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Review Article

Palmyraculture: An Insight into the Nano Medicines from Palmyra Palm *(Borassus flabellifer L.)*

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Abstract

Asia and Africa have always been grateful for their rich heritage and beautiful nature, which have evolved and been preserved over time. Among these natural beings is the Asian palmyra palm (*Borassus flabellifer* L.), which has been around since the prehistoric era. People in the past used this palm as a writing material. According to Tamil literature, it has 801 different uses. Palmyraculture, or the plantation and use of palmyra for a sustainable and eco-friendly way to satisfy a self-sufficient living, has grown in importance in today's world of technology and research. It has emerged as a potential anti-microbial agent against various bacterial infection, particularly in the field of medicine. However, this perennial gift of nature has entered the world of nanotechnology, where it serves as a sustainable source to the green synthesis of many types of nanomaterials such as gold, silver, zinc-oxide, bimetallic NPs, and also nanocomposites, nanofilms, nano-fibrillated cellulose, and diverse its applications towards a challenging field known as "nanomedicine." Furthermore, in this review, we have described various types of nanoparticles biogenically synthesized from different parts of Palmyra such as fruit, sap, toddy, leaves, sprout root, and seed, as well as their medical and other applications, their opportunities and challenges.

Keywords: Palmyra; Palmyraculture; Nanotechnology; Green Synthesis; Nanomaterials; Nanomedicines

Introduction

Asian Palmyra palm, also known as *Borassus flabellifer* L., is a member of the *Arecaceae* family that ranges from Western Africa and Madagascar to Eastern Indonesia and Papua New Guinea [1]. This is also densely populated in the southern part of the Indian union, which includes states such as Andhra Pradesh, West Bengal, Kerala, Tamil Nadu, Orissa, Gujarat, Bihar, Maharashtra, Madhya Pradesh, Karnataka, and Uttar Pradesh [3]. It is both an official tree of Tamil Nadu and Cambodia's national tree. Palmyra is also known as a species with multiple uses; Tamil literature describes it as a "celestial tree with 801 uses" [4]. The Palmyra-dependent self-sufficient lifestyle and eco-friendly community living that leads to sustainable progressive development in an area, on the other hand, it can be referred to as "Palmyraculture." Palmyra warriors are those who climb palmyra trees and extract palmyra milk (Toddy/Sap) from them. This massive fan-shaped tree is a dioecious plant that takes nearly 15-30 years to grow up to 30 meters in height and 1.5 meters at the base. Every part of this palm is valuable, which increases the number of workers employed in palmyra palm fields [5]. Some of its applications include the production of edibles such as honey, sugar, and jaggery, as well as the flavoring of spicy curries and the production of syrups. Rural people, on the other hand, mostly use their leaves, fiber, husks, beams, and "pannadai (In Tamil)" to make mats, baskets, brooms, ropes, fans, and 20 other item chores [6]. Because of its high tensile strength, it is used as the main constituent in the construction of bridges and buildings [7], and its flour is an important ingredient in pharmaceutical products [8]. In many cases, its fruit shell is also used to produce activated carbon, which is an efficient adsorbent [9]. For example, activated *Borassus flabellifer* male flower charcoal is an excellent adsorbent to remove Fe^{2+} from wastewater that is both inexpensive and environmentally friendly [10]. However, another one of the major life-saving applications of palmyra include medicinal uses. For example, studies done on palmyra tuber nutritional analysis shown that it has 8.54% protein,23.53% carbohydrate and 7.29% crude fibre [62]. Similarly, phytochemical screening done on palmyra fruits showed a high presence of alkaloids, tannins, flavonoids, glycosides, saponins and phenols [63]. In addition it is used for different ailments, for instance; its bark is used to make mouthwashes and dentifrice, palm sugar helps to reduce the inflammation and it reduces the obesity and diabetics, spadix of the palmyra reduces the heart burn and toddy is used to reduce the ulcers [64].

Nanotechnology is a rapidly growing and demanding field of research around the world [11], and it has been widely used over the last 20 years. However, because of its distinct physical, chemical, and biological properties, it is used as an anti-microbial in food technology, cosmetics [12], biotechnology, textiles, and as biosensors and nutrient carriers. Furthermore, it has evolved into a life-saving and all-purpose material with numerous applications in both the economy and society [13]. Bottom-up (sol-gel, spinning, chemical vapor deposition, pyrolysis, and biosynthesis), top-down (mechanical milling, laser ablation, thermal decomposition), physical, chemical [14], and biological synthesis are all methods for creating nanoparticles. It has a lot of application in the field of medicine especially as a nanomedicine therapeutics, it is used as a drug delivery vehicle, cancer therapy, treating rare hepatic diseases, Alzheimer's, toxic overdoses, and inflammatory bowel diseases. It is not only restricted to applications mentioned rather it goes beyond [65].

Nanomaterials can be synthesized using phytochemicals, microorganisms, fungi, and bacteria in the context of biological synthesis. This green approach, also known as "green nanotechnology," is environmentally friendly, inexpensive, and efficient when compared to other synthesis routes [16]. As a result, the review we've written focuses on the biosynthesis of nanomaterials from each part of palmyra palm, as well as its applications majorly in medicine and other fields.

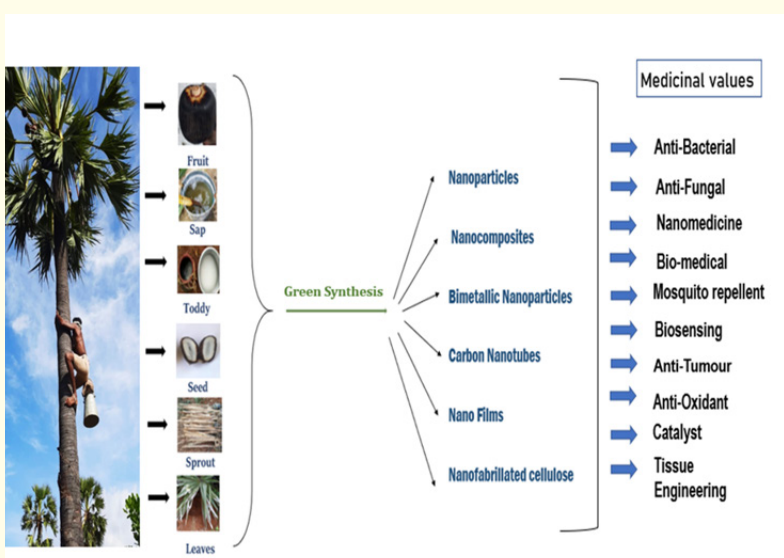

Figure 1: Palmyra palm parts used in green synthesis of nanoparticles and their medicinal properties (Model: Palmyra Warrior Sankar Ganesh, Place: Panaiyaanmai (Palmyraculture), The Centre for self-reliance and sustainable development, Kadayam, Tenkasi, Tamil Nadu).

Green Synthesis of nanomaterial using palmyra

Palmyra leaves

Since ancient times, when toddy tappers were cut with sharp sickles, they immediately crushed the palmyra leaves and applied the secretion of the leaves to the wound and the wound heals in a few days. There was no scientific evidence for it at the time, but after numerous studies on its phytochemical and pharmacological activity, it has proven to be a highly effective medicine against a variety of infections [37]. Furthermore, it is used as a non-edible source for thatching roofs, mats, fans, baskets, cooking fuel, and organic fertilizer for agriculture [38].

Zinc-oxide nanoparticles were biogenically synthesized using palmyra leaves, which contain a high concentration of biogenic compounds. Furthermore, this has not only proven effective as an antibacterial or antifungal agent but also as a material with a high capacity to degrade environmentally harmful dyes such as methylene blue and crystal violet [39]. Researchers have also used palm leaves and stalk to create Nano fibrillated cellulose. Its biocompatibility in human mesenchymal stem cells was evaluated, revealing that it is a potential matrix for stem cell differentiation and biomedical applications [40]. It is also used to green synthesize carbon nanodots (CD), a nanostructured material that has attracted a great deal of attention due to its physicochemical properties such as photobleaching resistance, high fluorescence, reliability, cost efficiency in production, good cell penetrability, and biostability. Nanodots have a wide range of applications in medicine, including biosensing, bioimaging, catalysts, and many others [41].

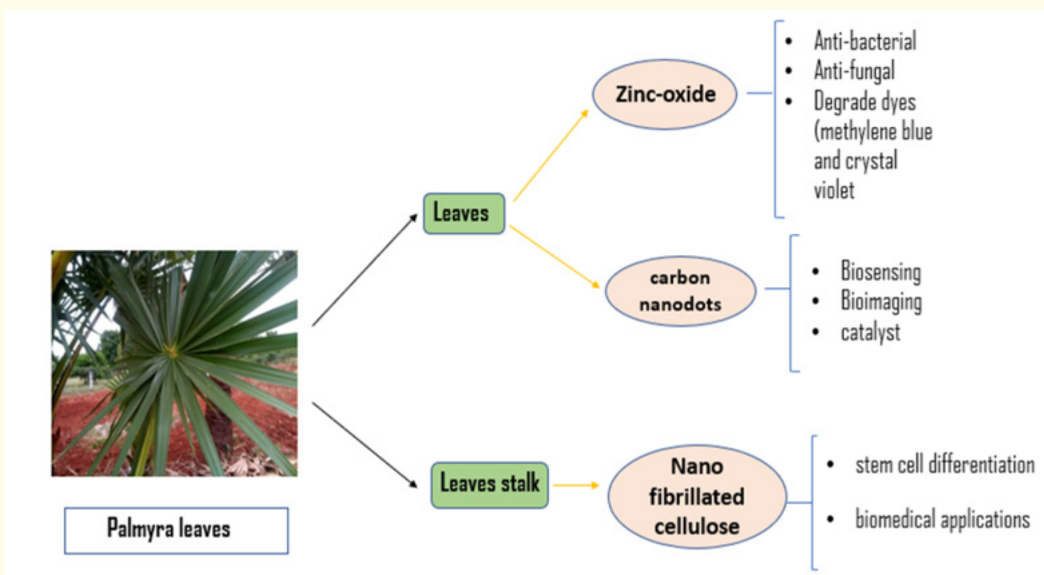

Figure 2: Green synthesis of nanomaterials using palmyra leaves and their applications.

Fruit of palmyra

Palmyra fruit is seasonal and has an orange or yellow mesocarp with a sweet, dense, and juicy pulp. It is a healthy fruit with vitamin A and C, tannins, sugars, and saponins [17], as well as iron, calcium, potassium, and zinc [18]. This is also used to make soft drinks, toffee, jams, and sweet treats [17].

A study demonstrated the process of green synthesis of copper and silver nanomaterials using palmyra fruit pulp, and it was evaluated for anti-tumor, antimicrobial, and antioxidant activity [20]. This, on the other hand, produced excellent results against prostate cancer cell lines and bacteria such as pseudomonas, Escherichia coli, Staphylococcus aureus, and Klebsiella pneumoniae. Further-

Figure 3: Palmyra fruit (Taken at Panaiyaanmai (Palmyraculture), The Centre for self-reliance and sustainable development, Kadayam, Tenkasi, Tamil Nadu).

more, copper-cobalt bimetallic nanoparticles were synthesized using palmyra tree fruit extract. This nanomaterial was extremely effective as a mosquito repellent against the *Culex* mosquito. This pesticide is safer, more common, and less hazardous to the environment [19].

Palmyra sap

Palmyra sap, also known as "pathaneer(In Tamil)," is an important ingredient in traditional medicine for diabetics, hyperglycemia, and hyperlipidemia. This can be consumed raw as sap or fermented to produce toddy [21]. Pathaneer, on the other hand, produces numerous byproducts such as brown sugar, wine [22], jaggery, treacle, candy, and so on [23], and also used to produce lactic acid by lactobacillus casei TISTR 1500 [24]. Palm water can be used to biologically synthesize silver nanoparticles (AgNPs) without the use of harsh chemicals, and it also improves the antibacterial activity of both gram-positive and gram-negative bacteria [25]. It is also an effective treatment for constipation and gastric ulcers. However, palmyra sugar, which is derived from sap, can also be used to create amorphous carbon in the form of nanofilms via the nano-spray method, which has good electrical and optical properties [26].

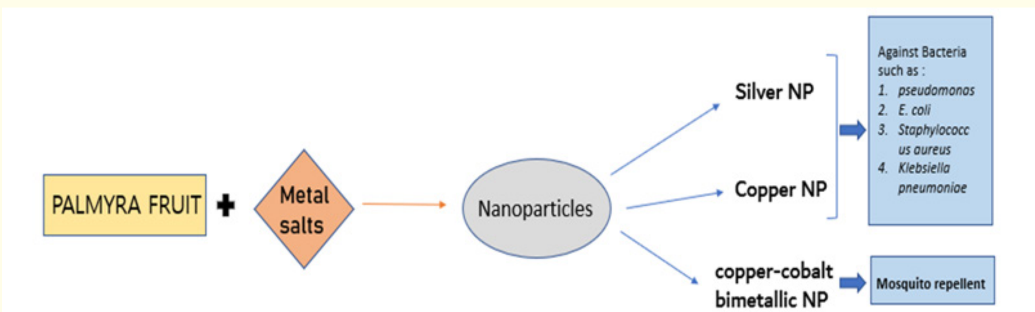

Figure 4: Synthesis of nanoparticles using Palmyra fruit and their applications.

Palmyra jaggery

Palmyra Jaggery is a proteinaceous, vitamin and mineral-rich sugar made by boiling palmyra sap [34] and is regarded as one of the best in the world. It has numerous anti-carcinogenic and anti-toxic properties. When compared to the rest of the world, India produces more than 70% of the jaggery. However, its business is losing money and requires immediate sustainability [35].

Silver nanoparticles can be synthesized using this jaggery by employing a green approach and the results show great anti-microbial efficacy against various bacterial samples such as *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*. However, when compared to the other three, it demonstrated high antibacterial activity against *Staphylococcus aureus* [36]. Unless combined with a nanomaterial, jaggery alone has no anti-bacterial efficacy. However, some of the properties of jaggery are determined by where it is grown and the climate in which it is grown, such as conductivity, corrosion activity, pH, and anti-microbial efficiency.

Palmyra toddy

Toddy is produced by various bacteria and fungi during the fermentation of palmyra sap. Sugar, primarily fructose, sucrose, and glucose, is the main component of fermented toddy. During the fermentation process, it is converted to ethyl alcohol [27]. Toddy is a probiotic drink with many nutraceutical benefits. It also contains 26 different primary amino acids [28] and is high in niacin, riboflavin, and thiamin. It also demonstrated remarkable antibacterial activity against microbes such as *Escherichia coli*, *Klebsiella pnemoniae*, and *Staphylococcus aureus* [29].

It is a major player in the biosynthesis of nanomaterials and also functions well as an antimicrobial. A recent study used palmyra toddy to synthesize bimetallic nanomaterials such as nickel and bismuth and tested it against five bacterial samples for an antimicrobial assay. This yielded very promising results and was found to be effective against all five bacteria [30]. According to research, Borassus toddy can be used to bio-synthesize indium tin oxide nanomaterials, which have a wide range of applications in medical, optical, structural, and electrical fields [31]. Furthermore, bimetallic nanoparticles such as Ag/Cu and Cu/Zn were synthesized using palmyra toddy, and when tested, it was found to be very effective as an anti-tumour (specifically against Nasopharyngeal cancer and Ehrlich ascites carcinoma) and anti-bacterial [33].

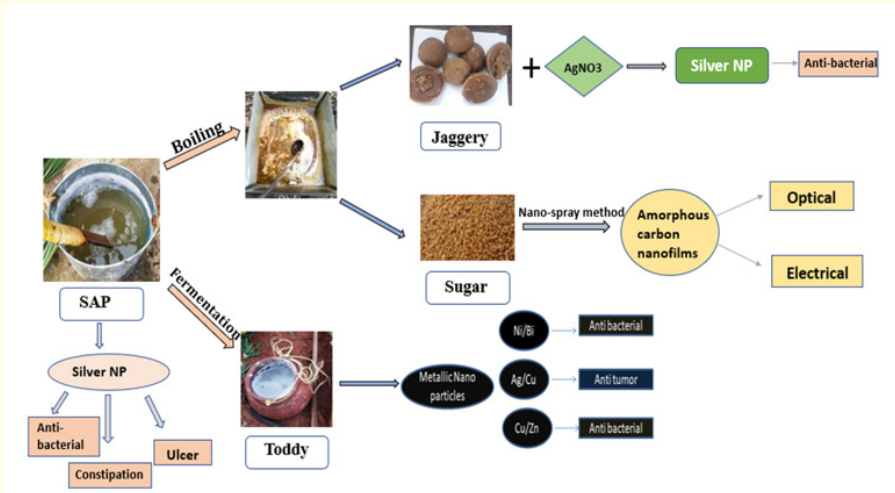

Figure 5: Green synthesis of Nanomaterials using palmyra sap/toddy and their applications.

Palmyra seed

Palmyra seeds have a high nutritional value and are a good source of carbohydrate, fiber, fat, amino acids, and protein [42]. Palm seeds also have potent antimicrobial and anti-inflammatory properties [43]. Even Palmyra's waste has not gone to waste; researchers have used its inedible seed coat to create nanomaterials such as iron oxide nanoparticles, which is an important nanomaterial with a wide range of applications in information technology, biomedical applications, bioremediation, and so on. Its antibacterial activity against bacteria such as *Escherichia coli, Bacillus subtilis, Staphylococcus aureus, Shigella,* and *Candida albicans* increased as its concentration increased [29].

Sprout of palmyra

Palmyra sprout, also known as a tuber, is an edible source of palmyra that can be boiled and consumed as a fibrous and nutrient-rich fruit composed primarily of lipid, protein, and carbohydrate [44]. This sprout root, on the other hand, is a great source for the synthesis of gold nanomaterials and an effective antibacterial that can be used in medicines to treat a variety of bacterial infections. Furthermore, additional research is being conducted to develop an antimicrobial food packaging system using palmyra-gold

Figure 6: Germinated Seeds of Palmyra (Place: Panaiyaanmai (Palmyraculture), The Centre for self-reliance and sustainable development, Kadayam, Tenkasi, Tamil Nadu).

nanoparticles to maintain food safety and reduce the spread of microbes [45]. Recently, silver nanoparticles were biosynthesized using palmyra sprout extract, and their phytochemical activity was investigated. The results revealed that the phytochemicals detected (phenols, glycosides, alkaloids, quinones, tannings, flavonoids, and coumarins) were important factors in the conversion of Ag+ to silver nanoparticles. Furthermore, it demonstrated adequate larvicidal potency against the *Culex* quinquefasciatus mosquito [46].

Carbon nanotubes are widely used in biomedicine [47], improving optical and thermal properties, renewable energy [48], environmental monitoring [49], aerospace applications [50], and so on. Borassus, on the other hand, has a larger role to play in the synthesis of carbon nanotubes, which provide real-time applications. Recent research indicates that the tuber peel, a waste product of the palmyra, was used to synthesize activated charcoal-loaded TiO_2 nanotubes, which improves the photocatalytic degradation of a water pollutant known as Rhodamine 6G dye [51,52].

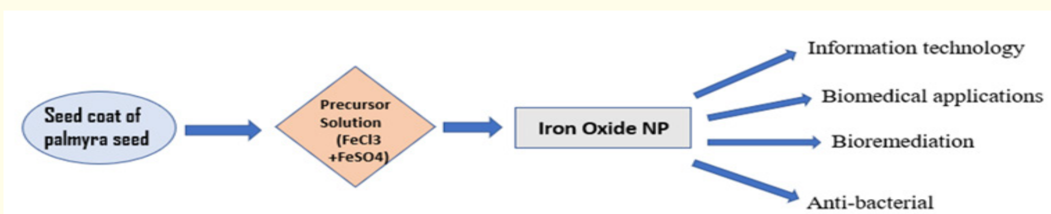

Figure 7: Green synthesis of Iron Oxide Nps using seed coat of palmyra and its applications.

Figure 8: Tuber of Palmyra (Place: Panaiyaanmai (Palmyraculture), The Centre for self-reliance and sustainable development, Kadayam, Tenkasi, Tamil Nadu).

Palmyra root is a nutrient-dense food that contains 8.54% protein, 25.53% carbohydrates, 7.29% crude fiber, and some fat. It also contains a lot of Vitamin E and has antioxidant properties. However, according to a study on its anti-microbial assay, indicated that, it has no activity against five bacteria (*B. subtilis, S. aureus, S. epidermidis, P. mirabilis,* and *E. coli*) [53]. Borassus root extracts are also important in nanotechnology, where they can be used to synthesize Ag-Co bimetallic nanoparticles cheaply and sustainably. Not only that but it has also been used as a potent larvicidal against various *Culex quinque fasciatus* mosquito populations [54].

Opportunities and challenges

Palmyra palm as a tree has numerous applications for each of its parts, providing us with numerous opportunities and potentially

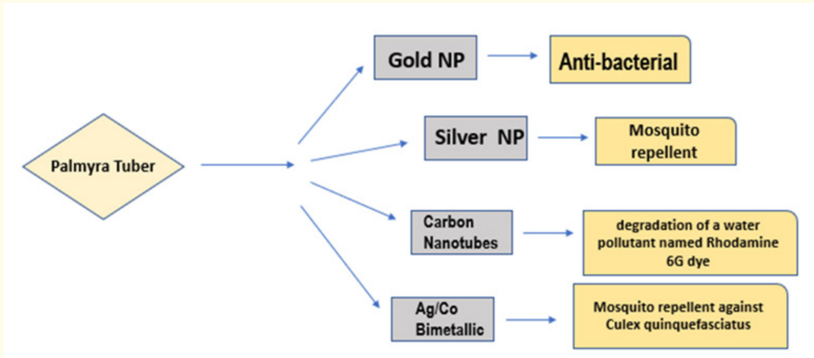

Figure 9: Green nanomaterial synthesis with palmyra tuber and its medicinal properties.

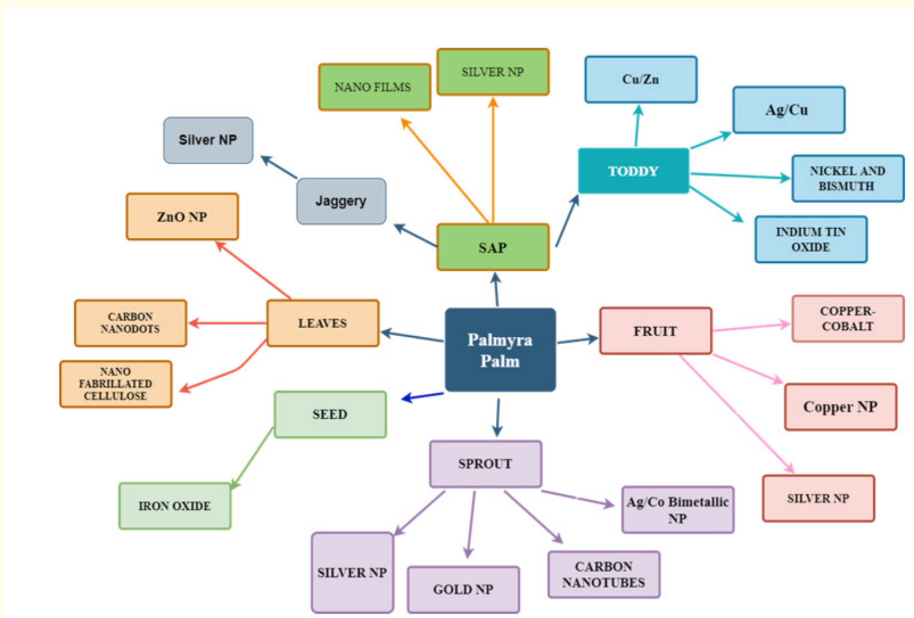

Figure 10: An overview of the various parts of palmyra used in the production of nanomaterials.

boosting the country's economy. This palm is valuable not only on the outside, but also on the inside, as it contains a lot of vitamin C, provitamin A, minerals, and fibers [18]. For centuries, its various parts, such as fruits, leaves, and seeds, have been used to treat medical ailments. Polyphenols, organo-sulfur compounds, carotenoids, alkaloids, flabelliferins, polysaccharides, and saponins are among the phytochemicals found in them [55]. It gives our bodies a lot of antioxidants, which act as defence mechanisms against reactive oxygen species (ROS) [56].

As a nanomedicine and pharmaceutical sector, nanotechnology has flourished in many ways. It has a wide range of applications in bio-sensing, tissue engineering, tumor detection, and the separation and modification of biological molecules and cells. These are all very advantageous, owing to their nano size and thus ease of manipulation [57]. COVID-19 and Nanotechnology research indicate that it has the potential to act as an anti-viral nanomedicine [58]. Even though it offers numerous opportunities, nanotechnology has several bottlenecks in a variety of ways. The first major issue is the toxicity of the nanomaterial. When it enters the human body, it has the potential to cause hepatotoxicity, nephrotoxicity, cardiotoxicity, and genotoxicity. Furthermore, gold nanoparticles can cyanidize and oxidize in the body, causing toxicity [59]. Because this area of nanotechnology has received the least attention, physiochemical studies have been neglected, and many other properties remain unexplored. Furthermore, in many studies on how it enters the body, what its mechanism is, and how it interacts with bacteria, the duration for degradation is largely ignored [60].

Toddy has been used in the environmentally friendly synthesis of numerous nanomaterials. Toddy, a natural probiotic vitamin drink, in particular, has numerous nutraceutical benefits. However, its toddy, which contains a high amount of nutraceutical values, is prohibited in Tamil Nadu, the southernmost state of the Indian union. As a result, Tamilnadu should reconsider its prohibition policy to provide people with a natural drink that they can sell for their daily wage [61]. According to a recent study, it can be used to make Covid-19 hand sanitizer [62]. As the saying goes, every cloud has a silver lining; these challenges may be difficult to overcome; however, if we can overcome, nanotechnology will have a significant impact on the future of the health sector, providing a potential solution to the untapped problems of curing various diseases such as cancer.

Conclusion

Since the prehistoric era, the Palmyra palm has been referred to as the most useful palm, having made significant contributions to Tamil, Asian, and African societies. Palmyra is a distinct tree with numerous applications in medicine, agriculture, information technology, biosensors, catalysts, and other fields. Furthermore, the field of nanotechnology has provided the greatest leap to the palmyra palm, by synthesizing nanomaterials such as silver, gold, Cu/Zn bimetallic, zinc oxide, carbon nanodots, nanocomposites, nanofilms, and nano fibrillated cellulose, and thus diversifying its applications towards one of the most important areas such as medicine. When nanotechnology is combined with the promising medicinal properties of palmyra tree, its efficacy increases with favorable outcomes. Along with many positive prospects, it also has many challenges that must be addressed through numerous studies and research. However, if properly tuned, Nanotechnology will undoubtedly be a boon to both humans and the economy for our future generations.

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