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## Wood apple: An underutilized miracle fruit of India

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**Abstract**

Many Indian plants with tremendous medicinal value against various human ailments are still underutilized among which wood apple is one such edible fruit plant. The leaves, bark, roots, fruits and seeds are used extensively in Ayurvedic medicine for the treatment of chronic diarrhea, dysentery and peptic ulcers, as a laxative and to treat myriad ailments. Extensive scientific studies have also validated its ethno medicinal properties and presence of a variety of bioactive compounds which possess anti-hyperglycemic, antidiabetic, anticancer, antimicrobial, hepatoprotective and various other such activities. This review majorly provides information about the nutritional values, phytochemistry, traditional and modern pharmacological aspects of largely underutilized and neglected wood apple.

**Keywords:** Wood apple, ethnomedicinal, phytochemicals, hepatoprotective, ayurvedic

**Introduction**

Wood apple also known as *Feronia lemonia* belonging to the family Rutaceae is one of the hardiest fruits grown in semi-arid and arid regions of India. It is an acidic fruit in unripe condition but gives pleasant flavor when ripe (Das and Das, 2003) [9]. Wood apple is indigenous to South India and Srilanka. It is one of the hard fruit crop found all over the plains of southern Maharashtra, West Bengal, Uttar Pradesh, Chhattisgarh and Madhya Pradesh. Common names in English include wood-apple, elephant-apple, monkey fruit, curd fruit and kathbel. The tree is commonly grown as a border plant in addition to being found in jungles. It is a rare phenomenon to find a well planted wood apple orchard. It is an ideal tree to be exploited for growing in wastelands common in wild dry plains, cultivated along roads, edges of fields and occasionally in orchards (Veeraraghavathatham *et al.*, 1996) [42]. The tree is very hardy, tolerant to draught and salinity and thrives better in deep, well drained soils of dry forests. The wood apple fruits are round to oval, 2 to 5 inches (5 - 12.5 cm) wide with a hard, woody, greyish-white, scurfy rind of about ¼ inches (6 mm) thick. Each fruit weighs about 150 to 500 g. The pulp represents 36 per cent of the whole fruit. There are two types of wood apple *viz.*, larger one with more sweet and smaller one with less sweetness. The fruit pulp is brown colour, mealy, odorous, resinous, astringent, acid or sweetish with numerous small white seeds scattered through it. The seeds contain non-bitter oil and are high in unsaturated fatty acids (Singh *et al.*, 2009) [38]. The unripe wood apple pulp is of pale gold color. As wood apple ripen, greenish white shell develops into a tough, brown speckled wooden shell that looks and feels similar to tree bark. Ripe fruits also emit a sugary yet musky aroma. Ideal, fully ripe wood apples are light brown to toffee brown color. Wood apple pulp has a remarkably long shelf life of two months if refrigerated. The quality of fruits is laid on its physico-chemical characteristics and nutrient composition which decides its consumer acceptability and marketing strategy (Shyamala Devi and Kulkarni, 2018) [37]. Wood apple has got tremendous medicinal potential. Every part of the fruit has got its medicinal property. The fruit is much used in India as a liver and cardiac tonic and when in unripe state, as a means of halting diarrhea and dysentery and for effective treatment for hiccup, sore throat and disease of the gums (Kerker *et al.*, 2020) [36]. Fruit pulp has anti-inflammatory, antipyretic and analgesic activity. In addition to this, wood apple also has antioxidant, anticancer, antidiabetic, antimicrobial and hepato-protective activity (Vidhya and Narain, 2011) [43]



**Fig 1:** Wood apple fruit

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Wood apple has an excellent flavour and nutritive value which makes this fruit to have a great potential for value addition especially in beverage industry. The fruit pulp can be used for the preparation of different value added products like preserve, candy, sherbet, juice, chutney, jam, jelly and squash. Wood apple beverage produces cooling effect in the same way as bael. Some people eat raw wood apple pulp with or without sugar (Anuradha, 2005) [3]. Many of the wood apple products are new to the consumers, since efforts need to be made to introduce them in the market and to evaluate consumer acceptance and economic viability of commercialization of such products. This not only will open new avenues as a means of augmenting the utilization of high yielding nutritious fruit to the best possible extent but will also give a fillip to the establishment of wood apple processing industry (Chandana, 2016) [6].

### Nutritional composition and phytochemicals

A variety of bioactive compounds like phenols, flavonoid, alkaloids, terpenoids, tannins, saponins, fat steroids, glycosides, gum mucilage and fixed oil have been reported in different extracts of wood apple which are responsible in various pharmacological activities of the fruit. Various parts of the plant such as its roots, fruits, bark and the leaves have been used to treat different ailments such as diarrhea, dysentery etc. since ancient times. Fruits are important food as they supply vitamins, minerals, carbohydrates, protein etc. that is why fruits are called protective foods (Srivastava and Kumar, 2002) [40]. The dietary and nutritional surveys have shown that people in India are suffering from vitamin A and vitamin C deficiency, besides minerals like calcium and iron which makes fruits to be an important part of our daily diet. Ripened fruits contain sour, sweet, aromatic refreshing pulp with an excellent flavour and are highly valued for its therapeutic value in Ayurveda and are known to cure liver disorder, diarrhoea and dysentery (Rao *et al.*, 1989) [34]. The pulp in ripened fruit is about 70% of total weight and seeds are embedded in the pulp. It contains about 70% moisture, 7.3% protein, 0.6% fat, 1.9% mineral matter, 2.3% acidity, 7.2% sugars, 0.07% iron, 0.08% phosphorus and it is rich source of riboflavin (77 mg / 100 g) and calcium (0.17%) (Chundawat, 1990) [8]. The ripe fruits contain sweet aromatic pulp, which has 74% moisture, 7.3 g protein, 15.5 g carbohydrates, 170 mg riboflavin, 2 mg vitamin C per 100 g of pulp and minerals, especially 0.17% calcium 0.08% phosphorus and 0.07% iron. The fruits contain phytochemicals (polyphenols, phytosterols, saponins, tannins, coumarins, triterpenoids), vitamins, amino acids etc.

**Table 1:** Chemical composition of wood apple

Characters	Composition
Moisture (%)	72.00 ± 2.04
Protein (%)	7.14 ± 0.24
Fat (%)	1.45 ± 0.09
Carbohydrates (%)	7.24 ± 0.12
Ash (%)	4.98 ± 0.02
Calcium (%)	0.12 ± 0.07
Phosphorus (%)	0.07 ± 0.002
Iron (%)	1.0 ± 0.03

(Pal *et al.*, 2019) [25].

The presence of various phytochemical compounds such as polyphenols, flavonoid, (imperatorin, bergapten and xanthotoxin), alkaloid, steroid and amino compounds which

possess antimicrobial, anti-inflammatory, diuretic, antiasthma and analgesic potential have been reported in the leaves of the wood apple. Further, 32 compounds were isolated and identified in oil out of which its major components were methyl chavicol (27.2%), thymol (24.4%), t-anethol(10.94%), p-cymen-7-ol (7.3%) and 1,4-dimethoxy-2-allylbenzene (Ahmad *et al.*, 1989) [1]. Apart from volatile oils, C-flavanoid glycosides have also been isolated from the leaves including orientin, vitexin, isovitexin and saponarin being the major components. Leaves are also reported to contain coumarins. Other coumarins include P-amyrin, lupeol, xanthotoxin, umbelliferone, isopimpinellin and imperatorin (El-Fishawy, 1994; El Khisy *et al.*, 1994) [12, 13].

Similarly, seeds of wood apple contain several phytochemical compounds such as psoralen, bergapten, orientin, vitexin and saponarin which are used in the treatment of many diseases such as acidity, ulcers, urinary disorders, treatment of piles or haemorrhoids, diarrhoea, ringworm and other chronic skin infections (Intekhaband Aslam, 2009) [16]. However, Bhanupriya *et al.*, (2016) also reported the presence of various anti-nutritional factors such as tannin, saponins, oxalate and phytate which interfere in absorption and metabolism of many nutrients such as amino acid, vitamins and minerals.

Likewise, many reports have been published citing various important compounds in the bark of wood apple such as Muthulakshmi *et al.*, (2012) [24] reported presence of phenol, nitrogen compound, vitamin compounds in the methanolic extract of the bark of wood apple which possess antioxidant, antimicrobial, anti-inflammatory, colour pigment, diuretics, antiasthmatic activity. In another study, it was reported that the methanolic extracts of bark of the fruit contain stanol, geranyl, umbelliferone, marmin, marmesin, aurapten, bergapten, isopimpinellin and peronol and exhibit pharmacological properties against various diseases (Jain *et al.*, 2012) [19].

### Ethno medicinal uses of wood apple

Importance of wood apple also lies in its curative properties, which makes the tree as one of the most useful medicinal plants of India. It has great demand in native system of Ayurvedic medicine. This plant is prescribed as a traditional medicine for the treatment of various ailments (Khare, 2007) [21]. It has a wide range of biological activities *viz.*, adaptogenic activity, hepatoprotectant and used against blood impurities, leucorrhoea, dyspepsia and jaundice. In India, fruit is used as a liver and cardiac tonic, in diarrhoea and dysentery, an effective treatment for hiccup, sore throat and gum diseases (Anitha *et al.*, 2016) [2].

The fruits and leaves are used in herbal preparations. It has curative value for various diseases of bones and joints, bilious diseases, prevention of capillary bleeding, cold, influenza, piles, dysentery, habitual constipation and scurvy. The unripe fruits which are sour, aromatic, astringent, constipating and alexipharmic by nature are used in the treatment of diarrhoea, pharyngodynia, pruritus in Ayurvedic medicinal system (Diengngan and Hasan, 2015) [11]. Generally, it is employed alone or in combination with *Aegle marmelose* and other medicine in the treatment of diarrhoea and dysentery (Panda, 2000) [26]. Pulp of the fruit mixed with cardamom, honey and cumin seeds are given as a medicine to cure indigestion, diarrhoea, piles, cirrhosis of liver in children due to malnutrition etc. Ripe pulp is reported to be rubbed to alleviate pain caused by venomous strings (Pullaiah, 2006)

[31]. It has also been reported to be a curative agent for the treatment of asthma, tumours and as a 'liver tonic' in the traditional systems of medicine (Pandey and Dravyaguna, 2001) [27].

The Ayurveda also mentions their use in the treatment of various ear ailments like earache, putikarnaand karnsarva. Freshly collected luke warm juice of kapittha (*Feronia limonia*), matulunga, smgvera is used for the treatment of ear ache (Dash and Kashyap, 1984) [10]. A useful remedy for the treatment of piles and hiccough mentioned in *Charakasamhita* (An Indian medicinal treatise) recommends the soup of kapittha and bilva (*Aegle marmelos*) (60-120 ml) to treat piles and the juice mixed with Pippli (*Piper longum*) and honey in hiccough (Khare, 2004) [22].

Being aromatic, astringent, carminative, purgative and sudorific in nature the leaves of the wood apple has been used in Ayurveda for the treatment of various ailments such as gastropathy, anorexia, diarrhoea, indigestion, flatulence, vomiting, hiccough and other troubled conditions of vatta and cardio tonic and in management of other cardiac debilities (Parajapati *et al.*, 2003) [28]. Tribal of Saurashtra region, Gujarat (Western India) apply the paste of wood apple leaves topically for the treatment of piles or haemorrhoids while the tribal population of Maharashtra (Western India) use leaf powder/extract to treat acidity/ulcers (Kamble *et al.*, 2010; Jadeja *et al.*, 2006) [20, 6].

### Pharmacological activities of wood apple

A variety of pharmacological activities such as antitumour, antimicrobial, antidiabetic, anti-inflammatory, analgesic, antioxidant, hepatoprotective, antimutagenic, antimalarial and other activities has been exhibited by the extracts and pure compounds derived from wood apple (Srivastava *et al.*, 2019) [41]. A summary of the findings of these studies performed is presented below:

#### Anti-tumour activity

Cancer is associated with abnormal cell growth with the potential to invade or spread to other parts of the body. Saima *et al.* (2000) [35] reported that an acidic heteropolysaccharide isolated from the tropical angiosperm *Feronia limonia* showed some significant *in vivo* carcinoma cell growth inhibition in the murine model. Similarly in another study, the antitumor activity of the ethanolic extracts of 12 medicinal plants of Bangladesh, including the vincristine-vinblastine producing *Catharanthus roseus* was studied using the potato disk bioassay technique. In this study, *Feronia limonia* showed 16.1% inhibition of crown gall tumors but found to be inactive because of the insignificant < 20.0% inhibition of tumors (Haque *et al.*, 2000) [15].

#### Antimicrobial activity

One of the major causes of morbidity and mortality in immune compromised patients is pathogenic microorganisms. Microorganisms like bacteria tend to become resistant to drugs, coupled to side effects of some antibiotics. This invites a vital need to control microbial infections using appropriate antimicrobials devoid of side effects. There is evidence that the ethanolic extract of wood apple leaves showed antibacterial activity against variety of bacteria such as *Shigella boydii*, *Shigella dysentery* and *Shigella flexnerii* and demonstrated the reduction in severity and frequency of diarrhoea (Bellah *et al.*, 2015) [5]. Kumar *et al.* (2010) [40] extracted the essential oil from the leaves of wood apple and

studied for chemical constituents and antibacterial activity against different clinically isolated Gram positive and Gram negative bacterial strains by disc diffusion and minimum inhibitory concentration assay. The GC and GC-MS analysis revealed that the leaf essential oil of wood apple contained fourteen compounds representing about 98.4% of the total oil. The major chemical compounds identified were Eudesma-4, 11-diene (46.3%), carvacrol (29.6%) and 1,5-cyclodecandine (13.4%). Researchers reported that the essential oil exhibited moderate antibacterial activity against all the tested bacterial strains with MIC values ranging from 125 to 500 µg/mL except *Proteus mirabilis*. In a recent study, the protein hydrolyze of wood apple seeds have also shown antimicrobial activity at 300 (mg/ml) against *Salmonella typhi*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Klebsiella pneumonia* (Sonawane *et al.*, 2013) [39].

#### Antidiabetic activity

Diabetes mellitus is a chronic metabolic disorder characterized by raise of blood glucose levels known as hyperglycaemia and other late complications such as retinopathy, nephropathy. Due to its fatal complications, diabetes is the seventh leading cause of death in the human society. Gupta *et al.* (2009) [14] evaluated the anti-diabetic activity of ethanolic extract wood apple fruits on blood glucose level in normal and streptozotocin induced diabetic rats. Results indicated that the blood glucose levels was significantly lowered in fasted, fed and streptozotocin induced diabetic male albino rats. It also improved the oral glucose tolerance. Marked degranulation in B-cells of extract treated rats, associated with the blood glucose lowering was observed. It was assumed that extract probably lowered the blood glucose concentrations by stimulating insulin secreting activity. Similarly in another study antidiabetic activity of wood apple fruits was analyzed in streptozotocin induced diabetic rats. Phytochemical screening at preliminary stage revealed the presence of high content of flavonoid compounds in methanolic extracts of wood apple. Treatment of diabetic rats with the extract at the dose of 200 and 400 mg kg<sup>-1</sup> for 30 days showed significant decrease in blood glucose levels and also decreased levels of serum cholesterol, regain of body weight in the subjects (Priya *et al.*, 2012) [30]. Similar results were also reported by Putta and Kilari (2014) [32], who also found significant antihyperglycemic, antihyperlipidemia activity of methanolic pericarp extracts of wood apple and significant protection against damage to kidney in streptozotocin induced diabetic rats. The authors suggested that the above mentioned activity could be due to its antioxidant potential.

#### Antioxidant activity

Antioxidant activity and antimutagenic effect of phenolic compounds in wood apple ripe fruit pulp was studied by analyzing the total phenolic content by Folin-ciocalteu method and antioxidant activity by the DPPH assay. The phenolic glycoside extract presented higher (229.0 mg/g, GAE) total phenolic content followed by phenolic ester (37.5 mg/g) and free phenolics (11.0 mg/g), whereas the antioxidant activity was found to be 88.7%, 11.8% and 3.8% respectively. Phenolic glycoside extract showed antioxidant activity higher than that of commercial antioxidant trolox (64.6%) and butylated hydroxytoluene (83.2%) (Phapale and Thakur, 2010) [29].

### Hepatoprotective activity

In a study aimed to evaluate the hepatoprotective potential of a methanolic extract and of marmesin isolated from the root bark of wood apple. Activity levels of aspartate aminotransaminase (AST) and alanine aminotransaminase (ALT), cell viability and cell death were evaluated in Hep G2 cells (human liver hepatoma cells) treated with CCl<sub>4</sub> in the presence or absence of wood apple extract or marmesin. It was found that the *in-vitro* co-supplementation of methanolic extract or marmesin significantly minimized alteration in levels of AST and ALT and improved cell viability. Oral administration of methanolic extract or marmesin significantly prevented CCl<sub>4</sub>-induced elevation in the plasma markers of hepatic damage and hepatic lipid peroxidation and a decrease in hepatic antioxidants. In-vivo hepatoprotective potential of methanolic extract and marmesin was evident from the minimal alterations in the histoarchitecture of liver (Jain *et al.*, 2012)<sup>[19]</sup>.

### Neuroprotective activity

Rakhunde *et al.* (2014)<sup>[33]</sup> studied the effect of methanolic extract of wood apple fruit (250 mg/kg, 500 mg/kg body weight) and Vitamin E as reference standard drug on 30 min induced ischemia, followed by reperfusion by testing the neuro behavioral tests. The biochemical parameters such as catalase, superoxide dismutase (SOD), malondialdehyde and nitric oxide were also measured in animals brain in control and treated rats. Authors found that the methanolic extract of wood apple fruit (250 mg/kg, 500 mg/kg body weight) treated groups showed a statistically significant improvement in the neurobehavioral parameters such as motor performance. The biochemical parameters in the brains of rats showed a significant reduction in the total nitrite ( $P < 0.01$ ) and lipid peroxidation ( $P < 0.01$ ), also a significant enhanced activity of enzymatic antioxidants such as catalase ( $P < 0.01$ ) and SOD ( $P < 0.05$ ), hence suggested the neuroprotective and antioxidant activity of wood apple on ischemia reperfusion induced brain injury.

### Conclusion

Several published studies indicate that the consumption of wood apple could ameliorate a wide range of illnesses. A fruit with such diverse values and immense capabilities indicates its potentialities for processing commercially into valuable products like jams, jellies, sweets, savory chutneys and juice (Chopra and Singh, 2001)<sup>[7]</sup>. The value added products of these fruits have expected to catch the national and international markets if it is properly focused. But the fruit is being utilized to a limited extent in the preparation of products. The review paper mainly emphasizes on the nutritional, food and medicinal value of this underutilized fruit and envisages enormous scope for future research and further pharmacological investigation on wood apple.

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