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RESEARCH ARTICLE

ORIGIN, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETIC DIVERSITY, BREEDING AND CULTIVATION OF CAMBODGE

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ABSTRACT

Malabar-tamarind belongs to the family Clusiaceae, genu *Garcinia* and species *Garcinia gummi-gutta.* Common names are in English: Cambodge Tree, Malabar-tamarind; Kannada: Manda huli, Mantulli, Punarpuli, Seeme hunnise, Upagi mara, Aradala, Aradaala; Malayalam: Gorakkapuli, Pinar, Kodampuli, Kudapuli, Marapuli, Meenpuli, Perumpuli, Pinampuli; Tamil: Gorakkapuli, Heela, Kottukkappuli, Panampuli; Indiabiodiversity, 2025). Vrukshamlah (Sanskrit); Bilatti-amli (Hindi); Kodakkapuli (Tamil) Punarpuli; Upaagi mara (Kannada); Korakkapuli, Kodampuli, Kudapuli, Kokakkappuli, Marapuli, Meenpuli, Perumpuli, Pinumpuli, Pinar (Malayalam). Foreign Name are in Chinese: Guan-mu, Dutch: Geelihars, English: Malabar tamarind, French: Gamboge, German: Gummiguttbaum. Danish (gummiguttræ); Dutch (geelhars); English (gamboge,brindal berry); French (mangoustanier ducambodge, gomme-gutte); German (gummiguttbaum); Hindi (upage mara, murugana huli); Japanese (garushinia kanbogia); Trade name (camboge tree). Chinese: Guan-mu, Dutch: Geelihars, English: Malabar tamarind, French: Gamboge, German: Gummiguttbaum. *Garcinia gummi-gutta* is a tropical species of *Garcinia* native to South Asia and Southeast Asia. Common names include *Garcinia cambogia* (a former scientific name), as well as brindle berry, and Malabar tamarind. The fruit looks like a small pumpkin and is green to pale yellow in color. Although it has received considerable media attention purporting its effects on weight loss, there are reports of liver toxicity associated with the *Hydroxycut* commercial preparation containing the fruit extract, with clinical evidence indicating it has no significant effect on weight loss. Garcinia is the largest genus of the Clusiaceae family comprising nearly 250 species. *Garcinia gummi-gutta* (L.) (Syn.: *Garcinia cambogia* (Gaertn.); Common name: Malabar tamarind), is one of the most important members of the Clusiaceae family. It is a small or medium sized tree up to 12 m tall with dark green and shining leaves. The leaves are elliptic obovate, 2-5 inch long and 1-3 inch broad. Fruits are ovoid, 2 inches in diameter, yellow when ripe, with 6-8 grooves; seeds 6-8 surrounded by succulent aril. The aril and the fleshy covering encasing the seed is edible when ripe. The differentiation between male and female trees is known only at the flowering stage which takes approximately 7 to 9 years. *G. gummi-gutta* is a common species found in the Western Ghats, from the Konkan southwards to Travancore eastwards. The species has now been introduced elsewhere in the subtropical region of Asia including China, Malaysia and the Philippines. It is a common fruit plant of the Western Ghats, attributed with a wide range of applications ranging from food, medicines and nutraceutics. The fruit rind of *G. gummi-gutta* is the major source of (−)-hydroxycitric acid (HCA). In addition, secondary metabolites such as xanthones, benzophenones, organic and amino acids were also reported from this plant. The potential beneficial effects include antioxidant, antihelmenthic, antidiabetic, antimicrobial, antiobesity and hyperlipidaemic properties. Reports on the toxicity and observations during clinical trials suggest that *G. gummi-gutta* is safe for human consumption. The consequences of using Garcinia gummi-gutta, often known as Malabar Tamarind, sustainably while diving into the complex web of genetic variation inside the crop. Botanical and genetic traits of this enigmatic species, revealing the morphological quirks and genetic differences that make it distinct. Examining the range and preferred habitats helps to highlight the ecological niches that are essential to its existence. It delves intently into the complex web of phytochemicals found in various plant parts and explains their range of biological functions. A crucial component of this study is a thorough examination of the techniques used to gauge the genetic diversity of populations of *G. gummi-gutta.* The assessment of *G. gummi-gutta*'s conservation status indicates that threats to the species' genetic richness need to be taken seriously and quickly addressed. The difficulties in attaining sustainable use are examined in detail, offering a comprehensive grasp of the nuances related to overexploitation and conservation initiatives.

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INTRODUCTION

Malabar-tamarind belongs to the family Clusiaceae, genu *Garcinia* and species *Garcinia gummi-gutta* (BTRBG, 1968; Inaturalist, 2025; Indiabiodiversity, 2025;,Wikipedia, 2025). Common names are in English: Cambodge Tree, Malabar-tamarind; Kannada: Manda huli, Mantulli, Punarpuli, Seeme hunnise, Upagi mara, Aradala, Aradaala; Malayalam: Gorakkapuli, Pinar, Kodampuli, Kudapuli, Marapuli, Meenpuli, Perumpuli, Pinampuli; Tamil: Gorakkapuli, Heela, Kottukkappuli, Panampuli (Awale, 2025; Indiabiodiversity, 2025). Vrukshamlah (Sanskrit); Bilatti-amli (Hindi); Kodakkapuli (Tamil) Punarpuli; Upaagi mara (Kannada); Korakkapuli, Kodampuli, Kudapuli, Kokakkappuli, Marapuli, Meenpuli, Perumpuli, Pinumpuli, Pinar (Malayalam) (Indiaflora, 2025). Foreign Name are in Chinese : Guan-mu, Dutch : Geelihars, English : Malabar tamarind, French : Gamboge, German : Gummiguttbaum (Indianspices, 2025). Danish (gummiguttræ); Dutch (geelhars); English (gamboge,brindal berry); French (mangoustanier ducambodge, gomme-gutte); German (gummiguttbaum); Hindi (upage mara, murugana huli); Japanese (garushinia kanbogia); Trade name (camboge tree) (Robson, 2025). Chinese : Guan-mu, Dutch : Geelihars, English : Malabar tamarind, French : Gamboge, German : Gummiguttbaum (Espicebazaar, 2025). Ethnobotanical uses of *Garcinia cambogia* is an economically important spice tree valued for the sun-dried smoked rind which is widely used as a flavour condiment, especially in fish curries. The dried rind of the fruit acts as a bacteriostatic agent and in combination with salt it is used to cure fish in India and Sri Lanka. It is also used as a substitute of Kokum butter (from Garcinia indica (Thouars) Choisy) and as a common additive to make meals more filling. The fruit rind is used medicinally to treat rheumatism and bowel complaints and it is employed as a purgative, hydragogue, anthelmintic and emetic. It is also used in veterinary medicine where a rinse is used to treat mouth diseases in cattle. The fruits are edible, but very acidic and are not generally eaten raw. A tonic prepared from the fruit, which contains a high concentration of vitamin C, is used in India to treat various heart diseases. Garcinia cambogia is not only used medicinally; the rind is used to polish gold and silver ornaments and as a substitute for acetic acid for the coagulation (Semwal *et al*., 2015). *Garcinia cambogia* is an expensive spice used for dried sun rind, in particular for fish curries, often used for flavors. For the treatment of fish with salt in India and Sri Lanka, a dried rind bacteriotic agent is used. It also substitutes for cocoa butter and is a common food additive for the treatment of rheumatism and darkness with a purging, hidragogue, anthelmintic and emethyl. *Garcinia cambogia*is a high-priced spice used for sun-dried smoked rind. According to ethnobotanical surveys, the plant is widely used by tribal people as a meal or dietary supplement, as well as in the treatment of different diseases such as stomach issues, skin diseases, and weight reduction treatments. The peel of the fruit contains high amounts of hydroxycitric acid (HCA), which is the active ingredient believed to be responsible for most of its weight loss benefits. The fruit is high in carbohydrate and starch, according to nutritional analysis. The fruits are high in nutraceutical bioactive components such as saponin, tannins, alkaloids, terpenoid, and phenolic compounds, according to a qualitative phytochemical study (Noreen *et al.,* 2023).

Five interesting things about Cambodge are 1) Cambodge has Gone through a Scientific Transformation, 2) Cambodge can be used in Different Ways, 3) Cambodge Aids in Weight Loss, 4) Cambodge has Several Medicinal Properties, and 5) Cambodge has Some Side Effects (Thottam, 2021). Cambodge is a tropical fruit that fares in green, red, and pale yellow in appearance. The tree from which Cambodge is harvested has the scientific classification “Garcinia gummi-gutta and is home to the Southernmost parts of ranging from Kerala to the shola forests of Nilgiris. It is also fairly common in Sri Lanka and Malaysia. The spice Cambodge is also known as Malabar tamarind. The sour flavour of Malabar tamarind is said to help in easing digestion in the body. It helps ease digestion by cleansing the tissues in the body and the absorption of minerals. Malabar tamarind or Cambodge is a tropical fruit that is ripened and then removed from the vine, uprooted, and left to dry in the sun. The dried rind is predominantly used as the condiment as we know it today. Cambodge is typically used to enhance flavor to dishes. Particularly in the southern region of India, it is used to enhance and highlight flavor in the curry style of cooking. It is ideal to grow it in semi-arid regions and can adapt to most forms of soil. It is drought-resistant and needs a dry season to properly prosper. When you buy Malabar tamarind make sure that the condiments you buy are of high quality so that you can get the best use of them (Thottam, 2021). The dried fruit of the Southeast Asian species Garcinia *cambogia* contains 30 to 50% hydroxycitric acid (HCA), which is believed to be the active ingredient of this weight-loss botanical product (Witkamp, 2010). Hydroxycitric acid has been demonstrated to have a satiety effect in rats; however, studies investigating HCA's effects in promoting weight loss in humans have been disappointing (Witkamp, 2010). Although modest weight loss has been observed in some HCA-treated groups, a larger, more rigorously controlled clinical study of obese subjects found that oral extracts of *Garcinia cambogia* are ineffective for weight loss (Witkamp, 2010). In addition, postulated mechanisms for weight-reducing effects of HCA have not been substantiated experimentally (Witkamp, 2010). Based on rodent studies, it was hypothesized that HCA increases fat oxidation, depresses de novo fatty acid synthesis, and reduces food intake (Witkamp, 2010). Results of two human studies on HCA, one in overweight females and one in fasting males have not supported this hypothesis. Adverse reactions have not been reported with oral use of Garcinia cambogia (Witkamp, 2010).

Fruit rind of *Garcinia* gummi-gutta, commonly known as *Garcinia cambogia* (syn.), is extensively used traditionally as a flavourant in fish curries due to its sharp sour taste (Semwal *et al.,* 2015). Additional ethnobotanical uses include its use as a digestive and a traditional remedy to treat bowel complaints, intestinal parasites and rheumatism (Semwal *et al*., 2015). This small fruit, reminiscent of a pumpkin in appearance, is currently most popularly used and widely advertised as a weight-loss supplement (Semwal *et al*., 2015). Studies have shown that the extracts as well as (−)-hydroxycitric acid (HCA), a main organic acid component of the fruit rind, exhibited anti-obesity activity including reduced food intake and body fat gain by regulating the serotonin levels related to satiety, increased fat oxidation and decreased **de novo** lipogenesis (Semwal *et al.,* 2015). HCA is a potent inhibitor of adenosine triphosphate-citrate lyase, a catalyst for the conversion process of citrate to acetyl-coenzyme A, which plays a key role in fatty acid, cholesterol and triglycerides syntheses (Semwal *et al*., 2015). The crude extract or constituents from the plant also exerted hypolipidaemic, antidiabetic, anti-inflammatory, anticancer, anthelmintic, anticholinesterase and hepatoprotective activities in in vitro and in vivo models (Semwal *et al.,* 2015). Phytochemical studies of various plant parts revealed the presence of mainly xanthones (*e.g.* carbogiol) and benzophenones (*e.g*. garcinol) together with organic acids (*e.g*. HCA) and amino acids (*e.g.* gamma aminobutyric acid) (Semwal *et al.,* 2015). Currently, a large number of **G.** cambogia/HCA dietary supplements for weight management are being sold although the possible toxicity associated with the regular use of these supplements has raised concerns (Semwal *et al.,* 2015). Complaints have been related to multicomponent formulations and at this stage **G.** cambogia has not been confirmed as the potentially toxic culprit (Semwal *et al*., 2015). Garcinia gummi-gutta (L.) Roxb. or the Malabar tamarind, commonly known by its previous scientific name Garcinia cambogia (Gaertn.) Desr. (Clusiaceae), is native to Southeastern Asia (Semwal *et al.,* 2015). The fruit rind is commonly used as a food preservative, flavouring agent or food-bulking agent, and as a traditional remedy to treat constipation, piles, rheumatism, oedema, irregular menstruation and intestinal parasites in many Asian countries (Semwal *et al.,* 2015). Earlier phytochemical reports on the plant led to the isolation of various organic acids benzophenones and xanthones as major constituents and numerous scientific studies have indicated biological activity such as anti-obesity, hypolipidaemic and anticancer activity amongst numerous others (Semwal *et al.,* 2015). Commercial products containing G**.** cambogia catapulted onto the market and have received considerable positive and negative media attention (Semwal *et al.,* 2015). Perhaps its most positive (and negative) connotation was with the television personality Dr Mehmet Oz. Dr Oz has been quoted as saying that **G.** cambogia is the “Holy Grail of Weight-Loss”. However, he has recently been reprimanded for his health claims in general by a senate subcomittee in the USA. **G.** cambogia is

also mentioned fleetingly as one of "Dr Oz's three biggest weight-loss lies" (Semwal *et al*., 2015). In an article in the popular media entitled "Garcinia cambogia: weight-loss supplement may be toxic to some", the author describes an incident of possible serotonin toxicity which may or may not be attributed to the concomitant consumption of **G.** cambogia and an antidepressant (Semwal *et al*., 2015). Garcinia supplements contain from 20 to 60% hydroxycitric acid (HCA), and many of these products are a combination of different active ingredients rather than **G.** cambogia alone (Semwal *et al*., 2015). This should also be considered when assessing the quality, efficacy and safety of these products. It has also been reported that in many products, the claimed concentration of HCA is lower than the value specified. HCA, an α-, β-dihydroxy tricarboxylic acid, is the key component present in the fruit rind which may be responsible for its weight-loss property (Semwal *et al*., 2015). The fruit contains approximately 10% to 30% HCA which can be isolated in the free form, as a mineral salt or as a lactone. HCA is available on the market in the form of its various salts such as calcium, magnesium and potassium as well as their mixtures. HCA also occurs in various bacterial species, which could be an alternative source for natural HCA (Semwal *et al*., 2015). In addition, hydroxycitric acid can be synthesised using citric acid as starting material. Citric acid first undergoes dehydration to form aconitic acid, which forms hydroxycitric acid **via** oxidation (Semwal *et al.,* 2015). It has been found that HCA reduced weight-gain by inhibiting adenosine triphosphate (ATP)-citrate lyase, the enzyme responsible for catalysing the extra mitochondrial cleavage of citrate to oxaloacetate and acetyl-coenzyme A (acetyl-CoA), a building block of fatty acid synthesis. Various studies suggested that HCA promotes weight-loss in humans without stimulating the central nervous system (Semwal *et al*., 2015). It is evident that many conflicting views on the efficacy and safety of **G.** cambogia exists (Semwal *et al.,* 2015).

The genus *Garcinia* L. belongs to the family Clusiaceae (Guttiferae). This family consists of approximately 200 species throughout the world, among which 36 species occur in India (Scielo, 2015). The Western Ghats region is considered as a secondary center of origin for *Garcinia* species, where six species are endemic (Scielo, 2015). The species *G. gummi-gutta* is reported to maintain the forest ecosystem stability in central Western Ghats (Scielo, 2015). Several studies have compared the species diversity in the forests. *G. gummi-gutta* with the other three primary forest species helped in restoring the endemic flora (Scielo, 2015). *G. cambogia* (Gaertn.) Desr. (Malabar tamarind) is distributed across the states of Maharashtra, Goa, Karnataka, Kerala and Tamilnadu. Malabar tamarind plants, grown widely in the gardens of Kerala. Kottayam and Ernakulam districts of Kerala are the famous regions for the cultivation and export of Malabar tamarind (Scielo, 2015). Its products such as fruit rind, resin, gum and seed oil play significant role in the economic development of countries such as Africa, India and Malaysia (Scielo, 2015). These trees can grow up to the height of 20 meters. There is a wide variability in the branching pattern and crown of the tree and extensive variation in fruit and seed characters (Scielo, 2015). The medicinal properties of the plant have been studied extensively. It acts as hydragogue, diuretic, anthelmintic, antiseptic, antibacterial, antioxidant, hypolipidemic and weight reducing agent (Scielo, 2015). Malabar tamarind contains various biologically important compounds such as xanthones, benzophenones and guttiferones (Scielo, 2015). Fruit rind is the most extensively studied part of the plant. However, the information on the genetic diversity of *G. cambogia* is very limited (Scielo, 2015). Different molecular markers have been used for the genetic diversity studies in different *Garcinia* species (Scielo, 2015). The plants studied were collected from four different locations of Maharashtra state of India. They showed low diversity at both morphological as well as molecular levels reported the reduced distribution and population size to alarming levels in *G. cambogia* and emphasized the necessity to characterize this species. They also reported about the threat to the species and the reasons for the genetic erosion of this resource (Scielo, 2015). An intra- and inter-species genetic relationship study was carried out among the species of *Garcinia*, namely *G. cambogia, G. cowa, G. hombroniana, G. indica, G. mangostana* and *G. xanthochymus* by using RAPD markers. The study reported high genetic diversity within *G. cambogia* species (Scielo, 2015). Till date there are no reports based on the molecular markers for the genetic diversity for these sampled accessions. DNA based molecular markers are the good choice for genetic diversity studies, as they are not affected by environmental factors and can detect the variation at DNA level (Scielo, 2015). Assessing the genetic variation between the accessions based on RAPD technique is accepted because of its high potential for detecting the polymorphism (Scielo, 2015).

Garcinia cambogia contains hydroxycitric acid, an inhibitor of citrate-cleavage enzyme (ATP-citrate lyase) that inhibits fatty acid synthesis from carbohydrate (Raina *et al*., 2016). Hydroxycitrate was studied by Hoffmann-LaRoche in the 1970s and was shown to reduce food intake and cause weight loss in rodents (Raina *et al.,* 2016). Although there have been reports of successful weight loss in small studies in humans, some of which included other herbs, the largest and best-designed placebo-controlled study demonstrated no difference in weight loss compared with a placebo (Raina *et al.,* 2016). *Garcinia gummi-gutta* (L.) Robs. (Clusiaceae) is an economically important fruit crop and the most widely distributed species in the Western Ghats of Kerala (Shameer *et al.,* 2016). Three varieties of the species *viz; G. gummi-gutta* (L.) Robs. var. *gummi-gutta*, *G. gummi-gutta* var. *papilla* (Wight) N. P. Sing., and *G. gummi-gutta* var. *conicarpa* (Wight) N. P. Sing., are reported in India (Shameer *et al.,* 2016). The variety *conicarpa* is morphologically distinct by the absence of leaf ligules and by the arrangement of stamens in a convex torus head, in addition to the conical nature of fruits. The difference in morphological variation has been manifested in chemical constitution as well (Shameer *et al.,* 2016). Dendrogram based on leaf volatile chemical distribution of the three varieties revealed nearly 75% correlation between var. *gummi-gutta* and var. *papilla,* while variety *conicarpa* showed less than 20% similarity with the other two varieties (Shameer *et al.,* 2016). HPTLC analysis also showed distinct chemical profile for the variety *conicarpa.* The morphological and chemical variation of *G. gummigutta* var. *conicarpa* suggests species status for the variety (Shameer *et al.,* 2016). The diversity among cultivated accessions of var. *gummi-gutta* is also discussed (Shameer *et al.,* 2016). Garcinia species are an important component of the forest flora of the Western Ghats, with 9 species and 2 varieties, of which 7 species and 2 varieties are endemic to the region (Shameer *et al.,* 2016). *Garcinia gummi-gutta* (L.) Robs. the most widely distributed species among these, is also an economically important fruit crop of Kerala (Shameer *et al*., 2016). The fruits are popularly known as Malabar tamarind or Kudampuli whose dried pericarp is used as a condiment and is used as an alternative of tamarind to impart a special flavour and taste to curries in Kerala (Shameer *et al*., 2016). Also the fruits are commercially important as a rich source of the much valued anti-obesity phytochemical hydroxycitric acid and several industrial units are located in central Kerala for extracting the value added product from the fruits (Shameer *et al.,* 2016). Moreover, the diversity among the cultivated variety has also been evaluated critically (Shameer *et al.,* 2016).

Garcinias are trees known for their delicious fruits and medicinal value (Murthy *et al*., 2018). *Garcinia mangostana* L. (mangosteen or purple mangosteen); *G. gummi-gutta* (L.) N. Bobson. (Malabar tamarind) and *G. indica* Choisy (kokum) are the major species cultivated in tropical countries (Murthy *et al*., 2018). Most *Garcinia* species are apomictic and hence, have narrow genetic diversity. However, germplasm exploration and analysis of genetic diversity using morphological and molecular markers depict variability in architecture of the tree, fruit shape, color, size, yield, nutrients, phytochemical levels, tolerance to drought and salinity, and other useful characteristics (Murthy *et al.,* 2018). Therefore, selection is the first criterion for the improvement of *Garcinia* species (Murthy *et al.,* 2018). Superior genotypes have been selected with respect to size and shape of the fruit, seed number, shelf life, fruiting precocity and external coloration, in all three *Garcinia* species from natural populations and released for cultivation (Murthy *et al*., 2018). Efforts have been made to improve these crops through mutation breeding as well (Murthy *et al*., 2018). Selection of rootstock and grafting has been carried out for the improvement of drought tolerance, salinity tolerance, tree architecture and early flowering (Murthy *et al*., 2018). Garcinias are trees or shrubs belonging to the family Clusiaceae and are native to Asia,

Australia, tropical and southern Africa, and Polynesia (Murthy *et al*., 2018). Around 250 species are reported from lowland tropical forests (Murthy *et al.,* 2018). *Garcinia* plants bear fruits which are edible and are popularly called *Garcinias* or *monkey fruit*. The fruits are small, yellow, white, green or reddish in color, with a sweet to savory in taste (Murthy *et al.,* 2018). Fruit juice or syrup is used as a coolant. Fruit rinds are processed as a condiment in various vegetarian and non-vegetarian preparations to impart flavor, taste and to improve keeping quality (Murthy *et al*., 2018). The seeds yield a protein and a butter or oil (Murthy *et al*., 2018). Garcinias contain phytochemicals which have pharmaceutical and therapeutic value (Murthy *et al.,* 2018). *Garcinia* species originate from the MalayArchipelago; he listed some of the wild as well as semi-domesticated major fruit yielding species (Murthy *et al.,* 2018). Among these, *G. mangostana*; *G. gummi-gutta* and *G. indica* are prominent cultivated species in various countries (Murthy *et al*., 2018). Malabar tamarind fruits are edible, whereas dried rind is used as a condiment and an acidulant in place of tamarind or lime and hence the name has been attributed to the plant. Fruit juice and syrup are used as a coolant and to reduce body fat (Murthy *et al*., 2018).

Garcinia gummi-gutta is an important tree crop valued for its dried fruit rinds as a souring agent in various dishes and source of hydroxycitric acid (HCA), an anti-obesity agent (Babu *et al*., 2021). Garcinia gummi-gutta (L.) Roxb. (Common name; Brindle berry, Malabar tamarind, 'Kudampuli') is a polygamodioecious, multipurpose fruit tree belongs to family Clusiaceae (Babu *et al*., 2021). It contains around 200 species, of which 36 were reported from India (Babu *et al*., 2021). Garcinia gummi-gutta is endemic to the Western Ghats and is believed to be its secondary centre of origin (Babu *et al*., 2021). Since decades, the tree is being cultivated or maintained in homesteads, and dried fruit rind used as a souring agent and as a condiment to flavouring dishes especially in Kerala state, South India (Babu *et al*., 2021). Acidity is due to hydroxy citric acid (HCA*); i.e*. 1, 2-dihydroxy propane-1, 2, 3-tricarboxylic acid, enriched in the rinds (Babu *et al*., 2021). It inhibits lipogenesis from carbohydrates by deactivating the enzyme ATP citrate lyase without affecting Kreb's cycle (Babu *et al*., 2021). Thereby HCA is extensively used as anti-obesity as well as anti-cholesterol agent all over the World (Babu *et al*., 2021). Because of increasing demand for the fruit rind in South Indian dishes and for the industrial extraction of natural HCA, the tree has now been recognized as a plantation crop in South India (Babu *et al*., 2021). In fruit crops like G. gummi-gutta it is essential to understanding the genetic diversity and it can be a key for cultivation, management, improvement and in situ conservation of germplasm (Babu *et al*., 2021). Morphological characteristics of qualitative and quantitative means can be attributed to dig up the systematic modification (Babu *et al*., 2021). Morphological markers in association with molecular markers have a significant role in the genetic mapping and diversity studies of fruit crops. SSR markers also known as microsatellites or short tandem repeats (STRs) having 1–6 bases long and are ubiquitous in the plant genome (Babu *et al*., 2021). Earlier, few attempts were made on molecular characterization of G. gummi-gutta. RAPD primers were used to assess the diversity of accessions (Babu *et al*., 2021). Also efforts were made using both RAPD and ISSR primers to access relatedness of 13 species of Garcinia including G. gummi-gutta (Babu *et al*., 2021). However, no attempt was made to explore the molecular diversity of G. gummi-gutta using species-specific SSR markers (Babu *et al*., 2021). Garcinia belongs to family Guttiferae (Clusiaceae) and the genus comprises approximately 200 species throughout the world, but most of them are found in Asia and Africa (Rajinder *et al*., 2021). More than 36 species of this genus are reported to grow in India, including Garcinia *cambogia* L., which is a tropical dicotyledonous tree and is also native to other countries of Southeast Asia (Rajinder *et al*., 2021). Other beneficial health effects of *Garcinia* in experimental studies are antiulcerogenic, antioxidative, antidiabetic, anti-inflammatory, cytotoxic effects, and hepatoprotective, erythropoietic, and miscellaneous effects (Rajinder *et al.,* 2021). Some of these effects are also contributed by polyisoprenylated benzophenones, namely garcinol and guttiferones present in the G**.** cambogia. However, human clinical data substantiating such therapeutic effects are lacking (Rajinder *et al*., 2021). A taxonomic revision of the genus Garcinia L. (Clusiaceae) in India is provided. Thirty three species and seven varieties are recognized, which include four recently described species, *G. assamica* Sarma *et al*., *G. gamblei* Shameer *et al., G. pushpangadaniana* Sabu *et al*. and *G. sibeswarii* Shameer *et al*. *Garcinia kydia* Roxb. is reduced to a variety of *G. cowa* Roxb. ex DC. Lectotypes are designated for six names (*G. acuminata* Planch. & Triana, *G. cadelliana* King, *G. cowa*, *G. cowa* var. *kydia* (Roxb.) (Mohanan *et al*., 2023). In the absence of supporting literature and herbarium specimens, the distribution of *G. brevirostris* Scheff, *G. merguensis* Wight and *G. jelinekii* Kurz is doubtful in India (Mohanan *et al.,* 2023). The genus *Garcinia* L., belonging to the family Clusiaceae Lindl. (nom. alt. Guttiferae), consisting mainly of trees, is a major component of the evergreen and semi-evergreen flora of India, with a high degree of endemism (Mohanan *et al.,* 2023). Economically, it is also one of the earliest explored plant groups as a fruit crop. References of 'Coddam pulli' or 'Cambog' and 'Mangoustan' appeared in pre Linnaean literature were the source of naming *Garcinia mangostana* L. and *Garcinia gummi-gutta* (L.) (Mohanan *et al.,* 2023). Further, all the workers who dealt with the floras of Indian regions (pre and post independent periods) considered the family with due importance in their floristic treatments and included many additions from time to time (Mohanan *et al*., 2023). Except for the revision of *Garcinia* L., there has been no serious effort to revise this genus in India in recent years. In this context, the present study on the taxonomic revision of Garcinia of India was undertaken (Mohanan *et al.,* 2023). Garcinia is the second-largest genus within the family Clusiaceae (Mohanan *et al.,* 2023).

This is an indication for the need of a comprehensive study of the genus throughout the world. *Garcinia* species are generally small or medium sized evergreen trees distributed in tropical regions, with high species richness in Southeast Asia and Africa (Mohanan *et al*., 2023). The centre of diversity of the genus is considered the Malaysian region, with some species reaching into India and the Micronesian islands and also extending to Australia, tropical Africa and the Neotropics (Mohanan *et al*., 2023). Garcinia is represented by 33 species and seven varieties in India, mainly concentrated in three phyto-geographical zones, the Western Ghats, Northeast India and the Andaman and Nicobar Islands (Mohanan *et al.,* 2023). The taxonomy of Garcinia in India is not well understood, especially due to the lack of detailed morphological studies based on fresh field collections (Mohanan *et al.,* 2023). Reassessment of the South Indian taxon, *Garcinia echinocarpa* Thwaites var. β. (*G. echinocarpa* var. *monticola* Maheshw.) as *Garcinia rubro-echinata* Kosterm. and the addition of one new species, *Garcinia dhanikhariensis* from Andaman and Nicobar Islands, are the only notable contributions (Mohanan *et al*., 2023). Present study provides an updated, comprehensive account of Garcinia in India. The finding of four new species during the study and typification of 11 names, including six designated in this paper, highlight the significance of the present revision (Mohanan *et al*., 2023). Centres of diversity and distribution of Garcinia in India (Mohanan *et al.,* 2023). During the present study, 33 species and seven varieties were recognized as native to the Indian region. As the genus occurs mainly in semi-evergreen to evergreen habitats, it reached the greatest diversity in three phytogeographical zones, *viz.,* the Western Ghats, Northeast India, and the Andaman and Nicobar Islands, where the above vegetation types form the major component (Mohanan *et al.,* 2023). Among these, one species (*Garcinia cambogioides*) shares distribution in both the Western Ghats and Northeast India, whereas three species (*G. cowa, G. dulcis* and *G. xanthochyma*) share distribution in Northeast India and the Andaman and Nicobar Islands (Mohanan *et al*., 2023). Maximum diversity is found in Northeast India, where 15 species and three varieties are recorded, followed by the Western Ghats, housing 11 species and two varieties, and the Andaman and Nicobar Islands, with 10 species and two varieties (Mohanan *et al*., 2023). With respect to endemism, the Western Ghats ranks first with nine species and two varieties, followed by Northeast India with three species and two varieties, and Andaman and Nicobar Islands with three species and one varieties (Mohanan *et al.,* 2023). The Agasthyamala Biosphere Reserve (ABR), situated at the southernmost end of the Western Ghats has the highest representation of the genus in an area with respect to species diversity and endemism, where six species are found, out of which four are restricted to the biosphere reserve (Mohanan *et al.,* 2023).

***Garcinia cambogia*,** a tropical fruit also known as the Malabar tamarind, is a popular weight-loss supplement (Monson, 2023). People say it blocks your body's ability to make fat and it puts the brakes on your appetite (Monson, 2023). Loss of excess weight could help could help keep blood sugar and cholesterol levels in check, too (Monson, 2023). You'll find it in bottles on the shelf at the store as well as mixed with other ingredients in diet products (Monson, 2023). The active ingredient in the fruit's rind, hydroxycitric acid, or HCA, appears to block an enzyme called citrate lyase, which your body uses to make fat. It also raises levels of the brain chemical serotonin, which may make you feel less hungry (Monson, 2023). Some research has found that garcinia cambogia may improve cholesterol levels, lowering triglycerides and LDL (the "bad" cholesterol) and raising HDL (the "good" cholesterol). You shouldn't use it if you're already on a prescription for your cholesterol (Monson, 2023). *Garcinia gummigutta*, also known as *Garcinia cambogia*, has been shown to have excellent properties beneficial against many health conditions (Noreen *et al.,* 2023). The use of *Garcinia cambogia* in traditional medicine has involved treating gastrointestinal ailments, intestinal parasites, rheumatism, digestive disturbances, among other ethnobotanical applications (Noreen *et al*., 2023). The fruit, which resembles a pumpkin in appearance, is presently most often used and heavily promoted as a supplement for weight loss (Noreen *et al*., 2023). According to studies, hydroxycitric acid (HCA), the main organic acid present in the fruit rind, has antiobesity properties that include lowering appetite and reducing body fat gain by regulating serotonin levels linked to satiety, increasing fat oxidation, and reducing *de novo lipogenesis* (Noreen *et al*., 2023). HCA is a strong inhibitor of the enzyme adenosine triphosphate citrate lyase, which converts citrate to acetyl-coenzyme A, a catalyst for the synthesis of fatty acids, cholesterol, and triglycerides (Noreen *et al.*, 2023). In *in vitro* and *in vivo* models, the plant's crude extract or components also have hepatoprotective, anti-cholinesterase, anti-inflammatory, anticancer, and anti-inflammatory effects (Noreen *et al.,* 2023). Studies on the phytochemistry of several plant components found that organic acids and xanthones, such as carbogiol and benzophenones, were also present (Noreen *et al*., 2023). There are already several *G. cambogia*/HCA dietary supplements available for weight loss, however there are some safety concerns about the potential toxicity of continuous usage of these supplements (Noreen *et al*., 2023). The majority of complaints have been in connection with multi-component formulations. *G. cambogia* has not been positively identified as a possibly harmful aggressor (Noreen *et al*., 2023). *Garcinia cambogia* is a native fruit of the South-East Asian region, with a diameter of approx. 1.5 inches and a green-to-yellow color change in the maturation process (Noreen *et al*., 2023). However, the fruits are too acidic to eat. Different parts are used as food preservatives, spices, and bulking agents for foodstuffs (Noreen *et al*., 2023). It is most often used for culinary purposes, especially for fish curries and 'Asam laksa. The *G. cambogia* fruit extract for constipation, hemorrhoids, and intestinal parasites has been used. Edemas, rheumatism and irregular menstruation are other medicinal uses (Noreen *et al*., 2023). Whilst many chemicals from cambogia have been isolated, hydroxycitric acid (HCA) is considered the weight-loss ingredient. Between 20 to 60% of hydroxycitric acid (HCA) is found in garcinia supplements, and many of these products contain many active components in addition to *Garcinia cambogia* (Noreen *et al.,* 2023). When evaluating the quality, effectiveness, and safety of these items, this should also be taken into account, as have been reported for other natural products in several studies (Noreen *et al*., 2023). Additionally, it has been stated that the claimed concentration of HCA in many products is lower than the amount stated. Many clinical studies have been performed on the effectiveness of cambogia for obesity (Noreen *et al.,* 2023). Cambogia is planted and manufactured in mass quantities and is an important economic product in India, thanks to its outstanding therapeutic value shows the image of *Garcinia cambogia* (Noreen *et al.,* 2023). Citric acid can also be used as the starting point for the manufacture of hydroxycitric acid. Dehydration of the acid first forms aconitic acid, which then undergoes oxidation to create hydroxycitric acid (Noreen *et al.,* 2023). According to research, HCA inhibits the enzyme adenosine triphosphate (ATP)-citrate lyase, which catalyses the additional mitochondrial breakdown of citrate into oxaloacetate and acetyl-coenzyme A (acetyl-CoA), a precursor to the production of fatty acids (Noreen *et al*., 2023). According to several research, HCA helps people lose weight without activating their central nervous system. It is obvious that there are numerous opposing opinions on the effectiveness and safety of *G. cambogia* (Noreen *et al.,* 2023). The genus *Garcinia* with about 250 species of trees and shrubs found throughout the tropics is a very important genus in the family Clusiaceae (Raj *et al.,* 2023). The genus is characterized by very high diversity in floral characters, which makes the taxonomy of the genus quite difficult (Raj *et al.,* 2023). *Garcinia* is very important as a subsistence tree crop, as the fruits of many species are used as fruits, as flavoring spice, as a source of nutritious juice, as a source of valuable phytochemicals such as garcinol and hydroxycitric acid (Raj *et al*., 2023). The genus is distributed in Asia, America, Australia, tropical and southern Africa, and Polynesia. Plants of the World Online (POWO) recognize up to 400 species (Raj *et al*., 2023). The genus is named after Laurentius Garcin (1683–1752), a Dutch army doctor and naturalist (Raj *et al.,* 2023). In India, species of *Garcinia* grow extensively in semiwild state, in the Konkan region of Maharashtra, Goa, coastal areas of Karnataka and Kerala, and evergreen forests of Assam, Khasi, Jaintia Hills, Nagaland, West Bengal, and Gujarat (Raj *et al.,* 2023). In Malabar and Konkan regions of Southern India, they are used in garnishing curries and as a replacement for tamarind (Raj *et al.,* 2023). The dried rind is the commercial product; it is especially valued in the preparation of fish curries; the special taste and flavor of the Goan fish curry owes its taste to this spice (Raj *et al*., 2023). Many species of *Garcinia* have fruit with edible arils and are eaten locally (Raj *et al.,* 2023).

A tropical species of Garcinia (Malabar tamarind/ Kudampuli) called *Garcinia gummi-gutta* L.(Robson) a native of South and Southeast Asia, belongs to the family Clusiaceae, is grown all over the world (Bini Sundar *et al.,* 2024). The species is indigenous to the Western Ghats of India and is found from Konkan to Kerala and in the Shola forests of Nilgiri hills up to an altitude of 2000 m (Bini Sundar *et al.,* 2024). It is an important fruit crop for Kerala's economy. Its fruit has medicinal benefit and has commercial possibilities for sauces. It yields a small, tasty exotic fruit whose dried pericarp is used in Keralan curries as a condiment and tamarind substitute to give unique flavour (Bini Sundar *et al*., 2024). It functions as a diuretic, hydragogue, anthelmintic, antibiotic, antioxidant, hypolipidemic, and weight - reduction agent (Bini Sundar *et al.,* 2024). Its fruits are rich source of highly prized anti-obesity phytochemical hydroxy citric acid (Bini Sundar *et al.,* 2024). As Garcinia comes under underutilized medicinal fruit tree, in order to conserve the germplasm, effective characterization of the genotypes using morphological and molecular markers would aid in greater way. Hence, the present investigation was taken up (Bini Sundar *et al.,* 2024). The plant *Garcinia gummi-gutta* (L.) Roxb. belongs to the family Clusiaceae. It is a wild tropical and subtropical plant (Soumya and Manimekalai, 2024). The fruits are popularly known as Malabar tamarind or Kudampuli whose dried pericarp is used as a condiment and is used as an alternative tamarind to impart a special flavour and taste to curries in Kerala (Soumya and Manimekalai, 2024). The fruits are commercially important as a rich source of the much valued antiobesity phytochemcial hydroxycitric acid and several industrial units are located in central Kerala for extracting the value added product from the fruits (Soumya and Manimekalai, 2024). *Garcinia gummi-gutta* extract standardised for 20% garcinol reduces adipogenesis and high fat. Garcinol, a polyisoprenylated benzophenone extracted from the fruit rind of *Garcinia gummi-gutta*, is known for its antioxidant, anti-inflammatory and anticancer activities (Soumya and Manimekalai, 2024).

Garcinia gummi-gutta is a tropical species of *Garcinia* native to South Asia and Southeast Asia (Inaturalist, 2025). Common names include *Garcinia cambogia* (a former scientific name), as well as brindle berry, and Malabar tamarind (Inaturalist, 2025). The fruit looks like a small pumpkin and is green to pale yellow in color (Inaturalist, 2025). Although it has received considerable media attention purporting its effects on weight loss, there are reports of liver toxicity associated with the *Hydroxycut* commercial preparation containing the fruit extract, with clinical evidence indicating it has no significant effect on weight loss (Inaturalist, 2025). Garcinia is the largest genus of the Clusiaceae family comprising nearly 250 species. Garcinia gummi-gutta (L.) (Syn.: Garcinia cambogia (Gaertn.); Common name: Malabar tamarind), is one of the

most important members of the Clusiaceae family (Agrienterprises, 2025). It is a small or medium sized tree up to 12 m tall with dark green and shining leaves. The leaves are elliptic obovate, 2-5 inch long and 1-3 inch broad. Fruits are ovoid, 2 inches in diameter, yellow when ripe, with 6-8 grooves; seeds 6-8 surrounded by succulent aril. The aril and the fleshy covering encasing the seed is edible when ripe (Agrienterprises, 2025). The differentiation between male and female trees is known only at the flowering stage which takes approximately 7 to 9 years (Agrienterprises, 2025). *G. gummi-gutta* is a common species found in the Western Ghats, from the Konkan southwards to Travancore eastwards. The species has now been introduced elsewhere in the subtropical region of Asia including China, Malaysia and the Philippines (Agrienterprises, 2025). It is a common fruit plant of the Western Ghats, attributed with a wide range of applications ranging from food, medicines and nutraceutics (Agrienterprises, 2025). The fruit rind of *G. gummi-gutta* is the major source of (−)-hydroxycitric acid (HCA). In addition, secondary metabolites such as xanthones, benzophenones, organic and amino acids were also reported from this plant (Agrienterprises, 2025). The potential beneficial effects include antioxidant, antihelmenthic, antidiabetic, antimicrobial, antiobesity and hyperlipidaemic properties (Agrienterprises, 2025).

Reports on the toxicity and observations during clinical trials suggest that *G. gummi-gutta* is safe for human consumption (Agrienterprises, 2025). The consequences of using Garcinia gummi-gutta, often known as Malabar Tamarind, sustainably while diving into the complex web of genetic variation inside the crop (Scaria *et al*., 2025). Botanical and genetic traits of this enigmatic species, revealing the morphological quirks and genetic differences that make it distinct (Scaria *et al.,* 2025). Examining the range and preferred habitats helps to highlight the ecological niches that are essential to its existence (Scaria *et al*., 20p25). It delves intently into the complex web of phytochemicals found in various plant parts and explains their range of biological functions (Scaria *et al*., 2025). A crucial component of this study is a thorough examination of the techniques used to gauge the genetic diversity of populations of *G. gummi-gutta* (Scaria *et al*., 2025). The assessment of *G. gummi-gutta*'s conservation status indicates that threats to the species' genetic richness need to be taken seriously and quickly addressed (Scaria *et al*., 2025). The difficulties in attaining sustainable use are examined in detail, offering a comprehensive grasp of the nuances related to overexploitation and conservation initiatives (Scaria *et al*., 2025).

Garcinia cambogia, or *Garcinia gummi-gutta*, is a sour-tasting tropical fruit. It has recently gained recognition as a weight-loss supplement (Balmoralpharmacy, 2025). In NZ, *Garcinia cambogia* is widely available in capsules or as part of the ingredient mix in a number of diet products (Balmoralpharmacy, 2025). *Garcinia cambogia* is native to Indonesia. It can also be found in India, Sri Lanka, Malaysia, and in some parts of Africa (Balmoralpharmacy, 2025). The fruit is usually green or yellow in colour. It looks slightly similar to pumpkins (Balmoralpharmacy, 2025). The fruit tastes sour. It can be made into a condiment (Balmoralpharmacy, 2025). It has antioxidant and antifungal properties (Balmoralpharmacy, 2025). The fruit contains hydroxycitric acid (HCA) that may help suppress the accumulation of fat in the body (Balmoralpharmacy, 2025). Garcinia cambogia is a tropical fruit not common in New Zealand. To date, there are only a few clinical studies about its effectiveness in losing weight (Balmoralpharmacy, 2025). You can purchase *Garcinia cambogia* in capsules, powders, and liquid forms from the Balmoral Pharmacy in Auckland, NZ (Balmoralpharmacy, 2025). *Garcinia cambogia*, also known as Malabar tamarind, is a small tree belonging to the family Clusiaceae (Google, 2025). Its scientific name is *Garcinia cambogia* (Gaertn.) Desr. (Google, 2025)**.** It's native to Southeast Asia, especially India, and is known for its acidic fruit rind, which is used in cooking and as a dietary supplement (Google, 2025). *Garcinia cambogia* is a popular weight loss supplement (Healthline, 2025). It is derived from a fruit of the same name, also called Garcinia gummi-gutta or Malabar tamarind (Healthline, 2025). The peel of the fruit contains high amounts of hydroxycitric acid (HCA), which is the active ingredient believed to be responsible for most of its weight loss benefits (Healthline, 2025). *Garcinia cambogia* is a small, pumpkin-shaped, yellow or greenish fruit. The fruit is so sour that it is generally not eaten fresh but rather used in cooking (Healthline, 2025).

ORIGIN AND DISTRIBUTION

Garcinia cambogia has a limited native global distribution, being restricted to India, Nepal and Sri Lanka, but it has been introduced elsewhere where it is distributed in the subtropical region of Asia including China, Malaysia and the Philipines. These trees are found mainly in the semi-evergreen to evergreen forests of Southwest India, predominantly in the Western Ghats (Maharashtra, Karnataka, Kerala and Tamil Nadu). This tree can grow on both hilltops and plain lands but grows (Semwal *et al.,* 2015). The variety *gummi-gutta* is distributed wildly in the evergreen forests of Western Ghats ranging, from 400 m to 900 m. It is fairly common and abundant in the forests of western Sri Lanka from sea level to 600 m and in Malaysia also. In Kerala, it is very popular in the Central Travancore areas, where maximum diversity is seen. Field studies revealed that the var. *gummi-gutta* is cultivated all over the low lands and mid lands of Kerala ranging from sea shore to the high lands up to 600 m. The other two varieties are restrictedly endemic to the Western Ghats. Variety *conicarpa* is a high altitude species (1350- 1950 m) distributed rarely in evergreen forests of South Western Ghats. var. *papilla* is also very rare in the evergreen forests of Southern Western Ghats and found in an altitude of 800-1850 m. Samples of *G. gummi-gutta* var. *papilla* were collected from Silent Valley, Palakkad district and *G. gummi-gutta* var. *conicarpa* were collected from from Kadalar, Rajamala, Kottamala forest regions of Idukki district and Vellarimala, Chembra hills of Wayanad district. Though varieties papilla and conicarpa were not included in IUCN categories, we suggest both to be included in 'endangered' category, based on their restricted distribution within small scattered populations (Shameer *et al*., 2016). *Garcinia gummi-gutta* (L.) Roxb. [Syn. *G. cambogia* (Gaertn.) Desr.] is native to Southern India and is found distributed in Sri Lanka and Nepal. It is popularly used as a culinary agent (in place of tamarind) in food preparation. In India, it is found in the Western Ghats as a semi-domesticated tree, which grows at an elevation range of 400–900 m. This plant is introduced to other tropical and subtropical regions of Asia including China, Malaysia and the Philippines (Murthy *et al.,* 2018).

It is a native of Western Ghats of Kerala (India). Its habitat extends from Konkan southward to Travancore and into the shola forests of Nilgiris. It is fairly common in Sri Lanka and Malaysia **(**Espicebazaar, 2025**).** Native to India, Sri Lanka, and parts of Southeast Asia (Google, 2025). It is a native of Western Ghats of Kerala (India). Its habitat extends from Konkan southward to Travancore and into the shola forests of Nilgiris. It is fairly common in Sri Lanka and Malaysia (Indianspices, 2025).

In India it is found in Goa : North Goa district, South Goa district; Karnataka : Chikkamagaluru district, Dakshina Kannada district, Hassan district, Shivamogga district, Udupi district, Kodagu (Coorg) district, Uttara Kannada district; Kerala : All districts of Kerala; Maharashtra : Mumbai Suburban district, Konkan; Tamil Nadu : Guthirayan Hills (Dharmapuri district), Coimbatore district, Dharmapuri district, The Nilgiri district, Tirunelveli district, Kanyakumari district (Indiaflora, 2025).

TAXONOMY

Selected species (Wikipedia, 2025a).

More than 400 accepted species are there.

1. *Garcinia acutifolia*
2. *Garcinia afzelii*
3. *Garcinia aristata*
4. *Garcinia assamica*
5. *Garcinia atroviridis – asam gelugur* (Indonesian), *asam gelugor* (Malaysian), *asam keping* (Malaysian)
6. *Garcinia benthamiana – asashi*
7. *Garcinia bifasciculata*
8. *Garcinia binucao* - *batuan* (Hiligaynon), *binukaw* (Visayan)
9. *Garcinia brasiliensis – bacupari-mirim*
10. *Garcinia brevipedicellata*
11. *Garcinia burkillii*
12. *Garcinia cadelliana*
13. *Garcinia cantleyana*
14. *Garcinia celebica* L.
15. *Garcinia clusiaefolia*
16. *Garcinia costata*
17. *Garcinia cowa* - cowa mangosteen
18. *Garcinia decussata*
19. *Garcinia diversifolia*
20. *Garcinia dulcis – mundu, rata*
21. *Garcinia echinocarpa*
22. *Garcinia epunctata*
23. *Garcinia eugeniaefolia*
24. *Garcinia forbesii* - *rose kandis*
25. *Garcinia gardneriana – bacupari*
26. *Garcinia gummi-gutta* – gambooge, garcinia cambogia, brindleberry, brindall berry, Malabar tamarind
27. *Garcinia hanburyi* – Hanbury's garcinia
28. *Garcinia hendersoniana*
29. *Garcinia hermonii*
30. *Garcinia holttumii*
31. *Garcinia hombroniana* - seashore mangosteen
32. *Garcinia humilis* – achachairú, achacha
33. *Garcinia imberti*
34. *Garcinia indica* – wild mangosteen, kokum
35. *Garcinia intermedia* – lemon drop mangosteen, *machare*
36. *Garcinia kingii*
37. *Garcinia kola* – bitter kola
38. *Garcinia lateriflora* – Kandis (Palawan)
39. *Garcinia leptophylla*
40. *Garcinia linii*
41. *Garcinia livingstonei* – African mangosteen, Lowveld mangosteen, Livingstone's garcinia, *imbe*
42. *Garcinia loureiroi* - (Khmer: ស្វាយ)
43. *Garcinia macrophylla – pungara*
44. *Garcinia madruno* (Kunth) Hammel – *charichuelo*
45. *Garcinia magnifolia – bebasajo*
46. *Garcinia maingayi*
47. *Garcinia mangostana* – purple mangosteen
48. *Garcinia microcarpa*
49. *Garcinia minutiflora*
50. *Garcinia monantha*
51. *Garcinia montana*
52. *Garcinia morella – ireevalsinni* (Tamil)
53. *Garcinia multiflora* Champ. – *dọc* (Vietnamese)
54. *Garcinia murtonii*
55. *Garcinia nigrolineata* Planch. ex T.Anderson
56. *Garcinia nitida*
57. *Garcinia oliveri*
58. *Garcinia opaca*
59. *Garcinia parvifolia* - Kundong, Brunei cherry, Asam aur aur
60. *Garcinia paucinervis*
61. *Garcinia pedunculata*
62. *Garcinia prainiana* – button mangosteen, *cherapu*
63. *Garcinia pseudoguttifera* - mo'onia tree
64. *Garcinia pushpangadaniana*
65. *Garcinia pyrifera*
66. *Garcinia quaesita*
67. *Garcinia rubro-echinata*
68. *Garcinia scortechinii*
69. *Garcinia semseii*
70. *Garcinia sessilis* Seem. – *heilala* (Tongan), *seilala* (Samoan)

71. *Garcinia spicata* - bitter garcinia
72. *Garcinia staudtii*
73. *Garcinia subelliptica* - fukugi tree
74. *Garcinia terpnophylla*
75. *Garcinia thwaitesii*
76. *Garcinia travancorica*
77. *Garcinia uniflora*
78. *Garcinia warrenii* F.Muell.
79. *Garcinia wightii*
80. *Garcinia xanthochymus* – yellow mangosteen, *gamboge*
81. *Garcinia zeylanica*

Homotypic Synonyms **(**BTRBG, 1968**).**

Cambogia gummi-gutta L. in Gen. Pl., ed. 5.: 522 (1754)
Cambogia gutta L. in Syst. Nat., ed. 10. 2: 1073 (1759), nom. superfl.
Garcinia cambogia Desr. in J.B.A.M.de Lamarck, Encycl. 3: 701 (1792), nom. superfl.
Garcinia gutta Roxb. ex Wall. in Numer. List: 141 (1831), nom. superfl.
Mangostana cambogia Gaertn. in Fruct. Sem. Pl. 2: 106 (1790), nom. superfl.

Garcinia gummi-gutta (L.) Roxb. [Syn. *G. cambogia* (Gaertn.) Desr.] (Malabar Tamarind) (Murthy et al., 2018).

Cambogia binucao Blanco
Cambogia gemmi-gutta L.
Cambogia solitaria Stokes
Garcinia affinis Wight & Arn.
Garcinia cambogia (Gaertn.) Desr.
Garcinia sulcata Stokes
(Wikipedia, 2025).

Garcinia cambogia, *Cambogia gemmi-gutta*, *Garcinia sulcata* (Awale, 2025).

Cambogia gummi-gutta L.

Cambogia solitaria Stokes

Garcinia affinis Wight & Arn.
Garcinia cambogia (Gaertn.) Desr.
Garcinia gutta Roxb.
Garcinia sulcata Stokes
Mangostana cambogia Gaertn.
Stalagmitis gutta (Roxb.) G. Don
(Indiabiodiversity, 2025).

Garcinia cambogia (Gaertn.) Desr. ; *Mangostana cambogia* Gaertn.; (Indiaflora, 2025).

Cambogia gummi-gutta **L.**
Cambogia gutta **L.**
Garcinia cambogia **Desr.**
Garcinia gutta **Roxb. ex Wall.**
Mangostana cambogia **Gaertn.**
(WFO, 2025
Included Variety (WFO, 2025).
Garcinia gummi-gutta var. gummi-gutta

Garcinia gummi-gutta var. papilla (Wight) N.P.Singh

Botanical Description

Garcinia is the largest genus of the Clusiaceae family comprising of 390 species. These polygamous trees or shrubs are mainly distributed in tropical Asia, Polynesia and Africa. Garcinia gummi-gutta (L.) Roxb. is one of the most medicinally important members of the Clusiaceae family. It is a small or medium size tree of up to 12 m tall with a rounded crown and drooping branches. Young branchlets are subterete and glabrous and the trunk and bark is reddish-brown and lenticellate. The leaves are dark green, shiny, opposite and decussate with 5–16 cm long petioles and 5–13 cm × 2–6 cm laminae. The leaves are elliptic, oblanceolate to obovate in shape, and the apex is usually acute and rarely obtuse. The polygamous flowers are in axillary or terminal clusters and the sepals are cream while the petals are pink in colour . Flowering occurs during the summer (March–May) while fruiting occurs during the rainy season (June–September). The ovoid fruits are about 5 cm in diameter with 6 to 8 grooves. The fruit can be yellow, orange or red when ripe and has 6 to 8 seeds surrounded by a succulent aril. Growth of the tree is slow and differentiation between male and female trees is known only at the flowering stage, at approximately 7–9 years (Semwal *et al.,* 2015). Fruits are small, edible, and acidic and are about 5 cm in diameter with 6–8 grooves. They are green in color before ripening and turn yellow to yellow or

red after ripening. Seeds are kidney-shaped with whitish to yellow arils. Sun-dried fruit rind is used as the condiment for flavoring the curries in place of lime or tamarind in Malabar regions of the Western Ghats in India. Therefore, this plant is popularly called Malabar tamarind. The fruit is commonly used as a preservative and flavoring agent. The dried fruit rind of Malabar tamarind is rich in α, β-dihydroxy tricarboxylic acid or hydroxyl citric acid (HCA) responsible for its anti-obesity property. Various commercial anti-obesity products made of Malabar tamarind fruits are available in the market (Murthy *et al.,* 2018).

It is a small to medium tree that grows to a height of 20 m with a rounded crown and horizontal or drooping branches. The leaves of the tree are dark green, shiny, ovate in shape, ranging from 2½ to 3½ inches in length and from 1 inch to 1½ inches in breadth. The tree bears small green fruits that are ovoid in shape and have a diameter of 1 to 1.5 inches, are yellow or red, and have six to eight grooves. The fruit resembles a small yellow or reddish pumpkin, or it may have a unique purple color. The fruit seeds are surrounded by a succulent aril part. The tree flowers during the hot season and fruits ripen during the rainy season. The dried fruit rind of G. cambogia is used for centuries in Asian countries for culinary purposes as a condiment and flavoring agent without any adverse effect. It possesses a distinct sour taste that it imparts to food and is used as an alternative to tamarind or lemon in curries and other ethnic food preparations to make them more filling and satisfying. Fruit rind is also eaten raw, perhaps at meals as an appetizer in parts of India. The dried fruit rind of G. cambogia combined with salt and other organic acids can lower the pH and thus provide a bacteriostatic effect for curing fish; this method of preservation of fish is known as Colombo Curing (Rajinder *et al*., 2021). In the Clusiaceae family Garcinia is the largest of 390 species. The plant is distributed primarily in tropical Asia. It has a circular crown and tilted branches up to 12 meters high and is small or medium sized. The young twigs are subtle, glabrous, reddish-brown and lenticellate. The hooks are dark-green and are brilliant on the face, with pétioles 5–16 centimeters long and 5–13 for linen 2–6 centimeters. The leaves are elliptic, oblanceolate, with the apex usually shaped acutely and rarely. The rose polygamous flora is axilla or terminal with a sepal and petal cream. Flowers occur in summer and fruiting occurs during rainy season (June-September). The eggs have a width of about 5 cm and diameters of 6 to 8 rags. When ripe, the fruit can be yellow, orange or red. It contains 6 to 8 succulent aril seeds. Tree growth is slow (Noreen *et al.,* 2023).

Cambodge is a tropical fruit commonly known as ‘Malabar Tamarind’ is a medium size evergreen dioecious tree with rounded crown and horizontal or drooping branches attaining a height of 18 m. Fruit is a berry having a size of an apple, yellow or red, 6 to 8 grooves, forming blunt lobes with tough rind, 6 to 8 seeds and succulent arils. Fruit is weighing 50 to 180 g (Indianspices, 2025). Cambodge or Malabar Tamarind is a tropical fruit. The berry, in yellow or red colour, has 6-8 grooves. It has blunt lobes with tough rind, succulent aril and 6-8 seeds. The rind is dried to obtain the spice. The tree is a native of Western Ghats from Konkan to the south down to Kerala. It is a common tree in Kerala. Cambodge is also found largely in Karnataka. It is a flavouring agent for ethnic fish delicacies in Kerala. Cambodge rind is rich in hydroxyl citric acid and is used in the manufacturing of anti-obesity drugs (Munnar, 2025). Leaves: Opposite, stalked, dark green, and shiny, typically elliptic to obovate in shape. Flowers: Borne in clusters, usually red but can also be yellow, with 4 petals. Fruit: A berry, yellowish or reddish in color, with 6-8 grooves and blunt lobes. The fruit has a tough rind, succulent arils, and 6-8 seeds. Bark: Dark and smooth (AI Overview, 2025). Cambodge is a tropical fruit commonly known as 'Malabar Tamarind' is a medium size evergreen dioecious tree with rounded crown and horizontal or drooping branches attaining a height of 18 m (AI Overview, 2025). Cambodge Tree is an evergreen, small or medium-sized understorey tree, 5-20 m tall, about 70 cm bole diameter, with a rounded crown and horizontal or drooping branches. The bark is dark and smooth. Leaves are opposite, stalked, dark green, shining, 13-18 by 4-8 cm, elliptic to obovate, hairless. Leaf-stalks are 1.2-2.2 cm long. Flowers are borne in clusters of 4-20, are usually red, but some trees have yellow ones. Petals are normally 4, each about 1.2 cm wide 1.1 cm long, anthers attached to a pistillode with a non-functional stigma. Female flowers occur singly or in clusters of up to 4. The stigmatic surface is normally enlarged, and there is no style. Female flowers have rudimentary and non- functional staminodes. Neither male nor female flowers produce nectar. Fruit is a green, ovoid berry, with 6-8 grooves, 5 cm in diameter, yellow or red when ripe. Seed 6-8, smooth, large, about 5 cm long and 2 cm wide surrounded by a succulent aril. Cambodge Tree is found in Western_Ghats and Sri Lanka (Awale, 2025).

Cambodge is a tropical fruit commonly known as ‘Malabar Tamarind’ is a medium size evergreen dioecious tree with rounded crown and horizontal or drooping branches attaining a height of 18 m. Fruit is a berry having a size of an apple, yellow or red, 6 to 8 grooves, forming blunt lobes with tough rind, 6 to 8 seeds and succulent arils. Fruit is weighing 50 to 180 g (Espicebazaar, 2025). Evergreen tree up to 20 m high; exudation pale yellow, sticky. Leaves: Elliptic, obelliptic-ovate, 6-13 cm x 2.5-6 cm. Male flowers: Tetramerous, 3-8 flowers on axillary fascicles, 1-1.7 cm x 1-1.2 cm, pedicel 7-12 mm long; sepals orbicular, margin membranous with fimbril like projections; petals oblong, pale yellow or orange yellow, membranous on margin; stamens in a globose head; rudimentary pistil absent or if present stigma discoid with 4 lobed clefts. Female flowers: Tetramerous, solitary or 1-3 fascicle on terminal or axillary, 1.5-2 cm x 1.5 cm; staminodes 10-20; ovary 4-12 locular, ca. 1 mm long, ovule one in each locule, subglobose or ovoid, grooved, stigmatic rays spreading, free nearly to the base, margin crenate, tuberculate. Fruits: Globose, 6-8 cm in diam., 6-10 grooved, yellow or orange yellow on ripening, pericarp very thick, fleshy. Seeds: 6-8, ovoid, 2-3.3 mm x 0.7-0.9 mm, compressed, surrounded by white or red pulpy aril (Agrienterprises, 2025). *Garcinia gummi-gutta* is an evergreen, small or medium-sized dioecious, understorey tree, 5 –20 m tall, about 70 cm dbh, with a rounded crown and horizontal or drooping branches. The bark is dark and smooth. Leaves opposite, petiolate, dark green, shining, 13-18 by 4-8 cm, elliptic to obovate, glabrous; petiole 1.2-2.2 cm. Flowers in clusters of 4-20, are usually red, but some trees have yellow ones. Petals normally 4, each about 12 mm wide 11 mm long; anthers attached to a pistillode with a non-functional stigma. Female flowers occur singly or in clusters of up to 4. The stigmatic surface is normally enlarged, and there is no style. Pistillate flowers have rudimentary and non-functional staminodes. Neither male nor female flowers produce nectar. Fruit a green, ovoid berry, 5 cm in diameter, yellow or red when ripe, with 6-8 grooves. Seed 6-8, smooth, large, about 5 cm long and 2 cm wide surrounded by a succulent aril (Robson, 2025). It is found in semi-evergreen to evergreen forests. In India, it is commonly found in the evergreen and shola forests of Western Ghats, Karnataka and Kerala. The tree is very much adapted to both hilltops and plain lands, but its performance is best in riverbanks and valleys. It also grows well in dry or occasionally water logged or flooded soils (Robson, 2025). Cambodge is an evergreen tree commonly found in the forests of Western Ghats, from Konkan to Kerala and the Shola forests of Nilgiris. Cambodge is a small or medium-sized tree with rounded crown and horizontal or drooping branches. The leaves are dark green, shining, elliptic obovate, 5 -12.5 cm long and 2-8 cm broad. Its fruits are ovoid (5 cm dia), yellow or red when ripe, with 6 - 8 grooves and contain 6-8 seeds surrounded by a succulent aril. The tree flowers during the hot season and fruits ripen during the rains. Cambodge contains tartaric acid (10.6 %), glucose (15%) and phosphoric acid (1.5%). The seeds of cambodge yield 31 % of edible fat resembling kokum butter (KSSDB, 2025). Trees up to 12 m tall. Trunk & Bark-uter bark reddish brown, lenticellate; blaze reddish. Branches drooping; young branchlets subterete, glabrous. Exudates-Latex yellow, profuse. Leaves simple, opposite, decussate; petiole 5-1.6 cm long, planoconvex or shallowly canaliculate above, slightly sheathing at base; lamina 5-13 cm x 2-6 cm; variable in shape from narrow elliptic, oblanceolate to obovate, apex usually acute, sometimes obtuse, base cuneate to attenuate, coriaceous or subcoriaceous; secondary nerves not prominent on both sides; tertiary nerves obscure. Flowers polygamous, in axillary or terminal clusters; calyx cream; petals pink. Berry, globose, 6-8 grooved, to 5 cm in diameter; many seeded (Ramesh *et al.,* 2025).

Cambodge Tree Species of Garcinia native to Indonesia. Common names include *Garcinia cambogia* (a former scientific name), as well as brindleberry, Malabar tamarind, Goraka, and *kudam puli* (pot tamarind). The fruit looks like a small pumpkin and is green to pale yellow in color. Cambodge Tree is an evergreen, small or medium-sized understorey tree, 5-20 m tall, about 70 cm bole diameter, with a rounded crown and horizontal or drooping branches. The bark is dark and smooth. Leaves are opposite, stalked, dark green, shining, 13-18 cm by 4-8 cm, elliptic to obovate, hairless. Leaf-stalks are 1.2-2.2 cm long. Flowers are borne in clusters of 4-20, are usually red, but some trees have yellow ones. Petals are normally 4, each about 1.2 cm wide 1.1 cm long, anthers attached to a pistillode with a non-functional stigma. Female flowers occur singly or in clusters of up to 4. The stigmatic surface is normally enlarged, and there is no style. Female flowers have rudimentary and non-functional staminodes. Neither male nor female flowers produce nectar. Fruit is a green, ovoid berry, with 6-8 grooves, 5 cm in diameter, yellow or red when ripe. Seed 6-8, smooth, large, about 5 cm long and 2 cm wide surrounded by a succulent aril. Cambodge Tree is found in Western_Ghats and Sri Lanka (Thenaruvi, 2025).

Tree

Leaves

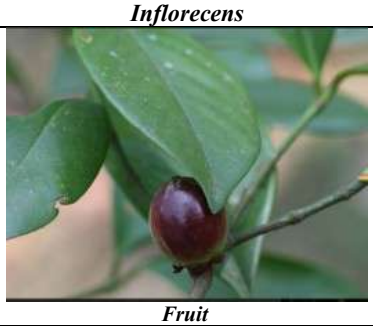
Leaf uipper surface

Lower side

Inflorecens

Male flower

Female



Fruit

Fruit

Gum oozig

Seeds

Seeds

Dried fruits

Fig. 1. Botanical Description

GENETICS AND CYTOGENETICS

The diploid chromosome number (2n) of *Garcinia cambogia* is 54. This means that the plant has 27 pairs of chromosomes in its somatic cells. *Garcinia cambogia* is a triploid species, with a diploid chromosome number of 2n = 54. The haploid number (n) is 27. The present study indicated that there is variation in chromosome number between the four species of Garcinia. *Garcinia pedunculata, Garcinia cowa* and *Garcinia lanceaefolia* was found to be 2n = 48 except in *Garcinia xanthochymus* with 2n = 72. So there is a scope for genetic assessment and breeding due to presence of variability in chromosome. The diploid chromosome number for *Garcinia cambogia* is 2n = 48. Some studies have reported 2n=54 for *Garcinia indica*. Other related species, like *Garcinia morella* and *Garcinia cowa*, are also diploids with 2n=48, while *Garcinia spicata* and *Garcinia pariflora* are triploids with 2n=72 (Gogoi *et al*., 2015).

GENETIC DIVERSITY

A collaborative crop specific exploration and collection mission to collect the germplasm and to study the population size of male and female/hermaphrodite trees of Malabar tamarind [*Garcinia cambogia* (Gaertn.) Desr.] in the area of its diversity was undertaken during July 2002 in Kerala and Karnataka. A total of 56 accessions of Malabar tamarind were collected. Two collections of Malabar tamarind were found to be very specific because of the uncommon fruit colour, which is pinkish red. All the collected accessions are grown at National Bureau of Plant Genetic Resources (NBPGR) Regional Station, Thrissur for characterisation and conservation. Extensive range of variability was found in fruit colour, shape, size and nature of branching and canopy of trees. Characterisation of 13 fruit and five seed characters was done for 51 accessions. The variability was found to be maximum for nipple length (74.8%) and minimum for fruit girth (12.8%). Two promising accessions were identified based on mean fruit weight (161 g) in IC 354028 and mean rind thickness (15 mm) and mean rind weight (125 g) in IC 354019 (Abraham, 2006).

The genetic relationship among twelve *Garcinia cambogia* (Gaertn.) Desr. accessions were evaluated using Random Amplified Polymorphic DNA markers. The samples were part of the germplasm collected and maintained at NBPGR Regional station, Thrissur, India. Out of thirty RAPD primers used for screening, seven primers produced a total of 128 polymorphic markers in twelve accessions. The Polymorphic Information Content (PIC) ranged from 0.28 (OPA18) to 0.37 (OPA9) and Marker Index (MI) ranged between 3.61 (OPA12) and 5.93 (OPA3) among the primers used. Jaccard's coefficient of genetic similarity ranged between 0.07 and 0.64. The dendrogram constructed based on the similarity matrix generated from the molecular and morphological data showed the genetic relationship among the sampled accessions. Mantel matrix test showed a positive correlation (r = 0.49) between the cluster analysis of RAPD data and morphological data. The clustering pattern in the molecular dendrogram and Principle Coordinate Analysis (PCoA) showed that the genotypes were diverse, which was in congruence with the similarity index values and morphological dendrogram. High frequency of similarity values in the range of 0.11 to 0.17 suggested the existence of high genetic diversity among the accessions. The high level of genetic diversity among the studied accessions of *G.cambogia* was also supported by the large variation in the morphological characters observed in the flowers, leaves, fruits and seeds of these sampled accessions (Scielo, 2015).

Fig. 2. *G. gummi-gutta* varieties A-C. Leaves, D-F. Male flowers, G-H. Female flowers, J-K. Fruits)

Critical evaluation of morphological characters through detailed qualitative and quantitative characters of male and female accessions of the varieties were carried out. The demarcating morphological features noted for the varieties are lamina shape, presence of leaf ligule, pedicel length, stamen arrangement, fruit shape and number of fruit grooves in fruits. Based on the distinguishing morphological features of var. conicarpa such as absence of leaf ligules, lamina shape, arrangement of stamens in convex torus head, pedicel length, conical nature of fruits and the fibrous nature of arils, the variety conicarpa need to be reinstated as species *G. conicarpa* (Shameer *et al*., 2016). Kerala seems to be the

centre of diversity of cambogia and wide variations in the morphological characters are observed in the leaves, flowers, fruits and seeds of *Garcinia gummi-gutta.* The diversity of var. *gummi-gutta* is more manifested among the cultivars, compared to the wild accessions. Fruits of 18 accessions of var. *gummi-gutta*, cultivated in different parts of Kerala extending from coastal region to middle land, were collected and studied for assessing the variability in size and shape. The large fruit size, pulpy aril and more number of seeds (4-8) per fruit were the favorable features of var. *gummi-gutta* supporting its wide distribution and preference for cultivation over the other two varieties. The processed pericarp of var. *gummi-gutta* is of great value for its delicate taste and flavour and the accessions were evaluated in terms of fruits size, rind thickness, acidity and yield. The average weight of fruits was 173 g. Previous studies on 13 fruit and five seed characters of 51 accessions of Malabar tamarind reported that the variability was found to be maximum for nipple length (74.8%) and minimum for fruit girth (12.8%) and the average fruit weight was 161g. Usually the branching pattern was horizontal, while pendulous drooping pattern has also been observed rarely. The average size of leaves was 7-12 cm x 3.5-5 cm while the leaf shape varied considerably from the typical elliptic to broad shapes. The apex and base of leaves were acute and rarely obtuse. The variation was also exhibited in flowers, fruits and seeds morphology. The fruit shape varied from globose, oblong and rarely to discoid shape. The thickness of fruit rind is a detrimental factor in food sector and the thickness varies from 6.25 mm to 16.03 mm among the selected accessions. The fresh weight of fruit was in the range 45.7-173.3 g. The number of grooves over the fruit surface also varied significantly from 5 to 11 (Shameer *et al.,* 2016). Genetic variability are given in Fig. 2- 6.

Fig. 3: *Garcinia gummi-gutta*: Flower variability.
a Solitary flower. b Two flowers.
c Three flowers. d Many flower

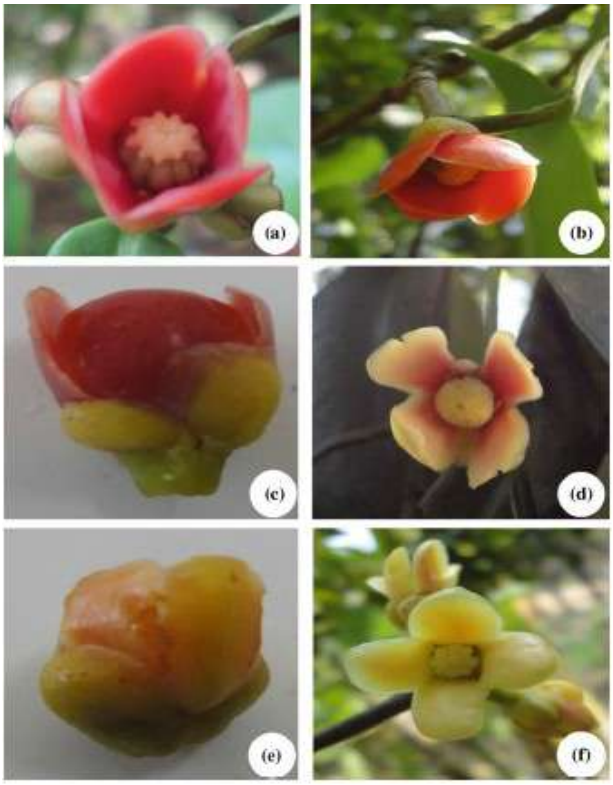


Fig. 4. *Garcinia gummi-gutta* variability in flower color. a Red flower. b Orange flower, c Reddish-brown flower, d Reddish-yellow flower. e Pinkish flower. f Yellow flower

Fig. 5. *Garcinia gummi-gutta* variability in fruit shape, size, color and number of furrow

Fig. 6. Diversity of *Garcinia gummi-gutta* var. *gummi-gutta* fruits

Malabar tamarind is naturally distributed in India, Sri Lanka and Nepal and it exhibits much natural diversity in semi-evergreen to evergreen forests of Southwest India, especially western Ghat regions. They collected a total of 56 accessions from Kerala and Karnataka provinces of India and assessed variability of fruit and seed characteristics. They reported variation in fruit length (43.0–82.0 mm), fruit girth (122–217 mm), nipple thickness (4.0–29.0 mm), nipple length (0.6–18.0 mm), number of ridges and furrows (5–10), number of secondary furrows (1–8), stalk length (2.0–7.0 mm), rind weight (7.5–56.0 g) and fruit weight (8.2–16.0 g). They also observed variation in the seed characters such as seed number per fruit (2–8), seed length (15.6–35.0 mm), seed width (7.9–33.0 mm), seed thickness (4.3–9.0 mm) and seed weight (0.6–3.0 g). They made selections from among the above accessions for fruit weight (161 g; IC354028) and for mean rind thickness (15 mm) and mean fruit weight (125 g; IC354019), for pinkish red color of fruits (IC 3544047 and 354063) and for half smooth surface (IC 3540070). Variability with respect to number of flowers per inflorescence/flowering twig, flower color (red, orange, reddish-brown, reddish-yellow, pinkish orange and yellow), variation of sex organs in the male and female flowers (male flowers without and with pistillode; female flowers without or with staminode), fruit shape, size, color and number of furrows was also apparent in our collections from Tamilnadu, Kerala, Karnataka and Goa, India. The Indian Council of Agricultural Research, Regional Research Centre, Thrissur released Malabar tamarind IC244100-2 (INGR No.04061) and IC244111-1(INGR No. 04062) which are maturing varieties (6–7 years) for the farmers (Murthy *et al*., 2018).

In this study, the genetic variation among 35 accessions of G. gummi-gutta was analyzed by employing quantitative morphological traits and species-specific SSR markers. Recorded quantitative morphological data were statistically significant ($p < 0.001$) based on One way ANOVA. Considerable diversity observed among the accessions in growth and yield characters like the total number of fruits/tree, the mean number of fruits needed to weigh 1 kg, mean fresh and dry rind yield/tree; morphometric trait like single fruit weight. Molecular profiling was done by screening 24 simple sequence repeats (SSRs) primer from a set of 32 primers based on precise, intense and reproducible banding pattern. Total 39 alleles were obtained in the 24 SSRs with an average of 1.63 alleles/locus with an average of 86.11% polymorphism. An average Polymorphic Information Content (PIC) of 0.239 and an average Marker Index of 0.005, revealing the less allelic hetrozygosity and specificity of SSR primers for the selected accessions. The two dendrograms prepared based on Unweighted pair group method of arithmetic means (UPGMA), and Jaccard's similarity coefficient showed wide genetic variation among the accessions. Quality and productivity of G. gummi-gutta can be improved by selecting the better performing and diverse accession for future breeding programmes (Babu *et al*., 2021).

Eleven Garcinia germplasm along with local check of Pechiparai were evaluated and underwent principal component analysis to assess genetic divergence and variation patterns during 2019 to 2022. The first two principal components, contributing significant Eigen values, explained 71.20% of the total variability. The Acc. Gg 9 was the top performer, exhibiting favourable yield and growth traits with lower pest and disease incidence, high biochemical compounds viz., hydroxy citric acid and tartaric acid compared to local check. Cluster analysis revealed four major clusters, offering diversity for breeding programs. Correlation studies highlighted traits such as number of fruits per tree, rind thickness, and tartaric acid showing significant positive correlations with yield per tree. Selection based on identified key traits was deemed crucial for

enhancing effectiveness. Additionally, DNA fingerprinting analysis indicated the potential use of RAPD markers (OPA03570) for differentiating Kudampuli cultivar PPI (K) 1 from the local check. Overall, the present investigation provides insights into optimizing Garcinia breeding programs, emphasizing trait-based selection and DNA fingerprinting for varietal differentiation (Bini Sundar et al., 2024).

BREEDING

Germplasm Collection, Conservation and Utilization: Extensive research work has been carried out by various research groups in collection, conservation and utilization of Garcinia germplasm, from its center of diversity (Abraham *et al.,* 2010a, b, c; Keatmetha *et al.* 2006; Mansyah *et al.,* 2010a). The International Plant Genetic Resources Institute (IPGRI) was also involved in large-scale collection and conservation of Mangosteen from Southeast Asian countries including Myanmar, Laos, Thailand, Cambodia, Vietnam, Malaysia, Brunei, Singapore. The Philippines, Indonesia and Papua New Guinea. Scientists from the National Bureau of Plant Genetic Resources (NBPGR) and various gricultural universities in India have been involved in extensive collection of Malabar tamarind and kokum in the Western Ghats, Andaman and Nicobar Islands and Northeastern India. Much emphasis in Garcinia germplasm collection in the past has been aimed at identifying the trees with outstanding fruit characters including fruit shape, size, rind thickness, attractiveness, number of arils per fruit, seed shape, size and color and yield. However, in recent years the focus has been on selection of germplasm for early maturity, early and late blooming, drought and disease tolerance (Murthy *et al.,* 2018).

Strategies of Conservation of Garcinia Germplasm: Various approaches have been proposed to conserve Garcinia genetic resources; among them the in situ based conservation strategies are very prominent because Garcinia seeds are recalcitrant. It was reported that mangosteen, Malabar tamarind, and kokum seeds are high in moisture content, possess no dormancy, exhibit low seed viability and short lived. Mangosteen, Malabar tamarind, and kokum seeds are described as agamospermic without a differentiated embryo, endosperm or embryonic axis. Therefore, seed storage is hampered. Freshly harvested seeds of these species can be stored at ambient temperatures for up to 30 days and seed longevity could be extended up to 60 days by storage at 15 °C. However, chilling treatment at 5 °C, leads to considerable loss of viability of up to 60%. Nevertheless, ex situ conservation methods are also followed for conservation of Garcinia germplasm and the gene banks are established at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India, wherein Malabar tamarind and kokum seeds are maintained in cold storage at 5–20 °C (Murthy *et al.,* 2018).

In Situ Conservation of Garcinia Germplasm: In situ conservation methods maintain plant populations in their distribution range, thus providing optimum conditions for manipulating the genetic variability of the species. This approach involves two methods: the first is the genetic reserve, which is defined as the location, management and monitoring of genetically-diversity wild populations within the defined areas for active and long-term conservation. The second is on-farm conservation, which involves the maintenance of traditional crop cultivars or landraces and farming systems by farmers within traditional agricultural systems. This latter conservation method has been gaining importance in recent years, although farmers have been using it for centuries (Murthy *et al.,* 2018).

Place	Number of sites
Alappuzha, Kerala	20
Ernakulum, Kerala	16
Kannur, Kerala	10
Kasaragod, Kerala	2
Kollam, Kerala	11
Kottayam, Kerala	9
Kozhikode, Kerala	10
Malappuram, Kerala	8
Plakkad, Kerala	1
Pathanamthitta, Kerala	10
Thiruvanathapuram, Kerala	1
Thrissur, Kerala	11
Wayanad, Kerala	1

Exploration and collection missions of the NBPGR regional station, Thrissur, India have identified 110 sites in 13 districts of Kerala for on-farm conservation of Malabar tamarind. Similarly, 59 in situ conservation sites were explored from the Western Ghats regions of India involving 5 districts of Karnataka, 2 each of Goa and Maharashtra and 1 of Kerala for conservation of kokum germplasm (Murthy *et al.,* 2018).

On-farm conservation of Malabar tamarind in India (Murthy *et al.*, 2018).

Place	Number of sites
Alappuzha, Kerala	20
Ernakulum, Kerala	16
Kannur, Kerala	10
Kasaragod, Kerala	2
Kollam, Kerala	11
Kottayam, Kerala	9
Kozhikode, Kerala	10
Malappuram, Kerala	8
Plakkad, Kerala	1
Pathanamthitta, Kerala	10
Thiruvanathapuram, Kerala	1
Thrissur, Kerala	11
Wayanad, Kerala	1

Seeds are collected manually from freshly harvested and fully ripened fruits before they fall. Immediately after harvesting, they are washed in running water to separate the fruit rind. The seed storage behaviour is recalcitrant. Viability can be maintained for 1-2 months in moist storage at 20°C (Robson, 2025).

Breeding

Most Garcinia species are apomictic and fruit and seed development in these species is through agamospermy *i.e*., production of seed without the fusion of gametes. The mode of embryo and seed development has been studied only in *G. mangostana* and it was reported that embryo development in mangosteen is from integuments rather from the egg. Therefore, Garcinia species are considered as exclusively apomictic and plants produced by seed or vegetative propagation are homogeneous and genetically identical. Consequently, variability observed in mangosteen, Malabar tamarind and kokum in the field/wild is likely due to difference of environmental conditions. Nevertheless, several studies have revealed that a population from apomictic reproduction does not always carrying the same genetic properties, even in obligate pomixes; variability in progenies and populations has been reported in obligate apomictic species Taraxacum. Hence, improvement of Garcinia species is mostly exploitation of existing genetic variability and improvement of these species is only through selection rather than conventional breeding (Murthy *et al.,* 2018).

The major breeding objectives for improvement of Garcinia species are as follows (Murthy *et al.,* 2018):

(a) *Fruit quality:* Great variability exists among natural population of mangosteen, Malabar tamarind and kokum with respect to fruit size, shape, content of fruit pulp, number of arils and seeds, and shelf life. Accordingly, selection of plants in respect to the above characteristics along with color, flavor, texture and nutritional value of fresh fruits is the main priority in the improvement Garcinia species.
(b) *Tree characteristics:* Mangosteen, Malabar tamarind and kokum trees raised from seeds have a long juvenile period (7–12 years for fruiting) and depict constraints of less fruitbearing capacity. Therefore, selection of early maturing, early and late blooming (in a year), and high yielding/fruit bearing plants/population is highly desirable.
(c) *Drought tolerance:* Garcinia species are sensitive to drought during the early growth period (up to 5 years) and shade should be provided during that period. Hence, selection of drought tolerant plants/populations is very much essential.
(d) *Rootstock improvement:* Information of rootstocks, stock-scion relationships is fragmentary in Garcinia species; thus, selection of root stock and scion with respect to wide geographic adaptability, resistance to biotic and abiotic stresses, and high productivity with good quality fruits is another area to be explored.

Use of Molecular Markers for Sex Typing: Mangosteen, Malarbar tamarind and kokum are dioecious with male and female individuals (Abraham *et al.* 2006; Richards 1990a). These species are apomictic and the existence of male or male function is debated (Richards, 1990a). Flowering starts in seed-grown plants after 10–12 years and will attain the stage of full bearing at the age of 12–15 years (Orwa *et al*., 2009). Sex determination in these species at an early juvenile stage would be useful for planning the male and female tree ratio in the orchards and enabling tree improvement programs. Recently, molecular tools were employed in dioecious taxa for early identification of sex and understanding the developmental and evolutionary pathways of sexual dimorphism. Specific molecular markers can be deduced from unique, single-copy segments of the genome and can be considered codominant and used in sex determination. Sequence characterized markers (SCAR) which are based on randomly amplified polymorphic DNA (RAPD) analysis are locus-specific, more reliable and more reproducible for molecular identification (Paran and Michelmore, 1993). Joseph et al. (2014) identified a sex-linked DNA fragment in *Garcinia gummi-gutta* (Malabar tamarind) by screening 150 RAPD primers. One of the RAPD primers (OPBD20) showed differential amplification associated male specific DNA. They sequenced the male specific DNA fragment (556 bp) and developed a sequence-characterized amplified region (SCAR) marker, CAM-566; based on this male specific marker they could identify the sex of plants at seedling stage itself. Similarly, Joseph *et al.* (2015) developed male specific SCAR marker (1501 bp) in *G. indica* (kokum) for identification ofmale individuals from females at a very early developmental stage (seedling stage). *Garcinia* species take 7–12 years to reach to reproductive stage (flowering stage) and thus SCAR markers are quite useful in these dioecious plants for sex typing at an early developmental stage (Murthy *et al*., 2018).

Improvement of Rootstocks and Grafting: Selection of rootstock has been studied in *Garcinia* species for the improvement of drought tolerance, salinity tolerance, tree architecture and early flowering. *Garcinia lateriflora*, *G. hombroniana*, *G. livingstonei*, *G. morella* and *G. xanthochymus* were used as useful rootstocks for the improvement of mangosteen (Osman and Milan, 2006). Similarly, *G. kydia* and *G. venulosa* were also useful rootstocks also partially compatible with mangosteen. These species have been shown to provide desirable characteristics such as precocity, dwarfness and plant architecture that promote easy picking of fruits and pruning (Osman and Milan, 2006). Cleft and softwood grating methods were used for grafting of mangosteen using different species of *Garcinia* rootstocks. Healthy rootstocks of about 30–35 cm in height are preferred and the size of scion should be around 6–12 cm long to achieve successful grafting (Osman and Milan, 2006). Softwood grafting has been followed for the improvement of kokum especially for imparting drought resistance and adaption to marshy soil (Haldankar *et al*. 1993). Studies have shown that rootstocks of *G. gummi-gutta*, *G. cowa* and *G. hombronina* were quite useful in transmitting drought resistance and to establish kokum plantation in rainfed areas. Seedlings of 0.25 cm thickness and more than 22 weeks of age were used as rootstock material for the purpose. Similarly, shoots of 0.5–0.6 cm thickness and 10–12 cm length were used for scions (Haldankar *et al.*, 1993; Fig. 19.10). Poor root initiation is the main hindrance for in vitro propagation of kokum. Chabukswar and Deodhar (2006a) developed an in vitro grafting technique for restoration of rooting competence. In vitro regenerated shoots of kokum obtained from nodal explants of mature trees were repeatedly grafted on to in vitro grown juvenile seedlings. After each grafting, some of the scions were tested for rooting competence and 75% regained the ability to root after the fifth grating (Murthy *et al.,* 2018).

Biologically active metabolites : *Garcinia gummi-gutta* (L.)Roxb. is an economically important fruit crop in Kerala. Garcinia plants contain broad range of biologically active metabolites which in the last few decades has received considerable attention due to the chemical compositions of their extracts with compounds which have been shown to have beneficial effects in several diseases. The bioactive molecules like hydroxycitric acid (HCA), flavanoids, terpenes, polysaccharides, procyanidines and polyisoprenylated benzophenone derivatives like garcinol, xanthochymol and guttiferone isoforms have been isolated from the genus Garcinia. The HCA has been known for its hypolipidemic property (Soumya and Manimekalai, 2024).

Aroma and Flavour: The dried rind of cambodge is used as a condiment of flavouring curries in Kerala. In Sri Lanka, the fruits are picked under-ripe, the thick pericarp cut into sections, dried in the sun and preserved for future use (KSSDB, 2025).

Uses: It is used along with salt in the curing of fish. It is rich in acids and possess marked antiseptic properties. The dried rind is also used for polishing gold and silver and as a substitute for acetic and formic acids in the coagulation of latex. An yellow, translucent resin from the tree is soluble in turpentine and gives an yellow varnish. A decoction of the fruit rind is given in rheumatism and bowel complaints. It is also used as a rinse for some veterinary diseases (KSSDB, 2025). Plant pacifies vitiated vata, kapha, obesity, hypercholestremia, diarrhea, colic, ulcers, inflammations and hyperperspiration. Useful parts are leaves and dried fruits. A decoction made from the plant (part not specified) is used in the treatment of rheumatism and bowel complaints. An extract obtained from the mature fruit rind, Hydroxy Citric Acid, is used as a treatment against obesity (Thenaruvi, 2025). The dried rind is used as a condiment for flavouring curries. In Sri Lanka the dried rind with salt is used for curing fish. The rind contains hydroxy citric acid and is widely employed in anti-obesity drugs (Indianspices, 2025). When the fruit is sun dried for several days, it becomes black with a shrivelled body (Wikipedia, 2025). Plant pacifies vitiated vata, kapha, obesity, hypercholestremia, diarrhea, colic, ulcers, inflammations and hyperperspiration. Useful parts are leaves and dried fruits (Awale, 2025). The dried rind is used as a condiment for flavouring curries. In Sri Lanka the dried rind with salt is used for curing fish. The rind contains hydroxy citric acid and is widely employed in anti-obesity drugs **(**Espicebazaar, 2025**).** The fruit rind is used as a spice and flavoring agent in cooking, and extracts are used in dietary supplements, particularly for appetite suppression and weight management, due to its high content of hydroxycitric acid (HCA) (Google, 2025). When the fruit is sun dried for several days, it becomes black with a shrivelled body. *Garcinia gummi-gutta* is used in cooking, including in the preparation of curries to add a sour flavor. The fruit rind and extracts of *Garcinia* species are used in many traditional recipes used in food preparation in Southeast Asian countries. In the Indian Ayurvedic medicine, "sour" flavors are said to activate digestion. The extract and rind of *G. gummi-gutta* is a curry condiment in India. It is an essential souring ingredient in the southern Thai variant of *kaeng som*, a sour curry (Inaturalist, 2025).

G. gummi-gutta is traditionally used as a condiment for flavouring curries and as a fish preservative. The traditionally smoke dried fruit rind of *G. gummi-gutta*, known as 'Malabar tamarind' was used for "Colombo curing" of fish, where the pickling was done in brine along with the smoke dried rinds of *G. gummi-gutta*. The species yield an yellow, adhesive gum resin similar to gamboge from *G. morella*, but of inferior quality and insoluble in water. The seeds yield an oil, which is used in medicine. The wood is grey, cross grained, shining, hard and can be used in furniture making. The dried rind was used for polishing gold and silver and also used as a substitute for acetic and formic acids in the coagulation of rubber latex. Though the tree has been mentioned in the 17th century treatise of medicinal plants, Hortus Malabaricus, the species is not part of the Ayurvedic medicine of ancient India. However, it was widely reputed in the folk herbal healing practices and has been used traditionally for the treatment of edema, delayed menstruation, ulcers, open sores, hemorrhoids, fever, rheumatism, and also against intestinal parasites. The astringent properties of the rind make it an indispensable ingredient in gargles for weak gums, bowel complaints, constipation, diarrhoea and dysentery. The plant is used in veterinary medicine, for mouth diseases in livestock (Agrienterprises, 2025).

Nutritive Value: Raw as well as dried fruits are excessively acidic in nature. Nutritional analysis of fruits shows 8.6% total sugars 3.1% fiber, and 2.1 mg sodium and 193.5 mg potassium. Other than these components, the fruits are rich in organic acids such as (-)-hydroxycitric acid (HCA), tartaric acid, and malic acids and the amount of HCA varies from 16–18%. The seed of Malabar tamarind yields protein 7.72% and fat-rich butter 11.21%, popularly called *uppagetuppa* (Murthy *et al.,* 2018).

Constituents	Content
Moisture	86.91%
Protein	0.28%
Fat	0.21%
Reducing sugar	5.92%
Non-reducing sugar	2.67%
Total sugars	8.6%
Fiber	3.1%
Mineral Matter	0.49%
Vitamin C	Traces
Iron	Traces
Sodium	2.1 mg
Potassium	169 mg
Energy	38.7 k Cal

The rind contains protein (1%), tannins (1.7%), total sugar (4.1%), pectins (0.9%) and fat (1.4%), moisture (80.0 g/100 g), all of which have been shown to have important therapeutic properties. It was reported that Garcinia leaves contained 75% moisture, 2.3% protein, 0.5% fat, 1.24% fire, 17.2% carbohydrate, 14% iron, 25% calcium and 10% ascorbic acid, and 10% oxalic acid. The seeds are very rich in triglycerides stearic, oleic and stearic. The plant also has lactone and citric hydroxycitric acid but in small amounts. The phytochemistry of *Garcinia cambogia* has not been well studied and published. Alkaloids, flavonoids, phenolic chemicals, saponins, tannins, polysaccharides, and proteins were discovered in preliminary phytochemical research. A few xanthones, benzophenones, organic acids, and amino acids have so far been isolated from diverse plant components. The presence of alkaloids, flavonoids, phenolic compounds, saponins, tannins, carbohydrates and protéins has been demonstrated by preliminary phytochemical studies. These phytochemicals exert several important functions, including antioxidant, antimicrobial, antidiabetic, immunomodulatory, and anti-inflammatory properties. To date, some xanthones, benzophenones, organic acids and amino acids have been found in different parts of the plant, all of which also have important nutraceutical properties as shown in the table. However, emergent studies suggest that garcinol may be a useful anti-cancer agent and a pleiotropic agent that modulates key regulatory pathways for cell signals with garcinol pharmacological activities (Noreen *et al.,* 2023). Although few high-quality studies have been done to define the composition of the fruit, its phytochemical content includes hydroxycitric acid which is extractable and developed as a dietary supplement. Other compounds identified in the fruit include the polyphenols, luteolin, and kaempferol (Inaturalist, 2025).

Biological activities of *Garcinia cambogia*

Organic activities *in vivo* as well as *in vitro* models were demonstrated to exist mainly from *Garcinia cambogia* fruits in different extracts and pure compounds. Clinical trials mainly report on anti-obesity activities in Cambodia/HCA supplements. Although the common use of weight loss supplements is cambogia and cambogia, many more studies have found positive antimicrobial, anti-ulcer and liver-protective effects (Noreen *et al*., 2023).

Anti-obesity activity of hydroxycitric acid (HCA)

There is increasing demand for natural substances that will help fight obesity worldwide.[Citation30,Citation31] The genus *Clusiaceae Garcinia* has a population of over 300 species from Asia and Africa including *Garcinia cambogia*, garcinia mangostana and garcinia atroviridis. The potential therapeutic effects of this genus include anti-obesity, anti-ulcerogenic, anti-oxidant, anti-diabetes, antifungal, anti-inflammatory, and anti-neoplastic. This has led to several investigations by pharmaceutical companies. Some of the bioactive compounds isolated from Garcinia include garcinol, isogarcin, (−) hydroxycitric (HCA), mangostin and xanthoquimol. *Garcinia cambogia* is the most commonly used supplement for weight loss or maintenance of the above-mentioned species. Anti-obesity characteristics were attributed to HCA, which is present in rind or fruit epicarps with 20–30% of dry weight. Many supplements containing HCA are currently available on the market to reduce weight. The HCA effects include the reduction of intake, including an increase in fat oxidation, the novo lipogenesis and hepatic glycogenesis stimuli, by means of serotonin levels regulation and metabolic changes. This increases the energy costs. HCA is a competitive adenosine-triphosphate (ATP), an enzyme that catalyses extramitochondrial lyasium oxaloacetate/acetyl-CoA collapses, limiting the availability of the ingredient acetyl-CoA, a key component of the dietary fatty acid synthesis as shown in the (Noreen *et al*., 2023).

Appetite-suppressant activity

Over the eight-week period, HCA and HCAL were administered to Wistar albino rats at 1,1 and 3,7 mmol and 5,5 kg 1-Day 1 concentrations in many studies, which measured average feed intake and gain in weight. Food intake in both HCA and HCAL was deleted and HCAL in all dosage groups was less consumed. Dose-dependent weight gain is considerably reduced. HCAL is superior compared with HCA because the rats showed a minimum weight increase and a maximum weight loss at the end of this study period. HCAL also found activity of antibestone in rats.The fluoxetine (100 mμM) plus clomipramine (10 mμM) was similar to that of serotonin-specific inhibitors. In isolated rats brain inhibitor slicing, HCA was inhibited by radioserotonin (10 μM to 1 mM) Serotonin deficiency conditions, such as depression and migraine, can help control the appetite, therefore cambogia extract as the ascophyl nodosum were found to be appetite modulatory (L). The formulation was provided to 28 individuals with a random crossover design over a week period without any differences in energy consumption between the groups (Noreen *et al.,* 2023).

Anticancer properties of garcinol

Cancers are uncontrolled cell growth and spread, caused by multiple factors including carcinogenic exposure, repeated damage to genes, oxidative stress, chronic inflammation, or hormonal imbalances. Most chemotherapy therapy has adverse toxic reactions that can be as effective against cancer cell growth as they can be relatively nontoxic without side effects. Recent evidence supports the therapeutic effects of non-nutrients in the diet, including the control of survival signaling and simultaneous activation of multiple death pathways in cancer cell growth. For its anti-cancer activity, garcinol, isolated from G, cambogia has recently been extensively investigated. Indication and Several studies recently explored the potential of non-nutritive dietary garcinol for various types of cancer. Cambogia has received great scientific attention. Several possibilities were also developed to explain the underlying mechanism for the chemical prevention and/or treatment of garcinol. Studies in Garcinia have shown the development and proliferation of four human leukemia cell lines to be affected by phytochemicals garcinol, isogarcinol and xanthochymol. The growth inhibitories were more powerful than garcinol infections in isogarcinol and xanthochymol (Noreen *et al*., 2023).

Hypolipidaemic and antioxidant activity

Flavonoids can inhibit different stages in which atherosclerosis, damage to endothelia, activation of leucocytes, adhesion platelets and aggregation and secretion occur. The plasma total cholesterol and atherogenic index have decreased by 1 to 2% by supplementing tea catechins with a rat diet. Tannic acid and Morin can cause beneficial plasma lipid changes in the heart disease-related type. Flavonoids' hypolipidemic and antioxidant activity from various sources have been extensively described. A study evaluated the hypolipidemic activity of the *Garcinia cambogia* fruit, which in Indian medicine has a high therapeutical value and is even now used in medicines for different diseases. A study investigated the antihyperlipidemic and antioxidant activities of the ethanolic extract of *Garcinia cambogia* on high fat diet-fed rats. Male Wistar rats were fed with either standard rodent diet or 30% high-fat diet and administered with GE at a dose of 400 mg/kg body weight/day for 10 weeks. At the end, lipid profile and oxidative stress parameters were estimated. Results of the study showed that administration of GE decreased food intake, plasma TC, TAG, non HDL-C, MDA, increased HDL-C and blood antioxidants GSH, GPx, catalase. GE also reduced TOS, OSI and elevated TAS in plasma and liver of fat-fed rats. Renal OSI was significantly reduced upon GE treatment. Garcinia was effective in ameliorating high-fat-diet-induced hyperlipidemia and oxidative stress. An in vitro antioxidant activity in fruit rin, hydroxyl radical scavenging, thiocyanate ferrous, total peroxide radical trapping and lipid peroxidation testing were reported in aqueous extract. In vitro protective effects against lipid and protein oxidation have been shown in garcinol and guttiferone K isolated from the fruit. The growth of plasma, platelet and thiobarbituric acid-reactive species induced by peroxynitrite in both cases has reduced significantly the growth of carbonyl groups. These compounds, however, did not inhibit the plasma and platelet nitrate induced by peroxynitrite (Noreen *et al.,* 2023).

Anti-inflammatory activity

The extract of the plant could contribute to the treatment inflammatory bowel conditions resulting from a dysregulated immune response. Various anti-inflammatory cambogia compounds have been shown. Inhibited NF-μB activation by Garcinol and/or JAK/STAT-1 activation. The expression of iNOS and carbon dioxide was inhibited in LPS activated macrophages and the growth in intracellular ROS was decreased by LPS.[Citation40] The emission of 40%–50% of arachidon metabolite Garcinol of human colon lines of adenocarcinoma (HT-29 and HCT-116) and immortal intestinal line of rats; (IEC-6). Mechanisms used were used to modifies the metabolism of arachidonic acid by blocking CPLA2 and reducing iNOS proteins by inhibiting activation of STAT-1. Cytocin signaling for cultivated human breast cancer (MDA-MB-231) and Rato Insulinoma Cell (INS-1E) has been found to inhibit the nuclear transfer of STAT-1 and the binding of DNA to Garcinol, guttiferone K and guttiferone M. Cytokine IFNμ induced activation of STAT-1 in MDA-MB-231 cells had obstructed all compounds. Garcinol (25 microns) followed by welltiferone M (50 microns) and guttiferone K were the most effective treatments (50 microns). Inhibited the cytokine-induced STAT-1 activation of Garcinol (25 μ M) and Guttiferone K (25 μ M), while guttiferone M was only slightly inhibited at similar concentration. In addition, in cells MDA-MB-231, garcinol inhibited 50 micro-activation of the NF-α-induced, whilst the intestinal K and intestinal M had low activity at the same level. In INS-1E cells, activation of garcinol and guttiferone K has been decreased by 25 μM significantly while guttiferone M has been detected as inactive. Hydroxycitrate of potassium magnesium (KMgHCA) given with 28 and 84 mg/day daily intakes. The

systematic blood stress and carageenic paw edema of Sprague–Dawley rats have improved without any toxic effect, with decreases of the CRP and TNF-α. The activity was considered moderate compared to the control group (Noreen *et al.,* 2023).

Hepatoprotective activity

The antioxidant properties of the extract are associated with the ethanol-causing lipid and peroxidant damage. Following treatment, the levels of serum AST, ALT and alkaline phosphatase (ALP) have demonstrated their normality. In-vitro reports show that 1% of cambogia extracts (50% HCA), while cambogia/HCA were suspected of causing hepatotoxicity in people, have reduced molecule damage and palmitate-induced aldehydes to attenuate lipotoxicity in HepG2 cells. In addition, Antichol containing active ingredients Cambogia avoided cholesterol-induced degeneration of liver fatty and changes in the antioxidant enzymes of the liver, including dismutases of superoxide, glutathione and catalase in rats. Another research examined at how *Garcinia cambogia* fruit extract affected ethanol-induced peroxidative damage in albino rats weighing 125 to 150 kg. The rats were given ethanol (7.11 grammes per kilogram of body weight per day) for 45 days. *Garcinia cambogia* fruit extract (1 g/kg body weight/day) was given orally to ethanol-treated rats for 45 days. The antioxidant enzymes, LPO, conjugated diene in the liver tissue, serum AST, ALT, and alkaline phosphatase, and lipid levels in both serum and liver tissue were measured at the end of the experiment. The results of this study revealed that co-treating rats with *Garcinia cambogia* dramatically reduced lipid levels as well as the peroxidative damage induced by ethanol, as evidenced by the enhanced antioxidant status. In *Garcinia cambogia*-treated rats, serum AST, ALT, and alkaline phosphatase levels were kept around normal. The increase in lipid peroxidation might be due to an imbalance in lipid metabolism. Both serum and liver lipids were reduced to near-normal levels after treatment with *Garcinia cambogia* fruit extract. *Garcinia cambogia*'s hypolipidemic characteristic decreases peroxidative damage, which is enhanced by ethanol (Noreen *et al*., 2023).

Anticholinesterase activity

In acetyl-cholinesterase enzymes, neuromuscular joints and cholinergic brain synapses play a crucial role for acetylcholine, a major neurotransmitter. This enzyme is responsible for the loss of cognitive capacity, the first stage of the disease of Alzheimer's. Cambogia fruit rind extract produced significant activity with cholinesterase inhibition of 30% and 30% and 67%, respectively, of 500 and 1000 µg/ml. The activity is comparable to the positive neostigmine control with inhibited 5 and 10 µg/mL of 78 and 92% cholinesterase (Noreen *et al.,* 2023).

Antimicrobial and anthelmintic activity

There has been increase in search of plants with antimicrobial substances, including antifungal, antibacterial, antiviral, and antiparasitic substances.The antimicrobial activity of Etherichia coli, Klebsiella pneumoniae and Pseudomonas aeruginosa with inhibition zone diameters ranging from 15 to 34 mm, was demonstrated by ethyl acetate, ethanole and hydroalcohol extracts from the fruit rind tested at a concentration of 25 mg/ml. In addition to ethanol and hydroalcoholic extracts, ethyl acetate extracts were found to be most active, while all test pathogens had hexane extracts not been found inactive. The inhibiting activities against the main HIV-enzymes, HIV-1 protease and HI V-1 were demonstrated through ethanolic and water minerals from cambogy leaves. Differently, there was activity against earthworms at various concentrations (*i.e*. 20, 40 and 60 mg/ml petroleum ether, chloroform and ethanol extracts obtained from cambogia sheets). The time required for earthworm paralysis was between 1.1 and 2.5 minutes, whereas the time needed to cause death was between 3.1 and 7.4 minutes. Positive control (Albendazole) caused 1.2 minutes of paralysis, and death at 60 mg/mL at 3.2 minutes. Anthelmine extract was shown to be strongest and chloroform and petroleum ether extracts were followed (Noreen *et al*., 2023).

Effects on fertility

An ethanol extract from the cambogia seeds was administered to male rats 6 days a week to examine its impact on testis histology as well as the sperm count for 6 weeks. The extract increased the sperm count and interstitial spaces considerably at doses of 100 and 200 mg/kg BW/day, causing degenerating and distorting the cells of the sperm series in all experimental rats.The level of testis meiosis-aktivating sterol, which may be responsible for the transmission of the spermatogenesis signal, was reduced by oral administration at 102 mmol/kg of BW to male rats, which is intermediate in cholesterol biosynthesis. The serum hormone levels – follicle-stimulating hormones, luteinizing hormone, estradiol and progesterone – have not changed in female rats, shows a subsequent study by the same group that (−) HCA administered at a dose of 154 mmol kg−1 day−1 for 4 weeks. The concentrations of follicle and corpus luteum, the follicular fluid ovarienic meiosis-activating sterol and the sterol testis have not changed over the course of the treatment. After treatment, body weight and abdominal fat decreased (Noreen *et al*., 2023).

Toxicity of *Garcinia cambogia*

The majority of research agrees that taking *Garcinia cambogia* in the recommended quantities, which is up to 2,800 mg of HCA per day, is safe for healthy persons. *Garcinia cambogia* has also been linked to certain negative side effects. Digestive problems, headaches, and skin rashes are the most prevalent. However, more significant adverse effects have been reported in other trials. *Garcinia cambogia* consumption well beyond the maximum suggested dosage has been shown in animal tests to induce testicular atrophy, or shrinkage of the testicles. It has been shown in rats that it can influence sperm production. One lady suffered serotonin poisoning as a result of taking *Garcinia cambogia* with her antidepressant medicines, according to one study. Furthermore, numerous case studies show that *Garcinia cambogia* pills may cause liver damage or even death in certain people (Noreen *et al*., 2023).

Health Benefits

Malabar tamarind fruit extract is used in the treatment of rheumatism and bowel complaints as a purgative, hydragogue, anthelmintic and emetic. It is also used in veterinary medicine to treat mouth diseases in cattle. The fruit rind is used to polish gold and silver ornaments and as a substitute for acetic acid for coagulation of rubber latex. The dried fruit rind is a unique source of HCA, which has a sour taste and has been safely used for centuries in Southeast Asian countries to make meals more filling (Murthy *et al.,* 2018).

Researchers have reported that *Garcinia cambogia* may (Hill, 2025):

Improve blood sugar: Animal research has shown that garcinia cambogia may lower blood sugar levels. However, more data is needed in humans to understand potential benefits.

Improve athletic performance: A few small studies have shown that HCA 250 mg daily may increase the time until exhaustion and improve breathing during exercise. These studies were very small, and more research is needed.

Lower inflammation: *Garcinia cambogia* may lower inflammation in the body. In animal studies, garcinia cambogia was found to lower the number of genes and enzymes that lead to inflammation in the body. If studied in humans, the supplement may be useful to treat pain and inflammation in various settings. More research is needed.

Garcinia cambogia supplements are available in pill, capsule, and powder form. They can be purchased as a single product or in combination with other supplements. The amount of *Garcinia cambogia* or HCA in each supplement varies (Hill, 2025).

Let's take a look at facts about *Garcinia cambogia* (Healthline, 2025a).

1. *Garcinia cambogia* is grown in Indonesia, India, Sri Lanka, Malaysia, and parts of Africa.
2. It's not technically called garcinia cambogia anymore. The tree has a new proper name: Garcinia gummi-gutta.
3. Other names for it are red mango, Malabar tamarind, pot tamarind, brindal berry, gambooge, and kokum butter oil tree.
4. The fruit of the *Garcinia cambogia* looks like a multilobed pumpkin and is usually green, yellow, or red.
5. It's normally the size of a large tomato but can grow to grapefruit size.
6. The sour flesh of the garcinia cambogia will pucker your lips. It's often pickled and used as a condiment.
7. After it's sun-dried and smoked, the blackened fruit, called kodampoli, gives a tart, smoky flavor to curries. It's most common in fish curry.
8. According to the Food and Agriculture Organization of the United Nations, the seeds have a 30 percent fat content. The seeds are sometimes used as a substitute for ghee, clarified butter that's a common ingredient in Indian food.
9. A number of health claims are made about garcinia cambogia extract. Among the conditions people use it for are diabetes, cancer, ulcers, diarrhea, and constipation.
10. Its biggest claim to fame is that extract supplements can help speed up weight loss, reduce appetite, and boost exercise endurance.
11. *Garcinia cambogia* contains a compound called hydroxycitric acid (HCA) that may inhibit an enzyme that helps your body store fat. Theoretically, the fat would instead be burned as calories.
12. Allegedly, garcinia cambogia can increase the levels of the neurotransmitter serotonin, a feel-good messenger in your body. This may enhance your mood and reduce stress-related eating.
13. The first rigorous research on the effectiveness of garcinia cambogia was conducted in 1998. The concluded that it doesn't perform any better than a placebo when it comes to helping you lose weight.
14. A 2011 research review showed that it can cause short-term weight loss, but the effect was small and the studies were flawed.
15. Garcinia cambogia can be found in Hydroxycut. The Food and Drug Administration (FDA)issued a consumer warning in 2009 cautioning consumers to immediately stop using Hydroxycut products after reports of jaundice and extreme liver damage in people who used Hydroxycut surfaced.
19. Other health problems associated with Hydroxycut included seizures, cardiovascular disorders, and rhabdomyolysis. However, because Hydroxycut contains many ingredients, it's difficult to pinpoint the cause.
20. From Japan found that rats fed high doses of garcinia cambogia lost significant fat. However, the high doses also caused testicular atrophy.
21. In 2012, pop television doctor Mehmet Oz announced to his audience that *Garcinia cambogia* is a revolutionary fat buster. The show's graphics read: "No Exercise. No Diet. No Effort."
22. In June 2014, Dr. Oz was chided for making unwarranted claims about garcinia cambogia and other products in an appearance before the Senate Subcommittee on Consumer Protection, Product Safety, Insurance, and Data Security.
23. *Garcinia cambogia* is available in capsules, tablets, powders, and liquids. Capsules should be taken on an empty stomach, 30 minutes to an hour before a meal.
24. According to ConsumerLab.com, many *Garcinia cambogia* supplements don't contain the amount of garcinia cambogia listed on the label. Instead, they found the doses were either too low or too high. If you take the capsules, buy a reputable brand and make sure they contain at least 50 percent HCA.
25. Most *Garcinia cambogia* supplements also contain other ingredients, some of which might not be listed.
26. When it comes to a recommended dose, most sources provide the recommended dose of HCA rather than garcinia cambogia itself. According to ConsumerLab.com, the recommended dose of *Garcinia cambogia* is 900 mg to 1,500 mg of HCA a day. This is consistent with doses used in a number of studies.
27. Side effects of *Garcinia cambogia* may include headache, nausea, dizziness, and dry mouth.
28. It isn't known if garcinia cambogia is safe during pregnancy or while you're breastfeeding, so it's best to discontinue use of the supplement during these times.
29. *Garcinia cambogia* may cause a decrease in blood sugar levels. People who have diabetes should discuss this with their doctor before taking the supplement.
30. People with Alzheimer's disease or dementia shouldn't take *Garcinia cambogia* because it increases acetylcholine levels in the brain. Many people with these conditions are given medications to alter the breakdown of acetylcholine.
31. *Garcinia cambogia* may interfere with the following medications and supplements: iron, potassium, calcium, antidepressants, statins, montelukast (Singulair), and warfarin (Coumadin).
32. As with other nutritional supplements, keep in mind that *Garcinia cambogia* isn't monitored by the FDA for safety and effectiveness.

Here are some of the health benefits that we can get with this wonder fruit. Reduces appetite. The fruit increases the level of serotonin in the body. This chemical helps curb cravings and appetite. It also regulates bowel movements of the body. Improves mood. Serotonin affects our emotion. A higher serotonin level improves the mood of an individual. In addition, there are studies suggesting that serotonin can help with depression. Blocks fat formation.

The active ingredient HCA blocks the enzyme that the body uses to form fats. It also decreases the production of bad cholesterol. Reduces the risk of developing type 2 diabetes. The fruit can help decrease glucose or blood sugar levels of the body. However, this is not recommended for people who are already diabetic (Balmoralpharmacy, 2025).

CULTIVATION

Cultivation

Garcinia gummi-gutta is grown for its fruit in Southeast Asia and South Asia. *Garcinia gummi-gutta* is one of several closely related *Garcinia* species from the plant family Clusiaceae. With thin skin and deep vertical lobes, the fruit of *G. gummi-gutta* and related species range from about the size of an orange to that of a grapefruit; *G. gummi-gutta* looks more like a small yellowish, greenish, or sometimes reddish pumpkin. The color can vary considerably. When the rinds are dried and cured in preparation for storage and extraction, they are dark brown or black in color (Inaturalist, 2025). Land preparation involves preparing 1 m^2 pits 10 m apart. Refill the pits with a mixture of topsoil and compost /fertilizer. Proper care should be given to avoid water stagnation in pits. In India, planting is generally done during July-October months. The crop can be raised as a pure or as a perennial intercrop of coconut, arecanut gardens. Clean the field free of bushes and thick shades. Weed once in three months and mulch the basin with black polythene or dry leaves to avoid drying. The percentage of male trees in population varies from 50-60 per cent and this also creates much difficulty in the cultivation of the crop. Problems such as lack of high yielder, planting grafts prepared from elite mother trees can solve variability in population and occurrence of male trees Fertilizer application involves using 10 kg of cattle manure or compost per seedling/graft during the first year. This is increased gradually to 50 kg annually at15 years (Robson, 2025).

Products

Food: The rinds of the ripe fruits are processed and used as a condiment in fish and prawn preparations to impart flavour and taste and to improve the keeping quality. In India, the dried seeds often yield a protein and fat-rich butter, popularly known as uppage tuppa Fruit juice or syrup is used as a coolant and helps reduce body fat. Fruit rind is marketed in large quantities, for example in India, export of over 50 tonnes (valued at 17 million rupees) have been recorded.

Timber: Its wood is used in construction and furniture making.

Lipids: Fat obtained from seed is used as vegetable butter.

Medicine: A decoction made from it is given for rheumatism and bowel complaints. In cattle, it is used as a wash for mouth diseases. An extract obtained from the mature fruit rind, Hydroxy Citric Acid, is used against obesity.

Other products: It contains 30% acid essentially (-)-hydroxy-citric acid, Camboginol and cambogin (Robson, 2025).

Diseases and Pests

Common diseases of mangosteen are similar to those of other tropical tree species; however, there are no reports on the diseases and pests of Malarbar tamarind and kokum. Pestalotiopsis leaf blight caused by *Pestalotiopsis flagisettula* is a leaf disease of mangosteen reported from Thailand. Furthermore, *P. flagisettula* is also responsible for fruit rot. From Thailand, Malaysia and NorthQueensland stem canker is also reported. Another major disease ofmangosteen is white thread blight disease caused by *Marasmielluss candens* which damages the leaves, twigs and branches. One more important disease is Diplodia fruit rot caused by Diplodia theobromae. Brown rot disease due to Phellinus noxius infects the trunk and roots. Some pests affecting mangosteen are Stictopetera sp. (leaf and fruit eater), Phyllocnistis citrella (leaf miner), *Curculio* sp. (fruit borer). Use of fungicides and insecticides are suggested for the control of fungi and insects, respectively (Murthy et al., 2018). Hard scales and beetles are the common pests infesting the crop. The hard scales the leaves and tender shoots. Both the beetles and grubs defoliate the crop inflicting heavy loss on yield. Seedling blight is very common in the nursery stage (Robson, 2025).

Weight loss claims

In late 2012, a United States celebrity doctor, Dr. Oz, promoted *Garcinia cambogia* extract as "an exciting breakthrough in natural weight loss". Dr. Oz's endorsements of dietary supplements have often led to a substantial increase in consumer purchases of the promoted products, despite having no or little scientific evidence of efficacy. While it has received considerable media attention purporting impact on weight loss, the evidence for *Garcinia cambogia* supports no clear effect, while gastrointestinal adverse events were two-fold more common over the placebo in a 2011 meta-analysis, indicating the extract may be unsafe for human consumption. Adverse events associated with use of such supplements ("side effects") — especially, liver toxicity, as well as gastrointestinal issues — led to one preparation being withdrawn from the market (Wikipedia, 2025). In late 2012, a United States celebrity doctor, Dr. Oz, promoted *Garcinia cambogia* extract as "an exciting breakthrough in natural weight loss". Dr. Oz's endorsements of dietary supplements have often led to a substantial increase in consumer purchases of the promoted products, despite having no or little scientific evidence of efficacy. While it has received considerable media attention purporting impact on weight loss, the evidence for *Garcinia cambogia* supports no clear effect, while gastrointestinal adverse events were two-fold more common over the placebo in a 2011 meta-analysis, indicating the extract may be unsafe for human consumption. Adverse events associated with use of such supplements ("side effects") — especially, liver toxicity, as well as gastrointestinal issues — led to one preparation being withdrawn from the market (Inaturalist, 2025).

Drug interactions

There is potential for *Garcinia cambogia* to interfere with prescription medications, including those used to treat people with diabetes, asthma, and clotting disorders (Wikipedia, 2025).

Safety

Always talk to your healthcare provider before trying a garcinia cambogia supplement. These products may interact with prescription medications, over-the-counter (OTC) drugs, or other natural products or supplements. Some products can also affect certain health conditions you may already have. Even though garcinia cambogia is considered a natural supplement, it is not guaranteed to be safe. It is not known whether *Garcinia cambogia* is safe in people who are pregnant or breastfeeding. Therefore, it is best for these people to avoid taking it (Hill, 2025).

Side Effects

When you take *Garcinia cambogia*, you might get Dizziness, Dry mouth, Headache, Upset stomach or diarrhea. The Food and Drug Administration considers it unsafe. In addition, garcinia cambogia may interact badly with Diabetes medicines, including pills and insulin, Pain medicines, Prescriptions for psychiatric conditions. You definitely don't want to use it when you're pregnant or nursing, or if you have liver problems. It is possible that manic symptoms may emerge as a side effect (Monson, 2023). Common side effects reported with garcinia cambogia include: Diarrhea, Flatulence (gas), Headache, Heartburn and Nausea and/or vomiting. The most serious side effect seen with garcinia cambogia products is liver damage. The way that garcinia cambogia causes damage to the liver is not understood. Symptoms of liver disease can be seen as soon as 1 to 4 weeks after starting the supplement. Signs and symptoms caused by liver disease include: Abdominal pain, Abnormal liver blood tests, Dark urine, Hepatitis (Inflammation of the liver), Jaundice (yellowing of the skin and eyes), Nausea and/or vomiting and Weakness. Many of the reported liver disease cases involved combination products that included *Garcinia cambogia*. However, liver disease was also reported in cases with products labeled as containing only garcinia cambogia (Hill, 2025).

Who should avoid taking garcinia cambogia?

People taking medication for diabetes, including insulin and metformin. Those with liver problems. People with kidney problems. Pregnant women and breastfeeding mothers. If you want to try this supplement but are currently in other forms of medication, ask your doctor first for approval. Common side effects include headache, dizziness, dry mouth, and nausea (Balmoralpharmacy, 2025).

Keto Diet and Garcinia Cambogia

When a person is on ketosis, the body uses fat as a fuel or energy source instead of carbohydrates. As a result, the individual is able to burn more fat and lose more weight in the process. Meanwhile, garcinia cambogia helps block fat formation in the body. Instead, the body now uses the fat as additional fuel. When you combine the ketogenic diet with the intake of this supplement, the weight-loss effect is assumed to be more effective (Balmoralpharmacy, 2025).

Apple Cider Vinegar and Garcinia Cambogia

Apple cider vinegar contains acetic acid as its main component. It can help lower blood sugar level in the body. It also suppresses appetite and improves body metabolism. Thus, apple cider vinegar is considered to be an effective tool for weight loss. Many believe that combining apple cider vinegar with this fruit will improve weight loss results. However, this assumption has no clinical basis yet (Balmoralpharmacy, 2025).

Herbal and Botanical Preparations Associated with Hepatotoxicity

Botanical preparations are *Atractylis gummifera and Callilepsis laureola*, Black Cohosh, Camphor Oil, Cascara, Chaparral, Comfrey and Pyrrolizidine Alkaloids, Dai-Saiko-To (Sho-Saiko-To, TJ-9, Xiao-Chai-Hu-Tang), Germander, Greater, Celandine, Green Tea *(Camellia sinensis),* Herbalife, Ju (Jin) Bu Huan, Kava, Ma Huang, Margosa Oil (Neem), Mistletoe, Noni Juice *(Morinda citrifolia),* Pennyroyal, Skullcap *(Scutellaria)* and Valerian *(Centella asiatica)* Weight Loss Aids (Granchi, 2018).

Adverse effects

In addition to possible liver damage, hydroxycitric acid can cause dry mouth, nausea, gastrointestinal discomfort, and headaches (Inaturalist, 2025; Wikipedia, 2025). When you take *Garcinia cambogia*, you might get Dizziness, Dry mouth, Headache, Upset stomach or diarrhea. The Food and Drug Administration considers it unsafe. In addition, garcinia cambogia may interact badly with Diabetes medicines, including pills and insulin, Pain medicines, Prescriptions for psychiatric conditions. You definitely don't want to use it when you're pregnant or nursing, or if you have liver problems. It is possible that manic symptoms may emerge as a side effect (Monson, 2023). In addition to possible liver damage, hydroxycitric acid can cause dry mouth, nausea, gastrointestinal discomfort, and headaches (Inaturalist, 2025).

Drug interactions

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Phytochemistry

The phytochemistry of G. cambogia has not been studied and reported comprehensively. Preliminary phytochemical studies revealed the presence of alkaloids, flavanoids, phenolic compounds, saponins, tannins, carbohydrates and proteins. Up to date, a few xanthones, benzophenones and organic and amino acids have been isolated from various parts of the plant (Semwal *et al*., 2015).

Biological activity

Various extracts, as well as pure compounds obtained mainly from G. cambogia fruit, have been shown to express biological activity in both in vitro and in vivo models. Clinical trial reports which are available, predominantly focus on the anti-obesity activity of G. cambogia/HCA supplements. Although G. cambogia and G. cambogia-containing supplements are most popular for weight management, various other studies reported positive anti-inflammatory, antidiabetic, anti-oxidant (Semwal *et al*., 2015).

Toxicity studies

Recently, the safety of G. cambogia supplements for weight control has been called into question in various news reports. To add to the confusion, some researchers state that G. cambogia is safe while others disagree. A number of reports about the toxicity of G. cambogia itself or G. cambogia-containing supplements are available and the majority of reports revealed that G. cambogia and/or HCA does not have significant toxic effects (Semwal *et al*., 2015).

Dosage: Recommended dosages of *Garcinia cambogia* vary based on the product. In humans, doses greater than 2,000 mg per day do not appear to help with weight loss or decrease cholesterol levels more than lower doses. Most studies range from daily doses of 1,000-2,800 mg (Hill, 2025).

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