CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

journal homepage: **http://chimie-biologie.ubm.ro/carpathian_journal/index.html**

EVALUATION OF POSTHARVEST BEHAVIOR OF COCONUT (*Cocos nucifera* L.)

Lucas Aguirre Juan Carlos[1,2*], Tobón Castrillón Cynthia[1], Cortés Rodríguez Misael[1]

[1]Universidad Nacional de Colombia - Sede Medellín. Calle 59 A N 63-20, Medellín, Colombia.
[2]Universidad del Quindío – Carrera 15 Calle 12 N, Armenia – Colombia.
**jclucasa@unal.edu.co*

https://doi.org/10.34302/crpjfst/2019.11.3.7

Article history:
Received:
21 March 2018
Accepted:
28 July 2019

Keywords:
Coconut water;
Coconut pulp;
Physical-chemical;
Physical properties;
Useful life.

ABSTRACT

Coconut is a Tropical fruit of interest for Colombia; one part of its production is used at industrial level; nonetheless, there is little diversification of products with added value and lack of availing of coconut water, the husk, and peel. The aim of this research was to evaluate the behavior of the physical and physical-chemical properties of coconut pulp (CP) and its coconut water (CW) during storage at 25 °C, to determine the adequate time for use as raw material for its transformation, using a completely random design (CRD) via analysis of variance (ANOVA) and Tukey tests, with 5% significance level. Where the independent variable were the control times at 15, 22, 29, 36, 43, and 50 days after harvest, at the rate of 3 coconuts/lot for each control time. Among the response variables we determined the percentage distribution of the CP, CW, and inner shell (endocarp), as well as properties of Xw, pH, soluble solids, acidity, a_w, color (L*, a*, b*), viscosity, and texture. Results showed general CP and CW deterioration after de 36 days of storage, mainly due to increased acidity, fermentation odors, loss of Xw, lipid oxidation (LO), and CP softening and discoloration, among others.

1.Introduction

Coconut represents a raw material of great interest in the Colombian Caribbean and Pacific. Its production was of 114,773 t in 2013, with the departments of Nariño, Córdoba, and Cauca the principal producers: 33.7, 26.1, and 15.1%, respectively (Agronet, 2013). At agro-industrial level, the kernel is used mainly to produce coconut milk (CM) and dehydrated coconut. In addition, coconut oil is used in the cosmetics sector (Debmandal and Mandal, 2011; Seow and Gwee, 1997). Compositionally, CP has been evaluated with Xw: 41.7±0.5%, fat: 40.2±1.2%, proteins: 4.1±0.3%, sugar: 5.6±0.2%, and raw fiber: 3.5±0.1%; while dehydrated CP present fat content values: 65.5±2.0%, protein: 6.8±0.4%, sugar: 6.5±0.3%, raw fiber: 9.2±0.2%, and carbohydrates: 6.0±0.2%. (Yalegama *et al.*, 2013). Other authors have evaluated the quality of Macapuno coconut in mature state during 42 days of storage, to simulate conditions in retail markets, finding that at 30 °C the fruit undergoes a high respiration rate between 40 and 60 mg CO_2 $kg^{-1}h^{-1}$ with 3-day maximum storage time. At 2 and 5 °C the respiration rate diminishes (4 and 20 mg CO_2 kg^{-1} h^{-1}, respectively) with a low rate of ethylene production (0.6 and 0.8 $Lkg^{-1}h^{-1}$, respectively), permitting a storage life up to six weeks (Luengwilai *et al.*, (2014). This weight loss limitation is also accompanied by darkening of the nucleus and of the degree of fat oxidation (Luengwilai *et al.*, 2014). The aim of this research was to evaluate the behavior of the physical and physical-chemical properties of CP and CW, Enano Malayo variety (manila), during storage at 25 °C to determine the adequate time for its processing as raw material for its transformation.

2. Materials and methods

2.1. Materials

The fruit yield was determined as percentage ratios of the CP, CW, and the inner shell (endocarp). The CP and CW characterization was performed in terms of humidity (Xw): AOCW method 930.15/90; water activity (a_w): spray point hygrometer (Aqualab series 3TE, Decagon, Devices, Pullman, WA, USA) (Cortés-Rodríguez *et al*., 2007); ºBrix: AOCW method 932.12/90; LO: the proportional mix (CP+CW) was evaluated by using the spectrophotometric method (Hornero-Méndez *et al.*, 2001) and determining the extractable oil through the method described by Bae & Lee, (2008) modified; viscosity of the CW (μ): rheometer (Brookfield DV-III Ultra (Brookfield Engineering Laboratories, Inc., USA) a 25 °C, ULA spindle and velocity at 250 rpm (Mirhosseini *et al.,* 2008); CP texture: determined the CP average firmness (F_{CP}) through penetration tests in a texture analyzer (TA-TA-XT2i, Stable Microsystems Ltd., United Kingdom), 25-kgf load cell, stainless steel probe (ϕ = 5 mm), rate of penetration: 1.0 mm s^{-1} and penetration distance of 3 mm (Prieto *et al.*, 2011); acidity index (IA): AOCW method 942.05/90, expressed as malic acid for CW and as lauric acid for CP; pH: AOCW method 981.12/90; color: coordinates of the CIELAB (L*:Luminosity, a*: red-green chromaticity, b*: yellow-blue chromaticity), X-Rite spectrophotometer, D_{65} illuminant, and 10° observer (Cortés, 2004). In addition, bromatological characterization was carried out: fat (AOCW method 920.39/90), proteins (AOCW method 955.04/90), total dietary fiber (AOCW method 985.29/90), and ashes (AOCW method 942.05/90). Calcium quantification was performed via atomic absorption spectrophotometry, according to NTC 5151 of 2003. A completely random design (CRD) was used to evaluate the results, with analysis of variance (ANOVA) and Tukey tests, with 5% significance level. The independent variable were the control times at 15, 22, 29, 36, 43, and 50 days after harvest, at the rate of 3 coconuts/lot for each control time and the response variables for CP and CW were: Xw, a_w, pH, color (L, a*, b*), IP, soluble solids. Texture and acidity index were also determined for CP. For CW: density and percentage of acidity and percentage distribution of CP, CW, and peel.

2.2.1. Samples

The study used coconuts (*Cocos nucifera* L.) of the Enano Malayo (Manila), Tumaco, Colombia varieties, with an age from bloom to harvest of 12 months. Three lots were evaluated (three samples/lot) up to 50 days after harvest (dah).

3. Results and discussions

The bromatological composition of CP at 15 dah (date received in the collection center) was the following: Xw: 53.5±6.4%, protein 3.3±0.3%, dietary fiber 12.9±2.5%, fat 19.9±3.0%, ashes 1.1±0.3%; additionally, calcium contents for CP and CW were statistically similar, 146.3±41.3 and 108.0±16.5 mg/kg, respectively. The bibliographic review reports a variability of results on the coconut composition, attributable to diverse factors, such as variety, agronomic management, edafoclimatological conditions of the production zone, state of maturity, among others (Siriphanich *et al.,* 2011). Yalegama *et al.*, (2013) reported for CP values of Xw: 41.7±0.5%, fat 40.2±1.2%, protein: 4.1±0.3, sugar: 5.6±0.2%, and raw fiber 3.5±0.1%; while Appaiah *et al.*, (2015) reported higher values of Xw (51.0±0.3%). Regarding calcium contents in CW, the same variability occurs, reporting in unripe (8.75±0.04 mg/100 mL), ripe (15.19±0.03 mg/100 mL), and over-ripe states (23.98±0.05 mg/100 mL) (Thuan-Chew *et al.*, (2014).

Tables 1, 2 presents the distribution of the coconut parts and the CP and CW properties during storage. The ANOVA presented statistically significant differences ($p < 0.05$) in the CW and CP percentage ratios and the CW properties (Xw, °Brix, density, IA, pH, μ and b*) with respect to the time factor; while there were no significant differences ($p > 0.05$) in the CP properties, or in the percentage ratio of the inner shell, the IP and in the CW a_w, L* and a*. The CW had a tendency to diminish the mass (30.1→15.4%), which has been observed during the physiological maturation during harvest by other authors and which continues during postharvest (Jackson *et al.*, 2004; Terdwongworakul *et al.*, 2009); while the CP and the peel tend to increase over time: (47.1→55.2%) and (26.0→33.8%), respectively. The CP and CW physiological phenomena are typical during maturation and senescence of this fruit, promoted by respiration, transpiration, and water absorption by the solid endosperm (Thuan-Chew *et al.*, 2014; Siriphanich *et al.*, 2011).

Table 1. Physical composition of CW and CP during storage

T (days)	**CW (%)**	**CP (%)**	**Inner shell (%)**		**L***	**a***	**b***	**μ (cP) Texture (N)**
15	30.1±5.2c	47.1±3.1a	26.0±3.8a	CW	51.0±1.5c	0.3±1.0a	-1.0±0.3a	0.7±0.1ab
				CP	71.8±4.3b	-1.1±0.2a	3.1±0.8ab	81.1±8.3a
22	22.8±9.1b	49.5±3.8ab	30.4±7.1ab	CW	52.2±0.44bc	-1.08±0.0b	-0.02±0.06b	0.7±0.1a
				CP	72.7±10.6b	-0.8±0.5ab	3.7±1.9ab	75.7±8.5a
29	22.3+5.7b	51.9±4.7ab	30.0±5.3ab	CW	49.0±3.7c	1.5±1.8a	-0.9±0.2a	0.7±0.1ab
				CP	67.4±5.2ab	-0.8±0.3ab	3.7±1.3ab	78.0±13.9a
36	21.1±6.2bc	52.9±8.9bc	29.5±7.1ab	CW	50.9±3.0c	0.6±1.0a	-1.0±0.2a	0.7±0.1ab
				CP	67.5±10.9ab	-1.2±0.2a	2.4±1.5a	71.2±6.3a
42	15.9±6.6ab	53.6±2.4ab	31.0±4.5ab	CW	50.7±2.0c	-0.4±1.9a	-1.1±0.4a	0.8±0.1bc
				CP	69.6±9.0b	-0.3±1.5b	4.2±1.9ab	73.1±15.0a
50	15.4±1.5a	55.2±3.6b	33.8±7.4b	CW	50.8±1.2c	2.4±2.8a	-1.2±0.3a	0.8±0.1bc
				CP	61.7±6.9a	-0.8±0.6ab	3.7±2.0ab	73.5±19.8a

CW: coconut water; CP: coconut pulp; **μ**: viscosity; The values in the same column of the same variable, with the same letters indicate that there are no significant differences ($p > 0.05$).

Table 2. Chemical composition of CW and CP during storage

T (days)		**Xw (%)**	**a_w**	**°Brix**	**ÍP ($meqH_2O_2$/ kg oil)**	**ÍA (p/v)**	**pH**
15	CW	96.1±0.8c	0.981±0.007b	3.7±0.6a	0.7±0.3a	0.04±0.01a	5.7±0.4cd
	CP	50.4±5.2bc	0.978±0.005a	6.4±3.0bc		0.51±0.24a	6.1±0.2b
22	CW	95.9±0,4c	0.974±0.011ab	4.0±0.4ab	2.1±2.5a	0.04±0.01a	6.0±0.3cd
	CP	48.5±5.3bc	0.978±0.005a	5.1±1.7ab		0.60±0.16ab	6.0±0.3b
29	CW	95.9±1.0c	0.952±0.076a	4.1±1.0ab	2.3±2.0a	0.07±0.02a	6.2±0.2a
	CP	47.9±4.6bc	0.979±0.003a	4.8±1.1ab		0.66±0.11ab	5.6±0.8a

36	CW	95.1±1.2cd	0.971±0.012ab	5.1±1.1bc	2.8±2.4a	0.08±0.01a	5.5±0.6b
	CP	51.2±6.7c	0.979±0.007a	4.0±1.9a		0.68±0.13ab	6.0±0.2b
42	CW	94.0±1.6abc	0.969±0.012ab	5.8±1.6cd	3.5±4.0a	0.08±0.02a	5.7±0.6b
	CP	45.8±3.9ab	0.976±0.005a	5.2±2.3ab		0.66±0.17ab	6.0±0.2b
50	CW	93.5±1.5ab	0.969±0.013ab	7.1±1.8cd	3.9±1.8a	0.14±0.01a	5.6±0.1b
	CP	50.1±6.0bc	0.978±0.005a	4.6±1.8ab		0.72±0.16bc	6.0±0.2b

CW: coconut water; CP: coconut pulp; Xw: % humidity; ÍP: peroxide index; ÍA; acidity index, expressed in expressed as malic acid for AC and as lauric acid for PC. The values in the same column of the same variable, with the same letters indicate that there are no significant differences (p>0.05

The bibliographic review reports that on full maturity, changes in percentage distribution of coconut (*Cocos nucifera L.*) present many fluctuations: CP (28→33 %p/p), CW (6→25 %p/p), peel (31→54 %p/p) (Jayalekshmy *et al.*, 1986; Siriphanich *et al.*, 2011; Appaiah *et al.*, 2015). The Xw of the CP had values between 51.2 and 45.8%, with CW showing values of 96.1– 92.5%, corresponding in all cases to high values of a_w (0.980 – 0.952), which makes these matrices perishable and favorable to microbial growth and degradation processes (Appaiah *et al.*, 2015; Haseena *et al.*, 2010). The soluble solids of the CW increase progressively throughout the storage time, which could be attributed to internal dehydration undergone by the fruit and it is coherent with the decrease previously mentioned of the percentage ratio of the CW and of the Xw of the CW (96.1±0.8 →93.5±1.5).

With respect to the CW's μ, it tends to increase mainly because of the higher content of soluble solids in the CW concentrated over time (3.7±0.6 →7.1±1.8). The CP firmness (F_{CP}) provided by the fiber content present and of rigid or hard nature (Yalegama *et al.*, 2013; Raghavendra *et al.*, 2009) behaved as a homogeneous group with high variability, fluctuating between 81.1±8.3 and 73.5±19.8 N. Some authors have reported CP softening during storage because of CP disintegration and deterioration due to fungal growth, where the most frequent found in the coconut peels are Aspergillus spp., Penicillium spp., Fusarium spp., and Curvulria spp. (Haseena *et al.*, 2010; Luengwilai *et al.*, 2014).

The IP displayed similar behavior during storage time (0.74±0.3→3.9±1.8 meqH_2O_2/kg); it is a useful indicator of the degree of oxidation of lipids, fats, and oils that reduces stability and produces the formation of unpleasant taste that affect quality negatively during storage, as well as consumer acceptance due to the rancid odor (Hornero-Méndez *et al.*, 2001). Some authors have defined the start of rancidity in coconut when IP reaches values of 35.5 meq O_2 peroxide/kg oil (Waisundara *et al.*, 2007), a value higher than the maximum reached for the CP+CW mixture at 25 °C (1.6 meq H_2O_2/kg oil) (11.3 meq O_2 peroxide/kg oil); however, at 29 days of storage a strong rancid odor became evident. Now then, changes in IP were low for CP and CW; nevertheless, a tendency is noted to increased acidity and diminished pH over time, which revalidates the fermentation odors and rancidity of the product.

Regarding the color of the CW, L* varied from 51.0±1.5 to 50.8±1.2, showing a translucent liquid phase with a light brown tone and/or yellowing, emitting bad odor that could be attributable to the contraction and discoloration of the skin, the fall of the perianthus, and fungal attack in the soft perianthus region (Haseena *et al.*, 2010); while chromaticities a* and b* had values close to zero in the chromatic plane a*, b*, indicating its achromaticity or placement in the zone of grey tones. The CP was bright white, where L* varied between 71.8±4.3 and 61.7±6.9; while chromaticity a* remained between -1.1±0.2 and -0.8±0.6, and lastly b* from 3.1±0.8 to 3.7±2.0, very similar behavior to that reported by Luengwilai *et al.*, (2014), where no statistically significant differences were noted in variables L* a*, while b* diminished 1.05 to -0.96.

Up to 29 to 36 dah, coconut does not show appreciable organoleptic changes that demerit its quality, but as of this time (42 dah) deterioration symptoms were observed (in CW and CP), like fermentation odors, fungal problems, softening and discoloration of the pulp, among others. This behavior coincides with that reported by Luengwilai *et al.,* (2014), who worked with Macapuno coconut, where peeled ripe coconut was stored at 2, 5, and 30 °C and its quality was evaluated after three days. During storage at 30 °C, the fruit showed a 3-day useful life. In contrast, with storage at 2 or 5 °C the storage life increased from three days to six weeks

4. Conclusions

The Enano Malayo coconut variety with acceptable quality for use as raw material in food processing must have a storage time below 29 dah. During this time, the physical-chemical and sensory characteristics of the products are within the acceptance limits; however, the fruit had high variability in CP and CW properties, which is due to the poor or almost null traceability available for this fruit.

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