Coconut water uses, composition and properties: a review

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Received 31 March 2011
Accepted 20 June 2011

Fruits, 2012, vol. 67, p. 87–107

DOI: 10.1051/fruits/2012002
www.fruits-journal.org

***Resumen Español**, p. 107*

Coconut water uses, composition and properties: a review.

Abstract — The product. Coconut water (*Cocos nucifera* L.) is an ancient tropical beverage whose popularity on the international market has been continuously increasing in recent years. **Uses**. Besides its various traditional uses, this refreshing liquid extracted from the coconut fruit has recently been described as a “sport beverage” and has drawn the attention of manufacturers as a natural functional drink. **Composition**. Coconut water has a low matter content (2% to 5% wet basis), mainly comprising sugars and minerals. Quality criteria, such as the water per nut ratio, Total Soluble Solids (TSS), total sugar per nut, and [reducing sugars / total sugars] ratio, are good indicators for estimating the suitability of coconut cultivars for the production of coconut water. Regarding these criteria, dwarf varieties are the most suitable cultivars to obtain a tasty product. **Properties**. The quality of coconut water can not only be attributed to sugars and minerals because it also has a typical flavour and some original properties. Although many authors have cited medicinal uses or growth-promoting activities, only a few publications have clearly identified the components responsible for these properties. **Discussion**. Results of former and recent investigations are discussed. Finally, suggestions are made for further research to increase our knowledge of this original tropical juice.

France / *Cocos nucifera* / coconuts / coconut water / plant developmental stages / maturation / quality / proximate composition

Utilisations, composition et propriétés de l'eau de coco : une synthèse.

Résumé — Le produit. L’eau de coco (*Cocos nucifera* L.) est un ancien breuvage dont la popularité est grandissante sur le marché international des boissons. **Usages**. Au-delà de ses usages traditionnels, ce liquide rafraîchissant extrait de la noix a été décrit comme une « boisson de réhydratation pour sportif ». Des industriels ont ainsi mis en exergue ses propriétés fonctionnelles naturelles. **Composition**. L’eau de coco a une faible teneur en matière sèche (2 % à 5 % en base humide), constituée de sucres et minéraux. Des critères comme le poids de l’eau par noix, les solides solubles totaux, la quantité de sucres totaux par noix, le rapport [sucres réducteurs / sucres totaux] sont de bons indicateurs pour sélectionner les cultivars adaptés à la production d’eau de coco. Au regard de ces critères, les variétés naines sont souvent les mieux adaptées à la production de cette boisson. **Propriétés**. La qualité de l’eau de coco est aussi liée à une flaveur typique et recherchée ainsi qu’à certaines propriétés spécifiques. Bien que plusieurs auteurs aient attribué à l’eau de coco des propriétés médicinales et aient prouvé son effet positif sur la croissance des cellules, peu de publications identifient clairement les molécules responsables de ces actions. **Discussion**. Pour la première fois, les recherches sur l’eau de coco, des plus anciennes au plus récentes, sont synthétisées et conduisent à proposer des pistes pour améliorer notre connaissance de ce jus de fruit tropical atypique.

France / *Cocos nucifera* / noix de coco / eau de coco / stade de développement végétal / maturation / qualité / composition globale

1. Introduction

Coconut (*Cocos nucifera* L.) has been described as the most important and extensively grown palm tree worldwide. Every part of the plant is useful and, in many cases, human life would be impossible in its absence [1]. The leaf and trunk provide building material, and the root is used as medicine [2]. The fruit is the most marketable part; the envelope (mesocarp), called the husk, is processed into rope, carpets, geotextiles and growing media. The hard brown shell (endocarp) can be processed into very high-quality activated charcoal. The inner part of the nut (endosperm) is divided into two edible parts: a white kernel and a clear liquid: coconut water [3].

For more than a century, the coconut pulp or kernel has been considered as a cash crop because of its high fat content; however, nowadays, coconut is more than just an oil seed. Copra, the dried kernel, was a very important international commodity in the first part of the 20th century. Food and chemical industries processed the lauric oil extracted from copra into margarine or detergent. However, in the past 20 years, the volume of world trade in copra has decreased by 75% while the export of "fresh coconuts" has increased by 300%[1]. The market for canned coconut milk, coconut cream and coconut juice/water is increasing considerably [4–6]. Coconut is no longer only an international oil commodity but is becoming a valuable fresh fruit.

Coconut water (CW) or coconut juice (not to be confused with coconut milk) is a sweet refreshing drink taken directly from the inner part of coconut fruits [7]. It differs from coconut milk, which is the oily white liquid extracted from the grated fresh kernel. In most cases, coconut water comes from small and scarce coconut tree plantations more related to "gardens". As a consequence, the coconut water remains a traditional and under-used resource which could thus be considered as an exotic beverage by most people living far from the coconut production area [8]. An increasing international demand for this product could be a highly positive issue for thousands of African and Asian small farmers.

Coconut water is not only a tropical beverage but also a traditional medicine [2], a microbiological growth medium [9] and a ceremonial gift [10], and can be processed into vinegar [11] or wine [12]. These various uses are possible thanks to the original biochemical composition of the juice. The particular mineral composition and reasonable total sugar content make coconut water a natural isotonic liquid. The characteristics of coconut water make it an ideal rehydrating and refreshing drink after physical exercise [13].

Current research on coconut water is rare and mainly focuses on i) specific uses (10%), ii) biochemical composition (50%) and iii) preservation techniques (40%).

This review on coconut water is the first part of a global synthesis on the topic. It presents its uses, from the traditional to the most sophisticated; details its biochemical composition, influenced by the stage of maturity and the variety; and describes its original properties. In a future *Fruits* issue, a second review will describe the preservation and processing of coconut water.

2. Uses

2.1. As a religious symbol

As it is a sterile and pure liquid, coconut water has been a religious symbol for a long time. In Asia, and especially in India, tender, *i.e.,* immature, coconuts are offered as ceremonial gifts and serve as purification media at traditional events [10].

2.2. As a natural beverage

Centuries ago, Polynesian, Melanesian and Micronesian mariners used coconut fruits as reserves of food and drink [1]. Thanks to this "naturally canned" beverage, they survived on their journeys from one island to the next

[1] www.faostats.org (accessed 15 January, 2007).

and colonised the entire Pacific Ocean. Nowadays, coconut water from immature nuts is still consumed as a refreshing drink by thousands of inhabitants of tropical regions. The most developed market for coconut water is Brazil, where sales of the beverage in long-life packages increased from 60 M in 2000 to 120 M units in 2006[2] [14]. The country's top-selling brand, which was produced by Amacoco, was acquired by PepsiCo in 2009 to complement "*one of the fastest growing beverage categories due to its natural hydrating qualities, great taste and nutritional benefits*" according to Massimo d'Amore, chief executive officer of PepsiCo Americas Beverages[3]. The Coca-Cola Company has followed PepsiCo and become an investor in ZICO Beverages, a Californian company that sells coconut water[4].

2.3. As medicine

Apart from its consumption as a natural drink, one of the most important uses of coconut water is medicinal [15]. In the Indian ayurvedic medicine, it is described as "*unctuous, sweet, increasing semen, promoting digestion and clearing the urinary path*" [10]. There are numerous references to medicinal uses of coconut in Sri Lanka, a country where coconut is consumed on a daily basis [2]. Out of the 40 raw or processed parts of the coconut plant cited by Ediriweera [2], five involve coconut water. Coconut water is traditionally prescribed for burning pain during urination, dysuria, gastritis, burning pain of the eyes, indigestion, hiccups or even expelling of retained placenta. In case of emergency in remote regions of the world and during World War II, coconut water was used as a short-term intravenous hydration and resuscitation fluid [16, 17].

2.4. As a growth medium for microorganisms and plants

In the early 1960s, coconut water was already known to favour microbial growth and especially *"Nata de coco"* bacterium [18]. *Nata de coco* is bacterial cellulose naturally produced at the coconut water/air interface. Native to the Philippines, *Nata de coco* has become popular in many other Asian countries. The "*Nata*" bacterium was later identified as *Acetobacter xylinum* [19]. Traditionally coconut water is also processed into wine [12] or vinegar [11] due to its sugar content and ability to ferment.

Coconut water (previously called "coconut milk") has been shown to induce division of mature cells [20, 21]. For example, the growth of spinach tissue on a medium supplemented with 10% to 15% (v/v) mature coconut water increased the weight of spinach callus after 5 weeks and accelerated shoot regeneration (4–5 weeks instead of 8–12 weeks without) [22].

Many authors reported that coconut water contains a growth factor that stimulates different bacterial strains and *in vitro* culture of plants [9, 23–25]. For this purpose, coconut water from immature fruits was reported to produce better results than water from mature fruits.

2.5. As a biocatalyst

Coconut water appears to be able to support the synthesis of proteins from recombinant DNA vectors [26]. Filtered coconut water from young Brazilian coconuts displayed high reductase activity at ambient temperature in a series of aliphatic and aromatic aldehydes and ketones, suggesting that coconut water is probably still under-used in the organic synthesis research field [27].

3. Biochemical composition

The coconut fruit takes between (11 and 12) months to reach full maturity. At

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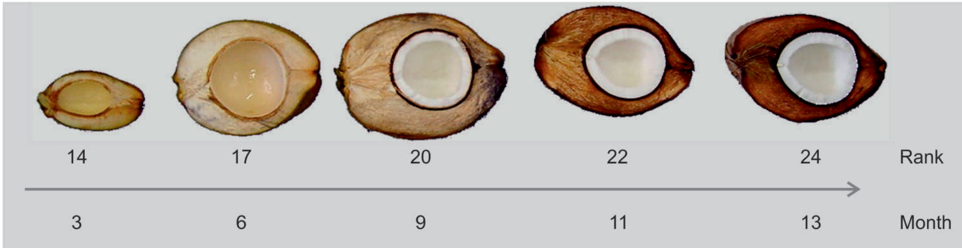
[2] Pagel G., Brazil's coconut water coming to a store near you, www.brazzilmag.com, article of 14/09/2004, seen on 02/03/2006.

[3] Heller L., PepsiCo Brazil acquisition to make it coconut water leader, AP-Food Technology, Decision News Media, www.ap-foodtechnology.com seen on 24/08/2009.

[4] Glover K., Coke follows Pepsi into coconut water market, CBS Interact. Bus. Netw., 2009, www.BNET.com seen on 18/02/2010.

Figure 1
Growing coconut fruit.



5 months, the kernel begins to form a thin layer of jelly around the inside of the endocarp or shell. The shell encloses the tender water, a clear sweet liquid. At this time the water is under pressure. During the ripening process, the pressure is released and the water is partially replaced by the kernel (*figure 1*). Little by little, the kernel grows and replaces the water by cells storing lipids [28]. Its composition changes as the nut grows [29]. At full maturity (12 months), coconut water represents between 15% and 30% of the weight of the nut. The amount of coconut water that can be harvested from each nut is about 300 mL, but depends to a great extent on the stage of maturity and on the variety of coconut. There are only three types of coconut varieties: tall (allogamous), dwarf (autogamous) and hybrid; the last often being a cross between dwarf (mostly mother) and tall (father).

Coconut water in its envelope is sterile and composed of both organic and inorganic compounds (almost all minerals found in food). Compared with other fruit juices, the dry weight of mature coconut water is very low: 5% to 6% *versus* 12% to 15% for apple juice. The main components of coconut water are soluble sugars (*table I*) but it also contains proteins, salts and a very

Table I.
Composition of the mature coconut water of 13 tall, dwarf and hybrid varieties, according to different authors presented in the reference list.

Coconut variety	Water vol. (mL per nut)	pH	Total solids	Total sugars	Sucrose	Reducing sugars	Glucose	Fructose	Proteins	Fats	Ash
			$g \cdot 100\ mL^{-1}$								
Laguna Tall [32]	–	5.6	–	3.2	2.4	0.6	–	–	–	–	–
Malayan Tall [40]	385	5.2	5.6	4.4	5.1	2.9	1.5	1.4	0.51	0.14	0.46
West African Tall (Nigeria) [97]	307	6.1	3.3	–	4.9	–	–	–	0.03	–	–
West African Tall (Côte d'Ivoire) [59]	154	5.5	4.6	1.9	–	0.6	–	–	–	–	–
Golden Dwarf [32]	–	5.5	–	3.2	2.3	0.8	–	–	–	–	–
West African Dwarf [97]	198	5.2	5.3	–	5.4	–	–	–	0.02	–	–
Malayan Yellow Dwarf [59]	229	5.8	3.9	2.8	–	0.7	–	–	–	–	–
Equatorial Green Dwarf [59]	189	5.4	4.4	2.3	–	1.1	–	–	–	–	–
Malayan Yellow Dwarf × West African Tall (PB121+) [59]	238	5.2	4.9	2.8	–	1.5	–	–	–	–	–
Malayan Dwarf × Rennell Tall [33]	–	5.6	–	2.3	0.1	2.1	1.7	0.4	–	–	–
Unknown variety [24]	–	–	4.0	1.8	0.7	1.1	0.5	0.6		0.66	–
Unknown variety [98]	–	5.6	4.7	2.6	–	–	–	–	0.55	0.74	–
Unknown variety [31]	–	5.1	–	–	–	–	–	–	0.14	–	0.40
Mean	243	5.5	4.5	2.7	3.0	1.3	1.2	0.8	0.25	0.51	0.43
SD	79	0.3	0.7	0.8	2.2	0.4	0.6	0.5	0.26	0.33	0.04

Table II.
Mineral composition of mature coconut water, according to different authors presented in the reference list.

K	Cl	S	Ca	Na	Mg	P	Mn	Al	Zn	Fe	Cu	References
mg·100 mL^{-1}										µg·100 mL^{-1}		
356	–	–	46.0	31.0	14.0	–	–	–	0.03	–	–	[33]
255	–	4	31.3	15.9	9.3	12.6	0.08	0.06	0.02	16	29.3	[40]
247	108	80	40.0	48.0	15.0	6.3	–	–	–	79	26.0	[31]
164	131	–	18.2	4.1	7.8	21.0	–	–	–	–	–	[38][a]
273	–	–	47.7	45.4	11.7	9.2	–	–	–	112	28.7	[39] [a]

[a] For these authors, the analysed coconut water was at an unknown maturity stage.

small quantity of oil, which contributes to its very low food energy level, *i.e.*, 44 cal·L^{-1}. The vitamin C content varies from (20 to 40) mg·L^{-1}. This is not high compared with other fruits such as orange or acerola, but it is sufficient to prevent oxidation for a limited period [30]. The vitamin B group is present in coconut water with 0.64 µg·mL^{-1} of nicotinic acid and 0.52 µg·mL^{-1} of panthotenic acid [31].

Sugars are the main fraction of soluble solids in coconut water [32, 33]. The main sugars in mature coconut water are sucrose, sorbitol, glucose and fructose [34, 35], followed by minor sugars including galactose, xylose and mannose.

The second constituents in terms of quantity are minerals (*table II*). They account for only 0.4% to 1% of the liquid volume, but nevertheless contribute to its isotonic properties. The osmolarity of coconut water is about 300 mOsm·L^{-1} [36–38]. Authors agreed that potassium is the main mineral element in coconut water [33, 38, 39]. According to Thampan and Rethinam, the major differences in mineral composition between immature and mature coconut water were due to potassium, chloride, iron and sulphur content [31], whereas Santoso *et al.* observed differences due to potassium, copper and sodium [40].

Coconut water also contains amino acids [23, 41]. Alanine, arginine, cysteine and serine contents are higher than in cow's milk [42]. One class of proteins, enzymes, has attracted the attention of several authors because they are involved in coconut water discoloration. Samples of green coconut water obtained from a Brazilian research centre and stored at –20 °C revealed peroxydase and tyrosinase (polyphenoloxydase) activity of, respectively, (0.3 and 5.0) U·mL^{-1} [43], where U is one unit of enzymatic activity defined as the amount of enzyme extract able to produce an increase in absorbance of 0.001 per minute.

Optimum activities of polyphenoloxydase (PPO) and peroxydase (POD) in green coconut water occurred at pH 6.0 and pH 5.5 and at temperatures of 25 °C and 35 °C, respectively [44]. Various levels of PPO and POD activity are reported in the literature (*table III*). Fast Protein Liquid Chromatography (FPLC) was used to determine the retention time of the enzymes. Respective molecular weights for POD and PPO were 49.2 kDa and 73.8 kDa by gel filtration and 44.63 kDa for peroxidase by electrophoresis (SDS-PAGE) [43]. These enzymes are assumed to be responsible for the discoloration (pink, yellow or brown) frequently observed in coconut water.

The [PPO / POD] ratio appears to vary considerably, ranging from 0.2 to 16.7. Even in similar coconut varieties, it fluctuates between 0.3 and 16.7, suggesting that enzyme activity probably depends on the history of the coconut fruit: variety, cultivation conditions, stage of maturity at harvest, storage conditions of the fruit and even

Table III.
Polyphenoloxydase (PPO) and peroxydase (POD) activities in fresh immature coconut water, according to different authors presented in the reference list.

Coconut variety, origin and maturity stage when available	PPO	POD	[PPO / POD] ratio	References
	(U·mL $^{-1}$)			
Green coconut, Brazil	32.1	114.3	0.3	[44]
Green coconut, Brazil	16.5	3.6	4.5	[102]
Green coconut, Brazil	5.0	0.3	16.7	[43]
Green Dwarf, Costa Rica, 8 months	75.0	9.9	7.6	[99]
Green Dwarf, Brazil	2.3	12.2	0.2	[100]
Green coconut, Brazil	0.1 – 34.8	0.1 – 6.2	1.1 – 5.6	[101]

mode of extraction of the coconut water (involving metal tools). As for avocado fruits [45], the relative importance of the enzyme activities and their substrates, mainly phenolic compounds, probably changes at different physiological stages of the fruit.

Besides sugars, minerals and proteins, a minor fraction is composed of aromatic compounds. Coconut water has a specific taste and flavour, different from the well-known fragrance of the coconut kernel. This beverage has a typical aroma *per se* which has never been fully characterised. Like organic acids composed of malic, succinic, citric, acetic and tartaric acids [24, 40], which contribute to the taste of coconut water, volatile compounds contribute to the aroma of the fresh liquid.

To our knowledge, there are only two publications describing the aromatic compounds of coconut water. The first article [46] analysed the solid phase microextraction (SPME)-headspace aroma compound of the mature water and kernel of an unknown variety of coconut from Cameroon. Aroma compounds were investigated by GC-FID (gaz chromatography flame ionisation detection) and GC/MS (gaz chromatography mass spectrum) using different achiral and chiral phase GC columns. More than 30 compounds were identified in the coconut headspace samples. The main compounds of the mature coconut water were nonanal (14.2%), nonanol (11.2%), heptanal (8.2%), ethyl octanoate (6.2%), heptanol (5.3%) and 2-nonanol (5.1%), while the coconut kernel was rich in delta octalactone (12.6%), ethyl octanoate (9.6%), nonanal (8.4%), nonanoic acid (7.2%), decanol (6.8%), decanal (6.2%) and nonanol (6.1%). Alcohols, ketones, thiols, carboxylic acids, phenols and esters with short carbon chains were also detected in the essential oil of the coconut water, extracted by hydro-distillation and solvent extraction [47]. Among these compounds, ester n-propyl ethanoate, which was present in both extracts, is probably responsible for the flavour of coconut water (*table IV*). Unfortunately, the first investigation [46] was carried out using mature coconut, which is far less aromatic than immature coconut water, and the second one [47] did not mention either the exact stage of maturity, or the exact coconut varieties studied.

Even though the authors identified the same main components of coconut water, considerable variations in content were observed between investigations. These differences may be due to i) the stage of maturity of the fruits [31, 40], ii) the variety [48–50] and iii) the cultivation conditions [39, 51].

3.1. Influence of the stage of maturity

The most significant change during the ripening process is the volume of nut water [52, 53]. As the nut matures, there is an increase in the nut water-holding capacity until the kernel begins to form a jelly inside the cavity of the fruit. Then, the water volume

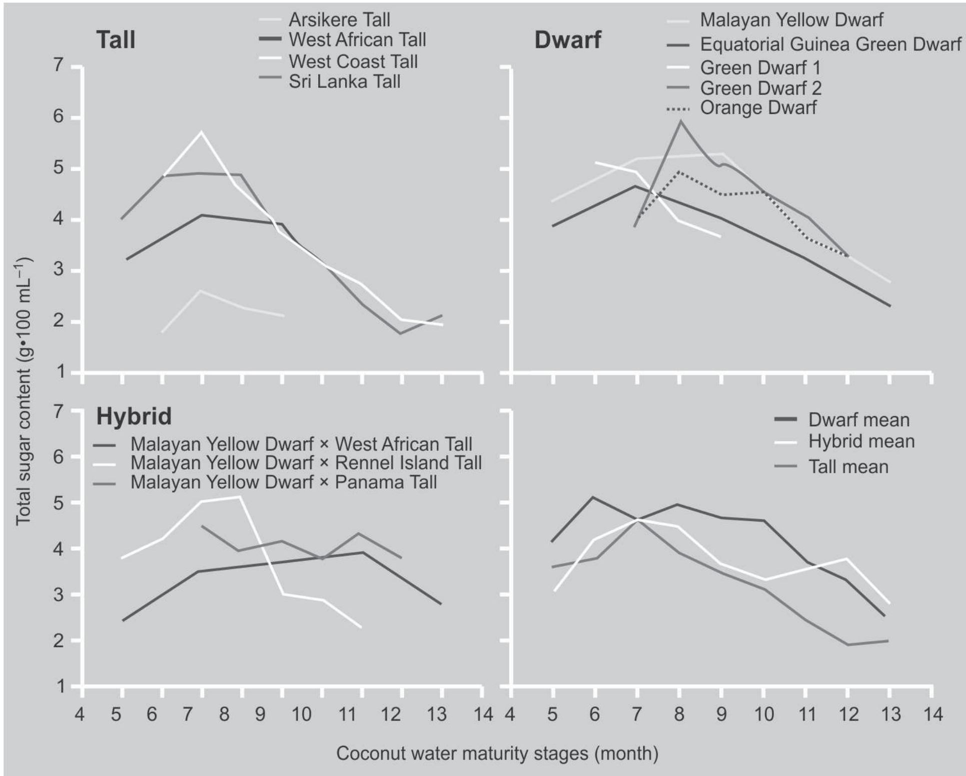
Table IV.
Aromatic compounds identified by SPME-headspace of mature coconut water from a Cameroon cultivar [46] and by hydrodistillation and solvent extraction of green and yellow coconut water (CW) from Brazil [47].

Jirovetz *et al.* [46]			Da Fonseca *et al.* [47]		Hydrodistillation		Solvent extraction	
Compounds	Linear retention index	% peak area	Compounds	Linear retention index	Green CW	Yellow CW	Green CW	Yellow CW
					% peak area		% peak area	
3-Methyl butanal	654	1.06	*n*-Propyl ethanoate	750	15.3	–	53.5	16.7
Butanol	657	2.17	1-Methylpropyl methanoate	752	–	–	4.1	–
2-Pentanone	687	0.12	3-Hydroxybutan-2-one	753	–	–	4.5	6.2
2-Pentanol	705	0.52	Methyl 2-hydroxypropanoate	754	–	0.9	–	–
3-Methyl butanol	737	0.69	4-Methylpentan-2-one	759	12.0	–	29.0	–
Pentanol	766	1.03	Ethyl 2-hydroxypropanoate	764	–	–	0.7	–
2-Hexanone	789	traces	Butane-1,3-diol	765	–	–	1.7	67.7
Hexanal	799	1.27	Butane-1,2-diol	766	–	–	3.1	3.0
Hexanol	865	3.02	Butane-2,3-diol	767	–	–	3.2	3.6
Heptanal	899	8.16	Ethyl carbonate	768	2.1	–	–	–
Heptanol	934	5.31	Hexan-2-ol	774	–	1.0	–	–
2-Heptanol	972	2.16	*n*-Butyl ethanoate	776	2.0		–	–
Octanal	1002	2.55	Furfural	781	14.5	0.8	–	–
Nonanal	1005	14.21	4-Hydroxy-4-methylpentan-2-one	784	30.5	–	–	–
Limonene	1031	1.1	2-Hydroxy-2-methylpentane	803	3.2	–	–	–
Octanol	1073	4.31	*p*-Menth-8-en-1-ol acetate	873	1.4	–	–	–
2-Nonanol	1086	5.14	Phenyl acetaldehyde	877	–	0.9	–	–
delta-Hexalactone	1088	1.48	4-Methoxybenzyl acetate	1069	–	5.3	–	–
Nonanol	1175	11.23	7,9-Di-tert-butyl-oxaspiro[4.5]deca-6,9-diene-2,8-dione	1235	–	4.5	–	–
Octanoic acid	1179	3.53	Methyl 6,9,12-octadecatrienoate	1241	–	4.2	–	–
Ethyl octanoate	1195	6.16	*n*-Hexadecanoic acid (palmitic acid)	1244	–	18.4	–	–
Decanal	1204	4.17	3,6-Dioxane-1,8-diol	1262	–	5.0	–	–
delta-Octalactone	1231	3.17	3-Mercaptodecane	1274	–	46.2	–	–
Decanol	1267	3.15	9-Octadecenoic acid (oleic acid)	1276	–	5.3	–	–
Nonanoic acid	1273	3.13	9-Octadecen-1-ol	1300	–	6.1	–	–
Undecanal	1306	1.15	Dioctyl adipate	1304	11.2	–	–	–
Undecanol	1365	3.25	–	–	–	–	–	–
Decanoic acid	1371	1.1	–	–	–	–	–	–
delta-Decalactone	1422	2.2	–	–	–	–	–	–
delta-Dodecalactone	1530	1.14	–	–	–	–	–	–

decreases as it is gradually used by the fruit to form the kernel.

Compared with other components of coconut water, sugars varied the most throughout the ripening process [37, 53–55]. After a period during which reports in the literature cited erroneous information originating from De Kruijff [56], *i.e.*, that "coconut water contains sucrose which becomes inverted during the maturation of the fruit", many authors including Gonzalez (1914) cited by Nathanael [57], Lahille [58] and, recently, Assa *et al.* [59] demonstrated that in fact the exact opposite is true. The latter

Figure 2
Total sugar contents of coconut water (% w/v) of tall, dwarf, hybrid varieties and means of tall, dwarf and hybrid varieties at different stages of maturity (5–13 months) [29, 33, 37, 52, 53, 55, 57, 59, 96].



clearly showed that sucrose appeared in the coconut water aged (6 to 8) months. From that stage, the sucrose content increased until it comprised about 40% of total soluble sugars (TSS) at the full maturity stage, while glucose and fructose fell, respectively, from 40% to 10% of TSS and 55% to 25% of TSS during the same period.

The results of the analysis of total (TS) and reducing sugars (RS) of coconut water from 13 coconut varieties covering a maturation period of 10 months were published in ten articles between 1914 and 2008. To summarise knowledge of the ripening process, we computed and analysed these results (*figures 2, 3*).

In tall coconut varieties, total sugar contents (TS) of coconut water increased from 5 months to reach the maximum at 7 months (*figure 2*). Subsequently, total sugars rapidly decreased until full ripeness at the age of 12 months. At this stage, ripe coconut water contained around 2% (w/v) of total sugars. In dwarf varieties, changes in total sugar content differed slightly. Like in tall varieties, changes in total sugars followed a more or less bell-shaped curve but reached the maximum at (6, 7, 8 or 9) months depending on the variety and the production area. Total sugar contents of ripe coconut water of dwarf varieties were higher: between 2.5% and 3.5% (w/v). There is a shortage of references to hybrid varieties in the literature. Only one of the studied hybrids (Malayan Yellow Dwarf × Rennel Island Tall) exhibited the same bell-curve shape. Another hybrid (Malayan Yellow Dwarf × Panama Tall, also called MAYPAN) exhibited more or less constant total sugar contents during maturation. The third hybrid (Malayan Yellow Dwarf × West African Tall, or PB121+) exhibited a slight increase in total sugars from (5 to 11) months followed by a decrease between (11 and 13) months. All coconut waters from hybrid varieties exhibited different total sugar contents and a wide range of metabolism.

Finally, the mean total sugar contents of tall, dwarf and hybrid coconut water aged from (5 to 12) months exhibited different

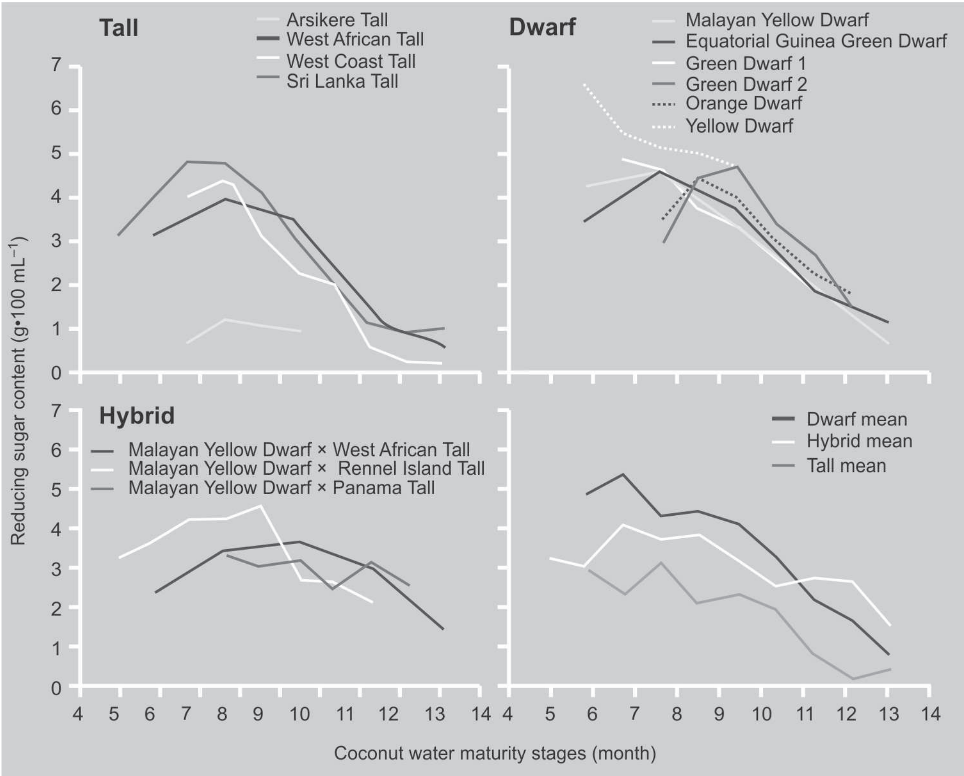


Figure 3
Reducing sugar contents of coconut water (% w/v) of tall, dwarf, hybrid varieties and means of tall, dwarf and hybrid varieties, at different stages of maturity (4–13 months) [29, 33, 37, 52, 53, 55, 57, 59, 96].

trends (*figure 2*). In dwarf varieties, coconut water had the highest total sugar contents and, in tall varieties, the lowest. As expected, the total sugar contents of the hybrid (dwarf × tall) coconut water were intermediate.

Changes in reducing sugar contents in the coconut water of tall, dwarf and hybrid varieties resembled those in total sugar contents (*figure 3*). Ripe coconut water in tall varieties had very low reducing sugar contents (nearly absent in the West Coast Tall variety). At full maturity, reducing sugars (such as glucose and fructose) were mainly replaced by sucrose. In dwarf varieties, reducing sugars remained higher than those in tall varieties, especially between (8 and 12) months. The particularity of the hybrids was higher reducing sugar contents at (12 and 13) months than those of tall and dwarf varieties. On average, the reducing sugar contents of coconut water in dwarf varieties was the highest throughout the ripening process, except for the last 3 months when hybrid varieties were higher. Whatever the stage of maturity, coconut water of tall varieties had the lowest reducing sugar contents.

3.2. Influence of the variety

At a given stage of maturity, the biochemical composition of coconut water is highly influenced by the variety. To obtain exhaustive information on the components of coconut water, data from nine articles representing 48 accessions of coconut palms and 42 different varieties were analysed (*table V*). The (6- to 7-) month stage was chosen because this was the stage most frequently cited in the literature. This stage of maturity is also claimed by many authors to be the most palatable for drinking coconut water. Rare data were also found on (8- or 9-) month-old fruits (not described here) [50, 59, 60]. Among the 42 varieties analysed, eighteen were tall, seventeen were dwarf and seven varieties were hybrids. Out of these, four dwarf varieties [Malayan Yellow Dwarf (MYD), Chowgat Orange Dwarf

Table V.
Composition of the immature coconut water of 42 coconut palm cultivars according to different authors presented in the reference list.

Cultivars (Age 6–7 months)	International code	Nut weight (g)	Water vol. (mL)	pH	TSS	Total sugars	Reducing sugars	Amino acids	Ash	K	Na	Titrable acidity (mEq·100 mL^{-1})	References
						g·100 mL^{-1}		mg·100 mL^{-1}		mg·kg^{-1}			
Arsikere Tall, India	Not available	1380	363	4.90	4.5	2.69	1.2	0.82	–	3080		0.19	[52]
New Guinea Tall	NGAT	–	358	–	–	5.80	3.0	1.40	–	2258	21.0	–	[48]
Philippines Ordinary Tall	PHOT	–	451	–	–	5.80	3.7	1.30	–	2273	24.0	–	
Fiji Longtongwan Tall	FJLT	–	390	–	–	4.90	3.6	1.40	–	2641	29.0	–	
Spikeless Tall (Spicata Tall)	SPIT	–	275	–	–	5.30	3.2	1.70	–	2617	38.0	–	
West Coast Tall	WCT	–	240	–	–	5.60	3.2	1.30	–	2797	37.0	–	
Andaman Ordinary Tall	ADOT	–	274	–	–	5.30	3.3	2.10	–	2272	27.0	–	
Jamaica Sanblas Tall	n.a.	–	263	–	–	6.00	3.4	1.70	–	2703	28.0	–	
Malayan Yellow Dwarf, Kasaragod, India	MYD	–	238	–	–	6.20	3.8	1.70	–	1998	36.0	–	
Malayan Orange Dwarf, Kasaragod, India	MOD	–	303	–	–	6.70	4.1	1.80	–	2142	35.0	–	
Gangabondam Tall	GB	–	267	–	–	5.60	3.5	1.70	–	2125	28.0	–	
Chowgat Orange Dwarf, Kasaragod, India	COD	–	351	–	–	7.00	4.7	1.80	–	2003	20.0	–	
Guam III Tall	GUCT	–	278	–	–	6.00	3.7	2.00	–	2434	34.0	–	
Malayan Tall, Indonesia	MLT	3000	553	4.70	5.8	4.76	3.7	–	863.6	2029	17.4	0.13	[40]
Chowgat Green Dwarf	CGD	–	320	5.17	5.2	5.12	4.9	–	349.9	–	–	0.04	[61]
Chowgat Orange Dwarf, Karnataka, India	COD	–	390	4.94	4.9	4.86	4.4	–	289.1	–	–	0.05	
Malayan Yellow Dwarf, Karnataka, India	MYD	–	480	5.02	4.7	4.70	4.3	–	282.7	–	–	0.05	
Malayan Orange Dwarf, Karnataka, India	MOD	–	240	4.83	4.6	4.54	3.9	–	281.6	–	–	0.07	
Tiptur Tall	TIT	–	350	4.89	4.5	4.48	3.7	–	312.8	–	–	0.06	
Chitta Gangapani Dwarf	Not available	–	450	–	–	6.00	–	–	–	–	–	–	[62]
Uddha Gangapani Semitall	Not available	–	370	–	–	6.80	–	–	–	–	–	–	
Sevvelanir Tall	Not available	–	300	–	–	6.00	–	–	–	–	–	–	
Chowgat Orange Dwarf, Kerala, India	COD	–	350	–	–	7.00	–	–	–	–	–	–	
Chowgat Green Dwarf	CGD	–	190	–	–	4.80	–	–	–	–	–	–	
Gangabondam Green Dwarf	GBGD	–	270	–	–	5.60	–	–	–	–	–	–	
Kenthali Orange Dwarf	KTOD	–	206	–	–	6.30	–	–	–	–	–	–	
Chowgat Orange Dwarf × West Coast Tall	CODxWCT	1550	341	5.97	6.6	6.08	3.8	1.87	–	2018	23.3	–	[50]
Laccadive Ordinary Tall × Chowgat Orange Dwarf	LCTxCOD	1570	341	5.10	6.4	6.07	3.9	1.91	–	2102	23.4	–	
Laccadive Ordinary Tall × Gangabondam Green Dwarf	LCTxGBGD	1597	266	4.78	6.2	4.91	3.3	1.61	–	2311	31.6	–	
West Coast Tall × Chowgat Orange Dwarf	WCTxCOD	1630	298	4.92	6.2	5.08	3.5	1.63	–	2536	30.3	–	
West Coast Tall × Gangabondam Green Dwarf	WCTxGBGD	1653	291	4.95	5.9	5.23	3.7	1.67	–	2602	27.5	–	
West Coast Tall × Malayan Yellow Dwarf	WCTxMYD	1671	278	4.93	6.1	5.44	3.3	1.82	–	2712	25.8	–	
Chowgat Orange Dwarf, Kasaragod, India	COD	1555	359	5.77	7.0	6.38	4.2	2.21	–	2092	23.3	–	
West African Tall	WAT	2160	320	5.10	5.4	4.10	4.0	–	–	–	–	–	[59]
Malayan Yellow Dwarf, Côte D'Ivoire	MYD	1384	284	5.20	6.4	5.20	4.5	–	–	–	–	–	
Equatorial Guinea Green Dwarf	EGD	1581	292	5.00	6.0	4.70	4.5	–	–	–	–	–	
Malayan Yellow Dwarf × West African Tall	MYDxWAT	2159	475	5.20	4.7	3.70	3.6	–	–	–	–	–	
Wenye N°2	Not available	1610	356	5.50	6.3	–	–	–	–	369	34.7	–	[49]
Wenye N°3	Not available	1480	295	5.51	6.0	–	–	–	–	358	31.3	–	
Local Tall, Hainan	Not available	2080	542	5.58	5.6	–	–	–	–	359	34.8	–	
Aromatic Dwarf	AROD	1360	279	5.58	7.7	–	–	–	–	338	30.1	–	
King Coconut	RTB	–	528	–	–	4.40	4.4	–	–	1990	20.0	–	[60]
Bodiri Tall	BDRT	–	235	–	–	5.30	5.1	–	–	2200	10.0	–	
Cameroon Red Dwarf, Sri Lanka	CRD	–	334	–	–	3.40	2.9	–	–	1500	11.0	–	
Sri Lanka Brown Dwarf	SLBD	–	458	–	–	3.30	3.1	–	–	2800	12.0	–	
Sri Lanka Yellow Dwarf	CYD	–	462	–	–	4.00	4.0	–	–	1500	13.0	–	
Sri Lanka Red Dwarf	SLRD	–	373	–	–	3.90	3.5	–	–	1520	19.0	–	
Sri Lanka Green Dwarf	PGD	–	277	–	–	4.80	4.6	–	–	2250	18.0	–	
Min		1360	190	4.70	4.5	2.69	1.2	0.82	281.6	338	10.0	0.04	–
Max		3000	553	5.97	7.7	7.00	5.1	2.21	863.6	3080	38.0	0.19	–
Mean		1731	338	5.16	5.8	5.22	3.8	1.67	396.6	2029	25.6	0.08	–

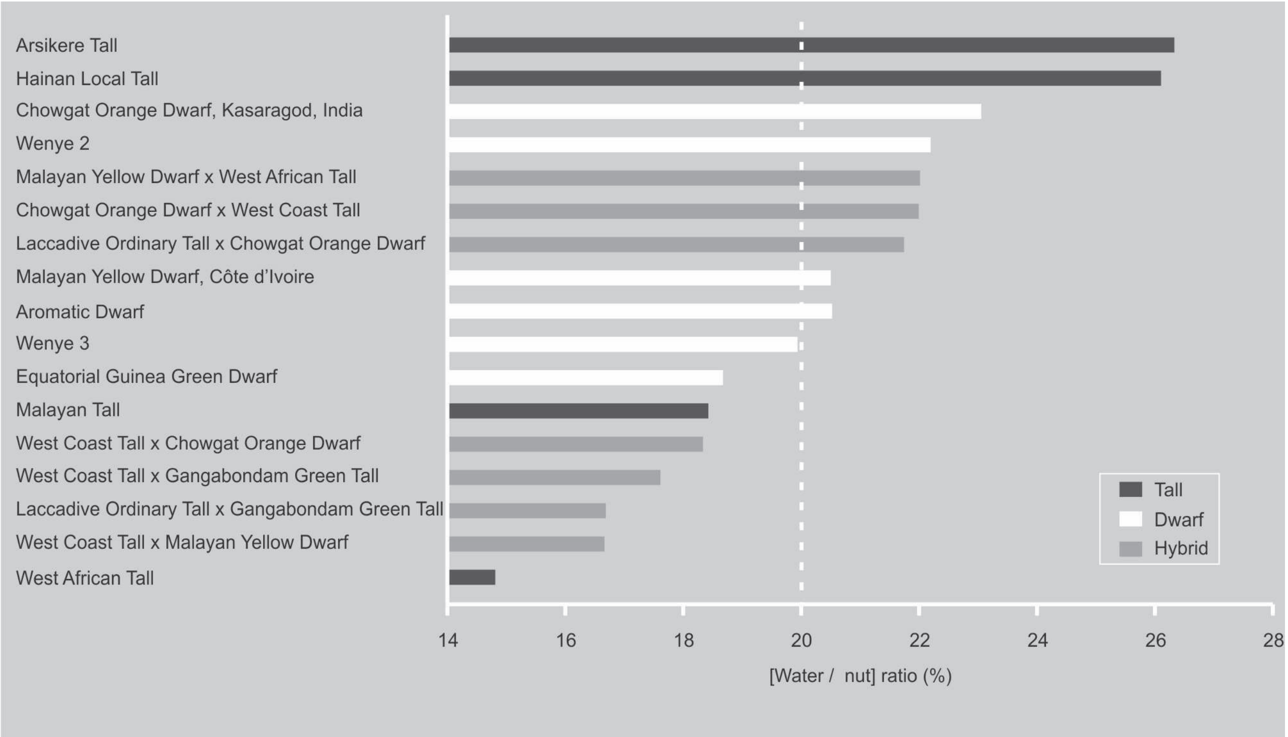


Figure 4
[Water / nut] ratio (% v/w) of 17 tall (T), dwarf (D) and hybrid (T × D) coconut cultivars [40, 49, 50, 59, 52].

(COD), Malayan Orange Dwarf (MOD) and Chowgat Green Dwarf (CGD)] were investigated several times by different authors [48, 50, 59, 61, 62].

Most authors who assessed the quality of tender coconut water used similar criteria: volume of water (mL), pH, total soluble solids (g·100 mL^{-1}), total sugars (% w/v), reducing sugars (% w/v), potassium content (mg·100 mL^{-1}) and sodium content (mg·mL^{-1}). A few authors also considered the weight of the nuts. Although it is often omitted in publications, weight is essential for the estimation of the [water / nut] ratio (% v/w). This ratio is a major economic indicator for the evaluation of the cost of transport from the field to the processing or consumption area. The [water / nut] ratio also helps to compute the amount of waste (green husk and shell) generated during processing or consumption of immature nuts. The [water / nut] ratio computed from the literature ranged between 14% and 26% (*figure 4*). For instance, a 7-month-old nut weighing 1.5 kg can include (1.1 to 1.3) kg of husk and shell, *i.e.*, waste. To prevent a major environmental problem during coconut water production, coconut varieties with high [water / nut] ratios (% v/w) should be selected. However, bulky biowaste can be transformed into floor and wall coverings, geotextiles, or growing media [63]. Some new uses need to be found for these by-products and further research is required in this field.

Whatever the variety, the total sugar contents of the coconut water in 6- or 7-month-old fruits varied from one- to two-fold: in the (2.7 to 7.0) g·100 mL^{-1} range (*table V*). The maximum amount of 7 g·100 mL^{-1} is close to that of orange juice [(8 to 10) g·100 mL^{-1}] or a soda [(from (10 to 12) g·100 mL^{-1}]. At 7 months, total sugars represented more than 75% of the total soluble solids (TSS). Total sugar contents (TS) are correlated with total soluble solids (R^2 = 0.622). Thus, the measurement of total soluble solids by hand refractometer might be a simple indicator for total sugar contents of 7-month-old coconuts.

By multiplying the volume of water (Vol in mL) by the total sugar contents (TS in g·100 mL^{-1}) or by the total soluble solid contents (TSS in g·100 mL^{-1}) when TS is

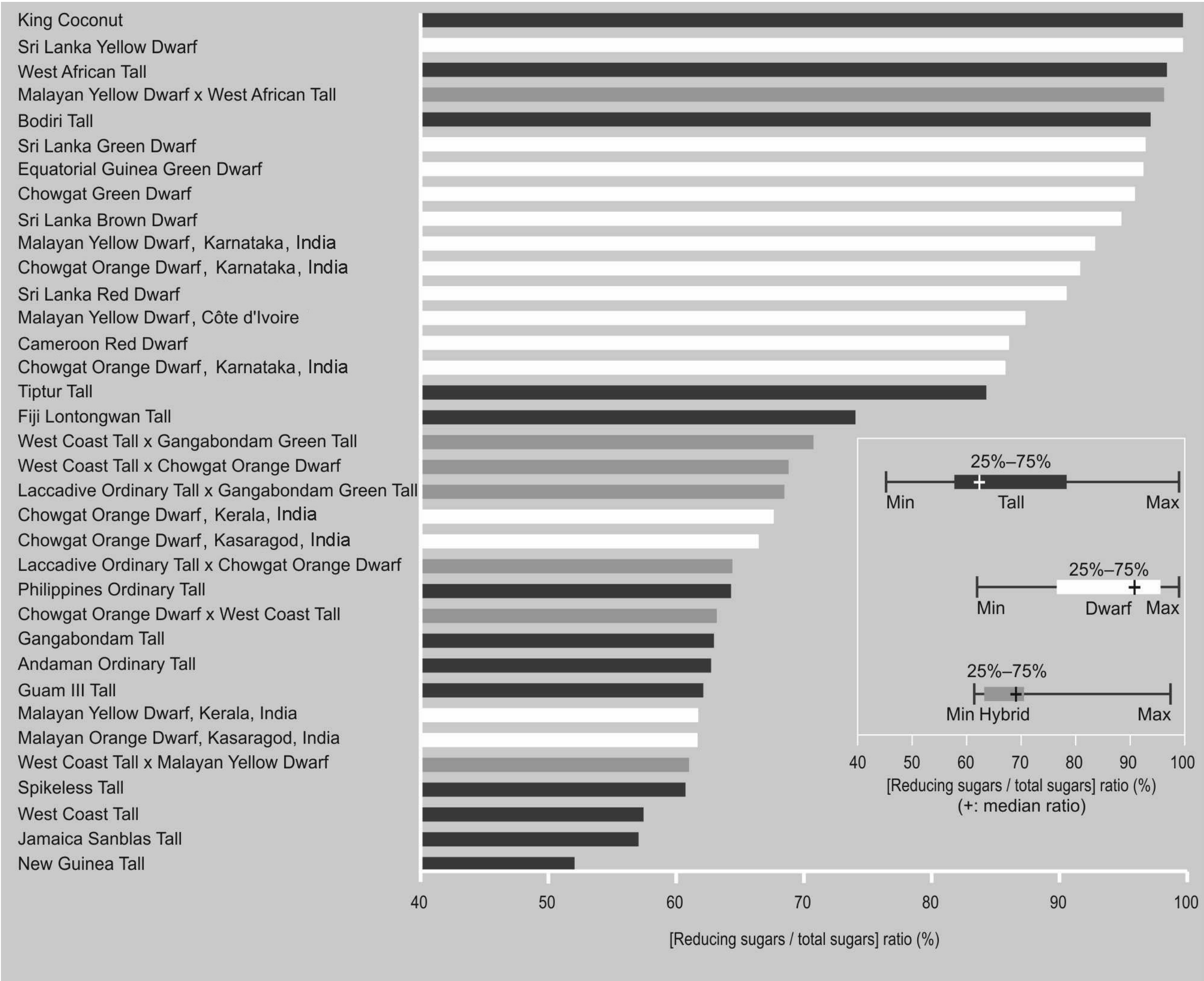


Figure 5
Ratio of reducing sugars to total sugars of the immature coconut water of 34 tall, dwarf and hybrid varieties [40, 48–50, 52, 59, 61].

correlated with TSS, [Vol × TS (or TSS) / 100], we obtain an estimation of the total sugars per nut (g per nut). Using data from *table V*, the total quantity of sugar of one immature coconut was estimated to be in the range of 9 g to 27 g (two to six teaspoons). Depending on the desired use (drink, fermentation medium, concentrated juice, etc.), a more or less sweet variety can be selected. Using varieties with high sugar contents may help start fermentation or facilitate concentration.

Reducing sugar contents (RS) of coconut water in 7-month-old nuts ranged from (1.2 to 5.1) g·100 mL^{-1} (*table V*). Contrary to total sugar contents (TS), the reducing sugar contents of coconut water appeared not to be correlated with either total soluble solids or total sugar contents. The [RS / TS] ratio ranged from 52% to 99% and varied among varieties (*figure 5*). Most coconut water from tall varieties had [RS / TS] ratios below 75%, whereas dwarf varieties generally had ratios higher than 75%. Fewer data were available concerning hybrids. A classification of coconut cultivars according to the [RS / TS] ratio of their water should be possible. However, this would require further investigation in a genetic resources collection.

Concerning potassium and sodium, the coconut water of an Arsikere Tall could exhibit 1.5 times higher potassium contents than a Malaysian Yellow Dwarf, both cultivated in India (*table V*). However, mineral contents are difficult to compare among varieties, since they are strongly dependant on cultivation practices and in particular on the fertilisers or manure applied to coconut palm orchards.

3.3. Influence of cultivation practices

Very few publications deal with the impact of the cultivation practices on the biochemical composition of coconut water, whereas many agronomic studies deal with the impact of supplementation inputs or cultivation practices on the production of ripe nuts [64, 65]. In 1992, Jeganathan was the only investigator who used coconut water as the main ingredient for the nutritional diagnosis of the plant in comparison with the usual investigation of the leaves [66]. Coconut water was highly sensitive to fluctuations in potassium and sodium inputs and also sensitive to phosphorus, sulphur and chloride supplementation.

The effects of nitrogen-phosphorus-potassium (NPK) and nitrogen-phosphorus (NP) supplementation on coconut water quality were investigated [67, 68]. Unlike potassium, nitrogen supplementation is expected to have a negative effect on the water volume, weight and number of fruits per bunch. It appeared that potassium supplementation had an effect on the potassium content of coconut water and the amount of soluble solids in 7-month-old nuts. The effect of phosphorus supplementation appeared to be similar. Electrical conductivity was negatively correlated with N supplementation. The sensory analysis of coconut water in nuts from fields fertilised with NPK was normal. However, it should be noted that the investigations were only carried out on 3-year-old coconut palms [67]. Even though these were dwarf varieties, and thus premature, these coconut palms were probably not at their maximum production stage but at their growing stage. As a consequence, these results need to be confirmed in varieties after production has stabilised.

Some field irrigation trials were carried out using salty water in Brazil. Coconut palms are being planted in increasing numbers in arid and semi-arid zones of the *Nordeste* despite the inappropriate climate. Marinho *et al*. investigated field irrigation using water at different salinity rates [(0.1; 5.0; 10.0; 15.0) $dS \cdot m^{-1}$ at 25 °C] [69]. These authors demonstrated that, using the green dwarf variety, nuts can be harvested at 7 months if the salinity of the irrigation water is below 10 $dS \cdot m^{-1}$. At higher concentrations, poor yields were obtained. The salinity of the water used for irrigation led to lower fruit mean weight and lower volume of water, but increased the electrical conductivity and the amount of total soluble solids. The coconut water had higher chloride and potassium ion contents [70].

The effects of a conventional cultivation practice *versus* an organic cultivation system on the quality of coconut water of 7-month-old nuts were investigated [51]. Except for the fact that fruits were heavier and longer using conventional cultivation practices, no difference in the quality of the coconut water was detected between the cultivation practices. Analyses by gas chromatography with electron capture and high-performance liquid chromatography with ultra-violet detection did not detect any pesticide residues in a set of 15 coconut water samples [71]. This result emphasised the organic nature of coconut water, which is often cultivated by small-scale farmers in developing countries with no chemical inputs [72].

4. Properties

Most of the original properties of coconut water are due to minor components such as minerals, volatile aromatic molecules, polyols or small peptides. Only a few of the molecules responsible for medicinal or nutraceutical properties have been scientifically investigated. As a beverage, the sensorial properties of coconut water have rarely been studied, especially colour and flavour.

4.1. Antioxidant activity

The antioxidant ability of coconut water was recently studied by a few authors, reflecting the increasing interest in the nutraceutical properties of natural products. Among 27 tropical fruits purchased in supermarkets and wholesale outlets in Singapore, coconut water had the lowest AEAC (L-ascorbic acid equivalent antioxidant capacity): 11.5 AEAC ($mg \cdot 100\ g^{-1}$) and an ascorbic acid (AA) content of 0.7 $mg \cdot 100\ g^{-1}$ [73]. The coconut kernel had higher values than the coconut water. The proportion of ascorbic acid in the AEAC of fruits varied greatly among species, from 0.06% in ciku (*Manilkara zapota*) to 70.2% in rambutan; it was only 6.1% for coconut water.

According to Mantena *et al.*, antioxidant activity was highest in fresh coconut water samples and decreased significantly on heating, acid or alkali treatments or dialysis [74]. The maturity of coconut drastically decreased the scavenging ability of coconut water against DPPH (1,1-diphenyl-2-picryl-hydrazyl), ABTS [2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid)] and superoxide radicals. Substantial antioxidant activity was also observed using the DPPH assay for extracts of two green and yellow coconut varieties obtained by hydrodistillation and petroleum ether extraction [47].

4.2. Growth-promoting factors

In comparison with nutrient broth, using sterilised clarified coconut water as a growth medium reduced the lag phase and enhanced the log phase of eight different microorganisms including *E. coli* and *S. aureus* [9]. Furthermore, after sterilisation and appropriate conditioning, a storage period of six months at ambient temperature did not affect the microbial growth capacity of coconut water.

Shantz and Steward first extracted some of the growth-promoting substances [75], which were later identified by Pollard *et al.* as sorbitol, myo-inositol and scyllo-inositol [21]. In fact, the latter (previously called *cocositol*) was first isolated from coconut leaves by Müller [76]. Myo-inositol was shown to play a major role in promoting cell division in carrot explants, followed by sorbitol and scyllo-inositol.

Cytokinins are a major group of phytohormones. They have different functions in plants including cell division, seed germination and tissue differentiation. Since 2004, a team of Singaporean researchers has regularly published papers on cytokinins in coconut water. In a series of seven articles Ge *et al.* [77–82] and Ma *et al.* [83] described previously uncharacterised coconut cytokinins. Nine phytohormones were detected and quantified in coconut water: zeatin-O-glucoside, dihydrozeatin-O-glucoside, kinetin (free base and riboside), which has strong anti-ageing effects on human skin [84], ZMP (*trans*-zeatin riboside 5'-monophosphate), gibberellins (GA_1 and GA_3), IAA (indole-3-acetic acid) and ABA (abscisic acid). A recent review of the chemical and biological properties of coconut water detailed the biological functions of these different cytokinins in both plant and human systems [85].

The presence of both polyols and phytohormones could explain the growth-promoting action of coconut water. Despite their very interesting and important results, the authors unfortunately worked on unidentified cultivars and purchased their coconut fruits in local supermarkets. Samples were immature green coconuts from Malaysia or Thailand. Nothing was known about their growing, harvesting and storage conditions, or their stage of maturity, which could have a major influence on the quality and amount of both polyols and phytohormones.

4.3. Medicinal and nutraceutical properties

As coconut water is considered to be a natural medicine in different civilisations, it was screened to identify defense peptides with bactericidal properties [86]. The aim was to find novel approaches to control resistance to commercial antibiotics. Using reversed-phase high-performance liquid chromatography (HPLC), three peptides < 3 kDa were purified and identified. These small peptides, namely Cn-AMPs, had molecular masses of 858 Da, 1249 Da and 950 Da. Cn-AMPs showed remarkable potential for the development of novel antibiotics from natural sources.

The suitability of coconut water for intravenous and oral hydration has also been reported. As an intravenous fluid, Anzaldo *et al.* infused (500 to 700) mL of coconut water into nine human volunteers and did not detect any significant change either in the electrolytic composition of the blood, or in blood pressure, pulse rate or respiration [37]. But, as stated by Campbell-Falk *et al.*, coconut water does not appear to be an ideal solution for long-term resuscitation but may serve as a temporary alternative in emergencies [16]. It should be noted that the latter result was based on mature coconut water. However, immature coconut fruits have a better mineral composition and a higher volume [87] and would be more suitable for future research on intravenous use. As an oral hydration fluid, Saat *et al.* compared the efficiency for rehydration after exercise of fresh young coconut water (CW), a carbohydrate-electrolyte beverage (CEB) and plain water (PW) [13]. Coconut water was significantly sweeter, caused less nausea, fullness and no stomach upset. It was also easier to drink in large quantities than the carbohydrate-electrolyte beverage and plain water.

Concerning blood pressure, a mixture of coconut water and Mauby bark syrup (*Colubrina arborescens*) from Trinidad and Tobago could have a beneficial effect on human hypertension [88]. Similarly, the presence of L-arginine (300 $mg \cdot L^{-1}$) in coconut water could have a cardioprotective effect through its production of nitric oxide, which favours vasorelaxation [89]. A similar hypolipidemic effect of coconut water and lovostatin (a lipid-lowering drug) was detected in rats fed a fat/cholesterol-enriched diet [90].

Concerning nutraceutical effects, coconut water reduced histopathological changes in the brain induced by hormonal imbalance in menopausal women [91]. A patented freeze-dried product, named Cococin™, was the main component of a dietary supplement and an anti-ageing skin cream [92].

Finally, the anti-cancer properties of cytokinins previously isolated from coconut water by Ge *et al.* have recently been the subject of medical research [77–82]. One of these cytokinins, kinetin, shows an antithrombotic activity [93] and a real potential power to reduce certain types of mammalian tumors [94].

4.4. Contribution to the nanoworld

Coconut water is now entering the nanoworld. A high-quality $NiFe_2O_4$ nanosized powder was prepared by a new route using a natural proteic solution of coconut water and metal ions [95]. The interest in using coconut water was that it naturally contains a large protein chain which can easily bind to metal ions. The magnetic properties of the resulting nanoparticles were size-dependent. This new method of preparation was revealed to be a cheap and efficient way to obtain high-quality nickel ferrite nanosized powders.

5. Conclusion and future prospects

Coconut water is not a common fruit juice. Its low acidity combined with well-balanced sugar content and isotonic mineral composition makes it a potential rehydration and sport drink. Quality criteria such as the water per nut ratio, Total Soluble Solids content (TSS), total sugar per nut, [reducing sugars / total sugars] ratio, and, to a lesser extent, potassium content, are good indicators for estimating the suitability of coconut cultivars for the production of coconut water as a beverage. From the synthesis of biochemical data, it is clear that dwarf coconut varieties, with their small nuts, high volume of water, high sugar contents and good organoleptic scores, are the most suitable cultivars to obtain a sweet and tasty product.

However, the quality of coconut water can not only be attributed to sugars and minerals because it also has a typical flavour (not yet clearly characterised) and some original properties. Although many authors have cited medicinal uses or growth-promoting activities, only a few publications have clearly identified the components responsible for these properties and none of them studied the potential therapeutic of combined coconut water hormones and sugars (polyols). In addition, none of these studies took into account either the origin or the stage of maturity of the coconut fruits.

It is thus important to investigate the biodiversity of coconut palm. With the assistance of COGENT (International Coconut Genetic Resources Network) and Bioversity International, many collection sites around the world (Port Bouët in Côte d'Ivoire, Aracaju in Brazil, Zamboanga in the Philippines, Kasaragod in India, Santo in Vanuatu, etc.) could be screened for quality criteria and functional properties of coconut water. An international survey could improve our understanding of the effects of climate and cultural conditions on the quality of coconut water. Such an investigation could lead to the discovery of the most suitable varieties for coconut water beverages or the emergence of some lead compounds for future medicine.

Acknowledgements

The authors wish to acknowledge Dr. Olivier Gibert and Mrs Daphne Goodfellow for the English revision of the manuscript.

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Usos, composición y propiedades del agua de coco: una síntesis.

Resumen — El producto. El agua de coco (*Cocos nucifera* L.) es una antigua bebida, cuya popularidad es cada vez mayor en el mercado multinacional de los refrescos. **Usos**. Más allá de su uso tradicional, este jugo refrescante extraído del coco se describió como una « bebida rehidratante para los deportistas ». De ahí que la industria resaltara las propiedades funcionales naturales de este fruto. **Composición**. El agua de coco posee un bajo contenido de materia seca (2 % a 5 % en base húmeda), compuesta, a su vez, por azúcares y minerales. Para seleccionar los cultivares adaptados a la producción de agua de coco, algunos de los siguientes criterios son muy buenos: el peso del agua por fruto, los sólidos totales solubles, la cantidad de azúcares totales por fruto, la relación [azúcares reductores / azúcares totales]. Habida cuenta de dichos criterios, con frecuencia, las variedades enanas son las que mejor se adaptan a la producción de este refresco. **Propiedades**. Asimismo, la calidad del agua de coco está relacionada a un sabor típico e intenso y a ciertas propiedades específicas. A pesar de que numerosos autores hayan atribuido al agua de coco unas propiedades medicinales y hayan demostrado su efecto positivo en el crecimiento de las células, aún existen pocas publicaciones que identifiquen claramente las moléculas responsables de dichas acciones. **Discusión**. Por primera vez, están recopiladas todas las investigaciones sobre el agua de coco, desde las más antiguas hasta las más recientes, y proponen nuevas pistas para mejorar nuestro conocimiento sobre este original zumo de fruta tropical.

Francia / *Cocos nucifera* / coco / agua de coco / etapas de desarrollo de la planta / maduración / calidad / composición aproximada