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Review Article

A review on phytochemical and pharmacological investigation of *Averrhoa carambola* fruit

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Abstract

Medicinal plants use as a Medicine in an ancient Indian traditional system. *A. carambola* used as a medicinal value and edible value in Ayurveda and Chinese medicine. Our aim of study *A. carambola* fruit review from selected database Journals Scopus, web of science, science direct, PubMed and so on from 2010-2024, in phytochemistry and pharmacological activies.

Keywords: *A. carambola*, AYUSH, Phytochemistry, Anticancer, Antioxidant, Anti inflammatory

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1. Introduction

Herbal medicine is the earliest known type of healthcare practiced by humans. Plants have consistently proven to be a reliable source of medication and a number of the presently available drugs are directly or indirectly derived from them.[1] Herbal medicines are preferred due to their historical and cultural significance and are mainly used for treating mild and chronic conditions.

The World Health Organization (WHO) estimates that nearly 80% of individuals in developing nations depend primarily on traditional medicine for their essential health care requirements.

The WHO has identified more than 21,000 plant species utilized globally for medicinal uses. In India, approximately 2500 plant species from over 100 genera are utilized in traditional medicine systems.[2]

Despite tremendous advances, modern conventional health care is currently dealing with major difficulties such as hazardous drugs, chronic illnesses, resistant infections, autoimmune diseases, and age-related degenerative disorders.[3] The modern allopathic system has developed various complex and costly diagnostic techniques that, at times, have made them unduly costly and not accessible to the average person. Many modern synthetic drugs can be more harmful than effective in treating disorders due to their significant adverse effects. In contrast, traditional therapeutic treatments based on plants are highly appreciated because they are safer, have no side effects, and are generally less expensive than many allopathic pharmaceuticals. Certainly, the plant kingdom continues to include a large number of plant species, including compounds with medical characteristics that have yet to be discovered.

A. carambola is gaining popularity due to the potential for ethno botany in future medical applications. Traditional folk medicine has made use of several parts of the tree. It also provides important nutrients like copper, potassium, folate, and pantothenic acid. The amount of Ascorbic acid in a mature fruit influences its flavour, whether sweet or sour.[4] The *A. carambola* medicinal plant consists of various parts, including roots, leaves, and stems, fruits, flowers, and seeds, each of which has its own medicinal properties in countries such as Malaysia, Brazil, India, and China.

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Star fruits have been reported to have a range of health benefits. These include antioxidant, hypoglycaemic, hypotensive, hypocholesterolemic, anti-inflammatory, anti-infective, anticancer, and immune-boosting properties. Star fruits are frequently used in Ayurvedic and Traditional Chinese Medicine (TCM) to treat a variety of clinical conditions, such as fungal skin infections, inflammatory skin disorders (eczema), fever, cough, diarrhea, and chronic headaches.[5,6] In some cultures, ripened fruit is used for the treatment of bleeding haemorrhoids.

When *A. carambola* was examined for its phytochemical content, it revealed the presence of alkaloids, phenylpropanoids, terpenes, saponins, phenols, and flavonoids as well.[7]

In the fruit, the primary sterols present include lupeol (a), iso-fucosterol (b), β-sitosterol (c), and campesterol (d). In addition to these sterols, four significant plant fatty acids are also present: linolenic acid, linoleic acid, oleic acid, and palmitic acid.[8,9]

The edible part of the fruit is recognized as a rich source of dietary fibres, pectin, cellulose, both reducing and non-reducing sugars, minerals, calcium, phosphorus, hemicellulose, and carotenoid compositions.[10] The *A. carambola* fruit contains gallic acid in the form of Gallo tannin, as well as epicatechin (g), proanthocyanidins, and L-ascorbic acid. Until now So far, around 132 compounds have been extracted and recognized from *A. carambola*.[11]

2. Conventional Applications

The *A. carambola* plant possesses significant medicinal potential, demonstrating a variety of benefits including anti-inflammatory, hepatoprotective, antimicrobial, antioxidant, neuroprotective, and antitumor properties. In both Ayurveda and Traditional Chinese Medicine (TCM), *A. carambola* is esteemed for its numerous health benefits, treating ailments like coughs, skin fungal infections, eczema, intense headaches, and diarrhea.[5,6]

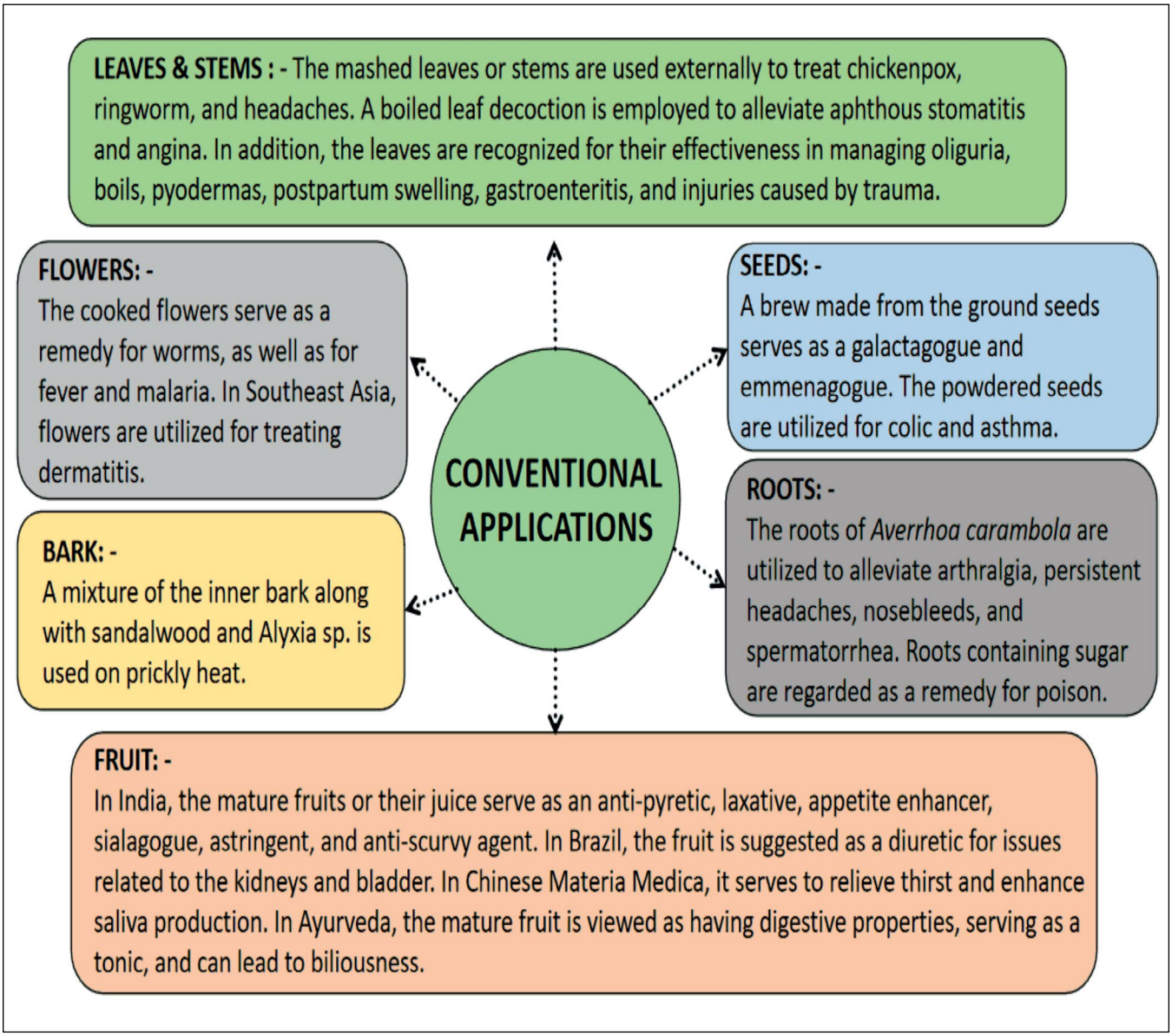

Figure 1: Traditional uses of *A. carambola*[12]

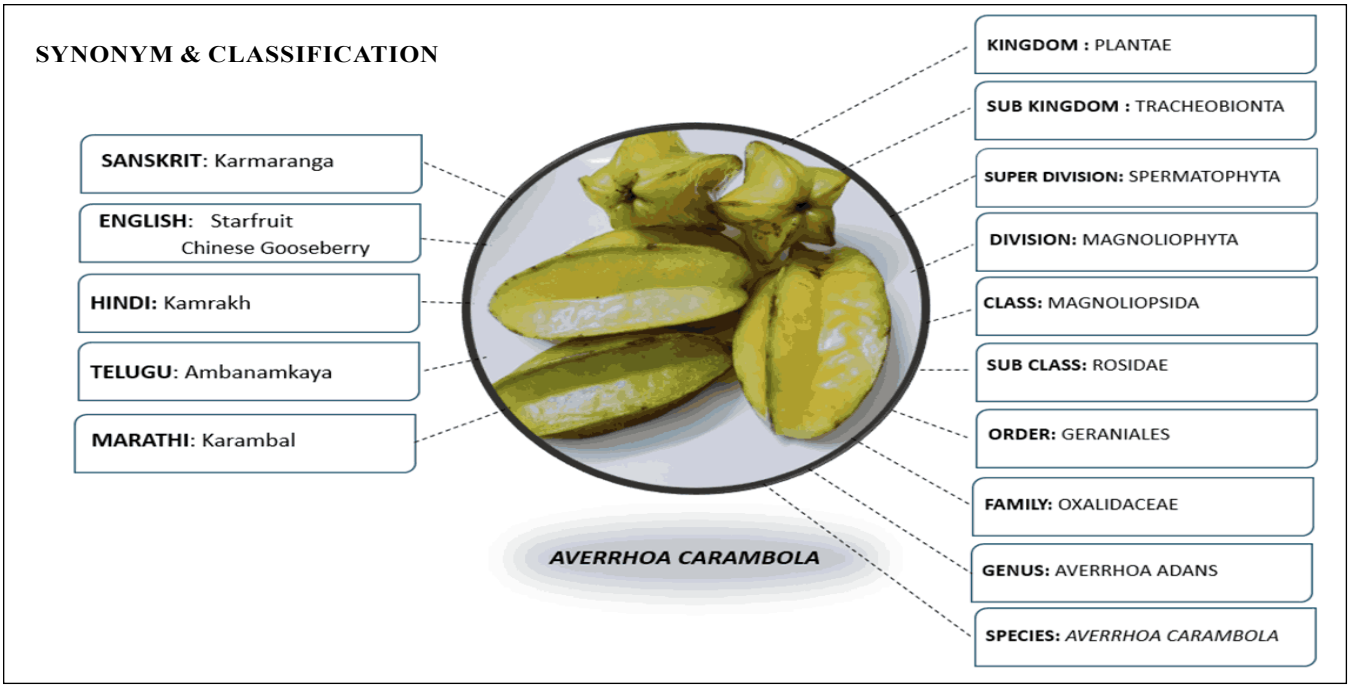

Figure 2: Synonym and classification of *A. carambola*[13–14]

3. Botanical Description

3.1. Plant

A. carambola is a small, multi-stemmed, slow-growing evergreen tree with a short trunk or shrub, reaching 5–7 m or 10 m in height and spreading 20–25 ft in circumference. Its numerous branches form a broad, rounded crown, giving it a bushy appearance. The trunk's diameter at the base is 15 cm.[15–16]

3.2. Leaves

The leaves are elliptical to oval-oblong in shape, alternate, spirally arranged, 15–25 cm long, imparipinnate, and briefly petiolate, with 5–11 green pedant leaflets that are 2–9 cm long and 1-4.5 cm wide. The medium-green, delicate, pubescent leaves have a smooth upper surface and a pale underside. The leaflets are sensitive to sudden shock and react to light, folding together at night.

Figure 3: Leaves of *A. carambola*

3.3. Flowers

The axils of the leaves yield purple to vivid purple flowers. The blooms are grouped in tiny clusters, and each cluster is connected to the tree by red stalks. The blooms are tiny, around 6mm in diameter, pedicellate, and have five petals with curved edges. They also include sepals.

3.4. Fruit

The fruits are green when they are small and unripe, but they change to yellow or orange once they are mature and ripe. The fruits are succulent with an elongated form, longitudinally 5-6 sided, ranging from 5-15 cm in length and up to 9 cm in width. The fruits are crunchy with a crisp texture and when sliced crosswise are star- shaped, which is how they got their name. The scent of the fruits is akin to oxalic acid, and their flavour ranges from extremely sour to slightly sweet or sweet. The flesh varies from light yellow to yellow, is translucent, and exceptionally juicy with no fiber.

Figure 4: Fruit of *A. carambola*

3.5. Seeds

Up to 12 flat, thin, 5 mm long seeds may be present, or none at all. A gelatinous aril envelops the brown seeds, which lose their viability a few days after being removed from the fruit. It is simple to grow star fruit from fully matured seeds.[15–16,7]

3.5.1. Microscopy of star fruit

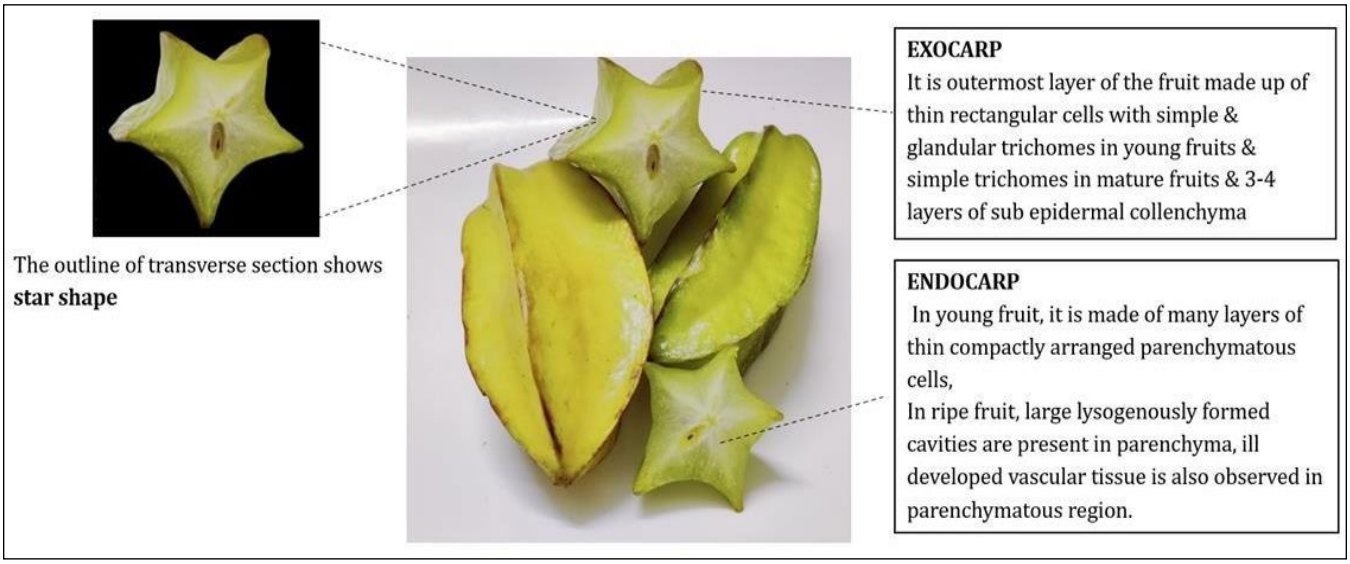

Figure 5: Microscopy of *A. carambola*[11]

3.5.2. Powder properties of A . carambola fruit

The powdered fruit of *A. carambola* revealed the existence of simple trichomes, parenchyma cells, cells filled with tannins, collenchyma cells, and sclerenchyma fibers.[7]

3.6. Microscopic analysis of leaves

The microscopy analysis showed the existence of upper and lower epidermis, phloem, xylem, vascular bundles, mesophyll, trichomes, and collenchyma. Mesophyll was divided into palisade and spongy parenchyma. The vascular bundles had an arc-like shape. Xylem was lignified, and phloem was non-lignified. A unicellular trichome was seen on the epidermis.[17]

3.7. Anatomy of leaf

The *Averrhoa* species displays distinct upper and lower epidermis composed of uniseriate, thin- walled parenchyma cells. The upper epidermis contains basic unbranched hairs, and the stalk varies in length with single-celled heads. The lower epidermis is characterized by papillae. The stomata are identified as rubiaceous (paracytic), featuring two subsidiary cells aligned alongside the stomatal pore. Mesophylls are single-layered near the midrib. Comparable findings were achieved by.[18]

In the leaf lamina, the palisade layer consists of three layers in *A. carambola*. The lower porous layer is made up of multiple air cavities. The mesophyll region contains the distribution of secretory cavities and canals. The vascular bundles of the vein have enlarged terminal tracheids. The clear spots of individual crystals alongside the vascular bundles of the vein create a dense covering. Oxalic acid frequently occurs in leaf tissues as dissolved potassium oxalate. It is typically encountered as small individual cubic crystals. The lower epidermis displays tiny, unbranched hairs as well . The existence of prismatic crystals in the leaf midrib's parenchyma was likewise noted by.[18]

The microscopy examination of the powder revealed thick, irregularly walled upper epidermis cells, prisms of calcium oxalate crystals, unicellular trachoma's, simple pitted vessels, anisocytic stomata, and xylem vessels in a longitudinal sectional view that displayed spiral thickening.[17]

4. Phytochemical Constituents

The entire *A. carambola* plant is rich source of many phytochemical components; currently; approximately 132 phytochemical compounds have been separated and identified from *A. carambola*. The most prevalent ones are flavonoids, terpenes, phenolic and phenylpropanoids which have been considered as the biologically active components responsible for multiple bioactivities.[7]

4.1. Phenylpropanoids

Phenylpropanoids can be classified as simple phenylpropanoids, lignins, and coumarins based on their substructure type. Among them 4 simple phenylpropanoids have been reported for the *A. carambola* fruit. Furthermore, four coumarins have been found in *A. carambola* fruit, compounds reticule and 6-O-methyl-reticulol are isocoumarins in structure, 5-methylmellein and 7-hydroxy-5-methylmellein.[19–20] Tarennanosides A, Fernando side, 7α-[(β-glucopyranosyl)oxy]-lyoniresinol,(+)-lyoniresinol3α-O-β-D-glucopyranoside,(−)-lyoniresinol3α-O-β-D-glucopyranoside,(−)-5′-methoxy-isolariciresinol3α-O-β-D-glucopyranoside,(+)-5′-methoxy-isolariciresinol3α-O-β-D-glucopyranoside,(+)-isolariciresinol3α-O-β-D-glucopyranoside, (−)-isolariciresinol3α-O-β-D-glucopyranoside were isolated from root of *A. carambola.*[21–22, 21, 23–38]

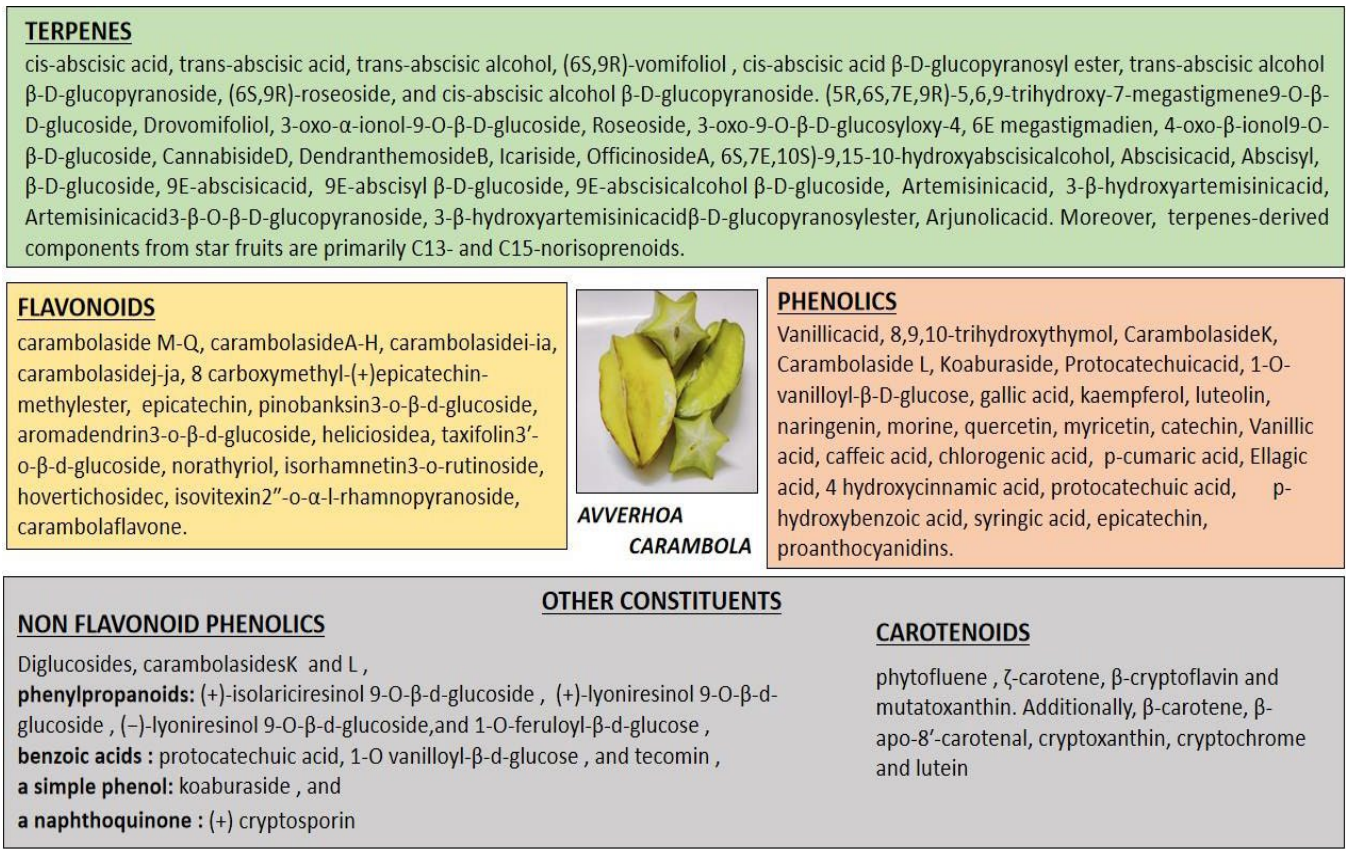

Figure 6: Phytoconstituents of *A. carambola*[21–40]

Table 1: Phytochemical constituents of *Averroha carambola*[21–40]

S. No	Chemical constituents	Isolated compounds	Plant part	Extracts	References
01	Flavonoids	Carambolaside M–Q, Carambolaside A– H, Carambolaside I–Ia, Carambolaside J– Ja, 8-carboxymethyl-(+)-epicatechin methyl ester, (+)-Epicatechin, (–)- Epicatechin, Aromadendrin 3-O-β-D- glucoside, Helicioside A, Norathyriol, Isorhamnetin 3-O-rutinoside, Hovertichoside C, Isovitexin 2″-O-α-L-rhamnopyranoside, Carambolaflavone	Fruit	EtOH, MeOH	23–26
		Carambolaside R1–R3, Carambolaside S1–S2, Carambolaside T1–T3, 3- Hydroxycarambolaside T1/T3/P, Isovitexin, Carambolaflavone A & B, Apigenin 6-C-(2″-O-α-L- rhamnopyranosyl)-β-D-glucopyranoside, Cyanidin-3-O-β-D-glucoside, Cyanidin- 3,5-O-β-D-diglucoside, C-glycosides, Carambola flavones A & B	Leaves	EtOH	27–32
		(+)-Catechin	Root	Aqueous	22
02	Terpenes	5R,6S,7E,9R)-5,6,9-trihydroxy-7- megastigmene-9-O-β-D-glucoside, Drovomifoliol, 3-oxo-α-ionol-9-O-β-D- glucoside, Roseoside, Cannabiside D, Dendranthemoside B, Icariside,	Fruit	EtOH, EtOAc, MeOH	26, 33–36
		Officinoside A, 6S,7E,10S)-Δ9,15-10-hydroxyabscisic alcohol, Abscisic acid (cis/trans), Artemisinic acid & derivatives, Arjunolic acid, Norisoprenoids (C13, C15)			

S. No	Chemical constituents	Isolated compounds	Plant part	Extracts	References
03	Phenolics	Vanillic acid, 8,9,10-Trihydroxythymol, Carambolaside K & L, Koaburaside, Protocatechuic acid, 1-O-vanilloyl-β-D- glucose, Gallic acid, Kaempferol, Luteolin, Naringenin, Morin, Quercetin, Myricetin, Catechin, Caffeic acid, Chlorogenic acid, p-Coumaric acid, Ellagic acid, 4-Hydroxycinnamic acid, p- Hydroxybenzoic acid, Syringic acid, Epicatechin, Proanthocyanidins	Fruit	MeOH, EtOH, Acetone	21, 37–12
		3-Hydroxy-4-methoxyphenol 1-O-β-D-apiofuranosyl-(1″→6′)-O-β-D- glucopyranoside, 4-Hydroxy-3- methoxyphenol 1-O-β-D-apiofuranosyl-(1″→6′)-O-β-D-glucopyranoside	Root	BuOH	21
04	Phenylpropanoids	Reticulol, 6-O-Methyl-reticulol (Isocoumarins), 5-Methylmellein, 7- Hydroxy-5-methylmellein	Fruit	MeOH, EtOAc	38
		Tarennanosides A, Fernandoside, 7α-[(β- glucopyranosyl)oxy]-lyoniresinol, (+)- Lyoniresinol 3α-O-β-D-glucopyranoside, (−)-Lyoniresinol 3α-O-β-D-glucopyranoside, (+)/(−)-5′-Methoxy- isolariciresinol 3α-O-β-D-glucopyranoside, (+)/(−)-Isolariciresinol 3α-O-β-D-glucopyranoside	Root	Aqueous, BuOH	21–22
05	Other Constituents	Non-flavonoid phenolics: Diglucosides, Carambolasides K & L, Phenylpropanoids, (+)/(−)-Lyoniresinol 9-O-β-D-glucoside, (+)-Isolariciresinol 9- O-β-D-glucoside, 1-O-Feruloyl-β-D- glucose, Benzoic acids, Protocatechuic acid, Tecomin, Koaburaside, (+)- Cryptosporin (naphthoquinone)	Fruit	MeOH	22
		Carotenoids: Phytofluene, ζ-Carotene, β- Cryptoflavin, Mutatoxanthin, β-Carotene, β-Apo-8′-Carotenal, Cryptoxanthin, Cryptochrome, Lutein (minor)	Fruit	EtOAc	11

5. Pharmacological Activities

The *A. carambola* plant holds incredible medicinal value and offers a wide range of health benefits. It's known for its anti-hypertensive, anti-inflammatory, anti-lipidemic, anti-microbial, anti-oxidant, anti-tumor properties, among others as highlighted in given figure. Research also highlights its potential in managing obesity, hepatoprotective, neuroprotective and protecting against ulcers. However, some components of the plant may have toxic effects on the nervous system.

5.1. Anti-hyper & hypo-glycemic activity

A. carambola fruit has the potential to regulate blood glucose level as its insoluble fiber rich fraction exhibit a more potent hypoglycaemic effect.[19] The effect of hydro alcoholic extract of *A. carambola* leaves on fasting blood sugar was experimented which result in lowering blood glucose levels.[20] The effect of ethanol extracts of *A. carambola* bark in streptozotocin-induced diabetic mice result in decrease in their blood glucose level. The extract of *A. carambola* roots possess the anti hyperglycemic effect which decrease the blood glucose serum level & protect the pancreatic cells in streptozotocin induced diabetic rats.[41]

5.2. Anti-hyper & hypo-lipidemic activity

Micronized insoluble fiber from the bagasse of *A. carambola* improved lipid levels in a murine model and prevented occurance of non- alcohol fatty liver in murine model.[42] The water-insoluble fiber rich fraction from the pomace of *A. carambola,* in in-vitro results in serum level and total cholesterol. The effect of methanolic extract of *A. carambola* leaves possess the most potent hypo-lipidemic activity which decreases the lipid profile parameters and atherogenic index levels in poloxamer-407-induced hyperlipidaemia rats.[43] The effect of *A. carambola* root on streptozotocin model showed improved liver function by decrease in level of lipid profile in serum and also in malondialdehyde in liver.[44]

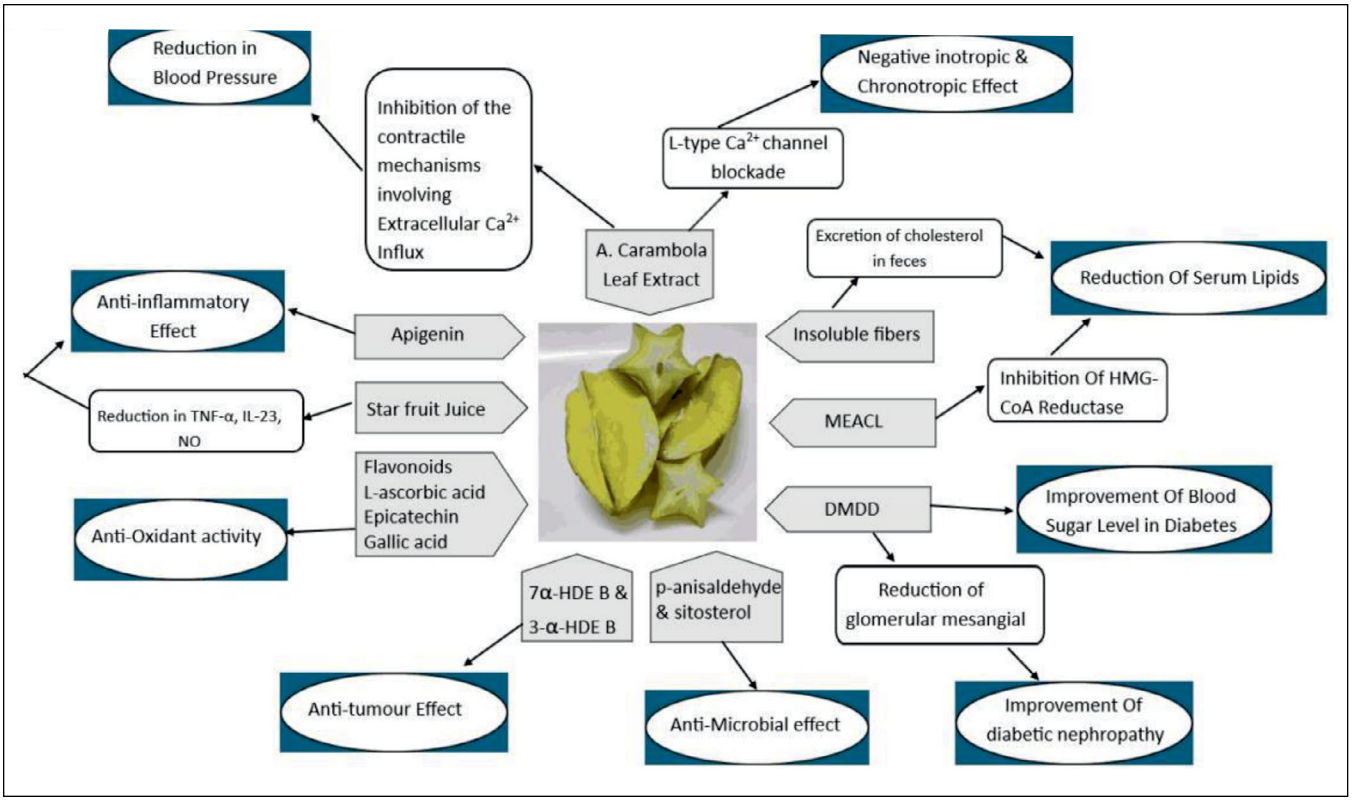

Figure 7: Diagrammatical representation of potential benefits of *A. carambola*[5–6]

5.3. Anti-hyper tensive activity

The flavonoids isolated from *A. carambola* fruit reduce systolic blood pressure, diastolic blood pressure, and mean blood pressure in healthy rats and rats with NG-nitro-L-arginine-methyl ester-induced hypertension. The flavonoids isolated from *A. carambola* fruit contain active compounds capable of lowering blood pressure. The aqueous extract of the *A. carambola* leaves showed significant anti-hypertensive effects by lowering mean arterial pressure in a dose-dependent manner in normotensive rats.[45] The ethanol extract of *A. carambola* roots, when administered orally in healthy rats, it effectively decrease blood pressure without causing any significant changes in heart rate.

5.4. Anti-inflammatory

The ethanol extract of *A. carambola* leaves and its fractions (ethyl acetate, butanol, and hexane), along with two flavonoids, showed significant anti-inflammatory effects in a mice model of croton oil-induced ear edema. The results in reduced edema dose-dependently and suppressed myeloperoxidase activity.[46] One study investigation, the aqueous extract of *A. carambola* when given IP inhibited carrageenan-induced rat paw inflammation.[47]

5.5. Anti -microbial

The antimicrobial properties of *A. carambola* stem extracts have been demonstrated through their ability to inhibit the growth of Staphylococcus aurous and Klebsiella species, as indicated by the minimal bactericidal concentration. The antimicrobial activity of *A. carambola* was further investigated using the disc diffusion method, where it was found that the methanolic extract, along with its petroleum ether, carbon tetrachloride, chloroform, and aqueous soluble fractions, effectively inhibited the growth of various gram-positive and gram-negative bacteria.[48]

5.6. Anti-obesity activity

The *A. carambola* peel extract and DMDD show significant role in treatments for metabolic disorders. *A. carambola* peel extract, primarily its bioactive component (epicatechin) inhibits fat cell formation and regulate key transcription factors involved in adipogenesis and lipid metabolism.[49] Whereas DMDD contribute for managing high-fat diet-induced obesity and insulin resistance in mice.[50]

5.7. Anti-oxidant

A. carambola has been shown to possess significant antioxidant activity, with its ability to scavenge reactive oxygen species and free radicals contributing to its health-promoting effects including detoxification, supporting the immune system, and protecting against cancer, oxidative stress, and lipoperoxidation.[11] The methanolic extracts of *A. carambola* primarily attributed to the efficient extraction of phenolic compounds. These extracts are utilized in studies assessing the fruit's ability to neutralize free radicals. The aqueous and ethanolic extract of *A. carambola* also been analyzed for their antioxidant properties some studies showed the aqueous extracts is lower compared to methanolic extracts due to the limited solubility of certain phenolic compounds, In contrast,

Ethanolic extracts have been found to exhibit significant antioxidant activity, comparable to methanolic extracts, as they can extract a broad range of phenolic compounds . The methanol extract obtained from *A. carambola* leaves exhibited a moderate, dose-dependent anti-oxidant activity when demonstrated in assay against DPPH and ABTS+. Another study revealed that ethanol extracts derived from the bark of *A. carambola* had anti-oxidant properties; it exhibited concentration-dependent anti-oxidant properties.[51]

5.8. Anti-tumor activity

The *A. carambola* exhibits antitumor effects by decreasing tumor incidence, tumor yield, and tumor burden in liver cancer mice. Its extracts also reduce lipid peroxidation and improve antioxidant enzyme activities.[52] The methanol extract of *A. carambola* leaf in the ehrlich ascites carcinoma mouse model minimize cell viability, body weight, and alters hematologic parameters while prolonging survival, indicate potential anticancer properties.[51] Some studies show that *A. carambola* extracts from root, may enhance the radiosensitivity of breast cancer cells, holding potential for treating metastatic breast cancer.[53]

5.9. Anti-ulcer activity

The leaf extracts of *A. carambola* have anti-ulcerogenic properties, attributed to terpenoids, flavonoids, and mucilage. The alcoholic aqueous extract of *A. carambola* leaves demonstrated anti-ulcer activity in an acidified-ethanol-induced ulcer model in rats. However, it showed no protective effects in indomethacin and acute stress-induced ulcer models in mice.[54]

5.10. Cardioprotective

The aqueous extract of *A. carambola* enhanced endothelial function in isoprenaline-induced ventricular remodeling in rats, decreased serum levels significantly, and decreased the ventricular remodeling index.[55] Diabetes mellitus mice developed by high glucose & high- fat diet, and application of STZ which had been treated with *A. carambola* roots in another study, had shown that DMDD could slightly improve cardioprotective activity.[56]

5.11. Cardiovascular effects

The aqueous extract of *A. carambola* leaves on cellular calcium influx by examining the left atrium of guinea pigs. The aqueous extract had a positive inotropic effect.[57] The effect of leave extract on normotensive rats under anaesthesia both in-vivo and in-vitro (rats and isolated rat aorta), there was a lowering of arterial blood pressure. It also block extracellular Ca2+ influx and the effects may be associated with the presence of apigenin (secondary metabolite of *A. carambola leaves*).[58]

5.12. Hepatoprotetive

The fruit juice of *A. carambola* exhibited potential liver-protective effects; it reduce dMAD and cAMP levels while enhancing the activities of succinate dehydrogenase, malondialdehyde, and superoxide dismutase in the liver of mice with diabetes induced by streptozotocin.[59] In a study, mice with acute liver injury treated with *A. carambola* root extract showed reduced malondialdehyde levels and increased superoxide dismutase, glutathione, and glutathione peroxidase activities. At the molecular level expressions of tumor necrosis factor-alpha, nuclear factor kappa B, and caspase-3 were down regulated, the hematoxylin and eosin staining revealed improved liver condition. In another study the impact of *A. carambola* -free phenolic extract was investigated in mice which show effective reduced in liver triglycerides and influenced key enzymes involved in lipogenesis, along with activating AMP-activated protein kinase α, suggesting its potential therapeutic role in hepatic steatosis.[60]

5.13. Neuroprotective activity

Some research concluded that DMDD isolated from *A. carambola* roots has potent neuroprotective effects against memory deficits and neuron apoptosis in APP/PS1 transgenic Alzheimer's disease mice. DMDD improved spatial learning, reduced neuronal loss, and inhibited Aβ1-42-induced apoptosis and suppressing caspase activity. These results demonstrated DMDD as a promising candidate for developing neuroprotective drugs for Alzheimer's disease.[61]

6. Neurotoxic effect

The neurotoxic fraction isolated from the *A. carambola* alters GABAergic transmission and glutamatergic transmission systems. Cortical administration of this fraction induces behavioural changes in animals, confirming its significant impact on GABAergic and glutamatergic systems.[62]

7. Conclusion

The fruit of *Averrhoa carambola L.* is commonly found across India. The plant seems to demonstrate a wide range of effects on various health issues. The phytoconstituents are reported to be present in the plant are primarily flavonoids, alkaloids, tannins, and phenolics, which are responsible for its therapeutic properties. Different parts of the plant have been studied for their antioxidant, analgesic, anti-inflammatory, hypoglycemic, and hepatoprotective activities.Therefore, based on the present literature review and Ayurvedic texts, it can be concluded that the plant possesses significant medicinal value and should be regarded as a vital gift from nature to humanity.

Numerous phytochemical research studies have been published, but still it needs to be progressed. Additional research is required to examine specific bioactive compounds that contribute to these pharmacological effects and their mechanisms of action. Nonetheless, there is limited data concerning the clinical study, toxicity assessment, and phyto-analytical investigations of this plant. With access to primary information, additional research can be conducted, including phytoanalytical investigations, clinical trials, toxicity assessments, and safety evaluations.

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