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Harvest timing and potassium doses on post-harvest quality of dwarf-green coconut water

Francisco Mickael de Medeiros Câmara[1]*, Eduardo Castro Pereira[2], Anderson Araújo Alves[2], Gustavo Alves Pereira[3], Elizangela Cabral dos Santos[2], Vander Mendonça[2]

[1]EPAMIG, Caldas, Brazil
[2]Federal Rural University of the Semi-Arid, Mossoró, Brazil
[3]Federal University of Piauí, Bom Jesus, Brazil
*Corresponding author, e-mail: mickaelmedeiros@hotmail.com

Abstract

Coconut is an expressive culture in tropical climate regions and its yield and fruit quality is directly linked to several factors, such as climatic conditions, fertilizer management, harvesting fruits period and other factors. Aiming to evaluate post-harvest of irrigated green dwarf coconut water quality due to potassium doses and different harvesting time, an experiment was carried out at the Federal Rural University of the Semi-Arid - UFERSA from January to November 2015. The experimental design was split-plot randomized blocks. Plots were 5 potassium doses (0, 150, 300, 450 and 600 g plant^{-1}) and the subplots 4 harvesting time of fruits (5, 6, 7 and 8 months after the opening of the inflorescence), 4 blocks and 2 plants for a total of 40 treatment plants. The experimental area consisted of coconut trees of green dwarf variety with four years old. Were evaluated the titratable acidity, soluble solids, ratio, electrical conductivity, pH, total sugar and levels of potassium, calcium, magnesium, sodium and chlorine from coconut water. Under the conditions studied, higher doses of potassium decreased qualitative characteristics of coconut water, the absence of potassium fertilization coconut trees had better results. The optimal harvest time is between 6 and 7 months old.

Keywords: *Cocos nucifera* L., Fertilization, Horticulture, Tropical zone

Introduction

Coconut water (*Cocos nucifera* L.) is an ancient tropical beverage whose popularity on the international market has been continuously increasing in recent years (Prades et al., 2012; Shah et al., 2015). It is extensively used around the world, mainly because of its health and nutritional benefits (Anurag & Rajamohan, 2011; Johnkennedy et al., 2013; Mulyanti et al., 2016; Prathapan & Rajamohan, 2011) that can be justified by its unique chemical composition of sugars, vitamins, minerals, amino acids and phyto-hormones (Bhagya et al., 2012; Farapti et al., 2013).

Fertilization is the practice of most impact on the productivity of this crop (Silva et al., 2009a), mainly the nitrogen and potassic fertilizers that are of great importance for fruit production, since they do not only affect the quantity produced, but also the fruit quality and number of female flowers (Silva et al., 2009b; Costa et al., 2009).

Potassium directly influences the productivity of the dwarf coconut tree as it activates enzymes involved in respiration and photosynthesis, among other functions (Ribeiro et al., 2011). Results obtained with potassium fertilization in studies with coconut have not been significant in terms of leaf content, fruit productivity and quality, despite substantial amounts of potassium fertilizers are applied to crops in general. With the high prices of chemical fertilizers, there is a need to optimize fertilization (Pinho, 2008).

The ideal harvest point of the fruit is associated to several indicators related to the plant, the fruit and the production characteristics. It also depends on certain chemical and sensory properties. It is known that the taste of coconut water is sweet and slightly astringent; the physic-chemical characteristics of water are mainly influenced by the variety and stage of maturation

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(Queiroz et al., 2009).

Due to the lack of information on the interaction of potassium fertilization and fruit harvest time in the quality of coconut water, this work aimed to evaluate the post-harvest quality of irrigated dwarf coconut water as a function of potassium doses and ages of the fruits.

Material and Methods

The experiment was conducted in the didactic orchard of the Federal Rural University of the Semi-Arid, located in the municipality of Mossoró, Rio Grande do Norte from January to November 2015. The geographical coordinates of the site are 5° 11'' S and 37° 20'' W, with an altitude of 18 m. According to the classification of Köeppen, the climate of the region is of type BSwh'', that is, hot and dry; with fairly irregular rainfall, annual average of 673.9 mm; temperature of 27 °C and relative humidity of 68.9% (Alvares et al., 2013).

The experimental design was used in slipt-plots randomized blocks, the plots being 5 potassium doses (0, 150, 300, 450 and 600 g plant^{-1} year^{-1}) and the subplots 4 harvesting ages of the fruits (5, 6, 7 and 8 months after opening of the inflorescence), 4 blocks and 2 plants per treatment totaling 40 plants.

The experimental area was composed of four years old dwarf coconut trees, spaced 7.5 m x 7.5 m. Before the beginning of the experiment, the soil was sampled in the experimental area to determine the amount of nutrients in the soil and, as a result, the doses used in the experiment were determined (Table 1).

Table 1. Soil chemical analysis of the experimental site, in the 0-20 and 20-40 cm layers, prior to the installation of the experiment.

Samples	pH	MO	P	K	Na	Ca	Mg	SB	t	CTC	N
	water	g kg^{-1}		mg dm^{-3}				cmolc dm^{-3}			g kg^{-1}
0-20	8.02	4.68	18.2	115.6	210.2	1.90	0.20	3.31	3.31	3.31	0.42
20-40	8.65	1.48	29.4	16.7	38.4	1.90	0.40	2.51	2.51	2.51	0.28

P e K Extractor: Mehlick 1; Al, Ca e Mg Extractor: KCl 1 mol l^{-1}; H+ Al Extractor: $Ca(Oac)_2$ 0.5 mol l^{-1} a pH 7.0.

As potassium source, potassium chloride (60% K_2O) was used, the doses were divided into three monthly applications and the fertilization was done manually in the area of crown projection and the area wetted by the irrigation system.

The clusters were identified sequentially as the inflorescence opened, using colored ribbons tied at the base of the cluster. To coincide the harvest period, the first bunches were marked and harvested with 8 months and the last harvested with 5 months, thus the clusters emitted in February were harvested in October, with 8 months old and the clusters emitted in May were also harvested in October at 5 months old. Two fruits per plant were collected from each plot to perform the evaluations.

To evaluate the effects of potassium fertilization and harvesting time onto physical-chemical composition of coconut water the titratable acidity (ATT), soluble sugars (SS), ratio SS/ATT, total sugars, electrical conductivity, pH as well as potassium, sodium, calcium, magnesium and chlorine contents were evaluated in fruit water.

The data were submitted to analysis of variance. The averages of the quantitative data were submitted to the regression analysis and response surface method ($p<0.05$), performed by the SISVAR and Sigma plot software (Ferreira, 2011).

Results and Discussion

The analysis of variance showed interaction between the potassium doses and harvest timing for all variables, except pH, where it was verified an isolated effect of the harvest timing of the fruits; and soluble solids presented no statistical differences among treatments. The response surface method was applied to all variables, however, only potassium, sodium and chlorine content in coconut water presented significant coefficient of determination with values of 0.51, 0.92 and 0.71, respectively.

The fruits with 6 and 7 months old presented the lowest values for total titratable acidity in the absence of fertilization, with mean values of 2.21 and 2.4%, respectively. With the increase of the doses, the coconut water acidity raised for these two stages of maturation, which presented an average around 4%. For the fruits with age of 5 and 8 months old the inverse effect occurred, acidity reduced with increasing doses of 6.13 and 4.15%, respectively, to values around 3.5% (Figure 1A).

These results are similar to those found by Kannangara et al., (2018). Despite acidity is not used as an analytical parameter to integral coconut water by Normative Instruction in Brazil, it plays important role as a sensory indicator of taste and aroma of beverages. Furthermore, the coconut water commonly present low acidity combined with well-balanced sugar content and isotonic mineral composition makes it a potential rehydration beverage (Charlo et al., 2009; Aroucha et al., 2010; Prades et al., 2012).

Fruits with 7 and 8 months old presented higher total sugars of 4.12 and 4.26%, at doses of 412.78 and

403.15 g plant^{-1}, respectively (Figure 1B). These values are close to those obtained by Silva et al. (2009b), with values of 4.66%. The fruits of dwarf and hybrid coconut trees intended for the *in natura* consumption of coconut water should be harvested mainly between the sixth and seventh months after the natural opening of the inflorescence. In this age, the highest values for fruit weight and coconut water production, fructose, glucose, brix levels and mineral salts, mainly potassium, occur, which give a better flavor to coconut water (Prades et al., 2012). In addition, the natural sweetness of coconut water increases the consumer's desire to voluntarily drink sufficient fluid (Kailaku et al., 2015).

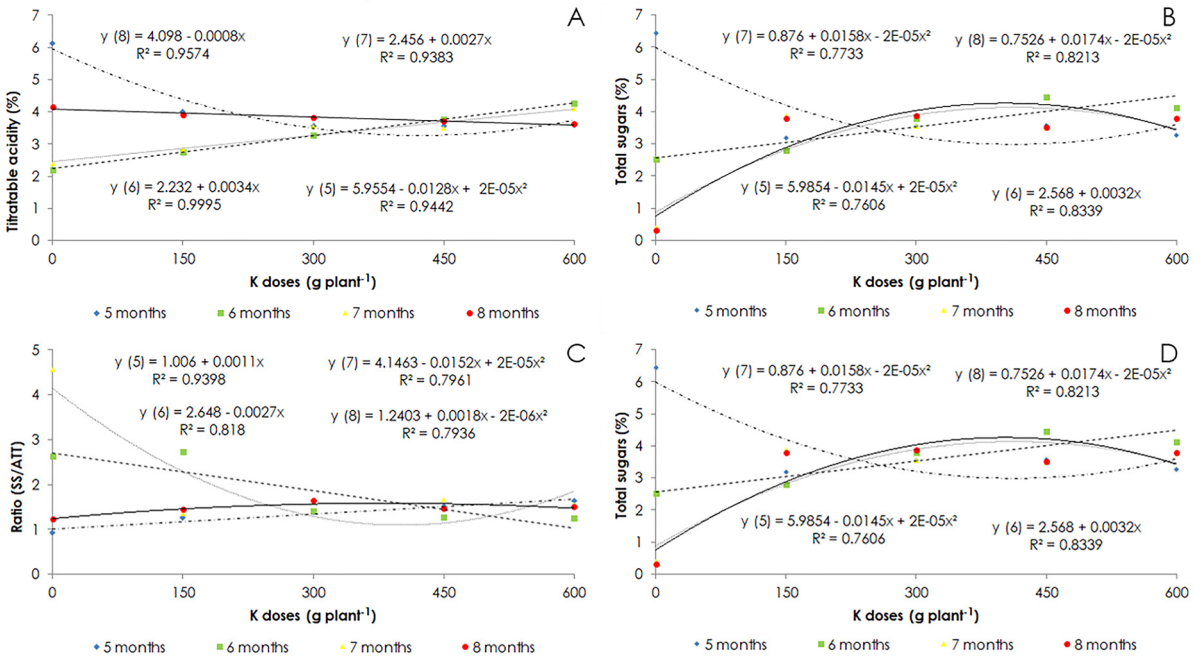


Figure 1. Titratable acidity (A), total sugars (B), ratio SS/ATT (C) and electrical conductivity (D) of dwarf-green coconut water as a function of potassium doses and harvest timing.

The best SS/ATT ratio occurred at dose 0 for fruits at the age of 7 months in which they presented a mean of 4.56, presented higher soluble solids in relation to the amount of acid in the water, but there was a decrease when potassium fertilization was increased. Fruits 5, 6 and 8 months old presented means close to 1.5 (Figure 1C). The sugar-acid ratio of fruits is determined by sugar and acid metabolism, which gives fruits characteristic taste and flavour. Balanced crop nutrition programmes help growers manage an acceptable SS/ATT balance in the coconut water (Ronggao et al., 2015).

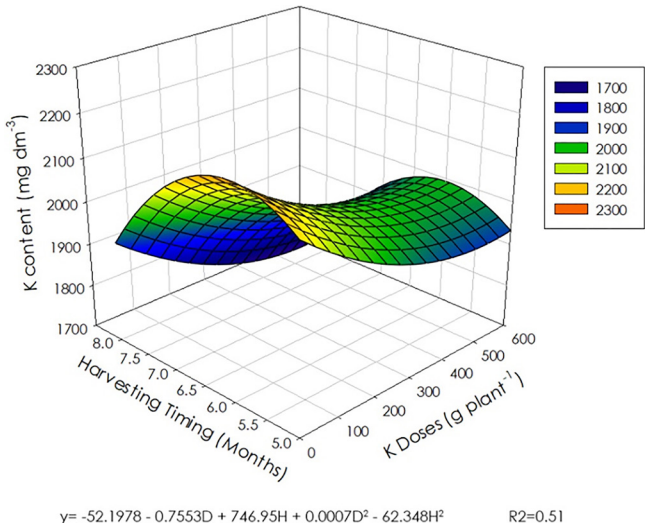
Electrical conductivity slightly increased with fertilization. The harvesting times were adjusted to the quadratic regression model, except for 8 months old fruits, where they presented averages around 6.5 to 7 dS m^{-1} (Figure 1D). The electrical conductivity is similar to that found by Ferreira Neto et al. (2007), where it decreased with the increase of the potassium dose, where fruits harvested at 7 months old had an average electrical conductivity of 5.23 dS m^{-1}.

The electrical conductivity raised among harvest timing, likely due nutrients uptake such potassium, chlorine and sodium, which act onto conducting capability. Silva et al. (2006) reported that due to the lack of studies evaluating the electrical conductivity it is still not possible to determine the best value for this variable, however, the electrical conductivity can be considered of great importance, influencing the taste and the nutritive value of coconut water.

The potassium content of coconut water decreased as the doses increased for all harvesting times. The higher K content (2,185.02 mg dm^{-3}) was found in 6 months old fruits without fertilization. It verifies a difference in the potassium accumulation in water of 190 mg dm^{-3}, between doses 0 and 600 g plant^{-1} (Figure 2). According to the current Normative Instruction this result is within coconut water identity and quality standard with maximum potassium content allowed for integral coconut water (2,300 mg dm^{-3}) (BRASIL, 2020).

The potassium is exported in greater quantity by the fruits and its content is important for improving the sensorial quality of the water of this fruit. The translocation of sugars is increased by higher potassium content, which increases the appreciation of this product by the

consumer (Aroucha et al., 2014), but it is verified that its availability to the plants affects the absorption and the accumulation of this nutrient by the fruits resulting in detriment to sugar accumulation.



y= -52.1978 - 0.7553D + 746.95H + 0.0007D² - 62.348H² R2=0.51

Figure 2. Potassium content (K) of dwarf-green coconut water as a function of potassium doses and harvest timing. D=K doses. H=Harvest timing.

Figure 3 shows similar responses for fruits at 8 months old in relation to the accumulation of Calcium and Magnesium. There was an increase in the contents of these nutrients with higher potassium doses. The maximum point of the curve for the calcium content was 326.47 mg dm^{-3} in the dose 499.18 g $plant^{-1}$ (Figure 3A), whereas the magnesium content increased linearly, presenting at the dose of 600 g $plant^{-1}$ the largest accumulation which was 326.25 mg dm^{-3} (Figure 3B).

Sodium accumulation occurred inversely to potassium doses increasing, presenting the higher content (347.18 mg dm^{-3}) at dose 134 g $plant^{-1}$ in 8 months old fruits (Figure 4A). Among harvesting times, chlorine was most accumulated nutrient (118.98 mg dm^{-3}) in fruits at 5 months old at 233.37 dose of potassium (Figure 4B). According to Normative Instruction to integral coconut water production the maximum sodium content is 300 mg dm^{-3} (BRASIL, 2020). In this sense, 8 months fruits are not allowed to water production or must be blended with lower sodium content water.

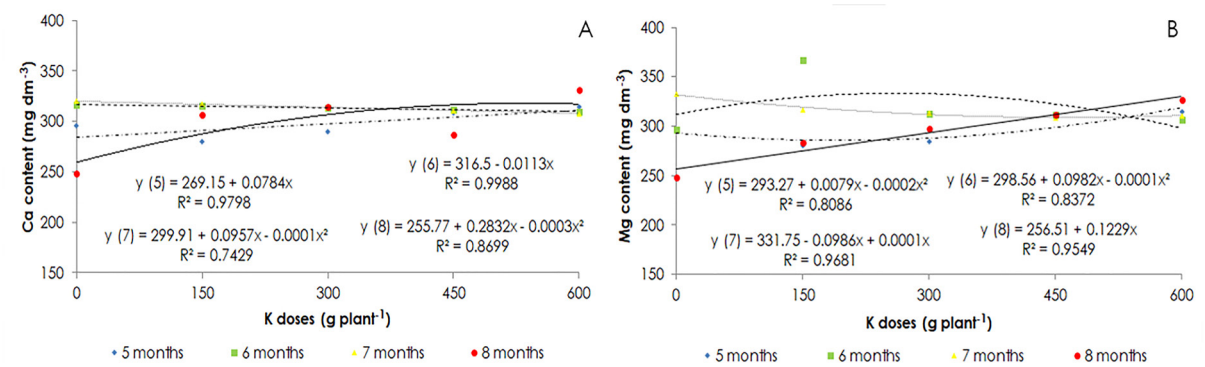
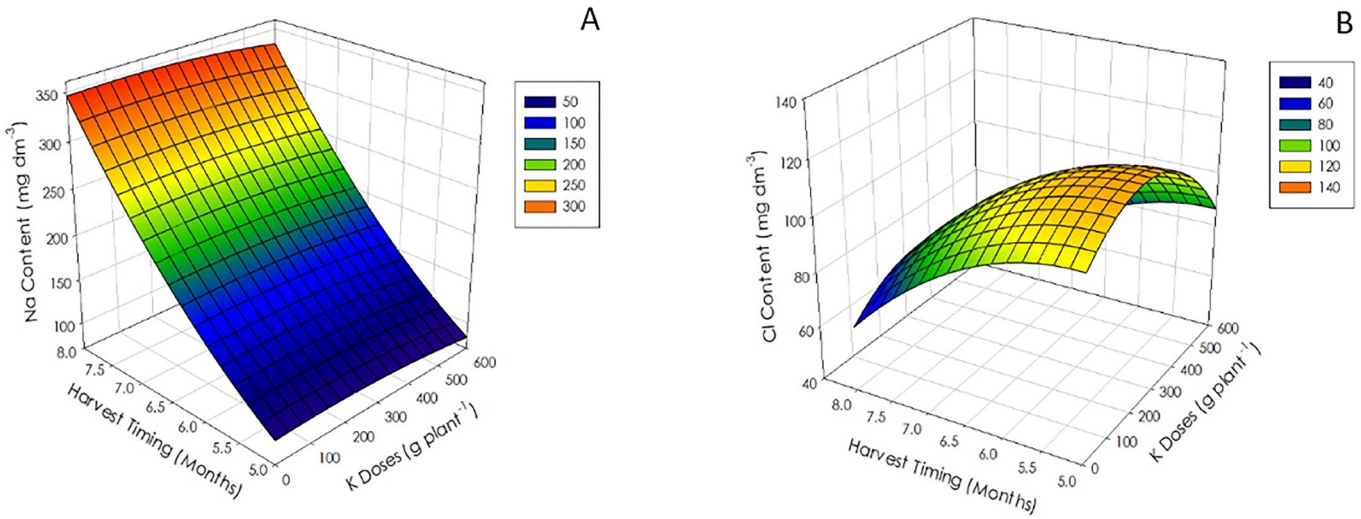


Figure 3. Calcium (A) and Magnesium content (B) of dwarf-green coconut water as a function of potassium doses and harvest timing.



9.7213 + 0.0172D - 50.0178H - 0.0063D² + 10.2570H² R^2= 0.92 v= -21.6766 + 0.1138D + 50.1127H - 0.0002D² - 4.9285H² R^2=0.71

Figure 4. Response surface of Sodium (A) and Chlorine content (B) of dwarf-green coconut water as a function of potassium doses and harvest timing. D=K doses. H=Harvest timing.

The mineral content of coconut water shows changes during the ripening process of the fruit. Potassium is the most abundant electrolyte during all maturation, sodium presents an increase, calcium, magnesium, chloride, iron and copper are stable during the maturation process and the sulfur has a slow increase (Prades et al., 2012).

According to Srebernich (1998), the levels of K, Ca, Mg, Mn and Zn minerals in coconut water are dependent on all factors (variety, crop and age), and while the potassium content increases, the other minerals decrease with the increase of the age of the fruit. The author also reports that the levels of sodium and copper increase with the age of the fruit. According to Jackson et al. (2004), the interaction of variety and stages of maturation have a significant effect on the composition of coconut water, the great variability in the composition of coconut water is influenced not only by the maturation of the fruit, but also by the composition of the soil where the plant is cultivated.

There was an isolated effect from the fruit harvest time for the pH variable, where the curve showed a quadratic effect in which there was an increase in pH up to the maximum point from 5.92 to 6.7 months old, around 201 days (Figure 5).

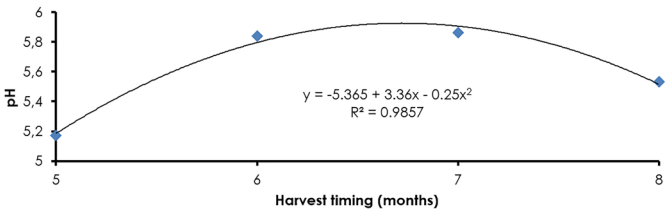


Figure 5. pH of dwarf-green coconut water as a function of harvest timing.

The pH was higher than those found by Aroucha et al. (2014) and Silva et al. (2009b), in coconut water of the dwarf green cultivar harvested in the Northeast in the 6 and 7 months old with average values of 5.16 and 4.96, respectively. In addition, these values agree with pH range of 4 up to 6.5 to physical-chemical parameters for the marketing of integral coconut water (BRASIL, 2020). This may have occurred in the alkalinizing effect of potassium (Daudt & Fogaça, 2008) in coconut water, affecting pH. However, Prades et al. (2012), showed several studies in coconut, with pH ranged from 5.1 to 6.1, average of 5.5, which is similar with our results.

Overall, potassium fertilization did not increase the quality parameters of coconut water, mainly due potassium content in the soil. Although potassium present major effect over production, imbalanced nutrition with potassium (K) is well known and becoming an important constraint to crop (Cakmak, 2010). According to Ribeiro et al. (1999), the range of 70 to 120 mg dm³ of K is considered ideal, in this study soil presented 115.6 mg dm³ (Table 1).

Conclusions

Under the conditions studied, higher doses of potassium decreased qualitative characteristics of coconut water. The optimal harvest time is between 6 and 7 months old.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.