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Azadirachta indica in Focus: Investigating Neem's Diverse Applications

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ABSTRACT:

Azadirachta indica, also known as neem, is a diverse and multidimensional tree that is native to the Indian subcontinent and has long been prized for its many health advantages. The extraordinary qualities of the neem tree and its wide variety of products are examined in this abstract, which also highlights its important contributions to environmental sustainability, medicine, cosmetics, and agriculture.

The value of neem is found in all of its parts, including the leaves, seeds, bark, and oil, each of which has special traits and uses. Bioactive substances such nimbin, nimbidin, and azadirachtin, which have strong insecticidal, antibacterial, and antifungal effects, are abundant in neem leaves. Neem is becoming a crucial tool in integrated pest management and organic farming techniques as a result.

Introduction

A member of the mahogany family Meliaceae, neem trees are. It belongs to the genus Azadirachta, one of two species, and is a native of India and Burma. It grows in tropical and semitropical climates. It is a tree with rapid growth that can develop to a height of 15-20 m, and in rare cases, 35–40 m. Despite being evergreen, it may lose most or almost all of its leaves after a severe drought. The branches are dispersed widely. The beneficial qualities of neem (*Azadirachta indica A. Juss*) have been acknowledged in Indian tradition for thousands of years. The neem tree has medicinal qualities in all of its parts. The Rutales (Order), Rutinae (Suborder), Meliaceae (Family), Melioideae (Subfamily), Melieae (Tribe), Azadirachta (Genus), and indica (Species) are the taxonomical divisions of neem. (01)

Neem tree, native to the Indian subcontinent, offers a wealth of bioactive compounds, with over 300 identified. This review explores extraction techniques for these compounds from various parts of the neem tree and discusses their diverse applications in medicine, environment, veterinary, cosmetics, and more. Additionally, it highlights the development of antimicrobial films using neem oil and Polyvinyl Alcohol to enhance food shelf-life effectively. (02)

Azadirachta indica, or neem, has been revered in India for its versatile therapeutic and agricultural uses since ancient times. This article explores its applications in treating diseases and as a natural insecticide, pesticide, and agrochemical. It also discusses neem's chemical constituents, commercial products, and safety considerations. (03)

Five provenances of *Azadirachta indica A. Juss*. (Neem) in northern and western India were examined for seed shape and oil content. Trees from the Hisar origin were found to have the highest average oil content. The majority of the provenances did not consistently and substantially show a correlation between seed morphological characteristics and seed oil concentration. The output of oil was not significantly impacted by the age of the tree. (04)

Neem oil, derived from *Azadirachta indica* seeds, is a potent and eco-friendly solution against disease-carrying mosquitoes. Its active ingredient, azadirachtin, disrupts mosquito development. Neem-based products offer non-resistance development, making them promising yet underexplored mosquito control agents, contributing to public health and environmental safety. (05)

The effectiveness of a photovoltaic-thermal solar dryer for drying neem leaves was investigated under varied weather conditions. The best working conditions were supplied by the sunny weather since drying could be done efficiently without affecting quality. The dryer showed positive energy and thermal efficiency, which made it easier to treat neem leaves effectively and sustainably. (06)

Neem oil was derived from neem seeds in this study and described. Because of the oil's unique properties, a phytocoil insecticide that could deter mosquitoes for up to four hours was developed. Packaging and production methods should be improved for broader adoption. (07)

In six Indian states, the study investigates the advantages of neem-coated urea (NCU) in the production of important crops. Utilising NCUs helped

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to achieve agricultural and sustainability objectives by increasing crop yields, by-products, and net returns, lowering production costs, and stopping urea diversion. (08)

Neem is prized for its many therapeutic benefits in Ayurveda, Unani, and contemporary medicine. Neem's leaves, flowers, seeds, and other parts provide treatments for a variety of skin problems, infections, and other issues. The immunomodulatory, anti-inflammatory, and other pharmacological advantages of neem leaf are highlighted in this paper. (09)

Botanical Name	*Azadirachta indica*
Family	Meliaceae
Subfamily	Melioideae
Tribe	Melieae
Common Name	Neem

Neem as Bio fertilizer/Organic Fertilizer

Neem's several benefits, which range from pesticide to antifungal, provide environmentally friendly pest control for agriculture. Neem-based treatments offer affordable, sustainable options for increasing food production as chemical pesticides lose their effectiveness. (10)

Neem oil and organic biofertilizers (E.M.-4, Multibion TM, Supermagro) were tested for their fungitoxic effects on in vitro entomopathogenic fungi (Metarhizium anisopliae, Beauveria bassiana). While M. anisopliae was severely suppressed by Multibionä, Supermagro and E.M.-4 were less damaging. Neem oil severely affected B. bassiana, negatively influencing germination, colony size, and conidiogenesis. (11) The rising global demand for food production has led to increased agrochemical use, posing environmental and soil quality concerns. Transitioning to organic solutions like neem (*Azadirachta indica*), known as the "Tree of the 21st century," is vital. Neem's biopesticidal properties, particularly azadirachtin, disrupt pest activities, and it serves as an eco-friendly, cost-effective organic fertilizer, supporting sustainable agriculture. (12)

Azotobacter, PSB, neem cake, and zinc sulfate enhanced radish quality by increasing plant height, leaf count, improved root features, greater yield, and shorter harvesting times. An experimental design with randomised blocks was used. (13)

On Mung beans, the combined application of foliar NPK, Neem-coated urea, and bio-fertilizers was investigated (12:32:16). NPK Foliar Application (12:32:16) + Rhizobium and NPK Application (12:32:16) + VAM both outperformed the other eight treatments in a number of different ways, demonstrating their efficacy. (14)

In a bid to tackle India's large pulse imports despite substantial production, a study explored the use of neem cake (NEC) and farmyard manure (FYM) alongside biofertilizers *Rhizobium leguminosarum* bv. phaseoli (RHL) and *Pseudomonas fluorescence* (PSF). The results indicated significant potential for improving soil fertility and pulse yield in organic agriculture through this integrated approach. (15)

Increases in soil organic carbon, changes in soil pH and electrical conductivity, and improved grain yield were all caused by neem cake and biofertilizers. They also had an impact on the soil's capacity to hold nitrogen, phosphate, and potassium. (16)

On the growth of neem seedlings, the effects of irrigation water salinity and bovine biofertilizer were investigated. Bovine biofertilizer treatment and soil drainage assisted in reducing but did not completely eradicate the impacts of salt. (17)

Indian neem seedlings' height, root length, stem diameter, and leaf development were all hampered by saline water. These effects of the salinity of the water were partially offset by bovine biofertilizer. (18)

Neem cake, nitrogen dosages, and biofertilizers (*A. chroococcum & A. brasilense*) were investigated for Trigoneila foenum-graecum, with results showing benefits for growth, yield, and quality, particularly with *A. brasilense*, as well as lower nitrogen costs and a reduction in disease in beds. (19)

Usage of organic additions to improve the growth and yield of wheat (HD 3086) on loamy sand soil. The best output was obtained when Azotobacter was combined with Mustard Oil Seed Cake (MOC), next Neem Oil Seed Cake (NOC), and finally FYM+NOC. Wheat growth and yield were enhanced by the addition of MOC and other oil seed cakes, with Azotobacter and MOC demonstrating the maximum nitrogen concentration in grain and straw. (20)

Nutrient levels in banana and neem were measured under varied conditions at various growth stages. T8 (50 percent RDF through inorganic fertilisers, organic manures with bio fertilisers) demonstrated improved nutrient content by mixing inorganic, organic, and biofertilizers. (21)

Neem-infused cyanobacterial biofertilizers increase rice yields while saving 25 kg N per hectare. Biofertilizer made from tobacco performs well. Positive nutritional balance vs a negative K balance. Shelf-life advice: 50:50 ratio, dry mixing, translucent packaging. Flakes of cyanobacteria for manufacture without carriers. (22)

The combination of organic and biofertilizers on guava were investigated. Fruit weight was increased with vermicompost and neem cake. The use of biofertilizers in farmyard manure greatly boosted yield. The best method for organic guava farming has been found. (23)

Biofertilizer combinations were tested on Rangpur lime seedlings in a pot experiment. PSB (Phosphate Solubilizing Bacteria) -3g + Gm (Glomus mosseae) 50g + Gf (Glomus fasciculatum) 50g plus the best growth, in terms of height, stem diameter, and survival rate, was produced by neem cake. (24)

The influence of coffee berry borer infestation, feeding preferences, ovipositional preferences, and

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developmental time were evaluated in relation to induced resistance developed in coffee plants through organic sources of nutrition. The length of the larval stage was greatly lengthened in the organically treated plots as a result of the neem tree, and it was greatest in FYM (Farm Yard Manure) + neem cake + azophos (18.76 + 3.14 days) as opposed to 13.41 + 2.25 in inorganic NPK. In contrast to the treatment with inorganic NPK (6.87), FYM + neem cake + azophos had the lowest growth index for berry borer (4.24). (25)

The soil quality is improved by vermicomposting empty fruit bunches with neem leaves, which can act as both a biofertilizer and a biopesticide. It is a viable agricultural resource because of its increased nutritional content, earthworm activity, and enzyme levels. (26)

Salinity levels, bovine biofertilizer, and soil drainage were studied for their effects on neem seedlings using a randomised block design with multiple treatments. Salinity hindered growth by up to 28%, although drainage and biofertilizers made things better. (27). By significantly enhancing the crop's height, stem diameter, root size and distribution (root surface area, root diameter, and root volume), root-shoot ratio, and soil physicochemical properties (CEC, N, p, K, Ca, and Mg), the application of neem leaf extract increased the crop's resistance to Fusarium wilt diseases. (28)

The greatest outcomes for several biochemical parameters in mung plant leaves and improved soil enzymatic activities were obtained when neem and bael leaf extracts were combined in a 1:2 ratio, demonstrating their potential as biofertilizers. (29)

An effective biocontrol technique is to vermicompost a mixture of neem leaves and empty fruit bunches from oil palms. Researchers discovered that 10% neem increased enzyme activity and microbial population, making it a viable biofertilizer and biopesticide. (30)

Neem derivatives, such as neem cakes and leaves, function as manure, biopesticides, fertiliser coatings, and soil conditioners in organic farming. These natural neem insecticides are inexpensive, biodegradable, and have low toxicity levels, making them an efficient agricultural alternative. (31)

Phytochemical of Neem

The dried neem leaves' aqueous extract was found to have a significant amount of saponins, a moderate amount of tannins and glycosides, and very little alkaloids, terpenes, flavonoids, sugars, pentoses, or carbohydrates. Anthraquinones, ketones, and monosaccharides were not present, indicating that the substance was pharmacologically active. (32)

Neem's potential for the creation of novel antimicrobial medicines for the treatment of infectious diseases is highlighted by phytochemical analysis and TLC separation of active components. This research shows promise for discovering novel phytochemicals that are more effective at fending off viruses. (33)

The phenol concentration was 1.03%, flavonoids 5.33%, and tannins 1.83% in the 50% ethanolic extract of Neem. Sitosterol, lupeol, rutin, ellagic acid, ferulic acid, and quercetin were all discovered using HPTLC. When compared to the ascorbic acid standard (IC50 = 42 g/ml), the extract had strong free radical scavenging properties (IC50 = 110.36 g/ml). Additionally, it showed considerable antibacterial activity that outperformed its impact on E. coli, especially against S. aureus. (34)

Azadirachta indica (neem) fresh, mature leaves were gathered, air dried, and aqueously extracted to screen for some active chemical components. The extract scored highly for saponins, moderately for tannins and glycosides, and poorly for alkaloids, terpenes, flavonoids, reducing sugars, pentoses, and entire carbs. Ketones, monosaccharides, and anthraquinones were not found in the extract. The extract was shown to possess pharmacologically active ingredients. (35)

The neem tree contains about 300 distinct phytochemicals, many of which have a wide range of uses. Neem leaf extracts in aqueous and alcoholic form are thought to have a variety of pharmacological effects, including anti-inflammatory, hypolipidemic, immune-stimulating, hepatoprotective, and hypoglycemic effects. (36)

When overexpressed, MCM7 (Minichromosome maintenance complex component 7), a crucial component in DNA replication initiation, is linked to cancer malignancy. In order to find possible natural compounds from neem (*Azadirachta indica*) for targeting MCM7, the work uses in silico drug design, molecular docking, ADME (Absorption, Distribution, Metabolism and Excretion) analysis, and MD (molecular dynamics) simulations. Top substances with promising binding affinities and favourable ADME and toxicity profiles, such as CAS ID: 105377-74-0, CID: 12308716, and CID: 10505484, are candidates for use as human anticancer drugs. (37)

Alkaloids, saponins, terpenoids, and flavonoids were detected in all portions of the neem plant according to qualitative study, however steroids, polyphenols, and tannins were only discovered in the leaves and stem-bark. Coumarins and glycosides weren't present. (38)

Neem Plant extracts showed antibacterial effects on the test organisms, however aqueous extracts had stronger antimicrobial effects than ethanolic extracts, it was discovered. As a result, at the highest dose of 50 mg/ml, the mean diameter zones of inhibition for aqueous extract ranged from 0.03 mm to 40.00 mm and for ethanolic extract from 0.50 mm to 21.00 mm. (39)

Aqueous and alcoholic neem extracts were tested for antibacterial activity, with methanolic seed extract showing the strongest effect. Phytochemical analysis identified flavonoids. Neem seed ethanolic extract exhibited promising neuroprotective effects, suggesting potential use in neurological disorders like Parkinson's. (40)

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The stem-bark of Neem showed higher overall phytochemical content than the leaf, which explains its traditional use as a germicidal chew stick. Alkaloids predominated, particularly in the leaf. Alkaloids were found in greater amounts in the leaf, stem-bark, and root, respectively (11.63%, 4.93%, and 3.79%), compared to flavonoids (2.19%, 2.72%, and 0.92%), saponins (0.70%, 1.12%, and 0.44%), tannins (0.33 mg/100, 0.50 mg/100, and 0.17 mg/100), and glycosides (0.23%, 0.27%, and 0.19%), among other phytochemicals (41).

Neem flower and seed oil included a number of chemicals that were discovered through phytochemical investigation to have substantial antioxidant potential. At a concentration of 200 g/ml, the antioxidant activity of flowers and Neem seed oil shows 57.77% and 68.30% free radical scavenging activity, respectively. For Neem flower extract, the lowest inhibitory concentration (IC50) was 80 g/ml and for Neem seed oil extract, it was 43 g/ml. Neem may have use in the food and pharmaceutical industries, according to research. (42 & 43)

Steroids, triterpenoids, reducing sugars, alkaloids, phenolic chemicals, flavonoids, and tannins were discovered in Neem by phytochemical study. The efficacy of *Azadiracta indica* leaf extract against *P. falcifarum* in vitro and *P. vivax* in vivo model may be attributed to the presence of pharmacologically active ingredients in the extract. (44)

The leaf of Neem contains 0.78% saponin, 0.68% steroid, and 0.12% phenol, whereas the stem bark contains 1.07% steroid, 0.28% saponin, and 0.11% phenol. Radal plot results indicate that whereas saponin is plentiful in the leaf, steroids are substantially concentrated in both, especially in the stem. The Neem plant's therapeutic potential for drug production is highlighted by the variety of active chemicals it contains. (45)

The existence of bioactive chemicals was discovered after crude Neem leaf extracts were subjected to in vitro phytochemical screening and antimicrobial testing against diverse infections. The bioactive elements of neem may be used in the creation of pharmaceutical products to improve healthcare. (46)

Antimicrobial Activity of Neem

Neem seed oils (*Azadirachta indica*) were examined for their phytochemical, antimicrobial, and antioxidant activities. The percentage yields of the extraction were 42.50%, 40.70%, 38.30%, and 28.50% for the n-hexane, ethyl acetate, methanol, and aqueous solvents, respectively. On Escherichia coli, Staphylococcus aureus, Aspergillus niger, and Candida albicans, the minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), and minimum fungicidal concentration of the neem seed extract were measured. The amount of neem seed extract that was combined had the maximum scavenging activity, 54.19 0.03% (47). Neem leaf extracts and Neem Ag-NPs exhibit significant antioxidant and antibacterial activity, offering promising bioactive potential. (48)

Extracts and fractions of *Azadirachta indica* stem bark are revealed, revealing a rich phytochemical profile. While the ethyl acetate fraction had potent antibacterial activity, the ethanol extract displayed outstanding antioxidant qualities. Exciting possibilities for the development of functional and therapeutic foods. (49)

Azadirachta indica leaf extract is used in the environmentally friendly production of copper nanoparticles. Copper oxide nanoparticles with a greenish hue are produced quickly. Their potential for use in medicine and their robust antibacterial capabilities were identified through several approaches used to characterise them. (50)

Neem gum acts as a secure stabilising agent, producing cost- and environmentally-conscious nanoparticles. The resultant nanoparticles, TiO_2, ZrO_2, and $TiZrO_2$, have strong antibacterial and antifungal properties, with TiO_2 having the strongest antibacterial effects. applications in biomedicine have exciting potential. (51)

Numerous infections, including drug-resistant ones, can be treated with neem, but this untapped potential highlights the need for more research into the plant's processes, clinical efficacy, and safety. The various qualities of neem may stimulate the global discovery of new antimicrobials in other herbal treatments. (52)

Neem (*Azadirachta indica*) extracts have been studied for their antibacterial activity, and studies have shown that they are efficient against Candida albicans and Staphylococcus aureus. Neem's numerous chemical constituents have the potential to be turned into synthetic medications that can treat bacterial and fungal illnesses. (53)

Neem plants generate biologically active substances, some of which are utilised in the creation of pharmaceuticals. A prospective source of helpful microorganisms with potential health advantages is the rhizosphere of Neem plants. (54)

Identification of different phytochemical elements in lemon grass, neem leaf, and a neem leaf + lemon grass combination. Significant antibacterial activity was produced by these ingredients, with the combination extract exhibiting the largest inhibition zone. (55)

Magnaporthe oryzae, a destructive rice blast disease, has been studied for its antifungal activity against neem tree, aloe vera, tobacco, and bitter leaf extracts. The outcomes demonstrated that neem tree extract was the most effective in efficiently inhibiting the pathogen's growth at higher extract concentrations. (56)

Neem extract exhibits strong antibacterial action, with the best results against Gram-positive pathogens, *Staphylococcus aureus,* and *Escherichia coli*. For several bacterial isolates, the investigation determines varying minimum inhibitory concentration values. (57)

The antibacterial activity of ethanolic extracts from the stems of *Tinospora cordifolia* and *Azadirachta indica*

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against bacteria causing subclinical mastitis in cattle is investigated. *Azadirachta indica* exhibits greater antibacterial action, indicating the possibility of using it in situations of subclinical mastitis. (58)

Escherichia coli, Klebsiella pneumoniae, and *Staphylococcus aureus* were among the clinical isolates against which the efficiency of neem leaf extract was investigated. When compared to *S. aureus*, which has a minimum inhibitory concentration of 100 mg/ml, *E. coli* has a minimum inhibitory concentration of 50 mg/ml. The Neem extract has a bacteriostatic impact on Gram-negative bacteria and a static effect on Gram-positive bacteria. (59)

The root, bark, leaf, flower, seed, and fruit of the neem tree all have biological properties. Neem trees also produce several active chemicals that have biological properties. The neem plant's many sections include biological substances with antibacterial, antiviral, and antifungal properties. Different chemicals have been extracted from different neem sections. (60)

Neem Products and its Applications

Neem and its compounds are used to treat seeds, apply fertiliser, improve nutrient utilisation, and increase grain yield in rice crops. Neem's sustainability is evident in rice-based cropping systems. (61)

Neem is considered a "biorational pesticide" for Integrated Pest Management (IPM) since it works well with chemical, botanical, and microbial pesticides. The manufacture of pesticides depends on neem oil, neem seed kernels, and neem cake, all of which are traded internationally. (62)

Because of the limitations of synthetic pesticides, neem-based treatments are becoming more popular for controlling cotton pests. They provide a solution that is affordable, eco-friendly, and adaptable with several different modes of operation. An excellent option for programmes that combine pest management. (63)

In the middle of the 20th century, synthetic insecticides gained momentum on once-important botanical pesticides. A rising interest in natural alternatives such as neem and product has been generated by worries about the environmental and health effects of synthetic pesticides. (64)

Neem trees can grow up to 30 metres tall, with branches that are only half that width. The up to 30 cm long, pinnately complex, glossy dark green leaves. Each leaf has 10–12 7 cm long by 2.5 cm wide serrated leaflets. It will flourish in regions that encounter intense heat of up to 48°C and will grow when there is little moisture. (65)

Azadirachtin, a tetranorterpenoid component of neem, works on mitotic cells and prevents microtubule polymerization. Numerous other neem ingredients, besides azadirachtin, have insecticidal effects. Nim80, Neemas are also neem compounds that have insecticidal properties. Additionally, a commercial substance called Parker oilTM is a powerful pesticide. When azadirachtin and NPV were combined, the weight loss of treated insects was greatest. (66)

Against mature and immature stages of the bean aphid (Aphis fabae Scop), azadirachtin was evaluated in two commercial formulations (Neem-Azal T/S and Neemix). The effectiveness of Neemix was clearly seen at all comparable parameters, and the toxicity of the tested compounds to nymphs increased in accordance with concentration and exposure time. As opposed to Neem-Azal T/S, which had no phytotoxicity at all, larger concentrations of Neemix than 2.0 l/100 ml water and exposure times longer than two days clearly showed phytotoxicity. (67)

Neem possesses benefits that are anti-malarial, anti-cancer, antioxidant, anti-diabetic, hepatoprotective, neuroprotective, and wound healing. In order to boost crop output, it is also applied to agriculture as insecticides and fertiliser. A source of nutrients like protein, minerals, fatty acids, and vitamins, the tree is also used as animal feed. (68)

Neem plant's anticancer qualities have mostly focused on its tumor-suppressing, immunomodulatory, tumor-preventive, protective, and apoptotic activities against different cancer types and their molecular pathways. (69)

Neem oil, which is made through the transesterification process, is a mono alkyl ester. Neem seeds have a 30–40% oil content. At a 3:1 molar ratio of methanol and neem oil, at temperature ranges between 55 and 61 °C, the most anticipated outcome, including a layer of glycerin and soap, has been investigated. It was clear that the calorific value, density, and kinematic viscosity of biodiesel fuel all fell within acceptable ranges. The ASTM 6751-02 suggested range for kinematic viscosity for biodiesel is 1.90 to 6.0 centistokes. (70)

Neem oil, castor oil, and coconut oil were used as the foundation for three different concentrations of liquid soap that also contained three different concentrations of lemongrass essential oil (0.2%, 0.4%, and 0.6%). Staphylococcus aureus can be prevented from growing by using liquid hand soap. (71)

The product made from pyrolyzing neem seeds was examined using GC-MS, and it was discovered that the primary components were Octadecanenitrile, Oleanitrile, 9-octadecenoic acid methyl ester, and Stearic acid methyl ester. The liquid product that is produced can be used as an important chemical feedstock. (72)

On Kufri Bahar, neem oil at 6.0% had the lowest average severity of terminal diseases (46.67%), followed by *Pseudomonas fluorescens* at 1.0% and Trichoderma viride at 2.0% at 64.67 and 66.67%, respectively. In comparison to the control (24.40 t/ha), the maximum tuber yields were 28.23 t/ha with neem oil at 6.0% and 28.10 t/ha with Trichoderma viride at 2.0%. (73)

Any kind of vegetable oil or animal fat can be converted to biodiesel through the process of methyl esterification.

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investigated the challenges involved in producing biodiesel from neem oil and the properties of the fuel, which is entirely made up of mono-alkyl esters created during the transesterification process. (74)

Neem oil is transesterified to create biodiesel. The fuel parameters of diesel and diesel-biodiesel blends, such as calorific value, viscosity, relative density, and carbon residue, were examined using the appropriate testing equipment. Blends of neem and ethanol biofuel with diesel are made in a variety of ratios. (75)

To improve the qualities of the bionanocomposite film, solution cast was used to incorporate nano zinc oxide at various concentrations (0.1, 0.3, and 0.5%) and neem essential oil. (76)

Neem oil and its constituents, such as azadirachtin, have long been used to preserve grains of food. Neem oil or its nanoemulsion has also been employed in active food packaging for fruits and vegetables made of chitosan, starch, or pectin. (77)

Oil cake (meal) comprising proteins and carbs is produced during the oil extraction process from *Azadirachta indica*. The antimicrobial and antioxidant capabilities of the proteins in neem oil cake have been converted into films, and the films show better antifungal action than antibacterial activity. (78)

Solution casting was used to create a polymer composite film including expanded polystyrene wastes, poly (ethylene-co-vinyl acetate), epoxidized neem oil, and cassava starch. This eco-friendly synthetic method provides a quick and affordable way to recycle used thermocol, adding partial biodegradability with the possibility to be used as packaging film and avoiding the use of harmful chemicals. (79)

Food's shelf life can be increased due to active packaging (AP), which gives the chance for interaction between the food and the environment outside. Neem essential oils are used in the active packaging to preserve the antibacterial, antioxidant, and microstructural qualities of the packaging. (80)

The biopolymer characteristics of neem leaf extract for food packaging have been investigated. Although weaker than conventional bioplastics, it effectively generates a green biopolymer with aseptic properties that holds promise for eco-friendly packaging materials. (81)

Neem oil (NO) had potent antibacterial activity, with inhibition zones of 18.83 to 30.00 mm and bacterial growth inhibition ranging from 30.81% to 99.70%. In trials on meat contamination, it is noteworthy that *C. maltaromaticum* shown longer susceptibility in comparison to neem cake extract. (82)

In greenhouse and outdoor environments, foliar treatments of fish emulsion and neem oil significantly decreased bacterial spoton tomato and bell pepper plants. They increased fruit productivity and show promise for programmes to control illness. (83)

Neem biodiesel and dimethyl carbonate have shown improved emission profiles at 80% load when used as alternative fuels in current engines, especially when combined with biodiesel blends and additives. It highlights the possibilities of biodiesel in modern automobiles with a variety of fuel additives. (84)

The effects of neem seed kernel aqueous suspension (NSKAS) and neem seed kernel hexane extract (NSKHE) on Nezara viridula nymphs were examined. The more potent NSKAS caused malformations and mortality. (85)

The components of neem, whether they are raw, enriched, or purified, including bioactive substances like azadirachtin, have an impact on the behaviour, development, survival, and reproduction of insect pests. Nearly all insect pests that damage stored goods are sensitive to neem compounds, however their susceptibility can vary. (86)

At various doses, neem seed oil successfully inhibited the growth of parasitoids and predators of green peach aphids. Its potential utility in integrated pest management, which protects beneficial insects, is suggested by field research.(87)

Spruce budworm larval populations were significantly decreased when black spruce trees were treated with neem seed extract that had various azadirachtin concentrations. Systemic injection demonstrated outstanding foliage protection while providing only moderate cone protection. (88)

Conclusion

Neem trees and the goods they produce represent the perfect synthesis of ancient knowledge and contemporary sustainability. The effects on human health and the environment of its uses in agriculture, medicine, cosmetics, and environmental preservation are extensive. Neem's potential is still being explored, and new uses are continually being discovered, highlighting its status as a natural wonder with limitless potential.

Numerous goods made from neem's leaves, seeds, bark, and oil offer vital solutions to some of society's most pressing problems. Its organic insecticidal, antibacterial, and antifungal qualities have transformed pest control in agriculture and promoted environmentally friendly farming methods. Neem has also made significant contributions to both conventional and modern medicine, addressing conditions relating to the skin, oral health, and even the need for contraception while minimising negative side effects.

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Table – 01- Some Commercial Product of Neem in Indian Market

Neem Product	**Application**
Himalaya Purifying Neem Face Wash	Face Wash
Neem Powder for Eating & Drinking Leaves	Diabetes/Skin Glow & Hair Nutrition, Skin Dehydration, Skin Whitening/Evens Skin Tone, Acne, Pimples/Hair Thicker & Stronger
Himalaya Wellness Neem Tablet	Skin Disease
Good Knight Naturals Neem Liquid Vapouriser Mosquito Repellent	to ward off mosquitoes
Neemveda Neem Turmeric	Tablets For Immunity
GNFC Neo Neem Shampoo	Shampoo for Hair
Himalaya Pure Skin Neem Facial Kit	Skin Facial Kit
Jiva Neem Ayurvedic Tablets	Natural Blood Purifier
B Natural Organic Cold Pressed	Neem Oil For Spray On Plants & Garden herbal pest repellent
Natural Health Products Neem Powder	for Eating & Drinking Leaves Diabetes/Skin Glow
Himalaya Herbals Purifying Neem Foaming Face Wash	Foaming Face Wash
Keya Seth Aromatherapy Neem Gel Moisturizer	Prevents Acne & Pimple, Rashes, Skin Allergies & Skin Eruption
ORGANIC INDIA Neem Ayurvedic Capsules	Blood Purifier, Anti Acne, Anti Bacterial & Fungal
Kapiva Neem Juice	Boost Immunity and Fight Infections
Jiva Neem Ayurvedic Tablets	Natural Blood Purifier, Skin Wellness, Controls Acne
Nimeasy Dishwash Liquid Gel	Kitchen Utensil Cleaner
Keya Seth Aromatherapy Skin Hydrating Neem Toner	Anti Acne & Pimple
NEEM Active Toothpaste	Toothpaste
Nimyle ITC's Eco friendly floor cleaner	Floor Cleaner
SBM NEEM & TURMERIC	Use to control gastritis, hyperacidity, Use to boosts immunity, Eliminates toxins
Earthbaby Handmade Neem & Aloevera bath soap	Bath Soap
Heilen Biopharm Neem (Azadirachta indica) Powder	For Skin Care & Hair Care
IFFCO URBAN GARDENS	Organic Fertilizer & Growth Promoter for Plants
TrustBasket Neem Cake Powder	Organic Fertilizer and Pest Repellent for Plants
Ugaoo Neem Cake Powder for Plants	Organic Fertilizer & Pest Repellent
Cocogarden Powder Neem Cake Natural Fertilizer	for better growth of plants and better yield of fruits and vegetables
Gardenify India Neem Khali Fertilizers Home Garden	Organic Fertilizer For Plants, Plant Food
SDF INDIA Neem Cake Powder	Organic Fertilizer and Pest Repellent for Plants

Table 2. The Numerous Neem Products for Insect Pest Control

S.N.	**Crops**	**Neem Products**	**Pests**
1.	Cabbage	Neem oil	*Plutella xylostella*
2.	Cauli- flower	Neem oil, neem seed neem extract, leaf extract	*Spodoptera litura*
3.	Egg Plant	Neem oil	*Leucinodes arbonalis*
4.	Potato	Neem oil	Colorado potato bee-tle
5.	Tomato	Neem oil	Tomato leaf miner
6.	Pumpkin	Neem seed kernel extract	Red pumpkin beetle
7.	Cucumber	Neem extract	*Tetranychus urticae*
8.	Ginger	Neem leaf	Rhizome rot
9.	Cowpea	Neem seed Extract	Cow pea Bruchid
10.	Pea	Neem seed kernelextract	Pea aphid
11.	Sorghum	Neem oil	Sorghum shoot fly

Reference

1. Maithani, A., Parcha, V., Pant, G., Dhulia, I., & Kumar, D. (2011). Azadirachta indica (neem) leaf: A review. *J Pharm Res*, *4*(6), 1824-1827.
2. Achutha, S., Nisha, S. K., Pushpa, S. B., & Andrews, S. (2023). Antimicrobial polyvinyl alcohol/neem oil flexible film for food packaging applications. *Materials Today: Proceedings*.
3. Brahmachari, G. (2004). Neem—an omnipotent plant: a retrospection. *Chembiochem*, *5*(4), 408-421.
4. Kaura, S. K., Gupta, S. K., & Chowdhury, J. B. (1998). Morphological and oil content variation in seeds of Azadirachta indica A. Juss.(Neem) from northern and western provenances of India. *Plant Foods for Human Nutrition*, *52*, 293-298
5. Chatterjee, S., Bag, S., Biswal, D., Paria, D. S., Bandyopadhyay, R., Sarkar, B., & Dangar, T. K. (2023). Neem-based products as potential eco-friendly mosquito control agents over conventional eco-toxic chemical pesticides-A review. *Acta Tropica*, 106858.
6. Gupta, A., Das, B., Biswas, A., & Mondol, J. D. (2023). Assessment of performance and quality parameters for drying neem leaves in photovoltaic-thermal solar dryer. *Thermal Science and Engineering Progress*, *43*, 101989.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2023) 13(3), 1500-1510 | ISSN:2251-6727

7. Saka, T., Khursheed, A., Abubakar, A. M., Pandit, G. K., Simon, P., & Hamoudou, M. (2023). Insecticide phytocoil production from neem based materials and characterization of neem oil extract. *International Journal of Basic and Applied Science*, *12*(1), 39-45.
8. Ramappa, K. B., Jadhav, V., & Manjunatha, A. V. (2022). A benchmark study on economic impact of Neem Coated Urea on Indian agriculture. *Scientific Reports*, *12*(1), 9082.
9. Subapriya, R., & Nagini, S. (2005). Medicinal properties of neem leaves: a review. *Current Medicinal Chemistry-Anti-Cancer Agents*, *5*(2), 149-156.
10. Acharya, P., Mir, S. A., & Nayak, B. (2017). Competence of biopesticide and neem in agriculture. *International Journal of Environment, Agriculture and Biotechnology*, *2*(6), 238987
11. Hirose, E., Neves, P. M., Zequi, J. A., Martins, L. H., Peralta, C. H., & Moino Jr, A. (2001). Effect of biofertilizers and neem oil on the entomopathogenic fungi Beauveria bassiana (Bals.) Vuill. and Metarhizium anisopliae (Metsch.) Sorok. *Brazilian Archives of Biology and Technology*, *44*, 419-423.
12. Devi, D., & Gogoi, R. (2023). Neem as a Potential Biopesticide and Biofertilizer-A Review. *Research Journal of Pharmacy and Technology*, *16*(4), 2029-2034.
13. Ahamad, S., Kumar, J., Silas, V. J., Lal, M., Kumar, Y., & Maurya, R. (2023). Effect of bio-fertilizer and micronutrient on growth and yield of radish (Raphanus sativus L.) var. Pusa Himani.
14. Sandilya, D. H., Gill, R., Sudha, E. J., Saini, H., & Khan, J. A. (2023). Impact of Biofertilizers, Neem coated urea and Foliar NPK (12: 32: 16) on growth and yield attributes of Mung bean.
15. Murugan, R., Swaminathan, C., Niemsdorff, P., & Karthikeyan, N. (2011). Effects of combined application of biofertilisers with neem cake on soil fertility, grain yield and protein content of black gram (Vigna mungo (L.) Hepper). *World journal of Agricultural sciences*, *7*(5), 583-590.
16. Hakeem, S. A., Thomas, T., & Shagufta, W. (2007). Effect of different levels of neem cake and biofertilizer on properties of soil, nutrient status and grain yield of black gram (Vigna mungo L.) type-9. *Plant Archives*, *7*(2), 847-849.
17. De Oliveira Mesquita, F., Oliveira Batista, R., Cavalcante, L. F., Bezerra Costa, F. G., de Luna Souto, A. G., da Costa Leite Coelho, D., ... & de Oliveira Filho, F. X. (2018). Behavior of neem seedlings ('Azadirachta indica') irrigated with saline water in the soil with biofertilizer and drainage. *Australian Journal of Crop Science*, *12*(12), 1950-1956.
18. Nunes, J. C., Cavalcante, L. F., Lima Neto, A. J. D., Rebequi, A. M., Diniz, B. L., & Gheyi, H. R. (2012). Behavior of neem seedlings under water salinity in a non-saline soil with biofertilizer application. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *16*, 1152-1158.
19. Tiyagi, S. A., Irshad, M., Zehra, K., & Rose, R. (2011). Effect of neem cake, biofertilizers and N-fertilizers on growth, yield attributes and soil fertility status in Trigoneila foenum-graecum in relation to disease management. *Journal of Medicinal and Aromatic Plant Sciences*, *33*(4), 439-446.
20. Verma, S. B., Singh, D., & Chauhan, R. M. (2018). Effect of neem (Azadirachta indica L.), mustard (Brassica juncea) de-oiled seed cake and bio-fertilizer on the growth and yield of wheat (Triticum aestivum L.). *Journal of Pharmacognosy and Phytochemistry*, *7*(5), 2416-2427.
21. Selvamani, P., & Manivannan, K. (2009). Effect of organic manures, inorganic fertilizers and biofertilizers on the nutrient concentration in leaves at different growth stages of banana cv Poovan. *Journal of Phytology*, *1*(6).
22. Devi, H. L., Mitra, S. K., & Poi, S. C. (2012, April). Effect of different organic and biofertilizer sources on guava (Psidium guajava L.)'Sardar'. In *III International Symposium on Guava and other Myrtaceae 959* (pp. 201-208).
23. Vijayakumari, B., & Janardhanan, K. (2004). Effects of biofertilisers on seed germination, and seedling growth and chemical constituents in neem (Azadirachta indica). *Journal of Tropical Forest Science*, *16*(4), 477-480.
24. Patil, S. R. (2016). Composite effect of various biofertilizers and neem cake on effectiveness and efficient growth of Citrus limonia (Rangpur lime) seedlings. *Recent Trends in PGPR Research for Sustainable Crop Productivity*, *84*, 2020-2023.
25. Irulandi, S., Ravikumar, A., Chinniah, C., Rajendran, R., & Kumar, P. V. (2010). Farm yard manure and neem cake on feeding preference, ovipositional preference and developmental period of coffee berry borer, Hypothenemus hampei. *Journal of Biopesticides*, *3*(3), 534.
26. Er, L. K., Aziz, N. A. A., Yin, K. H., Mustafa, M., Ismail, I. S., & Zainudin, N. A. I. M. (2012). Potential of neem leaf-empty fruit bunch-based vermicompost as biofertiliser-cum-biopesticide: Chemical properties, humic acid content and enzymes (protease and phosphatase) activity in vermicompost (Part I). *Scientific Research and Essays*, *7*(42), 3657-3664.
27. Mesquita, F. O., Cavalcante, L. F., Nunes, J. C., Souto, A. G. L., Medeiros, R. F., & Rodrigues, R. M. (2015). Formation of neem seedlings with application of bovine biofertilizer subjected to drainage and saline stress. *Bioscience Journal*, *31*(1), 47-54.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2023) 13(3), 1500-1510 | ISSN:2251-6727

28. Yi, U., Zaharah, S. S., Ismail, S. I., & Musa, M. H. (2021). Effect of Aqueous Neem Leaf Extracts in Controlling Fusarium Wilt, Soil Physicochemical Properties and Growth Performance of Banana (Musa spp.). *Sustainability*, *13*(22), 12335.
29. Singh, A. K., & Sahu, C. (2018). Efficacy of Neem (Azadirachta indica A. Juss) and Bael (Aegle marmelos (L.) Correa) Leaf Extracts as Biofertilizers in Cultivation of Mung Plant (Vigna radiata (L.) Wilczek). *Nature Environment & Pollution Technology*, *17*(2).
30. Er, L. K., Aziz, N. A. A., Mustafa, M., & Ismail, I. S. (2021). Biocontrol potential of neem leaf-based vermicompost as indicated by chitinase, protease and β-1, 3-glucanase activity. *Sains Malaysiana*, *50*(5), 1267-1275.
31. Gupta, A. K. (2022). Use of neem and neem based products in organic farming. *Indian Farming*, *72*(1).
32. Sarah, R., Tabassum, B., Idrees, N., & Hussain, M. K. (2019). Bio-active compounds isolated from neem tree and their applications. *Natural Bio-active Compounds: Volume 1: Production and Applications*, 509-528.
33. Susmitha, S., Vidyamol, K. K., Ranganayaki, P., & Vijayaragavan, R. (2013). Phytochemical extraction and antimicrobial properties of Azadirachta indica (Neem). *Global journal of pharmacology*, *7*(3), 316-320.
34. Pandey, G., Verma, K. K., & Singh, M. (2014). Evaluation of phytochemical, antibacterial and free radical scavenging properties of Azadirachta indica (neem) leaves. *Int J Pharm Pharm Sci*, *6*(2), 444-447.
35. Biu, A. A., Yusufu, S. D., & Rabo, J. S. (2009). Phytochemical screening of Azadirachta indica (neem) (Meliaceae) in Maiduguri, Nigeria . *Bioscience research communications*, *21*(6), 281-283.
36. Maji, S., & Modak, S. (2021). Neem: Treasure of natural phytochemicals. *Chem Sci Rev Lett*, *10*, 396-401.
37. Ahammad, F., Alam, R., Mahmud, R., Akhter, S., Talukder, E. K., Tonmoy, A. M., ... & Qadri, I. (2021). Pharmacoinformatics and molecular dynamics simulation-based phytochemical screening of neem plant (Azadirachta indica) against human cancer by targeting MCM7 protein. *Briefings in Bioinformatics*, *22*(5), bbab098.
38. Khanal, S. (2021). Qualitative and quantitative phytochemical screening of Azadirachta indica Juss. Plant Parts. *International Journal of Applied Sciences and Biotechnology*, *9*(2), 122-127.
39. Itelima, J. U., Nwokedi, V. C., Ogbonna, A. I., & Nyam, M. A. (2016). Phytochemical screening and antimicrobial activity evaluation of aqueous and ethanolic extracts of the leaf of Azadirachta indica Juss (neem) on some microorganisms.
40. Sharma, Y., Dua, D., & Srivastva, S. N. (2014). Comparative study of different parts of Azadirachta indica (neem) plant on the basis of anti-bacterial activity, phytochemical screening and its effect on rat PC–12 (Pheochromocytoma) cell line. *International Journal of Biotechnology and allied fields*, *2*(7), 144-154.
41. Ani, P. N., & Okolie, S. O. (2018). Comparative analysis of the phytochemical compositions of leaf, stem-bark and root of Azadirachta indica (neem). 3(5), 46-50.
42. Sani, Y. A. A. I. A., & Baburo, A. J. S. (2020). Phytochemical analysis & antioxidant activity of flower & seed oil extract of Azadirachta indica (Neem). *Int. J. Sci. Res. Dev*, *7*(12), 1.
43. Deshpande, P. K., Gothalwal, R., & Pathak, A. K. (2014). Phytochemical analysis and evaluation of antimalarial activity of Azadirachta indica. *The Pharma Innovation*, *3*(9, Part A), 12.
44. Aguoru, C. U., Alase, N., & Olasan, J. O. (2015). Gravimetric and Spectroscopic Phytochemical Investigation of Neem Tree (Azadirachta indica L.) in North Central Nigeria. *Journal of Global Bioscience*, *4*, 2108-2113.
45. Benisheikh, A. A. G., Muhammad, F. M., Kelluri, H., Aliyu, Z. M., Mallam, U. B., & Jibrin, M. W. (2019). Phytochemical extraction and antimicrobial studies on crude leaf extract of Azadirachta indica (Neem) in semi-arid region of Borno State, Nigeria. *International Journal of Research and Review*, *6*(12), 516-522.
46. Awode, A. U., Ezera, J. E., Adoga, S. O., & Wapwera, J. A. (2023). Phytochemical Screening, Antioxidant and Antimicrobial Activities of Neem Seed (Azadirachta indica) Extracts. International *Journal of Research and Innovation in Applied Science*, 8(7), 41-48
47. Chime, A. O., & Aiwansoba, R. O. Antifungal Activity of Neem (Azadirachta indica) Leaf Extract against Pathogens Associated with Tomato (Solanum lycopersicum L.) Fruit Spoilage. *African Scientist*,24(2), 297-303
48. Ahmed, M., Marrez, D. A., Mohamed Abdelmoeen, N., Abdelmoneem Mahmoud, E., Ali, M. A. S., Decsi, K., & Tóth, Z. (2023). Studying the Antioxidant and the Antimicrobial Activities of Leaf Successive Extracts Compared to the Green-Chemically Synthesized Silver Nanoparticles and the Crude Aqueous Extract from Azadirachta indica. *Processes*, *11*(6), 1644.
49. Adaramola, F., Adewole, S., & Adewole, O. (2023). Assessment of Phytochemicals, Antioxidant and Antimicrobial Activities of Aqueous Ethanol Extract and Fractions of Azadirachta indica Stem Bark. *International Journal of Science for Global Sustainability*, *9*(1), 13-13.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2023) 13(3), 1500-1510 | ISSN:2251-6727

50. Gurudevi, M. D., & Sirisha, C. (2023) Green Synthesis of Copper Nanoparticles Using Neem Leaf Extract and their Antimicrobial Activity, Dogo Rangsang Research Journal, 13(2), 383-389
51. Korde, S. A., Thombre, P. B., Dipake, S. S., Sangshetti, J. N., Rajbhoj, A. S., & Gaikwad, S. T. (2023). Neem gum (Azadirachta indicia) facilitated green synthesis of TiO2 and ZrO2 nanoparticles as antimicrobial agents. *Inorganic Chemistry Communications*, *153*, 110777.
52. Wylie, M. R., & Merrell, D. S. (2022). The antimicrobial potential of the neem tree Azadirachta indica. *Frontiers in pharmacology*, *13*, 891535.
53. Na'ala, S. I., & Sufiyanu, S. (2022). Antimicrobial Activity of Neem (Azadirachta indica A. Juss.) Aqueous and Methanolic Extracts against Pathogenic Bacteria (Staphylococcus aureus) and Fungi (Candida albicans). *International Journal of Science for Global Sustainability*, *8*(1), 5-5.
54. Sarah, R., Idrees, N., & Tabassum, B. (2022). A Review of Endophytic Microbiota of Medicinal Plants and Their Antimicrobial Properties. *Core Microbiome: Improving Crop Quality and Productivity*, 1-9.
55. Mohammed, C. A., Stephens, H. M., & Sadiq, A. (2022). Phytochemical Analysis and Antimicrobial Activity of Neem Leaf, Lemon Grass and Mixture of Neem Leaf & Lemon Grass Essential Oil Extract (S) Against Some Selected Gram Positive and Gram Negative Organisms. *IRE Journals*, 6(2), 32-38
56. Falade, M. J., & Asowata-Ayodele, A. M. (2022). Multi-seasonal evaluation of selected aqueous plant extracts for antimicrobial activities against rice blast. *International Journal of Plant Pathology and Microbiology*, 2(2): 38-45
57. Mehta, A., Jain, A., & Saxena, G. (2022). In vitro antibacterial activity of ethanolic extract of Neem leaves (Azadirachta indica Linn) against clinical isolates. *Pharmaceutical and Biomedical Research*, *8*(4), 301-310.
58. Solanki, P., Choudhary, S., & Soni, R. (2022). Evaluation of antimicrobial properties of ethanolic extracts of stem of Azadirachta indica (Neem) and Tinospora cordifolia (Giloy) in subclinical mastitis affected cattle. *The Pharma Innovation Journal*, 587-591.
59. Muhammad, A., Lawan, I. M., Abubakar, A., & Dangora, I. I. (2019). Antimicrobial Activity of Azadirachta indica (Neem) Leave Extract Against Some Clinical Isolates. *Dutse J Peace Appl Sci*, *5*(1b), 97-104.
60. Herrera-Calderon, O., Ejaz, K., Wajid, M., Shehzad, M., Tinco-Jayo, J. A., Enciso-Roca, E., ... & Chumpitaz-Cerrate, V. (2019). Azadirachta indica: Antibacterial activity of neem against different strains of bacteria and their active constituents as preventive in various diseases. *Pharmacognosy Journal*, *11*(6s).
61. Lokanadhan, S., Muthukrishnan, P., & Jeyaraman, S. (2012). Neem products and their agricultural applications. *Journal of Biopesticides*, *5*, 72.
62. Roychoudhury, R. (2016). Neem products. In *Ecofriendly pest management for food security*. Academic Press. 545-562
63. Gahukar, R. T. (2000). Use of neem products/ pesticides in cotton pest management. *International journal of pest management*, *46*(2), 149-160.
64. Isman, M. B. (1999). Neem and related natural products. *Biopesticides: Use and delivery*, 139-153.
65. Roshan, A., & Verma, N. K. (2015). A brief study on neem (Azarrdirachta indica A.) and its application–A review. *Research Journal of Phytomedicine*, *1*(1), 01-03.
66. Ahmad, A. (2012). Potential applications of neem based products as biopesticides. *The health journal*, *3*(4), 116-120.
67. Ahmed, A. A. I., Gesraha, M. A., & Zebitz, C. P. W. (2007). Bioactivity of two neem products on Aphis fabae. *Journal of Applied Sciences Research*, *3*(5), 392-398.
68. Tibebu, A., Haile, G., & Kebede, A. (2017). Review on medicinal value and other application of neem tree: senior seminar on animal health. *ARC Journal of Immunology and Vaccines*, *2*(2), 16-24.
69. Paul, R., Prasad, M., & Sah, N. K. (2011). Anticancer biology of Azadirachta indica L (neem): a mini review. *Cancer biology & therapy*, *12*(6), 467-476.
70. Ali, M. H., Mashud, M., Rubel, M. R., & Ahmad, R. H. (2013). Biodiesel from Neem oil as an alternative fuel for Diesel engine. *Procedia Engineering*, *56*, 625-630.
71. Uzwatania, F., & Ningrum, R. S. (2020). Formulation of liquid hand soap made from neem seed oil and lemongrass essential oil. *Indonesian Journal of Applied Research (IJAR)*, *1*(3), 155-162.
72. Nayan, N. K., Kumar, S., & Singh, R. K. (2013). Production of the liquid fuel by thermal pyrolysis of neem seed. *Fuel*, *103*, 437-443.
73. Lal, M., Chaudhary, S., Rawal, S., Sharma, S., Kumar, M., & Chakrabarti, S. K. (2021). Evaluation of bio-agents and neem based products against late blight disease (Phytophthora infestans) of potato. *Indian Phytopathology*, *74*, 181-187.
74. Ahilan, T., Suresh, P., & Dhanesh Babu, S. D. (2024). Performance and Emissions Investigation of Biodiesel Made from Neem Oil. *Physical Chemistry Research*, *12*(1), 11-19.
75. Sati, P., Singh, S., Joshi, U. C., Kumar, R., & Singh, Y. (2023, May). Performance study of 4-stroke 4-cylinder diesel engine using non-edible oils. In *AIP Conference Proceedings* (Vol. 2521, No. 1). AIP Publishing.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2023) 13(3), 1500-1510 | ISSN:2251-6727

76. Sanuja, S., Agalya, A., & Umapathy, M. J. (2015). Synthesis and characterization of zinc oxide–neem oil–chitosan bionanocomposite for food packaging application. *International Journal of Biological Macromolecules*, *74*, 76-84.
77. Kumar, S., Singh, N., Devi, L. S., Kumar, S., Kamle, M., Kumar, P., & Mukherjee, A. (2022). Neem oil and its nanoemulsion in sustainable food preservation and packaging: Current status and future prospects. *Journal of Agriculture and Food Research*, *7*, 100254.
78. Aramwit, P., Shubashree, K. R., Nagananda, G. S., Reddy, R., Kavya, S., & Reddy, N. (2022). Bioproducts from proteins in neem seed oil meals. *Biofuels, Bioproducts and Biorefining*, *16*(6), 1761-1771.
79. Salini, N. G., Resmi, B. G., & Antony, R. (2021). Biodegradable composites of waste expanded polystyrene with modified neem oil for packaging applications. *Journal of Elastomers & Plastics*, *53*(8), 975-991.
80. Sharma, S., Barkauskaite, S., Jaiswal, A. K., & Jaiswal, S. (2021). Essential oils as additives in active food packaging. *Food Chemistry*, *343*, 128403.
81. Shellikeri, A., Kaulgud, V., Yaradoddi, J., Ganachari, S., Banapurmath, N., & Shettar, A. (2018, June). Development of neem based bioplastic for food packaging application. In *IOP Conference Series: Materials Science and Engineering* (Vol. 376, No. 1, p. 012052). IOP Publishing.
82. Del Serrone, P., Toniolo, C., & Nicoletti, M. (2015). Neem (Azadirachta indica A. Juss) oil: A natural preservative to control meat spoilage. *Foods*, *4*(1), 3-14.
83. Abbasi, P. A., Cuppels, D. A., & Lazarovits, G. (2003). Effect of foliar applications of neem oil and fish emulsion on bacterial spot and yield of tomatoes and peppers. *Canadian journal of plant pathology*, *25*(1), 41-48.
84. Nayak, S. K., & Mishra, P. C. (2017). Application of neem biodiesel and dimethyl carbonate as alternative fuels. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *39*(3), 284-290.
85. Singha, A., Thareja, V., & Singh, A. K. (2007). Application of neem seed kernel extracts result in mouthpart deformities and subsequent mortality in Nezara viridula (L.)(Hem: Pentatomidae). *Journal of Applied Entomology*, *131*(3), 197-201.
86. Saxena, R. C. (2009). Practical applications of neem against pests of stored products. In *Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, Orlando, Florida, USA* (pp. 110-114).
87. Lowery, D. T., & Isman, M. B. (1995). Toxicity of neem to natural enemies of aphids . *Phytoparasitica*, *23*, 297-306.
88. Wanner, K. W., Helson, B. V., & Kostyk, B. C. (1997). Foliar and systemic applications of neem seed extract for control of spruce budworm, Choristoneura fumiferana (Clem.)(Lepidoptera: Tortricidae), infesting black and white spruce seed orchards. *The Canadian Entomologist*, *129*(4), 645-655.
89. Modi, G., & Soni, R.K. (2023). Evaluation of the quality of ground water at Kolayat and Nokha, Bikaner: An In-Depth Analysis of Physicochemical. *China Petroleum Processing and Petrochemical Technology*, 23(2), 700-708.
90. Sharma, P., & Modi, G. (2018). In vitro assessment of Antibacterial activity of Calotropis gigantea. *International Journal of Current Research in Life Sciences*, 7(06), 2347-2350.
91. Sharma, P., Modi, G., & Singh, A. (2018). In vitro Antibacterial activities assessment of Calotropis procera leaf extract. *International Journal of Current Research in Life Sciences*, 7(05), 2117-2120.
92. Modi, G., Gupta, G., & Babita (2023). A Review on Ethnomedicinal Plants and their traditional Uses in India. *European Chemical Bulletin* 12(8):8442-8452. doi: 10.48047/ecb/2023.12.Si8.768