


Coconut Water

Nature's miracle health drink

Chemistry, Health Benefits, Packaging,
Storage and Technologies : A Review

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Coconut water is a natural, nutritious, health, and therapeutic drink from coconut palm trees. The main nutrients of coconut water are minerals, sugars, protein, fat, and other minor nitrogenous and phenolic compounds, vitamins, etc. Coconut water has a typical flavor of coconuts due to delta-lactone and has polyphenol oxidase, peroxidase, and some other enzymes. The composition of coconut water depends on many factors such as soil, nut maturity, variety, and climate. Coconut water is classified as tender coconut water (TCW) and mature coconut water (MCW). TCW has been mainly used as a natural drink while MCW is usually discarded. MCW showed much better in hypolipidemic action in cholesterol-fed rats than TCW according to studies in experimental rats and therefore may be carefully collected and bottled for use also as a health drink. The healing therapies of tender coconut water have been scientifically proven. Experimental studies involving humans and animals showed that TCW can be used to prevent oxidative stress, provide antioxidant activity, prevent lipid peroxidation activity, improve lipid profile, control blood pressure, improve cardio protective activity, provide anti-inflammatory effects, diarrhea therapy, to increase hemoglobin levels, anti-diabetic effects and anti-thrombotic activities and probably many more.

The water available from the coconut produced in the country is estimated at 0.6 million KL valued

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Table 1. The average composition of coconut and by-products and its availability (3a)

Whole coconut		Estimated By-products*		
Production of coconuts/year (average during 2010-2015)	Kernel (33% of nut)	Coconut water (18% of nut)	Husk (33% of nut)	Shell (16% of nut)
India 22,167 million	7315 million nuts equivalent	3990 million nuts equivalent 3591 million nuts equivalent to 359100KL	7315 million nuts	3547 million nuts equivalent
World 67,040 million	22123 million nuts equivalent	12067 million nuts equivalent	22123 million nuts equivalent	10726 million nuts equivalent
Tender coconuts (10% of total production**) available	132 million nuts	399 million nuts ** 99750KL	132 million nuts equivalent	64 million nuts equivalent
Current Value at Rs.20/nut(taking 250ml/nut)*	-	**798crores	-	-

*Of the total coconut production in the country, 52 percent is consumed in raw-form. About 95 percent of this is used for household uses and about 5 percent is used for small-scale industrial use like manufacturing of desiccated coconut, coconut cream, coconut milk powder, Nata-de-coco, etc. About 10 percent of the total coconut production in the country is consumed as tender coconut, it is a natural soft drink for quenching thirst. The remaining 38 percent is processed into copra, a major portion being milling copra. (consumption pattern of coconut – Shodhgangashodhganga.inflibnet.ac.in › bitstreamPDF)

**3990-399=3591million nuts x100/1000=3591million litres= 359100KL

at Rs.6000 crores/year (calculated at Rs.20/nut). Coconut water gets spoiled within 24 hr of storage at room temperature (27°C) while at 10°C stable for 2 weeks and at -20°C to +2°C, it could be stored in glass/plastic bottles (pearl pet bottles) for about 2-3 months at the author's laboratory. The contents solidify into a transparent mass and could be easily reconstituted when brought to room temperature for experimental purposes). Available technologies may be used to add value to coconut water and also to provide health benefits to consumers. There is a demand to find a cheaper technology to make packaged coconut water by retaining the natural flavour and quality. Indian Specification for tender and mature coconut water is available.

Introduction

Cocos nucifera is a perennial plant, bearing fruit continuously for up to 60–70 years⁽¹⁾. In India,

coconut (*Cocos nucifera* L.) is also called “KalpaVriksha” and is grown in 17 states and 3 union territories, mainly grown in the southern part of India. The productivity and production of coconut have been significantly increasing in India. Coconut plantation supports the livelihoods of more than 10 million people in India. It gives the national agrarian economy accompanied an annual contribution of Rs. 9000 crores to the GDP and foreign exchange earnings of about Rs. 1200 crores⁽²⁾. India stands at the third position in the world area and first in production with a share of 17 % and 31 % respectively⁽³⁾. In India, coconut farming plays an important role especially in the economy of Kerala, Karnataka, Andhra Pradesh, and Tamil Nadu states and it generates a significant share in the agriculture income in India. Kerala has been called the “land of coconuts” and has a history of coconut cultivation. The coconut production in India during 2015-

16 was 22167 million nuts from an area of 2.09 million hectares⁽⁴⁾. Coconut oil contributes around 6 % as national edible oil besides the crop contributes Rs. 7000 crores every year to the Gross Domestic Product (GDP) in India⁽⁵⁾.

The global scenario of coconut, as per the statistics of 2015, coconut has been cultivated in more than 94 countries in the world in 11.988 million ha. The coconut production is at more than 67.04 billion nuts with a productivity of 5592 nuts ha⁻¹ in the world. Coconut cultivation gives livelihood security to millions of people in the Pacific and Asian regions, which combines more than 89 % of the global coconut area and 85 % of copra production earning more than 1.08 billion US\$ as export income. The production of coconut crop has increased almost two times from 1969 to 2015 over a period of five decades⁽⁶⁾. Indonesia, Philippines, India and Sri Lanka are the four major coconut

Table 2. Coconut processing units assisted under CDB/TMOC* during 2002-2016)

Product	Units	Processing capacity (Million nuts/year)	Coconut water potential availability calculated at 250ml water per nut **	
			KL	Value @ Rs.100/L
Copra and coconut oil	105	1221.07	-	-
Desiccated coconut powder	103	1011.45	252863	2528.63 crores
Virgin coconut oil	54	216.56	54140	541.40 crores
Ball copra	47	20.94	5235	52.35 crores
Tender coconut water	25	138.6	34650	346.50 crores
Coconut chips and other products	11	3.09	773	7.73 crores
Coconut Milk & Milk Powder	03	16.50	4125	41.25 crores
		Total	351786	3517.86 crores

*Jnanadevan R., Coconut sector experiencing an all-time high price. Indian Coconut Journal February 2018, pages 8-11. ** Codex Alimentarius commission (3a).

producing countries which amount to 78% of the global production^(7,8). The production of coconut in India and the World, and the estimated availability of coconut water for tender and mature types are provided in Tables 1 and 2. The data indicates that there is a huge availability of the raw material coconut water in the country. Table 1 shows the availability of coconut water and Table 2 shows the availability of mature coconut water that is wasted at present which can be preserved to be sold as a mature coconut water beverage.

The fruit is categorized into two stages of maturity i.e., tender coconut and mature coconut. Coconut water (CW) and coconut kernel (CK) are the edible portions of coconut. Tender coconut water is considered a refreshing and rehydrating drink as it contains sugars, vitamins, minerals, growth-promoting factors, proteins, and amino acids⁽⁹⁾. Tender coconut water is low in fat and low in calories (Tables 4 & 5). As coconut is a rich source of nutrients, it is likely to get contaminated with microbes. As



Table 3. Varieties suitable for tender coconut water production

Type of cultivar	Name of Cultivar
Dwarf	COD, CGD, Gangabondam, MOD, Cameroon Dwarf, King Coconut
Tall	Benaulim, Fiji, Cochin china, Guam III, FMS, West African Tall, Tripura Tall, Sakhigopal Tall, Jamaican Tall, East coast Tall, Zanzibar, Andaman Giant
Hybrids	CODxWCT, LCTxCOD, Chandrasankara&Chandralaksha

Table 4. Proximate Composition of tender and mature coconut water of India and US

Component	Tender coconut water	Mature coconut water	USDA reported values of tender coconut water
Moisture (g/100 g)	96.7	95.7	95
Fat (g/100 g)	0.2	1.2	0.2
Total protein (mg/dl)	150	450	720
Total sugar (%)	4.8	3.1	2.61
Total reducing sugar (%)	4.0	2.0	-
Ash (g/100 g)	0.3	0.3	-
Carbohydrates%(by difference)	2.65	2.35	3.71
Potassium mg%	300	257	200
Calcium mg%	40	44	24
Magnesium mg%	16	14	24
Sodium mg%	31.4	31.9	-
Iron mg%	4.2	4.0	-
Zinc mg%	0.8	0.2	-
Vitamin-C mg%	25	15	2.4
L-arginine mg%	30	150	-
Calorie calculated kcal/100g	13	22	19.5
Calorie kcal/100g calculated =(FatX9+ProteinX4+CarbohydrateX4)			

Table 5. Proximate Composition of Indian grown tender and mature coconut kernel 12, 12a, 14a)

Composition	Coconut kernel (tender)	Coconut kernel (mature)
Moisture (g/100 g)	85.3	51.0
Fat (g/100 g) dry basis(wb)	5.33 (0.78)	26.71(13.09)
Protein g/100g db (wb)	0.90* (0.13)	2.41* (1.18)
Ash (g/100g) (wb)	9.3 (1.37)	4.3 (2.11)
Carbohydrates % (calculated by difference) wb	12.42	32.62
Potassium (mg/100 g)	97.5	122.1
Sodium (mg/100 g)	34.7	21.6
Calcium (mg/100 g)	21.5	18.1
Iron (mg/100 g)	6.3	7.9
Zinc (mg/100 g)	1.9	2.2
Calorie calculated kcal/100g	57.2	253

na = not analysed, *Wynn T., (14a)

Table 6. Water and kernel content at different stages of maturity of Indian coconut (12)

	Tender coconut 1	Tender coconut 2	Mature coconut
Water content g/nut	312±12	308±7	117±43
Kernel content g/nut	80±5	142±14	330±20

long as the CW is inside the fruit, it is considered to be the most sterile liquid. The shelf life of CW and CK is short. A small crack in the shell can cause spoilage. Therefore the shelf life of CW and CK has to be increased to preserve and in transporting to other parts of the country. The CW and CK contained phytonutrients like phenolics and tocopherols that provide health benefits.

Botanical name: *Cocos nucifera L.*

Some of the cultivars grown in India are Andaman Tall (AT); Andaman Ordinary Dwarf (AOD); Arasikere Tall(AT);Malaysian Orange Dwarf (MOD); Malaysian Yellow Dwarf (MYD); Chowghat Orange Dwarf (COD); Chowghat green dwarf (CGD); Cameroon dwarf; King coconut, Gangabondam, Benaullim, Fiji, Cochinchina, Guam III, FMS, West African Tall, Tripura Tall, Sakhigopal Tall, Jamaican Tall, East coast Tall, Zanzibar and others such as West African Tall (WAT), Malaysian Yellow Dwarf (MYD), Equatorial Guinea Green Dwarf (EGD), etc.,

Varieties suitable for tender coconut water production

It has been reported that dwarf cultivars of coconut such as dwarf COD, Chowghat green dwarf (CGD), Gangabondam, MOD, Cameroon dwarf, and King coconut are suitable for tender coconut water production^(10,10a,8) (Table 3). Harvesting period for tender coconut water production is usually about 7 months period of maturity to have the maximum amount of water in the nut (8). The weight of tender coconut ranges from 850g to 2.8kg and coconut water ranges from 200 to 700ml with an average of 425ml for different varieties The tender coconut water comprises 95.5% water, 4% sugar, 0.1% fat, minerals such as calcium, phosphorus, iron, zinc, magnesium⁽⁸⁾.

Proximate composition of coconut water

The proximate composition of tender coconut water has been reported by Yong et al., (US)⁽¹¹⁾, Prakruthi Appaiah et al., (India)^(12,12a), Zulaikhah (Indonesia)⁽¹³⁾. The data provided by Yong et al.,⁽¹¹⁾ for US dwarf variety are water content, 206-565 and 393 g/nut; dry solids, 5.01-5.82 and 5-5.5g/100g energy value, 19 kcal/100g, protein, 0.12-0.72, and 0.52 g/100g; total lipid, 0.07-0.2 and 0.13 g/100g; ash, 0.39-0.87 and 0.47 g/100g; carbohydrates by difference, 3.71-4.76 and 4.41 g/100g; sugars, 2.61-5.23 and 3.42 g/100g; calcium, 24-27 and 32 mg/100g; magnesium, 6-25 and 9 mg/100g; iron, traces; sodium, 2-105 and 16 mg/100g; potassium 204-250 and 258 mg/100g; vitamin C as ascorbic acid, 2-7 and 7 mg/100g; vitamin B group (less than 1mg) traces for tender and mature coconut water respectively. Delta lactone is responsible for the typical flavour of coconut water; auxin and cytokines are growth hormones present in coconut water. The review also covers other minor components present in coconut water. The proximate composition of coconut water for Indian tender and mature coconut reported by Sandhya and Rajamohan⁽¹⁴⁾ and Prakruthi Appaiah *et al.*,^(12,12a) are provided in Tables 4, 5, 6, 7 and 8. Table 4 shows the proximate composition of tender coconut water and the mature coconut water of India and the US. Table 5 shows the proximate composition of tender and mature coconut kernel. Table 6 shows the water and kernel content of coconut at different maturity stages. Table 7 shows the chemical characteristics of the Indian coconut at different maturity stages. Table 8 shows the chemical characteristics of coconut water

at different maturity stages on a nut basis. A typical proximate composition of tender coconut water reported by USDA provided by Sangamitra et al.,⁽¹⁵⁾ which is also shown in Table 8 along with data for Indian grown tender coconut for comparison. The data indicates similarity in some of the parameters for the Indian and US tender coconuts. The amino acid composition of tender coconut water from dwarf viridis (wulung) variety from Indonesia is as follows.

Vitamin C (ascorbic acid)	32.5mg/L
Major amino acids include L-arginine	12.7mg/L
L-aspartic acid	115.6mg/L
L-glutamic acid	56.65mg/L
L-lysine	23.8mg/L
L-tyrosine	23.6mg/L
L-histidine+serine	47.3mg/L

According to Zulaikhah⁽¹³⁾ which also provides data of other chemical characteristics.

The composition of coconut water depends on many factors such as soil, nut maturity, variety and climate (16,17). Coconut water waste is converted into valuable products in food industries. Coconut water waste is rich in growth hormones auxin and cytokines which are known to trigger plant growth (18) and contain nutrients such as sodium, potassium, iron, calcium, etc., (19).

Quality standards for coconut water

Quality standards for coconut water in India are provided in Table 9^(20,21) BIS, 2009 and 2010). Some local specifications are also available for other countries⁽²²⁾. The specification and major general composition such as moisture, total solids, fat, protein, carbohydrate, ash, minerals composition (potassium and sodium), vitamin C, amino acid such as L-arginine content, pH, acidity as citric acid may be used to authenticate the quality and potability. Table 9 shows the draft BIS specification for Indian grown tender and mature coconut water.

The health benefits (healing therapies) of coconut water are given in Table 10 and the literature of research carried out in India is provided in Table 11. Many reviews are available on the subject and hence only a few are cited. Priya and Ramaswamy^(14b), Yong et al., 2009⁽¹¹⁾ and Zulaikhah⁽¹³⁾ reviewed chemical aspects, biological properties, and health benefits of coconut water from coconuts grown in India, the US

dwarf and Indonesian dwarf viridis wulung varieties.

Studies on health improvement in experimental animals and humans

Darilyn et al.,⁽²³⁾ studied the short term intravenous use of coconut water in humans and report the successful use of coconut water as a short-term intravenous hydration fluid for a Solomon Island patient. Bhagya et al.,⁽²⁴⁾ investigated whether tender coconut water (TCW) mitigates oxidative stress in a fructose-fed diet and treated with TCW (4 mL/100 g of body weight) for 3 subsequent weeks. TCW significantly lowered the systolic blood pressure and reduced serum triglycerides and free fatty acids. The overall results suggested that TCW treatment could prevent and reverse high blood pressure induced by high fructose diet probably by inhibition of lipid peroxidation, upregulation of antioxidant status and improved insulin sensitivity. Loki and Rajamohan,⁽²⁵⁾ studied the hepato-protective and antioxidant effects of tender coconut water (TCW) in carbon tetrachloride (CCl₄)-intoxicated female rats. Decreased activities of antioxidant enzymes in CCl₄-intoxicated rats and their reversal of antioxidant enzyme activities in TCW treated rats, shows the effectiveness of TCW in combating CCl₄-induced oxidative stress. The hepato-protective effect of TCW is also evidenced by the histopathological studies of the liver, which did not show any fatty infiltration or necrosis, as observed in CCl₄-intoxicated rats. Nair and Rajamohan⁽²⁶⁾ in their study evaluated the effect of coconut water on nicotine-induced reproductive dysfunction in the experimental male rat model system. Male Sprague Dawley rats were treated with tender and mature coconut water intragastrically and nicotine subcutaneously for 5 days. The findings indicated that the coconut water supplementation improves epididymal spermatogenic cell density ($p \leq 0.05$), sperm motility, and morphology which were altered by nicotine. Coconut water also shows a significant increase ($p \leq 0.05$) in testosterone levels in nicotine treated rats. Coconut water ameliorates the reproductive toxicity caused by nicotine due to the presence of nutrients L-arginine, ascorbic acid, minerals like calcium, and magnesium. The study may also corroborate the use of coconut water in Folk medicine to reduce the toxic effects of nicotine and alcohol in reproductive function in men. Preetha et al.,⁽²⁷⁾ studied the comparative effects of mature coconut water (*Cocos nucifera* L., Arecaceae) and glibenclamide in alloxan-induced diabetic rats. Treatment with a lyophilized form of mature coconut

Table 7. Chemical characteristics of Indian coconut (from Mysore) water and kernel at different maturity stages (12)

Type	Moisture %wb	Fat* %	Ash** %	Total solids %wb	Total sugars %wb	Acidity % as citric acid wb	pH
TCW1	97	0.2	0.3	3.4	4.2	0.4	4.5
TCW2	96	0.4	0.4	3.7	3.9	0.3	5.1
MCW	96	1.2	1.2	4.3	4.6	0.4	5.2
TCK1	85	37.0	9.3	15.0	-na-	-na-	-na-
TCK2	78	50.0	6.6	22.0	-na-	-na-	-na-
MCK	51	55.0	4.3	49.0	-na-	-na-	-na-

-na- = not analysed. *expressed on a dry basis; **expressed on a dry fat-free basis

water and glibenclamide in diabetic rats reduced the blood glucose and glycated hemoglobin along with improvement in plasma insulin level, showed altered levels of blood urea, serum creatinine, albumin, albumin/globulin ratio indicating that mature coconut water has a comparable effect to that of a well-known antidiabetic drug glibenclamide. Sandhya and Rajamohan⁽²⁸⁾ carried out a study to determine the effect of coconut water feeding in cholesterol-fed rats. Administration of coconut water counteracts the increase in total cholesterol, VLDL + LDL cholesterol, and triglycerides, while high-density lipoprotein cholesterol was higher, histopathological studies of liver and aorta revealed much less fatty accumulation, increased plasma L-arginine content, urinary nitrite level, and nitric oxide synthase activity indicated that both tender and mature coconut water have beneficial effects. Table 10 shows the healing therapies of tender coconut water. Table 11 shows the studies carried out on the health benefits of coconut water.

Side effects of drinking coconut water

Coconut water is a natural drink for all ages. Coconut water might decrease blood pressure. Taking coconut water along with medications for high blood pressure might cause the blood pressure to go too low. Hence people having hypertension may consume this carefully in appropriate quantities in consultation with the cardiologist (Tables 10 & 11).

Processing of coconut water for stability improvement

Coconut water (*Cocos nucifera* L.) is an ancient

tropical natural beverage from immature coconuts and it need careful collection and bottling to sell as a commercial product. Coconut water which is removed from the nut and is ready to drink is very sensitive to biological and chemical injuries. Thermal treatment, chemical additives, micro- and ultrafiltration have been studied and have been used in the industry. Preserving taste, aroma, and colour are still a problem in the industry.

Storage at low temperatures (10°C and below), heat treatment, additives treatment, concentrate preparation and spray drying techniques are being used to improve the storage life of coconut water. According to Chowdhury *et al.*,⁽²⁹⁾ the CW heated at 100 °C for 10 min can be stored for 6 months at ambient temperature. The untreated CK got spoiled within 24hr at room temperature with bad smell and further spoilage with bacterial and mold growth with successive days of storage. The treated CK could be stored for a long time (7 months) without any spoilage. The stability of CW and CK were less than 24hr at room temperature (27 °C) as indicated by its smell and taste as reported by Prakruthi *et al.*,⁽¹²⁾. The acidity of CW (as citric acid) increased with maturity from 0.36 to 1.84 % (TCW1), 0.35 to 1.84 % (TCW2), and 0.49 to 1.7 % (MCW) indicating the increase in the sourness of CW due to spoilage caused by microbial activity. The stability of CW could be increased to more than 24hr and up to 48 hr by heating CW at two different temperatures separately i.e., 80 and 95°C. After the heat treatment, though there was an increase in the acidity the CW was fresh in smell and taste. The authors have found the freshly opened tender coconut water kept in glass/pet bottles at -20°C to +2°C for experimental purposes showed fresh coconut smell and no sourness for 2-3 months. A technology-based on concentrate preparation has been developed at CSIR-CFTRI, Mysuru which can be purchased through CDB Kochi^(3,3b). A healthy food based on tender coconut water concentrate (tender coconut solids) has been developed with good sensory properties which may provide health benefits of tender coconut water^(30,31). Many other research institutes such as the DRDO-Defence Food Research Laboratory, Mysuru and some universities have also prepared/preserved tender coconut water with chemical additive treatments/ different processing methods such as spray drying and some products are available commercially^(3b). The Coconut Development Board has commissioned about 25 production units for the preservation of tender coconut water (Table 2). Due to the presence of many



Table 8. Chemical characteristics of Indian coconut (from Mysore) water at different maturity stages (data expressed on nut basis (12))

Type	Water g/nut	Fat g/nut	Total solids g/nut	Total sugars g/nut	Ash g/nut	pH	TPC mg/nut water
TCW1	312	0.624	10.8	13.1	1.0	4.5	4.4
TCW2	308	1.232	11.4	12.0	1.2	5.1	5.5
MCW	117	1.404	5.0	5.4	1.4	5.2	4.6

health beneficial components like minerals, sugars, enzymes, fat, phenolics, tocopherols, growth-promoting factors, cytokines etc., CW and CK can serve as a nutritive food at any stages of its maturity and can be used in the preparation of functional food supplements^(30,31). Both tender and mature coconut water hence may be used as a health beverage by carefully collecting and storing in appropriate containers at low temperatures or through additives treatment or through concentrate preparation/spray drying technique.

Jeyalekshmi *et al.*,⁽¹⁷⁾ studied the characteristics of coconut water at eight successive stages of maturity for titratable acidity, pH, total solids content, total and reducing sugar content, total nitrogen content and non-protein, the composition of fats and fatty acids as well as the content of ash and mineral constituents which changed during ripening which impaired the water quality. Campos, *et al.*,⁽³²⁾ have studied the chemical composition

of green coconut water. Both polyphenol oxidase and peroxidase were observed to be present and active in green coconut water. These enzymes showed optimum activity at pH 6.0 and 5.5 and at temperatures of 25°C and 35°C, respectively. Among the chemical and physical treatments investigated, heating at 90°C for 550sec and the addition of ascorbic acid were, individually, the most efficient for enzyme inactivation. The addition of ascorbic acid did not affect sensory properties, however, heat treatment at 90°C for longer than 100 sec decreased flavour quality. Combinations of heat treatment with potassium metabisulfite, ascorbic acid, or both additives did not affect flavour quality. Reddy, *et al.*,⁽³³⁾ developed a filtration system for sterile green coconut water in a two-stage laboratory-scale constant pressure filtration system with a pre-filtration unit by ordinary filter paper (Whatman No. 4) for removal of suspended particles, and a micro-filtration unit by cellulose nitrate membrane (0.2µm pore opening) for removal of microorganisms. Coconut water concentrate can be produced using the spray evaporation technique⁽³⁴⁾. Fresh coconut water obtained from freshly opened shells under hygienic conditions, the suspended solids and oils were removed by centrifugation before concentration, whereas minerals were removed from the centrifuged coconut water by passing it through the ionic resin packed column to get a sweet taste. The concentrate had a shelf life of 6 months to 24 months depending on the degree of concentration. Ten liters of coconut water would yield about 800g of concentrate. The concentrate can also be frozen

Table 9. Indian specification for tender and mature coconut water (20,21,22)

Parameter	Tender coconut water BIS (2009)	Mature coconut water
BIS (2010)		
Total solids g/100ml	4.71	3.9 - 5.5
Total sugar g/100ml	2.08	1.70 - 3.38
Reducing sugar g/100ml	0.08	0.23 - 1.30
pH	4.5	5.2
Ash content g/100ml	0.62	0.5 - 0.84

or preserved in cans and after dilution to the desired strength, it can be used in the production of carbonated or non-carbonated coconut beverages as a base as reported by Muralidharan and Jayashree⁽³⁴⁾. Recently a German technology is available for the production of spray-dried tender coconut powder (Fig.1, e). Alexia, *et al.*,⁽³⁵⁾ reviewed the work on coconut water preservation and processing. Thermal treatment combined with chemical additives is already used by the industry but other technologies such as micro- and ultrafiltration are not yet available on an industrial scale. Whatever the process, taste, aroma and colour (linked to enzymatic activities) are still difficult to control. Sangamithra *et al.*,⁽¹⁵⁾ reviewed the work on value-added products from coconut. Adingra *et al.*,⁽³⁶⁾ carried out a comparative study between the physicochemical properties of the coconut water of Guinea Equatorial dwarf variety stored at 28°C and 10°C during two weeks indicated that coconut water storage at the cool temperature of 10°C preserved nutrients during two weeks. A recent study by Archana *et al.*, reported during 2020⁽³⁷⁾ showed membrane processing of tender coconut water as a clean, green, and energy-efficient method for cold sterilization. Sensorial quality of ultra-filtered TCW was found to be good after three months storage period with zero microbial counts. Other processing methods/technology providers are shown in Table 12, which shows the technologies available on tender coconut water preservation and packaging

Packaging of coconut water and its business:

Fresh tender coconut water in the nut is available for sale in India throughout the year (Fig 1 c). The nut has to be cut open and then water to be sipped using a straw. The fresh/stabilized coconut water packed in tetrapak/pet bottles/sachets is also available only in some parts of India the

details of packaging technology available with the manufacturers (addresses provided in Table 12) (Fig 1 and 2). The coconut water packaging market stood at \$ 9.2 million in 2017 in India and it will reach \$ 25.4 million by 2023. Due to the stress and hectic lifestyle, there is a huge demand for coconut water to address the health concerns among consumers. There is a clear indication that the coconut market is exploding. Coconut water currently represents an annual turnover of US\$ 2 billion with more than 200 brands are now marketing coconut water.

The major packaged coconut water producers in India are

1. Jain Agro Food Products Private Limited, Bangalore, Karnataka,
2. Pure Tropic, Tiruppur, Tamil Nadu,
3. Dabur India Limited, Ghaziabad, UP
4. Manpasand Beverages Ltd, Savli Vadodara, Gujarat
5. Lifetree Agro Foods Private Limited, Kerala
6. Nilgai Foods Private Limited, Mumbai
7. Habit Wellness Private Limited, Mumbai
8. Madhura Agro Process Private Limited, Coimbatore, Tamil Nadu
9. Agricoles Naturel Foods Pvt Ltd, Kuttoor, Kerala
10. Nature's First India Private Limited, Krishnagiri, Tamil Nadu

Trade/brand names for packaged coconut water:

Packaged tender coconut water is also known by the following brand names internationally: Agua de Coco, Asian Coconut Water, Coconut Drink, Coconut Fruit Water, Coconut H2O, Coconut Juice, Coconut Palm Water, Coconut Rehydration Solution, Cocos nucifera, Eau de Coco, Eau de Coco Verte, Eau de Jeune Coco, Eau de JeunesNoix de Coco, Eau de Noix de Coco, Eau de Noix de Coco d'Asie, Eau du Fruit du Cocotier, Fresh Young Coconut Water, Green Coconut Water, Kabuaro Water, Young Coconut Water.

It is commonly practiced that the coconut water present in the mature coconut used for the production of virgin coconut oil is being wasted and allowed to putrify/dry in open pits in some industries due to reasons not known. Many kiloliters of this water are going as waste in this way and maybe carefully collected and processed/ vacuum concentrated for use at a later stage for use as a health drink. (Table 12 Fig 2.).

Many research institutions and universities are contributing to the production of wide varieties and hybrids of coconut, cultivation technologies, value-added products, and by-product utilization at the national level, and these are provided below and

Table 10. Healing therapies of Tender coconut water(3)

- 1 Feeding baby with intestinal disorders
- 2 Oral rehydration
- 3 Preventing body chillness
- 4 Preventing prickly heat, eliminating rash caused by chickenpox, measles, etc.
- 5 Killing the worms
- 6 A good drink in case of cholera
- 7 Diuretic
- 8 Treating kidney and urethral stones
- 9 Preventing urinary tract infection and urinary tract antiseptic
- 10 Intravenous injection in case of emergency
- 11 Detoxification in cases of toxins poisoning
- 12 A tonic for the elderly and the sick

technologies providers address shown in Table 12.

1. ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala
2. State Agriculture Universities
3. Coconut Development Board, Kochi, Kerala
4. CSIR-Central Food Technological Research Institute, Mysuru, Karnataka
5. Regional Research Laboratories under CSIR, and others.
6. Indian Institute of Technology, Kharagpur

Conclusion

Coconut water is a natural, nutritious, health, and therapeutic drink from coconut palm trees. Coconut water is classified as tender coconut water (TCW) and mature coconut water (MCW). While the tender coconut water is available which forms only 10%, the mature coconut water forming 90% gets wasted due to its diverse uses in daily food preparation, coconut processing industries, marriage, and religious functions such as offering to god in temples, etc., However, the mature coconut water wasted in industries processing coconut and the industries producing virgin coconut oil may be collected and preserved for bottling/spray-dried powder production. TCW can be used in many healing therapies such as to prevent oxidative stress, provide antioxidant activity, prevent lipid peroxidation activity, improve lipid profile, control blood pressure, improve cardio-protective activity, provide anti-inflammatory effects, diarrhea therapy, to increase hemoglobin levels, anti-diabetic effects and anti-thrombotic activities and probably many more such as anticancer and antiviral effects. Therefore, the tender and mature coconut water

Coconut water is tropical natural beverage from immature coconuts which need careful collection and bottling to sell as a commercial product. Coconut water is a natural and ready to drink beverage and is very sensitive to biological and chemical injuries.



need to be carefully collected, preserved, and bottled/ or spray-dried and packed for marketing later on as shelf-stable products using presently available technologies to add value to coconut water and also to provide health benefits to consumers. There is a demand to find a cheaper technology to make packaged coconut water by retaining the natural flavour and quality. Indian specification for tender and mature coconut water is available. The amount of coconut water (tender+mature) available from the present production is estimated at 0.6 million kilolitres valued at Rs.6000 crores/year. Although some attempts are being made to collect, process and pack tender and mature coconut water, its full potential to be realized to get value addition to the coconut growing farmers and the industry which in turn may meet the increasing demand of coconut water in the country and also provide health benefits to the consumers. ■