

An Overview of Phytoconstituents, Biotechnological Applications, and Nutritive Aspects of Coconut (*Cocos nucifera*)

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Abstract *Cocos nucifera* is one of the highest nutritional and medicinal value plants with various fractions of proteins which play a major role in several biological applications such as anti-microbial, anti-inflammatory, anti-diabetic, anti-neoplastic, anti-parasitic, insecticidal, and leishmanicidal activities. This review is focused on several biotechnological, biomedical aspects of various solvent extracts collected from different parts of coconut and the phytochemical constituents which are present in it. The results obtained from this source will facilitate most of the researchers to focus their work toward the process of diagnosing diseases in future.

Keywords Phytoconstituents · Anti-diabetic · Anti-inflammatory · Anti-parasitic · Biological applications · *Cocos nucifera* · Various extracts

Introduction

Natural sources have been considered as one of the nontoxic materials which play a higher role in various applicational studies [1–4]. Natural sources are used as drugs, synthesis of nanoparticles, catalyst [5–17], etc.. *Cocos nucifera* is said to be an important member in the palm family *Arecaceae* which is popularly known as coconut [18]. This plant was first originated in southeast parts of Asian countries [19]. Recent reports of the Food and Agriculture Organization (FAO) states that Indonesia produces *C. nucifera* in large scale [20]. Various parts of *C. nucifera* like coir, toddy, husk, water, and fiber play diverse roles in biological applications [21]. Different products that are extracted from *C. nucifera* are utilized for industrial and domestic purposes [22]. Oils that are extracted from *C. nucifera* by direct pressing technique

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were utilized for several bone disorders due to its curative property [23]. The major phyto-components present in *C. nucifera* are lignin, tannin, furfural, pentose, and cellulose [24]. *C. nucifera* was also said to be a thirst quencher in all over the world due to its water properties. The waste products from *C. nucifera* like coir dust and coir pith are utilized for several decoration purposes in mattress industry. *C. nucifera* flower can be utilized for several ornamental decorations, and various extracts of *C. nucifera* parts play a major role in the synthesis of metal nanoparticles which can be further subjected to various organic and environmental applications [25, 26]. Various phytochemicals from *C. nucifera* were identified, and the presence of phenols, tannins, flavonoids, steroids, triterpenes, and alkaloids were already reported [27]. This review explains about the various parts of *C. nucifera* extracts which play a major role in several biological applications that can facilitate most of the researchers to focus on green extracts and applications toward diagnosis.

Scientific Classification

C. nucifera is classified by their own characteristics like formation of leaves, fruits, and flowers. This belongs to angiosperm as it is a flowering plant and is also presented in *Magnoliophyta* division which can be further classified into two subclasses like *Liliopsida* and *Magnoliopsida*. Plants belonging to *Liliopsida* class are monocotyledons whereas plants belonging to *Magnoliopsida* are dicotyledons. Here, *C. nucifera* belong to *Liliopsida* class which is further subdivided into order of *Arecales* and placed in a genus of *Cocos* with species *nucifera* (Fig. 1). So, it was botanically classified as *C. nucifera* [28, 29].

Distribution

Initially, *C. nucifera* are widely distributed in southeast countries like Malaysia, Indonesia, and Philippines and present in the islands between Indian and Pacific oceans. Further, it is believed to be brought to India and East Africa. After the discovery of Cape of Good Hope, it was distributed toward American and African continents [30].

Fig. 1 *C. nucifera* plant



Applications of *C. nucifera*

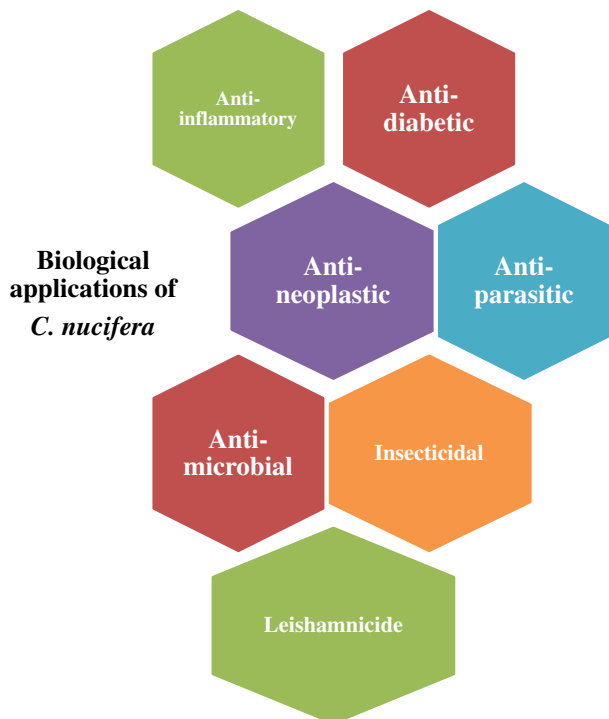
Most of the researching facilities are focused on easiest diagnosing process for various biological applications like anti-microbial, anti-inflammatory, anti-diabetic, anti-parasitic, anti-neoplastic, insecticidal, and leishmanicidal activities (Fig. 2) by using simplest process in an eco-friendly manner [31]. In this minireview, we report the various extracts of *C. nucifera* (Fig. 3) that have been utilized for the abovementioned biological applications.

Biocidal Activity

C. nucifera oil was extracted by the method of direct pressing technique from the nuts of *C. nucifera* and subjected against various disease causing strains like *Pseudomonas aeruginosa*, *Escherichia coli*, *Aspergillus niger*, *Pseudomonas vulgaris*, *Bacillus subtilis*, and *Staphylococcus aureus* by the process of skin inoculation and cream challenge test. Authors interpreted that *C. nucifera* oil can act as a good anti-microbial agent and also resulted that *C. nucifera* oil can withstand the heat shock property [32].

Aqueous crude extracts of *C. nucifera* husk fiber were collected and subjected against various microbial strains like *Candida albicans*, methicillin-resistant *S. aureus* and *E. coli* by agar diffusion method. Here, authors verified the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC). The result indicated the higher inhibition of methicillin-resistant *S. aureus* with the inhibitory concentration of 1024 $\mu\text{g/mL}$ [33].

Fig. 2 Biological applications of *C. nucifera*



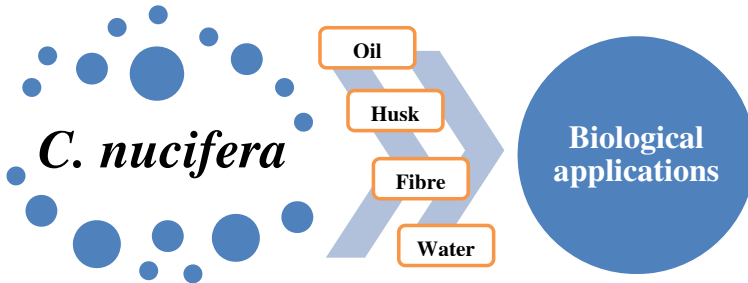


Fig. 3 Role of various parts from *C. nucifera* in biological applications

Methanolic extract was collected from *C. nucifera* husk fiber and was subjected against three microorganisms which contain fungi in it. The observed results indicated that *C. nucifera* husk fiber extract played a major role as anti-microbial agent, but it was found to be inactive against fungal strains which were studied and reported [34]. Virgin *C. nucifera* oil was very effective against some viruses like Visna virus, cytomegalovirus, and Epstein-Barr virus by the role of saturated fatty acids which help in breakage of virus cell membranes [35]. In South India, most of the rural people will brush their teeth with fibrous *C. nucifera* husks which were a common oral hygiene [36]. These studies summarize that the various extract constituents of *C. nucifera* can be utilized as anti-bacterial, anti-viral, and anti-fungal agents against different organisms. This can be facilitated up to the formulation of product level by young researchers to act upon the exact dose range against microorganisms [37].

Usually, coconut water is consumed directly but in recent years, people are preserving it for later usage. However, due to this, there is a possibility of pathogenic bacterial infection [38]. Luria-Bertani was used for this study. Two gram-negative strains such as *E. coli* and *Klebsiella pneumoniae* were used to screen anti-microbial studies. The results suggested that fresh coconut water is always safer until new technologies are invented.

Anti-Biofilm Activity

The coconut husk extract was screened for anti-biofilm activity using various methodologies [39]. The marine biofilm established on acrylic sections have been used to develop various microbes such as *Alteromonas* sp., *Gallionella* sp., and *Pseudomonas* sp. (Fig. 4). The physiological and morphological characters were used to identify the bacterial strain at the genus level. The disk diffusion method was adopted to screen the anti-microbial activity. Zobell Marine Agar 2216 was used for this study. The result showed promising activity. Further, the author has investigated the influence of the extract of husk on the extracellular

Fig. 4 Anti-biofilm assay of *C. nucifera*



polymeric substance of biofilm-forming bacteria. Zobell marine broth was used to maintain the biofilm-forming bacteria. By quantifying the protein and carbohydrate concentration, the extracellular polymeric substance was estimated. Author was interested to investigate the husk extract on the hydrophobicity and growth of biofilm forming bacteria. There was a significant variation observed in the absorbance between control and experimental medium such as *Alteromonas* sp., *Gallionella* sp., and *Pseudomonas* sp. The development of biofouling comprises an arrangement of actions with frequent interactions take place among fouling organisms.

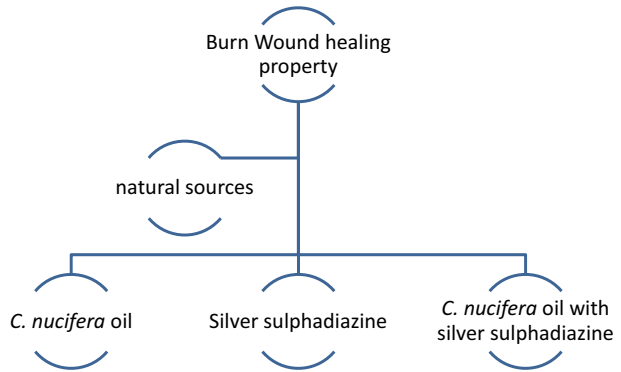
Anti-Inflammatory Activity

Authors have already stated that the traditionally available virgin *C. nucifera* oil plays a major role in various biological properties which resulted in moderate effects of anti-inflammatory on ethylphenyl propionate-, carrageenan-, and acid-induced edema in rats. However, it resulted in moderate analgesic effect on the acetic acid-induced response and in yeast-induced hypothermia by reducing animal models. Finally, the authors concluded that virgin *C. nucifera* oil can act as a good anti-inflammatory agent [40]. Different concentrations of *C. nucifera* husk fiber extract ranging from 10 to 100 mg/kg were prepared and evaluated for inflammation test with reference of morphine and acetylsalicylic acid. The results reported that inhibition of migrating cell by subcutaneous carrageenan injection can act as an anti-inflammatory agent [33]. On the other hand, hydrothermal extract of *C. nucifera* was subjected toward anti-inflammatory effect against various animal models and the results were compared with standard drug diclofenac and interpreted with significant activity of $p < 0.05$ when compared with the standard drug [41]. Raw *C. nucifera* water was tested for reduction of paw in early phase and later phase which resulted that *C. nucifera* water can be utilized as good anti-inflammatory agent [42]. Hence, *C. nucifera* water, hydrothermal extract, virgin *C. nucifera* oil, and husk fiber extract can act as a cheap anti-inflammatory agent by the role of various phytochemicals present in it.

Healing process

C. nucifera oil was used by the author to investigate its burn wound-healing property [43]. The author designed the work in such a way that comparison between *C. nucifera* oil, silver sulphadiazine and synergetic effect of *C. nucifera* oil with silver sulphadiazine. For this, wounds have been imposed on six rats. They have separated the rat into four groups. First group was taken as control, second to sulphadiazine-treated one, third was administrated by *C. nucifera* oil, and the fourth one injected by combination of oil and sulphadiazine (Fig. 5). Here, sulphadiazine was used as standard. Epithelialization time decreased significantly when the rats were treated with combination of *C. nucifera* oil and sulphadiazine. The author concluded that *C. nucifera* oil can be used as wound-healing agent. Coconut water has been considered as one of the most effective refreshing energy drinks. In one of the paper [44], the OVX rats were subjected to wound-healing assay. The sample used for this study was tender coconut juice. The results proved that cutaneous wound healing can

Fig. 5 Wound-healing assay of *C. nucifera*



be controlled by tender coconut juice. The reason for this response was the presence of estrogen-type substances. The report concluded that intake of tender coconut juice for minimum 2 weeks will cure the wound.

Anti-Oxidant Activity

The *C. nucifera* husk fiber of aqueous extract was subjected to free radical scavenging activity [33]. About 0.3 mM of 2,2-diphenyl-1-picryl-hydrazyl-hydrate solution was mixed with different concentration of *C. nucifera* extract and then incubated for 30 min under dark. After 30 min at room temperature, the absorbance was noted at 518 nm. The absorbance was converted to percentage inhibition value. The standard used for this studies were ascorbic acid, rutin, and quercetin. When comparing the EC_{50} value of *C. nucifera* extract with the standard, it shows remarkable action.

Anti-Diabetic Activity

Authors isolated coconut kernel protein from purified *C. nucifera* which was subjected for anti-diabetic activity in Sprague-Dawley rats. It resulted in the reduction of diabetes-related pancreatic damage by reducing glycogen level to normal in diabetic rats [45]. *C. nucifera* water can also act as anti-diabetic agent by increasing the insulin and liver glycogen levels and reduced glycated hemoglobin in diabetic rats. In addition, the significant reduction of liver functioning marker enzyme was studied and reported [46]. Injecting methanol extract of immature *C. nucifera* husk fiber inflorescence to diabetic rats resulted in significantly reducing fasting glucose levels and increasing insulin levels compared with a diabetic control drug [47].

Anti-Parasitic Activity

This comprises of anti-helminthic, ovicidal, and larvicidal activity of liquid and butanolic extract from the bark of the green *C. nucifera* and *C. nucifera* husk water. Author's inferred

that when compared to liquid extract, butanolic extract shows anti-helminthic activity against mouse nematodes with negative control group ($p > 0.05$). However, butanol extract of husk water shows significant results against mouse nematodes ($p < 0.05$). *C. nucifera* butanolic and aqueous extracts for ovicidal and larvicidal activity against *Haemonchus contortus* butanolic extract showed 100 % ovicidal activity. Their larvicidal effects were 81.30 and 99.80 % at 65 and 80 mg/mL, respectively [48].

Anti-Neoplastic Activity

The fiber extract of *C. nucifera* were tested [49] against human cell line erythroleukemia K562 and Lucena 1, a multidrug resistant. Both varieties of cytotoxicity cells were subjected to husk fiber extract which resulted in 50 % apoptosis of both the cells. This study has great potential for future researchers to focus their work on *C. nucifera*-mediated anti-neoplastic activity.

Leishmanicidal Activity

Authors collected polyphenolics-rich husk fiber extract and tested leishmanicidal activity against mice macrophages and promastigotes named *Leishmania amazonensis*. They resulted in MIC value of 10 $\mu\text{g/mL}$, and also, there was 182 % of nitric oxide production when compared with untreated macrophages [50]. From these above results, authors conclude that *C. nucifera* husk fiber can act as curative agent against leishmaniasis.

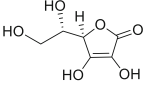
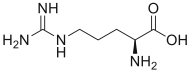
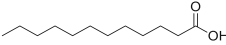
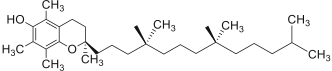
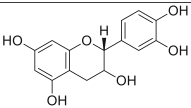
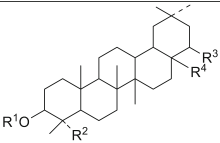
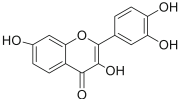
Insecticidal Activity

Authors collected the acetone extract of *C. nucifera* husk and tested for feeding stability against various insects like corn worm, fall army worm, and *Helicoverpa zea*. This showed decrease in growth rate and increase in % of mortality which implies that acetone extract can act as an insecticide for various pest [18, 51].

Anti-Malarial Activity

Authors collected five different Nigerian varieties of *C. nucifera* husk fiber and then processed the husk using ethyl acetate [52]. *Plasmodium berghei* strain was used for this study. They collected the strain from Obafemi Awolowo University, Nigeria. Successive extraction has been carried out using n-hexane, ethyl acetate, and methanol for 72 h per solvent. Phytochemical screening of ethyl acetate proved that the extract contains flavanoid, steroid, cardiac glycoside, phenol, tannin, alkaloid, etc. Hypoxanthine incorporation, histidine-rich protein 2 assays, and cytotoxicity test were carried out for the extracts. An anti-plasmodial activity was carried out for the ethylacetate fraction using *Plasmodium falciparum*. The IC_{50} value for the ethylacetate extract was 10.94 $\mu\text{g/mL}$, so it has been considered as an active one.

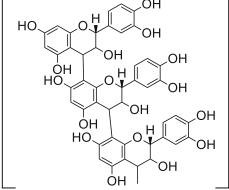
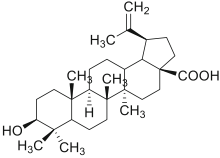
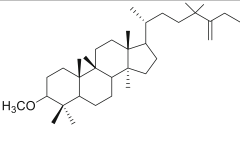
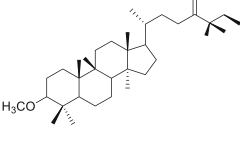
Table 1 Phytoconstituents present in various parts of *C. nucifera*

Coconut parts/Extract	Phytochemical compounds	Name of the compounds	Reference
Liquid albumen		Vitamin C	[19]
Liquid albumen Solid albumen		L-arginine	[64]
Coconut oil		Lauric acid	[19, 62]
Coconut oil		a-tocopherol	[61]
Coconut fiber		Catechin	[60]
Root		Saponin	[58-59]
Coconut fiber Root Inflorescence		Flavonoid	[47, 59-60]

Genetic Diversity

To access the diversity in coconut gene, different DNA-based markers have been used. The new start codon targeted polymorphism marker was applied for its estimation in coconut. Around 23 coconut accessions from different geographical location were analyzed in this study. Based on the amplification patterns, 15 primers were

Table 1 (continued)

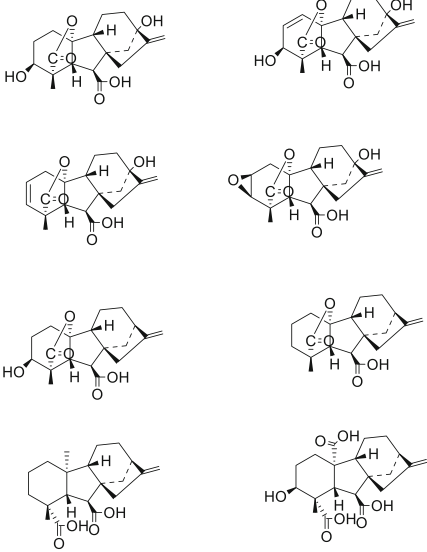
Coconut fiber Inflorescence		Tannins	[47, 60]
Leaves (epicuticular Wax)		Lupeol- methyl ether	[63]
Leaves (epicuticular Wax)		Isoskimmimol	[63]
		Skimmimol	

selected. Overall, 102 bands were produced during the studies. The results reveal that to detect DNA polymorphism, start codon targeted marker has been applied. In another report [53], RAPD marker has been utilized to find the genetic diversity among East African coconut.

Pyrolysis of Coconut Fibers for the Production of Bio-Oil

Pyrolysis of fiber has been considered as one of the important agricultural feedstock in Brazil. The amount of residue produced from the industry such as coconut and sugarcane are much more than others. Due to this reason, various residues have been subjected to pyrolysis. Pyrolysis is not only used to decrease the residue but can also be applicable to form bio-oil. The coconut residual fiber was subjected to fast pyrolysis to give bio-oil. Bio-oil obtained from the pyrolysis was subjected to GC × GC/TOF-MS and GC/qMS. The result reveals that bio-oil contains aldehyde, ketone, and phenol. Overall, 81 compounds were characterized in bio-oil [54].

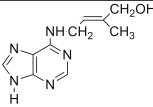
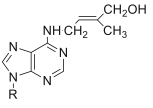
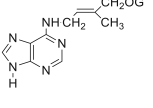
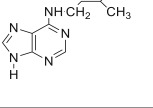
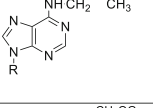
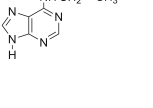
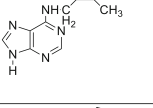
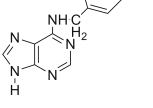
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Coconut water		Gibberellins	[55]
		GA ₁ , GA ₃ , GA ₅ , GA ₆ , GA ₇ , GA ₉ , GA ₁₂ , and GA ₁₃	

Biomolecules Responsible for the Biological Applications

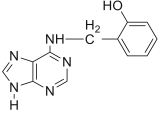
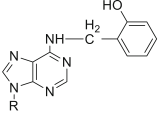
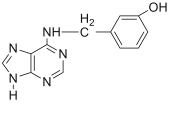
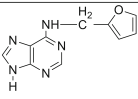
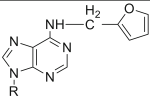
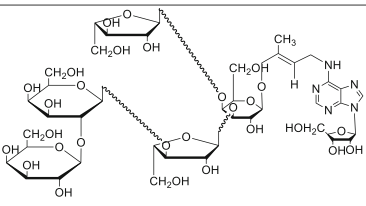
Various parts of the *C. nucifera* have been selected for the investigation purpose. Many researchers have proved the bioconstituent responsible for these properties shown in Table 1. Coconut water has more bioconstituents [55–57] such as gibberellins GA₁, GA₃, GA₅, GA₆, GA₇, GA₉, GA₁₂, and GA₁₃, trans-zeatin, trans-zeatin riboside, trans-zeatin O-glucoside, dihydrozeatin, dihydrozeatin riboside,

Table 1 (continued)

	trans-Zeatin	[56-57]
	trans-Zeatin riboside	
	trans-Zeatin O-glucoside	
	Dihydrozeatin	
	Dihydrozeatin riboside	
	Dihydrozeatin O-glucoside	
	Isopentenyl adenine	
	Benzylaminopurine	

benzylaminopurine, and ortho-topolin riboside. The coconut fiber was investigated [54, 58–60], and the result revealed that catechin, tannins, and flavanoids are responsible for the biological property. Saponin has been identified from the root of *C. nucifera* [59]. The α -tocopherol and lauric acid has been identified from the oil of *C. nucifera* [61–64]. So, these are all the bioconstituents essential in our day today life to safe guard our life.

Table 1 (continued)

		ortho- Topolin	
		ortho- Topolin riboside	
		meta- Topolin riboside	
		Kinetin (N ⁶ - furfurylami nopurine)	
		Kinetin riboside (N ⁶ - furfurylami nopurine riboside)	
Coconut Milk		Gazer	[59]

Conclusions and Future Prospects

C. nucifera is one of the widely spread plants in all over the globe. When compared to other plants extracts, *C. nucifera* extracts plays a major role in several biological applications which was still unrevealed. These extracts can help us to diagnose various diseases by cheap and simple methods. Still there is lack of work on *C. nucifera* and its biological studies. This minireview may facilitate the research community to focus toward *C. nucifera*-mediated biological applications in future.

This review may help most of the researchers focused toward collection of *C. nucifera* extracts and subjecting it for various biological applications. Various extracts of *C. nucifera* constituents can be utilized as diagnostic agent in several medicinal fields. At the same time, these extracts contain secondary metabolites with various functional groups. These functional groups can act as reducing agent in the field of nanoparticle synthesis. *C. nucifera* extracts can also be formulated as a product for various commercial applications.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

Ethical Clearance The current manuscript discuss on the phytoconstituents, biotechnological aspect and nutritive focus on coconut. The authors have not used any animals for their studies.

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