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Nutritional composition of *Averrhoa carambola*: Benefits and potential health effects

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Abstract
Carambola, commonly known as starfruit, is a tropical fruit renowned for its unique star-shaped appearance and rich nutritional profile. This fruit is a notable source of antioxidants, including vitamin C, flavonoids, and phenolic compounds. The antioxidant properties of carambola play a crucial role in neutralising free radicals and reducing oxidative stress, thereby contributing to various health benefits. These benefits encompass enhanced immune function, improved skin health, reduced inflammation, better heart health and supportive digestive health. Additionally, the antioxidants in carambola may help protect cognitive function and reduce the risk of chronic diseases. The low calorie and fat content of the fruits make it a healthy choice for those managing weight or looking to maintain a balanced diet. However, individuals with kidney conditions should exercise caution due to high oxalate content of the fruits. Carambola represents a valuable addition to a balanced diet, offering significant antioxidant benefits and supporting overall well-being.

Keywords: Carambola, antioxidant, oxalate, flavonoids, phenols

Introduction

Starfruit is a tropical fruit that has gained popularity not only for its distinctive star-shaped fruits but also for its impressive nutritional profile. Native to Southeast Asia (Gosh and Dhua, 1990), this fruit is celebrated for its refreshing taste and vibrant appearance, making it a visually appealing and nutritious addition to various culinary dishes. Ripe carambola are eaten fresh, sliced or served in salads or used as a garnish on seafood. They are also cooked in puddings, tarts, stews and curries (Manda *et al*., 2012) [11]. In Manipur, India they are taken as a popular dessert in which they are cooked with sugar to make jams/jelly. The fruits can be dried or further processed as juice, sherbet, jelly, jams, squash, pickles, etc.

Carambola fruits are of two distinct type based on taste: sweet and sour (Chadha, 2001) [2]. The sweet type are mild flavoured, rather bland taste, with less oxalic acid and the sour types are very sour, richly flavoured and have more oxalic acid. The fruit of Carambola is a powerhouse of essential vitamins and minerals. It is particularly rich in vitamin C, a potent antioxidant that plays a critical role in boosting immune function and protecting cells from oxidative damage (Chen *et al*., 2017) [3]. The ascorbic acid levels of the star fruit is believed to be responsible for its sweet or sour taste. It is a also a good source of potassium, copper, folate and panthothenic acid (Manda *et al*., 2012) [11]. It also provides a range of vitamins and folate which are important for energy metabolism and overall cellular function. In addition, carambola contains a variety of beneficial phytonutrients, including flavonoids and phenolic compounds. These compounds contribute to the fruit's antioxidant properties, helping to combat inflammation and reduce the risk of chronic diseases (Rufino *et al*., 2011) [13]. The fruit is also a source of dietary fibre, which supports digestive health and promotes regular bowel movements (Vasant and Narasimhacharya, 2014) [16]. Additionally, it contains several amino acids, such as thiamine, riboflavin, niacin, tryptophan, methionine, and lysine (Dasgupta *et al*., 2013) [6]. Despite its numerous benefits, individuals with kidney issues should approach carambola with caution due to its oxalate content, which can exacerbate kidney conditions (Chang *et al*., 2000) [4]. Overall, carambola offers a unique combination of vitamins, antioxidants and dietary fibre making it a valuable and healthful addition to a diverse and balanced diet.

Classification of carambola (Manda *et al*., 2012) [11]
Kingdom: *Plantae* – Plants
Subkingdom: *Tracheobionta* - Vascular plants
Superdivision: *Spermatophyta* - Seeds plant
Division: *Magnoliophyta* - Flowering plants
Class: *Magnoliopsida* - Dicotyledons
Subclass: *Rosidae*
Order: *Geraniales*
Family: *Oxalidaceae* - Wood-Sorrel family
Genus: *Averrhoa* Adans. - Averrhoa
Species *Averrhoa carambola* L. - carambola

Vernacular names (Dasgupta *et al*., 2013) [6]
Sanskrit - karmanga
Bengali - kamranga
Assamese - kordoi / rohdoi

Marathi - karambal
Telugu - ambanamkaya
English - carambola, starfruit
Filipino - balimbing, saranate
Hindi - kamrakh
Gujarati - kamrakh
Tamil - thambaratham
Indonesian, Malay - belimbing

Botanical description

The tree is evergreen, typically growing between 15 to 33 feet tall, and thrives in warm, tropical climates. Leaves are deciduous, arranged in a spiral pattern, and alternate (Babu *et al*., 2006) [1]. In carambola, flowers appear in clusters on leaf axils, leafless branches, terminal shoots, and occasionally on large branches or the trunk. They are small, bell-shaped, and measure 5-12 mm long, with short, dark-red pedicels. (Rymbai *et al*., 2019) [14]. Fruits are oval, elongated, or ellipsoid in shape, 6-15 cm long and 9 cm wide. They have a thin, waxy coating with orange-yellow skin and when fully ripe have juicy, crisp, yellowish translucent flesh. Seeds are arillate, 8-10 in number and yellow to light brown in colour (Govil and Kaur, 1989) [7].

Fig 1: A. Carambola tree, B. Leaves, C. Flower, D. Seeds

Cultivars

Carambola cultivars are mainly divided into two types: sweet and tart. Sweet-type fruits are sweet, mildly flavoured which makes them suitable for eating fresh, processing and home recipes. In contrast, tart-type fruits are very sour and have a strong flavor, with higher oxalic acid content, making them more appropriate for processing (Manda *et al*., 2012) [11]. Some tart carambola cultivars, like 'Golden Star,' can develop a sweet flavour if they are allowed to ripen to a golden yellow colour on the tree. Certain Chinese varieties, such as 'Xiangmi Yantao,' known for their high quality, are particularly sweet and are derived from sweeter strains (Ping Shen, 1999) [12]. In Australia, carambola cultivars are categorized into long and short styled types. Recent advancements in crop improvement through selection and introduction have enhanced fruit quality, especially sweetness and flavour in Florida and other regions (Rymbai *et al*., 2019) [14]. However, in India only local genotypes are currently available.

Nutritional composition

The fruit of *Averrhoa carambola* is rich in various nutrient substances, including minerals, vitamins, cellulose, hemicelluloses and pectin. It contains 60% cellulose, 27% hemicelluloses, and 13% pectin, which might help in regulating blood sugar levels (Lakmal *et al*., 2021) [10]. Carambola is also rich in natural antioxidants, including L-ascorbic acid, (-) epicatechin, and gallic acid in the form of gallotannins. A 100 g serving of this fruit offers 35.7 calories, 0.38 g of protein, 9.38 g of carbohydrates, 0.80 to 0.90 g of dietary fibre, 0.8 g of fat, 4.4 to 6.0 mg of calcium, 0.32 to 1.65 mg of iron, 15.5 to 21.0 mg of phosphorus, 2.35 mg of potassium, 0.003 to 0.552 mg of carotene, 4.37 mg of tartaric acid, 9.6 mg of oxalic acid, 2.2 mg of α-ketoglutaric acid, and 1.32 mg of citric acid. Additionally, it contains various amino acids, including 0.03 to 0.038 mg of thiamine, 0.019 to 0.03 mg of riboflavin, 0.294 to 0.38 mg of niacin, 3 mg of tryptophan, 2 mg of methionine and 26 mg of lysine per 100 g (Dasgupta *et al*., 2013) [6].

Carambola fruits are notably sour due to their high oxalic acid content, though sweeter varieties have minimal oxalic acid. The juice from some varieties has a pH between 1.9 and 2.0 and contains about 15-16 mg of vitamin C per 100 g, making it a significant source of this nutrient, though its content varies across regions in India. Additionally, the juice provides iron and phosphorus (Babu *et al*., 2006) [1]. For the first time, Herderich *et al*. (1992) discovered Carbon-13 norisoprenoid flavor precursors in starfruit. Many of these constituents degrade easily when the fruit pulp is heated under its natural pH conditions, which explains the presence of various C13 aroma compounds found in starfruit volatiles. They identified glycosidically bound precursors for C13 odorants, including a unique natural precursor for the strong aroma compound damascenone and proposed a pathway for its formation from non-allenic compounds.

Antioxidant activity

Research indicates that star-fruits are rich in proanthocyanins, in addition to Vitamin C and Gallic acid, which act as antioxidants. Antioxidants primarily function to neutralize reactive oxygen species (ROS), such as peroxides. Fatty acids are particularly vulnerable to oxidative harm from peroxides and hyperperoxides. Eating star-fruits can assist in detoxifying the body and support the immune system in protecting against cancer, ROS-related damage and lipid peroxidation (Muthu *et al*., 2016).

High fibre source

Star fruit are rich in fibres. It contains 60% cellulose, 27% hemicelluloses and 13% pectin. These water-insoluble fiber fractions (WIFFs) aid in digestion, lower blood glucose by slowing carbohydrate absorption, and help reduce cholesterol levels (Lakmal *et al*., 2021) [10]. Consuming star-fruit as a smoothie, with the fibre included, supports lipid removal and may lower cardiovascular risk. Additionally, star-fruit extracts have shown selective anti-brain-tumor activity (Tadros *et al*., 2004; Muthu *et al*., 2016) [15].

Renal problems

Research from the Florida Citrus Experiment Station in 1966 found that the golden star cultivar had oxalic acid levels of 5 mg/g in mature green fruits and 9.58 mg/g in mature yellow fruits. A Puerto Rican study revealed that ripe carambolas have an average of 0.5 g of oxalic acid per 100 ml of juice, mainly in its free form. Carambola contains oxalic acid, which can be dangerous for people with kidney failure, kidney stones, or those undergoing kidney dialysis. Consumption by individuals with kidney issues can lead to hiccups, vomiting, nausea and mental confusion. In some cases, it has been linked to fatal outcomes (Chang *et al*., 2000) [4].

Conclusions

Averrhoa carambola L., or starfruit, is widely found in India and is known for its broad therapeutic effects. Its medicinal properties are attributed to flavonoids, alkaloids, tannins, and saponins. Research highlights its antioxidant, analgesic, anti-inflammatory, hypoglycemic, hepatoprotective, antimicrobial and anti-ulcer activities. Both scientific literature and Ayurvedic texts recognize its significant medicinal value so it can be concluded that carambola holds significant nutritional value and is considered a valuable natural resource for human health.

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