g/100 mL, which is a decreasing pattern at later maturity (*unpublished data*). In contrast, the increasing pattern of total sugars in coconut kernel can be seen and lately dominated by proteins and lipids. The basic ion composition of king coconut water warrants its utilization as a rehydration beverage. It could serve as a source of electrolytes and for numerous biological applications as an essential component in studying cellular function, enzyme activation, gene expression, and metabolism of amino acids, lipids, and carbohydrates (Radenahmad *et al.*, 2009).

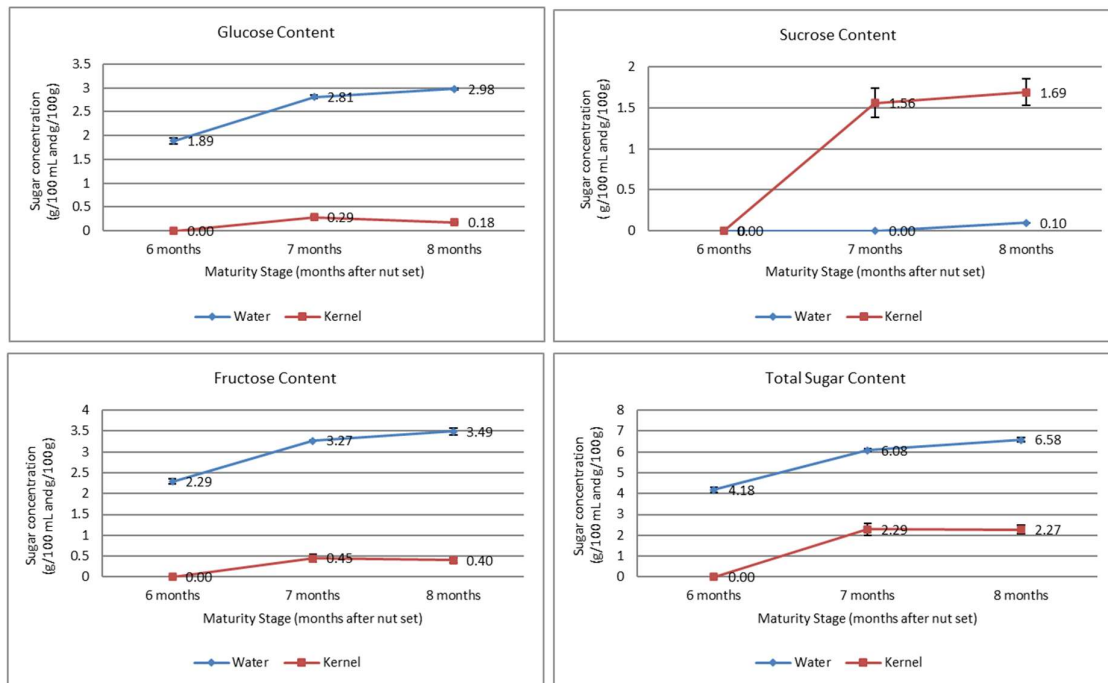


Figure 5: Changes in sugar contents of king coconut water and king coconut kernel at different maturity stages

Changes in mineral content

The total mineral content of king coconut water significantly decreased ($p < 0.05$) during 6 to 8 months period of maturity (Table 1). However, the total mineral content of king coconut kernel was significantly higher ($p < 0.05$) compared to the value of king coconut water at 8 months of maturity. According to Table 1, a recognizable movement of minerals from king coconut water to the kernel occurs with maturity. It appears that minerals in king coconut water might have been deposited in the kernel during maturation. However, total mineral content in the whole nut has significantly increased ($p < 0.05$) up to 7 months of maturity and significantly decreased ($p < 0.05$) at the stage of 8 months of maturity.

Table 1: Changes in mineral content of king coconut water and kernel with maturity

Minerals (mg/L; mg/kg)	6 Months		7 Months		8 Months	
	Water	Kernel	Water	Kernel	Water	Kernel
K ⁺	0.30 ± 0.00 ^a	n/d	0.25 ± 0.07 ^a	0.35 ± 0.07 ^A	0.25 ± 0.07 ^a	0.35 ± 0.07 ^A
Na ⁺	13.8 ± 2.55 ^a	n/d	13.00 ± 1.98 ^a	49.5 ± 2.69 ^A	10.2 ± 3.11 ^a	58.3 ± 6.93 ^A
Mg ⁺²	93.2 ± 9.62 ^a	n/d	45.5 ± 8.34 ^b	347.5 ± 9.19 ^A	45.4 ± 6.79 ^b	353.0 ± 42.43 ^A
Ca ⁺²	463 ± 32.53 ^a	n/d	183.5 ± 34.65 ^b	256 ± 2.83 ^A	205 ± 49.5 ^b	105 ± 5.66 ^B
Fe ⁺²	0.05 ± 0.00 ^a	n/d	0.05 ± 0.001 ^a	0.05 ± 0.01 ^B	0.05 ± 0.00 ^a	3.5 ± 2.55 ^A
Total	570.35 ± 45.35 ^b	n/d	242.30 ± 38.11 ^a	653.40 ± 11.42 ^A	260.9 ± 44.23 ^a	520.15 ± 44.8 ^B
Whole Nut	570.35 ± 45.35 ^c		895.70 ± 33.35 ^a		781.05 ± 3.89 ^b	

[†] Data is expressed as mean ± SD, n=20. The n/d refers to 'not detected' since no kernel development was observed at 6 months of maturity. The significance ($p < 0.05$) between maturity levels are denoted by lower- and upper-case letters within a row for king coconut water and kernel, respectively.

As shown in Table 1, Ca⁺² is the most prominent mineral followed by Mg⁺² in king coconut water, while Mg⁺² is the highly prominent mineral in the kernel. However, Fe⁺² and K⁺ were also detected in trace amounts in

the nut water and kernel. King coconut water and kernel can be considered as good sources of Ca^{+2} , Mg^{+2} , and Na^{+} . Furthermore, it is evident that the total mineral content in the average nut water volume varied as 163.40 ± 13.51 mg, 91.95 ± 18.56 mg, and 122.62 ± 14.21 mg for the 6, 7, and 8 months of maturity, respectively. Moreover, total mineral content in an average weight of kernel varied as 22.61 ± 8.56 mg and 59.60 ± 6.45 mg at 7 and 8 months of maturity, respectively. This result confirms the pattern of deposition of chemical constituents from nut water to kernel with maturity. Overall, results indicated that all the tested physico-chemical parameters varied significantly between king coconut water and kernel with the stage of maturity. Although the present study has focused mainly on the presence of electrolytes (Na^{+} , Ca^{+2} , and Mg^{+2} , K^{+} and Fe^{+2}), it is evident from the reviewed literature that coconut water contains a variety of inorganic ions such as chlorides (Cl^{-}), phosphates (PO_4^{-3}), and sulfates (SO_4^{-2}) (Richter *et al.*, 2005).

The majority of studies have shown that K^{+} is the predominant mineral followed by Na^{+} , Ca^{+2} , and Mg^{+2} in king coconut water (Gunathilake, 2012; Marapana *et al.*, 2017). In contrast, the present study indicates that Ca^{+2} and Mg^{+2} as the minerals occurring in the highest concentrations in king coconut water and the kernel, respectively. Several research studies reported different values for mineral concentrations present in king coconut water as shown in Table 2. It has been discussed that minerals present in king coconut water may depend on various factors such as, variety, soil properties, cultivation practices, fertilizer, and manure applications in king coconut palm orchards (Prades *et al.*, 2012b).

Table 2: Mineral concentrations present in king coconut water reported by different authors

Na^{+} (mg/L)	K^{+} (mg/L)	Mg^{+2} (mg/L)	Ca^{+2} (mg/L)	Fe^{+2} (mg/L)	Cl^{-} (mg/L)	References
87 ± 4.9	214 ± 26.2	42 ± 3.1	100 ± 4.2	–	–	Gunathilake, 2012
–	1900–2500	45–55	100–200	–	1200–600	Marapana <i>et al.</i> , 2017
105	312	30	29	0.14	183	Jayasinghe & Bandaranayake, 2005
105	250	–	–	–	–	Athauda <i>et al.</i> , 2015

Note: – not reported (data are not available or not given in the research article)

Selection of optimum harvest maturity for intended applications

The physico-chemical attributes of king coconut water and kernel, for different maturity stages, are given in Table 3, based on the local and international coconut standards (FAO, 2003; 2005) and data available in the literature (Burns *et al.*, 2020). This can help to identify the optimum maturity or harvesting stages of king coconut for any intended use or application. Since the present study has proven that there is a recognizable impact of maturity on physico-chemical attributes of king coconut water and kernel, it is advisable to match the best harvest maturity with the desired characteristics to experience a prime quality.

Table 3: Optimum harvesting stages of king coconut for the use of different applications

Application	Critical parameters	Optimum harvest maturity	References
Water based:			
Fresh nut exports	pH, TSS, Sugars	7 months	Ranasinghe & Wimalasekara, 2002
Saline water	Minerals (Na^{+} , K^{+} , Ca^{+2} , Mg^{+2})	6 months	Athauda <i>et al.</i> , 2015; Kailaku <i>et al.</i> , 2015; Kalina & Navaratne, 2018
Functional drink	Sugars (Sucrose)	7 months	Gunathilake, 2012; Marapana <i>et al.</i> , 2017; Segura-Badilla <i>et al.</i> , 2020
Culture media	pH, TSS, Sugars, Minerals	8 months	Baque <i>et al.</i> , 2011; Tharmila <i>et al.</i> , 2011; Naik <i>et al.</i> , 2020
Kernel-based:			
Source of antioxidants	pH, TSS, Sugars, Minerals	8 months	Kalina & Navaratne, 2019
Ready to eat desserts	Sugars	7 months	Kalina & Navaratne, 2018
Functional foods	pH, TSS, Sugars	8 months	Solangi & Iqbal, 2011

[†] Maturity is given as time in months after nut set or pollination

The sensory results of king coconut water and kernel at the maturity of stage 7 months was ranked with the highest score compared to other stages of maturity [Figures 6(a) and 6(b)]. Therefore, 7 months of maturity was selected

as the optimum stage with desired quality characteristics. As a result of the highest consumer preference for king coconut water and kernel at 7 months maturity, the study was further extended for the estimation of proximate composition for a better understanding of its nutritional values.

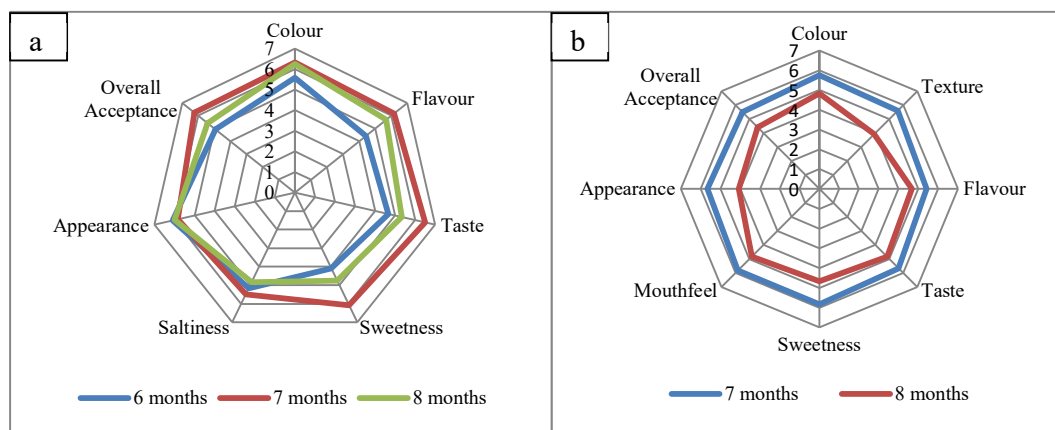


Figure 6: Sensory properties at different maturity stages of (a) king coconut water, and (b) king coconut kernel

This study was further extended to investigate the proximate/nutritional properties and physico-chemical attributes of the variety ‘*Nawasi Thembili*’ at 7 months of maturity (Table 4), which is the preferred maturity for consumption. The physico-chemical characteristics of king coconut water and kernel are highly dependent on variety, agronomic practices, and climatic conditions (Solanghi *et al.*, 2011). Total soluble solids present in king coconut water, which is mainly considered as sugars, were reported as increasing up to 7 - 8 months of maturity, and subsequently decreased in mature nuts with the formation of sucrose (Pue *et al.*, 1992; Richter *et al.*, 2005). This finding was evident by the absence of sucrose at the initial stages and the presence at 8 months of maturity in the present study.

According to Prades *et al.* (2012a), the maturity stage of 6 -7 months was identified as the most frequently used and most palatable stage when used as a beverage. Furthermore, varieties with high sugar contents could be selected depending on the preferred use as fermentation, concentrated juices, etc. Though the pH, TSS, and sugar content are known to be the most influencing parameters on organoleptic properties of king coconut water, it was proven that minerals, volatiles (aromatic), polyols (small peptides) play a vital role in preserving the characteristic flavour and sensory attributes of king coconut water (Prades *et al.*, 2012a).

Though king coconut water is more often cited in the literature, very limited research studies are available on king coconut kernel. King coconut kernel has been identified as a valuable source for several applications as reported by Arditti *et al.* (2008), and kernel extracts could be used in the orchid tissue culture process as an effective source of seed germination. Furthermore, it was reported that the kernel is a good source of antioxidants, oil, purine substances, and plant growth hormones with several nutraceutical properties (Zakaria *et al.*, 2006).

The present research work indicated that the physico-chemical composition of king coconut water and kernel widely varies with maturity and the specific applications derived from king coconut water and kernel should be matched with the precise stage of maturity with the most preferred attributes. However, the composition of king coconut is highly liable to be changed by a wide array of factors, such as selection of variety and cultivar, the effect of agronomy, climatic condition, and cultivation area; these should be thoroughly considered when focusing on optimal utilization.

Table 4: The nutritional and chemical composition of king coconut water and kernel

Nutritional and chemical parameters	King coconut water	King coconut kernel
Proximate composition (wet basis):		
Water (%)	94.46 ± 0.11	89.59 ± 0.34
Carbohydrates (%)	4.95 ± 0.14	6.60 ± 1.19
Protein (%)	0.08 ± 0.01	0.43 ± 0.09
Fat (%)	0.03 ± 0.01	1.80 ± 0.09
Crude fibre (%)	0.02 ± 0.01	0.46 ± 0.06
Ash (%)	0.44 ± 0.03	0.62 ± 0.03
Physico-chemical attributes:		
pH (at 25 °C)	4.73 ± 0.07	6.53 ± 0.13
TSS (Brix)	5.0 ± 0.1	6.3 ± 0.2
Total sugars (% wet basis)		
Glucose	2.81 ± 0.04	0.30 ± 0.01
Fructose	3.27 ± 0.01	0.45 ± 0.01
Sucrose	n/d*	1.56 ± 0.02
Acidity (%)	0.106 ± 0.004	-
Mineral content (mg/L; mg/kg)		
Na ⁺	13.0 ± 1.98	49.5 ± 2.69
K ⁺	0.25 ± 0.07	0.35 ± 0.07
Ca ⁺²	183.5 ± 34.65	256 ± 2.83
Mg ⁺²	45.5 ± 8.34	347.5 ± 9.19
Fe ⁺²	0.05 ± 0.001	0.05 ± 0.001

* Data is expressed as mean ± SD, n=20, proximate composition and physico-chemical properties of king coconut variety 'Nawasi' at 7-month maturity is given; acidity is expressed as % of ascorbic acid; n/d* is 'not detected'

CONCLUSION

The study concluded that king coconut water at 6 months of maturity is optimum when used as isotonic beverages with the highest electrolyte concentration. King coconut water at 7 months of maturity is optimal when used as 'fresh nut exports' as well as when sold in local retail markets with the highest sweetness. King coconut kernel at the stage of 7 months of maturity is best for use as ready-to-eat dishes/desserts with a smooth soft texture. Kernel at the stage of 8 months of maturity is optimum to produce kernel-based functional beverages and confectionaries with a hard texture and higher sugar content. Therefore, it is advisable to select the optimum harvest maturity compatible with intended applications for better utilization and satisfaction.

Conflict of interest statement

The authors declare that there are no conflicts of interest regarding the publication of this work.

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