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A concise review on tender and mature coconut water: Its application in food

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Abstract
The world, people drink coconut water because it is healthy, natural, and energising. It is a transparent liquid taken from the centre of young and old coconuts. This liquid is significant because it has a special combination of bioactive components that may be used in a variety of food industry applications. This review analyses the nutritional, physicochemical, and enzymatic benefits of young and mature coconut water as well as their uses in food items. It also offers a thorough summary of these aspects of coconut water. Non-Thermal and thermal processing methods are two preservation methods that can be used to increase the shelf life of coconut water. Further research is needed to explore the full potential of coconut water as an ingredient in food products and to optimize its use in the industry.

Keywords: Coconut water, *Cocos nucifera* L, phenolics, nutrition, food industry

1. Introduction

The coconut tree (*Cocos nucifera* L.), is revered as a priceless present from nature to people. Because every component of the tree has a distinct significance, sometimes it is referred as the "tree of life". The fruit is botanically referred to as a drupe, not a nut. The three small indentations (eyes) on hairy nuts were comparable to the head and face of a monkey, prompting early Spanish explorers to call it "Cocos" or "monkey face"; "Nucifera" defines "nut-bearing." It is rightly honoured in India as "Kalpavriksha" (Ahmad *et al*., 2020) [1]. Coconut is the primary supplier of fat in South Asian and South East Asian cuisines. The root is employed as a source of medicine, while the leaves and stem serve as building materials. The fruit is the most commercially viable portion; the husk, or mesocarp, is processed into rope, carpets, geotextiles, and growth medium. It is possible to create extremely high-quality activated charcoal by processing the hard-brown shell (endocarp). A white kernel and a transparent liquid make up the nut's endosperm, which is its edible interior: coconut nectar (Deen *et al*., 2021) [2]. The Arecaceae (Palmae) family, specifically the Cocoideae subfamily, under which coconuts are classified. The tall and the dwarf coconuts are the two primary categories. After planting, the tall types need 6 to 10 years to begin bearing fruit. The dwarf types bear early, or after 4 or 5 years, and grow quickly. Products made from coconut have a long history in Indian folk medicine, where they are revered and valued. It is thought to have antigingivitic, febrifugal, antiblennorrhagic, and ant bronchitis properties (Ali *et al*., 2022) [3].

With a production of 17.16 million metric tonnes of coconuts, Indonesia ranks as the world's top producer in 2021. Approximately 14.7 million metric tonnes of the world's output of coconuts were produced in the Philippines, which came in second In India, the four southern states of Kerala, Tamil Nadu, Andhra Pradesh, and Karnataka produce approximately ninety percent of the country's coconuts. The growth and development of coconut palms demand a consistent supply of potable groundwater, a humid atmosphere, and temperatures around 27 °C and 30 °C. Aerated soil, free-draining is frequently found in sandy beaches (Mat *et al*., 2022) [4].

The aqueous portion of coconut endosperm is known as coconut juice or coconut water (CW). It is distinct from coconut milk, the oily white liquid made from the freshly shredded kernel. CW is used as ceremonial gift, traditional medicine, growth medium for microorganism, and also as a tropical beverage. It may also be converted into vinegar or wine. CW takes up around 25% of the total weight of the nut. The liquid within it is colourless and transparent, and it has a flavour that is pleasantly sweet and acidic. Its total solids content is around 5% by weight. The liquid endosperm is sterile in its normal condition and is contained in a hermetic chamber (Prades *et al*., 2012) [5].

The nutritional content of CW varies according to environmental conditions such soil quality, location, variety, maturity, and others. Once the water has been removed from the interior chamber or otherwise separated, it quickly degrades. Microorganisms, physical pollutants, storage conditions, and the kinds of packing materials used are the main causes of spoilage. Enzyme activity (polyphenol oxidase and peroxidase) enhances during the handling, even under aseptic circumstances. By creating turbidity, off-flavor, discoloration and nutrient loss, they can have a substantial effect on the water quality (Appaiah *et al*., 2015) [6].

It is the major nourishing healthy beverage obtained from the palm trees and is naturally isotonic beverage with ingredients that are comparable to those found in blood plasma. Numerous elements, including minerals, vitamins, amino acids, antioxidants, growth hormones, and enzymes is present in CW. It also includes a number of vital substances for the body, including phytohormones like auxin, cytokines, and gibberellins, as well as potassium, magnesium, selenium, calcium, zinc, methionine, manganese, iodine, molybdenum and boron. Sugars make up the majority of the total soluble solids (TSS), which make about 5-8% of coconut water on average (Burns *et al*., 2020) [7]. The popularity of diet drinks shows that even soft drink producers recognise that customers have changed to a better eating habit. In fact, they've already switched over to "gluten-free" drinks for their beverage line up. Despite the fact that coco water is an old item that is often drunk fresh, pasteurised bottled coco water is a newcomer to the beverage market. The food and beverage sector has profited greatly from the rising popularity of coconut water as a nutritious and pleasant beverage in recent years. The marketing of coconut water has greatly contributed to its increase in popularity, with businesses utilising a variety of tactics to sell their goods (Hidalgo, 2017) [8]. Stressing the health advantages of CW is one among main marketing methods. CW is a great beverage for anyone searching for a healthy substitute to sugary drinks because it is low in calories, fat-free, and includes natural electrolytes. This has allowed several businesses to profit by marketing their CW as healthy and natural beverage that may improve digestion, hydration, and even sports performance (Prado *et al*., 2015) [9].

Increased use of CW as a healthful and pleasant beverage option is a result of the COVID-19 epidemic. Coconut water has gained popularity as a popular option for people wishing to prioritise their health and wellbeing at this trying time because of its hydrating and anti-inflammatory characteristics, as well as its flexibility as an ingredient (Zhang *et al*., 2020) [10]. Coconut water comes in two main varieties with distinct flavours, appearances, and nutritional profiles: tender coconut water (TCW) and mature coconut water (MCW). TCW, commonly referred to as "young coconut water," is the fluid that may be found inside a green, immature coconut. It tastes sweeter and is transparent with a translucent appearance. On the other hand, mature coconut water is the liquid that may be found within a brown, fully-grown coconut. It looks foggy and opaque, and has a partially nutty flavour (Arzeta *et al*., 2020) [11]. With increased availability of pre-packaged CW and the growing popularity of coconut water-based beverages and snacks, it is clear that coconut water consumption will continue to rise in the coming years. Whether consumed as a refreshing drink, added to smoothies or other beverages, or used in cooking, coconut water has become a staple in many people's diets and is likely to remain so in future. This review paper aims to provide a comprehensive overview of the current scientific literature on the nutritional and medicinal properties of both TCW and MCW. It will cover topics such as their nutrient profiles, health benefits, and potential therapeutic applications.

2. Nutritional and chemical composition

According to postharvest factors such coconut packing, transit, and storage circumstances, soil composition, and level of maturity, coconut water's chemical makeup might change. The amount of CW that might be extracted from each coconut is around 300 ml, this varies greatly depending upon maturity stages and coconut's variety. Depending on the cultivar and size, each nut may contain 200 to 1000 mL of water. Any nuts that are less than five months old have a bitter taste and are devoid of nutrients. The water content in mature coconuts is lower, and their endosperm soon hardens to form white edible flesh (Adubofuor *et al*., 2016) [12]. Although TCW and MCW both have comparable nutritional contents, customers typically choose young coconut water as a health drink, whether drunk immediately after harvest or ingested after being processed in a variety of packaged beverages. One cup (240 ml) of coconut water contains approximately 46 calories, 3 grams of sugar, 9 grams of carbohydrates, 1 gram of protein, and less than 1 gram of fat. It also have a good amount of the dietary fibers, providing around 2.6 grams per cup (Naik *et al*., 2022) [13].

For optimal nutritional and sugar content in the coconut liquid endosperm, coconuts should be collected during the seventh and eighth month of development. Invert sugar and amino acids build up in the CW during the early phases of ripening, when the endosperm is forming. TCW is higher in total phenolic and sugar than MCW. Both organic and inorganic substances which promotes the body's natural antioxidant system may be found in CW, which is sterile inside its protective shell. A coconut's water begins gradually losing its tastes and nutrients after it is cracked open. This is partly because CW contains the enzymes polyphenol (PPO) and, peroxidase (POD) which intracts with oxygen and degrade taste and nutrients (Prado *et al*., 2015) [9]. Different chemical and nutritional composition of both TCW and MCW is given in Table 1.

In CW, sugars make up the majority of the soluble solids. In MCW, the primary sugars are sorbitol, sucrose, fructose and glucose. It is followed by lesser sugars including xylose, galactose, and mannose. Glucose, fructose, and sucrose makes up majority of soluble solids and the main sugars found in CW. However, throughout maturity, the amount of sucrose (a non-reducing sugar) rises while the amounts of fructose and glucose (reducing sugars) fall. These alterations can be attributed to the production of sucrose at the cost of the glucose-fructose bond (Psomiadis *et al*., 2018) [14].

Minerals are second in terms of amount among the ingredients in coconut water. According to data, they make up between 0.4% and 1% of the ingredients in coconut water, which is sufficient to make the beverage isotonic (Appaiah *et al*., 2015) [6]. Potassium, sodium, calcium, zinc, iron, and magnesium were the six primary minerals found. Following potassium in abundance are sodium, calcium, magnesium, and calcium in coconut water. However, iron and zinc are only found in very small amounts. Potassium, chloride, iron, and sulphur levels made up the majority of the changes in the mineral composition of MCW and TCW. These minerals are crucial for keeping bodily fluids in balance, controlling blood pressure, assisting with healthy muscle and nerve function, and fostering strong bones and teeth. 600–700 milligrammes of potassium, 60 milligrammes of magnesium, and 40 milligrammes of calcium may be found in one cup of coconut water. Coconut water may be an excellent way to boost mineral intake and advance general health and wellbeing when incorporated into a balanced diet (Shubhashree *et al.*, 2014) [15].

As the coconut ages, its total protein and nitrogen content both rises. Globulin, albumin, glutelin, and prolamin are the main proteins. Despite not being a great source of protein, coconut water does contain the majority of the amino acids. Coconut water's amino acid content can change based on the age and kind of coconut used, as well as the surrounding environment. These amino acids and others can be found in coconut water: arginine, alanine, glutamic acid, cysteine, threonine, histidine, glycine, tyrosine, leucine, isoleucine, methionine, lysine, proline, phenylalanine, serine, tryptophan, and valine (Rahman *et al.*, 2018) [16]. Unlike the protein found in cow's milk, the protein from TCW is richer in amino acids such alanine, arginine, cysteine, and serine. Coconut water has a lot of arginine, which helps the body respond to stress. A healthy heart may be maintained with the help of arginine (Tuyekar *et al.*, 2021) [17].

Table 1: Nutritional composition of mature and tender coconut water (Value per 100g)

Composition	Unit	Mature coconut water (Value per 100g)	Tender coconut water (Value per 100g)	Reference
Proximate				(Naik *et al.*, 2022) [13]
Water	g	94.99	94.45	(Appaiah *et al.*, 2015) [6] (Tuyekar *et al.*, 2021) [17]
protein	g	0.72	0.52	
Fat	g	0.2	0.15	
Dietary fibre	g	1.1	-	
Ash	g	0.39	0.47	
Energy	kJ	79	78	
Carbohydrate	g	3.71	4,45	
Inorganic ions				
Calcium	mg	24.6	31.64	
Iron	mg	0.29	0.02	
Magnesium	mg	24	9.44	
Sodium	mg	105	265.76	
Vitamins				
Vitamin B1	mg	0.03	0.01	
Vitamin B2	mg	0.052	0.01	
Vitamin B3	mg	0.08	-	
Vitamin C	mg	2.4	7.8	
Fatty acid				
monounsaturated	g	0.02	0.03	
polyunsaturated	g	0.0054	0.0125	
Sugars				
Glucose	g	2.61	1.48	
Sucrose	g	2.32	0.51	
Fructose	g	2.55	1.43	
pH		5.2	4.8	
Calories	kCal	22	13	

3. Physiochemical properties of coconut water

3.1 Volume of CW

One of the main physical properties of MCW that altered was water volume. Following those from mature coconuts, the water volume collected from immature/tender coconuts was greatest. When a coconut is young and developing, CW makes up the majority of its contents. A mature coconut may only have 100 to 200 ml of water, but a young or delicate coconut normally has 200 to 300 ml. As the coconut ages, more of the water is absorbed by the growing coconut meat, which is the cause of the reduction in water content. Environmental elements like temperature and rainfall can also have an impact on how much coconut water is available in a coconut. A coconut tree will often yield coconuts with a higher water content than trees in dry places if it receives adequate rainfall (Rethinam *et al.*, 2019) [18]. Mahayothee *et al.*, (2016) [19] found that the main properties of CW are that it gets altered with age was amount of water present. For all kinds, the amount of water in the entire nut grew from 7 to 9 months, then dropped between 9 and 10 months. The larger the nuts grew, the more water they could contain as they developed. Nevertheless, during stages 9 and 10, the water volume fell because the nut's water started to congeal into a "jelly" on its inside, which reduced the amount of water in the nut. Although the 'jelly' stage can begin as early as the eighth month, this was the overall pattern for all the kinds. Devi & Ghatani, (2022) [20] observed that Depending on the environment in which the coconut was produced, a coconut's water content might change. Kerala, Tamil Nadu, Andhra Pradesh, and Goa were among the Indian states whose coconut water was examined for its chemical makeup in the study. it was discovered that there were considerable regional differences in the amount of coconut water. With an average water content of 271.3 ml per coconut, coconuts from Kerala had the greatest water content. With an average water content of 159.7 ml per coconut, the coconuts from Tamil Nadu contained the least water. Averaging 201.6 ml and 220.2 ml of water per coconut, respectively, the coconuts from Andhra Pradesh and Goa had a medium water content. According to a study, a crucial factor in influencing the amount of CW is the quantity of water that is present in the soil and the temperature. Higher amounts of coconut water may be produced by coconut plants in areas with heavy rainfall and humidity. On the other hand, dry and hot weather can cause water stress in coconut trees, which will reduce the amount of coconut water produced (Ulfa *et al*., 2022) [21].

3.2 Total soluble sugar (TSS) of coconut water

Total soluble solids (TSS), a measure of CW sweetness, it was discovered to be higher in MCW than in TCW. When coconut fruits reach full maturity (2 months), the kernel begins to form, which causes the TSS value to begin to decline at this time. As the kernel grows, it absorbs the soluble components present in the coconut water. Consequently, when coconuts became older, their TSS value declined (Kannangara *et al*., 2018) [22]. Seow *et al*., (2017) [27] observed that When compared to MCW, the TCW's, TSS was substantially greater ($P<0.05$). According to study, TSS of coconut water diminishes once coconut fruit has been fully mature for more than 9 to 10 months. The initial TSS values of the tender coconut and mature coconut could be increased by twofold, from 6.0 to 12.1°Brix and from 3.9 to 7.9°Brix, respectively, using the freeze-concentration procedure utilised in this study. The unthawed ice's retained water content is a factor in the elevated TSS of CW. Sanganamoni *et al*., (2017) [23] found that in general TSS of CW is in the range of 4.6 to 5.6ºBrix. The results of the ANOVA test indicated that UV treatment conditions have a substantial impact ($p<0.0001$) on the TSS of TENDER COCONUT WATER. The highest divergence in TSS that may be seen following UV therapy, however, is ±0.3 with regard to any replication. The TSS revealed just a modest improvement after receiving UV radiation at various treatment intervals (0.0-0.90 min). TSS readings showed very little variations at several distances, including 8.6, 13.7, and 18.6 cm. Furthermore, TSS values at various thickness levels, 1, 2, and 3 mm, at certain distance and time interval, such as 8.6 cm at 90 min, exhibited marginal variations. Tazeen *et al*., (2016) [24] conducted research on tender coconut water treated with various ozone concentrations. It was found that there was a minor increase in the TSS content of TCW immediately following ozone treatment. Higher values of R2 (0.9155) and adjusted R2 (0.8960) clearly indicate that ozone concentration, storage period, and exposure time had a positive impact on TSS at probability $p<0.0001$ and is suitable to explain the changes. The enhanced activity of microorganisms during the storage period, which also increased the turbidity of CW, can be the cause of the TSS rise. Gangwar *et al*., (2018) [25] performed a research study on the tender coconut water fermentation by probiotic *Bacillus coagulans*. TSS in TCW and probiotic fermented CW were discovered to be 5.0 and 6.0°Brix, respectively. This finding suggests that the difference in pH and sugars ingested during fermentation and the rise in viable cell count are related. The TSS concentration was 5.0 °Brix, showing that the most of the solids in TCW were soluble solids like sugars. The rise in viable cell counts during fermentation was the cause of the probiotic coconut water's increased total soluble solids content.

3.3 Titratable acidity (TA) of coconut water

Acidity is an important parameter, it is used as sensory indicator, due to its influence on the flavour and aroma of foods. Generally, it is common to find in the literature the acidity of CW being articulated in malic acid and citric acid. The maximum titratable acidity (TA) was found in tender coconut water, followed by those of mature and over-mature CW. The formula Titratable acidity TA= (N* M* V* 100)/Vc was used to calculate the percentage of malic acid in the coconut water. N represents normality of NaOH used, V represents amount of NaOH used, Vc represents volume of CW added, and M represents the malic acid factor (67.05) (Tan *et al*., 2014) [26]. Sanganamoni *et al*., (2017) [23] conducted research on TCW treated with various ozone concentrations and the range of CW's titratable acidity (% malic acid) was shown to be between 0.072 and 0.076. According to ANOVA results, there was no significant ($p>0.0001$) impact of the UV treatment settings on the tender coconut water's titrable acidity. Nevertheless, the findings demonstrate that when tender coconut water was exposed to UV light, there were slightly higher Titrable Acidity values compared to the untreated (Raw tender coconut water) control. A very slight change in titrable acidity value occurs under various UV light treatment circumstances. It is possible that the UV light's failure to stimulate the release of H+ during therapy is the source of this type of behaviour. Adubofuor *et al*., (2016) [12] studied the physicochemical and sensory characteristics of pasteurised CW from two varieties of coconut. Using distilled water and phenolphthalein as an indicator, 10ml of coconut water was diluted to 90ml, and the last 90ml was titrated with 0.1M NaOH solution to a faint pink end point. The test was carried out three times. After pasteurisation, both types' titratable acidity (TA) somewhat decreased, according to the results. Gangwar *et al*., (2018) [25], demonstrated a titratable acidity value of 0.18% (citric acid) due to the presence of ascorbic acid, on the fermentation of TCW by probiotic bacteria *Bacillus coagulans*. The amount of lactic acid that could be measured after fermentation was 0.53%. Due to the utilisation of sugars found in coconut water, lactic acid is the main byproduct of the conversion of carbs. *B. coagulans* is a common strain used to produce lactic acid; its thermophilic nature (growth at 52 °C) suggests that it is especially well-suited for commercial production of lactate without sterile conditions.

3.4 Total phenolic contents (TPC) of coconut water

Phenolic compounds are significant phytochemicals that have a variety of bioactive characteristics, such as antioxidant activity. In several investigations, the identification and quantification of phenolic chemicals in various fruits, vegetables, and their processed products has been documented. The measurement of TPC using the Folin-Ciocalteu reagent was also frequently used for a preliminary screening of putative high antioxidant sources. The TPC of CW is influenced by the coconut fruit maturity. The water from young coconuts had the greatest TPC, which was followed by the water from mature and over-mature coconuts. TPC decreased as maturity of the coconut increased. TPC's antioxidant abilities are diminished as a result of the decline in TPC (Tan *et al*., 2014) [26]. According to the chromatographic peaks of eight discovered compounds, salicylic acid and catechin are primary phenolic components found in the coconut flesh samples, whereas caffeic, gallic, salicylic, and p-coumaric acids were the main phenolic components found in the CW samples. The phenolic chemicals were present in the water at lower concentrations than in the meat. at coconut water, (+)-catechin and (-)-

epicatechin were present at quantities of 0.344 and 0.242 µg/mL, respectively (Mahayothee *et al*., 2016) [19]. Seow *et al*., (2017) [27] observed TPC in tender Coconut water was considerably greater ($P<0.05$) than TPC in Mature Coconut water, whereas fresh coconut waters had around a 2-fold higher TPC than freeze-concentrated coconut waters, independent of age. The presence of phenolic compounds in coconut water that would have been trapped inside the concentrate during processing may be responsible for the greater TPC level in freeze-concentrated coconut water. The phenolics component may become partly soluble in water and stay at a higher concentration in the concentrate if ice crystals form during the freezing process. As a result, the freeze-concentration method was successful in producing coconut water with a greater concentration of antioxidant content. The greatest prevalent antioxidants in human diet are phenolic compounds, which are widely present in fruits and vegetables. Because of their antioxidant capabilities, phenolic compounds are of great interest. Furthermore, most phenols are heat labile. The phenols in coconut water are reduced or eliminated when heated. The oxidation of these substances and their polymerization with proteins may be to blame for the decline in phenols. Following pasteurisation, the total phenols in both types significantly decreased ($p<0.05$) (Adubofuor *et al*., 2016) [12].

3.5 Others

Kannangara *et al*., (2018) [22] conducted Comparative analysis of CW in four different maturity stages and found that the samples' pH levels changed somewhat with maturation; generally, the pH of CW rose when coconuts reached full maturity between 7 and 9months following harvest, and then pH levels began to vary slightly. In this instance, pH gradually climbed throughout maturity months 1 and 2, reduced somewhat in maturity month 3, and then slightly increased during maturity month 4. The findings about the rise in pH with age corroborated those who discovered an increase in pH in their samples from 4.7 to 6.3 with maturity. Tazeen *et al*., (2016) [24] investigated how the pH of tender CW was affected by ozonation. With increased ozone concentration and prolonged exposure, the pH of tender CW fell. After treatment, the pH of TCW was higher (5.01) than it was for the control (5.0). According to the study, both the individual treatment settings and their combinations had a significant impact on pH at $P<0.0001$. Fructose, glucose, and sucrose are the main sugars that are known to promote to the sweetness of coconut water. Sugar concentration in coconut water often reduced in the following order: fructose > glucose > sucrose. Over-mature CW was shown to have the highest sugar concentration, followed by mature and immature coconut water. With maturity, the sucrose level increased significantly (P <0.05), but fructose and glucose amounts decreased significantly. The production of sucrose at the cost of fructose and glucose may be the cause of these alterations in the sugar content of coconut water. It has been shown that as coconuts mature, their non-reducing sugar content rises and their reducing sugar content falls. A fully-grown coconut's sucrose content may amount to up to 90% of the total sugar in coconut water (Tan *et al*., 2014) [26]. Sanganamoni *et al*., (2017) [23] researched and found Turbidity values of UV light processed TCW at different conditions and stated Turbidity is the cloudiness that a fluid exhibits as a result of many tiny particles that are often unseen to the unaided eye. A measurement of the amount of light scattering caused by soluble solids and suspended particles in TCW is what it is known as. TCW's turbidity was discovered to be between 3.8% and 3.6 percent. The UV treatment parameters (including sample treatment period, thickness, and sample distance from lamp source) had a substantial ($p<0.0001$) impact on TCW turbidity. However, the highest turbidity reduction with UV treatment is 1.32% with regard to any replication. Using the ABTS test, it was possible to assess how heat treatment affected the antioxidant capacity of vegetables. The microwave heat treatment of CW through different maturity stages was evaluated to see how it affected the scavenging capacity of ABTS radicals. It can be proven that there is a significant difference (p 0.05) between ABTS scavenging of TCW and MCW. The reaction to microwave heat treatments for TCW mostly consisted of a reduction in the overall amount of ABTS scavenging (< 100%), in contrast to mature coconut water, which showed an increase at 90 °C (111%) (Arzeta *et al*., 2020) [11]. With increasing maturity, the value of the crude fat content in CW rose. The meaty jelly-like region of the coconut is covered by the water-based component of the coconut, therefore the higher the fat content, the closer the coconut is to the stage of flesh development. The bigger fat molecules are less likely to be included in the ice fraction, which may have contributed to the rise in crude fat content of the freeze-concentrated CW and led it to collect at the concentrate juice in a manner like the way molecules of protein do (Seow *et al*., 2017) [27].

4. Preservation and processing of coconut water

4.1 Preservation of CW

As long as it stays inside the coconut's interior chamber, CW is sterile and safe. To maintain its quality before being extracted from the nut for further processing, it must first go through a time-consuming and challenging process after being retrieved from the internal chamber of the nuts. It is exposed to the outside atmosphere after the coconut water has been extracted from the nuts. Thus, the colour, turbidity, appearance, and many biochemical components of CW alter as a result of accelerated biochemical and enzymatic processes (Naik *et al*., 2022) [13]. Different non-thermal, thermal, and combinations of technologies (Hurdle technology) with extra additives is used in this area. The use of microwaves, ultrasonication, pulsed electric fields, plasma processing, ozone treatment, infrared heating, and dense phase carbon dioxide processing are a few of these methods. Other methods include standard thermal heating (Sterilisation or Pasteurisation). These product processing techniques might result in higher-quality goods with extended shelf life. The type of treatment applied, however, may affects the shelf life and quality. In order to use these approaches for industrial applications, it is also necessary to create a standardised process protocol (Rajashri *et al*., 2020) [28]. Coconut water may be processed and preserved, which not only results in a product with longer shelf life but also requires less handling and transportation. The ideal way to keep coconut water (in its natural container) is still using young, sensitive coconuts, although at room temperature, the nuts can only be kept for a maximum of six days. The best outcome was reached for the whole nut after 21 days at 12 °C with a treatment like sanitization, which entails immersion in a particular solution for a short period of time. Unexpectedly, sanitization had no positive effect on the nut's shelf life. Results for the whole nut in film wrapping were equivalent to or superior than these: PVC film lasted 30 days at 12 °C and PE film for 28 days at 12 °C. The immature, fragile coconuts were wrapped in paraffin and kept at 12 °C for 49 days to get the longest shelf life. The greatest results were obtained by preserving the entire nut for 28 days at either 12 °C or 17 °C (Chowdhury *et al*., 2009) [29].

4.2 Thermal processing of coconut water

The food processing industry has expanded throughout time because to its excellent safety record and growing market for new product development. Researchers and the food business are looking into alternative processing techniques as a replacement for conventional ones since consumers are demanding high-quality goods. Thermal processing is the term for applying heat to food goods with the intention of pasteurising, cooking, or preserving them. The attributes of food, such as its safety, sensory appeal, and nutritional content, can all be significantly affected by thermal processing (Huang *et al*., 2017) [30]. Thermal processing is frequently utilised to progress the product's quality and safety while also extending shelf life of CW. Since Bigelow and Ball created the first scientific model for determining the lowest amount of safety sterilisation method in 1920, the idea of thermal processing, which largely includes in-container sterilisation of food, has advanced significantly. The most common technique for protecting food from spoilage and prolonging its effective shelf life continues to be heat processing (Tola & Ramaswamy, 2018) [31]. The thermal processing of CW entails heating the liquid to accomplish certain goals including preservation, pasteurisation, and sterilisation. This procedure increases the overall quality of product, extends shelf life of the CW, and eliminates potentially hazardous microbes and enzymes. CW is often thermally processed using techniques such heat treatment, ultra-high temperature (UHT) treatment, and spray drying. Thermal processing, however, can also lead to adjustments in the physicochemical characteristics of the CW, like changes in the flavour, colour, and scent. Therefore, it's crucial to carefully analyse the desired goals and select the best thermal processing technique to get the required result without sacrificing the product's quality (Rojas *et al*., 2017) [32].

4.2.1 Microwave processing

By heating, pasteurising, and sterilising food products in the microwave, dangerous pathogenic bacteria and active enzymes can be controlled. In the case of microwave processing, the dielectric characteristics of materials are crucial because they reveal how biological material may transform microwave energy into heat and how electrostatic energy is conserved or lost in the electric field (Pinto *et al*., 2021) [33]. Arzeta *et al*., (2020) [11] conducted microwave heat treatments, CW from fruits in two ripening phases (mature and tender) was hired. At holding times of 0, 2, and 4 minutes and maximum temperatures of 70, 80, and 90 °C, three different heating scenarios were examined. The Folin-Ciocalteu technique and the ABTS radical scavenging capability were used to determine the Total Phenolic Content (TPC) for each combination of age of coconut age, boiling temperature, and holding period. The TPC (correspondingly 46.03 and 69.16 mg GAE/L) and ABTS radical scavenging capacity (422.31 and 549.1 mol TE/L, respectively) of TCW were shown to differ considerably (p 0.05) from MCW. Microwave heating result on TPC and antioxidant activity of mature and green CW. Franco *et al*., (2015) [34] conducted research about Dielectric properties of green coconut water relevant to microwave processing and effect of temperature and field frequency and concluded that electric conductivity and dielectric characteristics were assessed using an open-ended coaxial probe approach in anticipation of the continuous microwave processing of TCW at temperatures extending from 0 to 90 °C and frequencies ranging from 500 to 3000 MHz. Simulated sugar and salt solutions from GCW were tested as well to assess component contributions and interactions. In microwave heating at 915 MHz, ionic conduction is crucial, but at 2450 MHz, temperature-dependent equilibrium between ionic and dipolar processes was seen. Sugars have a negligible impact on loss or polarisation. Component interaction was decreased by ″ (12% at 915 MHz and 8% at 2450 MHz, respectively). As the temperature increased, it was feasible to monitor how the dielectric characteristics and the depth of the power penetration changed. Correlations were then modified to simulate temperature dependency. Pinto *et al*., (2021) [33] researched about Microbiological feasibility of microwave processing of CW. In this experiment, the feasibility of employing a microwave with a specific power of 115–135 W/mL to inactivate *Bacillus coagulans* spores in acidified TCW (pH 4.30–4.50) was examined. Four factors (microwave power, temperature, composition and amount of extra acids) were tested using a central composite design with four duplicates at the centre point. The amount of spore population decrease was measured after holding times of 5, 10, 15 and 20min. Temperature was the sole important factor for spore inactivation hence the Weibull model was used to characterise the survival curves. This model was updated in single step by integrating the time-temperature profile from 112 trials. At a reference temperature of 90 °C, the values for (time of the first decimal decline) and (temperature needed for a 10-fold change in) were 33.8 s and 5.06 °C, respectively. The reduction in *B. coagulans* spores and the kinetics features suggest that microwave processing might eventually replace more conventional techniques for treating coconut water.

4.2.2 Ohmic heating

In the continuous processing of food items with particulates, ohmic technology is regarded as a significant advancement. The process of ohmic heating includes passing an alternating electrical current through food products, which causes internal heat to be produced due to electrical resistance. This method was first created at the Electricity Research Council in Caphenhurst, United Kingdom. APV Internationals has only started to commercialise it. The fundamental idea behind ohmic heating, also known as the joule effect, is the dissipation of electrical energy into heat through the use of an electrical conductor. The current flow induced by the voltage gradients in the food and the electrical conductivity of the food material determine how much heat is generated (Jan *et al*., 2021) [35]. Kanjanapongkul & Baibua, (2021) [36] researched in Ohmic pasteurization was used to inhibit peroxidase (POD) and polyphenol oxidase (PPO) in CW. Because of its inherently high electrical conductivity, CW is perfect for ohmic heating process. At 70 and 80 °C, the PPO activity declined steadily throughout the course of the holding period and more rapidly at higher electric field intensities. PPO activity at 90 °C was steady for 3 min, then dropped to roughly 10% of its original activity. The heat-stable PPO percentage ranged from 0.07 to 0.15, and a biphasic model provided a good description of PPO inhibition. POD activity was stimulated at 70 °C, but it waned over the course of an exposure period at 80 °C, and it was entirely inactivated at 90 °C. The PPO activity was boosted during cold storage by the CW treatment using a conventional method for 3 or 6 minutes, and the CW coloured light pink on day 14. In contrast, the ohmic-heated CW lacked any pink colour. The outcomes revealed that ohmic heating was efficient and may be applied to stop CW from becoming pink. Zulekha *et al*., (2017) [37] investigated on how ohmic heating affected the amount of tyrosol, total phenolic content (TPC), antioxidant activity, and physicochemical quality of aromatic coconut water that had been pasteurised using both ohmic heating (100-300 V; 50 Hz, 74^{o} C for 15 s) and conventional heating (74^{o}C for 15 s). Using high performance liquid chromatography (HPLC) and a diode array detector, the amount of tyrosol was measured. The Folin-Ciocalteu test and the 2, 2-diphenly-1-picrylhydrazyl (DPPH) radical scavenging assay were each used to assess TPC and antioxidant activities. Aromatic coconut water that had been pasteurised using ohmic heating was able to maintain 97% of the tyrosol compared to the fresh sample, whereas conventional heating was only able to do so for 90%. The findings concluded that there was no discernible difference between the TPC of fresh fragrant CW and that of CW that had been pasteurised by ohmic heating (p>0.05). Higher turbidity values were found in both pasteurised samples, however there were no appreciable variations in total soluble solid, pH, or antioxidant activity between any of the samples (p>0.05). In conclusion, ohmic heating pasteurised aromatic coconut water better than conventional heating at retaining tyrosol. In order to maintain the quality and nutrients of aromatic coconut water, an alternate method called ohmic heating may be utilised. Coconut water's volatile components are affected by ohmic heating (temperature 100-140°C; duration 0-600 s). Researchers found that the content of volatile compounds varied, which could be related to the effective temperature. Using gas chromatography, more than sixty volatile substances in coconut water were found. The aforementioned experiment revealed that the volatile compounds 3-pentane-2-one and ethyl-octanoate are accurate markers of ohmic heating treatment (Naik *et al*., 2022) [13].

4.2.3 Others

The UHT (Ultra High Temperature) sterilisation method is successful in the elimination of microorganisms and enzymes, but nutritional and sensory alterations are frequently present, which impairs the quality and acceptability of the finished product. (Wurlitzer *et al*., 2021) [38] investigated the effects of ultra-high temperature (UHT) processing on the activity of the enzyme polyphenol oxidase and peroxidase in CW. Sulphite addition proved successful in preventing pink colouring in coconut water throughout storage and following sterilisation. The emergence of a reddish colour was preferred at sub-processing temperatures of 110 °C and 120 °C / 4.1s. The sample with the pink colour showed low activity for polyphenol oxidase and peroxidase, 0.28 and 0.40 UAE.mL^{-1}, respectively. This suggests that the pink colour obtained during heat-processed coconut water storage cannot be attributable to the enzymatic activity of these enzymes. Nasution *et al*., (2019) [39] investigated the effect of heating on aroma compound profile of mature coconut water from tall variety in this study. Solvent extraction, GC-TOFMS and HS-SPME were used to extract volatile aroma components, and the results were analysed. The findings demonstrated that heat treatment had an impact on the amount of volatile fragrance components in mature coconut water. Esters, particularly fatty acid esters, had significant alterations, increasing by 2-20%, whereas ketones, primarily acetoin-containing ketones, dropped by 2-21%. A descriptive sensory assessment and further study revealed that heat treatment might lessen the unfavourable ferment scent feature, most likely as a result of the acetoin content being lower. A descriptive sensory assessment along with additional study revealed that heat treatment might lessen the unfavourable ferment scent feature, most likely as a result of the acetoin content being lower. Furthermore, heat treatment resulted in a slight increase in the intensity of creamy, sweet and floral characteristics. This result may be related to the elevated concentration of fatty acid esters. In comparison to previous heat treatments, 15 minutes of heating at 85 °C had a somewhat higher intensity for the creamy and sweet qualities. Thus, this study has demonstrated that heating mature coconut water may change its aroma compound profile. Raghubeer *et al*., (2020) [40] research on the inactivation kinetics of polyphenol oxidase (PPO) and peroxidase (POD), as well as a few other quality characteristics of coconut water, the impact of pressure aided thermal processing (PATP) was assessed. Spectrophotometric techniques were used to calculate the activity of POD and PPO. PPO and POD enzymes from TCW showed no enzymatic activity after 120 s at 90 oC/400-600 MPa. When the temperature increased from 40 to 90 °C, both enzymes displayed inactivation behaviour. Comparatively more resistant to PATP treatment than the PPO enzyme was the POD enzyme found in coconut water. Coconut water's overall phenolic extraction significantly enhanced after PATP treatment. These findings demonstrate the potential of PATP for the quality-preserving inactivation of the PPO and POD enzymes in coconut water.

4.3 Non-thermal processing of coconut water

Food enzymes like POD and PPO have significant impact on how long TCW can be stored and how profitable it may be. Even when stored in a refrigerator, the catalytic activity of both enzymes produces a variety of unpleasant consequences in TCW. Similar to this, the catalytic processes and microbial activity might result in the creation of pink colour, browning, horrible flavours, and odours (Rajashri *et al*., 2022) [41]. Furthermore, *Clostridium botulinum* and other microorganisms are very likely to attack fresh TCW. In the food sector, thermal processing techniques including evaporation, pasteurisation, and sterilisation use the greatest energy. Colour, clarity, and sensory characteristics are negatively impacted by thermal treatments. Because sensitive compounds are destroyed during traditional thermal processing techniques, the organoleptic properties of the product are often altered, changing its inherent qualities (Prithviraj *et al*., 2021) [42]. In order to preserve and extend the shelf life of TCW, it is crucial to investigate non-thermal approaches. The food processing and preservation industries have adopted a variety of cutting-edge techniques. It has been successfully employed to increase the storage life of TCW using ozone, cold plasma, ultrasound, UV, microfiltration, high-pressure processing, and the combination of these treatments with moderate heating (Naik *et al*., 2022) [13].

4.3.1 Ultrasound processing
Ultrasound is described as sound waves with a frequency higher than the 20 kHz threshold for human hearing. The information delivered by backscattered sound waves is used by some creatures, such as dolphins and bats, to use ultrasound for navigation or hunting. One of the cutting-edge technologies created to reduce processing, increase quality, and guarantee the safety of food items is ultrasound. Food processing uses ultrasound to increase mass transfer, preserve food, aid in heat treatments, and manipulate texture and food analysis, among other beneficial impacts (Bhargava *et al*., 2021) [43]. Rojas *et al*., (2017) [32] evaluated the use of ultrasound technology (US) for inactivating/sensitizing coconut water POD. It was assessed whether US application will perform both alone and in combination with thermal processing. The great resilience of the enzyme was shown by the fact that it lost 27% of its initial activity after 30 minutes of US processing (286 W/L, 20 kHz). Following US pre-treatment, the enzyme became heat sensitive. More homogeneous heat resistance was produced as a result of using US. The findings imply that US is an effective technique for desensitising enzymes before thermal processing, especially for enzymes with great heat resistance. The implementation of this method might thereby lessen the negative consequences of prolonged exposure to high temperatures and/or extended processing durations associated with traditional thermal processing. Rajashri *et al*., (2020) [28] investigated the use of nisin and nonthermal treatments (ozone and ultrasound) to increase the shelf life of TCW. The fresh TCW treated with ozone and nisin demonstrated enhanced preservation as a result of the reduction in retention of phenolics (64%), microbial counts, and flavonoids (70%), and inactivation of PPO and peroxidase enzymes. Compared to ultrasound with nisin-treated TCW, heat-treated and ozone with nisin-treated TCW had sensorily acceptable storage times of 3 weeks and 2 weeks, respectively. Because of this, TCW may be preserved using ozone and nisin in a refrigerator. Jacob *et al*., (2022) [44] evaluated the application of ultrasound for the preservation of MCW. Based on the study's findings, the microbial population and MCW quality were significantly impacted by the ultrasonic process parameters. The optimal settings were established by numerical optimisation based on the desire function. In this study, sonication treatment resulted in a decrease in the amount of non-reducing sugars, total sugars, and microbial population while an increase in the amount of reducing sugars was found. For lowering microbial population and preserving the MCW's quality characteristics, it was shown that applying ultrasound for 10 min. at 60% amplitude was the most effective therapy.

4.3.2 High pressure processing
High pressure processing (HPP) is a highly hopeful approach for food corporate, because it offers a wealth of potential for creating novel shelf-stable foods with extended shelf-life, good organoleptic features and high nutritional content, - little processed but safe for consumers. HPP uses high pressure (between 400 and 600 MPa) at low process temperatures (about 45 °C). Most foods may be preserved with little impact on their flavour, texture, appearance, or nutritional content. Foods with a high moisture content that are solid or liquid can both be processed under pressure. despite being fatal to microorganisms. Pressure treatment has very little impact on the chemistry of food and does not destroy covalent bonds. HPP offers a way to preserve food quality without using significant thermal or chemical preservatives (Huang *et al*., 2017) [30]. Lukas, (2013) [45] studied to determine whether *Salmonella enterica serovar Typhimurium*, *E. coli* O157:H7, and also *Listeria monocytogenes* could grow in CW and to assess the efficacy of using High Pressure Processing to lower populations of these bacteria in CW. The 3 infections were implanted into CW one at a time, and bacterial populations were counted throughout the course of 24 hours. Following each pathogen inoculation, CW was subjected to 120 seconds of HPP (400, 5000, or 600 MPa) processing. Before and after treatments, the CW's levels of D-glucose, D-fructose, sucrose, and phenol oxidase were measured. The pathogens in the CW were counted after processing. Following treatments of 500 and 600 MPa, all three pathogens had decreasewd by more than 6-$\log_{10}$ CFU/ml, which was sufficient to reach the required 5-$\log_{10}$ CFU/ml reduction. None of the treatments significantly altered the D-fructose, D-glucose, sucrose, or phenol oxidase activity. Raghubeer *et al*., (2020) [40] investigated the use of HPP for inactivating vegetative pathogens and spoilage microorganisms in fresh unfiltered CW from nuts purchased from Florida and frozen CW from Brazil with pH >5.0 and storage at 4 °C. Through 120 days of storage at 4 °C, the microbial deterioration of uninoculated samples was examined for typical deterioration microbiota. Through 120 days, HPP samples had microbial counts of about 2 logs and no observable signs of spoilage. Upon being kept at 4 °C for 2 weeks, the non-HPP control samples began to spoil, producing gas, becoming cloudy, and smelling bad. González-Angulo *et al*., (2020) [46] evaluated the growth of Group II *Clostridium sp.* and non-toxic type E *C. botulinum* in raw and HPP (550 MPa, 3 min, 10 °C) Thai CW (pH 5.2). In HPP CW infected with 105 CFU/ml after 61 days, no spore germination or growth occurred, regardless of oxygen level (0.5 - 11 mg/l) or storage temperature (4 and 20 °C). The addition of selected germinants and free amino acids to filter-sterilized CW (pH 7.0) did not support the development of spores, but the addition of nutrient-rich laboratory media at low concentrations (6.25%) encouraged growth, indicating that the presence of nutrients is necessary for *C. botulinum* to develop in CW.

4.3.3 Other
Saranya & Sujatha, (2016) [47] experimented on PEF processing chamber with two parallel plate electrodes was filled with tender coconut water. Through electrodes, square pulses with a 35KV magnitude and 2.5 sec pulse width were applied to the TCW. The pulses were delivered for 2, 4, and 6 minutes. The processed sample was taken under sterile circumstances and in sterile containers. Studies on shelf life were done after the samples were kept at 5oC. Physical, chemical, and biological characteristics like acidity, TSS, and pH, as well as microbiological characteristics such as standard plate count and *e.coli*, and sensory characteristics such as taste, colour, and general acceptability were all tested on a regular basis. It was discovered that there was no discernible difference in the samples' pH, acidity, and TSS before and after processing. SPC count was discovered to be less than 5000 CFU/mL, and E. coli was not present. Additionally, it was noted that sensory characteristics remained unchanged

following PEF processing. The treated tender coconut water has an enhanced shelf life at 5ºC of 18 to 25 days. Augusto *et al*., (2015) [48] evaluated the photo-inactivation of PPO and POD in a CW model using UV. In relation to processing time, both enzymes displayed a continuous inactivation behaviour that could be explained by a two-portion inactivation kinetics. Molecular unfolding and aggregation-related events were suggested as a potential explanation for the observed photo-inactivation. After fifteen minutes of processing, the POD activity is only 5% of its initial value, and after thirty minutes of UV processing, it was just 1%. After fifteen minutes of processing, PPO activity was only 8% of its initial amount. After thirty minutes of UV processing, it was just 2%. The findings show the possibility for using UV light to deactivate both enzymes in CW. Gabriel *et al*., (2016) [67] examined the reference organism for the establishment of microwave atmospheric pressure plasma jet treated CW. Three major spoilage bacteria, *Staphylococcus sp., Klebsiella sp.*, and *Kluyvera sp*., were found and isolated in this investigation from rotten liquid endosperm. Plasma jet exposure of the individual samples from spoiling occurred at input powers of 450 and 650 W. At 450 W power level (2.76 to 5.98 min), it was observed that all organisms inactivated. The most resistant microorganism to plasma therapy was *Salmonella enteric*, overall. In order to assess the effectiveness of microbial inactivation of CW, Salmonella enteric can serve as the indicator organism. The most effective substitutes for thermal processing methods is membrane technology. The most popular technique for filtering CW is membrane filtration with UV sterilisation. However, to raise the calibre and protect the unique qualities of coconut water, research and innovation are still required. Lamdande *et al*., (2020) [49] examined the effectiveness of ultrafiltration and permeate flux for the cold sterilisation of CW. The ultrafiltration investigation was conducted in an acoustic field with an ultrasonic transducer operating at 1, 2, 3, and 4.5 bar at room temperature (25.2°C). Transmembrane flow increased by 30–50%, according to the scientists. Similar to this, PPO (97.89%), POD (95.10%), and turbidity (95.81%) activity decreased as a result of ultrasonication. Even three months after being stored, the treated CW maintained its great quality and acceptance, demonstrating the commercial viability of the membrane processing method.

5. Therapeutic and health benefits of coconut water

Coconut water has been called the “fluid of life” due to its medicinal benefits such as oral rehydration, treatment of childhood diarrhea, gastroenteritis and cholera. Dehydration, constipation, urinary tract infections, malnutrition, diarrhoea, exhaustion, boils, heatstroke, osteoporosis, kidney stones, and sterility are just a few of the health issues that CW may help avoid and treat. CW is frequently used as part of a patient's therapy while they are ill in order to help them recover. The benefits of coconut water include improved blood flow, less plaque development, and assistance in dilating blood vessels. Aspects of dietary fibre and amino acids that help reduce sugar absorption and increase insulin sensitivity are also present in CW (Zulaikhah, 2019) [50]. Mujahid *et al*., (2019) [51] researched to determine the benefit of TCW toward diarrhea from *Shigella sp* was studied through KirbyBauer test. Analysis of variance (ANOVA) was used to examine the testing results of TCW for the presence of Shigella sp. A 95% significant level Duncan test was used to continue the analysis. The study's findings showed that *Shigella* species can't thrive in any green coconut water. The best inhibitor is achieved by administering wulung green coconut water, which has an inhibition zone with a diameter of 16.6 mm. Tender coconut was characterised in Indian Ayurvedic medicine as being "unctuous, sweet, promoting digestion, increasing semen, and clearing the urinary path". Uddin *et al*., (2019) [52] investigated the anti-diabetic potential of CW against the rabbits with diabetic. Streptozotocin (80 mg/kg body weight) was used to put rabbits intoxicated, and diabetes was additionally given on. Weight loss, frequent urination, a lack of high-density lipoprotein, heightened blood glucose and cholesterol levels, and slow physical activity were all characteristics of the inebriated rabbits. When compared to the positive control, all the parameters returned to normal or near normal after two weeks of receiving CW at dose rates of 2.2 g/kg and 4.1 g/kg. For emergency plasma transfusions, coconut water was directly syphoned from the nut and given to wounded soldiers during the Pacific War (1941–1945) (FAO 2005). Due to its electrolyte content, it is thought that coconut water might be an essential option for intravenous hydration of patients in remote areas as well as oral rehydration (Halim *et al*., 2018) [53]. Zulaikhah & Sampurna, (2016) [54] conducted study to see if coconut water may reduce the oxidative stress brought on by exposure to mercury. For 30 days, the treatment group received 450 ml of tender coconut water per day, while the control group received water. The Elisa technique was used to measure the malondialdehyde (MDA) level in the 38 mining workers who were chosen at random and given a questionnaire. The Mann Whitney test was used to look for an anomalous distribution in the data. The two groups did not differ from one another. In the control group and the treatment group, the mean MDA levels were, respectively, 4.5 +/- 0.5 and 3.6 +/- 0.4. P-value: 0.000 was obtained from this investigation. These findings suggest that consumption of TCW can reduce the risk of oxidative stress brought on by mercury exposure in traditional gold miners. Nova *et al*., (2020) [55] research the effect of TCW to prevent lipid peroxidation, increase insulin plasma level and decrease glucose levels on pregnant rats with diabetics. 24 samples were utilised in this investigation, and they were separated into 4 groups at random: K1 (pregnant rats), K2 (pregnant rats + diabetic), K3 (pregnant rats + diabetic + glibenklamid 0.23 mg/kg BW), and K4 (pregnant rats + diabetic + TCW 8 mL/200 grBW). The findings demonstrated that whereas the average insulin plasma levels in groups 3 and 4 increased in comparison to group 2, they dropped in group 2 relative to group 1. In comparison to group 1, the average glucose and MDA levels in group 2 increased, while in groups 3 and 4, they dropped. P values of 0.000 ($p<0.05$) are present in the analysis's findings. TCW can inhibit the process of lipid peroxidation, increase insulin plasma levels reduce glucose levels, and in pregnant diabetic rats. TCW has been shown to remove toxins in cases of mineral poisoning and to lessen drug-induced overdosage toxicity. Due to the TCW's electrolytic impact, which is comparable to fructose's quicker absorption into the body and cells, drugs are helped to quickly enter the bloodstream and are easier to reach their peak concentration in the blood (Reddy *et al*., 2018) [56]. Green coconut water shows promise in treating infertility brought on by excessive prolactin levels. It has been claimed to be an oestrogen source and may be able to reverse infertility (Sunil *et al*., 2020) [57]. Chaubey *et al*.,

(2017) [58] examined the effects of CW, sodium-enriched CW, carbohydrate electrolyte sport drink, and sodium-enriched coconut drink on athletes' physical performance and markers of hydration. 8 adult male athletes were chosen using a purposive sample procedure. According to the findings, a physical performance test on a treadmill was performed three hours following the dehydration exercise test. Regarding treadmill performance, the standard deviation and mean of the total exercise duration of plain water was 43.62±5.92, for CW it was 44.00±5.65, for carbohydrate electrolyte sports drink it was 43.75±5.70, and for sodium-enriched olive CW it was 44.25±5.35, the variation was not statistically significant. The study found that, although differences across beverages were not significant, the sodium-enriched coconut drink had a better impact on performance than other drinks. However, more samples might be used to get more accurate results. TCW is thought to include phytoestrogen and other sex hormone-like compounds that can help postmenopausal women repair wounds and reduce their risk of dementia and dementia-related diseases. TCW can be used as ready to drink food product having natural health beneficial nutrients (Zulaikhah, 2019) [50].

Fig 1: Health benefits of coconut water

6. Application of coconut water

Numerous industries, including those in food, cosmetics, and medicine, use coconut water. Due to its excellent nutritional content and pleasant flavour, coconut water is employed in the food sector as a natural and nutritious beverage. Additionally, it can be used to make ice cream, smoothies, and other desserts. Due to its moisturising qualities, coconut water is utilised as a moisturiser in cosmetics. Additionally, it nourishes hair and encourages hair growth when added to shampoos and conditioners. In the field of medicine, coconut water is said to possess healing qualities that can aid in the treatment of kidney stones, electrolyte imbalance, and dehydration. Because of its significant potassium and mineral content, it is frequently utilised in sports drinks (Naik *et al*., 2022) [13].

6.1 Food industry

Badilla *et al*., (2020) [59] developed a synergetic drink based on CW. Inulin is used as a source of soluble fibre throughout the fermentation process together with lyophilized *Lactobacillus rhamnoses* SP1. The beverage required 8 hours to ferment, and a pH and hedonic scale evaluation determined that it had a 14-day shelf life when refrigerated. The resulting beverage had a pH of 3.48 and contained 82 10 8 CFU/ml of probiotics. It is found that CW may be treated by adding prebiotic and probiotic features with sensory acceptability and sufficient preservation qualities. Coconut water was put through two phases of fermentation in order to make vinegar: first, an alcoholic fermentation using baker's yeast, then an acetous fermentation using *A. aceti* TISTR 102 starter powder. The fermentation efficiency was increased to 89% by adding *A. aceti* TISTR 102 starter powder at 0.5% (w/v), which resulted in the entire production of 6.27 ± 0.02% acetic acid in 18 days. All of the sensory assessment test's sensory attributes like aesthetics, flavour, sourness, and general acceptability were given favourable ratings for the CW vinegar. It is one that is thought about and used on a domestic scale (Ngoc *et al*., 2016) [60]. Miskiyah *et al*., (2016) [61] investigated the use of CW vinegar as a natural preservative to inhibit microbial development in meat. CW and banana peel were used to make vinegar, and its effectiveness against *Escherichia coli* O157:H7 was evaluated. Treatments for chicken flesh included vinegar solution (1% acetic acid), lactic acid solutions (2%), acetic acid solutions (1%), and control. *E. coli* O157:H7 was injected into treated samples onto the surface of the chicken flesh. The findings demonstrated the efficiency of coconut water vinegar and banana peel vinegar as natural preservatives. Finally, it can be said that vinegar may have prevented E. coli O157:H7 development in chicken meat for 12 hours at 37^{O}Cand 9 days at low temperatures. A natural source of nutritional fibre, nata de coco is produced by static fermentation of any sugar-rich substrate with *Gluconacetobacter xylinum*. In CW medium, the yield of nata was about 250 gL-1. In the HS medium and MCW medium, respectively, *G. xylinum* (sju-1) produced more nata with thicknesses of 13 mm and 15 mm. The nata made from coconut water medium had a water retention capacity of 87.14%, was 41 N in hardness, and had 11.25g in crude fibre. Using natural colourant derived from beetroot root pigment, the produced nata was effectively manufactured in sugar syrup foundation. By employing *G. xylinum*, it may be determined that mature coconut water can be used to create nata, a fibre food with value (Gayathry, 2015) [62].

6.2 Others
As an organic ingredient, coconut has also been frequently utilised to improve and enhance plants, particularly when using tissue culture methods. In order to promote plant growth and development, they were followed by the combination of several kinds of plant growth regulators, including auxin, cytokinin, and gibberellin. It stimulates a variety of plant species' growth and development, including the elongation of their shoots and roots, the formation of their calluses, and the somatic embryogenesis of their embryos (Kamaruzzaman *et al*., 2018) [63]. The leftovers from small firms that make old CW and molasses, a by-product of the sugar industry, were combined to create the liquid fertiliser. Using the counting chamber approach, the separated microorganisms were first injected with a total of 1012. The phosphate rock was used as a supply of phosphate in the reactor. To determine the levels of NPK and C components, samples were collected and examined every 4 days. To create the fertiliser, three consortia microbe variables were tested: soil + old coconut water + molasses, enrichment cultures + old coconut water + molasses, and only old CW + molasses. After an 8-day incubation period, the EOM identified the highest (%) concentrations of N, P, K, and C at 0.09, 0.04, 10.5 and 1.74, respectively. A hydroponic system was used to apply the bio-fertilizer to the paddy test plants (Darmawan *et al*., 2020) [66]. Vitamins C, K, and A, which are included in coconut water, encourage the formation of collagen for plumper, healthier-looking skin. It maintains the softness and radiance of your skin thanks to its antioxidant and moisturising qualities. It functions as a natural cleanser and has antibacterial properties without drying out the skin. Due to its cleansing, anti-inflammatory, and antibacterial characteristics, it helps with acne healing and prevention. Fresh CW has a lot of kinetin, a plant growth hormone that slows down the start of ageing in human skin cells (Akinsulie *et al*., 2023) [64]. Majeed *et al*., (2020) [65] conducted a clinical trial on healthy female and male volunteers with hair loss to assess safety effectiveness and of a hair serum formulation combining freeze-dried coconut water, amla extract, sandalwood odorant, vitamin selenium, and peanut shell extract. In comparison to baseline, there was a significant improvement in the rate of hair growth (p<0.0001), hair density (p<0.0001), vellus hair density (p<0.0001), and terminal hair density (p<0.0001) after 90 days of application of the test product. In comparison to the baseline measurement, there was a significant decrease in hair loss both with and without the bulb (p< 0.0001) and hair thinning (p< 0.0001).

7. Conclusion and future prospects
CW is a naturally occurring, nutritious beverage made from coconut palm plants, which are frequently cultivated in tropical regions. In many parts of the world, coconut water is referred to as the "water of life" due to its success in therapy. With about 17.16 million metric tonnes of coconuts produced in 2021, Indonesia will be the world's top producer of the fruit. Because it contains electrolytes like sodium and potassium, coconut water is referred to as a naturally isotonic beverage. is a favourite beverage all around the world because of its many health advantages and tasty flavour? As a result of its abundance in vital minerals including potassium, magnesium, and calcium, it is a well-liked sports beverage among athletes and fitness maniac. As a tropical beverage, traditional medicine, microbial growth medium, and ceremonial gift, coconut water has several purposes. Additionally, its physicochemical characteristics and chemical make it a versatile ingredient for use in the food industry. A growing demand from consumers makes it essential to preserve, prepare, and distribute TCW. The Maillard reaction, the Maillard reaction's postponement, microbiological growth, and the effects of processing methods on product quality are the main barriers to the preservation of TCW. The potential of non-thermal processing techniques to keep coconut water's nutritive and sensory qualities intact is helping them gain appeal. The potential health advantages of CW and its uses in the food and pharmaceutical sectors both require more study.

8. Conflict of interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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