Coconut water: production, nutritional properties and health benefits

Água de coco: produção, propriedades nutricionais e benefícios para a saúde

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ABSTRACT
Coconut water (Cocos nucifera L.) is an undiluted, non-fermented beverage obtained from the liquid part of the coconut fruit. It is a versatile product in the industry and has been growing economically due to its functional character. The objective is to identify in the scientific literature different aspects of coconut water production and its nutritional characteristics applied to health. A narrative review of the literature was carried out, using the databases Scielo, Scopus, Repositório Alice da EMBRAPA, Periódicos CAPES and Google academic, applying the descriptors, coconut water, nutrition, composition, health, health benefits, economy, pasteurization, ultrapressure, ultrasound, ozone and their respective names in English, considering the Boolean operators “OR” and “AND”. Titles and abstracts were screened, considering the eligibility criteria: full text available in English and/or Portuguese; paid and/or free access; dissertations and theses, narrative, systematic review, observational and longitudinal studies, including clinical trials. Non-thermal processing methods were effective in maintaining the shelf life of the beverage, however ultrapressure showed alterations in the physical functionality and/or changes in the color of protein-rich foods. The presence of phytohormones, vitamins and amino acids
was detected, which are responsible for the antioxidant property of the product, as well as the beneficial effects on health. New studies are proposed to evaluate the effects of coconut water on human health, as it is a drink with market potential and accessible to consumers.

**keywords:** coconut water, production, health.

1 INTRODUCTION

Coconut water is an undiluted and non-fermented beverage obtained from the liquid part of the coconut fruit (Cocos nucifera L.), through an appropriate technological process (Brasil, 2020).

It has become a fashionable drink, known for its nutritional properties and a good source of fiber, vitamin C and several important minerals, in particular potassium and manganese (Alchoubassi et al., 2021). The highest concentrations of trace elements found were manganese, which makes coconut water a natural source of this element, covering
almost the entirety of the daily reference intake of manganese recommended by the European Food Safety Agency (3 mg/day) (European Food Safety Authority (EFSA), 2013).

Brazil is the fifth largest producer of coconut, with a share of 4.5% of the total world. Over the last decade, the annual growth of the activity was 0.8% of the harvested area and 0.1% of the world coconut production (Brainer & Ximenes, 2020). Coconut palm is being cultivated in almost all of Brazil, whose current area is 187.5 thousand ha with production of 1.6 billion fruits. In the Northeast region are concentrated, 80.9% of the country's coconut harvested area and 73.5% of its production (Brainer, 2021).

Coconut food products have been gathering supporters due to the availability of numerous forms of presentation, brands on the market, pleasant characteristics to the taste, digestive disorders issues, such as: intolerance and allergy to lactose and gluten. Another audience that has emerged in the sector are vegan and vegetarian consumers who base their diet on the consumption of vegetables, nuts and cereals and seek dairy-free products (without milk from animal sources), in addition to high performance athletes who use coconut as an electrolyte replenisher (de Oliveira, 2019).

Coconut water, in its natural form, have several beneficial effects on human health. It has a unique composition and can be used as an intravenous hydration. It has antidiabetic, antihyperlipidemic and beneficial effects on the digestive system (Rao & Najam, 2016).

Evidence points out that coconut water contains folate, phytohormones, cytokines, auxins and several other bioactive compounds that are of medicinal importance and have promising potential in improving human (Fowoyo & Alamu, 2018).

Thus, taking into account that coconut water is a product that has been growing economically over the years and has an appeal for being a beverage with functional and nutritional characteristics, the present study aimed to review the scientific literature on the different aspects of coconut water production and its nutritional characteristics applied to health.
2 MEODOLOGY

The present study will present a narrative review of the literature. For the elaboration, a consultation was carried out in the electronic databases Scielo, Scopus, Repository Alice da EMBRAPA, CAPES Periodicals and Google academic using the descriptors, coconut water, nutrition, composition, health, health benefits, economy, pasteurization, ultrapressure, ultrasound, ozone and their respective names in English, being considered Boolean operators “OR” and “AND” for combination of subjects.

A narrative review concerning the nutritional and technological aspects of vegetable oils with a predominance of medium-chain triacylglycerols used as a basis only scientific articles searched in electronic databases such as: Scopus, Scielo, Science Direct, Web of Science and Online Library Wiley (Lima et al., 2021). The criteria adopted for the selection of articles included publications in the English language, preferably between the years 2015 to 2021, relevant and recent research in the nutritional and technological area on the use of medium-chain fatty acids.

The selection of studies was initially carried out by screening the titles and later reading the abstracts, considering the following criteria: full text available in English and/or Portuguese; paid and/or free access; dissertations and theses, narrative review, systematic, observational and longitudinal studies, including clinical trials. With regard to exclusion criteria, abstracts of any order were rejected; works presented in congresses, symposia and included in proceedings; graduation studies assignments research outside the defined language. During the research, a lower time limit was not established for the search for articles. At the end of the search, the studies that met the inclusion criteria were added to a spreadsheet to facilitate data management.

3 RESULTS AND DISCUSSION
3.1 COCONUT PRODUCTION

Data provided by FAOSTAT, [s.d.] report that the world area harvested with coconut is 11.8 million hectares, producing 62.9 million tons. Only Indonesia, Philippines and India occupy 73.0% of this area and participate with 74.1% of world production.
The sale of coconut water throughout Brazil in 2020 was 21.9 tons, almost the same amount as the previous year. However, revenue was higher due to the 19.6% increase in price, possibly because of the increase in production costs related to imported inputs (Brainer, 2021).

The COVID-19 pandemic in 2019/2020 affected sales of packaged coconut water worldwide, especially in the US and EU, where the market is better established. The high demand scenario with a shortage of coconuts sold at a higher price went through a crisis during the pandemic period, in which supply did not meet demand. In Brazil, due to social isolation, there was a drop in demand, cancellation of orders and harvest interrupted because buyers suspended business, with a consequent fall in the price of coconut. Most farmers lost sales during the first quarter of 2020 and are still being affected by uncertain market conditions. Even in the face of favorable weather conditions for good production, the financial return will take longer, due to the difficulty of offering products at more remunerative prices, to a population that has low purchasing power (Brainer & Ximenes, 2020).

Among the varieties of the species Cocos nucifera L., the dwarf coconut tree is used mainly in the production of coconut water because it has superior sensory characteristics compared to other cultivars. The giant coconut tree is the most used in the fresh consumption of dried pulp, as well as in industrial use, to obtain derivatives such as coconut milk, from grated coconut. Meanwhile, the hybrid coconut tree (dwarf x giant) has been recommended for its dual aptitude based on parental characteristics, that is, to produce coconut water and dry coconut depending on the physiological maturity of the fruit at harvest (de Oliveira, 2019).

The giant coconut tree reaches between 20 and 30 meters in height, and can produce up to 80 fruits a year, with an economic life of 60 to 70 years. The dwarf coconut tree reaches up to 12 meters in height and has a useful life between 30 and 40 years. The main advantage of the dwarf variety is that the beginning of average production takes place two to three years after planting, while the production of the giant variety takes five to seven years (G. A. da Silva & Landau, 2020). Table 1 shows the differences between the dwarf, giant and hybrid cultivars.
Table 1. Characteristics of coconut cultivars.

<table>
<thead>
<tr>
<th>Characteristics/Cultivars</th>
<th>Dwarf</th>
<th>Hybrid</th>
<th>Giant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning of flowering (years)</td>
<td>2 to 3</td>
<td>3 to 4</td>
<td>5 to 7</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>30 to 40</td>
<td>50 to 60</td>
<td>60 to 70</td>
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<tr>
<td>Fruit size</td>
<td>Small</td>
<td>Medium/Large</td>
<td>Large</td>
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<tr>
<td>Growth</td>
<td>Slow</td>
<td>Intermediary</td>
<td>Fast</td>
</tr>
<tr>
<td>Size (height)</td>
<td>10 to 12 m</td>
<td>20 m</td>
<td>20 to 30 m</td>
</tr>
<tr>
<td>Production (fruits/years)</td>
<td>150 to 200</td>
<td>130 to 150</td>
<td>60 to 80</td>
</tr>
<tr>
<td>Average fruit weight</td>
<td>900 g</td>
<td>1200 g</td>
<td>1400 g</td>
</tr>
<tr>
<td>Destination</td>
<td>Water</td>
<td>Water/Agroindustry/Cooking</td>
<td>Agroindustry/Cooking</td>
</tr>
</tbody>
</table>

Source: (APROCOCO, 2020).

A coconut consists of three layers of husk, namely: exocarp, mesocarp and endocarp. The outermost layer, normally smooth with a greenish color, is called the exocarp. The middle layer is the fibrous bark, or mesocarp, that surrounds the hard woody layer called the endocarp. Inside the endocarp are the solid endosperm, which consists of coconut pulp, and the liquid endosperm, formed by coconut water. A soft coconut is one with a maturity of 6 to 9 months and its water is either consumed directly or processed into a variety of beverages (Zhang et al., 2020). In figure 1 it is possible to observe three types of cultivars of red dwarf coconut, yellow dwarf and green dwarf, which is the most used to obtain coconut water.

Figure 1 - Detail for the color of the epicarp (outer part) which represents one of the between Dwarf Red, Dwarf Yellow and Dwarf Verde cultivars (from left to right in the photo).

Source: (Embrapa et al., 2018).

The action of food enzymes, such as polyphenol oxidases (PPO) and peroxidases (POD), plays a key role in decreasing the storage time and market potential of coconut water. The catalytic activities of both enzymes have many unpleasant effects on coconut water, even during cold storage. Likewise, pink color formation, browning, off-notes and
odors are certain questionable outcomes of catalytic functions and microbial activity (Rojas et al., 2017).

Soft coconut water is highly sensitive to microbial attack within hours of its extraction from the fruit, which in turn results in the loss of nutritional components as well as a shortened shelf life (Mahnot et al., 2019). In this regard, certain substances inherent in coconut water, such as antimicrobial peptides and lauric acid, have been reported to act as an inhibitor of the growth of microbial strains (Raghubeer et al., 2020).

Therefore, it is essential to preserve the sensory and nutritional quality of the drink. Thermal processing methods are the most used preservation techniques for coconut water. However, these treatments decrease the general acceptance of the product and, at the same time, reduce its qualities (Ribeiro et al., 2017). For this reason, the industry has invested in non-thermal processing methods that aim to extend the shelf life of coconut water, but without causing sensory changes.

3.2 THERMAL PROCESSING METHODS

Thermal processing is the most commonly used approach to the manufacture and preservation of fruit and vegetable products. It includes several methods, which can be applied to solid or liquid foods (60 °C–200 °C), such as: steaming, cooking, boiling, roasting, microwaves, and the most common ones such as pasteurization and sterilization (Richardson, 2001).

3.2.1 Pasteurization

Pasteurization conditions are designed to inactivate the most heat-resistant, non-spore-forming pathogens and spoilage bacteria (H. C. Deeth & Lewis, 2017). Pasteurization processes can be categorized as low temperature, long time (LTLT; 62–65 °C for at least 30 min) or high temperature, short time (HTST; 72–82 °C for 15–30 s) pasteurization followed by rapid cooling to less than 10°C (Sun, 2005). One of the issues that has drawn the attention of industries concerns the appearance of a pinkish or brownish color in coconut water subjected to refrigerated storage at a temperature of 3 oC to 5 oC. Since, normally, a product treated by a HTST-type heat treatment undergoes
oxidation reactions or sugar caramelization during the heating phase (Abreu & Souza, 2017).

A study (Abreu & Souza, 2017) showed that the HTST thermal treatment allowed a shelf life of 30 days for coconut water without preservatives and under refrigeration at a controlled temperature of 4 °C (± 1 °C), which is established as a reference temperature for the conservation of products refrigerated foods on a commercial scale. However, it was observed that this temperature indication is not properly followed when the product is displayed on supermarket and store shelves and points of sale.

3.2.2 Sterilization

Sterilization is a heat treatment that aims to produce a commercially sterile product with an extended shelf life. This can be achieved by vessel sterilization (110–116 °C for 20–30 min) or ultra-high temperature (UHT) treatment (135–145 °C for 1–10 s) (H. Deeth & Lewis, 2016). Container sterilization inactivates some enzymes, results in browning due to Maillard reaction and cooked flavor (H. C. Deeth & Lewis, 2017). UHT treatment results in fewer chemical changes and a poor cooked taste, but some bacterial proteases or lipases can survive the process.

The selection of UHT processing time-temperature combinations should be based on the inactivation of heat-resistant spores with the least possible undesirable changes in physicochemical and sensory properties, as well as retention of nutritional values (Datta & Deeth, 2001; H. Deeth, 2010).

3.3 NON-THERMAL TECHNOLOGIES

Non-thermal technologies applied to coconut water are researched to address inherent limitations of conventional thermal processing. While it is agreed that thermal processing is effective in causing enzyme inactivation and providing antimicrobial effects, the demand for preserving the sensory and nutritional properties of products after treatment makes it necessary to implement emerging non-thermal technologies. Emerging food processing technologies combined with non-thermal technologies find application
in the preservation of coconut water and are in the line of commercialization (Prithviraj et al., 2021).

3.3.1 Ozone

Recognition of ozone as a GRAS (generally recognized as safe) substance in 1997, followed by FDA (Food and Drugs Administration) approval as an antimicrobial agent for direct use in food in 2001, has broadened the applications of ozone in the food industry (O’Donnell et al., 2012). Studies have shown that ozonation can be a good alternative as a non-thermal application technology, as it is relatively simple, fast and low cost, with efficient oxidizing action on microorganisms and enzymes. This action is associated with both its molecular shape and the hydroxyl, hydroperoxide and superoxide radicals generated by its decomposition (Pandiselvam et al., 2017; Prabha et al., 2015).

A Study (Rajashri et al., 2020) showed that the physicochemical and nutritional properties of coconut water were less affected by the treatment with ozone added nisin, being microbiologically safe for 3 weeks under refrigerated conditions when compared to coconut water treated with ultrasound and nisina, in which there were significantly greater losses of nutritional and functional content of coconut water. The greatest losses in ascorbic acid (62.58%), total sugars (31.81%), phenolic content (44.27%) and flavonoids (48.04%) were observed probably due to the production of free radicals that can degrade polyphenols, flavonoids, ascorbic acids, and sugars, oxidizing them.

3.3.2 High Pressure

High pressure processing, also known as high hydrostatic pressure, is a non-thermal food processing method that submits food (liquid or solid) to pressures between 50 and 1000 MPa (Considine et al., 2008).

During the high pressure treatment of certain protein-rich foods, resulting changes in physical functionality and/or changes in the color of the raw product occur that are significantly smaller than those experienced using conventional thermal processing techniques (Tao et al., 2014).
A study in which high pressure processing was applied to fresh coconut water for microbial stability and quality monitoring during cold storage showed the applicability of high pressure of 500 MPa at 5 min. In addition, the shelf life of the samples was extended to 25 days at 4 °C with a substantial delay in the loss of nutritional characteristics, such as: total amino acids, proteins, sugar, ascorbic acid, phenols and antioxidant capacity (Ma et al., 2019).

However, some disadvantages, such as: high capital investment for equipment, pressure conditions must be applied to the product properly, as inadequate values can retain microorganisms and enzymes and in order to guarantee the quality of the product, it must be transported at low temperatures (Ma et al., 2019; Raghubeer et al., 2020; Wang et al., 2016).

3.3.3 Ultrasound

Over the years, ultrasound technology has gained prominence for its potential use in the preservation of fruit juices. Studies show that high-intensity ultrasound can inactivate the main microorganisms and enzyme responsible for the deterioration reactions of products from vegetable source (Huang et al., 2017; Paniwnyk, 2017). Therefore, improvements in quality attributes and greater retention of bioactive compounds and nutrients are described in the literature.

One study (Rojas et al., 2017) evaluated the effect of ultrasound on the inactivation and sensitization of the enzyme peroxidase (POD) in coconut water. The application of ultrasound at an acoustic density of 286 W/L, frequency of 20 kHz, at 25 °C for 30 minutes achieved 27% inactivation of the POD enzyme. Ultrasound as a pre-treatment showed a positive result in reducing the thermal resistance of the POD, allowing shorter times and/or temperatures in subsequent thermal processing.

Despite this, equipment is necessary, which has a high cost, and must be of high power to ensure maximum inactivation of enzymes and microorganisms (Chemat et al., 2011; Ribeiro et al., 2017).
3.3.4 Ultraviolet Light

Ultraviolet light is a low-cost, non-thermal processing option for liquid foods used successfully to disinfect drinking water and to pasteurize fruit and vegetable juices. UVC rays between 200 and 280 nm are considered germicidal due to the formation of thymine dimers in the DNA of pathogens, causing the termination of replication, transcription and translation of the bacterial gene and resulting in the inactivation of the pathogen (Gautam et al., 2017).

A study performed in a continuous flow spiral UV reactor showed that treatment with UVC emitting 254 nm did not significantly change the physicochemical properties of soft coconut water, indicating aroma and flavor retention. Therefore, the natural properties of coconut water were not disturbed by UVC pasteurization (Gautam et al., 2017).

An investigation (Yannam et al., 2020) achieved 94 and 93% inactivation of polyphenoloxidase and peroxidase, respectively, using a fluence level of 400 mJ/cm2, in addition to showing no changes in essential amino acids. This inactivation is sufficient to prevent the pink discoloration caused by enzymatic browning in soft coconut water.

However, exposure to ultraviolet light for prolonged periods can damage the eyes and skin. In addition, it is a method that has low penetration power in food and it is difficult to predict the disinfection rate (Delorme et al., 2020; U.S. Food and Drug Administration, 2022; Yannam et al., 2020).

3.4 NUTRITIONAL COMPOSITION AND PHYSICOCHEMICAL CHARACTERISTICS

The chemical composition of coconut water can vary according to the post-harvest, such as the packaging, transport and storage conditions of the coconut, soil composition and the degree of maturation (Tan et al., 2014). Although both young and mature coconut water have equal nutritional values, for the most part, young coconut water is preferred by consumers as a health drink, whether consumed directly after collection or consumed after processing in various packaged beverages (Mahayothee et
al., 2016). Table 2 presents physicochemical nutritional data present in green coconut water.

The main sugars present in coconut water are fructose, glucose and sucrose and represent the largest fraction of soluble solids. However, during maturation, there is an increase in sucrose (non-reducing sugar) followed by a decrease in fructose and glucose (reducing sugars) contents. These changes can be explained due to sucrose formation at the expense of the glucose-fructose bond (Tan et al., 2014).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>References</th>
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<tr>
<td></td>
<td>(Tan et al., 2014)</td>
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<td>(Mahayothee et al., 2016)</td>
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<td>(Kailaku et al., 2017)</td>
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<td>(Seow et al., 2017)</td>
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<td>(Camargo Prado et al., 2015)</td>
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<tr>
<td>pH</td>
<td>4.78 ± 0.13</td>
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<td>5.58 ± 0.12</td>
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<td>5.60</td>
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<td>5.17</td>
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<td>5.01 – 5.94</td>
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<tr>
<td>Titratable Acidity (g/100mL)</td>
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<td>0.05 ± 0.01</td>
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<tr>
<td>Total Soluble Solids (°Brix)</td>
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<td>7.6 ± 0.21</td>
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<td>Phenolic Compounds (mg GAE/L)</td>
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<td></td>
<td>62.56</td>
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<tr>
<td>K (mg/100mL)</td>
<td>220.94 ± 0.32</td>
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<td>184.05</td>
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<td>372.10</td>
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<td>Na (mg/100mL)</td>
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<td>2.51</td>
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<tr>
<td>Ca (mg/100mL)</td>
<td>8.75 ± 0.045</td>
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<tr>
<td>Glucose (mg/100mL)</td>
<td>35.43 ± 0.51</td>
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<td></td>
<td>2.72</td>
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<td>-</td>
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<tr>
<td></td>
<td>1.886 – 2.159</td>
</tr>
<tr>
<td>Fructose (g/100mL)</td>
<td>39.04 ± 0.824</td>
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<tr>
<td></td>
<td>-</td>
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<tr>
<td></td>
<td>2.71</td>
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<td>-</td>
</tr>
<tr>
<td></td>
<td>1.847 – 2.379</td>
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<tr>
<td>Sucrose (g/100mL)</td>
<td>0.85 ± 0.01</td>
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<tr>
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<td>-</td>
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<tr>
<td></td>
<td>0.64</td>
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In terms of the constituents of coconut water, minerals come in second in terms of quantity. Data indicates that they represent about 0.4 to 1% of the composition of coconut water, being enough amount to characterize an isotonic drink (Sanganamoni et al., 2017; Tan et al., 2014). The presence of six main minerals was detected: potassium (K), sodium (Na), calcium (Ca), zinc (Zn), iron (Fe) and magnesium (Mg). Potassium is the most abundant mineral in coconut water, followed by sodium, calcium and magnesium. However, iron and zinc are present in relatively low concentrations (M. Kumar et al., 2021).
Regarding the profile of fatty acids, the short-chain ones increase during coconut maturation, while the long-chain ones decrease. Literature data show that lauric acid (C12:0) combined with myristic acid (C14:0) represent 70-75% of the percentage of total free fatty acids available in coconut water (Jirapong et al., 2015).

While solid endosperm contains high concentrations of fatty acids, with lauric acid (C12:0) being the highest concentration as maturation progresses (Assa et al., 2010), liquid endosperm contains many sugars (e.g. sucrose, glucose and fructose), sugar alcohols (e.g. sorbitol and mannitol), inorganic ions (e.g. K+, Na+, P+ and Mg++), vitamins (e.g. C, B3, B5 and niacin), lipids (mainly saturated fatty acids), amino acids (e.g. aminobutyric acid, glutamic acid and lysine), organic acids (e.g. malic acid and pyridoline) and phytohormones such as cytokinins and auxins (Yong et al., 2009).

The concentration of total protein and nitrogen increases as the coconut matures. The predominant proteins are globulin, albumin, glutelin and prolamin. Although coconut water is not a good source of protein, it does contain most of the amino acids (Rajamohan & Archana, 2018).

The active ingredients in coconut water include secondary plant metabolites such as: phytohormones, vitamins and amino acids. Among these metabolites, we can mention coumarin, 4-hydroxycoumarin, coumaric acid, ferulic acid, glucoside, procyanidin, shikimic acid and quinic acid which are known to demonstrate antioxidant and hepatoprotective effects in experimental settings (S. S. Kumar et al., 2018; Manna et al., 2014).

The pH and turbidity of coconut water increase as the coconut matures while the titratable acidity decreases with the ripening of the fruit. The decrease in titratable acidity may be due to the reduction in the amount of organic acids and ascorbic acid present in the water with maturity (M. Kumar et al., 2021).

Acidity is an important parameter, as it is used as a sensory indicator, due to its influence on the flavor and aroma of foods (Charlo et al., 2009). Generally, it is common to find in the literature the acidity of coconut water being expressed in citric acid and malic acid (Aroucha et al., 2010).
Total soluble solids are directly related to the sweetness and manifestation of flavor in coconut water and are usually represented by the sugars and organic acids naturally present in its composition (Vasconcelos et al., 2015). Total soluble solids content has been used more as a quality criterion than the point of harvest, since the characteristics of coconut water are influenced by seasonality (M. S. J. Silva et al., 2020).

3.5 HEALTH BENEFITS

3.5.1 Isotonic Natural Drink and its Effect

A study comparing the use of coconut water, an orange drink and water in physical exercise practitioners in hot conditions showed that previous consumption of coconut water resulted in lower urine production, indicating greater hydration capacity, not caused gastrointestinal discomfort, despite its composition, in addition to promoting an improvement in subsequent exercise capacity (Laitano et al., 2014).

Coconut water helps with hydration, with an impact similar to pure water, in addition to enabling a decrease in heart rate in situations of extreme exercise (Chagas et al., 2017).

3.5.2 Antioxidant and Anti-inflammatory Effect

Coconut water is sterile while it remains inside the fruit. It is made up of organic and inorganic compounds that play a vital role in supporting the human body's antioxidant system (Fowoyo & Alamu, 2018). In addition, it contains a large amount of micronutrients, such as inorganic ions and vitamins, which increase the body's natural antioxidant system. These micronutrients act directly on the body by quenching free radicals, which can damage cells, or they can indirectly increase the production of antioxidant enzymes (such as superoxide dismutase, catalase, and glutathione peroxidase) promoting the removal of harmful radicals (Agbafor et al., 2015).

Data collected from a study using the HPLC-MS/MS method to identify the main phenolic compounds in green dwarf coconut water and evaluate their effects on oxidative stress parameters and ethanol-induced liver damage in Wistar rats, demonstrated the presence of chlorogenic acid, caffeic acid, methyl caffeate, quercetin and ferulic acid.
isomers in green dwarf coconut water. In addition, the data showed that the consumption of coconut water and caffeic acid, at the concentrations used, has a hepatoprotective effect, confirmed by the values of gamma glutamyltranspeptidase and alanine aminotransferase (Bispo et al., 2017).

Another study evaluating the effects of coconut water in the prevention of myocardial infarction showed that it exerted significant antiperoxidative activities in rats administered isoproterenol hydrochloride, with its antioxidant property being superior to that of streptokinase, which is a potent antithrombotic. Part of this oxidative stress reduction effect refers to the presence of L-arginine, potassium, Mg, Ca, vitamin C and polyphenols (Prathapan & Rajamohan, 2011).

A study (S. S. Kumar et al., 2018) evaluated the antioxidant protection efficacy of coconut water in experimental rats induced by thermal stress and revealed the presence of polyphenolic compounds, namely, 4-hydroxycoumarin, 6-geranylnaringenin, ferulic acid, 4-O-glucoside and p-acid. coumaric, as well as four essential amino acids, namely L-phenylalanine, DL-tyrosine, D-tryptophan and L-isoleucine. These compounds act synergistically, being responsible for the prevention of systemic inflammation, mainly phenylalanine and isoleucine, which inhibit drug-induced inflammation in several experimental model systems, and with antioxidant potential, mainly polyphenolic compounds, indicating their direct involvement as a scavenger of free radicals.

### 3.5.3 Hepatoprotective Effect

One study showed that coconut water inhibits hepatocyte inflammation by reducing IL-1β-induced Tnf and Il6 transcript expression, while increasing acute phase protein (Serpine1 transcript) and antioxidant (HMOX1 protein) expression in primary hepatocytes mouse (Lakshmanan et al., 2020). Such data suggest that coconut water may favorably alter the antioxidant defenses and inflammatory response of hepatocytes as a component of its protective effects.

These findings are consistent with previous studies demonstrating that coconut water protects hepatocytes against H2O2-mediated oxidative damage and testes against heat-induced damage (S. S. Kumar et al., 2018; Manna et al., 2014).
3.5.4 Impact on Diabetes

Animal experiments have reported that coconut water can reduce blood glucose levels, regulate carbohydrate metabolism, and improve antioxidant capacity. Several studies have reported that coconut water can relieve kidney damage caused by diabetes (Nwangwa, 2012; Prathapan & Rajamohan, 2011; Preetha et al., 2012, 2013).

Another animal study found that coconut water can lower blood glucose in alloxan-induced diabetic rats (Pinto et al., 2015).

These results corroborate a study (Dai et al., 2021) that evaluated the effects of coconut water and glibenclamide in diabetic rats, showing the potential of coconut water to reduce glycemia and damage to the diabetic retina, but with no effect on the weight change caused by the disease. He speculates that this may be due to the antioxidant properties of coconut water.

4 FINAL CONSIDERATIONS

This review highlights the different aspects of coconut water production and how its nutritional composition can be applied for health benefits. It was possible to observe that coconut water is a fashionable drink that has been gaining the national and international market. However, it is a highly perishable product, and it is important to preserve the sensory, nutritional, and functional qualities of the drink. Non-thermal processing methods such as: use of ozone, ultrasound and ultraviolet light were effective in maintaining the shelf life of the beverage, however the ultrapressure method showed changes in physical functionality and/or changes in color of protein-rich foods. It was possible to evaluate the nutritional composition of coconut water, with special attention to the composition of minerals that guarantee the characteristic of an isotonic drink to the product. In addition, there is the presence of phytohormones, vitamins and amino acids that are responsible for the antioxidant properties of the product, as well as the beneficial effects on health.

Finally, further studies are suggested to evaluate the effects of coconut water on human health, as it is a beverage with market potential and accessible to consumers that could easily be used in the formulation of new products with functional appeal.
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