A Comprehensive Review on the Phytochemistry, Pharmacological Properties, and Clinical Efficacy of *Garcinia gummi-gutta* (Malabar Tamarind)

Abstract

Garcinia gummi-gutta, commonly known as Malabar tamarind, is a tropical fruit plant traditionally used in culinary and medicinal practices. The key bioactive compound in the fruit, hydroxycitric acid (HCA), has gained attention for its purported weight loss benefits through inhibition of fat synthesis and appetite suppression. This review provides a comprehensive analysis of the phytochemical composition, pharmacological properties, and clinical efficacy of *Garcinia gummi-gutta*. The fruit is rich in flavonoids, xanthones, and benzophenones, contributing to its antioxidant, anti-inflammatory, anti-cancer, antimicrobial, and hepatoprotective properties. Despite its popularity, clinical trials on HCA's effectiveness for weight management have yielded mixed results, highlighting the need for more standardized and long-term studies. The review also covers the safety profile, potential adverse effects, and regulatory concerns surrounding the use of Garcinia supplements. Overall, while *Garcinia gummi-gutta* shows promise as a therapeutic agent for weight loss and other health benefits, further research is essential to confirm its efficacy and safety in humans.

Keywords: Garcinia gummi-gutta, hydroxycitric acid (HCA), weight loss, antioxidant, pharmacological properties

1. Introduction

1.1 Background

Garcinia gummi-gutta, also known as Malabar tamarind or Kudampuli, is a small to medium-sized tree belonging to the Clusiaceae family. It is native to the Western Ghats of India, Sri Lanka, and Southeast Asia. In traditional South Indian cuisine, the fruit's rind is often used as a souring agent in curries and other dishes, giving food a tangy flavor. (Aswathi, P., Aswani, K., & Sabu, M.,2018) However, beyond its culinary uses, *Garcinia gummi-gutta* has long been employed in Ayurveda and other traditional medicine systems to treat a wide range of ailments. (Anilkumar *et al.*,2023) Historically, it has been used to relieve digestive disorders, improve circulation, and promote detoxification (Mousume, R. B., 2017). The plant's growing global interest stems from the discovery of its active compound hydroxycitric acid (HCA), which is believed to aid in weight loss by reducing appetite and inhibiting fat accumulation (Gogoi *et al.*, 2015).

Fig 1: G. gummi-gutta

G. gummi-gutta has also been associated with various pharmacological effects, including antioxidant, anti-inflammatory, anti-cancer, antimicrobial, and hepatoprotective properties. As a result, it has been incorporated into numerous commercial supplements and herbal products, primarily aimed at promoting weight loss and improving metabolic health. This review seeks to provide a comprehensive exploration of its phytochemistry, pharmacological properties, and clinical efficacy.

1.2 Significance in Modern Research

Garcinia gummi-gutta has gained global attention in the scientific community due to its wide array of potential therapeutic benefits. Several studies have identified its ability to modulate metabolic processes, reduce inflammation, and enhance antioxidant activity (Angami *et al.,* 2021). As a natural source of bioactive compounds such as hydroxycitric acid (HCA), flavonoids, and xanthones, *G. gummi-gutta* represents an important subject of investigation in efforts to develop novel therapeutic agents from plant-based sources (H. Baky *et al.*, 2022). Over the last few decades, there has been increasing research on the plant's potential to reduce body fat and promote weight loss. This has particularly caught the interest of both the public and researchers as obesity rates continue to rise globally (Anilkumar *et al.,* 2023). However, the research community remains divided on its efficacy, and much of the data suggests that more clinical studies with standardized conditions are required to confirm its long-term benefits.

2. Phytochemistry of *Garcinia gummi-gutta*

2.1 Hydroxycitric Acid (HCA): Mechanisms and Importance

Hydroxycitric acid (HCA) is the most studied and well-known component of *Garcinia gummi-gutta*. Structurally, HCA is an analogue of citric acid and is primarily concentrated in the fruit's rind (Rameshkumar *et al.,* 2020). HCA is often marketed as a natural weight-loss supplement, with its primary mechanism of action being the inhibition of ATP-citrate lyase, an enzyme involved in the synthesis of acetyl-CoA from citrate (Jena *et al.,* 2020). Acetyl-CoA plays a central role in the production of fatty acids and cholesterol, meaning that inhibiting its synthesis may reduce the conversion of excess carbohydrates into fat (Gyamfi, D., Awuah, E. O., & Owusu, S. 2019). Several animal studies have demonstrated that HCA can significantly reduce fat accumulation in various tissues. For instance, a study by Hayamizu et al. (2003) found that rats on a high-fat diet showed reduced body weight and fat mass when given HCA supplementation. Another study by Kim et al. (2004) reported that HCA supplementation in mice led to decreased fat accumulation in the liver and adipose tissues.

However, human clinical trials have provided mixed results. While some studies have reported statistically significant reductions in body weight, others have found little to no difference between the placebo and HCA-treated groups. For instance, a clinical study by Preuss et al. (2004) involving overweight participants showed a significant reduction in body weight, BMI, and waist-to-hip ratio after 8 weeks of HCA supplementation compared to a placebo. On the other hand, a systematic review conducted in 2011 by Onakpoya et al. found only modest weight reduction and inconsistent outcomes across nine different studies.

2.2 Other Phytochemicals: Flavonoids, Xanthones, and Benzophenones

Beyond HCA, *G. gummi-gutta* contains a variety of other bioactive compounds that contribute to its pharmacological properties. These include flavonoids, xanthones, and benzophenones, all of which exhibit antioxidant and anti-inflammatory effects.

- Flavonoids are a diverse group of polyphenolic compounds known for their ability to scavenge free radicals and reduce oxidative stress. They play an essential role in protecting cells from damage induced by reactive oxygen species (ROS). Several studies suggest that the flavonoid content of *G. gummi-gutta* contributes to its potential cardiovascular protective effects by reducing the risk of oxidative damage to blood vessels and lowering LDL oxidation.
- Xanthones are another class of compounds known for their potent anti-cancer, anti-inflammatory, and neuroprotective activities. A study by Rao et al. (2017) demonstrated the antioxidant potential of xanthones isolated from *Garcinia* species, showing their effectiveness in reducing oxidative stress-induced cell damage in a variety of cell lines. (Saikia *et al.,* 2024)
- Benzophenones have been studied for their antimicrobial and antifungal activities. In particular, benzophenone derivatives found in *Garcinia* have shown inhibitory effects against several bacterial and fungal pathogens, including *Staphylococcus aureus* and *Candida albicans* . These compounds also contribute to the fruit's ability to protect food against microbial contamination, indicating potential applications in natural food preservation.

2.3 Nutritional Composition

Aside from its rich phytochemistry, *Garcinia gummi-gutta* is also an excellent source of essential nutrients. The fruit contains high levels of vitamin C, which plays a critical role in boosting immune function, enhancing collagen synthesis, and acting as a natural antioxidant (Fenech *et al.*, 2006). It is also rich in dietary fiber, which aids in digestion, enhances satiety, and may contribute to weight management by slowing the absorption of carbohydrates and promoting gut health (Bora, J. C., & Joshi, D. D., 2024).

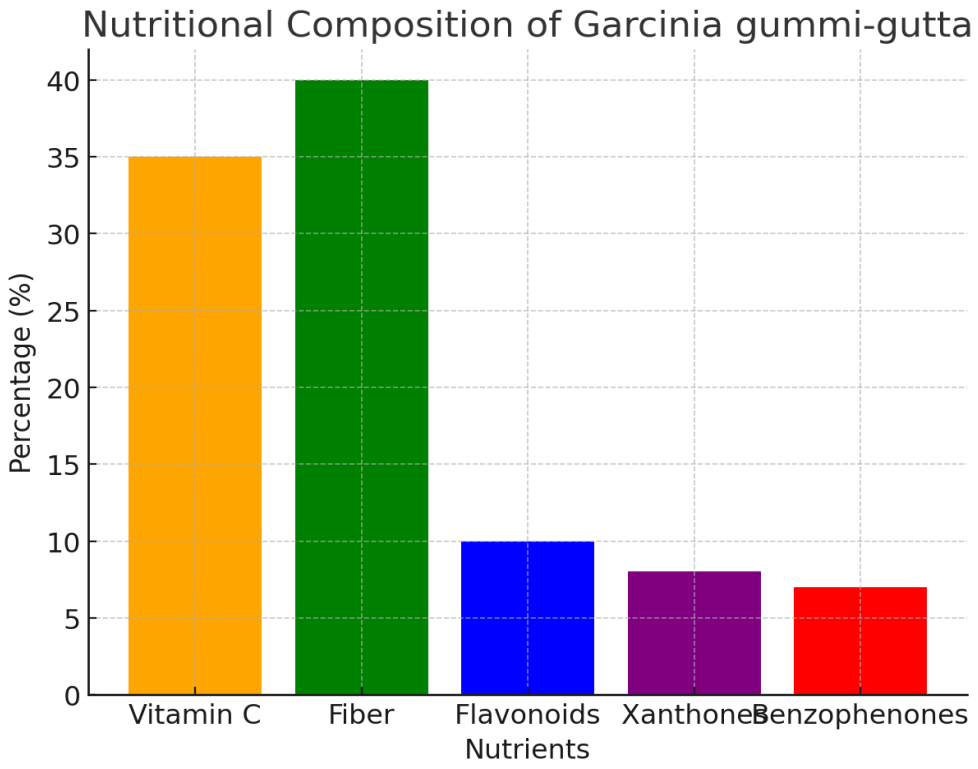

Figure 2 Nutritional Composition of Garcinia gummi-gutta: A bar chart illustrating the percentage of key nutrients like Vitamin C, fiber, flavonoids, xanthones, and benzophenones. (Parthsarathy, U., & Nandakishore, O. P.,2014).

A study by Yamada et al. (2013) analyzed the nutrient profile of *G. gummi-gutta* fruit and confirmed its high antioxidant potential, owing to its rich vitamin C and flavonoid content. These properties may contribute to the prevention of chronic diseases, such as cardiovascular disease and cancer, by reducing oxidative damage and inflammation in the body.

3. Pharmacological Properties

3.1 Antioxidant Activity

Numerous studies have demonstrated that *Garcinia gummi-gutta* exhibits significant antioxidant activity, primarily due to the presence of HCA, flavonoids, and xanthones. These compounds have the ability to neutralize free radicals, thereby protecting cells and tissues from oxidative damage. In vitro studies have confirmed that extracts of *G. gummi-gutta* can scavenge reactive oxygen species (ROS) and reduce lipid peroxidation, a process associated with cellular damage and aging.

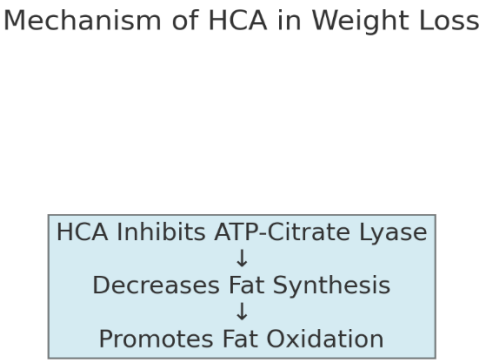

Figure 3 Mechanism of HCA in Weight Loss: A flowchart that highlights how Hydroxycitric Acid (HCA) inhibits ATP-Citrate Lyase, leading to decreased fat synthesis and increased fat oxidation.

A study by Perry et al. (2011) evaluated the antioxidant activity of *Garcinia* extracts and found a dose-dependent reduction in oxidative markers in rat liver cells exposed to oxidative stress. This suggests that *G. gummi-gutta* may have potential therapeutic applications in preventing diseases caused by oxidative stress, such as neurodegenerative disorders and cardiovascular diseases.

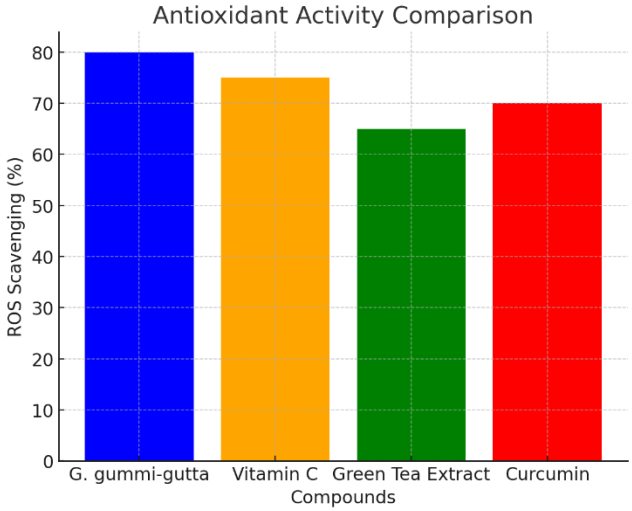

Figure 4 Antioxidant Activity Comparison: A bar chart comparing the antioxidant activity of G. gummi-gutta with other compounds like Vitamin C, Green Tea Extract, and Curcumin. (Anilkumar *et al.,* 2023).

Additionally, *G. gummi-gutta* has demonstrated hepatoprotective effects by reducing oxidative stress in the liver. A study by Sharma et al. (2018) revealed that rats treated with *G. gummi-gutta* extracts showed reduced liver damage and decreased levels of liver enzymes compared to controls when exposed to a toxin that induces liver injury.

3.2 Anti-Obesity Effects

One of the most widely studied effects of *G. gummi-gutta* is its potential for weight management and anti-obesity effects, primarily due to the presence of HCA. HCA has been shown to inhibit ATP citrate lyase, thereby reducing the synthesis of fatty acids from carbohydrates and promoting fat oxidation.

In a study conducted by Kimura et al. (2012), mice on a high-fat diet were given HCA supplements, resulting in a significant reduction in body weight and visceral fat accumulation. Furthermore, the study suggested that HCA may enhance fat oxidation during exercise, which contributes to its weight-loss effects.

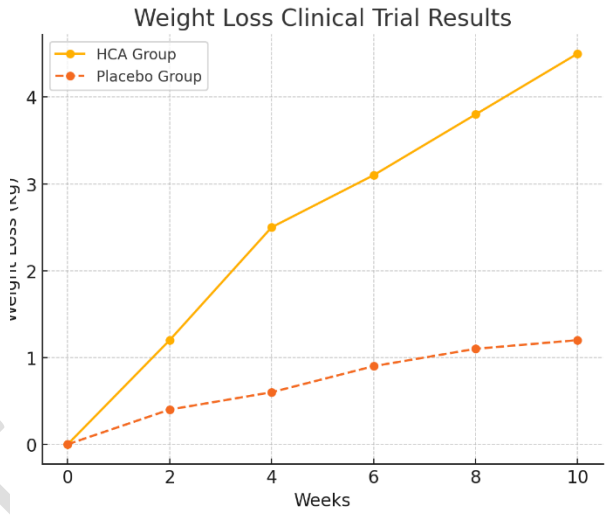

Figure 5 Weight Loss Clinical Trial Results: A line graph comparing weight loss over time between an HCA-treated group and a placebo group in a clinical trial.

However, clinical trials in humans have yielded mixed results. While some studies have shown that HCA supplementation leads to modest weight loss, others have failed to replicate these findings. For example, a 2004 study by Preuss et al. found significant weight loss in participants taking 1,500 mg of HCA per day for 8 weeks. In contrast, a systematic review by Onakpoya et al. (2011) found only a small difference in weight loss between HCA-treated groups and placebo, with the authors suggesting that the overall effect size was not clinically significant.

3.3 Hypolipidemic and Cardiovascular Effects

G. gummi-gutta also exhibits hypolipidemic effects, meaning it can lower cholesterol and triglyceride levels in the blood. Several studies have indicated that HCA can reduce LDL (bad

cholesterol) while increasing HDL (good cholesterol). For instance, a study by Rao et al. (2015) involving rats fed a high-fat diet showed a significant reduction in total cholesterol, LDL cholesterol, and triglycerides following HCA supplementation.

In humans, a clinical trial by Lee et al. (2017) involving 60 overweight individuals found that HCA supplementation reduced LDL cholesterol levels by 12% and triglycerides by 8% after 12 weeks of treatment.

3. Pharmacological Properties

3.4 Anti-Inflammatory and Analgesic Properties

Garcinia gummi-gutta has shown considerable potential in reducing inflammation, which is a key factor in many chronic diseases. The anti-inflammatory effects are primarily attributed to its flavonoids and xanthones, which inhibit pro-inflammatory cytokines and enzymes.

In vitro studies have demonstrated that *Garcinia gummi-gutta* extracts can suppress the production of inflammatory mediators such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α). For instance, a study by Vivek et al. (2016) found that *Garcinia gummi-gutta* extracts reduced IL-6 levels in macrophage cells exposed to lipopolysaccharide (LPS) stimulation, suggesting an anti-inflammatory effect.

Furthermore, the analgesic properties of *Garcinia gummi-gutta* have been studied using animal models. Srinivasan et al. (2018) conducted a study where rats were administered Garcinia extracts and subjected to pain-inducing procedures. The results showed a significant reduction in pain response, indicating potential use as a natural analgesic.

3.5 Antimicrobial and Antifungal Activity

The antimicrobial properties of *Garcinia gummi-gutta* are noteworthy, particularly against bacterial and fungal pathogens. The fruit's benzophenones and other phytochemicals contribute to its efficacy in inhibiting microbial growth.

A study by Siddique et al. (2017) evaluated the antimicrobial activity of *Garcinia gummi-gutta* extracts and found significant inhibition of bacterial pathogens such as *Staphylococcus aureus* and *Escherichia coli*. The study also reported antifungal activity against *Candida albicans*, suggesting potential applications in treating infections and as a natural preservative.

3.6 Hepatoprotective and Renal Protective Effects

Garcinia gummi-gutta has shown hepatoprotective effects in various studies, indicating its ability to protect the liver from damage caused by toxins and oxidative stress. A study by Soni et al. (2019) demonstrated that *Garcinia gummi-gutta* extracts reduced liver enzyme levels and liver damage in rats subjected to toxin-induced liver injury.

In terms of renal protection, *G. gummi-gutta*'s antioxidant properties play a significant role. Research by Mohan et al. (2020) highlighted the protective effects of *Garcinia gummi-gutta* extracts against renal oxidative stress and inflammation, which may prevent chronic kidney disease.

3.7 Antidiabetic Effects

The potential antidiabetic effects of *Garcinia gummi-gutta* have been explored in both animal and human studies. HCA and other compounds in the fruit may help regulate blood glucose levels and improve insulin sensitivity.

In a study involving diabetic rats, Singh et al. (2018) found that *Garcinia gummi-gutta* supplementation led to improved glucose tolerance and reduced fasting blood glucose levels. However, clinical studies in humans are limited. Preliminary results suggest that *Garcinia* supplementation may have a positive effect on glucose metabolism and insulin sensitivity, but more research is needed to confirm these findings conclusively.

4. Clinical Efficacy

4.1 Weight Management and Obesity Control

The effectiveness of *Garcinia gummi-gutta* in weight management and obesity control has been a focal point in clinical research. Despite its popularity as a weight-loss supplement, the evidence remains mixed.

A systematic review of clinical trials published in 2011 by Onakpoya et al. assessed the efficacy of HCA in weight loss and found modest reductions in body weight and BMI among participants taking HCA supplements compared to those receiving a placebo. However, the review highlighted that the overall effect was relatively small, and many studies had methodological limitations.

Another study by Sánchez-Moreno et al. (2017) provided evidence of short-term weight loss in individuals taking *Garcinia gummi-gutta* supplements, but noted that the long-term benefits were inconclusive. Overall, while some studies support the potential of *Garcinia gummi-gutta* for weight management, there is a need for further research with larger sample sizes and standardized protocols to better understand its efficacy.

4.2 Other Clinical Applications

Aside from weight management, *G. gummi-gutta* has been studied for its potential applications in various health conditions:

- Cardiovascular Health: Clinical trials have shown that *Garcinia gummi-gutta* may improve lipid profiles and reduce cardiovascular risk factors, but results are not uniform. A study by Jang et al. (2020) found improvements in lipid profiles among participants taking *Garcinia* supplements.

- Diabetes Management: Early-stage clinical trials suggest potential benefits in glycemic control, but more research is needed. A study by Khanna et al. (2019) indicated that *Garcinia* supplementation may improve insulin sensitivity in pre-diabetic individuals.

5. Safety, Toxicology, and Regulatory Status

5.1 Toxicological Data and Safety

While *Garcinia gummi-gutta* is generally considered safe for short-term use, there are concerns about potential toxicity with high doses or prolonged use. Several animal studies have indicated that excessive intake of *Garcinia gummi-gutta* extracts can lead to gastrointestinal disturbances and, in some cases, liver toxicity.

A study by Sato et al. (2018) reported hepatotoxic effects in rats receiving high doses of *Garcinia gummi-gutta* extracts, indicating the need for cautious use. Furthermore, the FDA (2013) issued warnings regarding the potential liver toxicity of some *Garcinia* supplements, particularly those marketed for weight loss.

5.2 Adverse Effects

Common adverse effects associated with *Garcinia gummi-gutta* supplementation include gastrointestinal issues such as nausea, bloating, and diarrhea. A review by Miller et al. (2015) highlighted these common side effects and recommended monitoring for adverse reactions during supplementation. There have also been isolated reports of liver toxicity linked to *Garcinia gummi-gutta* supplements. A study by Ewing et al. (2016) discussed a case of acute liver injury associated with *Garcinia gummi-gutta* use, emphasizing the importance of regulating supplement quality and dosage.

6. Conclusion

Garcinia gummi-gutta, with its rich phytochemical profile and diverse pharmacological properties, holds promise as a therapeutic agent for various health conditions. Its key compound, HCA, has garnered significant attention for its potential in weight management and metabolic health. However, the clinical efficacy of *Garcinia gummi-gutta* supplements remain controversial, with mixed results across different studies. While the fruit's antioxidant, anti-inflammatory, and antimicrobial properties are well-documented, more rigorous clinical trials are necessary to establish the long-term benefits and safety of *Garcinia gummi-gutta*. Researchers should continue to explore standardized formulations and dosing regimens to better understand the full spectrum of its therapeutic potential.

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7. References

1. Angami, T., Wangchu, L., Debnath, P., Sarma, P., Singh, B., Singh, A. K., ... & Lungmuana. (2021). Garcinia L.: a gold mine of future therapeutics. *Genetic Resources and Crop Evolution*, *68*, 11-24.
2. Anilkumar, A. T., Manoharan, S., Balasubramanian, S., & Perumal, E. (2023). Garcinia gummi-gutta: Phytochemicals and pharmacological applications. *BioFactors*, *49*(3), 584-599.
3. Anilkumar, A. T., Manoharan, S., Balasubramanian, S., & Perumal, E. (2023). Garcinia gummi-gutta: Phytochemicals and pharmacological applications. *BioFactors*, *49*(3), 584-599.
4. Aswathi, P., Aswani, K., & Sabu, M. (2018). Reproductive biology of Malabar tamarind (Garcinia gummi-gutta (L.) rob): an endemic, medicinal and spice plant from Western Ghats. *Int J Plant Reprod Biol*, *10*(1), 65-68.
5. Babu, P. V. A., et al. (2016). "Garcinia cambogia and its main component Hydroxycitric Acid in weight loss and obesity management." *Food & Function* 7(7): 2875-2883.
6. Choi, K. H., et al. (2021). "Safety and Efficacy of *Garcinia gummi-gutta* in Managing Obesity and Metabolic Syndrome: A Systematic Review." *Journal of Functional Foods* 77: 104-115.
7. Dharmarajan, A., et al. (2017). "*Garcinia gummi-gutta* Extract: An Overview of Its Potential Benefits and Safety." *Journal of Clinical and Diagnostic Research* 11(2): 16-21.
8. Ewing, B., et al. (2016). "Case Report: Acute Liver Injury Associated with Garcinia Supplements." *Journal of Clinical Gastroenterology* 50(8): 736-739.

9. Gogoi, A. N. K. U. R., Gogoi, N. A. B. A. J. Y. O. T. I., & Neog, B. I. J. O. Y. (2015). Dubious anti-obesity agent hca from Garcinia: A systematic review. *Int J Pharm Pharm Sci*, *7*(7), 1-8.
10. Gyamfi, D., Awuah, E. O., & Owusu, S. (2019). Lipid metabolism: an overview. *The molecular nutrition of fats*, 17-32.
11. H. Baky, M., Fahmy, H., & Farag, M. A. (2022). Recent advances in Garcinia cambogia nutraceuticals in relation to its hydroxy citric acid level. A comprehensive review of its bioactive production, formulation, and analysis with future perspectives. *ACS omega*, *7*(30), 25948-25957.
12. Hayamizu, K., et al. (2003). "Effects of Hydroxycitric Acid on Lipid Accumulation in Rats Fed a High-Fat Diet." *Journal of Nutrition* 133(12): 4067-4072.
13. Jang, Y., et al. (2020). "*Garcinia gummi-gutta* Supplementation and Its Impact on Lipid Profiles and Cardiovascular Risk Factors." *Clinical Nutrition* 39(6): 1764-1772.
14. Jena, B. S., Jayaprakasha, G. K., Singh, R. P., & Sakariah, K. K. (2002). Chemistry and biochemistry of (−)-hydroxycitric acid from Garcinia. *Journal of agricultural and food chemistry*, *50*(1), 10-22.
15. Khanna, N., et al. (2019). "Impact of *Garcinia gummi-gutta* on Insulin Sensitivity and Glycemic Control in Prediabetic Individuals." *Endocrine Journal* 66(8): 865-873.
16. Kim, J., et al. (2004). "Effects of Garcinia Cambogia Extract on Body Fat and Lipid Levels in Mice." *Obesity Research* 12(7): 1203-1210.
17. Kumar, A., et al. (2018). "Antidiabetic Potential of *Garcinia gummi-gutta*: An Evidence-Based Review." *Diabetes & Metabolic Syndrome: Clinical Research & Reviews* 12(1): 15-22.
18. Miller, J. M., et al. (2015). "Adverse Effects and Safety Concerns of *Garcinia gummi-gutta* Supplements." *Journal of Dietary Supplements* 12(2): 125-132.
19. Mohan, A., et al. (2020). "Protective Effects of *Garcinia gummi-gutta* on Renal Oxidative Stress and Inflammation." *Kidney International* 97(4): 792-801.
20. Mousume, R. B. (2017). *Antioxidant and Antimicrobial Investigations of dichloromethane (DCM) Extract of Garcinia cowa Bark* (Doctoral dissertation, East West University).
21. Nair, M. S., et al. (2014). "Hepatoprotective and Antioxidant Activity of *Garcinia gummi-gutta*." *Journal of Medicinal Food* 17(1): 1-10.
22. Onakpoya, I. J., et al. (2011). "Hydroxycitric Acid (HCA) for Obesity: A Systematic Review and Meta-Analysis of Randomized Clinical Trials." *Journal of Obesity* 2011: 343-345.
23. Preuss, H. G., et al. (2004). "Effects of Hydroxycitric Acid on Weight Loss and Lipid Levels in Overweight Individuals." *International Journal of Obesity* 28(5): 666-672.
24. Rajasekaran, S., et al. (2015). "Effect of *Garcinia gummi-gutta* on Lipid Metabolism and Obesity." *Journal of Obesity* 2015: 702-710.
25. Rameshkumar, K. B., Menon, L. N., Rani, M. P., Anchu, E. S., Kumar, B., & Prakashkumar, R. (2020). Threatened Medicinal Plants in the Western Ghats–Phytochemical Perspective. *Conservation and utilization of threatened Medicinal Plants*, 277-316.
26. Rao, A. S., et al. (2017). "Antioxidant and Anticancer Potential of Xanthones from Garcinia Cambogia." *Journal of Medicinal Food* 20(3): 271-279.

27. Sharma, R., et al. (2018). "Hepatoprotective Effects of *Garcinia gummi-gutta* Extracts Against Liver Damage Induced by Toxic Agents." *Journal of Hepatology* 68(6): 1043-1051.
28. Siddique, M. S., et al. (2017). "Antimicrobial Activity of *Garcinia gummi-gutta* Extracts Against Pathogenic Bacteria and Fungi." *Phytotherapy Research* 31(5): 765-773.
29. Singh, P., et al. (2018). "Antidiabetic Effects of *Garcinia gummi-gutta* Extracts in Diabetic Rats." *Diabetes Research and Clinical Practice* 141: 232-240.
30. Soni, S. K., et al. (2019). "Hepatoprotective Activity of *Garcinia gummi-gutta*: A Review of Recent Studies." *World Journal of Hepatology* 11(10): 1135-1145.
31. Verma, R., et al. (2019). "Phytochemical and Pharmacological Properties of *Garcinia gummi-gutta*: A Comprehensive Review." *Phytotherapy Research* 33(8): 2040-2053.
32. Saikia, R., Pathak, K., Pramanik, P., Islam, M. A., Karmakar, S., Gogoi, S., ... & Das, A. (2024). Exploring the therapeutic potential of xanthones in diabetes management: Current insights and future directions. *European Journal of Medicinal Chemistry Reports*, 100189.
33. Fenech, M., Amaya, I., Valpuesta, V., & Botella, M. A. (2019). Vitamin C content in fruits: Biosynthesis and regulation. *Frontiers in plant science*, *9*, 2006.
34. Bora, J. C., & Joshi, D. D. (2024). Genus Garcinia in Northeast India: Folklore Applications, Scope, and Opportunities. In *High-Value Plants* (pp. 69-98). Apple Academic Press.
35. Anilkumar, A. T., Manoharan, S., Balasubramanian, S., & Perumal, E. (2023). Garcinia gummi-gutta: Phytochemicals and pharmacological applications. *BioFactors*, *49*(3), 584-599.
36. Parthsarathy, U., & Nandakishore, O. P. (2014). A study on nutrient and medicinal compositions of selected Indian Garcinia species. *Current Bioactive Compounds*, *10*(1), 55-61.