Journal of Experimental Biology and Agricultural Sciences, April - 2025; Volume – 13(2) page 125 – 136

Journal of Experimental Biology and Agricultural Sciences

http://www.jebas.org

**ISSN No. 2320 – 8694**

# A comparative mini review of the phytochemicals and biological properties of haustorium and endosperm of *Cocos nucifera*

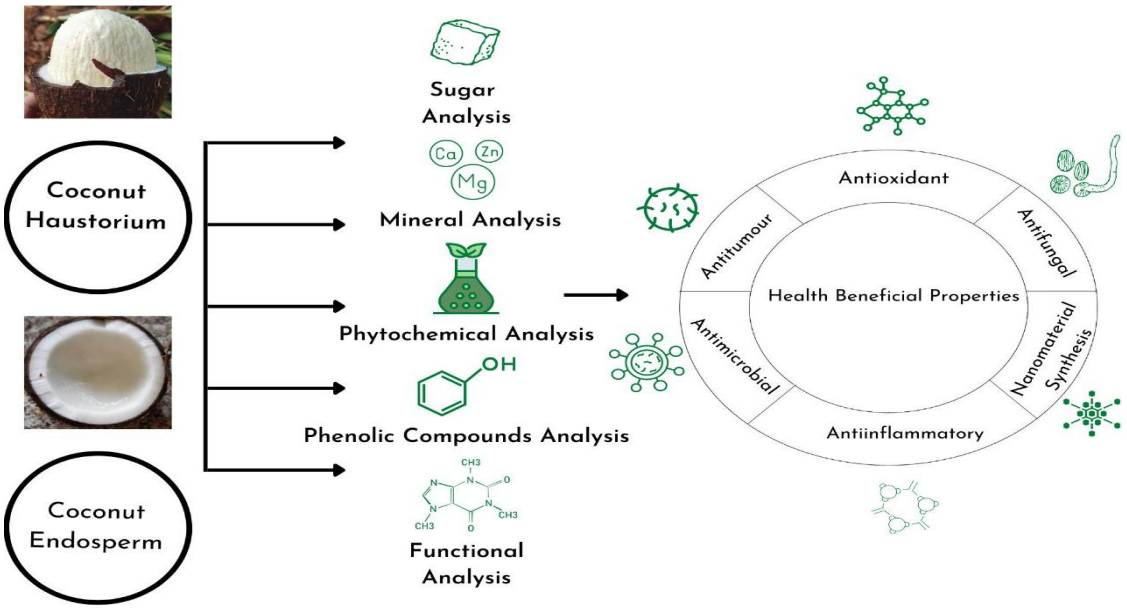
Yasodha S.[1], Vickram A. S.[1*], Rajeshkumar S.[2]

[1]Department of Biotechnology, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai - 602105, Tamil Nadu, India.
[2]Nanobiomedicine Lab, Centre for Global Health Research, Saveetha Medical College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai - 602105, Tamil Nadu, India.

Received – December 15, 2024; Revision – April 03, 2025; Accepted – April 20, 2025
Available Online – May 05, 2025

DOI: http://dx.doi.org/10.18006/2025.13(2).125.136

**GRAPHICAL ABSTRACT**




* Corresponding author
E-mail: vickramas.sse@saveetha.com (Vickram A. S.)

Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

KEYWORDS

Haustorium

Antitumour

Antioxidant

Antimicrobial

Endosperm

**ABSTRACT**

Natural substances derived from plants and herbs are excellent sources of therapeutic drugs, offering numerous vital properties that benefit human health. Recently, there has been increased interest in utilizing natural products. One notable plant with significant nutraceutical and health benefits is the coconut tree (*Cocos nucifera*). Humans use various products from the coconut tree, such as coconut oil, water, and husk. Previous research has extensively explored coconut fruit's endosperm's nutritional, antioxidant, and phytochemical properties. However, there are limited studies on the phytochemical and nutraceutical attributes of the coconut haustorium, an edible part of the fruit. The coconut haustorium possesses considerable benefits, including anti-inflammatory, antioxidant, antifungal, antimicrobial, antitumor, analgesic, antipyretic, antidiarrheal, and antidiabetic properties. This review aims to summarize and compare the phytochemical and nutraceutical properties of the coconut haustorium with those of its endosperm. The findings conclude that the coconut haustorium exhibits outstanding nutraceutical and phytochemical properties comparable to the endosperm.

## 1 Introduction

Plants contain a wide range of chemicals that play a crucial role in protecting us from various pathogens (Honig et al. 2023). Additionally, these plants have been important components of the human diet for most of the population since ancient times (Veiga et al. 2020). The *Cocos nucifera* tree, commonly known as the "Tree of Heaven," is recognized for its comprehensive benefits to humanity (Abhishek and Dwivedi 2021). This tree belongs to the Arecaceae family and is predominantly found in tropical and subtropical regions worldwide (Xiao et al. 2019; Prasad et al. 2022). Although Southeast Asia is its origin, it is now cultivated in nearly 90 countries due to its health benefits and economic importance. India is one of the leading countries known for coconut cultivation and is a founding member of the International Coconut Community (Hegde 2012). The parts of the coconut that are widely used include the endosperm, kernel, endocarp, shell, mesocarp, and fibrous layer. Furthermore, coconuts and their related products are excellent sources of alkaloids, flavonoids, phenols, and tannins (Arivalagan et al. 2018; Reddy et al. 2018). The active compounds in *C. nucifera* are responsible for their antibacterial, antifungal, antioxidant, antiviral, and anti-inflammatory properties (Zeng et al. 2024). Coconut husk concentrate is especially effective in treating infections caused by *Vibrio* spp. (Olatunde et al. 2019). Moreover, it can help treat various disorders, acting as an antiparasitic, antidepressant, antidiabetic, cardioprotective, and analgesic (Tayler et al. 2019; Zhang et al. 2023). The outer shell, husk, albumen, root, and coconut water are effective against diarrhea, amenorrhea, asthma, and urinary tract infections (Ct et al. 2023). Overall, coconut improves immunity and helps reduce liver damage (Mohamad et al. 2018).

A significant part of the coconut is its endosperm. The endosperm, the edible portion of the coconut, typically exists in two forms: solid (kernel) and liquid (coconut juice). During the initial stages of development, the endosperm appears as a translucent jelly that eventually hardens into white flesh, known as coconut meat (Angeles et al. 2018). Interestingly, the cellular structure of coconut does not fill the cavity, leaving a significant amount of liquid known as coconut water. This liquid is rich in minerals and has various health benefits (Naik et al. 2022). Naturally sterile, coconut water consists of approximately 5% solids by weight. In recent years, as people have become more health-conscious, coconut water has gained popularity and is extensively consumed compared to other artificial beverages. This growing demand has led to efforts to process coconut water for a longer shelf life. One of the main attractions of coconut water is its low caloric content of only 17.4 kcal per 100 grams, making it a favorite among athletes (Naik et al. 2022). Additionally, it contains essential amino acids, minerals, phytohormones, and vitamins such as C and B, alongside potassium, calcium, magnesium, sodium, cytokines, alanine, arginine, lysine, and glutamic acid (Tuyekar et al. 2021). The endosperm of the coconut is also rich in key nutrients and minerals, contributing to its status as a delicious edible part (Naik et al. 2022; Mat et al. 2022). Furthermore, coconut water exhibits antimicrobial properties, as demonstrated in a study against four infectious pathogens. At lower doses, there was no effect. However, significant inhibitory zones were observed at a 60 mg/mL concentration, measuring 28 mm against *Staphylococcus aureus* and at least 21 mm against *Pseudomonas aeruginosa*. This antimicrobial potency is attributed to its phytochemically active metabolites (Anyiam and Opara 2023).

Another significant part of the coconut fruit is the haustorium, which develops from the embryonic basal region during germination and is spongy in nature. The haustorium possesses commendable cardioprotective and antioxidant properties, gaining importance in recent studies (Valli and Gowrie 2021). Although there is a wealth of research on the health benefits of various coconut products, such as oil and endosperm, few studies focus on the coconut haustorium. Therefore, this review discusses the

overall significance of endosperm, followed by a detailed exploration of the coconut haustorium and, finally, a comparison of their beneficial features. The review also highlights that haustorium contains key minerals, antioxidants, amino acids, and other phytochemicals, making it more favorable than the endosperm due to its health benefits. However, no prior research on a standardized phytochemical analysis or biological studies has been conducted under uniform experimental conditions. This lack of research limits the ability to directly compare the therapeutic properties of the endosperm and the haustorium. Additionally, the mechanistic understanding of the haustorium's medicinal properties, such as its cardioprotective, anti-inflammatory, anticancer, and antioxidative effects, remains poorly defined.

## 2 Endosperm - Nutraceuticals and therapeutic properties

In *C. nucifera*, there are two elite varieties: Macapuno and Aromatic. The Macapuno variety is notable for its rich mineral content, which includes vitamins, sugars, amino acids, fatty acids, and macronutrients (Phonphoem et al. 2022). Macapuno is a valuable source of edible fiber, has a higher protein content, and has lower fat than the aromatic variety. The endosperm of the Macapuno type contains medium-chain fatty acids. When subjected to physicochemical analysis, it revealed significant amounts of phenolic compounds, alkaloids, and tannins, along with a lower content of flavonoids (Phonphoem et al. 2022). Furthermore, various assays were conducted to evaluate antioxidant activities. The liquid endosperm demonstrates excellent antioxidant properties and protects against DNA damage. Hence, the endosperm shows great potential as a nutraceutical in the food industry. Another study also highlighted the presence of omega-6 and omega-9 fatty acids in this variety. The phytochemical analysis of the endosperm suggests it can serve as an alternative source of antioxidants (Phonphoem et al. 2022).

### 2.1 Health promoting compounds of coconut fruit

Coconuts are rich in glucose, sodium, potassium, zinc, iron, calcium, vitamins C and E, and various other minerals (Hamilton et al., 2024), making them valuable for human health. When comparing coconut milk and oil, it is evident that coconut meat extract contains a significant amount of these minerals compared to coconut oil (Karunasiri et al. 2020; Patil and Benjakul 2018). The white fleshy layer found in coconut meat is part of the endosperm. Historically, this layer was not widely utilized due to its high caloric value (Kannaian et al. 2020; Mulyadi et al. 2019). However, recent research suggests that coconut meat possesses both nutraceutical and therapeutic properties. While coconut oil primarily comprises fats, it also contains a substantial amount of fiber, vitamins, and other essential minerals (Wallace 2019). Coconut oil has shown benefits for patients with Alzheimer's (Sandupama et al. 2022) because of its easy digestibility and absorption, facilitating rapid metabolism and conversion into ketones (Watanabe and Tsujino 2022). Ketones serve as alternative energy sources for individuals with cognitive impairments (Ramesh et al. 2021). De Vasconcelos et al. (2022) reported that coconut oil can reduce body weight. The lauric acid present in coconut oil enhances antifungal properties and boosts overall immunity in humans. Studies have demonstrated its effectiveness against dental microbes, showing an anti-pathogenic effect against *Streptococcus mutans* and *Candida* spp. (Baharvand et al. 2021). Furthermore, coconut oil has proven effective against viruses such as HIV; a clinical trial involving 15 patients with HIV infection found reduced viral counts and increased T lymphocytes (Angeles-Agdeppa et al. 2021).

Besides the endosperm, other parts of the coconut fruit have therapeutic effects on humans. For instance, the extract from coconut flower gel aids in wound healing. This has been demonstrated through studies conducted on male mice, which showed promising results. The healing effects of the gel extract are comparable to those of povidone-iodine. This efficacy is attributed to flavonoids in the female coconut flower extract, which act as antioxidants and reduce inflammation in the wound area. Therefore, inexpensive and effective wound-healing medications can be developed using the female coconut flower extract (Awaliyah et al. 2021). Another significant product is virgin coconut oil, extracted from coconut meat, which is widely used in many Asian countries. In the past, coconut oil was less favored due to its saturated fatty acid content. However, recent research has shown that it contains a high concentration of medium-chain triglycerides, which can help combat ailments such as cancer and diabetes (Duranova et al. 2024; Soliman et al. 2018). Furthermore, coconut oil possesses antioxidant, antimicrobial, and anti-inflammatory properties (Nasir et al. 2018). Additionally, it has a longer shelf life due to the presence of antioxidants (Perera et al. 2020). Some studies also suggested that coconut oil may be cardioprotective (Beegum et al. 2024). This is attributed to its composition, particularly the polyunsaturated fatty acids. However, most research has been limited to animal studies, with fewer trials conducted on humans. Thus, further studies are needed to assess the long-term effects of coconut oil on human cardiac health. In addition to its culinary applications, coconut oil is also used in personal care products (Satheeshan et al. 2020). Regarding mineral content, albumin and globulin are the key proteins in coconut endosperm (Patil and Benjakul 2018). The composition of these proteins varies depending on the type of coconut, which affects their emulsifying properties. Water-soluble albumin exhibits fewer emulsifying capabilities compared to globulin, which is salt-soluble. Consequently, more oil can be extracted from coconut meat rich in globulin (Patil and Benjakul 2019; Rodsamran and Sothornvit 2018). Numerous research studies have revealed the phytochemical and nutraceutical properties of the coconut fruit,

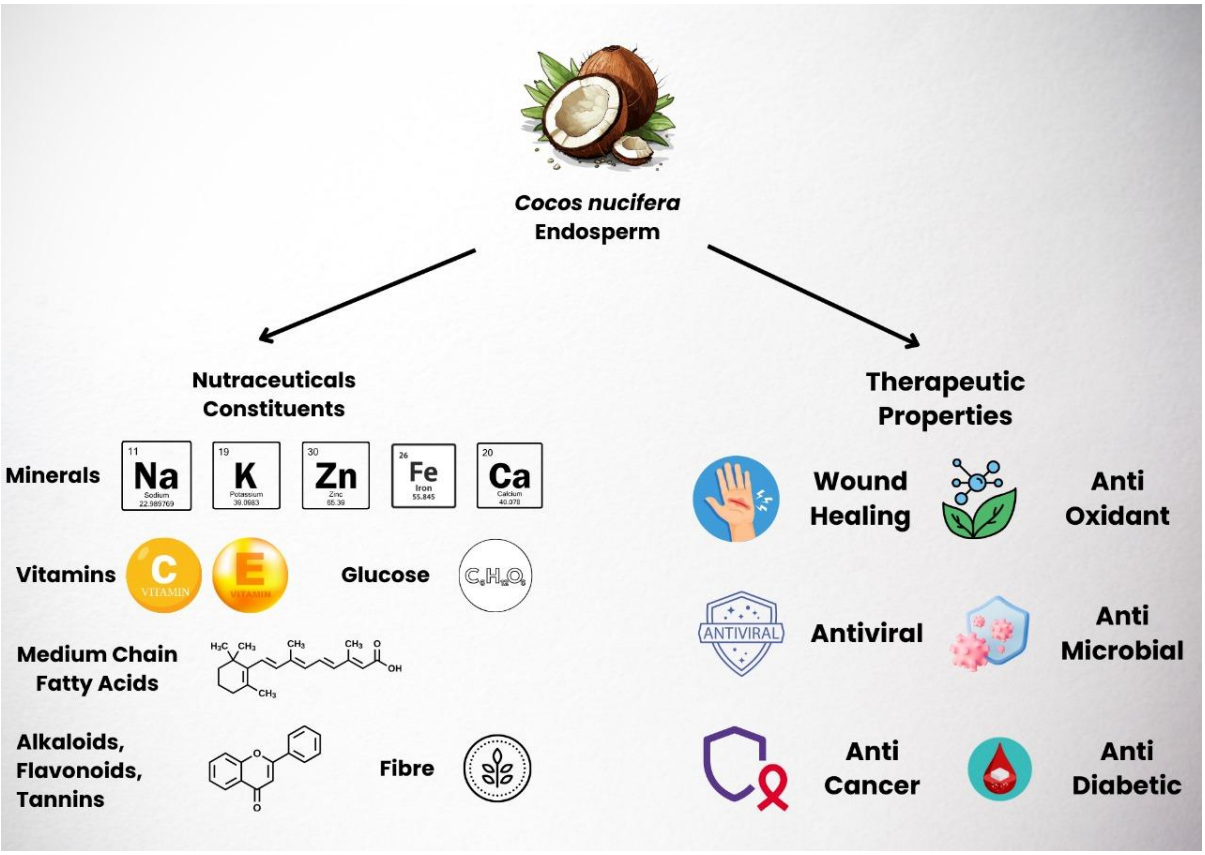



Figure 1 Nutraceutical and therapeutic properties of *Cocos nucifera* endosperm

including its flowers, endosperm, and shells. However, the haustorium of the coconut fruit is often overlooked and remains one of the least studied parts. The nutraceutical and therapeutic properties of the endosperm are illustrated in Figure 1.

**3 Haustorium of *Cocos nucifera* - Its valuable phytoconstituents**

One of the lesser-known coconut products that has recently gained attention is the haustorium, also referred to as the coconut apple (Zhang et al. 2022). A haustorium is formed inside the coconut cavity as a soft, spongy tissue during sprouting. This tissue fills the entire coconut within 8 to 16 months, during which it gathers nutrients from the endosperm to nourish the developing embryo (Rajamohan and Archana 2018; Tuhumuri et al. 2021). The coconut haustorium consists of two parts: an oil-rich outer portion and an inner portion rich in carbohydrates. Approximately 66% of the haustorium's composition is carbohydrates, with 64% being sugar (Manivannan et al. 2018; Senarath and Perera 2018). The process of haustorium formation in C. nucifera is illustrated in Figure 2.

During the initial stages, the haustorium absorbs nutrients and essential minerals from the endosperm. As the haustorium develops further, it absorbs triacylglycerols, leading to endosperm degradation. The absorbed oil is converted into sugars that provide energy for the growing fruit. Previous studies indicate that endosperm degradation starts with a liquid phase, followed by the breakdown of solid endosperm (Li et al. 2019). Additionally, the haustorium stores essential minerals and antioxidants that are rich in energy. The fatty acid composition of the haustorium has been compared with that of embryonic tissue growth in both *in-situ* and *in-vitro* germinated seedlings. It was noted that seedlings germinated *in-vitro* did not develop a prominent haustorium and, therefore, failed to absorb lauric acid from the endosperm (Beveridge et al. 2022). However, these *in-vitro* seedlings did contain medium and long-chain fatty acids. This suggests that the haustorium is crucial for the glycosylation cycle, which facilitates the conversion of lipids into sugars (Li et al. 2019). Furthermore, previous studies have reported a rapid increase in starch content during sprouting while soluble sugars decrease, after which the starch consistency is maintained. The abundant carbohydrates in the kernel are retained in starch form within the haustorium (Job et al. 2021; Manju et al. 2021).

**3.1 Haustorium- a storehouse of energy-rich substrates**

The haustorium is a storage area for essential nutrients, and the quantity of minerals and sugars stored depends on its size. Previous research indicates that larger coconut haustoria contain

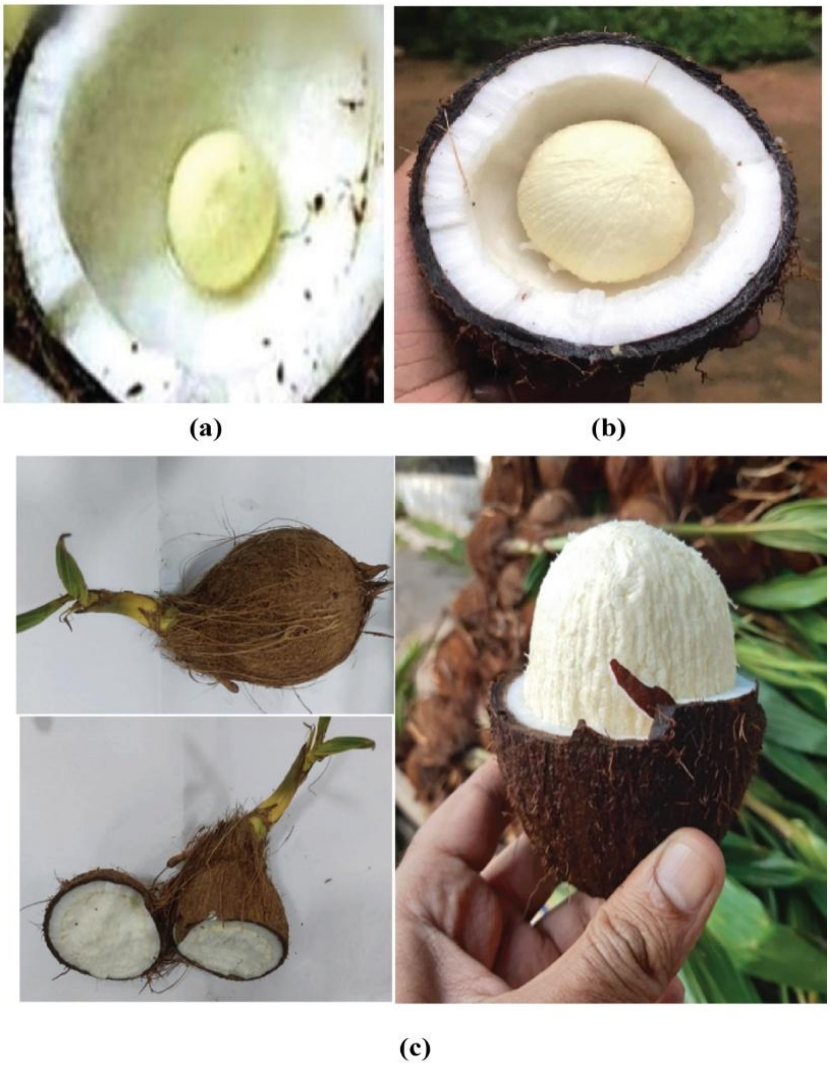



Figure 2 Formation of *C.nucifera* haustorium (a) Initial stage (b) Intermediate stage (C) Fully developed stage

higher amounts of soluble sugars and reducing sugars than their smaller counterparts. Regardless of the variation in sugar content, all haustoria are known to be rich in potassium and phosphorus. Additionally, the compositions of amino acids and fatty acids are reported to be higher in haustoria, enhancing their nutritional properties. The presence of these nutrients endows haustoria with significant antioxidant properties. These characteristics make haustoria valuable as a precursor to food items and dietary additives. Furthermore, the haustorium of the coconut fruit is utilized as a mineral enhancer, a precursor in pharmaceutical products, and an antioxidant (Zhang et al. 2022). Despite the abundant resources found in coconut haustoria, there is a need to enhance their commercial value. Therefore, a biochemical analysis was conducted during germination to improve the properties of the haustorium (Rakesh et al. 2021). The phytoconstituents of haustoria are illustrated in Figure 3.

**3.2 Benefits of haustorium on Human Health**

The coconut haustorium has been relatively underexplored in terms of its nutritional effects on humans, but some studies suggest it contains antioxidants that may offer therapeutic benefits. For the first time, research has quantified both primary and secondary metabolites in the haustorium. Additionally, the free radical scavenging activity of the cotyledon has been studied. Methanolic and chloroform extracts from the haustorium revealed significant amounts of carbohydrates and lipids. Notably, cardiac glycosides found among the secondary metabolites indicate that the haustorium could be vital in treating cancer and cardiac diseases (Valli and Gowrie 2021). Furthermore, the haustorium is rich in phenolics, tannins, and alkaloids, making it comparable to the endosperm of the coconut fruit. The antioxidants in coconut haustorium exhibit free radical sequestering activity equivalent to

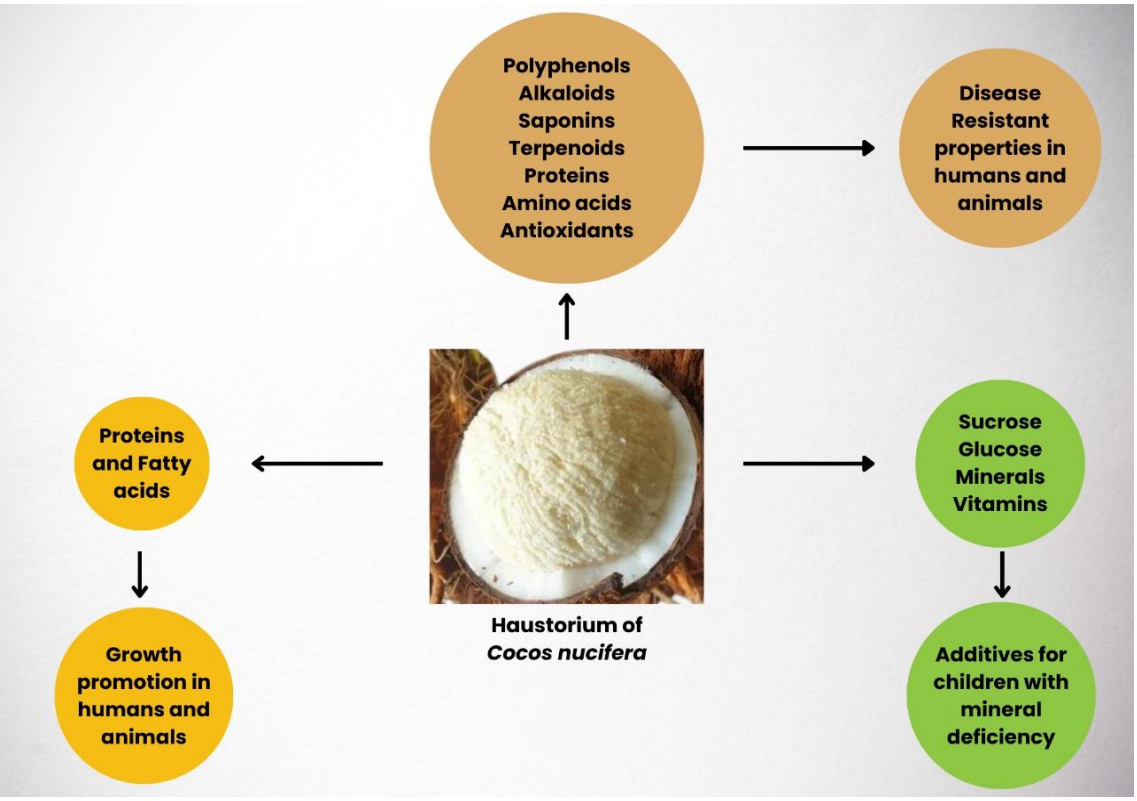



Figure 3 Phytoconstituents of *Cocos nucifera* haustorium

those in the liquid or solid endosperm (Kannaian et al. 2020). Myocardial infarction (MI) is a common condition in humans, often induced by isoproterenol (Bader Eddin et al. 2025). This leads to an increased heart rate, resulting in stress on the myocardium and oxygen deficiency, which ultimately causes myocardial cell death. Coconut haustorium contains proteins, flavonoids, antioxidants, polyphenols, and various minerals (Zhang et al. 2022). Studies have examined coconut haustorium's effects on reducing myocardial infarction for the first time. In a study, isoproterenol was administered to two groups of rats, with only one group receiving coconut haustorium afterwards. Results indicated that the group treated with coconut haustorium experienced significantly fewer MI effects than the untreated group. This suggests that coconut haustorium has notable benefits for individuals suffering from MI (Chikku and Rajamohan, 2012). Moreover, coconuts have high iron content, contributing to increased hemoglobin levels. Regular coconut intake helps maintain overall blood hematology. Studies have shown that administering coconut water to rats (Adeleye et al., 2023) and haustorium to mice (Pradawahyuningtyas et al., 2020) improved hemoglobin levels. Human trials indicate that incorporating haustorium powder into the diet of women aged 20 to 35 significantly increased their ferritin and hemoglobin levels, yielding results comparable to those obtained from iron tablet supplementation (Desmie et al., 2018).

Another significant aspect of haustorium is its potential to develop novel food products. A study compared peeled and unpeeled haustorium flour's physical, chemical, antioxidative, and functional properties. The unpeeled haustorium exhibited higher levels of fat and ash, while peeled coconut haustorium was richer in moisture, starch, fiber, amylose, and carbohydrates (Smita et al. 2019). The haustorium comprises about 66% carbohydrates, making it a primary source of dietary fibers, polyphenols, minerals, and antioxidants. Its high carbohydrate content is particularly beneficial in formulating baby food for lactose-intolerant children (Manju et al. 2021).

## 4 Comparative properties of the haustorium and endosperm of the coconut

The anticancer, antimicrobial, antifungal, and antioxidant properties of coconut haustorium are comparable to those of the coconut endosperm (Marasinghe et al. 2019; Valli and Gowrie, 2021). A comparison of the properties of coconut meat and sprouts is presented in Table 1.

The findings presented in Table 1 revealed that the coconut's endosperm and haustorium exhibit properties such as antioxidant, antitumor, anti-aging, antimicrobial, antifungal, and anti-inflammatory effects. Notably, some properties, like preventing

Table 1 GC-MS studies of methanolic extract of coconut endosperm and coconut haustorium

| Coconut meat | | |
|---|---|---|
| Compound and its nature | Therapeutic properties | References |
| Quinoline (Alkaloid) | Prevents malaria | Uzor 2020 |
| Methyl beta-D-galactopyrranoside (Monosaccharide) | Prevents cancer | Amin et al. 2021 |
| Dodecanoic acid, lauric anhydride (Glycerol and lauric acid derivative) | prevents cancer and acts as an antimicrobial | Matsue et al. 2019; Mori et al. 2025 |
| Glycerol Tricaprylate (triglyceride) | Acts as an anticonvulsant agent | Augustin et al. 2018 |
| Tocopherols (Vitamin E) | Antioxidant, prevents inflammation and acts as an anti-cancerous agent | Es-Sai et al. 2025 |
| Coconut haustorium | | |
| 1,2,4-Triazine-5-thiol, 3-amino-6-methyl (Triazole) | Preventing cancer, antimicrobial and tuberculosis | Karczmarzyk et al. 2020; El-Naggar et al. 2023 |
| Pent-1-yn-3-ene, 4-methyl 3-phenyl (Enyne derivative) | Prevents cancer and inflammation | Rajeshwari et al. 2024 |
| 3',4',5,7-Tetrahydroxyflavone or Luteolin | Acts as a neuroprotectant, anti-inflammatory, antioxidant and anticancer agent | Maryam et al. 2024 |
| Glucose (Monosaccharide) | Acts as an energy source | Zhang et al. 2022 |
| Ascorbic acid (Vitamin C) | Antioxidant | Manju et al. 2021 |
| Squalene (Triterpenoid) | Antioxidative agent | Rajeshwari et al. 2024 |

Table 2 Chemical content of coconut haustorium, coconut water and coconut kernel

| Chemicals | Coconut haustorium | Coconut water | Coconut kernel | References |
|---|---|---|---|---|
| Moisture (%) | 87 | 97 | 43.5 | Zhang et al. 2022; Parmar et al. 2021; Zhang et al. 2024 |
| Total carbohydrates (%) | 65 | 2.54 | 10.6 | |
| Ash (%) | 8 | 0.43 | 0.9 | |
| Protein (%) | 5 | 0.11 | 6 | |
| Fat (%) | 4 | 0.48 | 39 | |

Table 3 Fatty acid composition of coconut haustorium, coconut water and coconut kernel

| Fatty acid composition ((%)) | Coconut haustorium | Coconut water | Coconut kernel | References |
|---|---|---|---|---|
| Caprylic acid | 3 | 3.27 | 5.6 | Zhang et al. 2022; Zhang et al. 2024; Parmar et al. 2021 |
| Capric acid | 3 | 3.09 | 6 | |
| Lauric acid | 25 | 29.7 | 53 | |
| Myristic acid | 14 | 16 | 19 | |
| Palmitic acid | 19 | 11 | 7.4 | |
| Stearic acid | 7 | 4.3 | 2 | |
| Oleic acid | 15 | 7.3 | 5.5 | |
| Linoleic acid | 11 | 9.3 | 1 | |
| SFA | 72 | 77 | 93 | |
| MUFA | 16 | 10 | 5.5 | |
| PUFA | 12 | 12 | 1 | |

tuberculosis and allergic reactions, are exclusively associated with coconut haustorium. The haustorium is rich in phytochemicals and minerals, and it experiences minimal moisture loss when dried, making it convenient for storage and transport (Manju et al. 2021). Table 2 illustrates the chemical composition of coconut haustorium, coconut water, and the kernel. It shows that the fat content in coconut haustorium is significantly lower than that in the coconut kernel, making it a healthier food option.

Fatty acids in the coconut haustorium are compared with the content found in its endosperm, revealing that saturated fatty acids are minimal in the haustorium (Xiao et al. 2019). Table 3 illustrates the fatty acid composition of the coconut haustorium, coconut water, and kernel.

Ultimately, this review compares the amino acids in haustorium with those in coconut water and kernel, showing a similar quantity in both haustorium and its water (Table 4).

**5 Challenges and future prospects of coconut haustorium**

The nutrient properties of coconut haustorium vary among different varieties. A previous study indicated that the West Coast tall variety of coconut has a haustorium that contains high levels of tannin, oxalate, and phytic acid (Manju et al. 2021). These substances are considered anti-nutrients, making selecting a coconut variety that offers essential nutrients in balanced amounts is challenging. Another significant challenge is that the shelf life of coconut haustorium is only two days without refrigeration. Therefore, it is crucial to choose appropriate packaging to extend the shelf life of the haustorium (Preethi and Anil 2023). Additionally, key amino acids and calcium content are low in haustorium, so external supplementation of these components is necessary to create a balanced diet. However, haustorium is rich in carbohydrates and lauric acid, an important fatty acid found in breast milk, making it suitable for children who are lactose intolerant (Rajeshwari et al. 2024). Most research on haustorium has been conducted with animals, indicating a need for more human trials to bring haustorium-related products to the global market. The review discusses the use of haustorium in formulating haustorium flours, which opens up possibilities for creating novel and nutritious dietary food products (Smita et al. 2019). Looking to the future, efforts should focus on extending the shelf life of coconut-related products and helping farmers understand the economic value of coconuts to increase production. In-depth molecular studies are needed to explore haustorium's pharmaceutical potential and assess its action mechanisms.

Table 4 Amino acid content in coconut haustorium, coconut water and coconut kernel

| Amino acid | Coconut haustorium (mg/g Protein) | Coconut water (mg/g Protein) | Coconut kernel (mg/g Protein) | References |
|---|---|---|---|---|
| Histidine | 25 | 26 | 0.8 | Zhang et al. 2022; Zhang et al. 2024; Parmar et al. 2021 |
| Isoleucine | 34 | 12.5 | 1.3 | |
| Leucine | 47 | 20.5 | 2.5 | |
| Lysine | 47 | 46.2 | 1.5 | |
| Methionine | 22 | 7.7 | 0.6 | |
| Tryptophan | - | - | 0.4 | |
| Cysteine | 11 | 3 | 0.7 | |
| Phenylalanine | 35 | 21 | 1.7 | |
| Tyrosine | 27 | 8.4 | 1 | |
| Threonine | 40 | 31 | 1.2 | |
| Valine | 56 | 20.3 | 2 | |
| Aspartic acid | 102 | 77 | 3.3 | |
| Serine | 41 | 80 | 1.7 | |
| Glutamic acid | 111 | 259 | 7.6 | |
| Glycine | 38 | 15 | 1.6 | |
| Alanine | 60 | 194 | 1.7 | |
| Arginine | 76 | 37.7 | 5.5 | |
| Proline | 48 | 37.7 | 1.4 | |

Furthermore, in vivo studies and clinical trials should be conducted to evaluate its effectiveness and biocompatibility. Given its physiochemical properties and safety, haustorium also has the potential to be developed into a sustainable and compatible drug delivery system. Comprehensive research on haustorium could pave the way for new therapeutic and nutritional benefits.

**Conclusion**

The review provides an overview of the various parts of the highly nutritious coconut fruit that are essential for food supplements, pharmaceuticals, and the cosmetics industry. It includes a detailed description of the coconut haustorium, which previous researchers have largely overlooked. The review highlights the haustorium's phytochemical, antioxidant, and other nutraceutical properties. It also notes that haustorium can be utilized in the development of many novel food products due to its rich content of minerals and antioxidants. Furthermore, the review compares the features of the endosperm and haustorium of the coconut fruit. The comparison concludes that the haustorium contains holistic phytochemicals and is a potential nutrient reservoir comparable to the liquid and solid endosperm. This nutrient-rich profile can help alleviate various diseases and infections. Additionally, coconut haustorium is inexpensive and readily available, making it a valuable resource for developing countries facing food security challenges. The review emphasizes that coconut haustorium is rich in vitamins, minerals, and antioxidants while containing minimal lipids. Therefore, considering its numerous benefits, the haustorium is even more economically advantageous than other parts of the coconut.

**References**

Abhishek, T. S., & Dwivedi, S. A. (2021). Review on integrated pest management of coconut crop. *International Journal of Entomology Research*, *6*, 115-120.

Adeleye, G. S., Odesanmi, E. O., Ajeigbe, K. O., Omayone, T., Odetola, A., & Sobanke, A. O. (2023). Ameliorative Effects of Coconut Water on Hematological and Lipid Profiles of Phenylhydrazine-treated Rats. *Nigerian Journal of Physiological Sciences*, *38*(2), 255-264.

Amin, M. R., Yasmin, F., Hosen, M. A., Dey, S., et al. (2021). Synthesis, antimicrobial, anticancer, PASS, molecular docking, molecular dynamic simulations & pharmacokinetic predictions of some methyl β-D-galactopyranosideanalogs. *Molecules*, *26*(22), 7016. https://doi.org/10.3390/molecules26227016

Angeles, J. G. C., Lado, J. P., Pascual, E. D., Cueto, C. A., Laurena, A. C., & Laude, R. P. (2018). Towards the understanding of important coconut endosperm phenotypes: is there an epigenetic control? *Agronomy*, *8*(10), 225. https://doi.org/10.3390/agronomy8100225

Angeles-Agdeppa, I., Nacis, J. S., Capanzana, M. V., Dayrit, F. M., & Tanda, K. V. (2021). Virgin coconut oil is effective in lowering C-reactive protein levels among suspect and probable cases of COVID-19. *Journal of Functional Foods*, *83*, 104557. https://doi.org/10.1016/j.jff.2021.104557

Anyiam, I. V., & Opara, C. N. (2023). Phytochemicals and antimicrobial activity of coconut water (*Cocos nucifera*) on microbial pathogens. *GSC Biological and Pharmaceutical Sciences*, *25*(2), 273-282. https://doi.org/10.30574/gscbps.2023.25.2.0476

Arivalagan, M., Roy, T. K., Yasmeen, A. M., Pavithra, K. C., et al. (2018). Extraction of phenolic compounds with antioxidant potential from coconut (*Cocos nucifera* L.) testa and identification of phenolic acids and flavonoids using UPLC coupled with TQD-MS/MS. *LWT*, *92*, 116-126. https://doi.org/10.1016/j.lwt.2018.02.024

Augustin, K., Khabbush, A., Williams, S., Eaton, S., et al. (2018). Mechanisms of action for the medium-chain triglyceride ketogenic diet in neurological and metabolic disorders. *The Lancet Neurology*, *17*(1), 84-93. https://doi.org/10.1016/s1474-4422(17)30408-8

Awaliyah, S., Hernawati, H., Ariantara, W. S. R., & Handina, H. (2021). Wound healing activity of gel extract female coconut flower in mice (Mus musculus). *Moroccan Journal of Chemistry*, *9*(2) 9-2. https://doi.org/10.48317/IMIST.PRSM/morjchem-v9i2.27584

Bader Eddin, L., Nagoor Meeran, M. F., Kumar Jha, N., Goyal, S. N., & Ojha, S. (2025). Isoproterenol mechanisms in inducing myocardial fibrosis and its application as an experimental model for the evaluation of therapeutic potential of phytochemicals and pharmaceuticals. *Animal Models and Experimental Medicine*, *8*(1), 67-91. https://doi.org/10.1002/ame2.12496

Baharvand, M., Shokri, M., Hassani, S., Mirzaei, H., & Mahdian, M. (2021). Antibacterial effect of coconut water and coconut oil on Aggregatibacteractinomycetemcomitans. *Journal of Research in Dental and Maxillofacial Sciences*, *6*(3), 40-46. http://dx.doi.org/10.52547/jrdms.6.3.40

Beegum, P. S., Ramesh, S. V., Pandiselvam, R., Neema, M., et al. (2024). Perspectives on the cardioprotective, neuroprotective and anti-obesity functions of coconut (*Cocos nucifera* L.). *Food Bioscience*, *58*, 103756. https://doi.org/10.1016/j.fbio.2024.103756

Beveridge, F. C., Kalaipandian, S., Yang, C., & Adkins, S. W. (2022). Fruit biology of coconut (Cocos nucifera L.). *Plants*, *11*(23), 3293. https://doi.org/10.3390/plants11233293

Chikku, A. M., & Rajamohan, T. (2012). Dietary coconut sprout beneficially modulates cardiac damage induced by isoproterenol in rats. *Bangladesh Journal of Pharmacology*, *7*(4), 258-265. https://doi.org/10.3329/bjp.v7i4.12143

Ct, D. R., Palaninathan, V., & James, R. A. (2023). Anti-uropathogenic, antioxidant and struvite crystallization inhibitory potential of fresh and fermented coconut water. *Biocatalysis and Agricultural Biotechnology*, *47*, 102555. https://doi.org/10.1016/j.bcab.2022.102555

De Vasconcelos, M. H. A., Tavares, R. L., Junior, E. U. T., Dorand, V. A. M., et al. (2022). Extra virgin coconut oil (*Cocos nucifera* L.) exerts anti-obesity effect by modulating adiposity and improves hepatic lipid metabolism, leptin and insulin resistance in diet-induced obese rats. *Journal of Functional Foods*, *94*, 105122. https://doi.org/10.1016/j.jff.2022.105122

Desmie, N., Fatmasari, D., & Kumorowulan, S. (2018). Provision of coconut haustorium as an alternative to increase hemoglobin and ferritin levels among women of childbearing age. *International Journal of Allied Medical Sciences and Clinical Research*, *6*(3), 662-670.

Duranova, H., Kuzelova, L., Fialkova, V., Simora, V., et al. (2024). Coconut-sourced MCT oil: Its potential health benefits beyond traditional coconut oil. *Phytochemistry Reviews*, *24*, 659-700. https://doi.org/10.1007/s11101-024-09969-1

El-Naggar, M. A., Abu-Youssef, M. A., Haukka, M., Barakat, A., Sharaf, M. M., & Soliman, S. M. (2023). Synthesis, X-ray Structure, and Hirshfeld Analysis of [Ag (3-amino-5, 6-dimethyl-1, 2, 4-triazine) (NO3)] n: A Potent Anticancer and Antimicrobial Agent. *Inorganics*, *11*(9), 350. https://doi.org/10.3390/inorganics11090350

Es-Sai, B., Wahnou, H., Benayad, S., Rabbaa, S., et al. (2025). Gamma-Tocopherol: A Comprehensive Review of Its Antioxidant, Anti-Inflammatory, and Anticancer Properties. *Molecules*, *30*(3), 653. https://doi.org/10.3390/molecules30030653

Hamilton, P. D., Charles, K. T., Loh, A. M. B., Loïc, N. N. A., Germain, K., & Elie, F. (2024). Physicochemical, nutritional, antioxidant properties and stability monitoring of coconut (*Cocos nucifera* L.) water from two localities in Cameroon. *Heliyon*, *10*(23). https://doi.org/10.1016/j.heliyon.2024.e40712

Hegde, D. M. (2012). Carrying capacity of Indian agriculture: oilseeds. *Current Science*, *102*(6), 867-873.

Honig, M., Roeber, V. M., Schmülling, T., & Cortleven, A. (2023). Chemical priming of plant defense responses to pathogen attacks. *Frontiers in Plant Science*, *14*, 1146577. https://doi.org/10.3389/fpls.2023.1146577

Job, J. T., Rajagopal, R., Alfarhan, A., Ramesh, V., & Narayanankutty, A. (2021). Toxic effects of fluoride in intestinal epithelial cells and the mitigating effect of methanol extract of coconut haustorium by enhancing de novo glutathione biosynthesis. *Environmental Research*, *200*, 111717. https://doi.org/10.1016/j.envres.2021.111717

Kannaian, U. P. N., Edwin, J. B., Rajagopal, V., Shankar, S. N., & Srinivasan, B. (2020). Phytochemical composition and antioxidant activity of coconut cotyledon. *Heliyon*, *6*(2). https://doi.org/10.1016/j.heliyon.2020.e03411

Karczmarzyk, Z., Swatko-Ossor, M., Wysocki, W., Drozd, M., et al. (2020). New application of 1, 2, 4-triazole derivatives as antitubercular agents. Structure, in vitro screening and docking studies. *Molecules*, *25*(24), 6033. https://doi.org/10.3390/molecules25246033

Karunasiri, A. N., Gunawardane, M., Senanayake, C. M., Jayathilaka, N., & Seneviratne, K. N. (2020). Antioxidant and nutritional properties of domestic and commercial coconut milk preparations. *International Journal of Food Science*, *2020*(1), 3489605. https://doi.org/10.1155/2020/3489605

Li, J., Htwe, Y. M., Wang, Y., Yang, Y., et al. (2019). Analysis of sugars and fatty acids during haustorium development and seedling growth of coconut. *Agronomy Journal*, *111*(5), 2341-2349. https://doi.org/10.2134/agronj2019.02.0137

Manivannan, A., Bhardwaj, R., Padmanabhan, S., Suneja, P., Hebbar, K. B., & Kanade, S. R. (2018). Biochemical and nutritional characterization of coconut (*Cocos nucifera* L.) haustorium. *Food Chemistry*, *238*, 153-159. https://doi.org/10.1016/j.foodchem.2016.10.127

Manju, M., Aiswarya, A., Bindu, R. N., & Laija, S. (2021). Nutritional analysis of haustoria from three varieties of coconut (*Cocos nucifera* L.). *Annals: Food Science & Technology*, *22*(3), 362-368.

Marasinghe, S. S. K., Marikkar, J. N., Yalegama, C., Wimalasiri, S., et al. (2019). Comparison of inter-varietal differences in chemical composition and nutritional properties of coconut testa flour. *Journal of the National Science Foundation of Sri Lanka*, *47*(3), 349 – 356. http://dx.doi.org/10.4038/jnsfsr.v47i3.8699

Maryam, S., Khalid, S., Arshad, A., Abid, S., Iqbal, L. Z., Amjad, Y., & Faisal, S. (2024). Luteolin: A versatile flavonoid for anti-inflammatory, anticancer, and neuroprotective therapies. *GSC Biological and Pharmaceutical Sciences*, *29*(03), 119-137.

Mat, K., Abdul Kari, Z., Rusli, N. D., Che Harun, H., et al. (2022). Coconut palm: food, feed, and nutraceutical properties. *Animals*, *12*(16), 2107. https://doi.org/10.3390/ani12162107

Matsue, M., Mori, Y., Nagase, S., Sugiyama, Y., et al. (2019). Measuring the antimicrobial activity of lauric acid against various

bacteria in human gut microbiota using a new method. *Cell transplantation*, *28*(12), 1528-1541. https://doi.org/10.1177/0963689719881366

Mohamad, N. E., Yeap, S. K., Beh, B. K., Ky, H., et al. (2018). Coconut water vinegar ameliorates recovery of acetaminophen induced liver damage in mice. *BMC complementary and alternative medicine*, *18*, 195. https://doi.org/10.1186/s12906-018-2199-4

Mori, S., Fujiwara-Tani, R., Ogata, R., Ohmori, H., et al. (2025). Anticancer and Pro-Immune Effects of Lauric Acid on Colorectal Cancer Cells. *International Journal of Molecular Sciences*, *26*(5), 1953. https://doi.org/10.3390/ijms26051953

Mulyadi, A. F., Schreiner, M., & Dewi, I. A. (2019). An overview of factors that affected in quality of virgin coconut oil. *AIP Conference Proceedings*, *2120*, (1), 050007. https://doi.org/10.1063/1.5115683

Naik, M., Sunil, C. K., Rawson, A., & Venkatachalapathy, N., (2022). Tender coconut water: A review on recent advances in processing and preservation. *Food Reviews International*, *38*(6), 1215-1236. https://doi.org/10.1080/87559129.2020.1785489

Nasir, N. A. M. M., Abllah, Z., Jalaludin, A. A., Shahdan, I. A., & Abd Manan, W. N. H. W. (2018). Virgin coconut oil and its antimicrobial properties against pathogenic microorganisms: a review. *International dental conference of sumatera utara (IDCSU 2017)*, 192-199. https://doi.org/10.2991/idcsu-17.2018.51

Olatunde, O. O., Benjakul, S., & Vongkamjan, K. (2019). Coconut husk extract: antibacterial properties and its application for shelf-life extension of Asian sea bass slices. *International Journal of Food Science and Technology*, *54*(3), 810-822. https://doi.org/10.1111/ijfs.14000

Parmar, P. T., Singh, A. K., & Borad, S. G. (2021). Coconut (Cocos nucifera). In B. Tanwar, & A. Goyal (Eds) *Oilseeds: Health Attributes and Food Applications* (pp. 163-189). Springer Singapore. https://doi.org/10.1007/978-981-15-4194-0_7.

Patil, U., & Benjakul, S. (2018). Coconut milk and coconut oil: their manufacture associated with protein functionality. *Journal of food science*, *83*(8), 2019-2027. https://doi.org/10.1111/1750-3841.14223

Patil, U., & Benjakul, S. (2019). Use of protease from seabass pyloric caeca in combination with repeated freeze–thawing cycles increases the production efficiency of virgin coconut oil. *European Journal of Lipid Science and Technology*, *121*(5), 1800460. https://doi.org/10.1002/ejlt.201800460

Perera, D. N., Hewavitharana, G. G., & Navaratne, S. B. (2020). Determination of physicochemical and functional properties of coconut oil by incorporating bioactive compounds in selected spices. *Journal of lipids*, *2020*(1), 8853940. https://doi.org/10.1155/2020/8853940

Phonphoem, W., Sinthuvanich, C., Aramrak, A., Sirichiewsakul, S., Arikit, S., & Yokthongwattana, C. (2022). Nutritional profiles, phytochemical analysis, antioxidant activity and DNA damage protection of makapuno derived from Thai aromatic coconut. *Foods*, *11*(23), 3912. https://doi.org/10.3390/foods11233912

Pradawahyuningtyas, A., Priastomo, M., & Rijai, L. (2020). Antianemic Activity of Coconut (*Cocos nucifera*) Haustorium Waste Filtrate in Mice Induced by Sodium Nitrite. *Ad-Dawaa'Journal of Pharmaceutical Sciences*, *3*(2), 90-96. https://doi.org/10.24252/djps.v3i2.16477.

Prasad, A. B., Arunkumar, A., Vignesh, S., Chidanand, D. V., & Baskaran, N. (2022). Exploring the nutritional profiling and health benefits of Palmyra palm haustorium. *South African Journal of Botany*, *151*, 228-237. https://doi.org/10.1016/j.sajb.2022.01.027

Preethi, G. L., & Anil, B. (2023). Antioxidant Activity, Nutrient Analysis and Sensory Evaluation of Coconut Apple. *International Journal of Current Science Research and Review*, *6*, 4688-4693. https://doi.org/10.47191/ijcsrr/V6-i7-85

Rajamohan, T., & Archana, U. (2018). Nutrition and health aspects of coconut. In V. Krishnakumar, P. Thampan, & M. Nair (eds) *The Coconut Palm (Cocos nucifera L.)-Research and Development Perspectives*, (pp. 757-777). Springer, Singapore. https://doi.org/10.1007/978-981-13-2754-4_15

Rajeshwari, E. R., Sathanya, P. S., Vignesh, S., & Baskaran, N. (2024). Palmyra and coconut haustorium: a comprehensive review on nutritional composition, bioactive potential, value-added products and its health benefits. *Food Chemistry Advances*, *5*, 100836. https://doi.org/10.1016/j.focha.2024.100836

Rakesh, B., Ramar, A., Velmurugan, S., Vanitha, K., & Saranya, N. (2021). Comprehensive comparative morphology and developmental stages of coconut haustorium. *The Pharma Innovation Journal*, *10*, 2396-2399.

Ramesh, S. V., Krishnan, V., Praveen, S., & Hebbar, K. B. (2021). Dietary prospects of coconut oil for the prevention and treatment of Alzheimer's disease (AD): A review of recent evidences. *Trends in Food Science & Technology*, *112*, 201-211. https://doi.org/10.1016/j.tifs.2021.03.046

Reddy, E. P., Lakshmi, T. M., & Kiran, S. R. (2018). Tender Coconut Water Uses, Health Benefits, Good Nutritive Value and

Antioxidant Capacity. *Indian Journal of Public Health Research & Development*, *9*(4), 184. http://dx.doi.org/10.5958/0976-5506.2018.00280.2.

Rodsamran, P., & Sothornvit, R. (2018). Physicochemical and functional properties of protein concentrate from by-product of coconut processing. *Food Chemistry*, *241*, 364-371. https://doi.org/10.1016/j.foodchem.2017.08.116

Sandupama, P., Munasinghe, D., & Jayasinghe, M. (2022). Coconut oil as a therapeutic treatment for alzheimer's disease: a review. *Journal of Future Foods*, *2*(1), 41-52. https://doi.org/10.1016/j.jfutfo.2022.03.016

Satheeshan, K. N., Seema, B. R., & Manjusha, A. M. (2020). Development of virgin coconut oil-based body lotion. *The Pharma Innovation Journal*, *9*(5), 96-101.

Senarath, S. A. C. T., & Perera, O. D. A. N. (2018). Development and quality evaluation of ready-to-serve (RTS) beverage from coconut haustorium without any chemical preservatives. *Sri Lanka Association for the Advancement of Science Proceedings of the 74thAnnual Sessions*, 60-63. Retrieved from viduketha.nsf.gov.lk.

Smita, M., Bashir, M., & Haripriya, S. (2019). Physicochemical and functional properties of peeled and unpeeled coconut haustorium flours. *Journal of Food Measurement and Characterization*, *13*(1), 61-69. https://doi.org/10.1007/s11694-018-9919-9

Soliman, A. M., Lin, T. S., Ghafar, N. A., & Das, S. (2018). Virgin coconut oil and diabetic wound healing: histopathological and biochemical analysis. *European Journal of Anatomy*, *22*(2), 135-144.

Tayler, N. M., Boya, C. A., Herrera, L., Moy, J., et al. (2019). Analysis of the antiparasitic and anticancer activity of the coconut palm (*Cocos nucifera* L. ARECACEAE) from the natural reserve of Punta Patiño, Darién. *PLos One*, *14*(4), e0214193. https://doi.org/10.1371/journal.pone.0214193

Tuhumuri, E., Setiaji, B., Usman, S., & Sancayaningsih, R. P. (2021). Degradation of Copra quality as the result of the application of Sasi Kelapa for six months period in Waenalut Village, South Buru, Indonesia. *AIP Conference Proceedings*, *2360* (1). https://doi.org/10.1063/5.0059505

Tuyekar, S. N., Tawade, B. S., Singh, K. S., Wagh, V. S., et al. (2021). An overview on coconut water: As a multipurpose nutrition. *International Journal of Pharmaceutical Sciences Review and Research*, *68*(2), 63-70. http://dx.doi.org/10.47583/ijpsrr.2021.v68i02.010

Uzor, P. F. (2020). Alkaloids from plants with antimalarial activity: a review of recent studies. *Evidence-Based Complementary and Alternative Medicine*, *2020*(1), 8749083. https://doi.org/10.1155/2020/8749083

Valli, S. A., & Gowrie, S. U. (2021). Bioprospecting and Therapeutic Applications of Cocos nucifera L. Sprouts. *International Journal of Current Research and Review*, *13*(22), 35. .http://dx.doi.org/10.31782/IJCRR.2021.132211

Veiga, M., Costa, E. M., Silva, S., & Pintado, M. (2020). Impact of plant extracts upon human health: A review. *Critical reviews in food science and nutrition*, *60*(5), 873-886. https://doi.org/10.1080/10408398.2018.1540969

Wallace, T. C. (2019). Health effects of coconut oil—A narrative review of current evidence. *Journal of the american college of nutrition*, *38*(2), 97-107. https://doi.org/10.1080/07315724.2018.1497562

Watanabe, S., & Tsujino, S. (2022). Applications of medium-chain triglycerides in foods. *Frontiers in nutrition*, *9*, 802805. https://doi.org/10.3389/fnut.2022.802805

Xiao, Y., Xia, W., Mason, A. S., Cao, Z., et al. (2019). Genetic control of fatty acid composition in coconut (*Cocos nucifera*), African oil palm (*Elaeis guineensis*), and date palm (*Phoenix dactylifera*). *Planta*, *249*, 333-350. https://doi.org/10.1007/s00425-018-3003-x

Zeng, Y. Q., He, J. T., Hu, B. Y., Li, W., Deng, J., Lin, Q. L., & Fang, Y. (2024). Virgin coconut oil: A comprehensive review of antioxidant activity and mechanisms contributed by phenolic compounds. *Critical Reviews in Food Science and Nutrition*, *64*(4), 1052-1075. https://doi.org/10.1080/10408398.2022.2113361

Zhang, Q., Wang, X., Lin, Y., Lv, Z., et al. (2023). Virgin coconut oil attenuates lipopolysaccharide-induced depression-like behaviors: Integrating network pharmacology analysis and molecular mechanism evaluation. *Neuroscience Letters*, *810*, 137350. https://doi.org/10.1016/j.neulet.2023.137350

Zhang, Y., Kan, J., Liu, X., Song, F., Zhu, K., Li, N., & Zhang, Y. (2024). Chemical components, nutritional value, volatile organic compounds and biological activities in vitro of coconut (*Cocos nucifera* L.) water with different maturities. *Foods*, *13*(6), 863. https://doi.org/10.3390/foods13060863

Zhang, Y., Kan, J., Tang, M., Song, F., Li, N., & Zhang, Y. (2022). Chemical composition, nutritive value, volatile profiles and antioxidant activity of coconut (*Cocos nucifera* L.) haustorium with different transverse diameter. *Foods*, *11*(7), 916. https://doi.org/10.3390/foods11070916