

Review Article

A Comprehensive Review of An Important Medicinal Plant – *Averrhoa carambola* L.

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ABSTRACT: The use of plants as medicine is as old as human civilization. People of all ages in both developing and developed countries use plants in an attempt to cure various diseases and to get relief from physical sufferings. Natural products are a source for bioactive compounds and have potential for developing some novel therapeutic agents. *Averrhoa carambola* L., which is popularly known as the “Star Fruit” or “Kamrakh”, has various medicinal uses viz. antipruritic, antipyretic, anthelmintic, anti-inflammatory, anti-ulcer, antimicrobial etc. Over the past decades, many reports have appeared in mainstream scientific journals describing its nutritional and medicinal properties. The available literature on this plant divulges that it contains many phytoconstituents including tannins, terpenoids, saponins, flavonoids etc., some of which have proven pharmacologically to be medicinally significant. Fruits of *A. carambola* L. are a very good source of natural antioxidants due to the presence of L-ascorbic acid, (-)-epicatechin and gallic acid. It is also very rich in dietary fibers, especially insoluble fibers. The present review summarizes the information concerning the phytochemistry, pharmacology and toxicological studies of *Averrhoa carambola* L.

KEY WORDS: *Averrhoa carambola* L., starfruit, Kamrakh, medicinal uses, pharmacology, phytochemistry

INTRODUCTION

The Oxalidaceae family possesses seven genera representing more than two hundred species which are distributed principally in the tropical and subtropical regions of the world.^[1] The genus *Averrhoa* contains two species: bilimbi (*Averrhoa bilimbi* L.) and carambola (*Averrhoa carambola* L.). Carambola is also known as star fruit and is considered as the more important of the two species. The fruit is cultivated extensively in India and China.^[1] Selection and improvement of cultivars was initiated in Florida in 1935^[2] and by 1985, the fruit had attained the status of a popular commercial crop in the United State.^[3]

Averrhoa carambola L. has travelled sufficiently to acquire a number of regional names in addition to the popular Spanish appellation, which belies its Far Eastern origin. In the Orient, it is usually called *belimbing*, *belimbing* or *belimbing manis* (“sweet belimbing”) to distinguish it from the bilimbi or *belimbing asam*, *A. bilimbi* L. In Ceylon and India, the carambola has the alternate names of *kamaranga*, *kamruk* or other variants

of the native *kamrakh*. In Guyana, it is five fingers; in the Dominican Republic, it is *vinagrillo*; in Haiti, *zibline*; in some parts of the French Antilles, *cornichon*; in El Salvador, *pepino de la India*; in Surinam, *blimbing legi* or *fransman-birambi*. Venezuelans call it *tamarindo chino* or *tamarindo dulce*.^[4]

Botanical Description

The carambola tree is slow-growing, short-trunked with a much-branched, bushy, broad, rounded crown and reaches 20 to 30 ft (6-9 m) in height. Its deciduous leaves are spirally arranged and alternate, imparipinnate, 6 to 10” (15-20 cm) long, with 5 to 11 nearly opposite leaflets, ovate or ovate-oblong, 1 1/2 to 3 1/2” (3.8-9 cm) long; soft, medium-green, and smooth on the upper surface, finely hairy and whitish on the underside. The leaflets are sensitive to light and more or less inclined to fold together at night or when the tree is shaken or abruptly shocked. Small clusters of red-stalked, lilac, purple-streaked, downy flowers, about 1/4” (6 mm) wide, are borne on the twigs in the axils of the leaves (Plate 1A). Fruits are oblong, longitudinally 5- to 6-angled, 2 1/2 to 6” (6.35-15 cm) long and up to 3 1/2” (9 cm) in diameter, have thin, waxy, orange-yellow skin and juicy, crisp yellow flesh when fully ripe (Plate 1B). Slices cut in cross-section have the form of a star (Plate 1C). The fruit has a pronounced oxalic acid odor and the flavor ranges from very sour to mildly sweetish. The so-called “sweet” types rarely contain more than 4% sugar. There

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may be up to 12 flat, thin, brown seeds 1/4 to 1/2" (6-12.5 mm) long or none at all.^[4-7]

Classification

Division : Spermatophyta
 Sub-division : Angiospermae
 Class : Dicotyledonae
 Sub-class : Polypetalae
 Series : Disciflorae
 Order : Geraniales
 Family : Oxalidaceae
 Genus : *Averrhoa*
 Species : *carambola*

Distribution

The carambola is believed to have originated in Ceylon and the Moluccas^[4] but it has been cultivated in Southeast Asia and Malaysia for many centuries. It is commonly grown in the provinces of Fukien, Kuangtung and Kuangsi in Southern China, in Taiwan and in India. It is rather popular in the Philippines and Queensland, Australia and moderately so in some of the South Pacific islands, particularly Tahiti, New Caledonia and Netherlands New Guinea and in Guam and Hawaii^[4] The plant is found throughout India,^[1] particularly in Gujarat and Maharashtra states. It is also cultivated throughout the tropics and may be a native of Malaysia.^[6]

PROPAGATION

The carambola is widely grown from seed though viability lasts only a few days. Only plump, fully developed seeds should be planted. Seedlings are highly variable. It may also be propagated by air layering.^[6] However, root formation is slow and later performance may not be wholly satisfactory. Inarching is successful in India, shield-budding in the Philippines and the Forkert method in Java.^[4] Trees can be top-worked by bark-grafting, a popular technique in Java. For mass production, side-veneer grafting of mature, purplish wood, onto carambola seedlings gives best results for most workers.^[4]

Averrhoa carambola L. is also propagated using plant tissue culture techniques. The *in vitro* culture studies with *Averrhoa carambola* L. indicated that the different explants *viz.* cotyledon, hypocotyl, axillary bud and radicle obtained from *in vitro* grown seedling showed variable responses on Murashige and Skoog (MS) and Gamborg (B5) media supplemented with 2,4-Dichlorophenoxy acetic acid (2,4-D).^[8] Multiple shoots and adventitious shoot buds were obtained from various explants inoculated on 1/2 MS medium fortified with BAP (0.2-1.0mg/l) except from cotyledon supplemented with BAP (0.2mg/l).^[8] A maximum number of shoots was obtained from axillary buds inoculated on

1/2 Macro MS supplemented with BAP.^[8] According to Prashantha *et al.*^[9] sweet carambola can be propagated by nodal explants from seedlings cultured on Murashige and Skoog medium containing promoting agents. The best combination was found to be 2.0 mg/l benzylaminopurine and 0.2 mg/l naphthylacetic acid.

Rapid propagation of *A. carambola* was optimized using nodal segments as explants and zeatin (1.0 mg l⁻¹) as PGR.^[10] The MS medium supplemented with 0.5 mg l⁻¹ benzyladenine, 0.2 mg l⁻¹ NAA and 0.2 mg l⁻¹ gibberellic acid was optimal for the plantlet growth.^[10] A protocol was also developed from *Averrhoa carambola* L. endosperm for *in vitro* culture. Endosperm inoculated on MS medium supplemented with 2.0 mg/l 2,4-D and 0.2 mg/l benzyladenine gave the highest callus induction rate (94.7%), which was subcultured on MS medium.^[11] The optimal medium for multiplication of plantlets was MS supplemented with 2.0-2.5 mg/l zeatin and 0.05 mg/l NAA.^[11] Khalekuzzaman, *et al.*^[12] micropropagated the plant from nodal explants through axillary branching on MS medium supplemented with 1.0 mg l⁻¹ benzyladenine (BA) and 1.0 mg l⁻¹ Kinetin. Regenerated shoots were rooted by treating them with auxins and best root induction (70%) was observed in half-strength MS medium supplemented with 0.5 mg l⁻¹ Indole-3-butyric acid (IBA). Rooted plantlets were successfully established in soil.

A rapid one step procedure has been developed by Islam *et al.*^[13] for inducing direct shoot organogenesis in cultures of *Averrhoa carambola* L. Development of shoot buds occurred within four weeks of culture from intact seedlings raised on MS medium supplemented with BA (2.0 mg/l) was found to be the optimum. Addition of 0.2 mg/l IAA further increased shoot proliferation efficiency.

PHYTOCHEMISTRY

p-Anisaldehyde^[14] and β -sitosterol^[15] were isolated from carbon tetrachloride and chloroform soluble portion of the methanol extract of stem bark of *Averrhoa carambola* L.^[15] A preliminary phytochemical analysis of carambola fruits by Thomas *et al.*^[16] indicated the presence of saponins, tannins and flavonoids. Nordby and Hall^[17] reported that the major sterols present in the fruits of carambola are β -sitosterol, campesterol and isofucosterol; it also contained the four major plant fatty acids – palmitic, oleic, linoleic and linolenic acid.

Fruits of *Averrhoa carambola* L. are a very good source of natural antioxidants.^[18] They show the presence of L-ascorbic acid, (-) epicatechin and gallic acid in gallotannin forms.^[18] They also contain oxalic acid, tartaric acid, citric acid, α -ketoglutarate, succinate and trace of fumaric acid.^[14] According to Patil *et al.*^[19] the content of reducing sugars,

total sugars, soluble proteins, amino acids and oxalic acid increased with maturity of the fruit.

The cell walls of carambola fruit are comprised mainly of cellulose (60%) and hemicellulose (27%), with pectin polymers accounting for only 13 %. The carbohydrate portion of carambola cell wall is comprised mainly of cellulose (60%) and hemicellulose (27%), with pectin polymers accounting for only 13 %.^[20] The major classes of aroma-active volatiles that contribute to the fruity aroma were the esters, aldehydes, alcohols, ketones and isoprenoids, which contribute green and sweet notes of fruit aroma.^[21]

Carambola fruits are rich in dietary fiber, especially insoluble fiber and contains a high concentration of water-insoluble fiber-rich fraction (50.8 g/100g of pomace dry weight), which is predominate fiber fraction (~80% of the total dietary fiber).^[22]

PHARMACOGNOSY

A pharmacognostic profile of any plant helps in identification as well as in standardization of the quality and purity of the plant drug. Thomas *et al*^[6] reported a detailed pharmacognostical evaluation of *Averrhoa carambola* L. fruits which included examination of morphological and microscopical characters; physicochemical properties, phytochemical analysis and fluorescence study.

The fruit is oblong, longitudinally 5-angled, ripe fruits are golden yellow coloured, mildly sweet taste with aromatic odor. The length of the fruit ranges from 7.13 - 10.17 cm and the diameter of the fruits ranges from 4.08 - 5.45 cm. there may be 2 to 3 flat thin brown seeds or none at all.^[16] The outline of transverse section shows star shape. The pericarp shows two distinct regions; exocarp and endocarp. Exocarp is the outermost layer of fruit made up of thin rectangular cells with simple and glandular trichomes and three to four layers of hypodermal collenchyma. Endocarp consists of many layers of thin compactly arranged parenchymatous cells with large lysigenous cavities. The study of powdered fruits showed simple trichomes, fragments of parenchyma with lysigenous cavity, fibers, tannin filled cells, collenchymatous cells and vessel with spiral thickening.^[16] According to authors, the presence of trichomes and large oval lysigenous cavities can be used as anatomical markers to identify and check for adulteration/purity of drug.^[16]

The total ash, water soluble ash and acid insoluble ash of fruit powder was reported to be 6.97%, 0.77% and 0.40% respectively. The aqueous extractive value was found to be higher than alcohol. The powdered fruit showed characteristic fluorescence under ordinary light and ultraviolet light.^[16]

COMMERCIAL USES

The ripe fruit may be processed into fermented or unfermented drinks, jam or jelly, or can be eaten fresh or as dessert. The unripe fruit may also be eaten as vegetable. The sweet type is processed into wine in Surinam. In South China, carambola fruits are preserved in thin packages and exported to other countries.^[23] The fruit is a potential source of pectin, which was analyzed for checking the ability of the fruit to make wine.^[23]

MEDICINAL USES

The leaves of *A. carambola* L. are antipruritic, antipyretic, anthelmintic and are also useful in scabies, various types of poisoning, intermittent fevers and intestinal worms. It has also been reported to be useful for treating fractured bones although the authors do not explain its use. The leaves have been eaten as a substitute for sorrel.^[6] In Brazil, the leaves are recommended to treat diabetes.^[24] Treatment with hydroalcoholic extracts of the leaves resulted in reduction in fasting glycemia, which was not mediated by an inhibition of hepatic gluconeogenesis and / or an increased glucose uptake by muscles.^[25] Hydro alcoholic extracts of the leaves also showed anti-ulcer activity, with a different mechanism of action for the anti-ulcerogenic activity. As hydro alcoholic extract contains triterpenes, flavonoids, and mucilage, the partial anti-ulcer activity could be due to their effects.^[26] The mucilage present in hydro alcoholic extract could act directly to protect the gastric mucosa, avoiding gastric damage induced by necrotizing agents.^[26] Aqueous extract of the leaves act as an agent that strongly depresses the heart rate and the myocardial contractile force.^[27] The active compound has not been identified, but the action on L-type Ca²⁺ channels is important to explain the mechanism of action of this plant on the mammalian atrial myocardium.^[27]

In India, the ripe carambola fruit or its juice may be taken to counteract fever.^[6] A salve made of the fruit is employed to relieve eye afflictions.^[6] In Brazil, the carambola is a recommended diuretic for kidney and bladder complaints.^[6] In Chinese Materia Medica it is used to quench thirst, increase the salivary secretion and in fever.^[6] The fruits are useful in diarrhoea, vomiting, hyperdipsea, haemorrhoids, intermittent fever, hepatodynia, scabies and various kinds of poisoning and general debility.^[5] The fruit is sour, astringent to the bowels, allays thirst and is very useful for the treatment of intestinal worms.^[5] However, the fruits are not advised in cases of acidity, peptic ulcers, gout arthritis, skin diseases etc.^[5] The ripe fruit is a good remedy for bleeding piles, particularly for internal piles.^[5] It is also useful in relieving thirst and febrile excitement.^[6] The dried fruit is given in fevers; it is cooling and possesses antiscorbutic properties. It is considered as one of the best Indian cooling medicines.^[6]

PHARMACOLOGICAL PROFILE

Leaf

Cabrini *et al.*^[28] reported that ethanolic extracts from *A. carambola* L. leaf and its butanol, ethyl acetate and hexane fractions are effective in reducing croton oil-induced ear edema and cellular migration in mice. These results support the popular use of this plant for skin inflammatory disorders. A large group of natural substances has demonstrated anti-inflammatory activity. As previously shown, *A. carambola* is rich in flavonoids and tannins^[16] and particularly with flavones.^[28] Although the flavonoids evaluated in this study were ineffective, it would be interesting to determine the potential activity of the other compounds from the plant in order to elucidate the mechanism by which the plant influences the inflammatory process.^[28] It is also possible that these high flavonoid contents may act in a synergistic manner with other *A. carambola* components to achieve these bioactivities. Ferreira *et al.*^[25] reported that the reduction of fasting glycemia promoted by the treatment with hydroalcoholic extracts of the leaves was not mediated by an inhibition of hepatic gluconeogenesis and/or an increased glucose uptake by muscles.

Stem

Sripanidkulchai *et al.*^[29] have reported that stem extracts of *A. carambola* L. inhibited the growth of *Staphylococcus aureus* (MIC - 15.62 mg/ml or less) and *Klebsiella* sp. (MIC - 125 mg/ml). These authors also reported that stem extracts of *A. carambola* L. inhibited rat paw inflammation induced by carrageenan. Intraperitoneally, their anti-inflammatory effects were comparable to that of acetylsalicylic acid .

Fruits

Chau *et al.*^[30] reported that pomace of *Averrhoa carambola* L. was found to possess a high level of insoluble fiber-rich fractions (FRFs) including insoluble dietary fibers, alcohol-insoluble solid, and water-insoluble solid (46.0-58.2 g/100 g of pomace). These FRFs were mainly composed of pectic substances and hemicellulose. The physicochemical properties of these FRFs (e.g, water-holding capacities, swelling properties and cation-exchange capacities) were significantly ($P < 0.05$) higher than those of cellulose. The apparent abilities of these FRFs to adsorb glucose and reduce amylase activity implied that they might help control postprandial serum glucose. It was also reported that carambola is rich in dietary fiber especially insoluble fiber and contains a high concentration of water insoluble fiber rich fraction, which can be used as a promising cholesterol lowering ingredient in human diets or new formulations of fiber – rich functional foods.^[31] *A. carambola* L. fruits were found to possess a high level of insoluble dietary fiber, alcohol insoluble solid and water insoluble solid.^[32] These fiber rich fractions might help to control post prandial serum glucose.

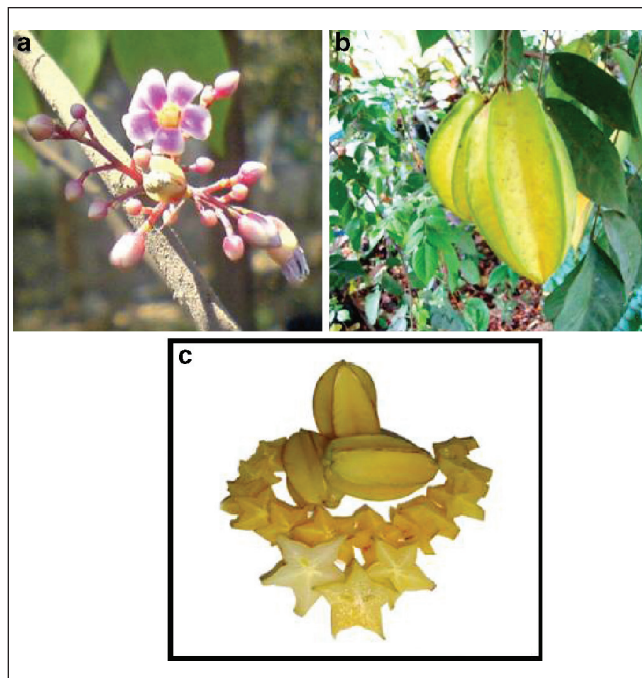


Figure 1: A. Flowers of *Averrhoa carambola* L. B & C. Fruits of *Averrhoa carambola* L.

TOXICOLOGICAL STUDIES

The toxicity of star fruit was first published in 1980.^[33] It was shown that fruit extracts in doses exceeding 8g/kg provoked convulsions in mice when injected into the peritoneal cavity. The first toxic effect to people was described by Martin *et al.*^[34] They reported an outbreak of intractable hiccups in eight patients, with regular hemodialysis program after ingestion of star fruit and all recovered after hemodialysis.

Chang *et al.*^[35] reported case reports of twenty patients with star fruit intoxication. Among the twenty patients, nineteen patients were uremic patients under hemodialysis or peritoneal dialysis; and one patient had advanced chronic renal failure (Cr 6.4 mg/dL) without dialysis. It was also concluded star fruit ingestion by patients with renal failure will cause high mortality, even after dialysis. There are no reports of star fruit neurotoxicity in people with normal renal function.^[36]

Thirty two cases of neurologic symptoms were documented following star fruit ingestion in uraemic patients.^[36] These observations indicated that star fruit intoxication may be harmful and even life threatening in uraemic patients on supportive or dialytic treatment. Hiccups and vomiting, which are common symptoms, could be used as an indication of star fruit intoxication in renal patients presenting with neurological and consciousness disturbances that have no apparent cause.

CONCLUSION

Medicinal plants are studied in depth by the herbal industry. *A. carambola* L. is a plant, which has both nutritional as well as medicinal uses. Studies have been conducted on different parts of *Averrhoa carambola* L., but there is a dire need for target based studies with a concentration on mechanism of action, lethal dose/ effective dose and bioavailability mechanism need to be conducted in future to explore scientifically the hidden curative potential of this plant. It is expected that this review will attract attention towards medicinal potential, applications and commercialization of various plant parts of *Averrhoa carambola* L.

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