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Research Article

Unlocking the Therapeutic Potential of *Camellia Sinensis*: A Comprehensive Review of Its Pharmacological Effects

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Abstract

Green tea, derived from the *Camellia sinensis* plant known for its retention of natural substances found in fresh leaves, ranks as the world's second most consumed beverage after water, with various pharmacologically active components including tea polyphenols, alkaloids, amino acids, polysaccharides, and volatile compounds, isolated and identified from it. Recent studies have highlighted green tea's versatile pharmacological activities such as antioxidant, anticancer, hypoglycemic, antibacterial, antiviral, and neuroprotective effects, though concerns have been raised regarding the potential toxic effects of green tea extract and its main ingredients, including hepatotoxicity and DNA damage, prompting this paper to provide a systematic and comprehensive review of the photochemistry, pharmacology, and toxicology of green tea, which has been extensively researched and demonstrated numerous health benefits, suggesting its potential in healthcare and disease prevention initiatives despite these concerns.

Keywords: *Camellia sinensis*; Pharmacology; Antimicrobial; Traditional use; Photochemical compounds

Introduction

Tea, with its origins in China, carries a profound history and has spread globally, captivating the palates of an astonishing 3 billion people worldwide. This popularity firmly establishes it as one of the most beloved non-alcoholic beverages [1]. Across different regions, tea undergoes diverse classification methods, resulting in various types. In China specifically, tea is commonly categorized into six main groups based on fermentation levels: green tea, black tea, white tea, yellow tea, Oolong tea, and dark tea [2]. Green tea, the earliest discovered type, is celebrated for its non-fermented nature. It retains a high concentration of natural compounds found in fresh leaves and experiences minimal vitamin loss, giving rise to its distinct profile of 'clear infusion with green leaves and robust flavor melding.' Notably, green tea offers numerous health benefits, attributed to its array of chemical components such as tea polyphenols, caffeine, theanine, and tea polysaccharides. These compounds exhibit pharmacological effects like anticancer [3], antioxidant [4], neuroprotective [5], and blood sugar-reducing properties [6]. Green tea is often recommended for individuals dealing with conditions such as hypertension, hyperlipidemia, coronary heart disease, arteriosclerosis, and diabetes. However, it's crucial to recognize that while "natural" may imply safety, caution is warranted. Though adverse effects from green tea are typically minimal, special care should be taken, particularly among pregnant women, children, and the elderly.

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Tea polyphenols are pivotal in shaping the color, flavor, and potential health benefits of tea [7]. Various factors, including tea type, processing methods, and fermentation level, profoundly affect the concentration of these compounds [8]. In a study by Gao et al. [9] an analysis of 16 common tea varieties highlighted green tea as having the highest levels of tea polyphenols. They suggested green tea as an optimal source for developing functional foods rich in these compounds [9].

Materials and Methods

The data were gathered through searches on PubMed, Google Scholar, and Web of Science, employing keywords such as green tea, chemical composition, pharmacology, tea polyphenols, antioxidant, cancer, diabetes, antibacterial, antiviral, immune T cells, and toxicology. Various related articles and websites were also consulted. Additionally, the references of selected articles were scrutinized for further investigation. Conference reports, case reports, and short communications were excluded, with no time limitation imposed on this review.

Pharmacological Activities and Clinical Trials

Antibacterial effects

The alcohol extract from black tea demonstrated activity when tested against Salmonella typhi and *Salmonella paratyphi* A. It exhibited activity against all strains of Salmonella paratyphi A, while only 42.19% of *Salmonella typhi* strains were inhibited by the extract [10]. The hot water extract from the entire dried plant and its tannin fraction showed activity against *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus Aureus* when tested on agar plates [11].

Anticancer effects

Catechin, when applied to pheochromocytoma cells in a cell culture setting, demonstrated activity. These cells were subjected to incubation with various concentrations of catechin for both short-term (2 days) and long-term (7 days) durations in Dulbecco's modified Eagle medium. The activity of superoxide dismutase was evaluated,

and its mRNA levels were determined using Northern blotting. After 2-day incubation, catechin notably boosted the activity of copper/zinc superoxide dismutase. However, its effects were not significant after 7 days. Conversely, there were notable changes in the activity of magnesium superoxide dismutase observed in both short- and long-term treatment groups. Additionally, corresponding alterations were detected in the mRNA levels [12].

Anticarcinogenic effects

The anticarcinogenic properties of tea phenols have been demonstrated in various studies involving rats and mice with transplantable tumors, carcinogen-induced tumors in the digestive organs, mammary glands, hepatocarcinomas, lung cancers, skin tumors, leukemia, tumor promotion, and metastasis. The mechanisms underlying this effect suggest that tumor inhibition may occur through both extracellular and intracellular mechanisms. These mechanisms include modulation of metabolism, blocking or suppression, modulation of DNA replication and repair, promotion, inhibition of invasion and metastasis, and induction of novel mechanisms [13]. The relationship between green tea consumption and cancer was examined in a study involving 8,552 Japanese women aged 40 or older. Over a 9-year follow-up period, 384 cases of cancer were identified. A negative correlation was found between cancer incidence and green tea intake, particularly among women who consumed more than 10 cups per day. Among lung cancer patients, consumption of two or more cups of tea per day reduced the risk by 95%, with a more pronounced effect observed in Kreyberg I tumors (squamous cell and small cells) and among light smokers [14]. Tea, taken by lung cancer patients at a dose of two or more cups per day, reduced the risk by 95%. The protected effect was more evident among Kreyberg I tumors (squamous cell and small cells) and among light smokers [15]. Topical application of green tea polyphenols, specifically epi-gallocatechin-3-gallate, to human skin prevented the penetration of Ultraviolet (UV) radiation. This was evidenced by the absence of immunostaining for cyclobutane pyrimidine dimers in the reticular dermis. In mice, topical administration inhibited UVB-induced infiltration of CDIIb + cells. Additionally, this treatment led to a reduction in UVB-induced immune regulatory cytokine Interleukin (IL)-10 in the skin and draining lymph nodes, along with an elevated amount of IL-12 in draining lymph nodes [16].

In human umbilical vein endothelial cells, green tea extract did not affect cell viability but significantly reduced cell proliferation in a dose-dependent manner. It also caused a dose-dependent accumulation of cells in the gastrointestinal phase. Furthermore, the extract decreased the expression of vascular endothelial growth factor receptors fms-like tyrosine kinase and fetal liver kinase-I/kinase insert domain containing receptor in cell culture, as detected by immunohistochemical and Western blotting methods [17]. Administration of green and black tea orally to hairless mice without any chemical initiators or promoters resulted in significantly fewer skin papillomas and tumors induced by UVA and UVB light. Black tea provided better protection against UVB-induced tumors than green tea. Additionally, black tea consumption was associated with a reduction in the number of sunburn cells in the epidermis of mice 24 hours after irradiation [18].

In cell culture, epigallocatechin-3-gallate activated proMMP-2 in U-87 glioblastoma cells in the presence of concanavalin A or cytochalasin D, leading to its activation that correlated with the cell surface proteolytic processing of Mt1-MMP to its inactive 43 kDa form. Treatment with non-cytotoxic doses of epigallocatechin-3-gallate reduced the amount of secreted proMMP-2 and increased intracellular levels of that protein [19]. Green tea polyphenols inhibited the photo labeling of P-glycoprotein (P-gp) by 75% and increased the accumulation of rhodamine-123 in the multidrug-resistant cell line CH (R) C5. This indicated an interaction with P-gp and inhibition of its transport activity. The modulation of P-gp was reversible, and epigallocatechin-3-gallate potentiated the cytotoxicity of vinblastine in CH (R) C5 cells. Similar inhibitory effects on P-gp were observed in human Caco-2 cells [20].

Anticataract effects

Tea, when administered to enucleated rat lens cultures, reduced the occurrence of selenite-induced cataracts in live rats. Rat lenses were randomly divided into normal, control, and treated groups, then incubated for 24 hours at 37 degrees Celsius. Oxidative stress was induced by sodium selenite in the culture medium of the control and treated groups (excluding the normal group). The treated group's medium was supplemented with tea extract. After incubation, glutathione and malondialdehyde levels were estimated in the lenses. The activity of superoxide dismutase, catalase, and glutathione peroxidase enzymes was also measured in different experimental sets. In live rats, cataracts were induced in 9-day-old pups from both control and treated groups by a single subcutaneous injection of sodium selenite. Before and for 2 consecutive days after the selenite injection, the treated pups were given intra peritoneal injections of tea extract. Cataract occurrence was examined on the 16th postnatal day using slit lamp examination. The organ culture study demonstrated positive changes in biochemical parameters, suggesting that tea mainly acted by preserving the antioxidant defense system [21].

Antifungal effects

Ethanol (50%) extractor the entire plant, in broth culture at a concentration of 1 mg/mL, was inactive on *Aspergillus fumigatus* and *Trichophyton mentagrophytes* [22].

Antidiarrheal effects

Administering hot water tea extract orally to rats was successful in alleviating diarrhea in all tested models. However, the effectiveness of the extract in treating diarrhea was notably reduced when naloxone (0.5 mg/kg, administered intraperitoneally) and loperamide were introduced [23].

Antihypercholesterolemic effects

Tea enriched with vitamin E, administered to male Syrian hamsters, led to reductions in plasma Low-Density Lipoprotein (LDL) cholesterol levels, LDL oxidation, and early atherosclerosis compared to hamsters consuming tea alone. The antioxidant effect of vitamin E is achieved through its integration into the LDL molecule. Over a period of 10 weeks, the hamsters were fed a semi purified hypercholesterolemia diet containing 12% coconut oil, 3% sunflower oil, and 0.2% cholesterol (control), along with variations of control and 0.625% tea, control and 1.25% tea, or control and 0.044% tocopherol acetate. In comparison to different concentrations of tea alone, hamsters fed the vitamin E-enriched diet showed significantly lower plasma LDL cholesterol levels by 18% ($p<0.007$), 17% ($p<0.02$), and 24% ($p<0.0001$), respectively. Aortic fatty streak areas were reduced in the vitamin E diet group compared to the control (by 36%, $p<0.04$) and low tea (by 45%, $p<0.01$) diets. Additionally, the lag phase of conjugated diene production was extended in the vitamin E diet compared to the control, low tea, and high tea diets by 41% ($p<0.0004$),

40% ($p<0.0004$), and 39% ($p<0.0008$), respectively. Furthermore, the rate of conjugated diene production was decreased in the vitamin E diet group compared to the control, low tea, and high tea diets by 63% ($p<0.002$), 57% ($p<0.005$), and 59% ($p<0.02$) respectively [24].

Anti-inflammatory effect

Epigallocatechin-3-gallate was shown to mimic its anti-inflammatory effects in modulating the IL-I β-induced activation of mitogen activated protein kinase in human chondrocytes. It inhibited the IL-I β-induced phosphorylation of c-Jun N-terminal kinase (JNK) isoforms, accumulation of phosphoc-Jun and DNA-binding activity of AP-1 in osteoarthritis chondrocytes, IL-I β but not epigallocatechin-3-gallate, and induced the expression of JNK p46 without modulating the expression of JNK p54 in osteoarthritis chondrocytes. In immune complex kinase assays, epigallocatechin-3-gallate completely blocked the substrate phosphorylation activity of JNK but not p38-Mitogen Activated Protein Kinase (MAPK). Epigallocatechin-3-gallate had no inhibitory effect on the activation of extracellular signal regulated kinase p44/p42 (ERKp44/p42) or p38-MAPK in chondrocytes.

Epigallocatechin- 3-gallate did not alter the total non phosphorylated levels of either p38- MAPK or ERKp44/p42 in osteoarthritis chondrocytes [25].

Epigallocatechin-3-gallate, when administered to primary human osteoarthritis chondrocytes at a concentration of 100 μM in cell culture, hindered the IL-I β-induced production of nitric oxide by disrupting the activation of Nuclear Factor (NF) kB [26].

When tea was introduced to cultures containing bovine nasal and metacarpophalangeal cartilage, as well as human no diseased osteoarthritis and rheumatoid cartilage, with or without agents known to accelerate cartilage matrix breakdown, it exhibited a chondroprotective effect. This effect could potentially benefit arthritis patients by reducing inflammation and slowing down cartilage breakdown. In these cultures, individual catechins were added, and the amount of released proteoglycan and type II collagen were measured using met achromatic assay and inhibition Enzyme-Linked Immunosorbent Assay (ELISA), respectively. The potential nonspecific or toxic effects of the catechins were evaluated through lactate output and proteoglycan synthesis. Catechins, especially those containing a gallate ester, were found to be effective at micro molar concentrations in inhibiting the breakdown of proteoglycan and type II collagen [27].

Antimutagenic effects

The cancer-fighting properties of tea phenols have been shown in various animal models, including rats and mice with transplantable tumors and tumors induced by carcinogens in different organs such as the digestive system, mammary glands, liver, lungs, skin, and blood. These studies indicate that the inhibition of tumors may result from a combination of extracellular and intracellular mechanisms. These mechanisms include the modulation of metabolism, blocking or suppression of tumor growth, regulation of DNA replication and repair processes, promotion of cell death in cancer cells, inhibition of cancer cell invasion and spread, and the induction of new mechanisms to combat cancer [28].

Green and black teas, when ingested orally by adult humans, exhibited effectiveness. Within 60 to 180 minutes post-administration, the active antimutagenic compounds were retrieved from the jejunal compartment through dialysis. The dialysate demonstrated an ability to hinder the mutagenicity of the food-based mutagen 2-amino-3,8-dimethylimidazo [4,5-f] quinoxaline on *Salmonella typhimurium*. The highest inhibition was observed at the 2-hour mark post-administration and was similar for both black and green teas. However, the maximum inhibition observed with black tea was diminished by 22%, 42%, and 78% in the presence of whole milk, semi-skimmed milk, and skimmed milk, respectively. Whole milk and skimmed milk almost entirely negated the antimutagenic activity of green tea, with a reduction of more than 90%, while semi-skimmed milk reduced it by more than 60%. The consumption of a homogenized breakfast alongside black tea nullified its antimutagenic activity. When both tea and the mutagen 2-amino-3,8-dimethylimidazo [4,5-f] quinoxaline were introduced into the system, the mutagenicity of the latter was effectively inhibited, with green tea exhibiting slightly stronger antimutagenic activity than black tea. The addition of milk had only a minor inhibitory effect on the antimutagenicity. The antimutagenic activity was correlated with a reduction in antioxidant capacity and a decrease in the concentration of catechin, epigallocatechin gallate, and epigallocatechin [29].

Chinese white tea, when tested on rat liver S9 in an assay for methoxyresorufin O-demethylase, suppressed the activity of methoxyresorufin O-demethylase and mitigated the mutagenic effects of 3-methylimidazo [4,5-f] quinoline (IQ) in the absence of S9. A mixture of nine major constituents found in green and white teas was combined to create artificial teas, following their relative levels in white and green teas. The complete tea demonstrated greater antimutagenic potency compared to the corresponding artificial tea. Additionally, polyphenols from green and black teas, when applied to the surfaces of ground beef before cooking, inhibited the formation of mutagens in a dose-dependent manner [30]. Green or black tea polyphenols significantly reduced the mutagenicity of various aryl- and heterocyclic amines, aflatoxin B1, benzo [a] pyrene, 1,2-dibromoethane, and, more selectively, 2-nitropropane, all of which involved an induced rat liver S9 fraction. Effective inhibition was observed with two nitrosamines that required a hamster S9 fraction for biochemical activation. However, no effect was observed with 1-nitropyrene and with the direct-acting compound 2-chloro-4-methyl-thiobutanoic acid in the absence of S9 [31].

Anti-neoplastic effects

Green tea, administered orally at a dose of 6 grams per day in six divided doses, to 42 patients who were asymptomatic but had exhibited progressive elevation of Prostate-Specific Antigen (PSA) levels despite hormone therapy, showed limited antineoplastic activity. Patients were allowed to continue the use of luteinizing hormone-releasing hormone agonists. However, those who had undergone other treatments for their condition within the previous 4 weeks or received long-acting antiandrogen therapy within the previous 6 weeks were excluded from the study. Patients were monitored monthly for both response to treatment and any adverse effects. A tumor response, defined as a decrease of 50% or more in the baseline PSA value, was observed in only one patient, representing 2% of the total cohort (with a 95% confidence interval of 1% to 14%). However, this response was not sustained beyond 2 months. At the end of the first month, the median change in the PSA value from baseline for the entire cohort increased by 43% [32].

Antioxidative effects

When administered orally to rats, tea resulted in decreased levels of Thiobarbituric Acid Reactive Substances (TBARS) in urine and

reduced levels of esterified and total cholesterol in plasma compared to a control group. However, the levels of TBARS in the liver and plasma, as well as cholesterol levels in the liver remained unaffected. The decrease in plasma cholesterol concentration could not be explained by an increase in fecal excretion of cholesterol or bile acids. Instead, it was hypothesized that the lower plasma cholesterol levels were linked to significantly higher acetate concentrations in the cecum, colon, and portal blood of the rats. Additionally, copper absorption was found to be significantly increased, while iron absorption remained unaffected [33].

Epigallocatechin gallate, tea polyphenols, and tea extract were introduced into human plasma along with a water-soluble radical generator called 2,2'-azobis (2-amidinopropane) dihydrochloride to induce lipid per oxidation. After a period of delay, lipid peroxidation began, but at a reduced rate that correlated with the dosage of polyphenols. Similarly, when epigallocatechin gallate and the extract were added to the plasma, they significantly inhibited the lipid per oxidation induced by 2,2'-azobis(2-amidinopropane dihydrochloride). The delay observed before measurable lipid per oxidation was due to the antioxidant properties of naturally occurring ascorbate, which was more effective at preventing lipid per oxidation compared to tea polyphenols and was unaffected by their presence. However, when eight volunteers consumed the equivalent of six cups of tea, their plasma did not exhibit increased resistance to lipid per oxidation over a 3-hour period [34].

Black tea leaves, when administered to human red blood cells, demonstrated effectiveness in mitigating oxidative stress induced by various triggers such as phenyl hydrazine, Cu2+-ascorbic acid, and xanthine/xanthine oxidase systems. The extract from black tea fully prevented lipid per oxidation in both the pure erythrocyte membrane and the entire red blood cell. Additionally, it provided complete protection against the degradation of membrane proteins. Studies on membrane fluidity, monitored using the fluorescent probe 1,6-diphenyl-hexa-1,3,5-triene, revealed significant disorganization that could be restored to normalcy upon the addition of black tea or free catechins. In comparison to free catechins, the tea extract appeared to be a superior protective agent against various forms of oxidative stress [35].

An ethanol/water (7:3) extract of green tea, when evaluated using 2,2-azino-di-3-ethylbenzthiazoline sulphonate, exhibited antioxidant activity comparable to that of ascorbic acid (10 mmol/L) [36]. The nonpolyphenolic fraction derived from residual green tea (post hot water extraction) demonstrated notable inhibition of hydro peroxide generation from oxidized linoleic acid in a manner dependent on dosage. Through the use of silica gel TLC plates, chlorophylls a and b, pheophytins a and b, β-carotene, and lutein were isolated. Each of these components exhibited significant antioxidant properties, with the order of suppressive activity against hydro peroxide generation being chlorophyll a >lutein>pheophytin a>chlorophyll b>β-carotene>pheophytin b [37].

Antiproliferative effects

When tested on human stomach cancer (MK-1) cells, green tea fractions revealed the presence of six active flavan-3-ols: epicatechin, epigallocatechin, epigallocatechin gallate, gallocatechin, epicatechin gallate, and gallocatechin gallate. Among these, epigallocatechin gallate and gallocatechin gallate exhibited the highest activity. Following them in decreasing order of activity were epigallocatechin, gallocatechin, and epicatechin gallate, with epicatechin displaying the lowest activity. This indicates that the presence of three adjacent hydroxyl groups (pyrogallol or galloyl group) in the molecule could be a critical factor in enhancing its activity [38].

Antispasmodic effects

The hot water extract and tannin fraction derived from the dried whole plant exhibited activity against spasms induced by pilocarpine and contractions induced by barium in the intestines of rabbits and rats [39].

Anti-yeast effects

Tea, taken by men and women age 30 to 70 years at a dose of 480.0 mL per day, produced a positive dose–response effect [40].

Cytochrome P50 expression

Fresh leaves from green, black, and decaffeinated black tea demonstrated an enhancement in lauric acid hydroxylation. However, decaffeinated black tea did not show a significant effect. Both green tea and black tea, but not decaffeinated black tea, stimulated the O-dealkylation of methoxy-, ethoxy-, and pentoxy-resorufin, indicating an up regulation of Cytochrome P450 (CYP) 1A and CYP2B. Immunoblot analysis revealed that green tea and black tea, but not decaffeinated black tea, increased the levels of hepatic CYP1A2 apoprotein. Hepatic microsomes from rats treated with green tea and black tea, but not those from decaffeinated black tea-treated rats, were more efficient than control microsomes in converting IQ into mutagenic species in the Ames test [40].

Dental enamel erosion

Herbal tea and traditional black tea, when tested on teeth, led to the erosion of dental enamel. Following tea exposure, sequential profilometric tracings of the specimens were captured overlaid, and the extent of enamel loss was determined by calculating the area of disparity between the tracings before and after exposure. The tooth surface loss caused by herbal tea (mean 0.05 mm^2) was notably higher compared to that caused by conventional black tea (0.01 mm^2) and water (0.00 mm^2) [41].

Tannin, catechin, caffeine, and tocopherol, when tested in vitro on tooth enamel, exhibited the ability to enhance the acid resistance of tooth enamel. These effects were significantly amplified when these components were combined with fluoride. A blend of tannic acid and fluoride displayed the most pronounced inhibitory effect (98%) on calcium release into an acidic solution. When tannin was combined with fluoride, it suppressed the formation of artificial enamel lesions compared to Acidulated Phosphate Fluoride (APF), as evidenced by electron probe microanalysis, polarized-light microscopy, and Vickers micro hardness measurement [42].

DNA effects

In cell culture, treatment with green tea extract at a dosage of 10 mg/L, equivalent to 15 mmol/L EGCg, for 24 hours did not confer protection to Jurkat cells against H_2O_2-induced DNA damage. The extent of DNA damage, as assessed by the Comet assay, increased in a dose-dependent manner. However, it plateaued at 75 mmol/L of H_2O_2 without any discernible protective effect from the extract. The DNA repair process, which concluded within 2 hours, remained unaffected by supplementation [43].

Fluoride retention

In cell culture, exposing Jurkat cells to green tea extract at a

concentration of 10 mg/L, corresponding to 15 mmol/L EGC g, for 24 hours did not provide protection against DNA damage induced by H_2O_2. The level of DNA damage, determined through the Comet assay, rose proportionally with increasing H_2O_2 concentration. However, it reached a plateau at 75 mmol/L of H_2O_2, with no evident protective impact from the extract. Furthermore, supplementation did not influence the DNA repair process, which was completed within 2 hours [44].

Gastrointestinal effects

When given to rats that had been fasted for three days, green tea restored the mucosal and villous atrophy induced by fasting to normal levels. However, black tea consumption did not yield any effect. Prior ingestion of black tea, green tea, and vitamin E before fasting protected the intestinal mucosa from atrophy [45].

The melanin extracted from tea leaves was characterized, revealing its similarity to standard melanin. Langmuir adsorption isotherms were employed to study Gadolinium (Gd) binding using melanin. The melanin-Gd preparation showed low acute toxicity, with an LD50 in the range of 1.25-1.50 g/kg in mice. Magnetic Resonance Imaging (MRI) properties of both melanin itself and melanin-Gd complexes were evaluated. Gadolinium-free melanin fractions exhibited slightly lower relaxivity compared to its complexes. The relaxivity of the lower molecular weight fraction was twice as high as that of Gd (DTPA) standard. Post-contrast images revealed that oral administration of melanin complexes at a concentration of 0.1 mm significantly enhanced longitudinal relaxation times (T1)-weighted spin echo images, providing uniform enhancement of MRI with the proposed melanin complex for contrast and delineation of the stomach wall [46].

Hypocholesterolemic effects

In human HepG2 cell culture, green tea increased both the activity and protein levels of LDL receptors. The ethyl acetate extract, containing 70% (w/w) catechins, similarly elevated LDL receptor activity, protein, and mRNA levels, indicating an effect at the receptor level of gene transcription, with catechins being the active components. The mechanism underlying green tea's up regulation of LDL receptors was investigated. Green tea reduced cellular cholesterol concentration by 30% and promoted the conversion of the Sterol-Regulated Element Binding Protein (SREBP-1) from its inactive precursor form to the active transcription-factor form. In line with this, mRNA levels of 3-hydroxy-3-methylglutaryl coenzyme-A reductase, the rate-limiting enzyme in cholesterol synthesis, were also increased by green tea [47].

Immunomodulatory effects

To assess the impact of tea on immune function related to transplantation, in vitro tests were conducted, including lymphocyte proliferation assays using phytohemagglutinin, mixed lymphocyte culture assays, and measurement of IL-2 and IL-10 production from mixed lymphocyte proliferation. Tea exhibited immunosuppressive effects, reducing all responsiveness in the culture. The immunosuppressive action of tea was attributed to a decrease in IL-2 production [48].

In cell culture experiments, tea was found to increase neopterin production in un stimulated peripheral mononuclear cells. Conversely, it effectively reduced neopterin formation in cells stimulated with concanavalin A, phytohemagglutinin, or Interferon (IFN)-γ [49].

Theaflavins exerted potent suppression on IL-2 secretion, IL-2 gene expression, and NF-κB activation in murine spleens enriched for CD4(+) T-cells. Additionally, theaflavins inhibited the induction of IFN-γ mRNA. Surprisingly, the expression of T(H_2) cytokines IL-4 and IL-5, which do not contain functional NF-κB sites within their promoters, was also suppressed by theaflavins [50].

Radical scavenging effects

When assessed with the 1,1-diphenyl-2-picrylhydrazyl radical, green tea displayed stronger activity associated with the galloyl moiety. The contribution of the pyrogallol moiety in the B-ring to the scavenging activity appeared to be less significant compared to that of the galloyl moiety [51].

Conclusion

This paper presents a comprehensive review of the pharmacological properties of *C. sinensis*. Chemical constituents such as catechin, caffeine, theanine, and tea polysaccharides found in *C. sinensis* exhibit various pharmacological activities and health benefits, including antioxidant, anti-tumor, and hypoglycemic effects. Tea polyphenols, acting as natural antioxidants, find extensive applications in the food and cosmetics industries. Furthermore, catechins in green tea are pivotal in preventing and treating conditions like diabetes, hepatitis, infections, cancer, and skin inflammation. However, understanding the mechanisms of action of active ingredients in green tea and translating research findings into clinical applications remain significant challenges for researchers. There is a dearth of toxicological studies on green tea, with limited reports primarily focusing on hepatotoxicity and cytotoxicity. Consequently, toxicity studies represent a promising area for future research endeavors.

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