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Revisión | Review

Star fruit (*Averrhoa carambola* L.): From traditional uses to pharmacological activities

[Fruta de la estrella (*Averrhoa carambola* L.): Desde los usos tradicionales a las actividades farmacológicas]

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Abstract
Averrhoa carambola L. (Oxalidaceae), commonly known as star fruit bears a great significance in traditional medicine. Traditionally, *A. carambola* was used in ailments such as arthralgia, chronic headache, boils and pyodermas, colds, cough, epistaxis, spermatorrhea, fever, food poisoning, gastroenteritis, malaria, malarial splenomegaly, oliguria, postpartum edema, sore throat, subcalorism and traumatic injury. Pharmacological investigations on *A. carambola* have demonstrated anti-inflammatory, antimicrobial, antifungal, antitumor and anti-ulcer activities. In addition, the plant possesses hypocholesterolemic, hypoglycemic, hypotensive, nephrotoxic, neurotoxic, negative inotropic and chronotropic effects. Phytochemical investigations have shown the presence of saponins, tannins, alkaloids and flavonoids. This review is an effort to update the pharmacological activities and clinical studies on *A. carambola*.

Keywords: *Averrhoa carambola*, Oxalidaceae, pharmacological activities, chemical constituents

Resumen
Averrhoa carambola L. (Familia: Oxalidaceae), comúnmente conocida como fruta de la estrella tiene una gran importancia en la medicina tradicional. La Medicina Tradicional reporta el uso de A. carambola en dolencias tales como: artralgia, dolor de cabeza crónico, forúnculos y piodermas, resfriados, tos, epistaxis, espermatorrea, fiebre, intoxicación alimentaria, gastroenteritis, malaria, paludismo, esplenomegalia malárica, oliguria, edema post-parto, dolor de garganta , subcalorismo y lesiones traumáticas. Investigaciones farmacológicas en A. carambola han demostrado efectos anti-inflamatorios, antimicrobianos, antitumorales, antifúngicas, y actividades anti-úlcera, hipocolesterolémico, hipoglucemiante, hipotensor, nefrotóxicos, y efectosneurotóxicos y cronotrópicos negativos. Proyecciones preliminares fitoquímicas han demostrado la presencia de saponinas, taninos, alcaloides y flavonoides. Esta revisión constituye un esfuerzo para actualizar las actividades farmacológicas y estudios clínicos sobre A. carambola.

Palabras Clave: *Averrhoa carambola*, Oxalidaceae, actividades farmacológicas, constituyentes químicos.

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INTRODUCTION:

Star fruit, *Averrhoa carambola* (Oxalidaceae) is found in America, Brazil, Australia, South-East Asia including Malaysia, Southern China, Taiwan and India. *A. carambola* tree is usually 3 to 5 m in height and can reach a maximum height of 10 m, with a finely fissured light brown bark and 15 to 20 cm long leaves. It bears large indehiscent yellowish-green berry fruit of 5 to 8 cm long with a characteristic shape resembling a five pointed star, and each cell of the fruit contains five arillate seeds (Morton, 1987; Margen, 1992).

In traditional medicine, the fruit was used for treating ailments such as cough, food poisoning, sore throat and malarial splenomegaly; the root for treating arthralgia, chronic headache, epistaxis and spermatorrhea; the leaves for treating boils, colds, gastroenteritis, oliguria, postpartum edema, pyodermas and traumatic injury, while the flowers for treating fever, malaria and subcalorism (Sung *et al.*, 1998). There are previous reviews on *A. carambola* describing mainly the botanical and cultivation aspects, traditional uses and some pharmacological activities (Avinash *et al.*, 2012; Gheewala *et al.*, 2012; Manda *et al.*, 2012). In this review, we summarize and update the phytochemical, pharmacological and clinical investigations on *A. carambola*.

PHARMACOLOGICAL PROPERTIES

Antioxidant capacity

Luximon-Ramma *et al*, (2003) examined the antioxidant capacity, total phenolics, proanthocyanidins, flavonoids and vitamin C contents of 17 commonly consumed exotic fruits from Mauritius including *A. carambola* . The antioxidant activities of *A. carambola* were found to be ranged from 11 to 17 μmol Trolox equivalent antioxidant capacity (TEAC)/g fresh weight, and 9 to 22 μmol ferric reducing antioxidant power (FRAP)/g fresh weight, for the acid and sweet fruits respectively. The total phenolics content was 1429 and 2099 μg/g fresh weight; proanthocyanidins 896 and 1321 μg/g fresh weight; total flavonoids 103 and 148 μg/g fresh weight and vitamin C content was 190 and 144 μg/g fresh weight, for the acid and sweet fruits respectively. There were strong correlations between antioxidant activity (assessed by both TEAC and FRAP) and total phenolics and proanthocyanidins contents. Flavonoids seemed to contribute less to the antioxidant potential of the fruit, while very poor correlation was observed between ascorbate content and antioxidant activity. The antioxidant capacity of *A. carambola* was found to be among the highest in the study group and the study concluded *A. carambola* to be a substantial source of phenolic antioxidants, thus it may exhibit potent health benefits.

Shui and Leong, (2006) showed that the residue of *A. carambola* fruit, which is normally discarded during juice drink processing, contains much higher antioxidant activity than the extracted juice using various methods for assessing antioxidant activity. Under optimized extraction conditions, the residue accounted for around 70% of total antioxidant activity and total polyphenolic contents, however it only contributed 15% of the weight of the whole fruit. Freeze-dried residue-powder, which accounted for around 5% of total weight, had total polyphenolic content of 33.2 ± 3.6 mg gallic acid equivalent (GAE)/g sample, total antioxidant activity of 3490 ± 310 and 3412 ± 290 mg L-ascorbic acid equivalent antioxidant capacity or 5270 ± 468 and 5152 ± 706 mg trolox equivalent antioxidant capacity per 100 g sample obtained by 2,2′-azino-bis-(3-ethylbenzthiazoline-6-sulfonic acid) free radical and 1,1-diphenyl-2-picryl-hydrazyl scavenging assays, respectively. It was also found to have 510.3 ± 68.1 mol ferric reducing/antioxidant power per gram sample. The residue-extract also shows strong antioxidant activity in delaying oxidative rancidity of soya bean oil at 110 °C. Antioxidant activity and polyphenolic profile of residue extracts were compared with extracts of standardized pyconogenol. High performance liquid chromatography coupled with mass spectrometry revealed that major proanthocyanidins in *A. carambola* fruit were different from their isomers in the standardised extracts of pyconogenol. The high content of phenolics and strong antioxidant activity of residue extract indicate that the residue powder may yield health benefits when used in functional food products and that residue extract should also be regarded as potential source of nutrients in future.

Ali *et al.*, (2011) screened 20 different kinds of fruits including *A. carambola* from Aizawal Market of Mizoram India for their antioxidant potential using DPPH, FRAP and total phenolics content assay. *A. carambola* showed moderate antioxidant activity among the tested fruits, the activity was found to be 81.03 ± 1.97 g of Trolox equivalent/100 g of fruit (DPPH assay), 78.770 ± 0.33 g of Trolox equivalent/100 g of fruit (FRAP assay)

and total phenolics contents were found to be 54.45 ± 0.43 g of gallic acid equivalent/100 g of fruit.

Moresco *et al.*, (2012) reported isolation of β-sitosterol from the *n*-hexane fraction; apigenin-6-*C*-β-L-fucopyranoside and apigenin6-*C*-(2"-*O*-α-L-rhamnopyranosyl)-β-L-fucopyranoside from the ethyl acetate fraction, and a new compound apigenin6-*C*-(2"-*O*-α-L-rhamnopyranosyl)-β-D-glucopyranoside from the *n*-butanol fraction. The antioxidant potential of the fractions was examined using the DPPH radical scavenging assay and reducing power of iron (III) to iron (II) ions. The ethyl acetate and *n*-butanol fractions showed the highest antioxidant potential to scavenge DPPH, with the IC_{50} values of 90.92 and 124.48 µg/mL, respectively. In the assay of reducing power**,** these fractions presented 135.64 and 125.12 mg/g of ascorbic acid equivalents, respectively. The antioxidant activity exhibited a significant correlation with the phenolic content (r^2 = 0.997), but a poor correlation with the flavonoids content (r^2 = 0.424). The *n*-hexane fraction was the only fraction to show toxicity on *A. salina* with LC_{50} of 800.2 µg/mL.

Anti-inflammatory activity

Cabrini *et al.*, (2011) examined the ethanol extract of *A. carambola* leaves, its hexane, ethyl acetate and butanol fractions and two isolated flavonoids, apigenin-6-*C*-*β*-l-fucopyranoside and apigenin-6-*C*-(2″-*O*-*α*-l-rhamnopyranosyl)-*β*-l-fucopyranoside for anti-inflammatory activity. The ethanol extract reduced edema in a dose-dependent manner, resulting in a maximum inhibition of 73 ± 3% and an ID_{50} value of 0.05 (range: 0.02–0.13) mg/ear. Myeloperoxidase activity was also inhibited by the ethanol extract, resulting in a maximum inhibition of 60 ± 6% (0.6 mg/ear). The tested fractions inhibited edema formation and myeloperoxidase activity, the ethyl acetate fraction was the most effective fraction, resulting in inhibition levels of 75 ± 5 and 54 ± 8% for edema formation and myeloperoxidase activity, respectively. However, the isolated compounds did not show any substantial anti-inflammatory activity.

Acetylcholinesterase inhibitory activity

Teh *et al.*, (2010) investigated the effects of *A. carambola* juice kept at different storage conditions on the activity of acetylcholinesterase in various organs of Sprague Dawley (SD) rats. Three groups (5 animals per group) of rats were administered with distilled water, and different star fruit preparations, freshly prepared star fruit juice and after 3 hours storage, respectively. The results showed a substantial decrease in the hepatic acetylcholinesterase activity in rats treated with star fruit juice highest activity was observed for the freshly prepared juice.

Antimicrobial and antifungal activity

Mia *et al.*, (2007) isolated two compounds *p*-anisaldehyde and β-sitosterol from the bark of *A. carambola*. The petroleum ether, carbon tetrachloride and chloroform fractions of the methanol extract of *A. carambola* when subjected to antimicrobial screening at 400 µg/disc demonstrated mild inhibition on microbial growth. The average zone of inhibition produced by the petroleum ether, carbon tetrachloride and chloroform soluble fractions were 8-12 mm, 8-12 mm, and 8-15 mm, respectively. The petroleum ether extract moderately inhibited the growth of *E. coli* and *S. dysenteriae* having the zone of inhibition of 12 mm each. On the other hand, the chloroform soluble fraction strongly inhibited the growth of *E. coli* with zone of inhibition 15 mm. In the case of fungi, mild inhibitory activity was exhibited by all extractives. The LC_{50} values obtained from cytotoxicity evaluation were 0.32, 0.70, 0.06 and 3.14 µg/mL for standard vincristine sulfate, petroleum ether, carbon tetrachloride and chloroform soluble fractions, respectively.

Antitumor activity

Li *et al.*, (2012) studied the biotransformation of dihydro-epi-deoxyarteannuin B by using suspension-cultured cells of *A. carambola*. One novel sesquiterpene, 7α-hydroxy-dihydro-epideoxyarte-annuin B, and one known sesquiterpene, 3-α-hydroxy-dihydro-epideoxyarteannuin B, were obtained upon the addition of dihydro-epi-deoxyarteannuin B. The study concluded that**,** cultured cells of *A. carambola* have the capacity to hydroxylate sesquiterpene compounds in a regio- and stereoselective manner. The inhibitory effects of 7α-hydroxy-dihydro-epideoxyarteannuin B and 3-α-hydroxy-dihydro-epideoxyarteannuin B on proliferation of K562 and HeLa cell lines were (59.29 ± 0.99, 84.04 ± 0.27 µmol/mL) and (40.63 ± 1.45, 41.54 ± 0.82 µmol/mL) , respectively.

Anti-ulcer activity

Goncalves *et al.*, (2006) examined the water-alcohol extract of leaves of *A. carambola* for its anti-ulcerogenic potential. The ethanolic extract at doses of 800 and 1200 mg/kg *p.o.*, only showed significant

anti-ulcer activity in the acidified-ethanol-induced ulcer model in rats. However, the extract did not show any activity in the indomethacin and acute stress ulcerogenic models. Thus**,** the study concluded ethanolic extract of *A. carambola as* having low anti-ulcer activity.

Negative inotropic and chronotropic effect

Vasconcelos *et al.,* (2005) examined the atrial isometric force in stimulated left atria and determined the chronotropic changes in spontaneously beating right atria. *A. carambola* leaves extracts (1.5 mg/mL) abolished the contractile force in a concentration-dependent manner in cardiac contractility in the guinea-pig atria. Among the methanolic, ethanolic, aqueous, and acetic acid extracts, the aqueous extract was found to be the most potent (EC_{50} = 520 ± 94 µg/mL). The aqueous extract abolished the positive Bowditch staircase phenomenon and reduced the inotropic response to $CaCl_2$, events that are dependent on the cellular Ca^{2+} inward current. In spontaneously beating atria, the aqueous extract promoted a negative chronotropic effect that was antagonized by 0.1 µM isoproterenol bitartrate. The EC_{50} of the aqueous extract increased from 133 ± 58 to 650 ± 100 µg/mL in the presence of this agonist.

Subsequently, Vasconcelos *et al.,* (2008) investigated the effects of the aqueous extract of *A. carambola* leaves on the cellular calcium influx by examining the left atrium of guinea pig and the pituitary GH_3 cells. In the atrium, the aqueous extract (1500 µg/mL) shifted to the right the concentration-effect curve of the positive inotropic effect produced by (±) BAY K 8644, an L-type calcium channel agonist. The aqueous extract increased EC_{50} (concentration required to promote 50% of the maximum effect) of the inotropic effect of BAY K 8644 from 7.8 ± 0.38 to 115.1 ± 0.44 nM. In GH_3 cells treated with 500 µg/mL of aqueous extract, the L-type calcium inward current declined by 30%. The extract did not change the voltage correspondent to the peak current. It was suggested that, at least in part, the negative inotropic effect of aqueous extract on the guinea pig atrium is due to a reduction of the L-type calcium current.

Electrophysiological effects

Vasconcelos *et al.,* (2006) examined the effects of the aqueous extract of *A. carambola* leaves on guinea pig heart. In this study, the aqueous extract induced many kinds of atrioventricular blocks (1st, 2nd, and 3rd degrees); depressed the cardiac rate from 136 ± 17 to 89 ± 14 bpm, increased the QRS complex duration from 27 ± 3.1 to 59 ± 11 ms and increased the QT interval from 229 ± 23 to 264 ± 19 ms. Additionally, it increased the conduction time between the right atrium and the His bundle (27 ± 6.5%), reduced the intraventricular pressure (86 ± 6%) and decreased the conduction velocity of atrial impulse (17 ± 3%). However, the conduction time from the His bundle to the right ventricle was not altered. Atropine sulfate did not change either the electrocardiographic parameters or the intraventricular pressure effects promoted by the *A. carambola* aqueous extract. Thus, the study suggested avoiding the use of such extracts since it can induce electrical and mechanical changes in the normal heart.

Hypotensive activity

Soncini *et al*., (2011) studied the hypotensive effect of the aqueous extract of *A. carambola* and its underlying mechanisms using isolated rat aorta. *In vitro*, the aqueous extract caused a reduction in the E_{max} response to phenylephrine without a change in sensibility. Furthermore, in a depolarized Ca^{2+}-free medium, the aqueous extract inhibited $CaCl_2$-induced contractions and caused a concentration-dependent rightward shift of the response curves, suggesting that the aqueous extract inhibited the contractile mechanisms involving extracellular Ca^{2+} influx. The study concluded the aqueous extract to be hypotensive in nature and suggested the effects to be in part, due to the inhibition of Ca^{2+}, which is in agreement with its uses in traditional medicine.

Hypocholesterolemic activity

Wu *et al.,* (2009) examined the potential hypocholesterolemic activity of different insoluble fibers prepared from *A. carambola* with or without micronization processing. After micronization, the cation-exchange and water-holding capacities of the *A. carambola* pectic polysaccharide-rich insoluble fibres were effectively increased from 8.5 to 22.4 mL/g. The *A. carambola* microsized insoluble fibers reduced the concentrations of serum triglyceride by and total cholesterol by 15.6% and 15.7%, respectively by means of enhancing the excretion of cholesterol and bile acids in the feces. The study suggests a new approach of micronization of the fruit which may help to improve physiological functions of food fibers in fiber-rich functional food applications. The study also indicates that the particle size is an important factor in

affecting the characteristics and physiological functions of insoluble fibers.

Hypoglycaemic activity

Ferreira *et al.,* (2008) examined the effects of the hydroalcoholic extract of leaves of *A. carambola* L. on fasting blood glucose. The hydroalcoholic extract treated animals showed significantly lower fasting blood glucose ($p < 0.05$). In contrast, livers from hydroalcoholic extract of these animals showed significantly higher ($p < 0.05$) glucose production from L-alanine. This effect was mediated, at least part of it, by an activation of the catabolism of L-alanine inferred by the increased hepatic urea and L-lactate production. Unlike L-alanine, the glucose production from L-glutamine, L-lactate and glycerol was not affected by the treatment. Likewise, the hydroalcoholic extract treatment did not affect the glucose uptake in soleus muscles, inferred by the incorporation of [^{14}C]-glucose to glycogen (glycogen synthesis) and [^{14}C]-lactate production. Thus, the study suggests that reduction of fasting blood glucose promoted by the treatment with hydroalcoholic extract of *A. carambola* was not mediated by an inhibition of hepatic gluconeogenesis and/or an increased glucose uptake by muscles.

Chau *et al.,* (2004b) investigated the hypoglycaemic effects of several insoluble fiber-rich fractions including insoluble dietary fiber, alcohol-insoluble solid and water-insoluble solid obtained from the pomace of *A. carambola* , by some *in vitro* methods. It was found that the three insoluble fiber-rich fractions could effectively adsorb glucose, retard glucose diffusion, postpone the release of glucose from starch, and inhibit the activity of *α*-amylase to different extents. The hypoglycemic effects of these insoluble fiber-rich fractions were significantly ($P < 0.05$) stronger than that of cellulose. Thus, it was concluded that these fiber-rich fractions could be incorporated as low-calorie bulk ingredients in high-fiber foods to reduce calorie level and assist the control of blood glucose level.

Nephrotoxic effect

Neto *et al.,* (2009) studied the effects of *A. carambola* fruit on patients with renal failure, who are not yet on dialysis and concluded that the fruit and its juice induces nephrotoxicity and neurotoxicity, which may sometimes be fatal. Patients with chronic kidney disease (stages 3–5 but not on dialysis) should be prohibited from eating the fruit. People with normal renal function must also be warned to avoid ingestion of large amounts of the fruit or juice especially on an empty stomach.

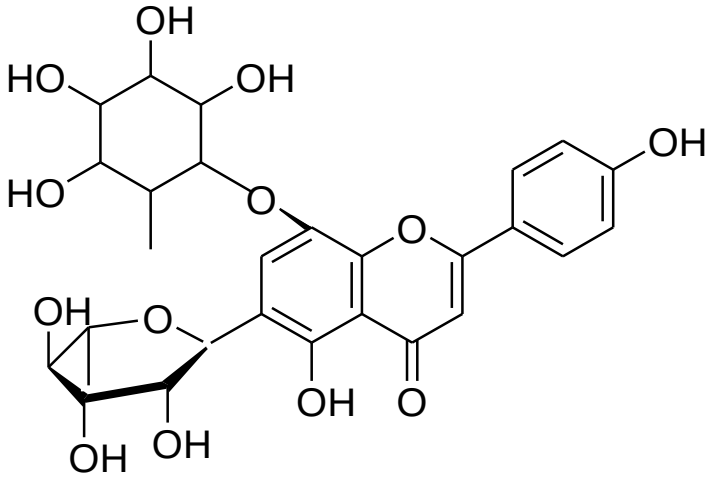
Neurotoxic effect

Carolino *et al.,* (2005) examined the effects of a neurotoxic fraction isolated from *A. carambola* on GABAergic and glutamatergic transmission systems. The fraction was obtained by sequential chromatography of the aqueous extract on anion exchange column, then on cation exchange column and, finally on reversed-phase high performance liquid chromatography (HPLC). The fraction did not affect GABA/glutamate uptake or release, or on glutamate binding, but effected GABA binding in a concentration-dependent manner (IC_{50} 0.89 mM). Video-electroencephalogram recordings showed that cortical administration of neurotoxic fraction, induced behavioral changes in animals, including tonic-clonic seizures, evolving into status epilepticus, accompanied by cortical epileptiform activity. The neurotoxic fraction has not yet been chemically characterized but the preliminary data suggested that it contains a non peptide molecule differing from oxalic acid and bearing a molecular weight less than 500.

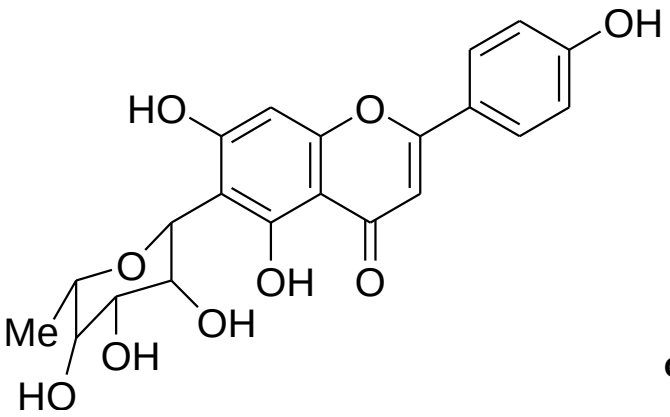
PHYTOCHEMISTRY:

Chemical constituents isolated from A. carambola

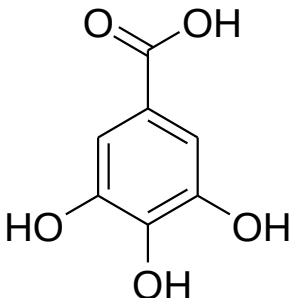
Averrhoa carambola has been the subject of phytochemical studies since late 1970s. The following are the chemical constituents isolated for *A. carambola*.



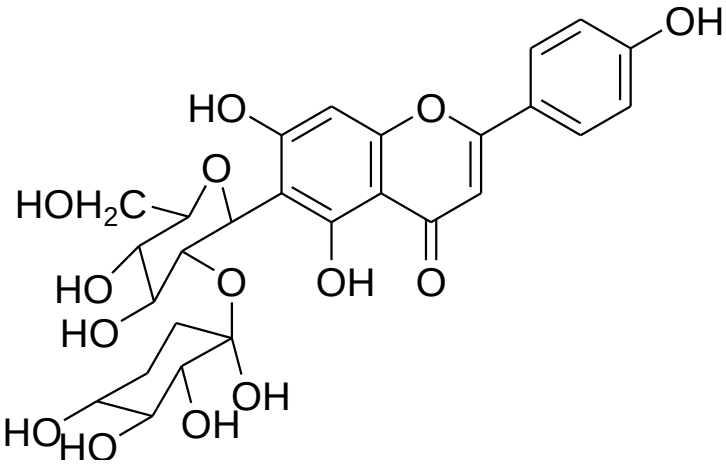
Apigenin-6-C-(2 -O-α -L-rhamnopyranosyl)-β-L-fucopyranoside *(*Araho *et al., 2005)*



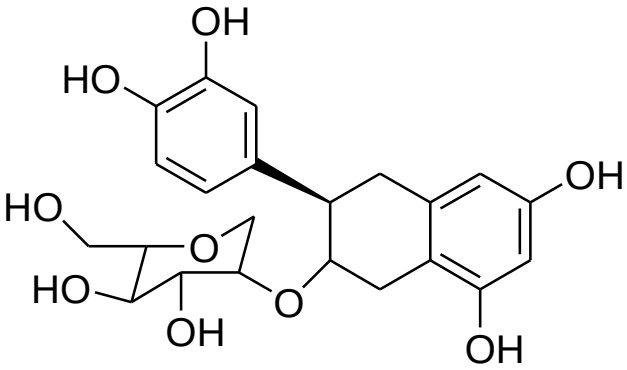
Apigenin-6-C-β-L-fucopyranoside (Araho *et al.*, 2005)



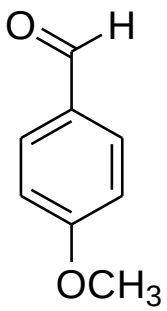
Gallic acid (Guanghou and Lai, 2004)



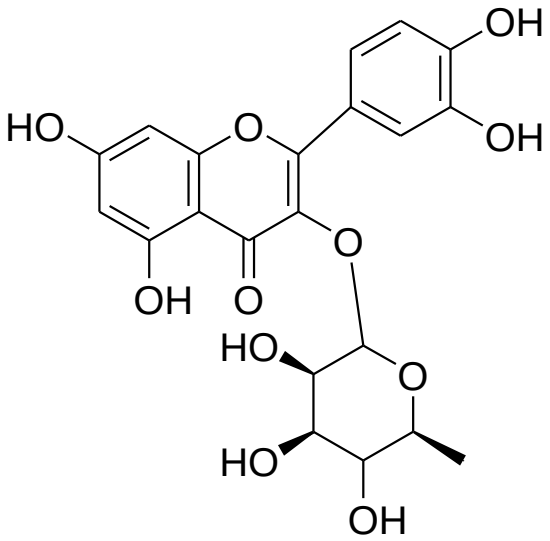
Apigenin- 6-*C*-(2”-*O*-α-L-rhamnopyranosyl)-β-D-glucopyranoside (Henrique *et al., 2011)*



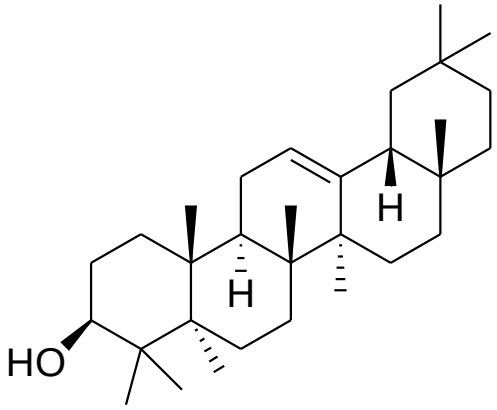
Quercetin-O-β-D-glucoside (Tiwari *et al.*,1979)



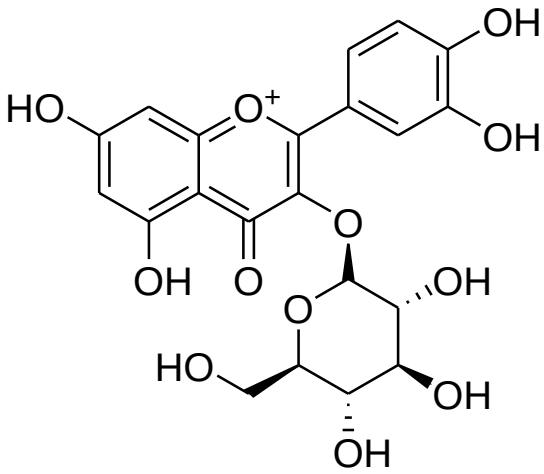
P-Anisaldehyde (Mia *et al.*, 2007)



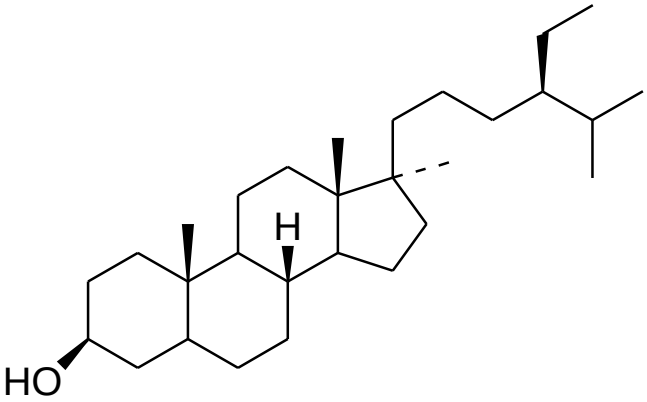
Quercetin-3-O- rhamonoside (Nina *et al.*, 2006)



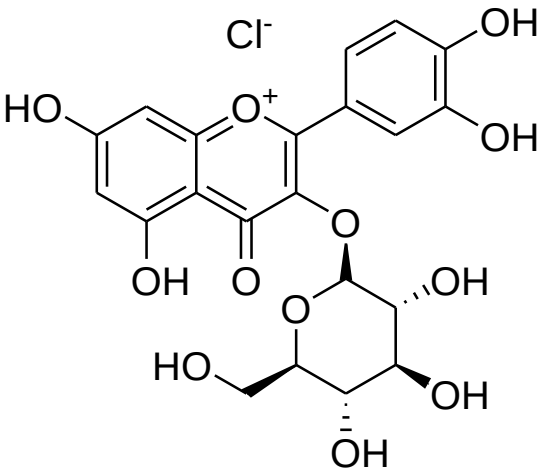
β-amirin (Tadros *et al.*, 2004)



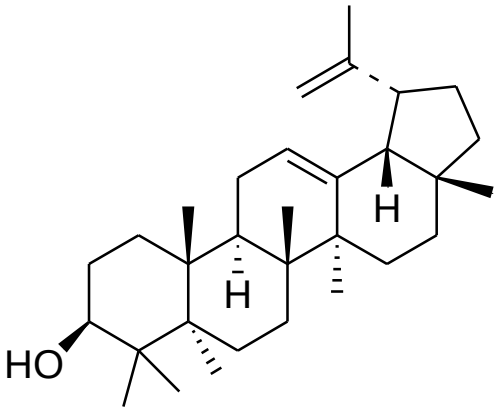
Cyanidin 3-O-β- D- glucoside (Gunasegaran, 1992)



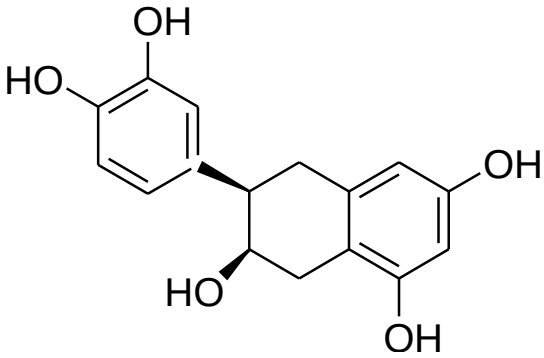
β-sitosterol (Ranganayaki *et al.*, 1980)



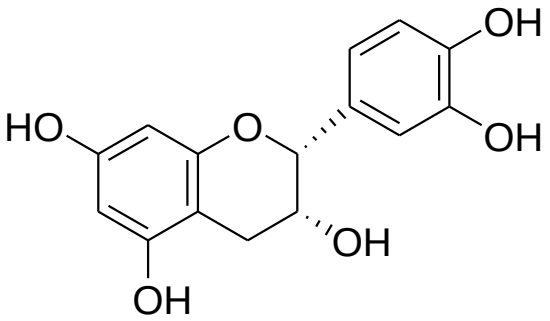
Cyanidin-3, 5-O-β-D-Diglucoside (Gunasegaran, 1992)



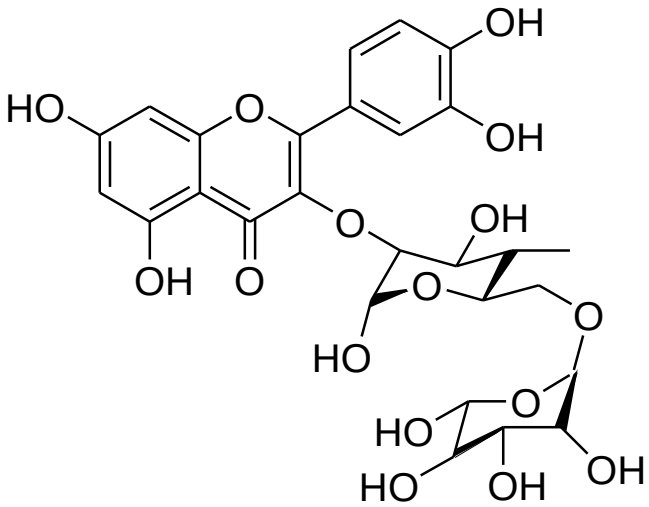
Lupeol (Ranganayaki *et al.*, 1980)



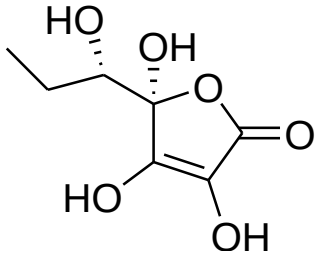
(−) Epicatechin (Guanghou and Lai, 2004)



Proanthocyanidin (Guanghou and Lai, 2004)



Rutin (Tiwari *et al.*, 1979)



Vitamin C (Guanghou and Lai, 2004)

C_{13}-aroma compounds

Herderich *et al.*, (1992) reported identifications of glycosidically bound constituents from star fruit (*A. carambola* L.) using HRGC and HRGC-MS techniques. The constituents were obtained from the extracts by Amberlite XAD-2 adsorption followed by methanol elution. The compounds identified were the ionone derivatives, namely 4-hydroxy-β-ionol, 3-hydroxy-β-ionol, 4-oxo-β-ionol, 3-hydroxy-β-ionone, 3-oxo-α-ionol, 3-oxo-*retro*-α-ionol (2 isomers), 3-oxo-4,5-dihydro-α-ionol, 3-oxo-7,8-dihydro-α-ionol (blumenol C), 3,5-dihydroxy-megastigma-6,7-diene-9-one (grasshopper ketone), 3-hydroxy-β-damascone, 3-hydroxy-5,6-epoxy-β-ionone, 3-hydroxy-5,6-epoxy-β-ionol, 3,4-dihydro-3-hydroxyactinidol, vomifoliol (blumenol A), 4,5-dihydrovomifoliol and 7,8-dihydrovomifoliol (Blumenol B). Several of these new constituents are easily degraded upon heat-treatment at natural pH condition of the fruit pulp, thus rationalizing the formation of a number of C_{13}-aroma compounds, which have recently been reported as star fruit volatiles.

β-Galactosidase

Balasubramaniam *et al.*, (2005) isolated β-Galactosidase (EC. 3.2.1.23) from *A. carambola* fruit and fractionated it using a combination of ion exchange and gel filtration chromatography into four isoforms, β-Galactosidase I, II, III and IV. The β-galactosidases exhibited the molecular weights 84, 77, 58 and 130 kDa, respectively. β-Galactosidase I, was the most prominent isoform. The purified β-galactosidase I was highly active in hydrolyzing (1 → 4) β-linked spruce and a mixture of (1 → 3)β- and (1 → 6) β-linked gum arabic galactans. The β-galactosidase I also exhibited the capacity to solubilize and depolymerize structurally intact pectins as well as to modify alkaline-soluble hemicelluloses, indicating in part changes that occur during ripening.

Pharmacognostic and phytochemical analysis

Thomas *et al.*, (2008) conducted preliminary pharmacognostic and phytochemical analysis and showed the presence of saponins, tannins, alkaloids and flavonoids. Furthermore, the study revealed that the water-soluble and alcohol soluble extractive values decreased gradually with ripening of fruit.

Analysis of oxalic acid

Wilson *et al.*, (1982) quantified oxalic acid in 15 Florida-grown *A. carambola* cultivars using simple and rapid high-performance liquid chromatographic (HPLC) method. Oxalic acid levels were found to vary among the cultivars examined from 0.08 to 0.73 g per 100/g of fruit.

FRUIT AND FIBRE-RICH FRACTIONS COMPOSITIONS

Fruit composition

Narain *et al.,* (2001) studied the composition of the fruit during maturation. The pH of the fruit increased with the advance in maturity, whereby the pH values were 3.44, 2.40 and 2.71 for ripe, green mature and half-ripe fruits, respectively. Increased calcium contents were observed at ripe stage (4.83 ± 0.27 mg/100 g of edible fruit) and it was significantly different than the fruits at green mature (3.55 ± 0.85 mg/100 g of edible fruit) or half-ripe stages (4.83 ± 0.27 mg/100 g of edible fruit). The titratable acidity, reducing sugars and tannin contents of the fruits vary significantly among the fruits at different stages of maturity.

Fiber-rich fractions

Chau *et al.,* (2004a) reported that the pomace of *A. carambola* possess a high level of insoluble fiber-rich fractions including insoluble dietary fiber, alcohol-insoluble solid, and water-insoluble solid (46.0–58.2 g/100 g of pomace). These fiber-rich fractions were mostly composed of pectic substances and hemicellulose. The physicochemical properties of these fiber-rich fractions (water-holding capacities, swelling properties, and cation-exchange capacities) were significantly ($P < 0.05$) higher than those of cellulose. The capacity of these fiber-rich fractions to adsorb glucose and reduce amylase activity implied that they might help control postprandial serum glucose. Thus the study suggested that the consumption and application of the insoluble fiber-rich fractions as low-calorie bulk ingredients in fiber enrichment.

CLINICAL STUDIES:

Clinical symptoms and outcomes in uraemic patients given A. carambola

Investigations of the clinical symptoms and outcomes of 32 uraemic patients ingesting star fruit showed that most common symptoms were persistent and intractable hiccups (in 30 patients; 93.75%), vomiting (in 22 patients; 68.7%), variable degrees of disturbed consciousness (mental confusion, psychomotor agitation; in 21 patients; 65.6%), decreased muscle power, limb numbness, paresis, insomnia and paresthesias (in 13 patients; 40.6%) and seizures (in seven patients; 21.8%). Patients who were promptly treated with hemodialysis, including those with severe intoxication, recovered without sequelae. The study concluded that hemodialysis, particularly on a daily basis, is the best treatment for star fruit intoxication. In adverse cases, continuous methods of replacement therapy may provide a superior initial procedure, since rebound effects are a common event. Peritoneal dialysis is of no use as a treatment, especially when consciousness disorders ensue (Neto *et al.*, 2003).

CONCLUSION

A. carambola has long been used in traditional medicine and has demonstrated pharmacological activities which support its use in traditional uses as an important therapeutic agent. However**,** the scientific evidences are limited in respect to its bioactive constituents, bioavailability, pharmacokinetics, and therapeutic importance including clinical trials. Thus**,** future work on bioactivity-guided isolation of the active secondary metabolites responsible for the pharmacological activities of *A. carambola,* and studies on their structure-activity relationships, mechanisms of actions, pharmacokinetics and toxicity are required for the development of *A. carambola* as a therapeutic agent. Furthermore, the extracts or fractions with potential bioactivities may be standardized and employed in clinical studies.

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