

Health Benefits of Green Tea and its Polyphenols: A Review

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Abstract

Tea is one of the most widely consumed beverages worldwide next only to water for enjoyment and health, and is available in various forms. Amongst all types of tea, Green tea is a popular drink, especially in Asian countries, although its popularity continues to spread across the globe. Various studies have been conducted since many years to understand the health benefits of Green tea which is derived from the leaves of the *Camellia sinensis* plant. Green tea is composed of polyphenols, caffeine, minerals, and trace amounts of vitamins, amino acids, and carbohydrates. Green tea contains more catechins, than black tea. There are four main catechins (polyphenols) found in Green tea: (-)-epicatechin (EC), (-)-epicatechin-3-gallate (ECG), (-)-epigallocatechin (EGC) and (-)-epigallocatechin-3-gallate (EGCG). All of them are known to boost the immunity in humans. Amongst these ECG, EGC, and EGCG have been shown to have antimicrobial action against a variety of microbes. Catechins are *in vitro* and *in vivo* strong antioxidants. In addition, the minerals and vitamins increase the antioxidant potential of this type of tea. Since ancient times, the traditional Chinese medicine has considered Green tea as a healthy beverage. It is known that the polyphenols present in Green tea stimulate the central nervous system and maintain overall health in humans. Much research is available depicting the health benefits of Green tea for a wide variety of implications, including different types of disorders. The current paper reviews such health benefits with a focus on its polyphenols.

Keywords: Green tea, polyphenols, catechins, immunomodulatory, antioxidant.

Introduction

Tea, which is prepared from leaves and buds of the plant *Camellia sinensis*, is the most popular drink ranking second among the most consumed beverages in the world such as coffee, beer, wine and carbonated soft drinks. Tea had its origin in China and has gained the popularity as world's finest taste drink in the past 2000 years. Records relate to the first century CE, with stories of the Buddhist monks Bodhidharma and Gan Lu, and their involvement with tea. [1] Bodhidharma gave the art of drinking tea to the world as a gift to be used along with one's meditation practice to help with focus. The tea prepared from the

leaves of *Camellia sinensis* would provide a stimulant to help keep students of Chan remain awake during Zazen, a meditative discipline that is typically the primary practice of the Zen Buddhist tradition. [2] In a recent research it has been observed that tea is indigenous to eastern and northern India, and was cultivated and consumed there for thousands of years. India stands as the second largest producer of tea in the world after China and makes up to 23-26% of the global tea production which includes the famous Assam tea and Darjeeling tea. Tea has been given the status of 'State Drink' of Assam state in India. [3] Around 80% of the total tea produced in India is consumed by the domestic population. The Tea Board of India conducted a study on consumption of tea in India in 2007. The key findings from the survey suggests that the tea consumption in India is skewed towards the northern and west-

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ern parts of the country with the contribution from the northern states accounting for about 32%, while that from the western region accounting for about 31%. The relatively low consumption belts of the East (including Northeast) accounts for about 19% while the southern states contributes towards 18% of the total domestic consumption of tea. Milk tea with sugar is the most popular choice with more than 80% of the households preferring the same. Recently, the consumption of non-milk tea without sugar is on the rising trend and is driven majorly by the increasing emergence of lifestyle-related disorders and increasing popularity of variants such as Green tea. Various formulations and variants of green tea are available in market including tea bags, extract, and powder and even in the form of capsules for human consumption.

The practice of Ayurveda in India has resulted in a long-standing tradition of herbal teas. Following our traditions, Indians have long utilised the medicinal benefits of various plants and spices such as Tulsi (holy basil), Elaichi (cardamom), Kali Mirch (pepper), Mulethi (liquorice), Pudina (mint), etc., and teas made with these plant leaves or spices have been in use for centuries.^[4] Tea is also mixed with these traditional herbs. The stronger and bitterer flavours of some of the medicinal additives is disguised with the sweet and milky taste of tea, while pleasant flavours such as cardamom, clove and ginger add a soothing flavour and aroma to the tea along with its health benefits.

Green tea is mainly produced from *Camellia sinensis* var. *Sinensis* by light steaming of freshly cut tea leaves. The Assam type (*Camellia sinensis* var. *assamica*) has a too high content of polyphenols, which would make Green tea taste excessively bitter.^[5] The production of Green tea is characterized by an initial heating process, which kills the enzyme polyphenol oxidase, which is responsible for the conversion of the flavanols in the leaf into the dark polyphenolic compounds that colour black tea. The other important process is rolling, in which leaves are cut and twisted. Depending upon the specific variants being used, the final form of Green tea is thus prepared.

Green Tea Composition

Green tea contains various nutrients, antioxidants and alkaloids, which have positive effects on overall health. There are many vitamins in green tea including vitamin A, vitamin D, vitamin B and vitamin C along with mineral like Manganese, Zinc and Chromium. Polyphenols are the most important clusters of Green tea leaf components, and as a result, Green tea is con-

sidered as an important dietary source of polyphenols, including various flavonoids. Flavonoids are phenol derivatives which are synthesized in certain amounts (0.5–1.5%) and are widely distributed among plants.^[6] The main flavonoids present in Green tea include catechins along with gallic acid and other phenolic acids such as chlorogenic acid and caffeic acid, and flavonols such as kaempferol, myricetin, quercetin along with essential oils.^[7] The four major catechins are (-)-epigallocatechin-3-gallate (EGCG) that represents approximately 59% of the total of catechins; (-)-epigallocatechin (EGC) (19% approximately); (-)-epicatechin-3-gallate (ECG) (13.6% approximately); and (-)-epicatechin (EC) (6.4% approximately).^[8]

Green Tea and Human Health

Green tea has been given the status of medicine and a healthful beverage since ancient times. The traditional Chinese medicine recommends use of *Camellia sinensis* for headaches, body pain, digestion complaints, depression, detoxification, as an energizer and, in general, to prolong the lifespan. Green tea leaves contain certain components which have its action on human health: xanthic bases (caffeine and theophylline), essential oils and particularly, polyphenols. Caffeine acts mainly upon the central nervous system, stimulating wakefulness, facilitating ideas association and decreasing the sensation of fatigue.^[9] Some of the effects caused by caffeine are influenced by theophylline tea content. Theophylline induces psychoactive activity, it also has a slightly inotrope and vasodilator effect, and a much higher diuretic effect than caffeine. Theophylline causes a non-specific relaxation on the bronchial smooth muscle, and respiratory stimulation is also observed. Essential oils are in a great extent volatile and they evaporate from the beverage after some time, thus it is not very convenient to overextend the brewing time. Among their properties, the one of facilitating digestion must be highlighted.^[10]

Immune Modulating Activity

The elimination of toxins and resistance to disease are functions of the immune system that are split into 2 divisions, which are the 'innate' (natural) and 'acquired' (termed specific or adaptive) immune system. Innate immunity is the first line of defence and it deals with preventing entry of infectious agents into the body and with the rapid elimination of these agents if they do enter. Acquired immunity is involved in the generation of memory of the invading pathogens upon a second encounter, therefore enabling the body to initiate an appropriate and generate a quicker immune response. The inflammatory process plays a key role in

innate and acquired immune function. Recent studies suggest that EGCG can vary the strength of both the innate and adaptive defensive abilities of the immune system.^[11] Green tea polyphenol epigallocatechin gallate has been shown to inhibit cyclooxygenase-2 and nitric oxide synthase expression by blocking excessive nuclear factor- κ B activation.^[12] A marked reduction in inflammatory mediators such as interferon- γ and tumor necrosis factor- α in the arthritic joints of Green tea-fed mice was observed.^[13] EGCG's anti-inflammatory property is mainly drawn from its inhibitory effect on production of proinflammatory molecules in a variety of monocytes/macrophages cell types and can also act as a modulator of Retinoic Acid-inducible Gene I (RIG-I) mediated immune responses.^[14] In an animal study, where mice were fed 1% EGCG diet produced more levels of TNF- α , IL-6, IL-1 β , and PGE2 in their splenocytes and macrophages as well as an elevated proportion of macrophages in spleen.^[15] In a murine model of cyclophosphamide induced immunosuppression, it was observed that Green tea has an immunostimulatory effect.^[16]

Antioxidant Activity

Green tea is considered a dietary source of antioxidant nutrients: Green tea is rich in polyphenols (catechins and gallic acid, particularly), but it also contains carotenoids, tocopherols, ascorbic acid (vitamin C), minerals and certain phytochemical compounds. These compounds increase the GTP antioxidant potential. Green tea Polyphenols (GTP) presents antioxidant activity *in vitro* by scavenging reactive oxygen and nitrogen species and chelating redoxactive transition metal ions. The antioxidant capacity of the Green tea polyphenols plays an important role in the anti-inflammatory actions. The early evidence of antioxidant properties of EGCG came from the experimental data that showed EGCG induced inhibition of soybean lipoxygenase (IC₅₀ = 10–20 μ mol L⁻¹). It has been reported that EGCG inhibits the TPA-induced oxidative DNA base modification in HeLa cells, inhibits Cu²⁺ mediated oxidation of low-density lipoprotein (LDL), reduced tert-butyl hydroperoxide-induced lipid peroxidation and also blocks the production of reactive oxygen species derived from NADPH-cytochrome P450-mediated oxidation of the cooked meat carcinogen, 2-amino-3-methylimidazo[4,5-f] quinoline. While using the oxygen radical absorbance capacity, Green tea has been found to have a greater antioxidant activity than brussel sprouts, garlic, kale and leafy vegetables like spinach.^[17] Green tea could be relevant for management of iron overload and oxidative stress. In an *in vitro* study, it was observed that EGCG can inhibit pro-inflammatory interleukin 8 (IL-8). Green tea also helps to reduce inflammation associated with Crohn's disease and ulcerative colitis.^[18]

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Cognition

Recent studies suggested that GTPs might protect against Parkinson's and Alzheimer's diseases and other neurodegenerative diseases.^[19] Studies have demonstrated GTP neuroprotectant activity in cell cultures and animal models, such as the prevention of neurotoxin-induced cell injury.^[20] A study in Japan showed that elderly Japanese people who consumed more than two cups of Green tea a day had a 50% lower chance of having cognitive impairment, in comparison to those who drank fewer than two cups a day or who consumed other tested beverages.^[21]

Antimutagenic and Anticarcinogenic Potential

Lifestyle-related diseases, including cancer, are also characterized as aging-related diseases, where aging may be the most potent causal factor. Therefore, prevention of lifestyle-related diseases will depend on slowing the aging process and avoiding the clinical appearance the disease. The role of Green tea in protection against cancer has been supported by ample evidence from studies in cell culture and animal models.^[22] Various animal studies have shown that Green tea inhibit carcinogenesis of the skin, lung, oral cavity, esophagus, stomach, liver, kidney, prostate and other organs.^[23]

Anti-Hypertensive Effect and Cardiovascular Disease Risk

Green tea has long been believed to possess hypotensive effects in popular Chinese medicine. Various human clinical studies indicate that the antioxidant properties of Green tea may help prevent atherosclerosis and particularly coronary artery disease. According to a Japanese research, Green tea reduces the levels of LDL cholesterol, thereby reducing the risk of coronary heart disease. Studies have found that regular consumption of tea protects against heart disease, with a study documenting that the risk was 36% lower for regular tea drinkers.^[24]

Oral Health

Oral diseases including dental caries, periodontal disease, and tooth loss may significantly impact a person's overall health. Earlier reports in experimental animals and humans suggested that Green tea consumption (without added sugar) reduces dental caries.^[25, 26] Linke and LeGeros indicated that frequent intake of Green tea can significantly decrease caries formation, even in the presence of sugars in the diet.^[27]

Body Weight Control

Obesity has increased at an alarming rate in recent years and is now a worldwide health problem. The effects of long-term feeding with tea catechins have been widely studied, and some investigators suggest a potential role of Green tea in body weight control. An inverse relationship exists among regular Green tea consumption, body fat percentage, and body fat distribution, especially for subjects who have maintained the habit of tea consumption for more than 10 years. [28]

Glucose Tolerance and Insulin Sensitivity

Epidemiological observations and laboratory studies have shown that Green tea has an effect on glucose tolerance and insulin sensitivity. Authors have reported that Green tea increases insulin activity. GTP significantly increases basal and insulin-stimulated glucose uptake of adipocytes. Various investigations have shown that EGCG does not only regulate the glucose level in blood, but also may rehabilitate damaged beta-cells, which are responsible for producing insulin. [8]

Green Tea for Skin Treatment

Polyphenols in the Green tea have been shown to modulate the biochemical pathways involved in inflammatory responses, cell proliferation and responses of chemical tumour promoters as well as ultraviolet light-induced inflammatory markers of skin inflammation. [29]

Side Effects of Green Tea

Hepatotoxicity is identified as the critical effect associated with consumption of green tea and its preparations. A recent systematic review of published toxicology and human intervention studies by Jiang Hu *et al* has shown that there are no toxic effects when green tea is consumed as brewed tea or extracts in beverages or as part of food supplement. [30]

Certain effects of tea over consumption (green or black) are due to three main factors: (1) its caffeine content, (2) aluminium presence, and (3) the effects of tea polyphenols on iron bioavailability.

The side effect reported from drinking Green tea is 'insomnia' due to the fact that it contains caffeine. However, Green tea contains less caffeine than coffee. There are, 30–60 mg of caffeine in 6–8 ounces of tea, compared to over 100 mg in 8 ounces of coffee. Regarding aluminium presence in green and black tea, some studies revealed the high capacity of this plant to accumulate aluminium. This aspect is important for patients with renal failures because aluminium can be accumulated by the body, resulting in neurological diseases. Green tea catechins may have an affinity for iron, and Green tea infusions can cause a signif-

icant decrease of the iron bioavailability from the diet. [28] Hence it is also important to draw attention on the need of further-in-depth studies on the nature and mechanisms of the active Green tea compounds, on the bioavailability of the different catechins in humans, and appropriate dose levels to act as functional food.

Recommended Dietary Intake

The average daily intake of catechins like EGCG resulting from the consumption of traditional green tea infusions ranges between 90 and 300 mg. European Food Safety Authority (EFSA) has assessed the safety of green tea catechins from dietary sources. EFSA has concluded that catechins especially EGCG from green tea infusions and similar drinks are generally safe up to levels of 800 mg/day. Experts considered catechins from green tea infusions brewed with hot water, and instant and ready-to-drink green tea beverages with similar catechin content, as generally safe. [31]

A safe intake level of 338 mg EGCG/day for adults was derived from toxicological and human safety data for tea preparations ingested orally. An Observed Safe Level of 704 mg EGCG/day is thought to be considered for tea preparations in beverage form based on the analysis of the human studies data. [30]

Conclusion

Green tea is consumed throughout the world in various forms. The years of safe consumption of this beverage, supported by numerous studies showing health benefits, warrant a general recommendation to consume it regularly. Based on the review of literature, the following health benefits of Green tea are prominently observed viz. Immunomodulatory, anti-cancer, anti-diabetic, improving cardiovascular health, aids in weight loss, reduces the risk of stroke, enhances brain's cognitive functions, lowers risk of alzheimer & dementia reduces stress and fatigue and improving arthritis by reducing inflammation.

Definitive conclusions concerning the protective effect of Green tea have to come from well-designed observational epidemiological studies and intervention trials. The development of biomarkers for Green tea consumption, as well as molecular markers for its biological effects, will facilitate future research in this area. Formulation based on these standardised biomarkers within the Green tea will help in assimilating the maximum health benefits shown *vide supra*. In the current time of pandemic the immune boosting property of Green tea phenols can be given consideration. Population and/or observation based studies have supported these facts further. Hence, formulation with

standardisation of the Green tea polyphenols with respect to the immunomodulatory activity can be an ideal choice of immune booster.

References

- James Norwood Pratt. Tea Dictionary. *Tea Society Press* 2010.
- Watts, Alan W. 1962. The Way of Zen, Great Britain: *Pelican books*. p. 106
- Reporter BS. Assam cabinet's nod to tea as 'state drink' of Assam. *Business Standard India*. 2012 October 17. Retrieved 2019-02-12.
- Waleja, Sonam Gopichand (2018-09-28). "Tea & its benefits". *Medium*. Retrieved 2020-08-03.
- Willson KC: Coffee, Cocoa and Tea. New York: *CABI Publishing*; 1999.
- Vison J, Dabbagh Y, Serry M, Jang J. Plant flavonoids, especially tea flavonols, are powerful using an in vitro oxidation model for heart disease. 1995. *J Agric Food Chem* 43:2800–2802.
- USDA: "USDA Database for the Flavonoid Contents of Selected Foods." *Beltsville: US Department of Agriculture*, 2003.
- McKay DL, Blumberg JB. The role of tea in human health: An update. 2002. *J Am Coll Nutr* 21:1–13.
- Varnam AH, Sutherland JP. Beverages: Technology, Chemistry and Microbiology. London: *Chapman & Hall*; 1994. p. 126-190.
- Bruneton J. Pharmacognosie. *Phytochimie. Plantes Me'dicinales*. Paris. *Technique et Documentation-Lavoisier*; 2001.
- Min SY, Yan M, Kim SB, Ravikumar S, Kwon SR, Vanarsa K, et al. Green tea epigallocatechin-3-gallate suppresses autoimmune arthritis through indoleamine-2, 3-Dioxygenase expressing dendritic cells and the nuclear factor, erythroid 2-Like 2 antioxidant pathway. 2015. *Journal of Inflammation*, 12(1):53.
- Surh YJ, Chun KS, Cha HH, Han SS, Keum YS, Park KK, et al. Molecular mechanisms underlying chemopreventive activities of anti-inflammatory phytochemicals: down-regulation of COX-2 and iNOS through suppression of NF-kappa B activation. 2001. *Mutat Res*;480-81:243-68.
- Haqqi TM, Anthony DD, Gupta S. Prevention of collagen-induced arthritis in mice by a polyphenolic fraction from Green tea. 1999. *Proc Natl Acad Sci U S A*;96:4524-9
- Ranjith-Kumar CT, Lai Y, Sarisky RT, Cheng Kao C. Green tea Catechin, Epigallocatechin Gallate, Suppresses Signaling by the dsRNA Innate Immune Receptor RIG-I. 2001. *PLoS ONE* 5(9): e12878.
- Pae M, Ren Z, Meydani M, Shang F, Smith D, Meydani SN, et al. Dietary supplementation with high dose of epigallocatechin-3-gallate promotes inflammatory response in mice. 2012. *J Nutr Biochem*. 23:526–31.
- Haque MR, Ansari SH. Immunostimulatory effect of standardised alcoholic extract of Green tea (*Camellia sinensis* L.) against cyclophosphamide-induced immunosuppression in murine model. 2014. *Int J Green Pharm*;8:52-7.
- Cao G, Sofic E, Prior RL. Antioxidant capacity of tea and common vegetables. 1996. *J Agric Food Chem*;44:3426–31.
- Dryden G, Song M, McClain C. Polyphenols and gastrointestinal diseases. 2006. *Curr Opin Gastroenterol*;22:165–70.
- Weinreb O, Mandel S, Amit T, Youdim MBH: Neurological mechanisms of Green tea polyphenols in Alzheimer's and Parkinson's diseases. *J Nutr Biochem* 2004, 15:506-516.
- Pan TH, Jankovic J, Le WD: Potential therapeutic properties of Green tea polyphenols in Parkinson's disease. *Drugs Aging* 2003, 20:711-721
- Juneja LR, Chu DC, Okubo T, Nagato Y, Yokogoshi H. L-Theanine a unique amino acid of Green tea and its relaxation effect in humans. *Trends Food Sci Technol* 1999;10:199–204.
- Chung FL, Schwartz J, Herzog CR, Yang YM. Tea and cancer prevention: Studies in animals and humans. 2003; *J Nutr* 133:3268–3274.
- Cabrera C, Artacho R, Giménez R. Beneficial effects of Green tea—a review. 2006. *J Am Coll Nutr*;25(2):79-99.
- Hirano-Ohmori R, Takahashi R, Momiyama Y. Green tea consumption and serum malondialdehyde modified LDL concentrations in healthy subjects. 2005. *J Am Coll Nutr*;24:342–6.
- Elvin-Lewis M, Vitale MK, Opjas T. Anticariogenic potential of commercial teas. 1980. *J Prosther Dent* 6:273–276.
- Mitscher LA, Jung M, Shankel D. Chemoprotection: a review of the potential therapeutic antioxidant properties of Green tea (*Camellia sinensis*) and certain of its constituents. 1997. *Med Res Rev* 17:327–332.
- Linke HAB and LeGeros RZ. Black tea extract and dental caries formation in hamsters. 2003. *Int J Food Sci Nutr* 54:89–95.
- Wu CH, Lu FH, Chang CS, Chang TC, Wang RH, Chang CJ. Relationship among habitual tea consumption, percent body fat, and body fat distribution. 2003. *Obes Res* 11:1088–1095.
- Sinjia VR, and Mishra HN. Green tea: Health benefits. 2008. *Journal of Nutritional & Environmental Medicine*. 17(4):232–242
- Hu J, Webster D, Cao J, Shao A. The safety of green tea and green tea extract consumption in adults – Results of a systematic review. 2018. *Regulatory Toxicology and Pharmacology*. (95):412-433.
- EFSA ANS Panel. Scientific opinion on the safety of green tea catechins. *EFSA Journal* 2018;16(4):5239-89.

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