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Morinda citrifolia L. (Noni) – Its Ethnobotanical Knowledge, Phytochemical Studies, Pharmacological Aspects, And Future Prospects

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ABSTRACT: Herbalism holds its root in ancient culture. According to WHO's recent data estimation ~70-80% of the global population is dependent on herbal medicines. The review aims to highlight the importance of plant species *Morinda citrifolia Linn.* more commonly known as Noni or Indian mulberry. It is small tropical and subtropical fruit-bearing tree or shrub species within the coffee family of kingdom Plantae (family Rubiaceae). The study of the phytochemical constituent in *Morinda citrifolia Linn.* roots, leaves, flowers, fruits, fruit juice (fresh and fermented), seeds indicated the presence of alkaloids, saponins, phenols, tannins, coumarins, glycosides, sterols, iridoids, flavonoids, AA/proteins, terpenes, anthraquinones, lignin, sugars, esters, etc. *Morinda citrifolia Linn.* is a traditional Polynesian plant that has been used therapeutically for ~over 2000-3000 years. The isolated phytochemical compounds from the whole *Morinda citrifolia Linn*. plant contains anticancer, antiepileptic, antidiabetic, immunostimulatory, antidementia, anti-inflammatory, analgesic, anti-parasitic, antioxidant activities. Leaves of *Morinda citrifolia Linn.* consists of vital elements such as potassium, calcium, iron, manganese, zinc. *Morinda citrifolia Linn.* holds significant importance in the global commercial market, a variety of beverages, herbal powder, essential oils, and other herbal products made from leaves, fruits, and seeds. Hence the review highlights the phytochemical constituent and ethnobotanical activities & pharmacological aspects and functional properties of the plant and recent advances in *Morinda citrifolia Linn*. research.

Keywords: *Morinda citrifolia Linn.*, Phytochemical constituent, Anthraquinone, Anticancer, Antioxidant activity.

INTRODUCTION

Herbalism holds its roots in ancient cultures. The therapeutic use of plants to cure disease and improve overall health and wellness. The WHO estimated the data that approximately 70–80% of the global population is dependent on nonconventional medicines predominantly on herbal medicinal sources in their healthcare (Chauhan, *et al.*, 2015).

Morinda citrifolia Linn (Noni or Indian mulberry) is a small tropical and subtropical fruit-bearing tree or shrub within the coffee family of the kingdom Plantae (family Rubiaceae). Its native range extends across Pacific Islands, Southeast Asia, Australasia (Australia, New Zealand, and some neighboring islands), and India (Pieroni, Andrea, 2005), in addition, it has become naturalized on many islands in the Caribbean, Bahamas, Bermuda, Florida Keys, and parts of Africa, Mexico (N. America) to Panama (C. America), Venezuela & Surinam (S. America) (Janick and Paull, 2008). It is a traditional Polynesian medicinal plant also known as 'Noni'. This plant is a member of the Rubiaceae family and has been utilized medicinally for over 2000- 3000 years (Nagalingam *et al.*, 2013). *Morinda citrifolia L.* is among the most popular herbal medicinal plants that are used to treat many health-related issues such as malignancy, common cold, diabetes mellitus, influenza, high blood pressure, pain, gastric ulcers, menstrual cramps, etc. it also has a large range of therapeutic claims, including antibiotic, anti-viral, anti-bacterial, antimycotic, anti-inflammation, anti-helminthic, anti-tumor, analgesic, the hypotensive, immune-enhancing effect (Carrillo-López, 2011).

Morinda citrifolia Linn. commonly called 'Noni', the fruit has many names used in different cultures around the world in Hawaii it is called Noni, Hai ba Ji in China, Luo ling in Taiwan, and Singapore, great morinda, cheese fruit in Australia, Mengkudu in Malaysia, Indian mulberry, beach mulberry, Bartundi (in Hindi) in India The leaves, roots, bark, stems, and fruits of this tree all serve as medicinal components. There is a great deal of research that supports the value of noni as a nutraceutical and the fact that it contains some phytochemicals such as lignans, oligo- and polysaccharides, scopoletin, iridoids, fatty acids, catechin, β-sitosterol, (sterols), alkaloids, damnacanthal, and flavonoids. Noni is also reported to possess the antioxidant potential and to aid with the treatment of several disease conditions (Nagalingam, *et al.*, 2013).
This paper attempts to report on the scientific evidence relating to Ethnobotanical knowledge, Phytochemical studies, Pharmacological aspects, and functional properties attributed to this medicinal plant.

Table.1. Taxonomical Classification: *Morinda citrifolia L.*

Domain	Eukaryota
Kingdom	Plantae
Sub-kingdom	Viridiplantae
Infra-kingdom	Streptophyta
Division	Embryophyta
Super-division	Spermatophytina
Class	Magnoliopsida
Superorder	Asteranae
Order	Gentianales
Family	Rubiaceae
Genus	Morinda L.
Species	*Morinda citrifolia L.*
Common Name	Noni, Indian mulberry

DISTRIBUTION

Morinda citrifolia L. is native species of Asia and Oceania (Australia). It can be cultivated in full or partial sun-light with well-drained and well-aerated soil free from nematodes, dry plants, and weeds. It can withstand/tolerate harsh conditions therefore it is also known as 'starvation fruit'.
It is cultivated in tropical–subtropical countries like;

Table.2. Distribution of *Morinda citrifolia Linn.* across the world

Continent/Country/ Region/States	Distribution	Origin (Native)	Notes	References
ASIA				(Govaerts, 2017)
Bangladesh	✓	✓	-	
British Indian Ocean Territory (BIOT)	✓	✓	-	
Chagos Island	✓	✓	-	
Cambodia	✓	✓	-	
Cocos Island / Keeling Island	✓	✓	-	
India	✓	✓	-	
• Andaman & Nicobar Island	✓	✓	-	
• Assam	✓	✓	-	
• Maharashtra	✓	✓	Wild & Cultivated	(Indian Biodiversity Portal, 2017)
• Karnataka	✓	✓	Wild & Cultivated	
• Tamil Nadu	✓	✓	Wild & Cultivated	
• Kerala	✓	✓	Wild & Cultivated	
Indonesia	✓	✓	-	(Govaerts, 2017)
• Java	✓	✓	-	
• Lesser Sunda Islands	✓	✓	-	
• Maluku Island	✓	✓	-	
• Sulawesi	✓	✓	-	
• Sumatra	✓	✓	-	
Japan	✓	✓	-	
Malaysia	✓	✓	-	
• Peninsular Malaysia	✓	✓	-	
• Sabah	✓	✓	-	

• Sarawak	✓	✓	-	
Myanmar	✓	✓	-	
Philippines	✓	✓	-	
Srilanka	✓	✓	-	
Taiwan	✓	✓	-	
Thailand	✓	✓	-	
Vietnam	✓	✓	-	
Papua New Guinea	✓	✓	-	
Oceania		✓		
Solomon Islands	✓	✓	-	
Australia	✓	✓	-	
• Northern territory	✓	✓	-	
• Queensland	✓	✓	-	
• Christmas Island	✓	✓	-	

Morinda citrifolia L. (Noni) has become naturalized to open shores and been cultivated in some parts of the USA (Mexico—Panama, Venezuela, Surinam, etc,.) and several Caribbean islands (Bahamas, Bermuda, Florida Keys) ((USDA-ARS, 2017 & USDA-NRCS, 2017), & is Invasive and cultivated in many parts of an African country (Prota, 2017).

BOTANICAL DESCRIPTION

Morinda citrifolia L is an evergreen shrub with a stem diameter of 15 centimeters or more and a height of 3–10 m when mature. Its sapwood is soft and yellow-brown. The bark of the plant is comparatively smooth to moderately rough and gray to light brown. Its four-angled, light green leaves are pinnately veined, glossy, and 1.5–2 cm long, attached by stiff petioles. Connate or distinct stipules are 10–12 mm long, and either entire or 2-3 lobed at the apex. Leaf-blades are glabrous and membranous, elliptic–elliptic-ovate, in sizes ranging from 20 — 45 centimeters in length and 7 to 25 centimeters wide. The tubular flowers of *Morinda citrifolia Linn.* (Noni blossoms) are perfect, with 75-90 heads ranging from ovoid to globose. A truncated calyx encloses the peduncle, which is approximately 10 to 30 mm long. The corolla is white, five-lobed, and has a greenish-white tube measuring approximately 7–9 mm long, and oblong-deltates lobes measuring approximately 7 mm in length. The five stamens are barely exserted, and the style measures about 15 mm. Yellowish-white, fleshy, soft syncarpous measure 5-14 cm in length, 3 to 7.5 cm in diameter, and smell fetid when ripe. The brown seeds with a distinct air chamber vary in length between 4 and 9 mm. A deep taproot and extensive lateral roots make this plant similar to citrus and coffee (Rojas-Sandoval J, 2017).

Fig.1. *Morinda citrifolia Linn.* (Noni or Indian mulberry)
(A) *Morinda citrifolia Linn.* Green leaves are opposite and simple; (B) *Morinda citrifolia Linn.* Pinnately veined semi-glossy leaves; (C) *Morinda citrifolia Linn.* Aggregate fruit; (D) *Morinda citrifolia Linn.* bracteate fruit and leaves; (E) *Morinda citrifolia Linn.* conspicuous erect Unripe fruit

MEDICINAL USES

Morinda citrifolia L. has one of many medicinal uses and has been used for centuries for its curative properties to treat various diseases and infections. Various combinations of the whole Noni plant were used by the Polynesians as herbal remedies (Wang, *et al.*, 2002). It does not matter how these medicinal plants are administered, as long as the focus is on their safe and effective use in medicine and complementary & alternative medicine (Souza, *et al.*, 2021). Moreover, the diversity of these plants promotes the discovery of bioactive compounds, mainly from medicinal plants that can be a food source, as well as used for ornamentation and as herbal medicines, as they have bioactive principles (Omar, *et al.*, 2020). It has been reported that the plant has approximately 200 or more phytochemicals that have been isolated and identified from the root, leaf, bark, and fruit, contains antioxidants, dyslipidemic, hypotensive, healing, antibacterial, analgesic properties, as well as it is reputed to have antituberculosis, antidiabetic, anticancer, anxiolytic, antifungal, antimicrobial, and immune-enhancing properties and they also contain Phytonutrients including phenolic compounds, organic acids, and alkaloids. Some members of this family also may have a high toxic potential (Souza, *et al.*, 2021).

Noni fruit juice, a nutraceutical dietary supplement that offers many benefits, is widely sold throughout the world. In addition to treating ulcerations and minor infections, the leaf of this plant is also used to treat broken bones, deep cuts, and wounds (Nagalingam, *et al.*, 2013).

TRADITIONAL MEDICINAL APPLICATIONS

Ayurvedic medicinal properties of *Morinda citrifolia Linn.* (Noni)

Rasapanchaka properties:

- Rasa/taste: Madhura – sweet; Amla – sour
- Guna / physical qualities: Guru– heavy; Snigdha–slimy
- Vipaka / metabolic properties: Madhura– undergoes sweet taste after digestion
- Veerya / potency: Sheeta – cold

Morinda citrifolia L. has been reported that the plant has many medicinal uses; it has been utilized over centuries for its curative properties to treat various infections and diseases by complementary alternative medicinal applications for ADD/ADHD, addictions, allergies, arthritis, emphysematous, brain disease, burns,

malignancy, heart disease, chemical intolerance, myalgic encephalomyelitis, diabetes mellitus, gastrointestinal disorder, adenomyosis, chronic fatigue syndrome, gouty arthritis, high blood pressure, immuno-compromisation, transmissible disease, inflammation, time zone change syndrome, encephalomyelitis disseminata, muscle and joint pain, polio, rheumatism, severed fingers, sinus, veterinary medicine (Nina and Heather, 2002).

Table No.3. Parts of the plant and their activities or proposed effects of *Morinda citrifolia Linn.*

Parts of Plants	**Activities or proposed effects**	
Leaves		Bacterial and parasitic infections, diabetes, tuberculosis, flu, Malaria, urinary tract infection (UTI), abdominal swelling, hernia, Vitamin A deficiency, rheumatism, inflammations, etc.
	Extract	Hypertension
	Flavoring	Wrap around meat for cooking
Bark / Stem		Bacterial infections, Cough, Diarrhea in Infants, Stomach ailments/ ulcers, it also treats badly infected cuts, etc.
	Decoction	Jaundice
	Extract	Hypertension
Root		Treat badly infected cuts
Seeds	Oil	Treat scalp infection (Insecticidal)
Flowers		Sties
Fruits	Unripe	Halitosis, Bacterial & Fungal infections, Menstrual cramps, Arthritis, Ulcers (gastric/oral), Toothache, Indigestion, etc.
	Ripe	Sore throat, Intestinal worm, small and deep cuts or wounds/ bruises, oral infections, loss of appetite, Tuberculosis, sprain, rheumatism, Ulcers, promote lactation, purgatives, brain stimulants, etc.
	Extract:	Hypertension

PHYTOCHEMICAL CONSTITUENTS

Table No.4. Phytochemical constituents present in Morinda citrifolia (Noni)

Parts of Plant	**Phytochemicals present**
Leaves	alkaloids, saponins, phenols, tannins, and steroids.
Roots	Phenols, coumarins, cardiac glycosides, steroids.
Seeds	flavonoids, steroids, phenols, carbohydrates, xanthoproteic, amino acids, ketose sugar, reducing sugar.
Flower	Iridoids and flavonoids.
Fruit	Alkaloid, anthraquinone, carbohydrate, cardiac glycosides, coumarin, emodin, flavonoid, glycosides, lipid, phenols, proteins/AA, reducing sugar, saponins, steroids, tannin, terpenoid

Morinda citrifolia Linn. (Noni/Indian mulberry) has been reviewed of many useful phytochemical constituents: amino acids, fatty acids, lignin, anthraquinones, glycosides, sterols, phenols, esters, flavonoids, etc.

- Leaves

  The ethanolic extracts of Morinda citrifolia L. leaves indicated the existence of alkaloids, saponins, phenols, tannins, and steroids, which have a significant role in pharmacological research (Meng *et al.*, 2017).

  According to Mi Mi Yee (2019), Potassium, calcium, iron, manganese, zinc elements in the ash sample of *Morinda citrifolia Linn.* leaves by Atomic Absorption Spectrometry (AAS) (Perkin Elmer A Analyst 880) are extremely important elements in the human body, out of all the elements, Potassium (K= 111.80ppm) and Calcium (Ca= 103.40ppm) were more predominant than other elements.
- Root

  Phytochemical studies showed that the Roots of *Morinda citrifolia Linn.* showed the presence of phenols, coumarins, cardiac glycosides, steroids in the ethanolic extract, which have a significant role in pharmacological research and is listed in the table below (Meng, *et al.*, 2017)**.**
- Seed

  In the present study, phytochemical constituents were evaluated in several components, including sucrose, flavonoids, steroids, phenols, carbohydrates, xanthoproteic acids, amino acids, ketose sugars, and reducing sugars, of the extract of Morinda citrifolia Linn seeds. Recent reports or studies have shown that *M. citrifolia* phytochemicals have effective nutraceutical and pharmaceutical use (Manju *et al.*, 2017). The whole *Morinda citrifolia Linn* plant can be used to treat a wide range of diseases and has a wide range of anti-infective properties (Manivasagan, *et al.*, 2020).
- Flower

  Morinda citrifolia Linn. (Noni blossoms) were examined for their major phytochemical content. Major phytochemicals in the *Morinda citrifolia Linn.* were quantitatively determined to be the Iridoids — deacetylasperulosidic acid, and asperulosidic acid, and Flavonoids— quercetin-3-*O*-*α*-L-rhamnopyranosyl-(1→6)-*β*-D-glucopyranoside and kaempferol-3-*O*-*α*-L-rhamnopyranosyl-(1→6)-*β*-D-glucopyranoside. The presence of these 4 phytochemicals may substantially contribute to the therapeutic properties of *Morinda citrifolia Linn.*— blossom. Altogether, these compounds are possibly used as markers for identifying and authenticating *Morinda citrifolia Linn.*— blossom substances. DPPH radicals were scavenged more effectively by *Morinda citrifolia Linn.*— blossoms than green tea, indicating strong antioxidant activity. *Morinda citrifolia Linn.*— blossoms did not show cytotoxic or genotoxic effects in toxicological studies (Shixin, *et al.*, 2012).

  Phytochemical studies showed that the Flowers (Noni blossoms) of *Morinda citrifolia Linn.* showed the presence of iridoids, and flavonoids in the aqueous extract, which is listed in the table below.
- Fruit

  Phytochemical Qualitative analysis of *Morinda citrifolia L.*– ethanolic, methanolic, and aqueous extract shows the presence of alkaloids, anthraquinones, carbohydrates, coumarin, emodin, flavonoids, glycosides, phenols, amino acids, saponin, steroids, quinone, tannins, terpenoids, diterpenoids, triterpenoids. Except for anthraquinone, carbohydrate, coumarin, all chemical constituents were present in the aqueous extract and anthraquinone & protein in methanolic extract. The presence of a wide range of bioactive compounds in aqueous and alcoholic extracts is following earlier studies that showed the presence of a broad range of chemical compounds in hydroalcoholic fruit extract of *M. citrifolia L.* The absence of anthraquinone in aqueous extract might be due to poor solubility in water. Phytochemical studies showed that the fruit of *Morinda citrifolia L.* showed the presence of the following phytochemicals in the ethanolic, methanolic, and aqueous extract, which is listed in the table below. (Ranvir, *et al.*, 2017)

  ***Morinda citrifolia* Linn. Fruit Juice**

  A phytochemical analysis determined that both fermented and fresh fruit juice primarily contained groups of large chemical compounds; the most prominent groups found were glycosides, polyphenols, and alkaloids. Moreover, the juice's fermentation state did not influence its composition. Therefore, the fermented juice contained all of the chemical compounds observed in the fresh juice. To end, compounds such as anthocyanin, coumarins, anthraquinones, triterpenoids, steroids, cardenolides, cyanogenic derivatives, free anthracene, C-heterosides, mucilage. Fermented *Morinda citrifolia* shows the potential of producing probiotic enzymes by reacting with lactic acid bacteria, hence, Noni fermented juice can be used as a probiotic juice (Sinha, *et al.*, 2021).

Table.5. Phytochemical constituent present in *Morinda citrifolia Linn.* Fruit fresh & fermented juice

Fruit juice of *Morinda citrifolia Linn.*	**Phytochemical present:**	
	Fresh juice: alkaloid, catechic tannin, gallic tannin, flavonoid, leuco-anthocyanin, saponosids, reducing compounds, O-heterosis	Fermented juice: alkaloids, catechic tannins, gallic tannins, flavonoids, leuco-anthocyanin, saponosids, reducing compounds, O-heterosis

Table.6. Phytochemical in Ethanolic extract of *Morinda citrifolia Linn.*

Sr. No.	**Phytochemical constituent**	**Leaves**	**Root**	**Fruit**
1	Alkaloid	✓	-	✓
2	Anthraquinone	-	-	✓
3	Carbohydrates	-	-	✓
4	Cardiac glycosides	-	✓	-
5	Coumarin	✓	✓	✓
6	Diterpenoid	-	-	✓
7	Emodin	-	-	✓
8	Flavonoids	-	-	✓
9	Glycosides	-	-	✓
10	Phenols	✓	✓	✓
11	Proteins/ AA	-	-	✓
12	Quinone	-	-	✓
13	Saponins	✓	-	✓
14	Steroids	-	✓	✓
15	Tannins	✓	-	✓
16	Terpenoids	-	-	✓
17	Triterpenoid	-	-	✓

Table.7. Phytochemical in Methanolic extract of *Morinda citrifolia Linn.*

Sr. No.	Phytochemical constituent	Fruit
1	Alkaloid	✓
2	Anthraquinone	-
3	Cardiac glycosides	✓
4	Carbohydrates	✓
5	Flavonoids	✓
6	Lipids	✓
7	Phenols	✓
8	Protein/AA	-
9	Reducing sugar	✓
10	Saponin	✓
11	Steroid	✓
12	Tannin	✓
13	Terpenoids	✓

Table.8. Phytochemical in Aqueous extract of *Morinda citrifolia Linn.*

Sr. No.	Phytochemical constituents	Seeds	Flower	Fruit
1	Alkaloid	-	-	✓
2	Carbohydrates	✓	-	-
3	Diterpenoid	-	-	✓
4	Emodin	-	-	✓
5	Flavonoid	✓	✓	✓
6	Glycosides	-	-	✓
7	Iridoid	-	✓	-
8	Ketose sugar	✓	-	-
9	Phenol	✓	-	✓
10	Protein/AA	✓	-	✓
11	Quinone	-	-	✓

12	Reducing sugar	✓	-	-
13	Saponin	-	-	✓
14	Steroid	✓	-	✓
15	Sucrose	✓	-	-
16	Tannin	-	-	✓
17	Terpenoid	✓	-	✓
18	Triterpenoid	-	-	✓
19	Xanthoproteic	✓	-	-

ISOLATED COMPOUNDS

- Leaves

Table No.9. Isolated compounds from *Morinda citrifolia Linn.* leaves (Ali Mohammad, *et al.*, 2016)

Chemical classification	Compounds	Activities
Glycosides	β-D-glucopyranoside	Antimicrobial, heart disease
	Citrofolinin-A	Fixative
	β-D-galactopyranoside	Antidiabetic, antioxidant, antihyperlipidemic
	Kaempferol	Antioxidant
	Quercetin (Rutin)	Anti-inflammatory, Lipoxygenase inhibitor
	Citrifolia side-B	Fixative, Suppressing UVB-induced Activator Protein-1 (AP-1) activity
Lignin	Americanin A	Antioxidant
Sterols	β-sterols	Lower blood cholesterol & blood pressure and stimulate the immune system
Amino Acids	Alanine	Antidiabetic
	Tryptophan	Insomnia, anxiety, and depression
	Threonine	CNS disorder
	Cysteine	Antioxidant
	Isoleucine	Energy production

	Leucine	Dietary supplement
	Phenylalanine	Skin disease use
	Arginine	Heart disease
	Glutamic acid	CNS disorder
	Serine	Brain development & metabolism
	Tyrosine	Antimalarial
	Valine	Immune & Nervous system
	Histidine	Antiulcer, antiallergic & arthritis
	Methionine	Antitoxic
	Proline	Skin infection/disorder, Muscle & Joint strength
	Aspartic acid	Increase muscle size & strength

- Stem/Bark

Table. No.10. Isolated compounds from *Morinda citrifolia Linn.* Stem/Bark (Almeida, *et al.*, 2019)

Chemical classification	**Compounds**	**Activities**
Anthraquinone	Damnacanthal	Antitumor
	1,3-dihydroxy-5-methoxy-6-methoxymethyl-2-methyl-9,10-anthraquinone	Bactericidal and antiviral
	1,3-dihydroxy-5-methoxy-2,6-bi-methoxy methyl-9,10-anthraquinone	
Coumarin	Scopoletin	Anticancer

- Root

Table No.11. Isolated compounds from *Morinda citrifolia Linn.* roots. (Ali, *et al.*, 2016)

Chemical classification	**Compound**	**Activities**
Anthraquinone	Alizarin	Textile dye, antigenotoxic
	Tri Oxy methyl anthraquinone monoethyl ether	—
	Morindone	Dyes, yellow and red colorants used for tapa cloth; anti-bacterial, anticancer.

	Damnacanthal	Anti-carcinogenic, antibacterial, antiseptic
	Rubiadine monomethyl ether	Antiviral
	Morindanidrine	Anti Inflammatory, anti-infection
	Morinda Diol	
	Morenone 1	Anticancer
	Morenone 2	
	Lucidin	Hypovolemia

- Root bark

Table No.12. Isolated compounds from *Morinda citrifolia Linn.* root bark (Mahanthesh, *et al.*, 2013).

Chemical classification	**Compounds**	**Activities**
Anthraquinone	Alizarin	Textile dye (red&yellow), antibacterial
	Trioxy methyl anthraquinone monoethyl ether	—
	Morindone	Natural dye, anticancer & anti-microbial
	Morinda Diol	Anti Inflammatory, anti-infection
	Morindine	Textile dye, Antibacterial
	Rubiadine monomethyl ether	Antiviral
Terpenes	Sorandjidiol	Anti Inflammatory, anti-infection, simple sugars
Monosaccharides	Pentose	
	Hexose	

- Seeds

Table. No.13. Isolated compounds from *Morinda citrifolia Linn.* seeds (Almeida *et al.*, 2019)

Chemical classification	**Compounds**	**Activities**
Fatty acids	Arachidic acid	—
	Lauric acid	Immunostimulant, cytotoxic
	Linoleic acid	Anti-inflammatory

	Oleic acid	Anticancer, hypotensive
	Palmitoleic acid	Immunostimulant
	Stearic acid	

- Flower

Table No.14. Isolated compounds from *Morinda citrifolia Linn.* flower (Noni blossom) (Arunachalam V., 2018).

Chemical classification	**Compound**	**Activities**
Irinoids	De-acetyl Asperulosidic acid	Antioxidant activity
	Asperulosidic acid	
Flavonoids	quercetin-3-O-α-L-rhamnopyranosyl- (1→6)-β-D-glucopyranoside	
	Kaempferol-3-O-α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranoside	

- Fruit

Table No.15. Isolated compounds from *Morinda citrifolia Linn.* Fruit (Ali Mohammad, *et al.*, 2016).

Chemical classification	**Compound**	**Activities**
Alkaloid	Xeronine	Antitumor, Anticancer
Anthraquinone	Alizarin	Natural dye, antigenotoxic
Glycosides	Asperuloside Tetraacetate	Antiobesity
Acids	Caprylic acid (Octanoic acid)	Antifungal
	Caproic acid	Antifungal
	Hexanoic acid	Antifungal, Antioxidant
Sugars	Arabinose	—
	Galactose	—
	Rhamnose	Neuroprotective
	Glucuronic acid	Antioxidant
Esters	Ethyl caproate	Antihypertensive (metabolic disease)
	Ethyl caprylate	Flavoring agent & scent

	Methyl octanoate	—
	Methyl decanoate	Wetting agent

- Whole plant

Table. No. 16. Isolated compounds *Morinda citrifolia Linn.* whole plant (Almeida *et al.*, 2019).

Chemical classification	Compounds	Activities
Alkaloids	Xeronine	Transform molecular structure of the protein, hypertension, atherosclerosis
Coumarin	Scopoletin	Analgesic, control serotonin in the body, treat obesity.

PHARMACOLOGICAL ACTIVITY

Table. No.17. Pharmacological properties of *Morinda citrifolia Linn.*

Leaves	Anticancer, heart diseases, anti-tumor, anti-inflammatory, antioxidant, antibacterial,
Stem	Anticancer, antitumor
Roots	Anticancer, heart diseases, antidiabetic, analgesic, anti-inflammatory
Seeds	Antioxidant
Flowers	Antioxidant
Fruit	Anti-tumor, anti-inflammatory, anti-cancer, antigenotoxic, neuroprotective, antiproliferative, antiepileptic, antidiabetic, immunostimulatory, antidementia, antiparasitic, antioxidant
Nanoparticles	Antibacterial, antitoxic, antimicrobial, antibiotic

- **Anticancer activity**

Leaves

The pharmacological properties of *Morinda citrifolia Linn.* have been studied for several years so that they can be used as an anticancer agent. It has been determined that the basic compounds in *Morinda citrifolia Linn.* are polyphenols and flavonoids. In studies of polyphenols, antioxidant properties have been observed, as well as the anticancer effects (Sharma *et al.*, 2015).

According to Hirazumi et al.,(1994), ethanolic extract of *Morinda citrifolia Linn.* Leaves also reduce the expression of epidermal growth factor receptor (EGFR) or a lung adenocarcinoma biomarker, in albino mice and act on Lewis lung carcinoma in synergetic mice (Hirazumi *et al.*, 1994).

Stem

NDAM, an anthraquinone in *Morinda citrifolia Linn.* stems, has been found to possess remarkable anti-cancer properties. According to in vivo study, NDAM is not toxic to animals when tested. In addition, nor-damnacanthal reduces the viability of breast cancer cells, MCF-7, and MDA-MB231 in vitro. As a result, the tumor size of 4T1 tumors has decreased in vivo and the number of T helper, cytotoxic T, and NK cells has increased. The potential of NDAM for the treatment of breast cancer can be explored further in studies using a larger sample size and different models of antitumor studies (Abu, *et al.*, 2018).

Roots

Morinda citrifolia Linn. is a perennial plant whose roots and leaves contain anthraquinones that are used medicinally to treat numerous chronic diseases such as heart conditions and cancer disease (Anekpankul *et al.*, 2007).

Fruit

The methanolic extract of the *Morinda citrifolia Linn.* fruit has been demonstrated to inhibit the proliferation of a wide variety of cell lines, including human breast adenocarcinoma cells, neuroblastoma cells, human kidney cells, baby hamster kidney cells, and African human epithelial 2 cells (Hep2). The ethanolic extract of Morinda citrifolia has been shown to have antiproliferative properties in B16-F10 melanoma cells (LAN5) (Candida *et al.*, 2014 & Hirazumi *et al.*, 1994).

Leaves and Fruits

Leaves and fruits of *Morinda citrifolia Linn.* have anti-tumor effects through suppression of cell proliferation and immune responses, indicated by subdued cyclooxygenase2 (COX2), an important marker of inflammation, and increased tumor suppressor genes (Lim, *et al.*, 2016). In addition to as a medicinal plant and food supplement, several cancer treatments use the *Morinda citrifolia Linn.* plant. Studies carried out by Lim *et al.* (2016) that ethanolic extract of Morinda citrifolia fruit or leaves suppresses inflammation by suppressing cyclooxygenase2 (COX2), an important marker of inflammation, which influenced the expression of tumor favoring. suppressor genes and the levels of concentrated fruit. It is also possible to prevent the mutation of genes by injecting 10% TNJ® in laboratory animals: carcinogenic compounds form DNA structures known as diffracts that cause mutation if they are not repaired. Inhibition of these structures may be achieved using Morinda citrifolia (Wang MY and Su C., 2001).

- **Antiepileptic Activity**

Fruit

Morinda citrifolia Linn. fruit extract (medicinal plant extract) was administered to animal use for many neuroprotective effects. Ayurvedic preparations have been evaluated for their antiseizure properties against rats subjected to the Maximal ElectroShock (MES) method. A daily dose of, for example, 200 and 400 mg/kg of the fruit extract were administered to the animals for 15 days after the seizure induced by the MES method, and the duration of the different phases of epileptic seizures was recorded and compared with the control group of animals and its possible mechanisms based on inhibition of prostaglandin synthesis and monoamine oxidase enzyme (McClatchey, 2002).

- **Antidiabetic Activity**

Fruit

Many studies have been conducted in response to diabetic patients who are embracing integrative or functional medicine. The antidiabetic effects of Morinda citrifolia have been investigated by Nerulkar *et al.*, (2012) in mice on a high-fat diet (Nerulkar *et al.*, 2012 & Torres MAO *et al.*, 2017). The glucose metabolism was improved through phosphorylation of the FOXO1 transcription factor. Similarly, Morinda citrifolia juice was effective in reducing blood glucose levels in diabetic rats. In combination with insulin, Noni produces a synergistic effect (Horsfall, *et al.*, 2008).

Root

A study by Kamiya *et al.*, (2008) was performed on the hypoglycemia and hepatoprotective properties in diabetes-induced rats. Diabetes induced by administered Streptozotocin. In diabetic experimental animals, Morinda citrifolia juice was administered twice-daily (2 ml/kg) and glibenclamide, a reference hypoglycemic drug, orally for 20 days. Significant reductions in blood glucose levels were noted in both groups.

- **Immunostimulatory Activity**

Fruit

Larger plants contain compounds that are immunomodulators or contain substances that can promote or suppress the body's immune responses, such as cytokine production. The immunomodulatory properties of Morinda citrifolia are related to both cellular and humoral responses. The co-administration of *Morinda citrifolia Linn.* Juice along with immunosuppressant drugs reduce the immunostimulatory result in mice if they corroborate the action of *Morinda citrifolia Linn.* like an immunomodulating agent which can interfere in the immune response under various pathological conditions. Two types of extract such as aqueous and hydroalcoholic extract of *Morinda citrifolia* fruit promote in vitro splenocyte proliferation and enhance B and T lymphocyte activity (Nayak S & Mengi S, 2010).

- **Antidementia activity**

Fruit

Ethanol is extracted from dried fruits of *Morinda citrifolia Linn*. Chloroform, ethyl acetate, and butanol were used to fractionate the sample with a data dose of 100 mg/ml. The result inhibited that *Morinda citrifolia* extracts were able to enhance blood circulation to the rats' brains, increasing their memory (Pachauri, *et al.*, 2012).

- **Anti Inflammatory Activity**

Fruit

Morinda citrifolia Linn. possesses anti-inflammatory properties, which have been demonstrated in both in vivo and in vitro models, involving a wide variety of pathological actions associated with inflammation. *Morinda citrifolia Linn.* juice decreases paw edema directly by inhibiting COX 1 & 2 and decreasing nitric oxide production in the J774.G8 cell line, which is a dose-dependent process that demonstrates the anti-inflammatory action of the plant (Dussossoy *et al.*, 2011). Aqueous extract of *Morinda citrifolia Linn.* fruit possesses anti-inflammatory properties, reduces leukocyte migration.

Leaves

The Serafini *et al.*, (2011) study found that the aqueous extracts of *Morinda citrifolia Linn.* leaves are effective at reducing inflammation, significantly reduced leukocyte migration, and may be used as an alternative to treat pain and inflammation- including those resulting from oxidation.

Roots

Morinda citrifolia Linn root extract with chloroform fraction exhibits anti-inflammatory properties that significantly reduce histamine level and enhance paw edema at a concentration of 3 g/kg. Damnacanthal was used alone and edema was decreased at concentrations of 10–100mg/kg. Likewise, other anthraquinones isolated from the methanolic fraction of the *Morinda citrifolia Linn.* compound fruit extract showed potent anti-inflammatory activity during an induced inflammation model mice (Okusada, *et al.*, 2011).

- **Analgesic activity**

Roots

Morinda citrifolia Linn. roots are used to examine the analgesic activity of the plant. Rats were used to test the analgesic properties of the aqueous extract using a hot plate method. The extract showed activity when infused into the peritoneal at a dose of 800 mg/kg. Naloxone was used as a standard drug in the writhing test as well (Younos, et al., 1990 & Jubilee, *et al.*, 2020).

- **Anti-parasitic activity**

Fruit

Using the aqueous and ethanolic extract of Morinda citrifolia fruits, analyses were carried forward to test their antiparasitic activity against *Ascaridia galli* in chickens at a dose of 50mg/ml and 25mg/ml, respectively. The ethanolic extract had a higher parasite death rate than the aqueous extract and suggested better efficacy at higher doses (Brito, *et al.*, 2009).

- **Antioxidant Activity**

Fruit, Seeds, and Leaves

Morinda citrifolia Linn. is also an excellent source of natural antioxidants. Cell-mediated immunity and antioxidant enzyme activities can be modulated in vitro by the various parts of Morinda citrifolia, such as fruit juice with or without seeds or leaves juice (Ali, 2020).

Leaves

According to Calzuola *et al.* (2006), the hydroalcoholic plant extract of *Morinda citrifolia Linn.* displays antioxidant activity and significant reduction of oxygen superoxide in vitro. The treatment consisted of administering 50 mg/kg of ethanolic extract of *Morinda citrifolia Linn.* leaf to mice with lymphoma for 14 days in an attempt to stimulate the production of antioxidant enzymes such as catalase, glutathione peroxidase, and superoxide dismutase.

Flower

A 500 mg/mL concentration of noni blossom aqueous extract scavenges radicals (mean ± standard deviation) with an activity of 88.11 ± 0.01%, which is greater than green tea at 76.60 ± 0.05% ($P < 0.0001$). According to the study, noni blossoms have an enhanced ability to scavenge the DPPH radical, when compared with green tea, suggesting they might be used as an antioxidant in commercial food products (Arunachalam V, 2018).

NANOPARTICLES

- **CuONPs Antibacterial activity**

The synthesis of Copper oxide (CuO) nanoparticles from the aqueous extract of *Morinda citrifolia Linn.* leaves and study of their antibacterial activities. The high nutritional value of *Morinda citrifolia Linn.* could induce therapeutic effects together with antimicrobial & antioxidant properties. Copper oxide (nanoparticles) based on *Morinda citrifolia Linn.* leaf extract were synthesized by green methods and characterized by X-ray diffraction spectroscopy (XRD), Scanning electron microscopy (SEM), ultraviolet- differential reflectance spectroscopy (UV-DRS), Zeta potential, and Fourier transform infrared spectroscopy (FTIR).

XRD: XRD analysis of CuO nanoparticles confirms the formation of an amorphous orthorhombic structure with an average crystalline size– of 28.2nm

FTIR: FTIR analyzed the aspects of the functional group (aldehydes & ketones) and the chemical affiliation. The absorption peak of CuO is observed at 465 cm^{-1}. Hence, the leaf extracts contain a chemical compound that caps CuO Nanoparticles.

Zeta Potential: zeta potential popularly remains an accepted predictor for a bacterial surface charge. Its potential for CuO nanoparticles is 6.45mv. The potential for CuO nanoparticles for the synthesis of nano-drugs is studied by employing zeta potential.

SEM: SEM analysis shows and confirms the morphology of the prepared crystalline nanoparticles CuO of nearly similar charge and size within 28.2nm. It shows the clear surface choice, hence CuO nanoparticles were synthesized.

UV-DRS: used to monitor the band-gap Eg 2.17ev higher as compared to other bulk values. The sample has strongly measured radiation peek below at 570 nm.

Antibacterial activity:

Nanomaterials, as antibacterial, enhance antibiotic activity. CuO nanoparticles were analyzed for antimicrobial activity by the agarose diffusion method. CuO nanoparticles discharged 253x a lot of ions as compared to Silver nanoparticles (Ag NPS) manufacturing higher antibacterial activity, presumably because of Oxidation. Prepared samples were ascertained that CuO nanoparticles victimized *Morinda citrifolia Linn.* leaf inhibiting higher to *Flavobacterium psychrophilic* bacteria compared to *Enterobacter sp., E. coli,* & *Klebsiella sp.* Hence, CuO nanoparticles can be used to fabricate medicine by ecofriendly modulation or formulation such as mucus, brain, spleen. Thus CuO nanoparticles were one of the important properties which could play an important role in the potential antibacterial mechanism, the effectiveness of nanomedicines (Dayana, *et al.*, 2021).

- **AgNPs Antibacterial activity**

The green chemistry synthesis of Silver nanoparticles (AgNPs) with an extract from distinct parts of *Morinda citrifolia Linn.*, such as fresh leaves (EML), fruit(EMF), and dried seed(EMD). In morphology, the synthesized AgNPs/EM were spherical, with a mode size of 11 nm (AgNPs/EML), 7 nm (AgNPS/EMF), and 3 nm (AgNPs/EMDS). The results obtained from the UV-Vis spectroscopy analysis are consistent with the SPR values obtained at 434, 436, and 438 nm for AgNPs/EML, AgNPs/EMF, and AgNPs/EMDS, respectively.

Morales-Lozoya *et al.* (2021) evaluated the effects of metallic precursor concentration (F or DS in EM) on the physical properties (morphology, size, and polydispersity) of NPs synthesized. Analysis of the FTIR spectrum of each EM and its AgNPs. Alcohols and phenols exhibit vibrations associated with O-H stretching at about 3400 cm^{-1}. Aliphatic C-H stretching vibrations are represented by bands around 2900 cm^{-1}, whereas aromatic C=C stretching vibrations are represented by bands around 1600 cm^{-1}. Bands for C-O stretching are around 1000 cm^{-1}. The above vibration bands are caused by the presence of phytochemical compounds in the EM, which reduce and stabilize AgNPs (Karthik, *et al.*, 2017).

AgNPs can be obtained through biosynthesis, thus reducing the toxic effects of the reagents used in conventional chemical synthesis (Liliana, *et al.*, 2019). By considering this alternative, the antibacterial activity of the AgNPs/EM synthesized with EML, EMF, or EMDS was determined. The antimicrobial activity by agarose well diffusion test was carried out to evaluate the zone of inhibition formed by the bio-AgNPs, both in E. coli (gram-negative) and S. aureus (gram-positive) bacteria.

Antibacterial activity depends on the size of the nanoparticles. Small NPs possess a higher affinity for the cell wall, which makes them easier to penetrate the bacterial cell wall than bigger NPs. Due to the smaller size, AgNPS/EMDS demonstrated higher antibacterial activity than AgNPS/EMF and AgNPS/EML. Antibacterial activity of AgNPs/EMDS is more effective against E. coli as compared to S. aureus.

Ag reacts with the cell wall in higher amounts with a wide surface-volume ratio. The extract alone does not show any antibacterial activity. The difference in the bacteriostatic activity, against *Escherichia coli* and *Staphylococcus aureus*, is likely due to the thickness of the murein layer of the cell wall, present in *Staphylococcus aureus*, which averts the action of bio-AgNPs, on the plasma membrane.

The mechanism of the antibiotic action of the AgNPs, type-Trojan horse, is based on the production of ROS. The type-Trojan horse mechanism involves the intracellular release of Ag-ions from the AgNPs, that interact with the proteins of the respiratory chain of the cell membrane. As a result of this interaction, the intracellular oxygen is reduced, which then increases the production of ROS, resulting in bacterial cell death (Mousavi-Khattat, *et al.*, 2018).

Compared to Staphylococcus aureus, AgNPs/EMDS had higher bacteriostatic activity against Escherichia coli. Comparatively to the other extracts used in this study, EMDS is more effective for the synthesis of AgNPs, since the NPs obtained with it are smaller and have higher bacteriostatic activity. The aforesaid is due to the EMDS chemical composition, in addition to the H_2O solubility of the extracted compounds (soluble sugars & proteins), which serve as a reducing-stabilizing agent. In addition to their biocompatibility and lower toxicity, these bio-AgNPs have the potential to be used to combat problems related to environmental bacterial resistance.

POTENTIAL COMMERCIAL APPLICATIONS

Morinda citrifolia Linn exhibits a wide range of unique and versatile medicinal properties. This species is paramount herbal remedies and dietary or nutritional supplements traded on the global market. Beverages (fermented and fresh juice drinks), powders (from dried fruits), oil (from seeds), and leaf powders are the principal industrial products (Almeida, *et al.*, 2019).

Since the 1990s, products derived from Morinda citrifolia fruit have been commercialized in the United States and have been distributed worldwide. Morinda citrifolia Linn is claimed to have several beneficial effects. In 2003, the European Commission approved the juice of Morinda citrifolia Linn as a novel food (EFSA, 2006). Based on a toxicological assessment, Noni juice was considered safe, except for people with chronic kidney disease, because of its high potassium level stated by EFSA experts (Youngken, *et al.*, 1960).

Morinda citrifolia Linn is frequently utilized as a windbreak to provide support for pepper vines (Ampelopsis Arborea) and as a shade tree in coffee plantations (Tan, 2001). The plants can sometimes be used as ornamentals, however, this practice is not very common because of the strong and offensive odor from its ripe fruit, which tends to attract insects and flies. The roots and bark of *Morinda citrifolia Linn.* were traditionally used in natural dyeing (red and yellow), the trunk is used as firewood, and the leaf is used in cooking (vegetables), wrapping, and flavoring. It has a notable ability to survive in harsh environments even in drought conditions therefore it is also known as “Starvation fruit”.

Morinda citrifolia Linn likely has a relatively low carbon & water footprint compared to other foods. Since there is no known significant damage to air, water, land, soil, forests, etc. cultivation of *Morinda citrifolia* is relatively sustainable (Ethical consumer guide, 2022).

CONCLUSION

Morinda citrifolia is one of the most important medicinal plants that is mentioned in Ayurveda possessing numerous phytochemical and pharmacological properties. Different Bioactive compounds have been isolated from different parts of the plant and have been tested against various properties. Damnacanthal and Morenone 1 & 2 (Roots), Alizarin (Root bark), Scopoletin (Stem), Kaempferol, and Americanin A (Leaves), Asperulosidic acid (Flower), Xeronine (Fruit) are some of the isolated compounds showing potential effects against various activities.

The plant was also tested for its Phytochemical constituents and showed the presence of amino acids, lignins, saponins, flavonoids, anthraquinones, glycosides, etc. Steroids and Cardiac glycosides (Roots), Alkaloids (Leaves), Iridoids and Flavonoids (Flower), Tannins and Coumarins (Fruit) are some of the major phytochemicals that were found to be present in the ethanolic extract of M. citrifolia which has been of interest because of their antiviral, anti-inflammatory, antifungal properties. Besides that, Potassium and Calcium elements were predominantly observed in the plant sample by Atomic Absorption Spectrometry (AAS) method.

The current review discussed the pharmacological activities of M. citrifolia which included antibacterial, antifungal, anticancer, anti-inflammatory, antidiabetic, antiepileptic, immunostimulatory, antidementia, antiparasitic, analgesic, antioxidant effects. The review also focused on the chemical constituents of Morinda citrifolia as a promising medicinal plant for therapeutic purposes in the scientific field.

Copper oxide and Silver nanoparticles have been synthesized using the green synthesis method in the plant sample and showed potential antibacterial and antioxidant properties that were carried out from different parts of the plant like leaves, fruit, and dried seeds. The biosynthesized Mc-Ag NPs and Mc-Cu NPs possess many effective antimicrobial activities against two bacterial strains: *Staphylococcus aureus* (gram-positive) and *Escherichia coli* (gram-negative) and have paved the way in the field of nanomedicine against various effects and from the therapeutic point of view.
Recent findings on M. citrifolia have proved its potential commercial applications such as in the field of beverages (fermented and fresh drinks), powder (dried fruit), oil (seeds). It also has an ornamental application, dyeing, flavoring agent, etc. It has a notable ability to survive in harsh environments even in drought conditions therefore it is also known as "Starvation fruit", thus it will aid in the development of new applications and development of products with minimum adverse effects.

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