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Review paper

HUMAN NUTRIENT METHODS

Authenticity and the Potability of Coconut Water - a Critical Review

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Abstract

Background: The content of the endosperm of the coconut (*Cocos nucifera* L.) contains "coconut water". This practically sterile liquid which is prized for its delicate, albeit labile, flavor when fresh, has had a recent dramatic increase in global demand. The organoleptic superiority of water from young coconuts means that degree of maturity at harvesting is the most influential factor in yield and composition.
Objective: To provide a guide to establishing the authenticity and the potability of samples of coconut water.
Method: Review and evaluate the literature on the factors that determine the composition and stability of coconut water.
Results: Data is presented on the variances in natural composition, maturity, processing-induced compositional changes, adulterations, product recalls, classical and instrumental methods of analysis and on the available composition standards of coconut water.
Conclusions: Advice is provided for official food analysts, and others, on prudent approaches as how to ascertain the authenticity and potability, or otherwise, of coconut water samples.

The coconut fruit (strictly, a drupe) is well known and *Cocos nucifera* L., is regarded as an important and much-grown crop globally. The drupe envelope (mesocarp or husk), is extensively marketed after processing as rope, carpets, geotextiles and growing media (1). Activated charcoal can be made from the shell (endocarp). The inner part (endosperm) consists of a white kernel within which is a liquid, "coconut water". The dried kernel meat, referred to as copra, is used as desiccated coconut or extracted for oil. Coconut water is the clear, colorless liquid extracted, without expressing the coconut meat, directly from the inner part of the coconut fruit. It is sometimes referred to as "coconut juice" (e.g., in the Codex Alimentarius standard, see below) and, erroneously, as coconut milk which is a white liquid made from the grated fresh kernel (1). Coconut water is practically sterile in the coconut and is widely consumed as a drink, prized for its delicate, albeit labile, flavor when fresh. Coconut water has attracted religious symbolism in Asia, has reputed health benefits, contains phytohormones (auxin, cytokinins and gibberellins), has been investigated as a growth medium, and as biocatalyst for microorganisms and plants (1, 2). Although not ideal, it has been used direct from the coconut *in extremis* as a short-term intravenous hydration fluid (3, 4).

C. nucifera is a monotypic member of the Arecaceae family. There are three varieties: Tall (*C. nucifera* var. *typica*), Dwarf (*C. nucifera* var. *nana*) and Hybrid (a cross between Dwarf and Tall). Cross breeding of these varieties has resulted in numerous cultivars. According to Konan et al. (5), the three most popular cultivars worldwide in 2011 were West African Tall, Malaysian Yellow Dwarf and "PB121" Hybrid. A report in 2016 cited Green Dwarf, King Coconut, Aromatic Green Dwarf (Nam Hom) and Chowgat Orange Dwarf as the most popular cultivars for coconut water consumption (6). Numerous other cultivars are used in the production of coconut water. Each variety exhibits diverging characteristics including fragrance (7).

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Coconuts are grown in various regions around the world. Indonesia has the world's largest production, followed by the Philippines and India. These three countries were reported in 2018 to account for some 78% of global coconut production, with 12 other countries making up the remaining 22% (8). South America and Asia reportedly accounted for over 90% of world consumption to 2018 (6). European sales of coconut water seem likely to increase from a low baseline. Indeed in recent years there has been a dramatic increase in the UK and global demand for coconut water (9) due to its reputed potential as a sports drink and a natural isotonic drink (10). In 2016 some 45% of the UK supply of coconut water originated in Thailand (11).

The increase in its consumption (12) and potential for variation in composition in commercial products makes a review necessary of the likely problems that may arise in the confirmation of the authenticity and the potability of samples submitted for examination. In recent UK surveillance of imported products described as coconut water 60% (7 of 12 samples) were found to contain added sugar albeit the sample size was small, and some of the implicated brand owners questioned the analytical procedure (13).

Natural Sugar composition and other variances

Coconut water contains sugars, minerals, vitamins, amino acids, enzymes, volatile aromatic compounds and other biochemical compounds (14). The composition of raw coconut water is determined by a range of factors including growing region, which influences soil, environmental conditions and fertilizer application, variety and cultivar, and the stage of maturity at harvesting. The range of coconut growing areas is large (8) and each region grows particular cultivars resulting in compositional variations among commercially available coconut products (15). For example, Prades et al. (1) reported that the variation in total sugars in water from mature coconuts, from various varieties and origin, was in the range of 1.8–4.4 g/100 mL. However, owing to the organoleptic superiority of water from young green coconuts, maturity at harvesting is the most influential factor in yield of water and its composition.

Maturity at Harvesting

The coconut fruit takes on average 11–12 months to mature, during this period fruits can be divided into three categories based on chemical composition of their water: Immature or Tender (6–8 months), Mature (9–11 months), and Overly-mature (12 months or older) (5, 15, 16). The volume of coconut water per nut and its composition were studied by Jackson et al. (15) and Tan et al. (16) (among others). The volume was found to be maximal in coconuts aged 6–9 months. In general, the turbidity of the coconut water increased with maturity, the pH tended to rise, with inverse changes in acidity and the soluble solids (°Brix, the total sugar content) tended to increase but fall off with maturities above 12 months, with a general decrease in Brix values from around 7 months onwards. The standard deviation of these data was usually small. Although there were statistically significant differences between cultivars, the specific cultivars would not be known in detail by the ultimate consumers when purchasing retailed products. Figure 1 illustrates typical total sugar findings (the standard deviations of the data have been omitted for simplicity).

The variations in volume and composition with variety and nut maturity have important influences on the trade in coconut water products. Although water from immature coconuts is regarded as the best for human consumption, large volumes of mature coconut water are available as a waste product from copra and coconut milk/cream production (5, 6, 17). Most commercial products are blends of coconut water from various undeclared sources including amounts of fragrant varieties (7) and in many cases without a statement about added sugar or other additives (18). This raises serious problems in attempting to test processed coconut water samples for authenticity apart from the question of their potability.

Table 1 collates data for sugars from a number of authors (1, 10, 14, 16), who collected data from 14 papers published mainly in the 20th century. The sugars data exhibit some variability,

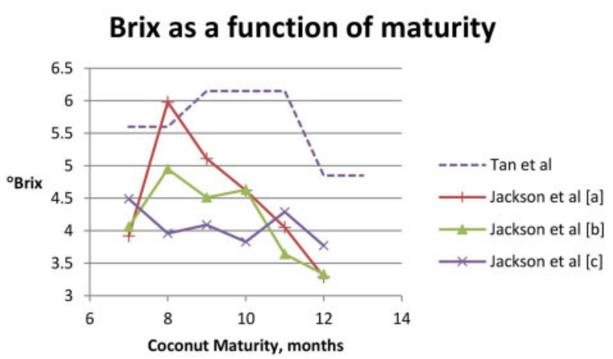

Figure 1. Total sugars (Brix) in coconut water as a function of cultivar and maturity, (Data from Jackson *et al.* [16] (a,b & c are different cultvars) and Tan *et al.* [17].

Table 1. The sugar concentrations in coconut water

	Water from young coconuts, mean[a]	Water from young coconuts, range[a]	Water from intermediate coconuts, mean[b]	Water from mature coconuts, mean[c]	Water from mature coconuts, range[c]
Total sugars(g/100 mL)	2.92	0.9 to 5.2	5.54	2.5	1.4 to 4.4
Sucrose (g/100 mL)	**0.08**	**0.06 to 0.09**	**0.66**	**1.88**	**0.1 to 6.4**
Glucose (g/100 mL)	2.18	0.4 to 3.5	2.45	1.62	0.2 to 3.0
Fructose (g/100 mL)	2.29	0.4 to 3.9	2.43	1.56	0.3 to 3.3
Glucose/ Fructose ratio	0.95	0.9 to 1.0	1.00	1.16	0.8 to 1.5
Reducing sugars/ Total sugars ratio	**1.02**		**0.88**		**0.68**

[a] Assumed <6 months old; data adapted from (14) and (16).
[b] Stated 8–9 months (10), mean of three varieties, Dwarf, Tall and Hybrid, the standard deviations of the data were small.
[c] Assumed to be 12 months old; data adapted from (1, 14, 16).
Bold draws attention to data which may help to distinguish young from mature coconut water. Units: g/100 mL and g/100 g assumed to be equivalent.

as would be expected for natural products; however, they distinguish coconut water from fruit juices in general which must meet minimum Brix levels (typically 7–11.2% with some exceptions) (19). It may also be possible to distinguish water from young coconuts from water from mature coconuts based on (a) their sucrose content, which increases at the expense of glucose and fructose as the fruit matures, and (b) the reducing sugars to total sugars ratio (Table 1). Turbidity, which tends to increase with maturity, may also serve as a visual screening mechanism (young coconut water should be visually clear) and pH data in the above studies may also assist. Sorbitol concentrations and formol values (20) have also been considered to be useful in characterisation of young versus mature coconut water.

As with fruit juices, coconut water contains significant concentrations of potassium (mean K = 2019 mg/kg, r = 338–3080 mg/kg, n = 31 from nine studies) (1). The same authors (1) collate contradictory sodium data, citing low concentrations of sodium (mean Na = 25.6 mg/kg, r = 10.0–38.0 mg/kg, n = 31 from five studies) and separately five data points from five different studies with a mean Na of 289 mg/L (r = 41–480 mg/L). Although it is tempting to suggest the lower data arise from a decimal point error equally divergent sodium data are seen elsewhere (15) (Na 15.5–1050 mg/kg) hence the most that can be said is that coconut water sodium ion concentrations are highly variable. Comparison with RSK values (Richtwerte und Schwankungsbreiten bestimmter Kennzahlen, standard values and ranges of certain analytical characteristics [of fruit juices]) (21) may also be valuable and also states sodium ion levels may be variable.

Processing-induced compositional variances

Freshly extracted coconut water is not stable. A variety of processing methods are available for the production of stable products. A FAO guide is available on good practice for the small-scale production of bottled coconut water in coconut growing areas (22). The FAO guide gives harvesting and processing precautions to avoid contamination or spoilage and recommends several compositional standards (see below). A variety of thermal and non-thermal processing methods have been explored (23, 24) in addition to the use of additives (such as L-ascorbic acid (25), potassium sorbate and sodium metabisulfite (26), citric acid, ascorbic acid, L-cysteine (27) and sodium sulfite (28)) to ensure products' sterility and stability to enable long-term worldwide commercialization. The various processing methods and use of additives affect the chemical composition and the organoleptic properties of products. High pressure carbon dioxide (HPCD) treatment was found to produce microbial stability and preserve the nutritional and sensory attributes of coconut water (29). In a further detailed study of the effects of thermal processing (TP) versus HPCD of coconut water on its volatile components, 73 compounds were isolated and structures assigned to all but six of them by head space solid-phase microextraction-gas chromatography-mass spectrometry. The authors found apparent changes induced by HPCD were fewer than by TP such that the sensory characteristics were comparable with those of fresh untreated samples (30). High power ultrasound has been shown to be synergistic with HPCD in reduction of microbiological organisms (31). The variation in composition under different thermal processing conditions, with and without the addition of sulfite, was studied by Sucupira et al. using nuclear magnetic resonance (NMR) (32). These authors appear to have been the first to apply NMR combined with principal component analysis to the evaluation of the composition of coconut water and were able to quantify sucrose, α and β-glucose, fructose, ethanol, and malic acid. Sulfite addition and processing to 136°C were effective to prevent pinking and maintain the levels of the main organic compounds.

Pesticides

The use of pesticides appears essential to the productivity and preservation of coconut palms. Hence, it is important to determine their residues in coconut products to determine their fitness for consumption and compliance with established maximum residue levels. A multi-residue Liquid chromatography-Mass spectrometry/Mass spectrometry method has been developed for ten legal and illegal pesticides used in coconut production (33).

Product recalls

Only seven RASFF (34) notifications for coconut water were found in a search of the Rapid Alert System for Food and Feed Portal for relevant entries between August 2011 and June 2019, see Table 2, among a much larger number for other coconut products. Three alerts were for additives (sulfites or benzoic acid), one for inadequate thermal processing and three for milk protein allergens. The RASFF does not record authenticity issues.

Standards for coconut water

The Codex Alimentarius standard for "aqueous coconut products" (35) refers only to coconut milk and coconut cream. Coconut water is regarded as a juice and is subject to the general provisions of the Codex Alimentarius General Standard for Fruit Juices and Nectars (36), which sets general compositional, labelling and purity, including food additives, requirements. An

Table 2. EU Rapid Alert System for Food and Feed (RASFF) notifications

Ref	Date	Product	Substance/hazard	Analytical result	Status	Origin
2017.APQ	April 7, 2017	Coconut drink	Presence of milk protein	>449 mg/kg	Not (yet) placed on the market	China
2017.APU	April 7, 2017	Coconut drink	Presence of milk protein	>449 mg/kg	Not (yet) placed on the market	China
2016.1291	November 14, 2016	Coconut drinks	Inadequate thermal processing	n/a[a]	Distributed to EU countries	Poland
2015.1539	January 11, 2016	Coconut juice	Casein (milk protein)	>13.5mg/kg	Distributed to EU countries	China
2013.BAD	May 27, 2013	Coconut juice	Sulfite - unauthorized	100 mg/L	Not placed on the market	Thailand
2012.0072	February 17, 2012	Coconut juice with pulp	Undeclared sulfite	39 mg/L	Information not available	Thailand
2011.BRL	August 19, 2011	Coconut water	E 210 - benzoic acid, unauthorized	94.8 mg/L	Not placed on the market	Brazil

[a] n/a, not availiable

Search criterion "coconut," searched on 15th June 2019, search date range between 01 August 2011 and 15th June 2019.

important general requirement that has significant bearing on market authenticity is that "*For directly expressed fruit juices, the Brix level shall be that as expressed from the fruit and the soluble solids content of the single strength juice shall not be modified, except by blending with the juice of the same kind of fruit*" (paragraph 3.1.1 (a) of the Standard (see also 37)). This requirement is reproduced in national standards, for example that of Bhutan (38). Hence, added sugars are not permitted. There are two specific requirements for which coconut water is mentioned by name in the standard, (a) a minimum Brix level of 5.0% for reconstituted (i.e., from concentrated) coconut water and a minimum of 25% coconut water inclusion in any "nectar" made from coconut water. European law (37) (which should be consulted for general authenticity, purity and labelling requirements) on fruit juices and similar products also applies to coconut water. However, no explicit compositional criteria are given therein.

Thus, to date, no comprehensive international compositional standards have been set for coconut water or for the methods of its production and preservation for retail sale worldwide. However, several local standards have been drafted. In 2006 in the Philippines, the Bureau of Agriculture and Fisheries developed the Philippine National Standard (PNS/BAFPS 28: 2006) for chilled package young coconut water products, consumed locally, specifying some chemical and sensory properties, microbiological standards and labelling requirements (39). Sabapathy and Bawa in 2007 (40) noted that "mature" and "tender" coconut water contained 0.2 and 4.4% reducing sugars, respectively, and proposed minimum product quality requirements for preserved "tender" coconut water. Their standards included preparation from 4–5-month-old nuts, microbiological, packaging and labelling criteria as well as the following chemical criteria: total solids 3–4%, total sugars 3–4% and pH 4.9–5.2. A "natural taste and flavor" was required with no artificial colors and flavorings but nisin was permitted as a preservative. The FAO good practice guidelines mentioned above (22) for the application of "middle-level" technology, for the small-scale production of chilled bottled coconut water in St. Vincent and Jamaica gave physicochemical characteristics of pH (5–5.4) and Brix (5–6.5). A draft standard was then produced for packaged natural coconut water (41). Two Indian Standard Specifications have been developed for packed tender coconut water (42) and for packed matured coconut water (43) reflecting the work of Sabapathy and Bawa (40). A summary of these standards is in Table 3.

The European Fruit Juice Association (AIJN) has been working on a reference guideline for coconut water. A provisional guideline was developed in 2017 and was adopted as a "full" guide in 2019. These guidelines form part of the AIJN Code of Practice, which is available to subscribers only. The authors have had sight of the section on coconut water through the good offices of the British Soft Drinks Association (BSDA) that, through its Fruit Juice Quality Control scheme has been looking at the authenticity of coconut water products on the UK market (F. Palmer, The British Soft Drinks Association, personal communication). The AIJN reference guideline seeks to define acceptability criteria for coconut "water"/coconut juice. The parameters are listed under two sections, one containing parameters that characterize absolute quality requirements and a second section relevant to the evaluation of identity and authenticity. The guideline emphasizes that a valid conclusion regarding the authenticity of a particular sample can only be reached after expert interpretation of all the analytical data. It is

Table 3. Summary of draft standards for coconut water

	Philippine National Standard (PNS/BAFPS 28: 2006) (39)		Jamaican Standard (DJS CRS 3: 2010) (41)	Draft Indian Standard (FAD 10(2009)C) (42, 43)	
Commodity	Chilled young coconut water	Chilled young coconut water drink	Packaged natural coconut water	Packed tender coconut water	Packed matured coconut water
Local name	Buko juice	Buko juice drink			
Source	100% buko juice refers to unmodified natural aqueous liquid of 6–9-month-old coconut [a]	Buko juice with the addition of potable water (not more than 20%) ± permitted sweeteners [a]	Undiluted natural untreated clear liquid endosperm of the coconut, harvested 7–9 months after pollination (no solid endosperm)	Natural aqueous liquid endosperm of the 5–6-month-old coconut, without addition of solid endosperm	Natural aqueous liquid endosperm of the 12-month-old coconut, without addition of solid endosperm
Appearance	clear to slightly turbid	clear to slightly turbid	Clear to translucent		
Total soluble solids (°Brix)	4.0–7.5	6.0–10.0	3.8–6.9	4.71 g/100 mL [Total solids]	3.9–5.5 g/100 mL [Total solids]
Total sugars			3.34–6.52 g/100 mL	2.08 g/100 mL	1.70–3.38
Reducing sugars			3.19–5.50 g/100 mL	0.08 g/100 mL	0.23–1.30 g/100 mL
Non-reducing sugars			0.28–1.44 g/100 mL	1.28 g/100 mL [Sucrose]	0.98–3.14 g/100 mL [Sucrose]
Total titratable acidity % m/m	0.03–0.08	0.02–10	0.072–0.090 As citric acid		
pH	4.60–5.10	4.30–6.25	4.6–5.5	4.5	5.2
Total fat			0.55–1.55 g/100 mL		
Specific gravity	1.023–1.070	1.020–1.220			
Ash			0.39–0.84 g/100 mL	0.62 g/100 mL	0.5–0.84 g/100 mL
Potassium mg/L	Not less than 1400	Not less than 1100			
Additives		See above, and must be labelled	None permitted	Nisin (to a limit prescribed in Indian law)	

[a] Buko juice/drink with the addition of tender solid endosperm from 6 to 8-month-old coconut is also permitted.

not usually prudent to regard a sample as adulterated when only some parameters do not fall within the values quoted in the second AIJN section.

Overall the AIJN sets a greater number of guideline parameters than the other standards cited above and although numerical values differ they are generally within the same order of magnitudes.

Non-classical analysis

The standards summarized in Table 3 rely for the most part on classical analytical techniques. More advanced approaches have been proposed including Raman spectroscopy, FTIR, NMR in combination with chemometrics or GC-MS. Purkayastha et al. showed good correlation between the data obtained by NMR, FTIR and GC-MS in a quality prediction study on the effects of L-ascorbic acid addition to micro-filtered coconut water (44). Richardson et al. (45) described Raman spectroscopy with chemometrics to assess potential adulteration of fresh coconut water by added sugars to conceal aqueous dilution. Coconut water from seven young (6–9 month) Costa Rican coconuts was pasteurized, diluted and sugars added singly (glucose, fructose, sucrose), in mixtures or as high-fructose corn syrup (HFCS). It was possible to detect added single sugars with limits of detection (LOD) in the range 1.9–2.6%, detection of added mixtures of sugars and HFCS were more difficult, (total samples examined = 155). The authors concluded that Raman spectroscopy has potential as a rapid accurate analytical method for the detection of adulteration in this product, with the ability to discern small abnormalities in sugar ratios within coconut water (45). The same research group applied ^{1}H NMR and chemometrics to the problem of adulteration of coconut water with water–sugar mixtures. A LOD of added sugars of 1.3% was achieved (45 samples) and the chemical shift and line-shape of the malic acid signal appeared to be diagnostic for exogenous sugar mixtures (46). However, one issue here is that the levels of the three main sugars in coconut water (sucrose, glucose and fructose) are inherently variable and the predictive ability of Raman and ^{1}H NMR with chemometrics applied to commercial samples may be more problematic than the limited experimental data might suggest.

The concentrations of free and total sulfur (IV) compounds in coconut water have been determined using high resolution continuum source molecular absorption spectrometry. The sulfite bound to organic compounds is released by addition of sodium hydroxide prior to generation of sulfur dioxide. The method was shown to be statistically equivalent to a reference method and was applied to coconut water samples taken in Brazil ($n = 5$) with results between 13.0 and 55.4 mg/L for free sulfite and 24.7 and 66.9 mg/L for total sulfur (IV) compounds (47). Addition of sulfites to coconut water is not permitted in European food additive law.

Stable isotope ratio mass spectrometry (SIRMS) analysis is a powerful authentication approach widely applied for authenticity and geographic origin investigations (48). In particular, carbon SIRMS is valuable in detecting exogenous sugars. Most plants can be classified according to their photosynthetic cycles as C_3 or C_4 depending on the number of carbon atoms in first molecules formed. The enzymes responsible cause enrichment of ^{13}C to different extents, providing a means to differentiate C_3 plant products such as coconut water from C_4 plant products, such as cane sugar and maize derived syrups (49–51). Psomiadis et al. (52) applied this technique to coconut water including additional LC to separate individual sugars prior to SIRMS, finding the latter to improve the LOD for added C_4 sugars. Subsequent analysis of 24 coconut waters on the (presumably Austrian) retail market implied 38% contained undeclared exogenous C_4 sugars. Imaizumi et al. (53) applied carbon SIRMS to detect coconut water adulteration in Brazil. Brazilian law permits up to 1% added sugar in coconut water. Coconut water ($n = 13$ locations, 17 different brands) and cane sugar were analyzed by elemental analysis-SIRMS. The coconut water exhibited carbon isotope ratios between −26.40 and −23.76%. Of the 17 brands examined, 11 (65%) appeared to contain exogenous sugars (53).

DNA

The genetics of the coconut have been extensively studied (see for example (54)). It is known that nucleic acids are present in coconut water (55) at relatively low yields and not of cellular double stranded DNA but of microRNA hybrids (56, 57). Hence, PCR authenticity studies are, to our knowledge, lacking but may prove interesting should they be carried out.

Discussion

Coconut water is known to be adulterated by a variety of means (see Figure 2).

Due to the lability of fresh tender coconut water, commercial coconut water products are stabilized blends of a variety of waters to achieve products of wide acceptability of taste and odour. No European standard exists for the chemical composition of such products. Thus following a check for appearance (lack of appreciable turbidity), organoleptic acceptability and sterility, further investigation of samples should focus on conformity of labelling with regard to absence or otherwise of added sugar, the presence of any preservative and other additives, pesticides and heavy metals. Classical analysis should be carried out for total soluble solids (°Brix), total sugars, reducing sugars, non-reducing sugars (by difference), pH and total titratable acidity (as citric acid), total fat, potassium, sodium and (optionally) specific gravity and mineral matter (ash). It is also probably worth checking the concentrations of malic and citric acids, as the former is the major organic acid of coconut water and high levels of citric acid indicates an addition (58). The results can be compared with the standards set out in Table 3, which may

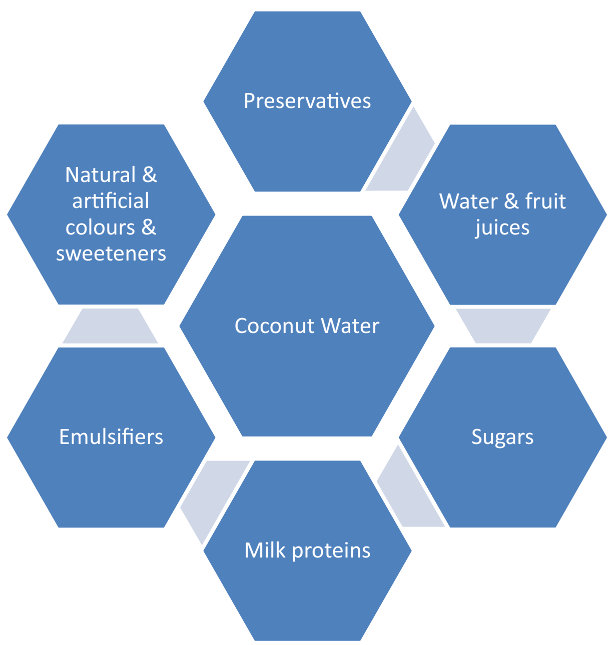

Figure 2. Previously identified adulterants.

enable an opinion to be formed as to the authenticity of the sample. Suspicions of non-compliance might, at this stage, be further investigated by documentary checks and a review of the audits of the supply chain. Further analytical investigations might involve Raman, FTIR or ^{1}H NMR spectroscopy albeit access to chemometrics and a suitable database of authentic and non-authentic spectra will be necessary. Stand-alone determination of the carbon stable isotope ratio of the bulk sample by elemental analysis IRMS, or of its component sugars separated by HPLC, will provide almost certain proof of adulteration with exogenous sugars if ratios above around –21‰ are found. By analogy with the work of Elfein and Raezke on honey (59) and given the protein content of coconut water the use of the carbon isotope ratio of the extracted protein as an internal standard would be worth experimental exploration.

Although there is no apparent commercial incentive for the addition of cow's milk as such or as skimmed milk powder, several RASFF notifications arose for milk proteins in coconut water. The unexpected and unlabelled presence of a major allergen such as milk is a risk to persons with milk allergy (60) and a potential offence under food labelling law. Hence although it is in our opinion more likely to be a risk of occurring in coconut milk, analysts should remain alert to the possibility and consider screening for milk protein, e.g., by ELISA (61).

Conclusions

Coconut water can be distinguished from fruit juices and many soft drinks by its appearance (including turbidity), organoleptic qualities, lower soluble solids (°Brix), sugars profile, higher pH and lower acidity (Table 1 and Figure 1), taking due account of its potassium, L-malic and citric acid contents. Some differentiation between coconut water with optimum taste from young fruits and that from more mature fruits may be attempted from the same parameters, and from sorbitol concentration. Suspicions formed by these data should be further investigated by documentary and audit checks. Raman, FTIR or ^{1}H NMR spectroscopy with chemometrics have been applied to investigate coconut water authenticity. However, access to appropriate chemometric techniques is required and current published databases of authentic and non-authentic spectra do not appear to be large enough and unlikely to have had due regard to the latest recommended composition guidelines (62). Stand-alone determination of the carbon stable isotope ratios of the bulk sample and/or of its component sugars will provide almost certain proof of adulteration with exogenous sugars if ratios significantly above around –21‰ are found. Although even here care is needed as data as high as –21.3‰ have been reported for authentic coconut water from Thailand (58). Screening for milk protein should be considered albeit evidence for its inclusion in coconut water is sparse. The presence of free RNA in coconut water is known; to our knowledge PCR authenticity studies remain lacking, but may prove interesting.

Based on our review of the literature we make three recommendations:

(1) Experimental exploration of the use of the carbon isotope ratio of extracted protein as an internal standard for carbon SIRMS should be undertaken.
(2) A weight of evidence approach should be taken to assess coconut water authenticity bearing in mind the above conclusions.
(3) Sight of the local standards and AIJN reference guideline acceptability criteria for coconut water would be essential for any official analyst before issuing an adverse opinion against a sample of coconut water.

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Disclaimer: The views expressed herein are entirely those of the authors. Any view, information or advice given should not be taken as an authoritative statement or interpretation of the law, as this is a matter for the courts.

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