Green tea: Health benefits

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REVIEW

Green tea: Health benefits

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Abstract
The plant *Camellia sinensis* yields a variety of white, green and black tea. Tea is one of the most widely consumed beverages in the world, next only to water for enjoyment and health. In general, green tea has been found to be superior to black tea in terms of health benefits. The major components of interest are the polyphenols which are responsible for the antioxidant and other health benefits of green tea. The major polyphenols in green tea are flavonoids. The four major flavonoids in green tea are the catechins, epicatechin (EC), epigallocatechin (EGC), epicatechin gallate (ECG) and epigallocatechin gallate (EGCG). Epigallocatechin gallate is viewed as the most significant active component. The processes used in the manufacture of black tea are known to decrease levels of the monometric catechins to a much greater extent than the less severe conditions applied to other teas. Much research is available depicting the health benefits of green tea for a wide variety of implications, including different types of cancer, heart disease, liver disease, etc. There is also a wide range of uses for green tea in diabetes, exercise enhancement, inflammatory bowel disease, skin disorders, hair loss, weight loss and iron overload. This paper will review the major health benefits of green tea, focusing on the catechins.

Key words: *Green tea, catechins, EGCG, health benefits, polyphenols*

Introduction

Tea is one of the most widely consumed beverages in the world, next only to water [1,2] and well ahead of coffee, beer, wine and carbonated soft drinks [3]. It can be categorized into three types, depending on the level of fermentation, i.e. green (unfermented), oolong (partially fermented) and black (fermented) tea. The term fermentation is often used incorrectly in tea processing. The more correct term should be oxidation, which means exposure to air while drying without any additives during the process. Another form of tea is white tea which is made from new growth buds and young leaves that have been steamed to inactivate polyphenol oxidation and then dried. The buds may be shielded from sunlight to prevent formation of chlorophyll. Of the ~ 2.5 million metric tons of dried tea manufactured, only 20% is green tea and less than 2% is oolong tea [4].

Green tea is consumed as a popular beverage worldwide, particularly in Asian countries like China, Korea and Japan. There is hardly any other food or drink reported to have as

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many health benefits as green tea. The Ancient Chinese Proverb 'Better to be deprived of food for three days, than tea for one' indicates the importance of tea in the day-to-day life of Chinese. The Chinese have known about the medicinal benefits of green tea since ancient times, using it to treat everything from headaches to depression. In her book 'Green Tea: The Natural Secret for a Healthier Life', Taylor [5] stated that green tea has been used as a medicine in China for at least 4000 years.

The chemical composition of green tea varies with climate, season, horticultural practices and position of the leaf on the harvested shoot. The major components of interest are the polyphenols. The major polyphenols in green tea are flavonoids. The four major flavonoids in green tea are the catechins, epicatechin (EC), epigallocatechin (EGC), epicatechin gallate (ECG) and epigallocatechin gallate (EGCG) (Figure 1). Epigallocatechin gallate is viewed as the most significant active component. The leaf bud and first leaves are richest in EGCG. The usual concentration of total polyphenols in dried green tea leaves is ~ 8–12% [6–8]. Other compounds of interest in dried green tea leaves include gallic acid, quercetin, kaempferol, myricetin, caffeic acid and chlorogenic acid [6,9]. Table I shows the chemical composition of green tea leaves.

Health benefits

The secret of green tea lies in the fact that it is rich in catechin, polyphenols, particularly EGCG. The EGCG is a powerful anti-oxidant: besides inhibiting the growth of cancer cells, it kills cancer cells without harming healthy tissue. It has also been effective in lowering LDL cholesterol levels, inhibiting the abnormal formation of blood clots, reduction of platelet aggregation, lipid regulation and inhibition of proliferation and migration of smooth muscle cells. Inhibition of abnormal blood clots formation takes on added importance when you consider that thrombosis (the formation of abnormal blood clots) is the leading cause of heart attacks and stroke. Any of these factors might be promising in reducing cardiovascular diseases. The major and most chemo-preventive constituent in green tea responsible for these biochemical or pharmacological effects is (-)-epigallocatechin-3-gallate. Understanding the molecular mechanisms of these effects of green tea is a subject of investigation in many laboratories [8].

Green, oolong and black teas all come from the leaves of the Camellia sinensis plant. What sets green tea apart is the way it is processed. Green tea leaves are steamed, which prevents the EGCG compound from being oxidized. In contrast, black and oolong tea are

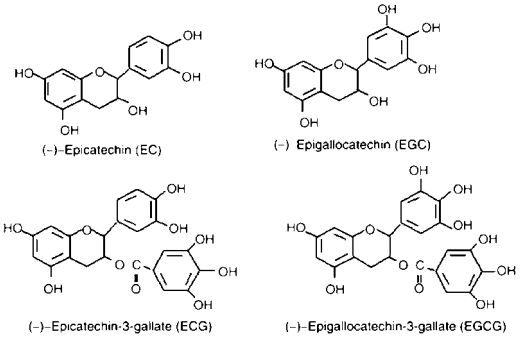

Figure 1. Major polyphenols in green tea.

Table I. Chemical composition of green tea leaves (http://www.bodyofmine.com).

Constituent	Percentage (% of dried leaf)
Polyphenols	37.0
Carbohydrates	25.0
Caffeine	3.5
Protein	15.0
Aminoacids	4.0
Lignin	6.5
Organic acids	1.5
Lipids	2.0
Ash	5.0
Chlorophyll	0.5

made from fermented leaves, which results in the EGCG being converted into other compounds that are not nearly as effective in preventing and fighting various diseases. In general, green tea has been found to be superior to black tea in terms of antioxidant activity, owing to the higher content of EGCG [10]. The processes used in the manufacture of black tea are known to decrease levels of the monometric catechins to a much greater extent than the less severe conditions applied to other teas. The production and consumption of the partially fermented oolong tea are confined to China [1].

Today, scientific research in both Asia and the west is providing hard evidence for the health benefits long associated with drinking green tea. For example, in 1994 the *Journal of the National Cancer Institute* published the results of an epidemiological study indicating that drinking green tea reduced the risk of esophageal cancer in Chinese men and women by nearly 60%. University of Purdue researchers recently concluded that a compound in green tea inhibits the growth of cancer cells. There are also reports indicating that drinking green tea lowers total cholesterol levels, as well as improves the ratio of good cholesterol (HDL) to bad cholesterol (LDL) [11].

Links are being made between the effects of drinking green tea and the 'French Paradox'. For years, researchers were puzzled by the fact that, despite consuming a diet rich in fat, the French have a lower incidence of heart disease than Americans. The answer was found to lie in red wine, which contains resveratrol, a polyphenol that limits the negative effects of smoking and a fatty diet. In a 1997 study, researchers from the University of Kansas determined that EGCG is twice as powerful as resveratrol, which may explain why the rate of heart disease among Japanese men is quite low, even though $\sim$ 75% are smokers.

To sum up, here are just a few medical conditions in which drinking green tea is reputed to be helpful: cancer, rheumatoid arthritis, high cholesterol levels, cardiovascular diseases, infection and impaired immune function.

Anti-carcinogenic property

The cancer-protective effects of green tea have been reported in several population-based studies. For example, cancer rates tend to be low in countries such as Japan where green tea is regularly consumed. It is not possible to determine from these population-based studies whether green tea actually prevents cancer in people. However, emerging animal and clinical studies are beginning to suggest that EGCG may play an important role in the prevention of cancer. It has been suggested that EGCG and other tea catechins suppress tumour growth by inhibiting the release of tumour necrosis factor-alpha, which is believed

to stimulate tumour promotion and progression of initiated cells as well as pre-malignant cells [12]. Furthermore, EGCG was shown to reduce specific binding of both the 12-Otetradecanoylphorbol-1-3-acetate (TPA) type and the okadaic acid-type tumour promoters (the two major classes of tumour-promoting agents) to their receptors. This 'sealing' effect of EGCG is achieved by its interaction with the phospholipid bilayer of the cell membrane [13]. When non-Hodgkin's lymphoma cells were transplanted into mice, green tea prevented 50% of the tumours from taking hold and significantly inhibited growth of the tumours [14].

Many laboratory studies have shown that topical treatment or oral consumption of green tea polyphenols inhibits chemical carcinogen- or ultraviolet radiation-induced skin tumourigenesis in different animal models [8]. According to Hirofumi Tachibana's team at Kyushu University in Japan, green tea protects against a range of cancers, including lung, prostate and breast cancer due to the presence of EGCG. Their research showed that growth of human lung cancer cells that have a cell receptor called *67 LR* is slowed significantly after drinking just two or three cups of green tea. The research also showed that *67 LR* is involved in the propagation of prion diseases such as mad cow disease in humans. So knowledge of EGCG's effect on *67 LR* might have implications in the treatment of these diseases [15].

Experimental studies conducted in *in vitro* and *in vivo* models indicate that GTPs or EGCG prevents photocarcinogenesis following several mechanisms involving multiple molecular targets, as summarized in Figure 2 [16].

Epidemiological observations suggesting an inverse correlation between tea consumption and the incidence of cardiovascular diseases have been well established [17]. A recent review [18] gives an overview of the effects of polyphenolic compounds in tea on the function of the cardiovascular system, especially on various signal transduction pathways in cardiovascular cells. The underlying mechanisms of tea polyphenols in preventing cardiovascular disease, however, are yet to be well understood. It is widely known, but still open to question, why the incidence of coronary events (death definitely or probably due to coronary heart disease or non-fatal myocardial infarction) in Japanese is substantially lower than in Western populations.

Recently, in Japan, a large population-based cohort study of 40 530 subjects showed green tea consumption to be inversely associated with mortality due to cardiovascular disease [17]. It was also observed that green tea consumption was significantly higher in

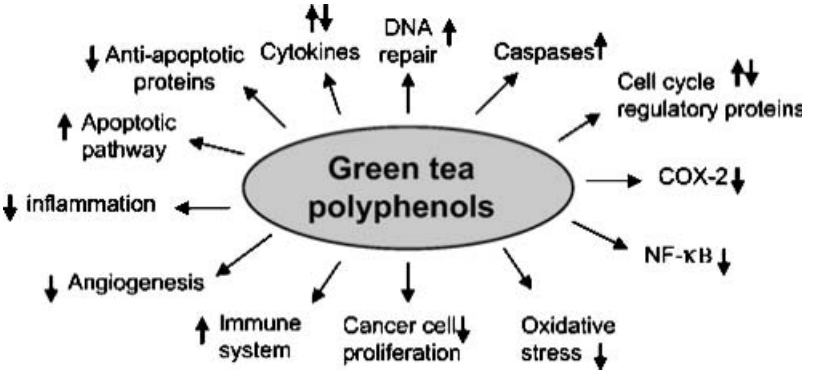

Figure 2. Molecular targets of GTPs.

patients without coronary artery disease than in those with coronary artery disease. The review by Stangl et al. [18] compiles existing data on the beneficial effects of tea on the cardiovascular system. These molecular effects appear to be real. However, most effects of tea polyphenols in cell culture systems are obtained with rather high doses of these compounds, doses that are not compatible with tea intake in daily life. In addition, the bioavailability of tea catechins is very low. Because tea is comprised of many different ingredients, it is unresolved whether the beneficial effects of tea are due to EGCG or tea flavins or combinations of any of tea's ingredients. The possibility that dietary tea intake reduces the risk of cardiovascular events remains open to the need for further clinical trials to clarify the effects of tea polyphenols in humans in order to recommend their use against cardiovascular diseases.

Green tea for skin treatment

Treatment of green tea polyphenols to skin has 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. Topical treatment with EGCG on mouse skin results in prevention of UVB-induced immunosuppression and oxidative stress. The protective effects of green tea treatment on human skin either topically or consumed orally against UV light-induced inflammatory or carcinogenic responses are not well understood. Based on documented extensive beneficial effects of green tea on mouse skin models and very little in human skin, many pharmaceutical and cosmetic companies are supplementing their skin care products with green tea extracts.

Research using pooled human keratinocytes (skin cells) to study the normal growth of the skin cells alone and comparing it to the growth of the cells when exposed to EGCG revealed that EGCG reactivated dying skin cells. Cells that migrate toward the surface of the skin normally live about 28 days and, by day 20, they sit on the epidermis getting ready to die and slough off. Current research seems to show that EGCG reactivates epidermis cells [19].

Anti-fungal activity

The anti-fungal activity of catechin is pH-dependent. The concentration of EGCG causing 90% growth inhibition of tested strains of *C. albicans* was 2000 mg L^{-1} at pH 6.0, 500–1000 mg L^{-1} at pH 6.5 and 156–250 mg L^{-1} at pH 7.0. Among catechins, pyrogallol catechin showed stronger anti-fungal activity against *C. albicans* than catechol catechin. The addition of 6.25–25 or 3.12–12.5 mg L^{-1} EGCG to amphotericin B 0.125 or 0.25 mg L^{-1} (below MIC) at pH 7.0 resulted in enhancement of the anti-fungal effect of amphotericin B against amphotericin B-susceptible or -resistant *C. albicans*, respectively. Combined treatment with 3.12–12.5 mg L^{-1} EGCG plus 0.5 mg L^{-1} amphotericin B (below MIC) markedly decreased the growth of amphotericin B-resistant *C. albicans*. When fluconazole-susceptible *C. albicans* was treated with 25–50 mg L^{-1} EGCG and fluconazole 0.125–0.25 mg L^{-1} (below MIC), its growth was inhibited by 93–99.4% compared with its growth in the presence of fluconazole alone. The combined use of 12.5 mg L^{-1} EGCG and fluconazole 10–50 mg L^{-1} (below MIC) inhibited the growth of fluconazole-resistant *C. albicans* by 98.5–99.7% [20].

These results indicate that EGCG enhances the anti-fungal effect of amphotericin B or fluconazole against anti-mycotic-susceptible and resistant *C. albicans*. Combined treatment

with catechin allows the use of lower doses of anti-mycotics and induces multiple anti-fungal effects. It is hoped that this may help to avoid the side effects of anti-mycotics.

Anti-viral effects

EGCG and ECG were found to be potent inhibitors of influenza virus replication in cell culture. This effect was observed in all influenza virus sub-types tested, including A/H_1N_1, A/H_3N_2 and B virus. Quantitative analysis revealed that, at high concentration, EGCG and ECG also suppressed viral RNA synthesis in cells, whereas EGC failed to show a similar effect. Similarly, EGCG and ECG inhibited the neuraminidase activity more effectively than the EGC. Neuraminidase is an antigenic glycoprotein enzyme found on the surface of the influenza virus. Neuraminidase has functions that aid in the efficiency of virus release from cells [21].

Cholesterol reduction

Although green tea diet has a reputation for boosting health, scientific proof of it's health benefits are still somewhat mixed. However, in an article published in the *Archives of Internal Medicine*, American researchers collaborated with their Chinese counterparts to discuss the beneficial effects of green tea diet on cholesterol levels. Using 240 men and women (average age 55 years) who possessed mild-to-moderately high LDL cholesterol levels, the researchers instructed them to retain their usual low-fat diet, green tea diet intake and activity levels. After 12 weeks, it was found that those who consumed green tea diet extract with their regular meals lost more than 15% of their total LDL cholesterol levels. Although the researchers never explained how green tea diet influenced cholesterol levels, previous studies have shown that certain compounds in green tea diet play a role in reducing the amount of cholesterol absorbed by the body, increasing amount of cholesterol excreted and thus keeping cholesterol from being stored in the liver. Subsequent studies were made to test the findings of the first group of researchers. Their results were however contradictory and they reported that green tea diet has no significant effect on the cholesterol profiles of their subjects [22].

Population-based and clinical studies indicate that the antioxidant properties of green tea may help prevent atherosclerosis, particularly coronary artery disease. According to 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 one study documenting that the risk was 36% lower for tea drinkers [23].

In another experiment, Serum malondialdehyde-modified LDL concentrations and urine 8-epi-prostaglandin (PG) F (2alpha) were measured in 22 healthy male non-smokers to determine inhibition of LDL oxidation by green tea. Subjects drank seven cups/day of water for 2 weeks and drank seven cups/day of green tea for the next 2 weeks. Of the 22 subjects, 20 had been in the habit of drinking green tea before the study. Plasma catechin concentrations significantly decreased at the end of the water period and then increased at the end of the green tea period. Although no change in plasma LDL-cholesterol concentrations (110 ± 33 vs $113 \pm 28\,\mathrm{mg\,dL^{-1}}$; p=ns) was found, malondialdehyde-modified LDL concentrations (84 ± 45 vs $76 \pm 40\,\mathrm{IU\,L^{-1}}$; $p<0.05$) and the ratio of malondialdehyde-modified LDL/LDL-cholesterol (0.74 ± 0.21 vs 0.65 ± 0.20; $p<0.02$) significantly decreased at the end of the green tea period. However, no significant changes were observed in urine 8-epi-PGF (2-alpha) concentrations, in

platelet aggregation or in plasma TXB (2), 6-keto-PGF (1alpha) or matrix metalloproteinase concentrations [23]. Preliminary research also indicates that tea polyphenols may reduce the activity of platelets. Pre-incubation with EGCG concentration-dependently inhibited thrombin- induced aggregation and phosphorylation of p38 mitogen-activated protein kinase and extracellular signal-regulated kinases-1/2. In contrast, EGCG stimulated tyrosine phosphorylation of platelet proteins, including Syk and SLP-76, but inhibited phosphorylation of focal adhesion kinase. Other catechins did not inhibit platelet aggregation [24].

One population-based study by Tokunaga et al. [25] found that men who drink green tea are more likely to have lower total cholesterol than those who do not drink green tea. The subjects were 13 916 workers (8476 men and 5440 women) aged 40–69 years at over 1000 workplaces in Nagano prefecture, central Japan. They did not have morbid conditions affecting serum cholesterol levels. Serum concentrations of total cholesterol, high-density lipoprotein cholesterol and triglycerides were measured at the screening. Green tea consumption was statistically significantly associated with lower levels of serum total cholesterol in both men and women, whereas its associations with serum triglycerides and high-density lipoprotein cholesterol were not statistically significant. The inverse association of serum total cholesterol with green tea consumption appeared to level off at the consumption of more than 10 cups/day. Excluding the outlying subjects drinking more than 10 cups/day (0.4%), the regression analysis adjusting for age, body mass index, ethanol intake, smoking habit, coffee intake and type of work showed that daily consumption of one cup of green tea was associated with a reduction in serum total cholesterol by $0.015\,\mathrm{mmol\,L^{-1}}$ (95% confidence interval, 0.006–0.024; $p<0.001$) in men and $0.015\,\mathrm{mmol\,L^{-1}}$ (95% confidence interval, 0.004–0.025; $P<0.01$) in women. After additional adjustment for selected dietary factors, the inverse association remained statistically significant; one cup of green tea per day was associated with a reduction in serum total cholesterol by $0.010\,\mathrm{mmol\,L^{-1}}$ (95% confidence interval, 0.001–0.019; $p=0.03$) in men and $0.012\,\mathrm{mmol\,L^{-1}}$ (95% confidence interval, 0.001–0.022; $p=0.03$) in women.

Effects on HIV

A recent study appearing in the *Journal of Allergy and Clinical Immunology* stated that EGCG found in green tea can help to boost one's immune system, therefore helping to prevent HIV. The EGCG prevents the binding of HIV to human T-cells, the first step in HIV infection. One study [26] demonstrated that EGCG inhibited the binding of human immunodeficiency virus (HIV) to human CD4 (+) lymphocytes, which is a crucial step in HIV infection. For infection to develop, the viruses need entry into CD4 (+) lymphocytes through a step dependent on adhesion to the CD4 molecule and subsequent intracellular viral proliferation. Epigallocatechin gallate showed a strong affinity for CD4 and, by binding them, could effectively inhibit the binding of the HIV envelope (gp120). This data opens new perspectives for the treatment of this life-threatening disease. Additional research is necessary for the clinical application of EGCG as an anti-HIV drug.

University of Sheffield Research Professor Mike Williamson stated that, 'Our research shows that drinking green tea could reduce the risk of becoming infected by HIV, and could also slow down the spread of HIV', however was quick to point out that, 'It is not a cure, and nor is it a safe way to avoid infection, however, we suggest that it should be used in combination with conventional medicines to improve quality of life for those infected' as well as the fact that the research is in very early stages [27].

Antioxidant properties

The early evidence of antioxidant properties of EGCG came from the experimental data that showed EGCG induced inhibition of soybean lipoxygenase (IC50 = 10–20 $\mu mol\,L^{-1}$). Later, it was reported that EGCG inhibited TPA-induced oxidative DNA base modification in HeLa cells, inhibited Cu^{2+} mediated oxidation of low-density lipoprotein (LDL), reduced tert-butyl hydroperoxide-induced lipid peroxidation and blocked the production of reactive oxygen species derived from NADPH-cytochrome P450-mediated oxidation of the cooked meat carcinogen, 2-amino-3methylimidazo[4,5-f] quinoline. When using the oxygen radical absorbance capacity, green tea was found to have a greater antioxidant activity than brussel sprouts, garlic, kale and spinach [28].

Other benefits

Studies have shown that green tea extract also possesses anti-inflammatory activity due to their polyphenolic constituents present [29]. Due to the popularity of recent findings, green tea has almost become synonymous with weight loss and diet. The addition of green tea into diet pills and weight loss supplements is perhaps spurred by reports of harmful side-effects of other drugs like ephedra. For 4000 years, green tea diet has been used all throughout Asia as a beneficial health and medicinal drink. Green tea diet is different from all other tea diets because its liquid is extracted by steaming the leaves of the Camellia sinensis plant as opposed to full oxidation. In this way, green tea diet manages to preserve a lot more antioxidants and keep them intact for the body to use. Green tea diet is an excellent source of polycatechin polyphenols, a group of antioxidants that act on free radicals. These free radicals have harmful effects on the body since they are the major causes of diseases and ageing. With green tea diet's polycatechin polyphenols, a person has a better chance of avoiding ailments and keeping healthy for a much longer period of time. New evidence is emerging that green tea can even help dieters. In November 1999, the American Journal of Clinical Nutrition published the results of a study at the University of Geneva in Switzerland. Researchers found that men who were given a combination of caffeine and green tea extract burned more calories than those given only caffeine or a placebo.

The EGCG in green tea diet also acts with the compound caffeine (a small amount of this is found in green tea). The interaction of these two compounds causes green tea diet to promote thermogenesis in the body. It has been noted by a study published in the *American Journal of Clinical Nutrition* that, with the consumption of green tea diet, the body's total 24-hour energy expenditure is increased by up to 4%. This is roughly equivalent to losing more than 10 pounds of weight a month. Green tea diet helps increase the body's metabolic rates. With its thermogenic properties, it is only natural that green tea diet can also promote faster metabolism of fats and sugars. Excess glucose found in the body is turned into fats by the hormone insulin. Because green tea diet has an inhibiting effect on insulin, green tea diet therefore helps keep sugar from being stored as fats and, instead, sends them directly into the muscles for immediate use. Green tea can even help prevent tooth decay. Just as its bacteria-destroying abilities can help prevent food poisoning, it can also kill the bacteria that cause dental plaque. Meanwhile, skin preparations containing green tea—from deodorants to creams—are starting to appear on the market [29].

There is also epidemiological evidence that drinking green tea (but not black tea or oolong tea) may help prevent diabetes [30], although it is worth noting that this is evidence

of an association and that future studies are needed to confirm the effect. Green tea has been used traditionally to control blood sugar in the body. Animal studies suggest that green tea may help prevent the development of type 1 diabetes and slow the progression once it has developed [31]. EGCG has been found to increase insulin sensitivity and may repair damaged beta cells [32,33]. High-performance liquid chromatography fractionation of tea extracts utilizing a Waters Symmetry Prep C18 column showed that the majority of the insulin potentiating activity for green tea was due to EGCG. Several known compounds found in tea were shown to enhance insulin with the greatest activity due to EGCG followed by ECG, tannins and theaflavins. Caffeine, catechin and EC displayed insignificant insulin-enhancing activities. Addition of lemon to the tea did not affect the insulin-potentiating activity. Addition of 5 g of 2% milk per cup decreased the insulin-potentiating activity one third, and addition of 50 g of milk per cup decreased the insulin-potentiating activity ~ 90%. Non-dairy creamers and soy milk also decreased the insulin-enhancing activity [33].

A study in Japan [34] 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.

A cup of green tea contains between 15–50 mg of caffeine. Certain cognitive benefits are associated with caffeine consumption, such as a reduction in the likelihood of Parkinson's disease and a temporary increase in short-term memory. However, caffeine is addictive and overuse can result in harmful side-effects such as an increased likelihood of certain sleep disorders [35]. Researchers at the University of Chicago stated that polyphenols help inhibit the growth of bacteria that cause bad breath [36]. Green tea could be relevant for management of iron overload and oxidative stress. Green tea may also help to reduce inflammation associated with Crohn's disease and ulcerative colitis [37]. It was determined that EGCG can inhibit pro-inflammatory interleukin 8 (IL-8) in a study of human lung alveolar epithelial cells (A549 line), doing the same in the gastrointestinal tract seemed possible.

Harmful side effects

To date, the only negative 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. Green tea contains vitamin K and *may* interfere with warfarin [38]. However, that was based on one individual consuming a gallon of green tea daily while on the medication. Based on current literature, there does not appear to be any significant side effects or toxicity associated with regular green tea consumption. Patients sensitive to caffeine should use caffeine-free green tea or a caffeine-free extract.

Effects of fluoride

In general, the level of fluoride in tea is inversely related to the EGCG contents. The more natural EGCG in the tea leaves, the less fluoride. According to Andreas Schuld of the Canadian 'Parents of Fluoride Poisoned Children' tea is very high in fluoride content, much higher than the Maximum Contaminant Level (MCL) set for fluoride in drinking water. Decaffeinated teas have an even higher fluoride content as compared to their

caffeinated counterparts. According to him, fluoride could possibly reduce the anti-cancer properties of tea or even cause cancer, as fluoride is considered a cancer promotor. For instance, he mentions a 1998 study which found positive correlation between colon cancer and tea intake. The high fluoride content could also cause neurological and renal damage, especially in the presence of aluminum. Additionally, the high fluoride content could cause osteoporosis, arthritis and other bone disorders [39].

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. This article demonstrates the benefits of green tea for its anti-inflammatory and antioxidant potential. It has been used to treat cardiovascular diseases, oral cavity diseases, cardiovascular uses and Parkinson's disease. There is also a wide range of uses for green tea in diabetes, exercise enhancement, inflammatory bowel disease and skin disorders. Most impressive are the well-controlled epidemiologic studies, aimed at altering the brain ageing process, which can serve as neuroprotective agents. Although the human clinical data is still limited, this article shows that green tea has its place in both the conventional and alternative medical communities.

***Declaration of interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

1. Cheng TO. Will green tea be even better than black tea to increase coronary flow velocity reserve? Am J Cardiol 2004;94:1223.
2. Vinson JA. Black and green tea and heart disease: a review. Biofactors 2000;13:127–32.
3. Rietveld A, Wiseman S. Antioxidant effects of tea: evidence from human clinical trials. J Nutr 2003;133:3285S–92S.
4. Pastore RL, Fratellone P. Potential health benefits of green tea (camellia sinensis): a narrative review. Diet Nutr 2006;2:531–9.
5. The miracle of green tea. http://chinesefood.about.com/library/weekly/aa011400a.htm. Date of access 7 Nov 2007.
6. Graham HN. Green tea composition, consumption, and polyphenol chemistry. Preventive Med 1992;21:334–50.
7. Min Z, Peigen X. Quantitative analysis of the active constituents in green tea. Phytother Res 1991;5:239–40.
8. Katiyar SK, Elmets CA. Green tea polyphenolic antioxidants and skin photo protection (review). Int J Oncol 2001;18:1307–13.
9. US Department of Agriculture. USDA database for the flavonoid contents of selected foods. Beltsville, MD: US Department of Agriculture; March 2003.
10. Cheng TO. Tea is good for the heart. Arch Intern Med 2000;60:2397.
11. Cheng OT. All teas are not created equal—the Chinese green tea and cardiovascular health. Int J Cardiol 2006;108:301–8.
12. Fujiki H, Suganuma M, Kurusu M. New TNF-alpha releasing inhibitors as cancer preventive agents from traditional herbal medicine and combination cancer prevention study with EGCG and sulindac or tamoxifen. Mutat Res 2003;523–4:119–25.
13. Fujiki H, Suganuma M, Okabe S. A New concept of tumor promotion by tumor necrosis factor-alpha, and cancer preventive agents (-)-epigallocatechin gallate and green tea—a review. Cancer Detect Prevent J 2000;24:91–9.
14. Bertolini F, Fusetti L, Rabascio C, Cinieri S, Martinelli G, Pruneri G. Inhibition of angiogenesis and induction of endothelial and tumor cell apoptosis by green tea in animal models of human high-grade non-Hodgkin's lymphoma. Leukemia 2000;14:1477–82.

15. Dulloo AG, Duret D, Rohrer D, Girardier L, Mensi N, Fathi M, Chantre P, Vandermander J. American Journal of Clinical Nutrition 1999;70:1040-5.
16. Katiyar S, Elmets CA, Katiyar K. Green tea and skin cancer: photo immunology, angiogenesis and DNA repair. J Nutr Biochem 2007;18:287–96.
17. Mukamal KJ, Maclure M, Muller JE, Sherwood JB, Mittleman MA. Tea consumption and mortality after acute myocardial infarction. Circulation 2002;105:2476–81.
18. Stangl V, Dreger H, Stangle K, Lorenz M. 2007. Molecular targets of tea polyphenols in the cardiovascular system. Cardiovasc Res 2007;73:348–58.
19. Lee MJ, Maliakal P, Chen L. Pharmacokinetics of tea catechins after ingestion of green tea and (-)-epigallocatechin-3-gallate by humans: formation of different metabolites and individual variability. Cancer Epidemiol Biomarkers Prevent 2002;11:1025–32.
20. Hirasawa M, Takada K. Multiple effects of green tea catechin on the antifungal activity of antimycotics against Candida albicans. J Antimicrobial Chemother. 53, 225–9.
21. Song JM, Lee KH, Seong BL. Antiviral effect of catechins in green tea on influenza virus. Antiviral Res 2005;68:66–74.
22. http://www.northernohiorailfan.com/Green_Tea_Diet_Review.html. Accessed 10 Nov 2007.
23. Hirano-Ohmori R, Takahashi R, Momiyama Y. Green tea consumption and serum malondialdehyde-modified LDL concentrations in healthy subjects. J Am Coll Nutr 2005;24:342–6.
24. Lill G, Voit S, Schror K, Weber AA. Complex effects of different green tea catechins on human platelets. FEBS Lett 2003;546:265–70.
25. Tokunaga S, White IR, Frost C. Green tea consumption and serum lipids and lipoproteins in a population of healthy workers in Japan. Ann Epidemiol 2002;12:157–65.
26. Nance CL, Shearer WT. Is green tea good for HIV-1 infection? J Allergy Clin Immunol 2003;112:851–3.
27. Kuriyama S. Green tea may do wonders for brain. Am J Clin Nutr 2006;83:355–61.
28. Cao G, Sofic E, Prior RL. Antioxidant capacity of tea and common vegetables. J Agric Food Chem 1996;44:3426–31.
29. http://www.secretsofgreentea.com/green-tea-diet-review.
30. Takatoshi M, Satoshi H, Akira S, Ichiro T, Tadashi H. Green tea extract improves running endurance in mice by stimulating lipid utilization during exercise. Am J Physiol Regulat Integrat Comparat Physiol 2006;290:R1550–6.
31. Waltner-Law ME, Wang XL, Law BK, Hall RK, Nawano M, Granner DK. Epigallocatechin gallate, a constituent of green tea, represses hepatic glucose production. J Biol Chem 2002;277:34933–40.
32. McKay DL, Blumberg JB. The role of tea in human health: an update. J Am Coll Nutr 2002;21:1–13.
33. Anderson RA, Polansky MM. Tea enhances insulin activity. J Agric Food Chem 2002;50:7182–6.
34. 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.
35. Bhagwat S, Beecher GR, Haytowitz DB, Holden JM, Dwyer J, Peterson J, Gebhardt SE, Eldridge AL, Agarwal S, Balentine DA. ''Flavonoid composition of tea: Comparison of black and green teas'', USDA Agricultural Research Service; in web page http://en.wikipedia.org/wiki/Potential_effects_of_tea_on_health.
36. Wu, C, Zhu, M. Compounds in tea stop bad breath-Halitosis-polyphenols prevent growth of bacteria-Brief Article, USA Today (Society for the Advancement of Education), August, 2003.
37. Dryden G, Song M, McClain C. Polyphenols and gastrointestinal diseases. Curr Opin Gastroenterol 2006;22:165–70.
38. Taylor JR, Wilt VM. Probable antagonism of warfarin by green tea. Ann Pharmacother 1999;33:426–8.
39. ''Green Tea, Fluoride and the Thyroid''; Andreas Schuld, Parents of Fluoride Poisoned Children (PFPC), Vancouver, B.C., Canada; 1999 August 24; In: webpage at http://bruha.com/fluoride/html/green_tea_f.html.