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Review Article

Green Tea Extract: An In-Depth Review of Its Potential in Weight and Blood Sugar Regulation

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Abstract

Obesity has emerged as a major public health concern, contributing to the growing occurrence of long-term health problems, including elevated blood pressure, diabetes, and cardiovascular disorders. As a result, there is an increasing interest in exploring effective strategies for weight management and metabolic health. Green tea extract (GTE), known for its rich composition of bioactive polyphenolic compounds, especially catechins like epigallocatechin gallate (EGCG), has gained attention for its potential therapeutic effects in combating obesity and associated metabolic disorders. This review integrates data from diverse scholarly databases, including Google Scholar, ResearchGate, ScienceDirect, and PubMed, to comprehensively evaluate the phytochemical profile, pharmacological actions, and safety considerations of GTE, with a particular focus on its anti-obesity, antioxidant, and metabolic benefits. Preclinical and clinical evidence suggest that GTE promotes fat oxidation, enhances insulin sensitivity, and stimulates thermogenesis, all of which contribute to its role in weight management and metabolic regulation. Additionally, its potent antioxidant properties help mitigate oxidative stress, thereby offering protection against cellular damage and chronic disease progression. Although the results are promising, further studies are required to establish the ideal dosages, assess the long-term safety of GTE, and optimize its clinical uses. This review highlights the potential of GTE as a valuable therapeutic adjunct in the management of obesity, while emphasizing the need for continued investigation into its broader health benefits.

Keywords: Green tea extract, Catechin, Epigallocatechin gallate, Anti-obesity, Antioxidant

1. Introduction

Obesity has evolved into a global health crisis, with its incidence doubling in the last forty years, now impacting more than a third of the global population[1,2]. A body mass index (BMI) of 30 kg/m^2 or higher is considered obese. Obesity is a complicated disorder that is influenced by a number of behavioural, environmental, genetic, and socioeconomic factors. This widespread issue is no longer limited to high-income countries but now impacts low- and middle-income nations as well, such as India, where more than 135 million people are impacted, with women experiencing higher rates[3,4]. Obesity significantly increases the chance of developing numerous health issues, such as heart diseases, high blood pressure, and type 2 diabetes[5]. Although BMI is commonly used for diagnosing obesity, it has limitations, particularly in accurately reflecting body fat percentage across different ethnic groups. Managing obesity requires a combination of dietary changes, lifestyle modifications increased physical activity, and when necessary pharmacological treatments[6]. Certain herbal extracts like green tea, have shown potential in supporting weight loss and improving metabolic function as part of a comprehensive obesity management strategy.

Green tea extract (GTE) has gained substantial scientific interest in recent years due to its potential health-promoting properties and its diverse applications across industries, especially in nutraceuticals and functional foods. Green tea extract is a concentrated form of the active compounds naturally occurring in the leaves of *Camellia sinensis*, the same plant used to prepare traditional green tea. *Camellia sinensis*, a member of the Theaceae family, originates from China. Green tea is derived from an evergreen plant that is mainly cultivated in tropical and temperate regions of Asia, including countries like China, India, Japan, and Sri Lanka. And it is also grown in various countries across Africa and South America[7,8]. Bioactive compounds, especially polyphenols like catechins, have been shown to exhibit a broad spectrum of pharmacological and therapeutic effects. Green tea extract contains the most well-known catechins: epicatechin gallate, epigallocatechin, and epicatechin[9,10]. Green tea extract offers a wide array of pharmacological benefits, anti-inflammatory, antioxidant, and cardioprotective benefits. It may help with weight loss, enhance insulin sensitivity, and boost brain health[11].

2. Botanical description

Figure 1: Leaves of Green tea

Camellia sinensis is an evergreen shrub that typically reaches a height of 1 to 3 meters, characterized by a dense branching structure. The leaves of the plant are dark green and glossy, varying in shape from elliptic to oblong-elliptic, the size typically falls between 5 and 12 cm in length and 1.8 to 4.5 cm in width. These leaves have a leathery texture, serrated margins, and a pointed or blunt apex (Figure 1). Younger leaves are covered with short, silvery hairs on the underside, while mature leaves become mostly glabrous or slightly hairy. The petioles are 3-7 mm long, initially pubescent but becoming smooth with age. Tea plants produce small, fragrant, white flowers that bloom between October and February, often appearing singly or in small clusters. These flowers consist of five to eight obovate petals and numerous stamens fused at the base. The fruit is a brownish-green capsule containing one to four seeds, which are spherical or flattened. The plant thrives in humid, temperate regions with acidic soils, making it ideal for cultivation in subtropical and tropical climates[12].

3. Phytochemical constituents

Tea leaves are rich in a diverse range of bioactive substances, which contribute to their distinct taste and health-enhancing properties. These include alkaloids such as caffeine, polyphenolic compounds like catechins and flavonoids, essential vitamins, and minerals. Tea leaves also contain purines, volatile oils, and polysaccharides, all of which play a role in their flavor profile and potential health benefits[13].

3.1. Alkaloids- Green tea leaves are rich in purine alkaloids, primarily caffeine, along with smaller amounts of theobromine and theophylline. The refreshing effect of tea is primarily attributed to these three alkaloids, which serve as the key active components responsible for this stimulating action[10]. The chemical structures of the alkaloids present in green tea are shown in figure 2.

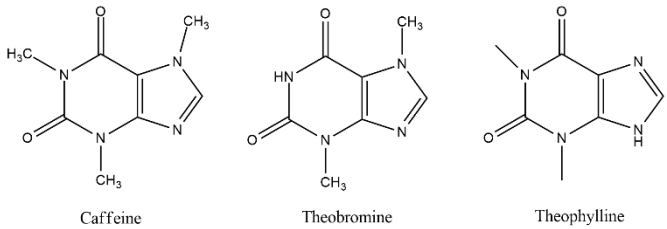

Figure 2: Structural representations of alkaloids present in green tea

3.2. Polyphenols- Main active ingredients in teas are polyphenols, with catechins being the most important category in green tea. These catechins contains epigallocatechin, epicatechin-3-gallate, epigallocatechin-3-gallate (EGCG), epicatechin, along with gallocatechins and gallocatechin gallate. The chemical structures of the polyphenol present in green tea are shown in Figure 3. Among them, EGCG stands out as the most prevalent and extensively researched catechin in green tea[14].

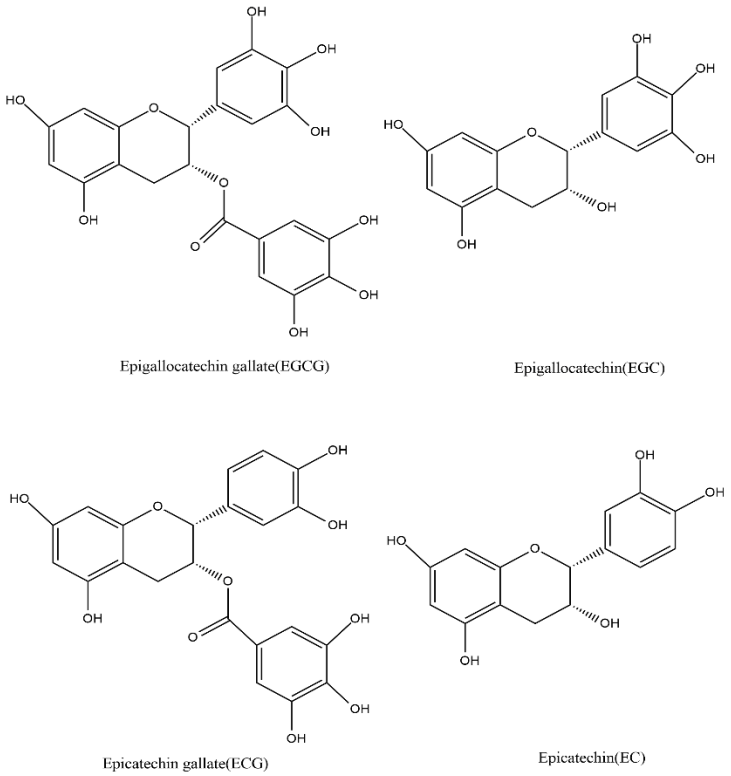

Figure 3: Structural representations of Catechins Present in Green tea

Green tea includes an array of flavanol glycosides, especially quercetin-3-glucosyl-rhamnosyl-glycosides, myricetin-3-glycosides, and kaempferol-3-glucosyl-rhamnosyl-galactoside. These glycosides are composed of sugar units, including monosaccharides like glucose, galactose, rhamnose, and arabinose, as well as disaccharides and trisaccharides[15].

3.3. Others- Green tea extract also contains a variety of other components, including amino acids, fibers, carbohydrates, lipids, pigments, and minerals[16].

4. Pharmacological activities

Green tea and its polyphenolic compounds are known to offer numerous health benefits, helping to prevent and manage a range of diseases, including obesity, blood sugar level, and weight management. Additionally, green tea exhibits antioxidant activity, antimicrobial properties, skin health, and has neuroprotective effects, supporting overall brain health[17].

4.1. Obesity, blood sugar level and weight management

4.1.1. *In vitro* studies

In the *in vitro* experiment, the mitochondrial metabolism of brown adipocytes was notably enhanced when co-treated with 50 µg/mL of Enzymatically Modified Isoquercetin (EMIQ) and Heat-Transformed Green Tea extract (HTGT) for 48 hours. This treatment led to a 2.9-fold increase in the levels of brown adipocyte markers including UCP1, along with mitochondrial proteins like COXIV. Moreover, enhanced mitochondrial activity was indicated by 1.57- and 1.39-fold increases in the maximal and basal oxygen consumption rates, respectively. Mitochondrial staining also revealed a 1.68-fold increase in fluorescence intensity in C3H10T1/2 adipocytes, suggesting improved mitochondrial function and distribution. These findings suggest that HTGT and EMIQ co-treatment enhances mitochondrial activity and thermogenesis in brown adipocytes, supporting their potential as agents for promoting energy expenditure and combating obesity[18].

The study investigated that (−)-epigallocatechin gallate (EGCG) may contribute to anti-obesity effects by modulating insulin sensitivity and glucose uptake in adipocytes, key processes in fat accumulation. EGCG reduced insulin-triggered glucose absorption in a dose- and time-sensitive way, decreasing adipocyte's ability to convert excess glucose into fat. The study determined that the receptor in charge of mediating this action is the 67-kDa laminin receptor (67LR). It was found that the effects of EGCG are additionally regulated through the pathway associated with AMP-activated protein kinase (AMPK), a critical regulator of energy metabolism that facilitates fat oxidation and inhibits lipid accumulation. By reducing insulin's fat-promoting effects and activating AMPK, EGCG may help prevent excessive fat storage, enhance fat burning, and improve metabolic health, positioning it as a promising agent for combating obesity[19].

4.1.2. Pre-clinical studies

The study examined the weight-reducing effects of green tea extract using both zebrafish larvae and obesity models in adult subjects. Zebrafish larvae were treated with 100 µg/mL of GTE, leading to a notable decrease in visceral fat caused by a high-fat diet. daily dosage of 250 µg/g body weight per day GTE also reduced adipose tissue volume and lowered plasma triglyceride and cholesterol levels. RNA sequencing of liver tissues indicated that the impact of green tea extract could be connected to the activation of the Wnt/β-catenin and AMPK signaling pathways. These findings imply that green tea could play a role in preventing and managing obesity[20].

The effects of GTE on lipid metabolism were examined in obese male C57BL/6J-Lepob/ob mice, which were administered a high-fat diet supplemented with 0.05 g of GTE per 100 g of the diet over a 12-week period. GTE supplementation led to a significant decrease in adipose tissue weight and hepatic triglyceride levels, while simultaneously increasing plasma HDL-cholesterol levels and improving the HDL-cholesterol to total cholesterol ratio. GTE also suppressed fatty acid synthesis enzymes without affecting fatty acid oxidation. These results suggest that GTE may help reduce obesity by modulating lipid metabolism[21].

This study explored the effects of green tea on insulin sensitivity and glucose tolerance in a rat model Sprague-Dawley. The rats were allocated into two groups for the in vivo study: the control group received standard chow and deionized water, while the experimental group received the identical chow along with a green tea solution (0.5 g of freeze-dried green tea powder dissolved in 100 mL of water) instead of plain water. After 12-week period, the group receiving green tea demonstrated significantly reduced fasting plasma concentrations of insulin, triglycerides, glucose, and free fatty acids compared to the control group. Additionally, the green tea group exhibited a significant increase in both insulin binding to adipocytes and insulin-stimulated glucose uptake. The *in vitro* experiment also examined the effect of a 0.075% green tea polyphenol extract on insulin activity, noting a significant enhancement in both baseline and insulin-stimulated glucose uptake in adipocytes. These findings suggest that polyphenols in green tea play a key role in improving insulin sensitivity in rats[22].

4.1.3. Clinical studies

A randomized, double-blind study was conducted to evaluate the effects of a high concentration of green tea extract (856.8 mg EGCG) on cholesterol levels, fat reduction, and hormones associated with obesity in women with abdominal fat accumulation. Over a 12-week period, 102 women with a BMI of 27 kg/m^2 or higher and a waist circumference of 80 cm or more were randomly divided into the EGCG group and the placebo group. The results revealed notable decrease in weight ($p = 0.025$), BMI ($p = 0.018$), and waist circumference ($p = 0.023$) in the EGCG group, along with a 5.33% decrease in total cholesterol and lower LDL levels. Additionally, EGCG

treatment lowered ghrelin and increased adiponectin levels. No adverse effects were reported, suggesting EGCG was well-tolerated. These findings indicate that high-dose EGCG may support weight reduction and improve fat metabolism, potentially through changes in ghrelin and adiponectin[23].

A controlled, double-blind, randomized trial was performed to assess the effects of GTE on weight loss and obesity-related hormone levels in overweight women. The study included 78 women (BMI > 27 kg/m2), aged 16–60, who had not received weight-control treatments in the preceding three months. Participants were randomly allocated to receive 400 mg of green tea extract three times a day or a placebo for a duration of 12 weeks. No notable differences were found between the GTE and placebo groups in terms of body weight, BMI, or waist circumference. However, GTE markedly enhanced lipid profiles by raising HDL cholesterol and decreasing LDL cholesterol and triglycerides. While the placebo group only displayed a decrease in triglycerides and a rise in ghrelin, GTE also resulted in increased levels of adiponectin and ghrelin. The study found that, although GTE had no obvious impact on weight, it did enhance lipid profiles and hormones linked to obesity[24].

4.2. Antioxidant

4.2.1. *In-vitro* studies

The *in vitro* antioxidant properties and bioactive components of green tea extracts (GTE) were assessed. Antioxidant activities were assessed using DPPH and FTC methods, while polyphenols and catechins were measured chemically. The results indicated that GTE from ultrahigh pressure extraction had the highest antioxidant activity, with significantly higher levels of polyphenols and catechins than other methods. The study concluded that ultrahigh pressure extraction not only yields more bioactive components but also enhances free radical and reactive oxygen species scavenging, demonstrating its potential for extracting active ingredients from plants[25].

Green tea was extracted by maceration with 96% ethanol, then its antioxidant activity was assessed using the DPPH assay and a comprehensive phytochemical screening. The extract was found to contain tannins, saponins, flavonoids, and steroids/triterpenoids. The total ash value was 1.06%, the acid-insoluble ash content was 0.099%, and the moisture content was found to be 14.25%. The antioxidant potential, assessed by the DPPH method, resulted in an IC_{50} of 11.83±0.005 µg/ml. These results show that the ethanol extract of green tea exhibits significant antioxidant properties[26].

4.2.2. Pre-clinical studies

Green tea extract, renowned for its antioxidant properties, was evaluated for its potential to reduce muscle necrosis in the mdx mouse model of Duchenne muscular dystrophy (DMD). The mice were fed diets enriched with 0.01% or 0.05% green tea extract for 4 weeks. Muscle degeneration was measured in the soleus and elongator digitorum longus (EDL) muscles, while oxidative stress was assessed in cultured C2C12 myotubes exposed to tert-butyl hydroperoxide. A dose-dependent reduction in necrosis was seen in the fast-twitch EDL muscle, while no changes were detected in the slow-twitch soleus muscle. Green tea extracts also reduced oxidative stress in the myotubes. The smaller dosage in mice (0.01%) compares to nearly 1.4 liters (7 cups) of GTE per day in people, indicating that GTE might reduce muscle degeneration in Duchenne Muscular Dystrophy through its antioxidant properties[27].

4.2.3. Clinical studies

The study investigated the impact of GT on oxidative stress biomarkers in men following resistance exercise. 14 participants were divided into a control group and a green tea (GT) group, which consumed 2g of green tea leaves (dissolved in 200 mL of water) Three times daily for a duration of 7 days. Before and after exercise, blood samples were collected to measure various indicators, including total antioxidant capacity (FRAP), reduced glutathione (GSH), polyphenols, lipid hydroperoxide (LH), creatine kinase (CK), and others. Results showed that GT consumption reduced post-exercise LH levels, increased GSH and FRAP, and prevented the rise in CK and xanthine oxidase (XO) activity. GT also decreased AST activity and lowered hypoxanthine and uric acid levels. The study concluded that green tea, rich in polyphenols, may protect against exercise-induced oxidative damage and highlighted the need for better dietary guidance for athletes[28].

The purpose of the study was to investigate the antioxidant effects of green tea and determine how different doses impact its effectiveness. Ten healthy individuals (5 males, 5 females, aged 23 ± 25 years) participated, having undergone overnight fasting before testing. Plasma antioxidant activity was measured initially, then again at 60 and 120 minutes after consuming 150 mL of green tea. The tea was brewed by soaking 2.5 g of dried green tea leaves in 150 mL of water at 80°C for 2 minutes. In the following weeks, participants consumed 300 mL (containing 5.0 g of leaves) and 450 mL (containing 7.5 g of leaves) of green tea. The results showed a 1.1% increase at 60 minutes and a 2.1% increase at 120 minutes after drinking 150 ml of tea, though neither change was statistically significant. After the ingestion of 300 ml, the TAC (Total antioxidant capacity) exhibited a substantial rise of 7.0% at 60 minutes and 6.2% at 120 minutes ($P < 0.0001$). Following the administration of 450 ml, the TAC elevated by 12.0% at 60 minutes and 12.7% at 120 min ($P < 0.0001$). The study determined that green tea consumption markedly elevated plasma TAC in a dose-dependent manner, exhibiting more substantial increases at higher dosages[29].

4.3. Safety studies

4.3.1. *In-vitro* studies

This study investigated the antimutagenic effects of petroleum ether, chloroform, methanol, and water extracts of green tea using *Salmonella typhimurium* strains TA-98 and TA-100. The mutagenicity induced by sodium azide (10 µl) and daunomycin (6 µl) was assessed by measuring histidine revertant colonies. The addition

of 10 µl of each green tea extract to mutagen-treated plates significantly reduced the number of revertant colonies. Further, when the S9 fraction was included, all extracts still inhibited mutagenicity, with the ethanolic extract showing the highest antimutagenic activity. These results imply that green tea extracts, have protective effects against sodium azide and daunomycin-induced mutagenicity in *S. typhimurium*[30].

This study compared the antimutagenic effects of plant extracts (tomato, spinach, carrot, paprika, onion, kiwi, and green tea) using the Ames test and CAPL method. Green tea showed the strongest antimutagenic activity, with over 60% inhibition of mutagenicity, while other extracts like paprika, carrot, and spinach had moderate to weak effects. Green tea also demonstrated the highest antioxidant capacity[31].

4.3.2. Preclinical studies

To assess the safety of the extract, ICR mice were given oral doses of GTE at 0, 625, 1250, and 2500 mg/kg body weight per day for 28 days. Various parameters were assessed, including hematological parameters, serum biochemistry, urinalysis, histopathology, body weight, organ weights, and lipid levels. The results indicated no adverse effects on body weight, organ weights, or any other measured health parameters. Moreover, GTE notably reduces cholesterol, and triglyceride levels, mainly due to its elevated catechin concentration. The study determined that the no-observed-adverse-effect level (NOAEL) for green tea extract was 2500 mg/kg body weight/day, indicating that it is safe at this dosage and may have positive effects on lipid metabolism[32].

The study established the oral lethal dose (LD_{50}) of GTE in mice by administering doses between 100 and 5000 mg/kg body weight and monitoring the effects over a 10-day period. No significant variations were observed in body weight, plasma urea, creatinine, or SGOT levels. Antioxidants like reduced glutathione, superoxide dismutase, and catalase showed slight increases, but these were not significant. The LD_{50} of GTE as found to exceed 5000 mg/kg body weight, suggesting that there is no acute toxicity. However, it was recommended to limit the consumption of highly concentrated GTE (up to 3%) to no more than four cups per day[33].

The study was conducted to investigate the geno-protective effects of GTE against the genotoxicity induced by metronidazole and tinidazole in mice. Thirty-six mice were divided into 6 groups, with treatments including metronidazole, tinidazole, and GTE, either alone or in combination. Tinidazole significantly increased chromosomal aberrations in bone marrow and spleen cells compared to the control. GTE showed geno-protective properties against the genotoxicity induced by both metronidazole and tinidazole by decreasing these abnormalities. Tinidazole had a greater impact than metronidazole on chromosomal aberrations[34].

Rats were administered two different green tea catechin (GTC) formulations—one heat-sterilized (GTC-H) and the other unheated (GTC-UH)—at doses up to 2000 mg/kg/day over a 28-day period. No deaths occurred, and most health indicators (body weight, clinical observations, organ assessments) were unaffected. GTC-H led to reduced body weight and food intake in male rats receiving high doses (1000 and 2000 mg/kg/day). The no-observed-adverse-effect level (NOAEL) for GTC-H was identified as 1000 mg/kg/day, attributed to localized gastric effects, while the systemic toxicity NOAEL for all preparations was established at 2000 mg/kg/day[35].

4.3.3. Clinical studies

A 24-week study assessed the safety and quality of life outcomes of green tea polyphenol (GTP) supplementation and Tai Chi (TC) exercise in postmenopausal women with osteopenia. A total of 171 women were randomly assigned to four groups: placebo, GTP, placebo + TC, and GTP + TC. Safety was evaluated by monitoring liver and kidney function, and no adverse effects were observed. Both GTP supplementation and TC exercise had no impact on liver or kidney function. However, TC exercise enhanced emotional and mental health quality of life, whereas GTP had no impact on quality of life. Both GTP (500 mg/day) and TC (3 hours/week) were determined to be safe[36].

A 12-week randomized, double-blind study was conducted with 102 women having central obesity, who were administered either high-dose green tea extract (856.8 mg EGCG daily) or a placebo. The treatment group showed significant fat reduction, along with decreases in BMI, waist circumference, and levels of total cholesterol and LDL. Moreover, ghrelin levels were reduced, while adiponectin levels were elevated in the treatment group compared to the placebo. No serious adverse events were reported, suggesting that high-dose green tea extract is both safe and potentially effective for weight loss and improving lipid profiles[23].

5. Mechanisms of action

5.1. Antioxidant

EGCG and other green tea polyphenols are well-known for their powerful antioxidant effects, which have been extensively studied. EGCG modulates critical signaling pathways, including Akt and JNK, to prevent oxidative damage and reduce reactive oxygen species levels, including hydrogen peroxide (H_2O_2)-induced apoptosis. The substance also increases the activity of antioxidative enzymes like catalase, and glutathione peroxidase, superoxide dismutase, which contribute to cellular defense mechanisms[37,38]. Moreover, EGCG activates the Nrf2-Keap1 signaling pathway, a crucial regulator of antioxidant and detoxification gene expression, leading to the upregulation of downstream genes like heme oxygenase 1, NADPH quinone oxidoreductase 1, and glutathione S-transferase[39]. These effects help restore cellular redox balance and reduce oxidative stress. Structural modifications to EGCG, such as esterification with lipophilic groups, enhance its antioxidant activity and bioavailability. Compared to other polyphenols like ECG, EGC, and EC, EGCG exhibits superior antioxidant activity, which underscores its potential for therapeutic use in oxidative stress-related diseases. These findings highlight EGCG's complex mechanisms in mitigating oxidative damage, emphasizing its role in both direct ROS

(Reactive oxygen species) scavenging and the activation of cellular antioxidant defenses[11].

5.2. Anti-obesity

Green tea exerts anti-obesity effects through multiple mechanisms, primarily driven by its polyphenolic compounds, caffeine, and L-theanine. Tea polyphenols regulate fat metabolism by modulating pathways such as SKN-1/Nrf and MAPK, inhibiting preadipocyte differentiation, promoting lipolysis, and reducing fat accumulation. They also enhance microbiota-dependent adipocyte thermogenesis, increasing energy expenditure and fat oxidation[40]. Caffeine synergistically boosts fat oxidation, especially when combined with polyphenols, while L-theanine induces browning of white adipose tissue via the AMPK/α-ketoglutarate/Prdm16 pathway, further promoting fat burning. Additionally, tea influences hormones like adiponectin, improving insulin sensitivity and supporting metabolic health. Together, these mechanisms make tea a potent agent in managing obesity by promoting fat loss, improving metabolism, and enhancing energy expenditure[41].

6. Conclusion

In conclusion, green tea extract, especially its active catechins like EGCG, demonstrates strong potential in supporting weight management and improving metabolic health. By promoting fat oxidation, enhancing thermogenesis, and improving insulin sensitivity, GTE provides a natural and effective means for addressing obesity and metabolic dysfunction. Furthermore, its powerful antioxidant properties help protect against oxidative stress, contributing to overall health and disease prevention. The accumulated evidence positions green tea extract as a valuable and versatile tool in obesity management and metabolic support, warranting its continued exploration for broader therapeutic applications.

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References:

1. Chooi YC, Ding C, Magkos F. The epidemiology of obesity. Metabolism. 2019;92:6-10. https://doi.org/10.1016/j.metabol.2018.09.005
2. Mehrzad R. Definition and introduction to epidemiology of obesity. In: Mehrzad R, editor. Obesity. Elsevier; 2020. p. 1-6. https://doi.org/10.1016/j.metop.2025.100375
3. Soni P, Kumar DS, Kishore PK. An overview on obesity. J Med Sci Clin Res. 2018;6(1):32188-93. https://dx.doi.org/10.18535/jmscr/v6i11.150
4. Ahirwar R, Mondal PR. Prevalence of obesity in India: A systematic review. Diabetes Metab Syndr Clin Res Rev. 2019;13(1):318-21. https://doi.org/10.1016/j.dsx.2018.08.032
5. Caballero B. The global epidemic of obesity: An overview. Epidemiol Rev. 2007;29(1):1-5. https://doi.org/10.1093/epirev/mxm012
6. Chimurkar RP, Kumar J. An overview on obesity: A review. Int J Res Pharm Sci. 2020;11(2):2256-60. https://doi.org/10.26452/ijrps.v11i2.2185
7. Senanayake SN. Green tea extract: Chemistry, antioxidant properties and food applications–A review. J Funct Foods. 2013;5(4):1529-41. https://doi.org/10.1016/j.jff.2013.08.011
8. Namita P, Mukesh R, Vijay KJ. Camellia sinensis (green tea): A review. Glob J Pharmacol. 2012;6(2):52-9.
9. Sen AK, Sen DB, Zanwar AS, Balaraman R, Shah U, Maheshwari RA. Catechins and theaflavins: An overview on therapeutic application. J Nat Remedies. 2022;22(3):330-46. http://dx.doi.org/10.18311/jnr/2022/30181
10. Zhao T, Li C, Wang S, Song X. Green tea (Camellia sinensis): A review of its phytochemistry, pharmacology, and toxicology. Molecules. 2022;27(12):3909. https://doi.org/10.3390/molecules27123909
11. Xing L, Zhang H, Qi R, Tsao R, Mine Y. Recent advances in the understanding of the health benefits and molecular mechanisms associated with green tea polyphenols. J Agric Food Chem. 2019;67(4):1029-43. https://doi.org/10.1021/acs.jafc.8b06146
12. Shrivastava RR, Pateriya PP, Singh MS. Green tea - A short review. Int J Indig Herbs Drugs. 2018;3(2):12-21.
13. Rani R, Nagpal D, Gullaiya S, Madan S, Agrawal SS. Phytochemical, pharmacological and beneficial effects of green tea. Int J Pharmacogn Phytochem Res. 2014;6(3):420-6.
14. Khan N, Mukhtar H. Tea polyphenols in promotion of human health. Nutrients. 2018;11(1):39. https://doi.org/10.3390/nu11010039
15. Wang Z, Sha Y, Yu X, Liang Y. Determination of flavonol glycosides in tea samples by ultra-high performance liquid chromatography-photodiode array detection-tandem mass spectrometry. Chin J Chromatogr. 2015;33(9):974-80. https://doi.org/10.3724/sp.j.1123.2015.04028
16. Ikbal A, Roy S, Pat K. Health benefits of green tea: A mini review. J Entomol Zool Stud. 2020;8:1424-30.
17. Bansal S, Syan N, Mathur P, Choudhary S. Pharmacological profile of green tea and its polyphenols: A review. Med Chem Res. 2012;21(11):3347-60. http://dx.doi.org/10.1007/s00044-011-9800-4
18. Im H, Lee J, Kim K, Son Y, Lee YH. Anti-obesity effects of heat-transformed green tea extract through the activation of adipose tissue thermogenesis. Nutr Metab. 2022;19:14. https://doi.org/10.1186/s12986-022-00648-6
19. Hsieh CF, Tsuei YW, Liu CW, et al. Green tea epigallocatechin gallate inhibits insulin stimulation of adipocyte glucose uptake via the 67-kilodalton laminin receptor and AMP-activated protein kinase pathways. Planta Med. 2010;76(15):1694-8. https://doi.org/10.1055/s-0030-1249877
20. Zang L, Shimada Y, Nakayama H, et al. RNA-seq based transcriptome analysis of the anti-obesity effect of green tea extract using zebrafish obesity models. Molecules. 2019;24(18):3256. https://doi.org/10.3390/molecules24183256
21. Kim HJ, Jeon SM, Lee MK, et al. Antilipogenic effect of green tea extract in C57BL/6J-Lepob/ob mice. Phytother Res. 2009;23(4):467-71. https://doi.org/10.1002/ptr.2647
22. Wu LY, Juan CC, Ho LT, et al. Effect of green tea supplementation on insulin sensitivity in Sprague-Dawley rats. J Agric Food Chem. 2004;52(3):643-8. https://doi.org/10.1021/jf030365d
23. Chen IJ, Liu CY, Chiu JP, Hsu CH. Therapeutic effect of high-dose green tea extract on weight reduction: A randomized, double-blind, placebo-controlled clinical trial. Clin Nutr. 2016;35(3):592-9. https://doi.org/10.1016/j.clnu.2015.05.003
24. Hsu CH, Tsai TH, Kao YH, et al. Effect of green tea extract on obese women: A randomized, double-blind, placebo-controlled clinical

trial. Clin Nutr. 2008;27(3):363-70. https://doi.org/10.1016/j.clnu.2008.03.007

25. Jun X, Deji S, Ye L, Rui Z. Comparison of in vitro antioxidant activities and bioactive components of green tea extracts by different extraction methods. Int J Pharm. 2011;408(1-2):97-101. https://doi.org/10.1016/j.ijpharm.2011.02.002

26. Nazliniwaty T, Laila L. Antioxidant activity test of green tea (Camellia sinensis L. kuntze) ethanolic extract using DPPH method. Sci Technol Publ (Indonesia). 2020. http://dx.doi.org/10.5220/0010087307520754

27. Buetler TM, Renard M, Offord EA, Schneider H, Ruegg UT. Green tea extract decreases muscle necrosis in mdx mice and protects against reactive oxygen species. Am J Clin Nutr. 2002;75(4):749-53. https://doi.org/10.1093/ajcn/75.4.749

28. Panza VS, Wazlawik E, Schütz GR, et al. Consumption of green tea favorably affects oxidative stress markers in weight-trained men. Nutrition. 2008;24(5):433-42. https://doi.org/10.1016/j.nut.2008.01.009

29. Sung H, Nah J, Chun S, et al. In vivo antioxidant effect of green tea. Eur J Clin Nutr. 2000;54(7):527-9. https://doi.org/10.1038/sj.ejcn.1600994

30. Santhy KS, Geetha B. Antimutagenic effect of green tea extracts in reverse mutation assay. Int J Pharm Med Biol Sci. 2013;2(1):62-7.

31. Bunkova R, Marova I, Pokorna Z, Lojek A. Analysis of plant extracts antimutagenicity using the Ames test and the cytogenetic analysis of peripheral blood lymphocytes. Food Sci Technol Int. 2005;11(2):107-12. https://doi.org/10.1177/1082013205052764

32. Hsu YW, Tsai CF, Chen WK, Huang CF, Yen CC. A subacute toxicity evaluation of green tea (Camellia sinensis) extract in mice. Food Chem Toxicol. 2011;49(10):2624-30. https://doi.org/10.1016/j.fct.2011.07.007

33. Gupta J, Afzal M. In vivo assessment of possible toxicity risks of green tea extract in mice. Int J Bioassays. 2015;4(2):3636-41.

34. Kahtan M, Hassan AF, Al-Shawi NN, et al. The genoprotective activity of aqueous green tea extract against metronidazole and tinidazole genotoxic effect. Res J Pharm Technol. 2020;13(2):889-94. https://doi.org/10.5958/0974-360X.2020.00168.7

35. Chengelis CP, Kirkpatrick JB, Regan KS, et al. 28-Day oral (gavage) toxicity studies of green tea catechins prepared for beverages in rats. Food Chem Toxicol. 2008;46(3):978-89. https://doi.org/10.1016/j.fct.2007.10.027

36. Shen CL, Chyu MC, Pence BC, et al. Green tea polyphenols supplementation and Tai Chi exercise for postmenopausal osteopenic women: Safety and quality of life report. BMC Complement Altern Med. 2010;10:1. https://doi.org/10.1186/1472-6882-10-76

37. Kim HS, Quon MJ, Kim JA. New insights into the mechanisms of polyphenols beyond antioxidant properties; lessons from the green tea polyphenol, epigallocatechin 3-gallate. Redox Biol. 2014;2:187-95. https://doi.org/10.1016/j.redox.2013.12.022

38. Chi X, Ma X, Li Z, et al. Protective effect of epigallocatechin-3-gallate in hydrogen peroxide-induced oxidative damage in chicken lymphocytes. Oxid Med Cell Longev. 2020;2020:7386239. https://doi.org/10.1155/2020/7386239

39. Yang CS, Chen T, Ho CT. Redox and other biological activities of tea catechins that may affect health: Mechanisms and unresolved issues. J Agric Food Chem. 2022;70(26):7887-99. http://dx.doi.org/10.1021/acs.jafc.2c02527

40. Xu XY, Zhao CN, Li BY, et al. Effects and mechanisms of tea on obesity. Crit Rev Food Sci Nutr. 2023;63(19):3716-33. https://doi.org/10.1080/10408398.2021.1992748

41. Luo Q, Luo L, Zhao J, Wang Y, Luo H. Biological potential and mechanisms of tea's bioactive compounds: An updated review. J Adv Res. 2024;65:345-63. https://doi.org/10.1016/j.jare.2023.12.004