

Biochemical profile of coconut water from coconut palms planted in an inland region

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Abstract

Objective: To analyze the biochemical profile of coconut water from dwarf coconut palms planted in non-coastal regions, during the maturation period (sixth to ninth month).

Methods: Eight of 15 coconut palms planted in a non-coastal region were selected by lots and their coconuts sent to a laboratory for extraction and analysis of the coconut water. Coconut water from a total of 45 coconuts, from the sixth to ninth months' maturity, were analyzed to measure glucose, electrolytes, total proteins and osmolarity and to identify the sugars contained.

Results: The analysis of coconut water from the sixth to ninth month did not find any differences in the median concentrations of sodium (3 mEq/L; 2 and 3), glucose (0.6 g/L; 0.3 and 17.3) or total proteins (9 g/L; 6 and 12), but detected a reduction in the concentration of potassium (64 mEq/L; 46 and 99), calcium (6.5 mmol/L; 5 and 8.5), magnesium (8 mmol/L; 3.9 and 9.8), chloride (38.5 mEq/L; 30 and 48.7) and osmolarity (419 mOsmol/L; 354 and 472). With relation to the sugars, identified by chromatography on paper, an increase was observed from the sixth to the ninth month in the concentration of fructose (68 mg/ μ L; 44 and 320) and glucose (299 mg/ μ L; 262 and 332) and in conjunction with a concentration of sucrose (340 mg/ μ L; 264 and 390).

Conclusions: The biochemical profile of coconut water varied as the coconuts matured, observing reductions in the concentration of potassium, calcium, magnesium, chloride and osmolarity. Descending paper chromatography revealed an increase in the concentration of fructose and glucose and also a reduction in the concentration of sucrose.

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Introduction

The coconut palm is considered the tree of life, since it is one humanity's principal vegetable resources. Every part of this plant can be utilized: roots, husk, leaves, inflorescence and fruit.¹ The fruit of the dwarf coconut palm, particularly the green dwarf coconut palm, are cultivated for their liquid content, whereas the fruit of the giant coconut palm and the hybrids are cultivated for their albumin, which can be used *au naturelle* or processed into grated dried solids or coconut milk.² Flavor varies depending on the stage of maturation of the fruit.

Coconut water is the juice of the endosperm found within the cavity of the coconut, which begin to form around 2 months after the natural opening of the inflorescence. According to research, coconut water accounts for 25% of the weight of the fruit, and its basic composition is 95.5% water, 4% carbohydrates, 0.1% fat, 0.02% calcium, 0.01% phosphorous, 0.5% iron, in addition to amino acids, vitamin C, B complex vitamins and mineral salts.¹

In some countries coconut water is used as a solution for oral hydration, as part of the daily diet and as a protein supplement when nutritional deficits are intense. During the Second World War, coconut water was even used instead of saline solution during emergency surgeries.¹

Some studies suggested that coconut water can be used for intravenous rehydration.^{3,4} Other studies suggest that coconut water can be used for electrolyte replacement in a wide range of situations.⁵⁻⁷ Studies have compared the chemical composition of coconut water with teas,⁸ still soft drinks,⁷ carbonated soft drinks,^{7,8} isotonic drinks⁹ and oral rehydration solution (ORS).¹⁰

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There are a small number of studies that have related the composition of coconut water to the stage of maturation of the coconut^{6,11} or with the region where the coconut palms grow (coastal or inland).^{6,12}

We therefore decided to carry out the current study with the following objectives: to analyze the biochemical profile of coconut water from dwarf coconut palms planted in inland areas at different stages of maturation of the coconuts, from the sixth to the ninth months; to determine the concentrations of sodium, potassium, chloride, calcium, magnesium, glucose, total proteins and osmolarity of coconut water from the sixth to the ninth months; to identify the sugars contained in coconut water from the sixth to the ninth months.

Methods

This was a cross-sectional study analyzing coconut water from coconut palms in inland regions. Eight of the fifteen coconut palms growing at the Lagoa Azul farm, which is on the banks of the River Araguaia, in the municipality of Britânia, (Goiás state, Midwest Region, Brazil) were chosen for the study by lots. At least one coconut from each palm was to be analyzed at different stages of maturity from the sixth to the ninth months. As a result of climatic issues in the Midwest Region of Brazil, the maximum number of coconuts obtained at eight and nine months was four and five, respectively. The coconuts were air freighted to the laboratory, arriving a maximum of 24 hours after being harvested. Immediately upon arrival at the laboratory they were perforated and the fluid collected for analysis.

Concentrations of the following electrolytes were assayed: sodium, potassium, chloride, calcium and magnesium. The concentrations of glucose and total proteins were also determined, together with the osmolarity of the coconut water. Sodium and potassium were assayed by flame photometry,¹³ and chloride was determined by the Schales & Schales titrimetric method.^{14,15} Glucose assays were by enzymatic reaction with glucose oxidase and peroxidase;¹⁵⁻¹⁷ calcium was measured by the o-cresolphthalein complexone method;^{15,18} magnesium, by the magnon-sulphonade method^{15,19} and total proteins with biuret reagent,^{15,20} and in all cases analysis was performed by spectrophotometry. Osmolarity was measured with a freezing point osmometer.¹³ We employed descending paper chromatography^{21,22} to identify the following sugars: fructose, glucose, sucrose and galactose.

The comparison between different months of maturity was made using the Kruskal-Wallis test, complemented by Dunn's multiple comparison test using Jandel Sigma Stat software.²³

Significance was defined at less than 5%. The study was approved by the Research Ethics Committee at the Universidade Federal de São Paulo – Escola Paulista de Medicina.

Results

Table 1 lists median values (with 25th and 75th percentiles) for the study parameters and also the level of significance of statistical differences,²³ broken down by maturity.

Increases were observed in the median volume of coconut water, the weight of the coconut shells and the total weight of the coconuts, as they matured. Thus, the more mature the coconut, the greater the volume of coconut water, the heavier the shell and the heavier the total weight.

The analysis of electrolytes did not reveal any difference in the median (with 25th and 75th percentiles) sodium concentration (3 mEq/L; 2 and 3) of the coconut water as the coconuts matured, and it should also be pointed out that these concentrations were low throughout the study period. Differences were observed in the median concentration of potassium (64 mEq/L; 46 and 99), calcium (6.5 mmol/L; 5 and 8.5), magnesium (8 mmol/L; 3.9 and 9.8) and chloride (38.5 mEq/L; 30 and 48.7) in the coconut water. The concentration of these electrolytes dropped from the sixth to the ninth month of maturation, and the elevated concentration of potassium during all months stood out.

An increase was observed in the median (with 25th and 75th percentiles) glucose concentration of coconut water (0.6 g/L; 0.3 and 17.3) from the sixth to the ninth month of maturation, and there were no differences between the median concentrations of total proteins (9 g/L; 6 and 12) for the months studied. The median osmolarity of the coconut water (419 mOsmol/L; 354 and 472) was observed to reduce from the sixth to the ninth month of maturation.

With relation to the sugars identified by descending paper chromatography, the presence of fructose, glucose and sucrose were all detected in the coconut water. An increase was observed in the median concentration of fructose (68 mg/μL; 44 and 320) and glucose (299 mg/μL; 262 and 332) as the months passed, while sucrose concentration (340 mg/μL; 264 and 390) reduced between the sixth and ninth months of maturation of the coconut.

Discussion

Coconut water is often used as an alternative solution for oral rehydration, particularly in regions where mothers' knowledge of oral rehydration is lacking, thus avoiding incorrect preparation of sugar-salt solutions.^{24,25}

Table 1 - Median values (with 25th and 75th percentiles) for each of the parameters investigated, broken down by coconut maturity

| | Maturity in number of months | | | | | | | | p | Comparisons between months where p < 0.05 † |
|----------------------|------------------------------|----------|------------|----------|-----------|----------|-----------|-----------|---------|---|
| | 6 (n = 18) | | 7 (n = 18) | | 9 (n = 4) | | 9 (n = 5) | | | |
| | Median | 25-75 | Median | 25-75 | Median | 25-75 | Median | 25-75 | | |
| Total weight (g)* | 526 | 486-478 | 627 | 442-984 | 1173 | 761-1586 | 1627 | 1214-1956 | 0.053 | |
| Weight of shell (g)† | 407 | 363-535 | 527 | 393-777 | 898 | 635-1212 | 1203 | 962-1556 | 0.016 | 6 x 9 |
| Volume (ml)* | 55 | 30-110 | 80 | 19-370 | 272 | 130-365 | 325 | 225-380 | 0.061 | |
| Sodium (mEq/L)* | 2.5 | 2.0-3.0 | 2.5 | 2.0-3.0 | 3.5 | 2.5-5.5 | 2 | 1.8-3.2 | 0.618 | |
| Potassium (mEq/L)† | 100 | 80-125 | 51 | 43-65 | 40 | 37-44 | 49 | 44-69 | < 0.001 | 6 x 9 |
| Chloride (mEq/L)† | 47 | 40-58 | 31 | 25-43 | 38 | 30-39 | 30 | 24-34 | < 0.001 | 6 x 9 |
| Calcium (mmol/L)† | 5.3 | 4.4-7.2 | 8.1 | 6.5-10.6 | 7 | 5.6-9.4 | 4.6 | 2.8-5.4 | 0.003 | 6 x 7; 7 x 9 |
| Magnesium (mmol/L)† | 9.8 | 9.2-10.3 | 5.6 | 4.3-9.3 | 3.4 | 3.2-4.1 | 3.4 | 2.1-4.3 | < 0.001 | 6 x 7; 6 x 8; 6 x 9 |
| Glucose (g/L)* | 0.4 | 0.2-2.3 | 0.9 | 0.3-18.0 | 13.5 | 4.6-19.0 | 16.5 | 12.1-17.9 | 0.097 | |
| Proteins (g/L)* | 9.5 | 8.0-15.0 | 9 | 5.0-12.0 | 5.5 | 4.0-10.5 | 6 | 6.0-7.5 | 0.118 | |
| Osmolarity (mOsm/L)† | 452 | 385-485 | 421 | 358-470 | 282 | 205-346 | 406 | 358-423 | 0.037 | 6 x 8 |

* Kruskal-Wallis test.

† Multiple comparison tests (Dunn's method).

The majority of studies that analyzed the composition of coconut water did not mention the location where the trees were planted,^{3-5,7-10} although some did state that they studied coastal coconuts^{6,11,12} and a single study analyzed inland coconuts.¹²

The median sodium concentration observed in coconut water in this study was very similar to all of the previously-published research,^{3-5,8-12} varying from 0.4 to 14.8 mEq/L, with the exception of one study that found an elevated mean sodium concentration (32.5 mEq/L).⁷ Comparing the composition of the ORS recommended by the World Health Organization (WHO)²⁶ (Table 2) with the results of studies that have analyzed coconut water, it will be observed that the sodium concentration in the coconut water is far below that in the ORS and that, in the results from the current study, the figure is practically 30 times lower (Table 2).

Since the first study of the chemical composition of coconut water, the mean observed potassium concentration has always been above 30.0 mEq/L. There was no difference between the potassium concentration of coconut water from coastal and inland palms, nor between more and less mature coconuts.^{6,11} No significant difference was observed between the potassium concentration of the coconut water studied here and the results of other studies, irrespective of whether they used coastal or inland coconuts. In the results of the current study, in common with those of the others, potassium concentration was above that in rehydration oral salts (20 mmol/L) (Table 2).

On the other hand, both in this study and in other publications, the chloride concentration was below that recommended by the WHO for ORS, with a decline in observed concentrations during the present study from the sixth to the ninth month of maturation of the coconut.

The glucose concentration of coconut water varies (0.01 to 40.3 g/L) in studies that analyzed coconuts from inland and coastal regions. In the current study the concentration of glucose was below what is recommended for ORS by the WHO at all different stages of maturation of the coconuts (Table 2).

We found that this study and all the others recorded coconut water osmolarity values above 280 mOsm/L. Comparing the osmolarity of coconut water and the WHO ORS, we observe that the majority of studies published figures above the recommended level – including the current study.

Currently the WHO recommends a reduced ORS, with lower concentrations of glucose and sodium and, consequently, lower osmolarity²⁷ (Table 2). When we compared the coconut water studied here with that solution, we observed that the potassium concentration is at least twice that of the reduced ORS, while the sodium concentration is at best 18 times less than the recommended level. With relation to chloride, concentrations were lower than in the reduced ORS, in particular from the seventh to the ninth months, at around half that recommended by the WHO. The concentration of glucose reached levels close to that in the reduced ORS by the eighth and ninth months

Table 2 - Results for electrolytes and glucose concentrations and osmolality of coconut water from coconuts at varying stages of maturity, as observed by this study and as published by others, together with the composition of the World Health Organization oral rehydration solution

| Authors | Maturity | Sodium mEq/L | Potassium mEq/L | Chloride mEq/L | Calcium mmol/L | Magnesium mmol/L | Glucose g/L | Osm mOsm/L |
|------------------------------------|----------|-----------------|--------------------|-------------------|-------------------|---------------------|----------------|---------------|
| Vigliar et al. | 6 m | 3 | 98 | 48.7 | 6 | 9.4 | 2.9 | 422.7 |
| | 7 m | 3.1 | 62.1 | 36.3 | 8.6 | 6.4 | 9.2 | 419.6 |
| | 8 m | 4 | 40.2 | 34.4 | 7.5 | 3.6 | 11.8 | 275.8 |
| | 9 m | 2.4 | 57.2 | 28.8 | 4.4 | 3.4 | 14.2 | 395.4 |
| Kuberski et al. ⁶ | 5 m | 1.1 | 44.8 | - | 4.8 | 5.5 | 22.3 | - |
| | 6 m | 0.4 | 45.1 | - | 4.9 | 5.4 | 22.1 | - |
| | 7 m | 2 | 54.3 | - | 5.2 | 4.7 | 24.8 | - |
| | 8 m | 2.5 | 51.9 | - | 5.4 | 5 | 23.9 | - |
| | 9 m | 5.8 | 53.8 | - | 5.9 | 5.2 | 21.4 | - |
| Msengi et al. ¹² | 10 m | 6.9 | 51.5 | - | 5.8 | 5.4 | 7.6 | - |
| | ±7-8 m | 0.5 | 82 | 38.3 | 3.7 | 14.4 | 28.6 | - |
| Fagundes Neto et al. ¹¹ | ±7-8 m | 0.8 | 82 | 38.8 | 3.6 | 12.4 | 27.5 | - |
| | 5 m | 2.9 | 64.9 | 44.8 | 4 | 1.7 | 25.9 | 362.9 |
| | 6 m | 1.3 | 61.7 | 43.7 | 3 | 1.5 | 37.3 | 372.7 |
| | 7 m | 5 | 66.9 | 48.4 | 3.2 | 1.9 | 40.3 | 402.4 |
| | 8 m | 11.2 | 65.8 | 50.4 | 3.2 | 1.8 | 33.9 | 384.7 |
| | 9 m | 14.8 | 54.9 | 41.2 | 2.6 | 2 | 22.1 | 336.8 |
| | 10 m | 12.6 | 54.2 | 37.1 | 3.6 | 2.3 | 10.8 | 325.9 |
| | 11 m | 13.6 | 54.2 | 19.4 | 3.7 | 2.6 | 2.7 | 319.7 |
| 12 m | 13 | 42.7 | 39.7 | 3.2 | 1.8 | 0.4 | 290.3 | |
| ORS-WHO ²⁶ | - | 90 | 20 | 80 | - | - | 20 | 311 |
| Reduced-ORS-WHO ²⁷ | - | 75 | 20 | 65 | - | - | 13.5 | 245 |

ORS = oral rehydration solution; Osm = osmolality; WHO = World Health Organization.

of maturation. The osmolality of the coconut was almost double that of the reduced ORS, with the exception of the eighth month.

In a Brazilian study that analyzed coconut water from a coastal region at different stages of coconut maturation,¹¹ some components of the coconut water varied considerably. Osmolality in that study was above 300 mOsm/L throughout (probably because of the high concentrations of carbohydrates), and this study also observed similar levels. The glucose concentration in that study passed 200 mmol/L (35 g/L), whereas in this study the maximum level observed was 79 mmol/L (14 g/L). Sodium concentration was low throughout the maturation process, also confirmed here. The differences may be the result of the location of cultivation, in the study by Fagundes Neto the palms were at the coast and in this study they are planted inland.

Research by Kuberski⁶ identified the sugars contained in coconut water, detecting glucose, sucrose and fructose in the proportion of approximately 50, 35 and 15%, respectively, but their study did not relate whether these

proportions remained constant during different months. The current study found that the proportions of these sugars varied depending on the stage of maturation of the coconuts: glucose, from 34 to 45%; sucrose, from 53 to 18% and; fructose, from 12 to 36%.

The majority of studies did not analyze trace elements such as calcium and magnesium. The concentration of these trace elements did not exceed 17 mmol/L in the coconut water studied by many of the authors mentioned,^{3,6,7,11,12} in common with this study. Taking into account reference daily nutrient intakes,²⁸ according to age group and calcium and magnesium concentrations during the seventh month, it is possible that nutritional deficiencies of these trace elements could be prevented by the daily ingestion of coconut water.

Before ending, we emphasize that the results of this study should be analyzed and interpreted with prudence, taking account of the possible limiting effect of the lower number of coconuts analyzed at months eight and nine. This was the result of climatic conditions in the Midwest Region of Brazil, where it did not prove possible to obtain

a larger number of coconut water samples during those two months. On the subject of the total number of green coconuts analyzed to construct a biochemical profile of coconut water, four^{5,6,8,10} of the seven^{3,5,6,8,10-12} studies that mentioned the number of coconuts analyzed, the median (percentiles 25 and 75 in parenthesis) was eight (5.5-32.5) coconuts. It should be pointed out that the only study in the literature that employed coconuts from inland areas used 25 of them, but that study did not analyze them at different stages of maturity. On the other hand, the present study analyzed a total of 45 coconuts, which were studied at different stages of the maturation process, and it was factors related to the climate that barred the investigation of a larger number of coconuts during the last months of maturation. Further studies should be carried out to better characterize the biochemical profile of the water in green inland coconuts at different stages of maturity.

In conclusion, the biochemical profile of the coconut water from dwarf coconut palms planted in an inland region varied from the sixth to the ninth month of maturation, with reductions observed in the concentrations of potassium, calcium, magnesium, chloride and in osmolarity, from the sixth to the ninth month. The elevated concentration of potassium means that coconut water could possibly be used to replace that electrolyte. Daily consumption of coconut water may possibly prevent nutritional deficiencies of calcium and magnesium. When we compared coconut water with ORS, we observed that neither the concentrations of glucose, sodium, potassium and chloride, nor the osmolarity of the coconut water from inland palms met the WHO recommendations for ORS.

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