Physico-chemical characteristics and stability aspects of coconut water and kernel at different stages of maturity

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Abstract Coconut water and kernel are the edible portions of the coconut. A study was carried out to evaluate the physico-chemical characteristics, phytonutrients and stability of coconut water (CW), kernel (CK) at different stages of maturity and commercial coconut products (CCP). The moisture content of CW, CK and CCP were in the range of 95–97 g 100 g⁻¹, 50–85 g 100 g⁻¹ and 0.4–3 g 100 g⁻¹ respectively. Fat content in CW was low (4–115 mg 100 g⁻¹) whereas in kernel it was high (37–56 g 100 g⁻¹). The CW was acidic in nature (pH 4.5–5.2). Ash content of CK decreased with maturity (1.0–1.5 %) whereas that of CW remained steady (0.3–0.4 g 100 g⁻¹) with maturity. The total sugar content (3.9–4.6 g 100 g⁻¹) and acidity (0.3–0.4 g 100 g⁻¹) of CW did not change with maturity. The phenolics content increased in water (1.4–4.3 mg 100 g⁻¹) and kernel with maturity (18.5–24.8 mg 100 g⁻¹). The fatty acid composition of the oil extracted from the CK had increased saturated fatty acids (C_{12:0}) (38–48 g 100 g⁻¹) and decreased monounsaturated fatty acid (C_{18:1}) (13–5 g 100 g⁻¹) with maturity. The percentage of medium chain fatty acids increased with different stages of maturity (47–78 g 100 g⁻¹). The CW and CK contained higher amount of phenolics (1.4–4.3 mg 100 g⁻¹ and 18.5–24.8 mg 100 g⁻¹ respectively) and total tocopherols of CK (0.14–0.59 mg 100 g⁻¹) when compared to CCP. This study indicated that CW and CK could serve as valuable raw materials for the preparation of functional food supplement.

Keywords Analysis · Coconut water · Coconut kernel · Commercial coconut products · Physico-chemical characteristics · Stability

Introduction

Cocos nucifera is a perennial plant, bearing fruit continuously for up to 60–70 years (Banzon 1990). It is mainly grown in the southern part of India. The fruit is categorized in to two stages of maturity i.e., tender coconut and mature coconut. Coconut water (CW) and coconut kernel (CK) are the edible portions of coconut. Tender coconut water is considered as a refreshing and rehydrating drink as it contains sugars, vitamins, minerals, growth promoting factors, proteins and amino acids (Shaw and Srivastava 1963). It is free from fat and low in calories. Darilyn et al. (2000) reported that coconut water is the most sterile liquid and can be administrated intravenously in small doses to the patients. Minerals are the vital compounds required by the body. CW contains plenty of minerals like potassium, calcium, magnesium, iron, sodium, phosphorus, zinc, manganese, copper, sulphur, aluminium, boron, selenium and chlorine. Potassium is the major mineral in CW and sodium being the next (Jean et al. 2009).

The CK contains amino acids, minerals, antioxidants like phenolics, tocopherols (Abdul and Zafar 2011). CK is the major edible portion of coconut that has been used in the extraction of oil, coconut milk, cream, in bakeries, cooking and so on. Coconut oil can be used both for edible as well as industrial applications. CK contains 50–60 % fat. Coconut oil is rich in medium chain fatty acid (MCFA) (59.7 %) having 92.7 % saturated fatty acids (SFA), 6.1 % monounsaturated fatty acids (MUFA) and 1.2 % polyunsaturated fatty acids (PUFA). Lauric acid is the main fatty acid in coconut oil (49.1 %) (Bhatnagar et al. 2009). MCFA is easily burnt for the energy production rather than storing in the body (Kiyasu et al. 1952).

As coconut is a rich source of nutrients, it is likely to get contaminated with microbes. As long as the CW is inside the fruit, it is considered to be the most sterile liquid. The shelf life of CW and CK is short. A small crack in the shell can cause the

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spoilage. Therefore the shelf life of CW and CK has to be increased to preserve and in transporting to other parts of the country. In the present study, we have evaluated physical, chemical, phytonutrient composition and stability aspects of CW and CK at different stages of maturity ranging from tender coconut to mature coconut.

Materials and methods

Coconuts at different stages of maturity were collected from local vendors of the Mysore city and coconut kernel (CK) and coconut water (CW) were separated in the laboratory. They were categorized into tender coconut kernel (TCK1 and TCK2), matured coconut kernel (MCK), tender coconut water (TCW1 and TCW2) and mature coconut water (MCW). The commercial coconut kernel based products (CCP) viz. Copra, Palmo coconut milk powder (CMP-P), Maggi coconut milk powder (CMP-M) and coconut powder (CP) were purchased from the local super market. All reagents and chemicals used were of analytical grade. Standard α -tocopherol, gallic acid, iron, zinc, sodium, potassium and calcium were procured from Sigma Chemicals Co., St. Louis, USA. Standard FAME mix (C18:0 - C18:2, FAME MIX RM-5) was obtained from Supelco Inc., Bellefonte, PA, USA.

Physico-chemical characteristics of CW, CK and CCP

The physicochemical characteristics viz. moisture content, fat content and ash content of the samples were analyzed. The total acidity, transmittance, total solids and total sugars of CW at different stages of maturity were also estimated.

Moisture content About 5 g of the ground samples were taken in aluminum moisture cups and placed in an oven at 100 ± 1 °C for 2 h or till a constant weight was obtained. The moisture content was expressed on dry basis (method no. Ac 2–41 1997) (AOCS 1997).

Fat content Fat was extracted from dried kernel according to AOCS Official Butt-tube Method Ac 3–44 (AOCS 1998). The dried CKs were ground to a fine powder, packed in 26 mm $\times$ 60 mm thimbles and extracted with hexane in Soxhlet apparatus. The extracts were desolventized by vacuum flash evaporation (Rotavapor RE 121A, Buchi, Switzerland) at controlled temperature and were subjected to various analyses. Fat content of coconut water samples were estimated by counter current solvent extraction of 100 mL of water using petroleum ether (100 mL $\times$ 3) in a separatory funnel. The petroleum ether extracts separated, desolventised, dried and weighed to get the fat content.

Ash content Ash content of the dried and defatted coconut samples was determined gravimetrically according to AOCS Ba 5a-49 (AOCS, 1997). A known weight of the sample was initially charred on a tared silica crucible and placed in a muffle furnace at 550 °C for 6 h till the charred material became white. The dish was allowed to cool to room temperature in a desiccator and reweighed. The difference in weight was taken as total ash content (AOCS, 1997).

Total acidity The total acidity of CW was determined by titrating 10.00 mL of sample taken in neutralized alcohol with 0.1 N sodium hydroxide (NaOH) using phenolphthalein as indicator. The percentage of total acidity was expressed as percentage citric acid (Campos et al. 1996).

Transmittance Transmittance of CW was determined spectrophotometrically (Shimadzu corporation, Kyoto, Japan, model UV – 1601) at 610 nm (Campos et al. 1996).

Total solids The total solids was determined by removing water from 100 g of CW sample using rotavapor (RE 121 Rotavapor, Buchi make, Switzerland) (AOAC 2000).

Colorimetric estimation of total sugars in CW

Total sugars of the samples were estimated according to phenol-sulphuric acid method. Different aliquots (0.010–1.0 mL) of CW were pipetted into tubes and were made up to 2.0 mL with distilled water. One milliliter of 5 % solution of phenol was added and 5 mL of concentrated sulfuric acid was added directly against the liquid surface as it helps in proper mixing. The tubes were incubated for 10 min, shaken and were then kept in water bath at 25 to 30 °C for 10 to 20 min. After the appearance of pale yellow orange color, absorbance was determined at 490 nm spectrophotometrically (Shimadzu corporation, Kyoto, Japan, model UV – 1601). Blank was prepared by substituting distilled water for the sample CW. The total sugars was calculated by using the calibration curve prepared using standard glucose (10–80 μ g range) (Dubios et al. 1956).

Extraction and colorimetric estimation of total phenolics content (TPC)

The phenolics extraction from the samples was carried out according to Kapila and Dissanayake (2008). The phenolics were extracted from samples using 80 % methanol. For CK, 1.000 g of sample was mixed with 5.0 mL of 80 % methanol, heated for few 5 min on water bath and vortexed for 2 min (twice). The samples were centrifuged at 2,500 rpm for 10 min at room temperature. The methanol water layer was collected in another tube and this step was repeated for four times. The

extracts pooled and made up to 20 mL with 80 % methanol. For CW, it was used in aliquots directly.

The TPC was determined using the Folin–Ciocalteu reagent. Different aliquots were mixed with 0.20 mL of Folin–Ciocalteu reagent and were kept for 3 min. About 1.00 mL of 15 % Na_2CO_3 solution was added and made up to 7.00 mL with distilled water. The tubes were incubated for 45 min and centrifuged at 2,000 rpm for 10 min at room temperature. The absorbance was determined at 765 nm using a UV-Visible spectrophotometer (Shimadzu corporation, Kyoto, Japan, model UV – 1601). The TPC ($\text{mg } 100 \text{ g}^{-1}$) was calculated using gallic acid as a standard compound (Osawa and Namiki 1981).

Mineral composition by Atomic Absorption Spectroscopy (AAS)

Iron, zinc, sodium, potassium and calcium content of coconut samples were analyzed by atomic absorption spectroscopy (AAS, iCE 3000AA, Thermo scientific, USA) (Raghuramulu et al. 2003).

Fatty acid composition of fat from CK and CCP by GC

The fatty acid methyl ester of the fat extracted from the CK of different stages of maturity (TCK1, TCK2 and MCK) and CCP (CMP-P, CMP-M and CP) were prepared by transesterification according to AOCS Official Method (1998). Analysis was carried out using gas chromatograph (model-GC-15A, Shimadzu Corporation, Kyoto, Japan) equipped with a Flame Ionization Detector (FID) and a stainless steel column of 3 m length $\times$ 0.5 mm ID, coated with 15 % diethylene glycol succinate on 60–80 mesh chromosorb WAW. The operating conditions were as follows: column temperature 180 °C, injector temperature 220 °C and detector temperature 230 °C. A reference standard FAME mix (Supelco Inc., Bellefonte, PA, USA) was analyzed under the same operating conditions to determine the peak identity. The fatty acids were expressed as relative area %.

Tocopherols and tocotrienols composition of oils extracted from CK and CCP by HPLC

Tocopherol and tocotrienols contents of oils from CK and CCP were analysed by HPLC according to the AOCS Official Method Ce 8–89 (AOCS 2007). The analysis of tocopherols and tocotrienols was achieved by normal phase HPLC separation on silica column (LichroCART 250–4, Lichosorb Si60 (5 μm) 25 $\text{cm} \times 4 \text{ mm}$ id, Merck KGaA, Darmstadt, Germany) employing Shimadzu HPLC system consisting of LC-10A pump, injector fitted with 20 μl loop and fluorescence detector (FLD). The mobile phase was hexane: isopropyl alcohol (99.5:0.5, v/v) at the flow rate of

1 mL min^{-1} . The excitation wavelength of 290 nm and an emission wavelength of 330 nm were kept for the fluorescence detection of all the peaks. The tocopherols and tocotrienols were identified and expressed as α -tocopherol (99 % purity, Sigma Chemicals Co., St. Louis, USA) as suggested by AOCS Official methods for recommended practices (AOCS 2007). The tocopherols were expressed as $\text{mg } 100 \text{ g}^{-1}$ of oil.

Stability of CW and CK of different maturities

The storage stability was studied by storing the samples at room temperature (25 °C) with daily analyses of acidity in case of CW and for CK, it was observed for the appearance such as sliminess, colour change or bacterial and fungal growth. The CK was kept in a temperature controlled oven at 105 °C for 3 h to remove the moisture. The CW was heated in a beaker on water bath for 30 min at two different temperatures (80 and 95 °C) separately. The beakers were closed with aluminium foil. Acidity of treated CW were analysed daily and for CK, change in appearance was observed.

Statistical analysis

All the analyses were carried out in triplicates and the average values $\pm$ standard deviation (SD) are reported. One-way ANOVA was used to calculate significant difference among the coconut and oil samples (Steele and Torrie 1980). A two-tailed p value was determined to show the significant differences at $p \text{ value} \leq 0.05$.

Results and discussion

The volume of coconut water (CW) and coconut kernel (CK) content (w/w) per nut were determined for 20 coconuts and average values are presented in Table 1. The results showed that the ratio of CW to CK decreased with maturity and vice versa. According to Jayalekshmy et al. (1986), the quantity of coconut water decreased and the quantity of kernel increased with maturity.

The physico-chemical characteristics of CW and CK such as moisture, fat, ash, transmittance, total sugar and total solids were determined (Table 2). The mean moisture content of CW remained almost similar i.e., 96.7 $\text{g } 100 \text{ g}^{-1}$, 96.4 $\text{g } 100 \text{ g}^{-1}$ and 95.7 $\text{g } 100 \text{ g}^{-1}$ (minor variations - statistically different) during maturation indicating that these have almost similar total solids content of 3.4 $\text{g } 100 \text{ g}^{-1}$, 3.7 $\text{g } 100 \text{ g}^{-1}$ and 4.3 $\text{g } 100 \text{ g}^{-1}$ respectively. The fat content in CW was very less showing 0.2 $\text{g } 100 \text{ g}^{-1}$, 0.4 $\text{g } 100 \text{ g}^{-1}$ and 1.2 $\text{g } 100 \text{ g}^{-1}$ based on the maturity. Raissa and co-workers (2007) have reported that the fat content in CW increased with the maturity. The ash

Table 1 Composition of coconut at different stages of maturity

Composition	TC1	TC2	MC
Water content g/nut	312±11.7 ^a	308±7.2 ^a	117±42.5 ^b
Total solids g/nut	11±0.2 ^a	11±0.1 ^a	5±0.1 ^b
Kernel content g/nut	80±4.5 ^a	142±14.4 ^b	330±19.5 ^c
water/kernel	4:1	2:1	1:3

TC1 Tender Coconut 1, TC2 Tender Coconut 2 and MC Mature Coconut. Values are mean±SD of coconut water and kernel from 5 individual nuts separately and also from 20 numbers of nuts pooled together. All analyses carried out in triplicate ($n=15$ for 5 individual nuts, $n=3$ for pooled samples). Values with different superscript in row indicates significant difference at $P<0.05$

content of TCW1, TCW2 and MCW was 0.3 g 100 g⁻¹, 0.4 g 100 g⁻¹ and 0.3 g 100 g⁻¹. The total sugars content in CW remained almost similar with maturity showing 4.2 g 100 g⁻¹, 3.9 g 100 g⁻¹ and 4.6 g 100 g⁻¹ at different stages of maturity. The results were similar to that of Campos et al. (1996) and Jayalekshmy et al. (1986). There was a slight increase in the total solids content depending on the maturity i.e., TCW1 (3.4 g 100 g⁻¹), TCW2 (3.7 g 100 g⁻¹) and MCW (4.3 g 100 g⁻¹). Jayalekshmy et al. (1986) have reported that there is a steep decline in the total solids content in CW up on maturation. The transmittance of CW at 610 nm showed variation (82.9 g 100 g⁻¹, 76.7 g 100 g⁻¹ and 88.7 g 100 g⁻¹) with maturity. Acidity of CW (expressed as citric acid) increased marginally with maturity i.e., 0.4 g 100 g⁻¹, 0.3 g 100 g⁻¹ and 0.4 g 100 g⁻¹. The pH of CW was almost similar i.e., 4.5, 5.1 and 5.2 with maturity. Acidity, fat and turbidity increased with the stages of maturity. Ash and water content decreased with the maturity (Jose et al. 2004).

The moisture content of coconut kernel (CK) decreased (85.3 g 100 g⁻¹, 78.2 g 100 g⁻¹ and 51 g 100 g⁻¹) and the fat content increased with maturity for TCK1, TCK2 and MCK (37.3 g 100 g⁻¹, 50.2 g 100 g⁻¹ and 54.5 g 100 g⁻¹) respectively on dry basis. While ash content in CK (defatted) decreased on maturity showing 9.3 g 100 g⁻¹, 6.6 g 100 g⁻¹ and 4.3 g 100 g⁻¹. The physico-chemical characteristics of commercial coconut products (CCP) like moisture, fat and ash content were also analysed (Table 2). The moisture content of the CCP was low as they were dried products. The fat content of copra and coconut powder (CP) was 63.3 g 100 g⁻¹ and 66.6 g 100 g⁻¹ respectively whereas coconut milk powders (CMP-P and CMP-M) was 44.7 g 100 g⁻¹ and 42.9 g 100 g⁻¹ respectively. The ash content of copra (3.8 g 100 g⁻¹) was less while CMP-P (10.6 g 100 g⁻¹) showed high ash content when compared to CMP-M (3.5 g 100 g⁻¹) and CP (6.3 g 100 g⁻¹). These results for coconut samples were in agreement with the report of Rachel and co-workers (2010).

The mineral components and their salts help in maintaining the acid–base balance of the body system (Njoku and Ohia 2007). The mineral composition of CW, CK and CCP- Copra is presented in Table 3. The potassium content was high in CW than in CK. In TCW1 and TCW2 the potassium content was 249.6 mg 100 g⁻¹ and 256.2 mg 100 g⁻¹ whereas in MCW, it was 154.6 mg 100 g⁻¹. Sodium is the second highest mineral in CW. It was almost same in all the stages of maturity of CW (31.4–38.3 mg 100 g⁻¹). Calcium and iron were present in lower concentrations. The calcium content of TWC1, TCW2 and MCW was 3.6 mg 100 g⁻¹, 4.9 mg 100 g⁻¹ and 4.9 mg 100 g⁻¹ respectively. The iron content of TCW1, TCW2 and MCW was 4.2 mg 100 g⁻¹, 4.6 mg 100 g⁻¹ and 4.0 mg 100 g⁻¹ respectively. The zinc content of

Table 2 Composition of coconut water, coconut kernel at different stages of maturity and commercial coconut kernel based products

Samples	Moisture (g 100 g ⁻¹)	Fat (g 100 g ⁻¹)	Ash (g 100 g ⁻¹)	Total sugars (g 100 g ⁻¹)	Total solids (g 100 g ⁻¹)	Transmittance (%)	Acidity (g 100 g ⁻¹)	pH
TCW1	96.7±0.11 ^a	0.2±0.01 ^a	0.3±0.00 ^a	4.2±0.10 ^a	3.4±0.20 ^a	82.9±0.50 ^a	0.4±0.00 ^a	4.5±0.00
TCW2	96.4±0.00 ^b	0.4±0.01 ^b	0.4±0.00 ^b	3.9±0.10 ^a	3.7±0.10 ^b	76.7±0.80 ^b	0.3±0.00 ^b	5.1±0.00
MCW	95.7±0.01 ^c	1.2±0.02 ^c	0.3±0.01 ^c	4.6±0.30 ^b	4.3±0.10 ^c	88.7±0.21 ^c	0.4±0.00 ^c	5.2±0.00
TCK1	85.3±2.21 ^d	37.3±0.31 ^d	9.3±0.40 ^d	na	na	na	na	na
TCK2	78.2±0.12 ^e	50.2±0.31 ^e	6.6±0.10 ^e	na	na	na	na	na
MCK	51.0±0.30 ^f	54.5±0.30 ^f	4.3±0.20 ^f	na	na	na	na	na
Copra	3.8±0.51 ^g	63.3±0.30 ^g	3.8±0.32 ^{fg}	na	na	na	na	na
CMP-P	0.4±0.10 ^h	44.7±0.72 ^h	10.6±0.51 ^h	na	na	na	na	na
CMP-M	1.4±0.00 ^h	42.9±0.71 ⁱ	3.5±0.40 ⁱ	na	na	na	na	na
CP	1.8±0.01 ^h	66.6±0.10 ^j	6.3±0.20 ^j	na	na	na	na	na

na not applicable, TCW1 Tender Coconut Water 1, TCW2 Tender Coconut Water 2 and MCW Mature Coconut Water, TCK1 Tender Coconut Kernel 1, TCK2 Tender Coconut Kernel 2, MCK Mature Coconut Kernel, CMP-P Palmo Coconut Milk Powder, CMP-M Maggi Coconut Milk Powder, CP Coconut Powder. Values are mean±SD of coconut water from 5 individual nuts separately and also from 20 numbers of nuts pooled together. All analyses carried out in triplicate ($n=15$ for 5 individual nuts, $n=3$ for pooled samples). Values with different superscript in column indicates significant difference at $P<0.05$

Table 3 Mineral composition of coconut water and kernel at different stages of maturity

Samples	Minerals (mg 100 g ⁻¹)				
	K	Na	Ca	Fe	Zn
TCW1	249.6±9.21 ^a	31.4±1.72 ^a	3.6±0.30 ^a	4.2±0.30 ^a	0.8±0.21 ^a
TCW2	256.2±6.20 ^a	38.3±1.61 ^b	4.9±0.60 ^a	4.6±0.70 ^a	0.7±0.10 ^a
MCW	154.6±8.60 ^b	31.9±1.51 ^a	4.9±0.11 ^a	4.0±0.40 ^a	0.2±0.00 ^b
TCK1	97.5±2.61 ^c	34.7±3.41 ^{ab}	21.5±1.31 ^b	6.3±0.41 ^b	1.9±0.31 ^c
TCK2	95.3±6.41 ^c	23.7±1.60 ^c	18.5±0.31 ^c	7.9±0.12 ^c	1.7±0.11 ^c
MCK	122.1±3.00 ^d	21.6±2.52 ^d	18.1±0.42 ^c	7.9±0.00 ^d	2.2±0.10 ^c
Copra	120.3±9.12 ^e	15.5±0.40 ^e	14.6±0.40 ^d	7.9±0.12 ^e	2.9±0.11 ^d

TCW1 Tender Coconut Water 1, TCW2 Tender Coconut Water 2, MCW Mature Coconut Water, TCK1 Tender Coconut Kernel 1, TCK2 Tender Coconut Kernel 2 and MCK Mature Coconut Kernel. Values are mean±SD of coconut water and kernel from 5 individual nuts separately and also from 20 numbers of nuts pooled together, 4 numbers of copra. All analyses carried out in triplicate ($n=15$ for 5 individual nuts, $n=3$ for pooled samples and $n=12$ for 4 copra). Values with different superscript in column indicates significant difference at $P<0.05$

TCW1 (0.8 mg 100 g⁻¹), TCW2 (0.7 mg 100 g⁻¹) and MCW (0.2 mg 100 g⁻¹) was the lowest compared to other minerals. The potassium content of kernel increased with maturity i.e., TCK1 (97.5 mg/100 g), TCK2 (95.3 mg 100 g⁻¹) and MCW (122.1 mg 100 g⁻¹). The sodium content also decreased with maturity i.e., TCK1 (34.7 mg 100 g⁻¹), TCK2 (23.7 mg 100 g⁻¹) and MCK (21.6 mg 100 g⁻¹). There was an increase in the calcium content in kernel when compared to the CW i.e., TCK1 (21.5 mg 100 g⁻¹), TCK2 (18.5 mg 100 g⁻¹) and MCK (18.1 mg 100 g⁻¹). It decreased with maturity. The iron content was same at different stages i.e., 7.9 mg 100 g⁻¹. The zinc content of TCK1, TCK2 and MCK was 1.9 mg 100 g⁻¹, 1.7 mg 100 g⁻¹ and 2.2 mg 100 g⁻¹. Copra contained low amount of potassium (120.3 mg 100 g⁻¹), sodium (15.5 mg 100 g⁻¹), calcium (14.6 mg 100 g⁻¹) and slightly high amount of iron (7.9 mg 100 g⁻¹) and zinc (2.9 mg 100 g⁻¹). The high potassium to sodium ratio is the additional benefit in the diet of people with high blood pressure. The results of CW mineral composition were in good agreement with the report of Jean et al. (2009). The mineral composition of kernel was similar to the reports of Abdul and Zafar (2011).

The fatty acid composition of fat extracted from CK at various stages of maturity shows pronounced changes in certain fatty acids. There was an increase in the relative proportion of fatty acids up to 14:0 and decrease in the higher unsaturated fatty acids. Saturated fatty acids progressively increased from tender to mature coconut (8:0, 10:0, 12:0 and 14:0). There was an increase in C_{8:0} content (5.6 g 100 g⁻¹, 10.6 g 100 g⁻¹ and 14.7 g 100 g⁻¹ respectively) and C_{10:0} content (3.5 g 100 g⁻¹, 6.0 g 100 g⁻¹ and 8.9 g 100 g⁻¹ respectively) with maturity. The major fatty acid being lauric acid (C_{12:0}) increased with different stages of maturity. The C_{12:0} of oils extracted from TCK1, TCK2 and MCK were 38.2 g 100 g⁻¹, 47.5 g 100 g⁻¹ and 48.2 g 100 g⁻¹ respectively. The C_{14:0} content of oils from TCK1 (21.9 g 100 g⁻¹), TCK2 (18.8 g 100 g⁻¹) and MCK (12.9 g 100 g⁻¹) was decreasing.

Fat extracted from tender coconuts have high amount of C_{18:1} and it decreased with maturity (13.2 g 100 g⁻¹, 6.6 g 100 g⁻¹ and 4.9 g 100 g⁻¹ respectively). The level of C_{18:2} in mature coconut decreased when compared to the tender coconut i.e., 3.5 g 100 g⁻¹, 1.5 g 100 g⁻¹ and 0.8 g 100 g⁻¹ respectively. The percentage of SFA (TCK1-83.3 g 100 g⁻¹, TCK2-92.0 g 100 g⁻¹ and MCW-94.2 g 100 g⁻¹) increased where as the percentage of MUFA (TCK1-13.3 g 100 g⁻¹, TCK2-6.6 g 100 g⁻¹ and MCK-4.9 g 100 g⁻¹) and PUFA (TCK1-3.5 g 100 g⁻¹, TCK2-1.5 g 100 g⁻¹ and MCK-0.8 g 100 g⁻¹) decreased with maturity. The content of MCFA was increased with maturity (47.3 in TCK1, 64.1 g 100 g⁻¹ in TCK2 and 71.8 g 100 g⁻¹) in MCK (Table 4). The fatty acid composition of coconut oil was in agreement with the literature report of Bhatnagar et al. (2009). While the content of different fatty acids varied with maturity.

Tocopherols and Tocotrienols are the fat-soluble antioxidants in coconut oil, palm oil and oil from bran sources such as rice bran and wheat bran having vitamin E activity. No other vegetable oils contain tocotrienols in significant amounts. They act against the lipid peroxidation of membrane polyunsaturated fatty acids. The tocopherol and tocotrienol composition of coconut oil extracted from the CK of different stages of maturity (TCK1, TCK2 and MCK) and CCP (CMP-P, CMP-M and CP) are presented in Table 5. The result showed that α -T and β -T were the major tocopherol and α -T₃, γ -T₃ and δ -T₃ were the major tocotrienols present in the coconut oil. The α -T was dominant among all tocopherols and tocotrienols in all the samples except CMP-P oil (0.4 mg 100 g⁻¹) and it was ranging from 0.25 mg 100 g⁻¹ for CMP-M oil to 4.5 mg 100 g⁻¹ for TCW1 oil. The β -T level showed that it was less than 0.15 mg 100 g⁻¹ in coconut oil extracted from the different samples. δ -T was absent in coconut oils except TCK1 (≤ 0.01 mg 100 g⁻¹) and this indicated its presence only in the initial stages of maturity of coconut as tender coconut. The α -T₃ level ranged from ≤ 0.01 mg 100 g⁻¹ (copra

Table 4 Fatty acid composition of oils extracted from coconut kernels at different stages of maturity and commercial coconut kernel based products

Fatty acids (g 100 g ⁻¹ of oil)	TCK1	TCK2	MCK	Copra	CMP-P	CMP-M	CP
C _{6:0}	nd	nd	nd	nd	nd	0.5	nd
C _{8:0}	5.6	10.6	14.7	9.6	12.3	10.4	10.7
C _{10:0}	3.5	6.0	8.9	6.4	7.5	7.1	6.9
C _{12:0}	38.2	47.5	48.2	51.5	52.1	49.9	51.7
C _{14:0}	21.9	18.8	12.9	19.1	17.9	19.1	18.1
C _{16:0}	13.5	8.2	5.2	6.9	6.0	7.2	6.6
C _{18:0}	0.6	0.9	4.3	1.1	1.4	1.7	1.2
C _{18:1}	13.2	6.6	4.9	4.3	2.4	3.4	4.0
C _{18:2}	3.5	1.5	0.8	1.1	0.4	0.6	0.9
SFA	83.3	92.0	94.2	94.6	97.2	95.9	95.2
MUFA	13.2	6.6	4.9	4.3	2.4	3.4	4.0
PUFA	3.5	1.5	0.8	1.1	0.2	0.6	0.9
MCFA	47.3	64.1	71.8	67.5	71.9	67.9	69.3
Fat/nut	4.4	15.5	88.0	–	–	–	–

nd not detected, *TCK1* Tender Coconut Kernel 1, *TCK2* Tender Coconut Kernel 2, *MCK* Mature Coconut Kernel, *CMP-P* Palmo Coconut Milk Powder, *CMP-M* Maggi Coconut Milk Powder, *CP* Coconut Powder. All analyses carried out in triplicate ($n=15$ for 5 individual nuts). Values provided are mean of triplicate samples and the cv is <1 %

oil and CMP-M oil) to 0.6 mg 100 g⁻¹ (CMP-P oil). The MCK did not show the presence of α -T₃. The γ -T₃ levels showed that it ranges from ≤ 0.01 mg 100 g⁻¹ to 0.3 mg 100 g⁻¹. TCK1 contained maximum of γ -T₃ (0.3 mg 100 g⁻¹) and CMP-M contained minimum of γ -T₃ (≤ 0.01 mg 100 g⁻¹) among all the samples. The presence of δ -T₃ was observed in TCK1 oil (0.1 mg 100 g⁻¹) and TCK2 oil (0.5 mg 100 g⁻¹). The maximum level of total tocopherols was 5 mg 100 g⁻¹ of oil as according to the Codex specification for coconut oil (Codex standard 2003), which is observed in the present study also. The comparatively low level of total tocopherols in the oil

extracted from the CCP such as CMP-P (1.1 mg 100 g⁻¹), CMP-M (0.25 mg 100 g⁻¹) was most probably due to the loss during the product formulation. The recommended dietary intake level of tocopherols is 10 mg or 14.9 IU per day per person which can protect the DNA damage in human peripheral blood lymphocytes (Michael Fenech et al. 1997).

The results showed that the tocopherols content of the oil extracted from CK decreased with maturity showing 5.25 mg 100 g⁻¹, 3.05 mg 100 g⁻¹ and 1.97 mg 100 g⁻¹ of oil respectively for TCK1, TCK2 and MCK. The CCP showed less tocopherols and tocotrienols content when compared to the

Table 5 Phytonutrients of coconut kernels at different maturity and commercial coconut kernel based products

Samples	Tocopherols (mg 100 g ⁻¹ of oil)			Total T	Tocotrienols (mg 100 g ⁻¹ of oil)			Total T ₃	Total (T+T ₃)	TPC (mg 100 g ⁻¹)
	α T	β -T	δ T		α T ₃	γ -T ₃	δ T ₃			
TCW1	nd	Nd	nd	nd	nd	nd	nd	nd	nd	1.4 $\pm$ 0.10 ^a
TCW2	nd	Nd	nd	nd	nd	nd	nd	nd	nd	1.8 $\pm$ 0.20 ^a
MCW	nd	Nd	nd	nd	nd	nd	nd	nd	nd	4.3 $\pm$ 0.40 ^b
TCK1	4.5 $\pm$ 0.28 ^a	0.2 $\pm$ 0.07 ^a	Traces	4.7 $\pm$ 0.35 ^a	0.2 $\pm$ 0.14 ^a	0.3 $\pm$ 0.00 ^a	0.1 $\pm$ 0.00 ^a	0.6 $\pm$ 0.14 ^a	5.3 $\pm$ 0.49 ^a	125.4 $\pm$ 4.3 ^c
TCK2	2.0 $\pm$ 0.14 ^b	Trace	nd	2.0 $\pm$ 0.14 ^b	0.4 $\pm$ 0.07 ^a	0.2 $\pm$ 0.14 ^{ab}	0.5 $\pm$ 0.00 ^b	1.1 $\pm$ 0.21 ^b	3.1 $\pm$ 0.35 ^b	111.3 $\pm$ 2.4 ^d
MCK	1.8 $\pm$ 0.38 ^b	0.1 $\pm$ 0.00 ^a	nd	1.9 $\pm$ 0.38 ^{bc}	nd	0.1 $\pm$ 0.00 ^b	nd	0.1 $\pm$ 0.00 ^b	2.0 $\pm$ 0.38 ^c	50.6 $\pm$ 3.4 ^c
Copra	2.4 $\pm$ 0.00 ^b	Traces	nd	2.4 $\pm$ 0.00 ^b	Traces	nd	nd	nd	2.4 $\pm$ 0.00 ^c	14.4 $\pm$ 0.7 ^f
CMP-P	0.4 $\pm$ 0.00 ^c	nd	nd	0.4 $\pm$ 0.00 ^d	0.6 $\pm$ 0.00 ^b	0.1 $\pm$ 0.00 ^b	nd	0.7 $\pm$ 0.00 ^a	1.1 $\pm$ 0.00 ^d	42.3 $\pm$ 2.0 ^f
CMP-M	0.3 $\pm$ 0.07 ^c	Traces	nd	0.3 $\pm$ 0.07 ^d	Trace	Traces	nd	nd	0.3 $\pm$ 0.07 ^e	22.8 $\pm$ 1.7 ^g
CP	2.1 $\pm$ 0.00 ^b	0.1 $\pm$ 0.00 ^a	nd	2.2 $\pm$ 0.00 ^{bc}	0.3 $\pm$ 0.00 ^a	nd	nd	0.3 $\pm$ 0.00 ^c	2.5 $\pm$ 0.00 ^{bc}	13.9 $\pm$ 1.2 ^h

nd not detected, Traces ≤ 0.01 mg 100 g⁻¹, *TCK1* Tender Coconut Kernel 1, *TCK2* Tender Coconut Kernel 2, *MCK* Mature Coconut Kernel, *CMP-P* Palmo Coconut Milk Powder, *CMP-M* Maggi Coconut Milk Powder, *CP* Coconut Powder. All analyses carried out in triplicate ($n=15$ for 5 individual nuts). Values with different superscript in column indicates significant difference at $P<0.05$

Table 6 Phytonutrient composition of coconut water and kernel at different stages of maturity

Samples (wet materials)	TPC (mg 100 g ⁻¹)*	Total tocopherols (mg 100 g ⁻¹)	Ash (g 100 g ⁻¹)
TCK1	18.5±4.31 ^a	0.14±0.00	1.4±0.21 ^a
TCK2	24.3±2.41 ^b	0.29±0.00	1.5±0.10 ^a
MCK	24.8±3.41 ^b	0.59±0.01	1.0±0.00 ^b
TCW1	1.4±0.10 ^c	Nil	0.3±0.00 ^c
TCW2	1.8±0.21 ^c	Nil	0.4±0.01 ^c
MCW	4.3±0.40 ^c	Nil	0.3±0.00 ^c

*Total phenolics content as gallic acid equivalent. *TCK1* Tender Coconut Kernel 1, *TCK2* Tender Coconut Kernel 2, *MCK* Mature Coconut Kernel, *TCW1* Tender Coconut Water 1, *TCW2* Tender Coconut Water 2 and *MCW* Mature Coconut Water. Values are mean±SD of coconut water and kernel from 5 individual nuts separately and also from 20 numbers of nuts pooled together. All analyses carried out in triplicate ($n=15$ for 5 individual nuts, $n=3$ for pooled samples). Values with different superscript in column indicates significant difference at $P<0.05$

CK (Copra-2.4 mg 100 g⁻¹, CMP-P-1.1 mg 100 g⁻¹, CMP-M-0.3 mg 100 g⁻¹ and CP-2.5 mg 100 g⁻¹). Bhatnagar et al. (2009) had reported that coconut oil contained around 1.7–2.9 mg of tocopherols 100 g⁻¹ of oil as per our previous reports (Bhatnagar et al. 2009; Raja Rajan et al. 2010). The coconut oil contains 1.7 mg 100 g⁻¹ of tocopherols (Raja Rajan et al. 2010). The fat content in coconut water was

negligible and was present in coconut kernel analysis to varying extents depending on maturity.

The total phenolics (expressed as mg 100 g⁻¹ gallic acid equivalent) contents of CW increased with maturity showing 1.4, 1.8 and 4.3 mg 100 g⁻¹ and that CK decreased showing 125.4, 111.3 and 50.6 mg 100 g⁻¹ with maturity. The TPC of copra, CMP-P, CMP-M and CP was 14.4 mg 100 g⁻¹, 42.3 mg 100 g⁻¹, 22.8 mg 100 g⁻¹ and 13.9 mg 100 g⁻¹ respectively (Table 5) indicating that coconut milk powders had varied amounts of TPC. Campos et al. (1996) had reported that CW contained 6.86 mg catechin 100 ml⁻¹ of TPC. The commercial coconut products (CCP) showed less of tocopherols and phenolics content when compared to CK.

The CW and CK contained phytonutrients like phenolics and tocopherols that provide health benefits. The TPC in TCK1, TCK2 and MCK (wet basis) were 18.47 mg 100 g⁻¹, 24.26 mg 100 g⁻¹ and 24.76 mg 100 g⁻¹ equivalent gallic acid respectively where as the total tocopherols content were 0.14 mg 100 g⁻¹, 0.29 mg 100 g⁻¹ and 0.59 mg 100 g⁻¹ of wet kernel respectively (Table 6). The TPC and total tocopherols and tocotrienols content of both CW and CK increased with maturity (wet basis). Raissa and co workers (2007) had reported that the mean total phenolics content of three different varieties of CW were around 21.22–36.9 mg 100 g⁻¹. Our results were similar to that of one variety of CW studied by them. Phenolic compounds are the secondary plant

Table 7 Effect of heat treatment on stability of coconut water and coconut kernel at different stages of maturity

Sample	Temperature °C	Acidity (g 100 g ⁻¹)			Sensory attribute (smell)
		0 h	24 h	48 h	
TCW1	Fresh (27 °C)	0.36	0.61	Spoiled	Bad smell on 24 h
	80 °C	0.32	0.41	0.92	Bad smell on 48 h
	95 °C	0.33	0.38	0.8	Bad smell on 48 h
TCW2	Fresh (27 °C)	0.35	0.8	Spoiled	Bad smell on 24 h
	80 °C	0.36	0.33	1.01	Bad smell on 48 h
	95 °C	0.35	0.3	1.12	Bad smell on 48 h
MCW	Fresh (27 °C)	0.49	1.08	Spoiled	Bad smell on 24 h
	80 °C	0.48	0.54	1.34	Bad smell on 48 h
	95 °C	0.46	0.53	1.45	Bad smell on 48 h
Sample	Temperature °C	Appearance 0 h	24 h	48 h	Stability
TCK1	Fresh (27 °C)	Fresh	Bad smell	Mold growth with obnoxious smell	12 h<24 h
TCK1	Treated (27 °C)	Fresh	Fresh	Fresh	7<8 months
TCK2	Fresh (27 °C)	Fresh	Bad smell	Microbial growth	12 h<24 h
TCK2	Treated (27 °C)	Fresh	Fresh	Fresh	7<8 months
MCK	Fresh (27 °C)	Fresh	Fresh but little slimy	Bad smell	24>48 h
MCK	Treated (27 °C)	Fresh	Fresh	Fresh	7<8 months

TCW1 Tender Coconut Water 1, *TCW2* Tender Coconut Water 2 and *MCW* Mature Coconut Water, *TCK1* Tender Coconut Kernel 1, *TCK2* Tender Coconut Kernel 2 and *MCK* Mature Coconut Kernel. Values are mean±SD of coconut water from 5 individual nuts separately and also from 20 numbers of nuts pooled together. All analyses carried out in triplicate ($n=15$ for 5 individual nuts, $n=3$ for pooled samples). Values provided are mean of triplicate samples and the cv is <1 %

metabolites, naturally occurring antioxidants that protect the cell from oxidative damages. According to Augustin and Gary (2000), the amount of polyphenols to be taken by an adult is an average of 1 g/day/person.

The stability of CW and CK were less than 24 h at room temperature (27 °C) as indicated by its smell and taste. This was also followed by determining the total acidity of CW. The acidity of CW (as citric acid) increased with maturity from 0.36 to 1.84 % (TCW1), 0.35 to 1.84 % (TCW2) and 0.49 to 1.7 % (MCW) indicating the increase in the sourness of CW due to spoilage caused by microbial activity. The stability of CW could be increased to more than 24 h and up to 48 h by heating CW at two different temperatures separately i.e., 80 and 95 °C (Table 7). After the heat treatment, though there was an increase in the acidity the CW was fresh in smell and taste. The treated samples spoiled after 48 h where as the untreated samples spoiled within 24 h. According to Chowdhury et al. (2009), the CW heated at 100 °C for 10 min can be stored for 6 months at ambient temperature. The untreated CK got spoiled within 24 h at room temperature with bad smell and further spoilage with bacterial and mold growth with successive days of storage. The treated CK could be stored for long time (7 months) without any spoilage (Table 7).

Conclusion

The physical, chemical and phytonutrient composition of CW and CK varied during different stages of maturity. The stability of CW and CK was normally for 12 and 24 h respectively at room temperature (27 °C). The stability can be increased by thermal process. Due to the presence of many health beneficial components like tocopherols, phenolics, minerals, sugars, etc., CW and CK can serve as a nutritive food at any stages of its maturity and can be used in the preparation of functional food supplements.

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