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Coconut (*Cocos nucifera* L.: Arecaceae): In health promotion and disease prevention

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ABSTRACT

Coconut, *Cocos nucifera* L., is a tree that is cultivated for its multiple utilities, mainly for its nutritional and medicinal values. The various products of coconut include tender coconut water, copra, coconut oil, raw kernel, coconut cake, coconut toddy, coconut shell and wood based products, coconut leaves, coir pith *etc*. Its all parts are used in someway or another in the daily life of the people in the traditional coconut growing areas. It is the unique source of various natural products for the development of medicines against various diseases and also for the development of industrial products. The parts of its fruit like coconut kernel and tender coconut water have numerous medicinal properties such as antibacterial, antifungal, antiviral, antiparasitic, antidermatophytic, antioxidant, hypoglycemic, hepatoprotective, immunostimulant. Coconut water and coconut kernel contain microminerals and nutrients, which are essential to human health, and hence coconut is used as food by the peoples in the globe, mainly in the tropical countries. The coconut palm is, therefore, eulogised as 'Kalpavriksha' (the all giving tree) in Indian classics, and thus the current review describes the facts and phenomena related to its use in health and disease prevention.

1. Introduction

The coconut [*Cocos nucifera (C. nucifera)* L.] is an important fruit tree (Figure 1) in the world, providing food for millions of people, especially in the tropical and subtropical regions and with its many uses it is often called the "tree of life"[1]. At any one time a coconut palm has 12 different crops of nuts on it, from opening flower to ripe nut. India is the third largest coconut producing country, after Indonesia and the Philippines, having an area of about 1.78 million hectares under the crop. Annual production is about 7 562 million nuts with an average of 5 295 nuts/hectare[2]. In India, the four south Indian states namely Kerala, Tamil Nadu, Karnataka and Andhra Pradesh account for around 90% of the coconut production in the country[2]; the overall state wise coconut production is depicted in Figure 2.

For thousands of years, coconut products have held a respected and valuable place in Indian folk medicine. It is believed to be antiblenorrhagic, antibronchitis, febrifugal, and antigingivitic. In Ayurvedic medicine, the oil, milk, cream and water of the coconut are all used to treat hair loss, burns and heart problems. In India, the use of coconut for food, and its applications in the Ayurvedic medicine were documented in Sanskrit 4 000 years ago. Records show that in the United States, coconut oil was one of the major sources of dietary fats, aside from dairy and animal fats, prior to the advent of the American edible oil (soybean and corn) industry in the mid 1940s[3]. Virgin coconut oil (VCO) is completely non-toxic to humans, and is referred to as the "drugstore in a bottle". In India, the coconut has religious connotations; it is described as "The fruit of aspiration" and a coconut is offered to the gods and cut at the start of many new projects. Coconut water is produced by a 5 month old nut that during World War II, was used in emergencies, and put directly into a patient's veins. From ancient times the coconut is used as a very effective remedy for intestinal worms of all kinds. Boiled toddy, known as jaggery, with lime makes a good cement. Nutmeat of immature coconuts is eaten or extracted cream is used on various foods.

2. Botanical description

Coconut *(C. nucifera)* belongs to the family of the

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Arecaceae (Palmae), the subfamily *Cocoideae*. There are mainly two distinct groups of coconut *i.e.* tall and the dwarf. The tall varieties grow slow and bear fruits 6 to 10 years after planting[2]. Its copra, oil and fiber are of good quality. This type is comparatively hardy, and lives up to a ripe age of 80 to 120 years. As male flowers mature earlier than the female flowers, this type is highly cross-pollinated. Nuts mature within a period of 12 months after pollination.

The dwarf varieties are fast growing and bear early *i.e.* takes 4 to 5 years[2]. Due to overlapping of male and female phases, the dwarf varieties are self-pollinated. The nuts are yellow, red, green and orange colored. These are less hardy and require favorable climatic conditions and soil type for better yield.

a b

Figure 1. Coconut (*Cocos nucifera*).
a: apical part of the tree with green coconut; b: fruit halves.

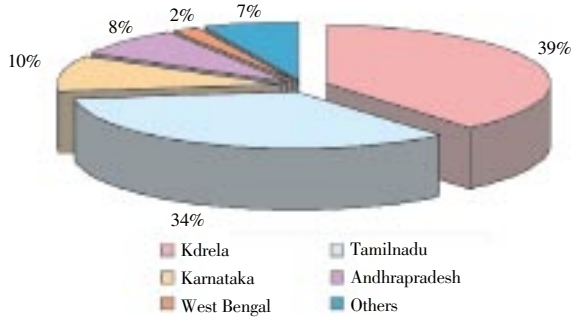

Figure 2. State wise coconut production in India.

3. Historical cultivation

Cultivation of coconut depends on soil type, slope of land, and rainfall distribution. It grows well on well drained loamy and clayey soil. A year-round warm and humid climate favors the growth of coconut. A mean annual temperature of 27 ℃, an evenly distributed rainfall of 1 500-2 500 mm per annum, and relative humidity above 60% provide the ideal climatic conditions for the vigorous growth and yield of the palm[1]. Under good climatic conditions, a fully productive palm produces 12-16 bunches of coconuts per year, each bunch with 8-10 nuts.

For the cultivation of coconut, usually 7-8 month old seedlings, raised from fully mature fruits are used for transplants. Nuts are planted in nursery after about 16 weeks. Usually 70-150 trees/ha are planted; with triangular spacing of 10 m, 115 palms/ha; and for group or bouquet planting, 3-6 palms planted 4-5 m apart[4]. It is desirable to transplant in rainy season. During first 3 years, seedlings are watered during drought, with an application of 16 L/tree of water, twice a week. Female flowers set in 12 months and fruits set to maturity in 8-10 months with a yield of 60-100 nuts/tree. A coconut tree under its lifetime can produce up to 10 000 nuts.

4. Nutritional values

Coconut has multifarious utility. The tender coconut water (TCW), the liquid endosperm, is an excellent natural soft drink. It has a caloric value of 17.4/100 g. Coconut water contains vitamin B, namely, nicotinic acid B3 (0.64 μg/mL), pantothenic acid B5 (0.52 μg/mL), biotin (0.02 μg/mL), riboflavin B2 (<0.01 μg/mL), folic acid (0.003 μg/mL), trace amount of thiamine B1 and pyridoxine B6[5]. Besides coconut water contain sugars, sugar alcohols, vitamin C, folic acid, free amino acids, phytohormones (auxin, 1, 3-diphenylurea, cytokinin), enzymes (acid phosphatase, catalase, dehydrogenase, diastase, peroxidase, RNA polymerases) and growth promoting factors[6].

Copra, the dried kernel, which is mainly used for oil extraction, contains about 65% to 75% oil[2]. The unopened spathe is tapped for toddy, which is converted into jaggery, vinegar and sugar. The kernel (wet meat) is mainly used in making curries, chutney, toffee, sweet and for other cooking purposes[2]. The composition of dessicated coconut has been documented by Bawalan and Chapman[7]; herein the important nutrition components are depicted in Figure 3. Whereas, the nutritional components of coconut milk extracted from freshly shredded meat are different as recorded by Bawalan and Chapman[7]; Figure 4 and 5 represent the composition of fresh coconut milk. Coconut oil is one of the most important edible oil for domestic use. The fatty acid composition and triacylglycerol combinations of VCO has been studied and recorded by Marina *et al*[8]. In the current review, the fatty acid and components are represented in Figure 6 and 7.

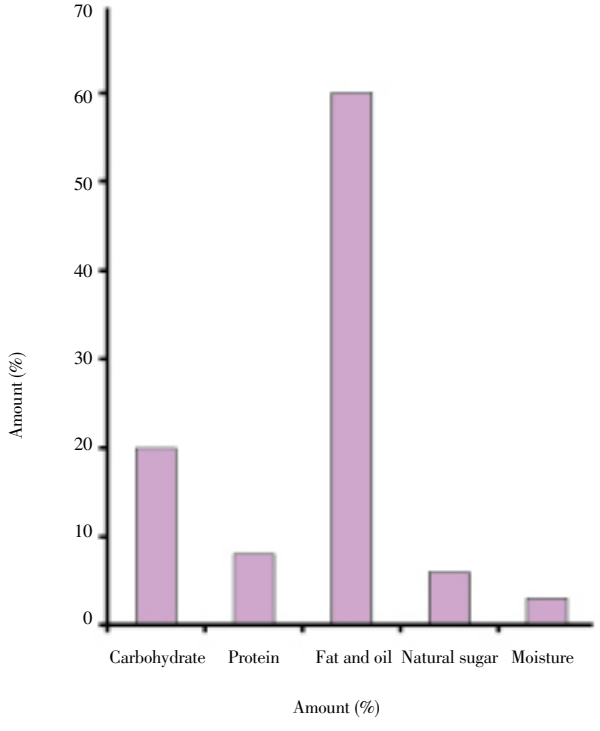

Figure 3. Composition of dessicated coconut.

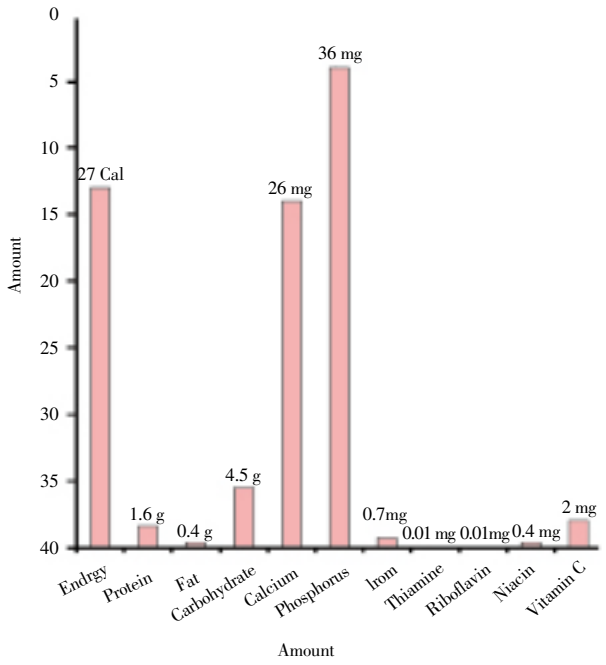

Figure 4. Nutritional composition of coconut milk (bar not up to scale).

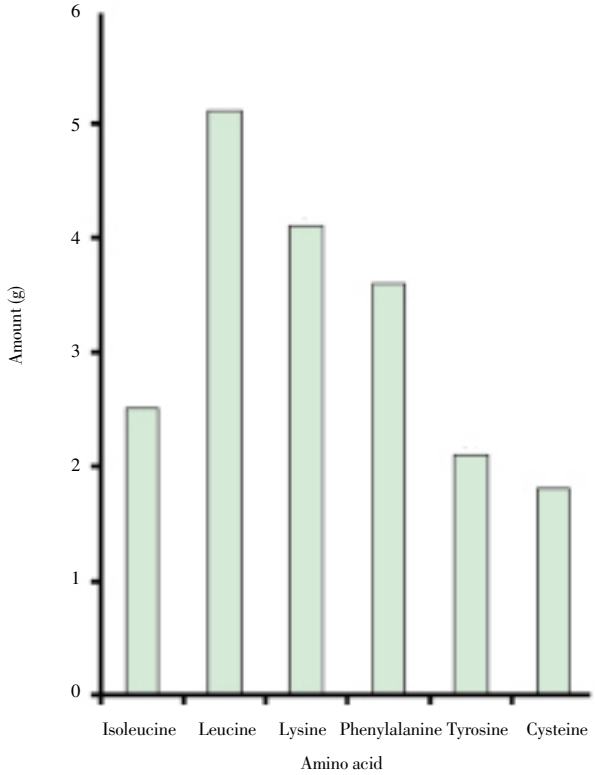

Figure 5. Amino acid content of coconut milk.

5. Medicinal values

5.1. As an electrolyte

It is highly rich in inorganic ions such as K (290 mg %), Na (42 mg %), Ca (44 mg %), Mg (10 mg %), P (9.2 mg %) *etc*.[9]. The concentration of these electrolytes in TCW generates an osmotic pressure similar to that observed in blood[9] and does not affect plasma coagulation. The high amount of K in TCW is reported to lower the blood pressure[10]. The ethanolic extract of *C. nucifera* endocarp was found to have a vasorelaxant and antihypertensive effect, through nitric oxide production in a concentration and endothelium-dependent manner, due to direct activation of nitric oxide/guanylate cyclase pathway, stimulation of muscarinic receptors and/or via cyclooxygenase pathway[11].

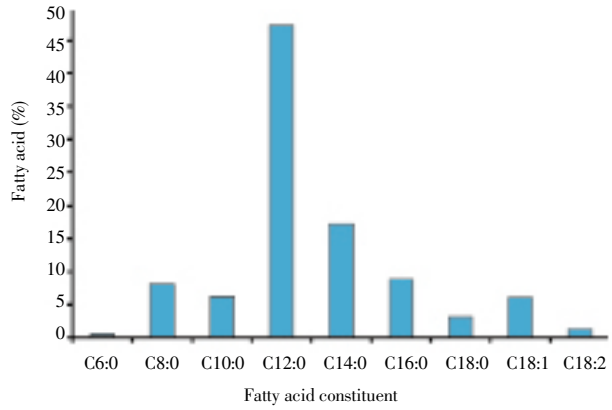

Figure 6. Fatty acid composition of virgin coconut oil.

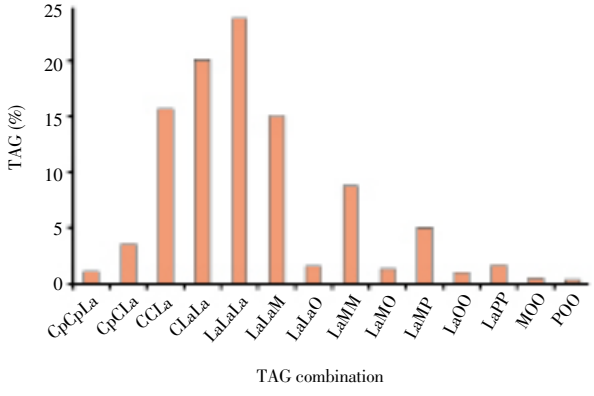

Figure 7. Triacylglycerol composition of virgin coconut oil.
TAG: triacylglycerol, Cp: caproic, C: capric, La: lauric, M: myristic, P: palmitic, O: oleic.

5.2. Antidote effect

TCW is found to eliminate poisons in case of mineral poisoning, and ameliorate drug induced over dosage toxicity[9]. The TCW aids the quick absorption of drug and makes their peak concentration in the blood easier by its electrolytic effect, which is similar to fructose coupled faster absorption into the cells and body[9].

5.3. Antioxidant effect

A free amino acid, L-arginine (30 mg/dL), is present in TCW which significantly reduce the free radical generation[10]. TCW also contain vitamin C (15 mg/100mL) that significantly reduce lipid peroxidation when introduced in rats[10]. VCO is capable of increasing antioxidant enzymes when supplemented with diets in rats[12].

5.4. Cardioprotective effect

Coconut is composed of the fatty acids caprylic acid C-8:0

(8%), capric acid C-10:0 (7%), lauric acid C-12:0 (49%), myristic acid C-14:0 (18%), palmitic acid C-16:0 (8%), stearic acid C-18:0 (2%), oleic acid C-18:1 (6%), linoleic acid C-18:2 (2%)[6]. It is abundantly (65%) endowed with medium chain saturated fatty acids (MCFAs), which allows them to be directly absorbed from the intestine and sent straight to the liver to be rapidly metabolized for energy production and thus MCFAs do not participate in the biosynthesis and transport of cholesterol[13]. Coconut water has cardioprotective effects in myocardial infarction due to rich content of mineral ions, especially potassium. Nevin and Rajamohan showed that VCO lowered total cholesterol, triglycerides, phospholoipids, low density lipoprotein (LDL), very-low-density lipoprotein (VLDL), and increased high density lipoprotein (HDL)-cholesterol levels[14]. The polyphenol fraction of virgin coconut oil was found to prevent *in vitro* LDL-oxidation.

5.5. Antithrombotic effect

VCO has significant antithrombotic effect over copra oil[15]. A coconut oil-based diet high saturated fatty acid (HSAFA)-diet lowers postprandial t-PA (tissue plasminogen activator) antigen concentration, and this may favorably affect the fibrinolytic system and the Lp(a) (lipoprotein-a) concentration compared with the high mono and polyunsaturated fatty acid (HUFA)-diet. The proportions of dietary saturated fatty acids more than the percentage of saturated fat energy seem to have a beneficial influence on Lp(a) levels[16].

5.6. Antiatherosclerotic effect

Chlamydia pneumoniae, is suspected of playing a role in atherosclerosis by provoking an inflammatory process that result in the oxidation of lipoproteins with induction of cytokines and production of proteolystic enzymes, a typical phenomena in atherosclerosis[13]. Some of the pathogenic gram-negative bacteria with an appropriate chelator have been reported to be inactivated or killed by lauric acid and monolaurin as well as capric acid and monocaprin[13].

Besides causing viral infection, the herpes simplex virus (HSV), cytomegalovirus (CMV) and Epstein-Barr virus (EBV) have a role in the in the pathogenesis of atherosclerotic plaques after angioplasty and the presence of viral DNA in the grafts used for bypass surgery constitute a potential risk for atherosclerosis or restenosis[17]. The components catechin, epicatechin along with condensed tannins (B-type procyanidins) were present in the water extract obtained from coconut husk fiber, that showed inhibitory activity against acyclovir-resistant herpes simplex virus type 1[18]. In fact, all members of the HSV family are reported to be killed by the fatty acids and monoglycerides (MG) from saturated fatty acids ranging from C-6 to C-14[20], which include approximately 80% of the fatty acids in coconut oil. Monolaurin is not formed in the body unless there is a source of lauric acid in the diet, and coconut is a rich source of monolaurin.

5.7. Hypolipidemic effect

VCO is capable of reducing lipid peroxidation content[15]. The hypolipidemic effect of coconut protein is due to the high content of L-arginine[19]. Besides the high polyphenol content in coconut is capable of maintaining the normal levels of lipid parameters in tissues and serum[14] aided by trapping of reactive oxygen species in aqueous components such as plasma and interstitial fluid of the arterial wall thereby inhibiting LDL oxidation, reversal of cholesterol transport and reducing intestinal absorption of cholesterol[20].

5.8. Anticholecystitic effect

It is urinary antiseptic and is effective in the treatment of kidney and urethral stones[21]. Monooctanoin (from caprylic acid) is a digestion product of medium chain triglycerides, is a cholesterol solvent that has been used for the dissolution of retained cholesterol gallstones following cholecystectomy. Complete gallstone dissolution has occurred in approximately 50%-75% of patients receiving monooctanoin; although mechanical stone removal is still considered to be the treatment of choice for retained gallstones, monooctanoin use appears promising for stone dissolution in patients in whom mechanical removal has been unsuccessful or is impossible[21].

5.9. Antibacterial activity

TCW has numerous medicinal properties, according to Effiong *et al*[9], including good drink for cholera patients because of its saline and albumen content; checking urinary infection, and diarrhea. The most abundant and potent MCFA in coconut is lauric acid, which comprises nearly 50% of coconut's fat content. The MCFAs and their derivatives *e.g.*, MGs found in coconut are effective in destroying a wide assortment of lipid-coated bacteria by disintegrating their lipid membrane. For instance, they can be effective against bacteria that can lead to stomach ulcers, sinusitis, dental cavities, food poisoning, and urinary tract infections.

Monoglycerides, especially Monolaurin, has been used to protect intravenously administrable oil-in-water emulsion compositions against growth of *Escherechia coli (E. coli)*, *Pseudomonas aeruginosa (P. aeruginosa)*, *Staphylococcus aureus (S. aureus)* and *Candida albicans (C. albicans)*. The compositions can be medicaments containing lipophilic drugs, especially Propofol, and/or total intravenous nutritional compositions[22].

Coconut oil, obtained from its nuts, in concentrations of 5% to 40% (w/w) exhibited bactericidal activity against *P. aeruginosa*, *E. coli*, *Proteus vulgaris*, and *Bacillus subtilis*, which was attributed to monolaurin that enhanced absorptivity due to the presence of surface active emulsifying agents used in formulating the cream made from coconut oil[23].

Emulsions of 1.25 mM monocaprin in citrate-lactate buffer at pH 4 to 5 caused a >6- to 7-$\log_{10}$ reduction in viable counts of *Salmonella* spp., *E. coli* in 10 min and *Clostridium jejuni* was also more susceptible to monocaprin emulsions at low pH[24]. Lauric acid, which is also present in mother's milk, helps to protect a delicate nursing baby from harmful pathogens[25]. Thus, like many other important medicinal plants having antibacterial property[26,27], *C. nucifera* is also excellent against different pathogenic bacteria causing

several life-threatening infection to humans[28].

5.10. Anticaries activity

Decoction obtained from coconut tree roots are used as mouthwash and gargle. *In vivo* assays demonstrated that *C. nucifera* extract had low toxicity and did not induce dermic or ocular reactions[29]. Thus, considering its low toxicity, husk fiber extracts of *C. nucifera* have potential in the treatment of oral diseases[30]. Coconut flour has antimicrobial properties due to its high lauric acid content that has been used as medicaments for some oral infections such as mouth sores[31]. The glycolipid compound, sucrose monolaurate, present in coconut has anti-caries effect due to reduced glycolysis and sucrose oxidation in a non-competitive manner caused by *Streptococcus mutans* and thus prevents *in-vitro* dental plaque. In a clinical trial association of coconut soap and 0.05% sodium hypochlorite was used as a disinfecting agent in the reduction of denture biofilm and stomatitis[32].

5.11. Antidermatophytic activity

The traditional use of coconut oil as a lotion in many parts of the world is well founded. Coconut oil was shown to have antiseptic effects and is used as an efficient, safe skin moisturizer[33]. Monolaurin has statistically significant *in vitro* broad-spectrum sensitivity against gram-positive and gram-negative bacterial isolates from superficial skin infections[34]. VCO and monolaurin have been suggested for proactive treatment of atopic dermatitis colonization due to their *in vitro* broad-spectrum activity against *S. aureus*[35]. Its selective antibacterial effects[20] make it useful for topical applications.

5.12. Antiviral effect

Coconut oil is very effective against a variety of viruses that are lipid-coated such as visna virus, CMV, Epstein-barr virus, influenza virus, leukemia virus, pneumono virus, hepatitis C virus. The MCFA in coconut oil primarily destroy these organisms by disrupting their membranes, interfering virus assembly and maturation[36]. The monoglycerides are active; diglycerides and triglycerides are inactive against these viruses. Of the saturated FAs, lauric acid has greater antiviral activity than either caprylic acid, capric acid, or myristic acid. Monolaurin acts by solubilizing the lipids and phospholipids in the envelope of the virus, causing the disintegration of the virus envelope[36]. The antiviral effects of the FAs and MGs are additive, and total concentration is critical for inactivating viruses[13].

5.13. Antifungal effect

The antimicrobial spectrum of monolaurin is broad including fungal species such as *Aspergillus* sp., *Penicillium* sp., *Cladosporium* sp., *Fusarium* sp., *Alternaria* sp., *C. albicans*, *Fonsecaea pedrosoi* and *Cryptococcus neoformans*[18]. Rihakova *et al* reported two different types of antifungal effects in *Aspergillus. niger (A. niger)*, one by inhibition of spore germination and another by inhibition of the radial growth, at monolaurin concentrations of 0.5 mg/mL and > 1 mg/mL, respectively[37]. They can also help combat yeast overgrowth, such as candida and thrush. VCO has been used in the treatment of *Candida* infections full stop after inections Ogbolu *et al*[38] compared the susceptibilities of the *Candida* isolates to VCO and fluconazole using the agar-well diffusion technique and found that *C. albicans* had 100% susceptibility to coconut oil at an minimum inhibition concentration (MIC) of 25% (1:4 dilution), while fluconazole had 100% susceptibility at an MIC of 64 μgm/mL (1:2 dilution). Capric acid caused the fastest and most effective killing of the *C. albicans* strains while lauric acid was the most active at lower concentrations and after a longer incubation time *C. krusei* showed the highest resistance to coconut oil with an MIC of 100% (undiluted), while fluconazole had an MIC of > 128 μg/mL.

5.14. Antiprotozoal activity

The polyphenolic-rich extract of *C. nucifera* at 10 μg/mL is a strikingly potent leishmanicidal substance which inhibited the growth of both promastigote and amastigote developmental stages of *Leishmania amazonensis* after 60 min, presenting no *in vivo* allergenic reactions or *in vitro* cytotoxic effects in mammalian system[18,39]. In traditional Mexican medicine, *C. nucifera* has been used to treat trichomoniasis[40].

5.15. Anticancer effect

The aqueous extract from *C. nucifera* husk fibers may be a source of new drugs with antineoplastic and anti-multidrug resistance activities[41]. It is of great interest for cancer therapy to identify new compounds that are able to overcome resistance mechanisms and lead to tumor cell death.

5.16. Immunostimulatory effect

The virgin coconut oil enriched with Zn increased Tc cells, Th cells, IL-2, but maintained the number of neutrophil and NK cells, while the IgG level changed from equivocal to negative in Candidiasis patient[42]. The coconut globulin, cocosin, is a legume class, 208 kDa reserve protein which belongs to the fourth group of proteins. Vigila and Baskaran showed an increasing levels of RBC, WBC, platelet, neutrophil, monocytes, eosinophil, B-lymphocytes, T-lymphocytes and Hb after feeding coconut protein to immunosuppressed animals, thus indicating strong immunomodulatory activity of coconut protein[43].

5.17. Antidiabetic effect

The coconut kernel protein has potent anti-diabetic activity through reversal of glycogen levels, activities of carbohydrate metabolizing enzymes and the pancreatic damage to the normal levels due to its effect on pancreatic β-cell regeneration by means of arginine[44].

5.18. Hepatoprotective activity

Hepatoprotective effect of TCW is evidenced from the histopathological studies of liver, which did not show any fatty infiltration or necrosis, as observed in CCl_4-intoxicated rats[10].

5.19. Disinfectant activity

Coconut soap has been used as disinfecting agents against *Strepto mutans* and *C. albicans* when associated with brushing complete dentures with coconut soap[32]. A disinfectant named lautericide has been prepared containing acetate amine of coconut acid as the active agent, which exerted a bactericidal and fungicidal action at 0.04% to 0.5% concentrations upon exposures for 2 to 10 minutes[45].

5.20. Insect repellant

The repellency of 10 % dodecanoic acid (DDA) against tick has been validated and patented[46]. The active ingredient, DDA, is a naturally occurring carboxylic acid that is the main acid in coconut oil. The coconut oil has been in use, as a vehicle, for the preparation of control agents against many disease vectors, and the oil also showed some degree of repellency against mosquitoes when used as control in many studies[47].

5.21. Eco-friendly biodiesel

The Philippines has discovered that coconut methyl ester (CME) or coco-biodiesel derived from coconut oil is better than conventional diesel fuel. The World Fuel Charter allows blends of up to 5% of biofuel however only 1% mix of coco-biodiesel is required which is enough to significantly reduce smoke emissions. The higher cetane number of CME (70) than diesel (56) implies that CME burns more completely, resulting in more mileage and lower emissions[48]. Also, CME is safer to handle and store than diesel because it requires a higher temperature to ignite it. Further CME being nearly sulphur-free, is much less polluting than diesel. In terms of lubricity also, CME has an edge over diesel.

5.22. Hormone like effect

Young coconut juice is believed to contain phytoestrogen and other sex hormone-like substances which can be used in hormone replacement therapy, in reducing the risk of dementia and in wound healing in postmenopausal women, as studied by Radenahmad in ovariectomized rats[49].

6. Conclusion

The coconut palm exerts a profound influence on the rural economy of the many states where it is grown extensively and it provides sustenance to more than 10 million people. The export earnings derived by India from coconut are around Rs 3 000 million. It is no wonder coconut culture is spreading even to non-traditional belts that were, until recently, considered unsuitable for the purpose.

India's thrust now shall be to exploit the wealth potential of the crop in all respects. Moreover coconut is an ecofriendly crop which permits coexistence of multi-species plants. It enriches soil fertility in association with other crops and is quite amenable to organic farming if appropriate intercrops are grown in the inter-spaces. Due to multifarious uses, the future of the crop is very bright irrespective of the locations where it is grown in the world.

The versatile coconut tree is a source of various chemical compounds, which are responsible of the various activities of the tree. Recently, modern medicinal research has confirmed many health benefits of the multiple coconut products in various forms. Hence extensive investigation is needed to exploit their therapeutic utility to combat diseases. A drug development program should be undertaken to develop modern drugs with the compounds isolated from coconut. Modern drugs require to be developed after extensive investigation of its bioactivity, mechanism of action, pharmacotherapeutics, after proper standardization and clinical trials. As the global scenario is now changing towards the use of non-toxic plant products having traditional medicinal use, development of modern drugs from *C. nucifera* should be emphasized for the control of various diseases. Coconut imbibing a tremendous potential deserves a special attention of the scientific fraternity to emerge as a milestone for medical science of this millennium due to its various medicinal uses. Further evaluation needs to be carried out on *C. nucifera* in order to explore the concealed areas and their practical clinical applications, which can be used for the welfare of the mankind.

Conflict of interest statement

We declare that we have no conflict of interest.

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