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A REVIEW ON NONI: INSIGHTS INTO BOTANY, ETHNOPHARMACOLOGY, PHYTOCHEMISTRY, AND COMMERCIAL PROSPECTS

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ABSTRACT: *Morinda citrifolia*, known as Indian mulberry, Nuna, or ach in India and "*Morinda citrifolia* (Noni)" in Hawaii and Polynesia, a medicinal plant with a long story of traditional use. It possesses numerous biological activities, including antibacterial, antiviral, antifungal, anticancer, anthelminthic, analgesic, hypotensive, anti-inflammatory, and immune-boosting effects due to its diverse phytochemicals. Its increasing popularity has led to its incorporation into various products across industries, serving as a natural source for chemical reagents, eco-friendly pesticides, and medications. Different parts of *Morinda citrifolia*, such as the fruit, seeds, bark, leaves, and flowers, are utilized for their unique nutritional and therapeutic benefits, particularly the fruit, valued for its rich chemical composition. This review explores the botany, ethno-pharmacological applications, phytochemistry, pharmacological activities, safety and quality, economic potential, and marketed products of *Morinda citrifolia's* fruit, seeds, leaves, and roots. Additionally, it examines the phytochemical compounds identified through *in-vitro* and *in-vivo* studies.

INTRODUCTION: The *Morinda citrifolia* a plant in the family Rubiaceae. The name was derived from the Latin words "Morus" or mulberry and "indicus" or Indian. The species name suggests that the leaves of the plant are similar to those of some citrus trees. It called Nuna or ach in India, Indian mulberry in Hawaii, Mengkudu in Malaysia and cheese fruit or the painkiller bush in the Caribbean.

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As a rich source of proteins, vitamins, minerals, coenzymes, carbs, and alkaloids, *Morinda citrifolia* an exemplary nutrient-rich plant. Some antibacterial, antifungal, antioxidant, and anti-inflammatory activities have been demonstrated by various studies.

Some studies also reported that feeding terrestrial animals, such as Nicobaric fowl, crossbred beef calves, and broiler birds, with Noni enhances growth and immune response [1]. *Morinda citrifolia* highly used because of its versatility; every part of the plant, from the roots, stems, fruits, and leaves, has been used for ages in East Asian cultures to manage various conditions, such as burns, arthritis, headaches, diabetes and high blood pressure.

Morinda citrifolia (Noni) components are more widely tribute globally today because of their commercialization as herbal supplements. That has expanded their use not only in the food industry, but also in medicine, pharmacy, biotechnology, material science, and even nanotechnology. All the components of Noni, with found to be commercialization have been opened up to worldwide utilization and not only restricted to food sectors but utilized in biotechnology, material science, medicine, pharmacy, and even nanotechnology [2].

Botany:

Source and Spread across Regions: More than 102 species of trees, shrubs, and vines belonging to the genus *Morinda (*Rubiaceae) are found in temperate, tropical, and subtropical regions [3]. *Morinda citrifolia*, *Morinda lucida*, and *Morinda officinal* have been utilized historically all over the world [4]. According to ethnobotanical and ethnopharmacological research, almost every portion of the *Morinda* species has therapeutic significance, particularly when used to cure diseases been found to be diseases including typhoid, diabetes, hepatitis, cancer, and malaria. One or more dry or juicy fruits are produced by members of genus [5]. Originating in Southeast Asia, Noni now widely used countries of Mexico, Panama, Colombia, Venezuela, the Caribbean and the West Indies. East of Polynesia, it reaches all the way to India. It's resilience in tough, dry, salty, and coastal environments demonstrated by the fact that it flourishes at elevations of more than 200 meters and bears fruit all year round. Polynesian societies have cultivated and farmed the Noni for more than a millennium, using it as a dye, food, and medicine. Originating in western Polynesia (Samoa, Tonga, Niue, 'Uvea/Futuna, Rotuma, Tuvalu); Micronesia (Pohnpei, Guam, Chuuk, Palau, Marshall Islands, Northern Marianas); Hawaii, the line islands, Marquesas, Australia, Pitcairn, and the Cook Islands, it found all over the Indo-Pacific region [6].

Plant Description: *Morinda citrifolia* grows between three and ten meters tall as a shrub or small tree. Broad and oval in shape, the leaves measure 5 to 17 cm in length and 10 to 40 cm in width. The petioles that cluster on the peduncle leave behind distinct ring-like impressions from the tiny, tubular, white blooms. Green white, the colour of the corolla. It's round, juicy, slightly wrinkled fruit has an embossed feel, 3-10 cm in length and 3-6 cm in width. The fruit turns from green to yellow to nearly white as it ripens, and it crowned with tiny red brown buds that hold the seeds. A pungent, rotten smell, similar to butyric acid, released by mature fruit. A number of firms, triangular, reddish-brown pits with four seeds that are 3.5 mm in diameter are present in the pulpy, luscious fruit, which bitter, light yellow to white when ripe, and gelatinous. *Morinda citrifolia* leaves are non-toxic up to oral acute, sub-acute, and sub chronic toxicity in rats and exhibit potent antioxidant activity. Inspired by traditional Polynesian methods, leaves are frequently used to make medicinal teas and other products that improve health. Products made from the plant leaves have been available in Japan. Some manufacturers now sell capsules containing powdered leaves [7].

Because of its possible antimicrobial, anti-cancer, anti-inflammatory, and antioxidant properties, *Morinda citrifolia* fruit juice has recently become popular as an alternative medicine. Nevertheless, there currently little scientific proof supporting the health advantages of *Morinda citrifolia* fruit juice, despite its widespread use. Because of its rich phytochemical and nutrient profile, it has become a popular health supplement worldwide over the last ten years. Numerous health conditions, such as arthritis, diabetes, high blood pressure, muscle pain, menstrual problems, headaches, heart diseases, aids, cancer, gastric ulcers, sprains, depression, age-related issues, digestive disorders, atherosclerosis, vascular issues, and even drug addiction, are being treated with the juice in alternative medicine. There are many obstacles in the way of modernizing the production of *Morinda citrifolia* fruit juice into a more traditional medicinal product.

Through *in-vitro* research, a number of the fruit's biological properties have been documented, including tyrosine kinase inhibition, cyclooxygenases-1 and -2, antioxidant activity, and angiogenesis suppression. Many of the discovered individual bioactive chemicals, however, lack structural characterization because the majority of these research have relied almost exclusively on crude extracts or fractions.

The n-butanol-soluble fraction of the fruit's methanol extract has so far yielded two bioactive substances: neo-lignin and Americanin A, which have been associated with these biological activities [8]. *Morinda citrifolia* easily recognized by its broad leaves, tubular white blossom, and its oval, "grenade-like" yellow fruit with a bumpy surface separated into polygonal pieces. Its broad spread over the Polynesian lands may be explained by the air sac at one end of its triangular, reddish-brown seeds, which likely aid in buoyancy. When the fruit reaches maturity, it tastes harsh and has a strong smell. *Morinda citrifolia* not regarded as endangered because it a wild species [9].

FIG. 1: *MORINDA CITRIFOLIA* (NONI) FRUIT

FIG. 2: *MORINDA CITRIFOLIA* (NONI) PLANT

Vernacular Name: Several common names for *Morinda citrifolia*, depending on the local languages. The table contains the names that are used in various nations [10].

TABLE 1: VERNACULAR NAMES OF *MORINDA CITRIFOLIA*

Sr. no.	Country	Name
1	Australia	Great Morinda or cheese fruit
2	Tahiti	Nono
3	China	Ba ji tian
4	Hawaii Polynesia Puerto Rico	Noni
5	Malaysia Indonesia	Mengkudu
6	Cayman Islands Jamaica	Hog Apple
7	French West Indies	Belimbi
8	El Salvador	Rhubarbecaraïbe
9	India	Indian Mulberry

Cultivation: Originating in Southeast Asia, Oceania, and tropical Australia, *Morinda citrifolia* eventually made its way from Polynesia to India. It now widely grown in tropical areas, especially in Latin America, with notable cultivation in nations like Mexico, Colombia, and Venezuela. Costa Rica, Panama, Kenya, Florida, and the West Indies are some of the other places where it flourishes. The Andaman and Nicobar Islands are home to the majority of *Morinda citrifolia* populations in India are found growing wild beside the coastlines of Kerala, Karnataka, Tamil Nadu, and Odisha [11].

Climate and Soil: *Morinda citrifolia* (Noni) a remarkable plant celebrated for its ability to thrive in a diverse range of soil conditions. It can tolerate acidic, saline, and alkaline soils, effectively growing in pH levels from 4.4 to 9. The plant shows a strong capacity to adapt to various altitudes and climates, flowering in tropical, arid, and humid environments. The plant thrives in mot to moderately mot settings and can even tolerate brick water. It withstands temperatures ranging from 20 to 38 °c and performs best at elevations of 1,500 to 2,000 meters. While it prefers well-drained soils, plant also capable of adapting to different drainage conditions, including regions that experience seasonal water logging. Its impressive adaptability enables it to endure annual rainfall levels between 250 and 4,000 mm, showcasing its ability to flourish in a wide array of environments [12].

Propagation: Traditionally, Noni plants have been propagated using stem and root cuttings or seed. Seeds are, however challenging to use for commercial planting since they are covered by a hard seed coat, which prevents the uptake of water and triggers dormancy. Propagation *via* cuttings also a low 83.3% success rate. Infections also hinder the establishment of new large orchards using tree clones vegetative grown. Most of the Noni plants are propagated through roots by

cuttings, though the method rapidly loses the potential rooting ability due to the parent plant getting older. Also, the species *Morinda citrifolia* exhibits relatively high genetic and morphological variation within its fruits and leaves [13].

Nutrient Management: Moreover, when the plants are fertilized with cow dung and potassium chloride (KCL), it increases the fruit per plant on Noni, and the fruits per plant are higher than in coffee. The supply of key elements like Nitrogen. Phosphorus, Potassium, Calcium, Magnesium, Sulphur, Iron, and Zinc sufficient on the Noni plants, while boron (B) and manganese (Mn) are deficient compared to coffee trees. The cow dung fertilization capable of elevating the phosphorus and potassium pools in the foliar layer, which results in positive effects on fruiting and yield in Noni plants [14].

Diseases and Pests: Numerous problems, such as root-knot nematodes, soft fruit rot, dry fruit rot, leaf blight, and anthracnose, frequently damage Noni plants [15].

TABLE 2: DISEASES OF *MORINDA CITRIFOLIA*

Sr. no.	Diseases	Cau sative agents
1.	Anthracnose	*Colletotrichum gloeosporioides*
2.	Dry Fruit Rot	*Colletotrichum gloeosporioides*
3.	Dry Fruit Rot and Leaf Blight	*Alternaria alternate*
4.	Soft Rot of Fruits	*Pantoea agglomerans*
5.	oot-Knot Nematode	*Meloidogyne incognita*

Medicinal Aspects of Noni Plant:

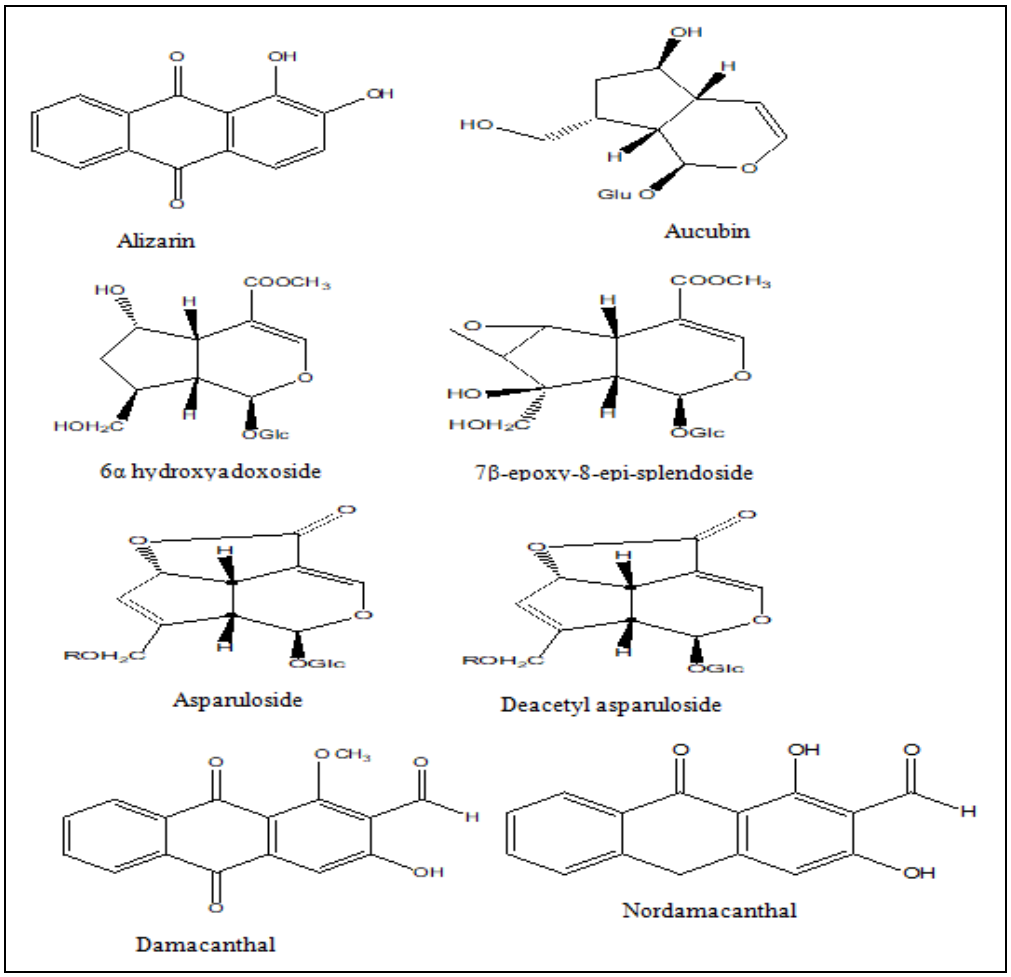
Ethnopharmacological uses: Ethnobotany the scientific study of how various cultures utilize medicinal plants to treat diseases and infections. In countries such as China, Thailand, Africa, Tahiti, Hawaii, Fiji, India, and those practicing Ayurveda, various parts of plants are traditionally used for treating both acute and chronic infections. *Morinda citrifolia* fruit juice used in Taiwan to treat hypertension and diabetes. The Nonifruit juice frequently used to cure diabetes, diarrhoea, high blood pressure, and headaches on the tropical pacific lands. Furthermore, powdered *Morinda citrifolia* leaves are combined with fresh palm wine in Southeast Asian nations like Brunei, Timor Lest, Myanmar, Indonesia, Cambodia, Malaysia, the Philippines, Laos, Vietnam, Singapore, and Thailand as an anthelmintic treatment for ailments like high blood pressure, swollen spleen, diabetes, cough, and malaria. In Thailand, fever and malaria are treated with *Morinda citrifolia* wood and bark. In Liberia, people macerate the dried stem bark and leaves of *Morinda morindoides* in water to treat worms, malaria, and fever [16].

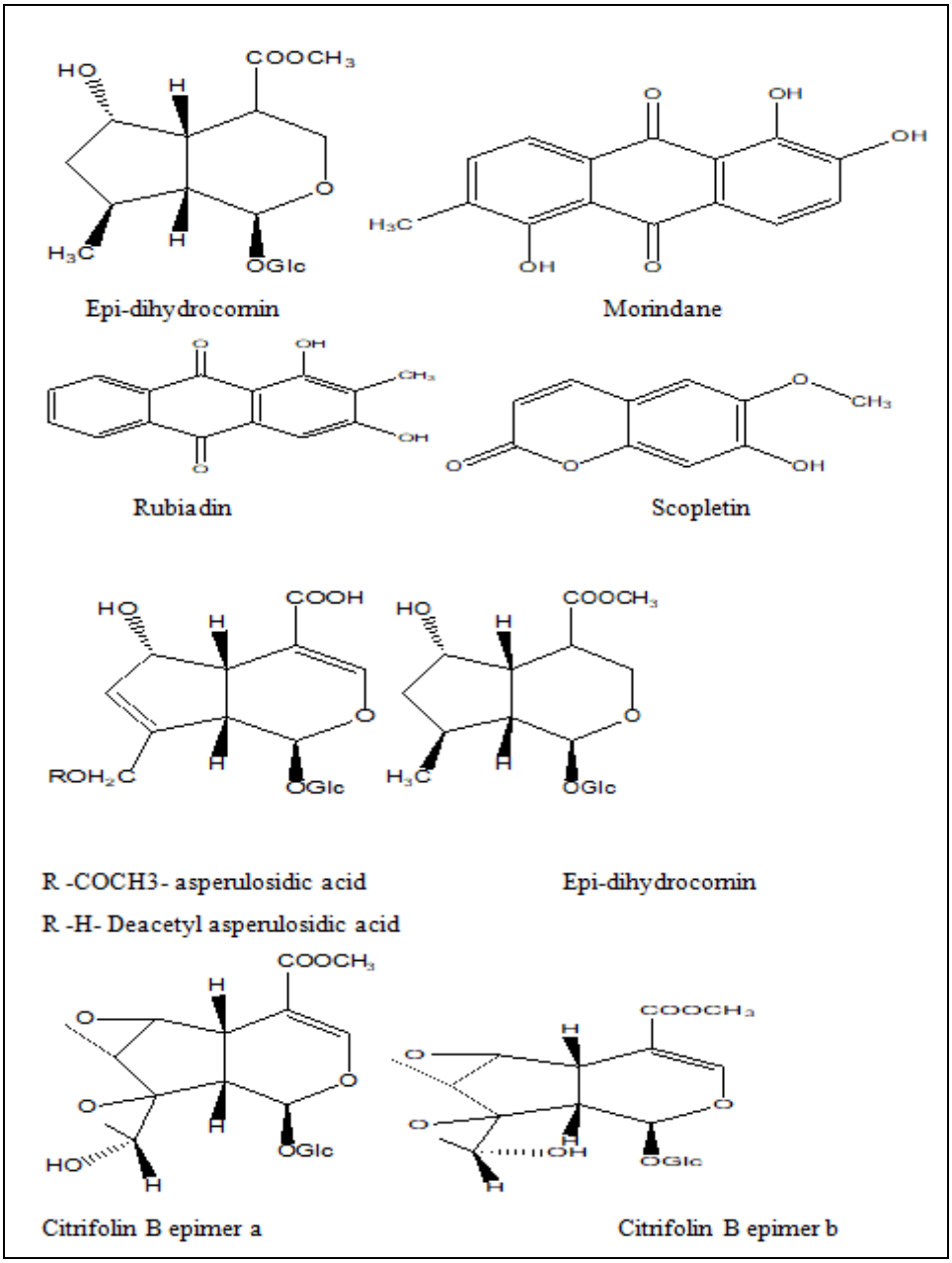
Phytochemistry: Numerous essential components of the *Morinda citrifolia* (Noni) plant have been identified in all of its parts. Flavonoids, proteins, amino acids, lipids, carbohydrates, acids, glycosides, and vitamins are the primary classes into which these chemical constituents can be divided [17]. Proteins, dietary fibre, and soluble solids constitute the majority of the fruit's dry matter, with water comprising approximately 90% of the fruit. The fruit's protein content is particularly notable, with amino acids such as aspartic acid, glutamic acid, and oleucine accounting for 11.3% of the juice's dry matter.

Usually, a sugar unit composed of one to three glucose molecules joined to one or two short-chain fatty acids or an alcohol to form these compounds. Amphiphilic characteristics are imparted by the chemical structure, which may help explain the soapy flavour observed in some mature fruits. The fruit also contains a variety of iridoids, including notable composites such as asperuloside, asperulosidic acid, and deacetylasperulosidic acid.

Additionally, scopoletin, rutin, and deacetylasperulosidic acid (DAA) have been identified as chemical marker standards from freeze-dried Noni fruit and leaf powder. Using methods including Nuclear magnetic resonance, Mass spectrometry (MS), and High-performance liquid chromatography (HPLC), they verified the identification and purity of these markers (>98%) [18]. Calcium, phosphorus, sulphur, and potassium are the main minerals that make up 8.4% of the dry matter in *Morinda citrifolia* (Noni) fruit. Selenium also presents in the juice. *Morinda citrifolia* fruit contains a variety of vitamins, including ascorbic acid and pro-vitamin A, with concentrations ranging from 24 to 158 mg per 100 g of dry matter. They also identify phenolic compounds as the primary functional micronutrients in *Morinda citrifolia* juice, including alizarin, aucubin, nor-

damnacanthal, scopoletin, morindone, damnacanthal, rubiadin, rubiadin-1-methyl ether, and other anthraquinone glycosides. Among these, researchers highlight damnacanthal for its strong anti-carcinogenic properties [19]. Glycolipid are notable among the phytochemicals found in fruit because of their distinct compositions and structures in mature *Morinda citrifolia* (Noni) fruits. These substances are composed of an alcohol or one or two short-chain fatty acids connected to a sugar moiety composed of one to three glucose units. Some mature fruits have a soapy flavour that may be attributed to the amphiphilic qualities the structural arrangement imparts [20]. The fruit contains various iridoids, including significant compounds such as Asperuloside, Deacetylasperuloside, and Asperulosidic acid. It also includes minor Iridoids like Citrifolinin B epimers A and B, 6β, 7β-epoxy-8-epi-splendoside, Epihydrocornin, Ehydro-methoxygaertneroside, and 6α-hydroxyadoxoside. Additionally, researchers have identified several flavonol glycosides in the fruit, such as rutin, narcsoside, and nicotifloroside. The fruit also contains several lignans, including morindolin, o-prinpin, balanophonin, 3, 3'-bdemethylpinoresinol, americanol A, americanin A, and americanoic acid A, along with many other known and unknown lignans. *Morinda citrifolia* (Noni) fruit contains various compounds, including a range of 1-hydroxyanthraquinones, which show lower concentrations of the coumarin scopoletin. Researchers have also identified newer compounds, such as 5, 15-dimethylmorindol and 2-methoxy-1, 3, 6-trihydroxyanthraquinone. In addition, they have isolated several other compounds, including succinic acid diesters, d-β-sitosterol and its 3-O-glucoside, ursolic acid and 19-hydroxyursolic acid, cytidine, borreriagenin, epiborreriagenin, the iridoid derivative 4-hydroxy-3-methoxy-cinnamaldehyde, β-hydroxypropiovanillone, and vanillin [21]. A preliminary phytochemical analysisis of *Morinda citrifolialinn's* leaves revealed the presence of alkaloids, reducing sugars, carbohydrates, terpenoids, flavonoids, glycosides, phenolic compounds, and α-amino acids [22].





Pharmacology: Additionally, the review highlights the biological activities of *Morinda citrifolia*, such as its antitumor, antibacterial, antiseptic, antifungal, antiviral, leishmanicidal, anti-inflammatory, antinociceptive, analgesic, antioxidant, neuro-protective, wound healing, antiallergic, anti-angiogenic, antiemetic, anti-nausea, anti-gastric ulcer, and anti-esophagitis effects. It showcases its anthelmintic, antimutagenic, antipsychotic, anxiolytic, photoprotective, anti-wrinkle, and periodontal tissue regeneration activities.

Immunostimulatory Activity: It has been demonstrated that fruit juice, combined with immunosuppressive drugs, reduces immune-stimulatory effects in mice, suggesting that fruit acts as an immunomodulator capable of altering immune responses in various clinical contexts. Both hydroalcoholic and aqueous fruit extracts enhance B and T lymphocyte activity, as well as splenocyte proliferation *in-vitro*. However, aqueous extracts reduce lymphoproliferative activity and decrease the *in-vitro* production of INF-γ and IL-2 in middle-aged F344 inbred rats. In contrast, Noni juice containing seeds stimulates cytokine production and promotes lymphocyte proliferation in both young and aged mice [23].

Antitumor Activity / Anti-cancer Activity: Researchers have recognized *Morinda citrifolia* as

a potential dietary supplement to aid cancer patients. Studies on ethanolic extracts from Noni leaves show that these extracts influence immune response pathways and tumour cell activity by increasing the expression of tumor-suppressive genes and inhibiting COX-2, a key inflammatory signalling molecule, as observed in mice models.

In both animal and cellular cancer models, *Morinda citrifolia* demonstrates anti-cancer properties through mechanisms such as inducing cell cycle arrest, enhancing pro-apoptotic activity, and inhibiting cell migration. Additionally, it inhibits the AKT/NF-Kb signalling pathway, that is necessary to halt the development of cancer cells and trigger apoptosis. Cell death is caused by this mechanism, which also decreases the apoptotic inhibitor Bcl-2, downregulates the proliferation markers PCNA and Ki67, and activates the apoptotic protein caspase-3 [24].

Fresh plant leaf extracts have been shown *in-vitro* to inhibit the growth of multiple cancer cell lines, such as human hepatocellular carcinoma, human cervical carcinoma, and human epidermis carcinoma. This suggests that the plant may have chemo preventive potential for cervical and epidermis cancers. Additionally, ethyl acetate extracts inhibit the growth of MCF-7 and MDA-MB-23 cells, which are linked to breast cancer [25].

Antidiabetic Activity: Researchers investigated the hypoglycaemic effects of chemical compounds in the roots of plant using rats with diabetes induced by streptozotocin. They found that the butanol fraction of the methanolic root extract, which contained compounds such as 3-O-beta-D-primeveroside and damnacanthal 3-O-beta-D-lucidin, significantly lowered blood glucose levels. Furthermore, Noni-fermented fruit juice yielded similar results in diabetic rats, showing both hypoglycaemic and hepatoprotective effects [26]. Additionally, it has been demonstrated that Noni fruit extract successfully lowers blood glucose levels in male mice without relying on glucagon's effect on the response. Animals with severe glucagon-induced hyperglycaemia responded much more strongly to the Noni extract [27].

Ant-obesity Activity: Studies show that Noni juice reduces cholesterol levels in adult smokers by lowering plasma LDL, triglycerides, and high-sensitivity C-reactive protein (hs-CRP), a critical marker for assessing cardiac risk. This reduction helps alleviate smoking-related hyperlipidaemia [28].

Researchers also investigated how ethanolic extracts from Noni leaves affect fatness in Sprague-Dawley rats induced by a high-fat diet. The extracts significantly improved various obesity-related parameters, including blood levels of insulin, leptin, triglycerides, body fat, and overall fat content [29].

Antimicrobial Activity: Researchers assessed the antimicrobial properties of plant leaf extracts using the Kirby-Bauer disk diffusion test against a range of common food-borne pathogens, including *Morganella morganii, Proteus vulgaris, Proteus mirabilis, Photobacterium damselae, Hafnia alvei, Clostridium perfringens, Citrobacter younger*, *Enterobacter aerogenes*, *Enterobacter amnigenus*, *Enterobacter cloacae*, and *Vibrio alginolyticus*. Extracts showed varying degrees of antibacterial activity and resistance, with plant displaying the largest mean zone of inhibition (ZOI) at 11.4 mm [30].

Antibacterial Activities: Dentists commonly use irreversible hydrocolloids as moulding materials for tooth restorations. Studies show that plant extract improves the effectiveness of hydrocolloid powder and reduces microbial contamination during dental impressions[31].

Anti-inflammatory Activity: The fruit juice has anti-inflammatory properties when administered to raw 264.7 cells in the presence of lipopolysaccharide (LPS). Phytochemical analysis is and bioassay-driven methods have identified five compounds in Noni fruit juice: Asperulosidic acid (1), Rutin (2), Nonioside a (3), deca-2,4,7-trienoate -2-o-β-d-glucopyranosyl-β-d-glucopyranoside (4), and (2e,4e,7z) tricetin (5). LC/MS and NMR spectroscopy were used to determine the structures of these substances. In anti-inflammatory experiments, compounds 1-4 significantly reduced the production of nitric oxide (NO), a pro-inflammatory mediator, in lps-stimulated macrophages. After investigating the mechanism underlying these compounds' anti-inflammatory effects, the researchers found that compounds 1–5

reduced the expression of ikkα/β, i-κbα, and nf-κb p65 in lps-stimulated macrophages while also inhibiting the generation of no. Chemicals 1-4 also reduced the expression of nitric oxide synthase and cyclooxygenase-2. These findings suggest that Noni fruit juice's active components have anti-inflammatory properties that could aid in the treatment and prevention of inflammatory diseases [32].

Antioxidant Activity: The fruit bio-fermented beverage has a high concentration of flavonoids and iridoid glycosides, which emphasizes its potential as an antioxidant. These active ingredients have been recognized by researchers as possible indicators of quality control. Th drink's distinct chemical makeup, which distinguishes it from other samples, raise the possibility that it may be a viable new source of health benefits.

The drink demonstrated significant antioxidant activity in the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, with an IC50 value of 14.94±0.76 µg/ml, which similar to trolox's ic50 value of 8.47±0.16 µg/ml. Furthermore, a low phenolic content of 0.75±0.01 mg Gallic acid equivalent (GAE)/g was found by examination utilizing the Folin-Ciocalteu reagent method [33].

Neuropharmacological Investigations: The neuropharmacological effects of the fruit studies using both *in-vivo* and *in-vitro* models have revealed that the fruit exhibits anti-depressive and anti-anxiety properties.

Antidepressant Activity: The methanolic extract of plant and its bioactive components, scopoletin and rutin, have demonstrated antidepressant properties, with rutin and scopoletin. Polynesians have traditionally utilized the fruit of *Morinda citrifolia* to alleviate depression. To further understand the antidepressant-like effects of the fruit, this study employs preclinical mouse models and behavioural tests, including the elevated plus maze (EPM), light/dark test (LDT), and tail suspension test (TST). The study an early attempt to investigate the potential processes underlying the antidepressant-like effects of the fruit [34].

Anxiolytic Activity: The anxiolytic effects of the fruit occur through the benzodiazepine GABAergic and/or serotonergic (5-HT1A) systems, while its antidepressant effects are linked to the noradrenergic and/or serotonergic systems [35].

Anti-osteoarthritis Effects: Researchers used preclinical animal models and cartilage explant cultures to evaluate how the plant leaf extract affects inflammation and joint cartilage deterioration associated with osteoarthritis. They induced osteoarthritis by injecting monosodium iodoacetate intraarticularly into the right knee of the participants. The extract, which contains active compounds like epicatechin and scopoletin, prevented cartilage explants from producing glycosaminoglycan and nitric oxide when exposed to interleukin-1β. After 28 days of treatment, the extract significantly reduced the mRNA expression of biomarkers linked to joint cartilage breakdown, such as collagenase and aggrecans, in both joint tissues and serum. Additionally, the extract increased the bone formation marker PINP and improved the structure of articular cartilage and chondrocyte cellularity [36].

Anti-nociceptive Effect: Researchers used several pain models, including the acetic acid-induced writhing test, radiant heat model, tail immersion model, and formalin-induced pain paradigm in SWS albino mice, to assess the effects of powdered freeze-dried Noni on nociceptive responses. They used naloxone to verify the central activity of Noni, while pethidine and diclofenac served as standards to evaluate the peripheral and central analgesic effects, respectively. The results revealed that oral administration of Noni significantly reduced writhing, particularly when combined with diclofenac. At a dose of 500 mg/kg, Noni notably inhibited paw biting and licking behaviours in the formalin-induced pain model during both phases of pain. The central analgesic effect of Noni was further confirmed by the reversal of its analgesic action after intraperitoneal injection of naloxone in the tail flick test, showing effects similar to those observed with pethidine [37].

Wounds Healing Activity: Researchers used oral leaf ethanol extract and Noni leaf extract to evaluate *Morinda citrifolia's* capacity for healing. They found that Noni exhibited therapeutic effects by speeding up the healing process, as seen by less wound contraction and quicker re-epithelialization in every instance [38].

Anti-gastric Ulcer and Oesophagitis: Researchers investigated the effects of the aqueous extract of fruit and its constituent, scopoletin, using rat models of gastrointestinal disorders, including acute and chronic stomach ulcers induced by acetic acid, acid reflux esophagitis, and acute gastritis induced by ethanol and serotonin.

They found that administering doses ranging from 0.63 to 2.50 g/kg significantly reduced gastric lesions caused by alcohol and serotonin, promoted healing of acetic acid-induced gastric ulcers, and effectively controlled acid reflux esophagitis. Scopoletin showed similar effects, suggesting that both the Noni extract and its key component could potentially serve as treatments or preventive measures for gastrointestinal inflammatory disorders [39].

Photocatalytic Treatment: In order to create ecologically acceptable molybdenum-doped zinc oxide (ZnO) nanoparticles and ZnO/g-C_3N_4 nanocomposites, researchers employed plant extract as the reducing agent. In order to produce a nanocomposite that demonstrated improved photocatalytic degradation efficiency for dyes like methyl orange (MO) and methylene blue (MB), they mixed molybdenum-doped zinc oxide with g-C_3N_4. The following are some benefits of the environmentally friendly synthesis method:

(i) It more eco-friendly compared to the conventional chemical synthesis of nanomaterials.

(ii) It enhances photo catalytic dye degradation efficiency without relying on harmful chemicals as reducing agents [40].

The innovative approach not only contributes to sustainable practices but also presents effective solutions for environmental challenges related to dye pollution.

Schistosomiasis Treatment: The focus of the study was schistosomiasis, a parasitic condition that may initially present with no symptoms but can progress to severe illness and even death. Researchers aimed to investigate the *in-vivo* pharmacological effects of the dry extract of plant and to develop a pharmaceutical dosage form for treating schistosomiasis. They characterized the aqueous extract by analysing its pH, dry residue, and density, and processed it using freeze-drying. The study included acute toxicity testing, rheological analysis, *in-vivo* pharmacology, and phytochemical screening of the dry extract [41].

Quality and Safety:

Adulterants: The Noni plant, a member of the Rubiaceae family and adverted as having a number of unsubstantiated nutritional and health advantages. High-performance thin-layer chromatography (HPTLC) and headspace-solid-phase micro extraction coupled with gas chromatography and mass spectrometry (HS-SPME/GC/MS) are techniques for confirming the legitimacy of commercial Noni juices.

Toxicity: Two distinct doses of fruit and edible leaf water extracts were given to female mice over a six-month period in order to evaluate their long-term toxicity. According to the study, drinking water containing a high concentration of the fruit extract (2 mg/ml) had serious harmful effects. A 40% death rate after three months was one of these outcomes, along with decreased albumin levels, hypo activity, increased grooming, sunken eyes, slumped posture, decreased liver size, and higher levels of the liver injury marker (aspartate aminotransferase). These findings are consistent with reports of human liver damage brought on by long-term Noni fruit juice use. On the other hand, leaf extracts showed no discernible damage at any dose. Strong anthraquinones can be detected in the plant's seeds and skin, which are known to strongly induce quinone reductase, makes it impossible to rule out the likelihood that the fruit extract directly caused hepatotoxicity. Since there are no comparable long-term toxicity findings in animal models, the work adds to our understanding of chronic pooling from the fruit [42].

Marketed Products of Noni: Following are list of some marketed products made from Noni. These products are available in various forms, including juices, supplements, and topical applications:

Noni Juices: Researchers conducted a safety study of TAHITIAN NONI® Juice from Tahiti with ninety-six healthy volunteers. Participants drank either 0 ml (placebo), 30 ml, 300 ml, or 750 ml of Noni juice every day for 28 days. A placebo was added to any volume differences in order to

standardize all daily dosages to 750 ml. Haematology, Biochemistry, urinalysis, vital signs, and adverse events were evaluated at baseline (0 weeks), 2-4 weeks, and at week 6 of the trial. Each volunteer also had electrocardiogram (ECG) readings recorded at week six and during pre-study assessment. Participants in the Noni groups had 20% to 50% fewer adverse events overall during the experiment than those in the placebo group. A noteworthy decrease in consistent adverse events ($p < 0.1$) was seen in the 300 ml Noni juice group, and the other Noni juice groups showed a similar pattern. There was no indication of negative dose-related effects, nor were there any other clinically relevant disparities between the study's data and parameters. According to the study, it safe to consume up to 750 ml of Tahitian Noni juice every day [43].

Noni Supplements: Researchers conducted a double-blind placebo-controlled trial. Over the course of three menstrual cycles, 100 university students who were at least 18 years old participated in a double-blind, placebo-controlled study. 400 mg of Noni capsules or a placebo were given to participants at random.

In addition to evaluating pain, menstrual blood loss, and laboratory measures (ESR, haemoglobin, and packed cell volume) before and after treatment, the research team also investigated baseline demographic characteristics, such as age, parity, and BMI. 100 of the 1,027 women who were screened sifted the eligibility requirements and were randomized; 42 of them received Noni, while 38 were given a placebo.

At randomization, no significant differences were seen in mean bleeding or pain scores, or in any of the covariates. Over the course of the three menstrual cycles, both groups showed a slow improvement in their bleeding and pain levels; however, the Noni group's improvement was not substantially different from the placebo groups. Comparing Noni to a placebo, the study found that Noni did not significantly lessen menstrual pain or bleeding [44].

Noni Topical Products: Nonileaf extract serves as a natural sunscreen. With 89.1063 mg/l of rutin flavonoid found in the leaves, Noni leaf extract has a higher flavonoid content than the fruit and functions as a natural sunscreen. The Noni leaf extract contains a variety of additional phytochemical substances in addition to flavonoids. Alkaloids, tannins, triterpenoids, saponins, coumarins, anthraquinones, carotenoids, organic acids, and reducing agents were found in the Noni leaf extract after phytochemical screening using a 70% ethanol maceration process [45].

Researchers have found that incisional wounds, like those following surgery, can greatly impact a patient's quality of life and lead to several complications. Reactive oxygen species (ROS) and persistent inflammation are two key factors that hinder the healing process. A study on Wistar rats showed that applying Noni ethanol extract cream to incisional wounds led to more collagen deposition and faster healing compared to using just the base cream [46].

Noni Dietary Products: Numerous physiologically active substances, such as minerals, fatty acids, vitamins, amino acids, and carbohydrates, are present in Noni. These bioactive components have potential for a number of uses in the food sector, despite the fact that the entire medicinal and nutritional benefits of the plant are still not fully recognized.

In cookie recipes, Noni said to be a good substitute for wheat flour. Higher amounts of protein, calories, carbs, ash, and fibre were found in cookies made with a combination of wheat flour and Noni fruit powder than in cookies made with just wheat flour. A possible substitute for using Noni fruit powder and exploiting its functional advantages, they also demonstrated positive sensory attributes in terms of look, scent, texture, colour, and flavour [47].

Economic Potential: The global Noni juice market expected to increase at a compound yearly growth rate of 7.1% from its 2023 valuation of about used 68 million to used 109.6 million by 2030. Derived from the Noni fruit, Noni juice well known as a nutritional tonic and valued for its role in complementary medicine as well as its possible health advantages. *Morinda* holdings, *Morinda citrifolia* (Noni) biotech, and royal *Morinda citrifolia* (Noni) Fiji are important participants in

the global Noni juice market; the market leader holds roughly 35% of the market. North America represents the largest market, accounting for approximately 22% of the global share, while natural Noni juice compress around 65% of total sales. The food and beverage sector the primary application, responsible for about 70% of total usage. The research report provides insights into the development of the Noni juice industry chain, current market status, and major companies in both developed and emerging markets. It also highlights innovative technologies, patents, popular applications, and market trends related to Noni juice. North America and Europe are experiencing growth as governments promote consumer education, while demand for Noni juice in the Asia-pacific region, particularly in China, rapidly increasing due to strong domestic demand, supportive policies, and a robust manufacturing base.

CONCLUSION: The *Morinda citrifolia* (Noni) plant considered a "gift of nature" in traditional Polynesian culture because it contains several pharmacologically active ingredients that have therapeutic properties. In traditional medicine, Noni fruits have been used to treat a variety of ailments, including diabetes, cancer, arthritis, colds, and microbial infections. Current scientific research has confirmed Noni's bioactive properties. Numerous clinical, *in-vivo*, and *in-vitro* studies have examined the impact of the fruit, leaves, and extracts from it on various biological systems. These studies include a wide range of topics, such as Noni fruit ripening and maturation, as well as Noni product safety, processing, storage, and quality assurance. *Morinda citrifolia* comes in a variety of forms, such as topical treatments, supplements, and liquids.

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