Review Article

Green tea: Chemical composition, biological effects and health benefits

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Abstract

Green tea widely consumed as a dietary supplement. It has polyphenolic compound which is called epigallocatechin-3-gallate (EGCG). Green tea plant mostly grows in warm climate and higher altitude. For commercial picking of leaves, plant takes 3-5 year to fully grow. Green tea is less processed or non-oxidative form so it has maximum antioxidant property than other forms of tea Now days, it is widely used to reduce weight. Green tea has poly phenolic content named EGCG and has maximum antioxidant property. It has many health benefits like anti-inflammatory, anti-carcinogenic and antibacterial activity. Besides many health benefits, consuming high amount of green tea may cause many side effects. Excess consumption of green tea and its concentrated extract shows restlessness, CNS stimulation, headache, hepatotoxicity and other side effects. Now a day, society is not so much aware about the use of green tea and individual is taking this with any consultation with medical practitioner.

Keywords: Antioxidants, epigallocatechin-3-gallate, hepatotoxicity, flavonoids, restlessness

Introduction

Green tea is widely consumed as a dietary supplement. In China, green tea is used for medicinal purposes since 4000 years. In England, it is consumed as daily basis as beverage (Gupta et al., 2014). It can be divided into three categories which are depending on its oxidation process. Non oxidative form is called green tea, partially oxidized form is oolong tea and completely oxidized form is black tea. There is another form of tea which is called white tea. It is made up from new growing bud and young leaves which are covered to sunlight so that buds not form chlorophyll and then steamed to prevent its oxidation of polyphenolic content and then dried (Sinija et al., 2008).

Green tea has polyphenolic compound which is called epigallocatechin-3-gallate (EGCG). Green tea is less processed or non-oxidative form so it has maximum antioxidant property than other forms of tea. Besides polyohenolic content, green tea contains flavanoids and glycosides (Khurshid et al., 2016). Green tea has many health promoting effects like anticarcinogenic, anti-inflammatory and antibacterial effects. Now days, it is widely used to reduce weight as dietary supplements.

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Drinking green tea has many health benefits but it has some side effects also if consumed in excess quantity or more than five cups on daily basis (Nawab et al., 2015). Green tea contains caffeine which shows many side effects if takes in excess. It can stimulate central nervous system which leads to insomnia, restlessness and tremors. Green tea also affects liver and interferes with the metabolism of drugs like MAO inhibitors (Creasy et al., 2013).

Green Tea

Green tea belongs to the Theaceae family of an evergreen plant *Camellia sinensis*. It may be used as capsular extract or brewed drink for reducing weight (Brown et al., 1999). In 17th century, green tea was exported from India to Japan but presently about 2.5 million tons of tea leaves are produced in Asia (Chacko et al., 2010).

Camellia sinensis is a evergreen tree of upto 30 feet height but it constantly shorten to a height of about 3 feet for commercial purposes for easy pricking of tea leaves. Flavor and aroma of the tea depends on climate and altitude. Green tea plant mostly grow in warm climate and higher altitude. For commercial picking of leaves, plant takes 3-5 year to fully grow (Fernadez et al., 2002).

When plant is fully mature, the leaves are plucked by the tea plukers by hand. Youngest leaves which have small bud in the middle are picked from the plant. After the picking of leaves,

theses are exposed to steam but prevent to get fermented. By steaming the leaves turn to roll. Rolled leaves are dried by the hot air up to crisp. By going through this process, green tea have some astringent and yellowish-green flavor just like fresh green leaves (Lantano et al., 2015).

Chemical composition

Phytochemical studies suggested that green tea have about 4000 bioactive compounds. Bioactive compounds are those chemical (secondary metabolite) which present in plant naturally (Tariq et

Figure 1. *Camellia sinesis* Plant

Table 1. Principle components of green tea

Components	Green Tea (% weight of extract solid)
Catechin	30-42
Flavonoids	5-10
Other flavoniods	2-4
Gallic acid	0.5
Ascorbic acid	1-2
Other organic acid	4-5
Minerals	6-8
Methylxanthines	7-9
Volatiles	0.02

al., 2010). The main chemical constituents of green tea are phenols, alkaloids, Flavoniods, tennins and steroids. About one third part of green tea is made up of polyphenols which include catechins like epigallocatechin gallate (EGCG), epigallocatechin (EGC), epicatechin-3-gallate and epicatechin (EC). Besides these polyphenoles others are flavonoids and their glycosidic derivatives that are carotenoids, quinic acid, chlorogenic acids and trigalloylglucose. Other chemical constituents of green tea are methylxanthin, caffeine, lignin, minerals which are manganese or aluminium. EGCG is the major component of green tea which has maximum beneficial pharmacological activities (Yang et al., 1998; Nagle et al., 2006).

Benefits of green tea

Anti-carcinogenic activity

Cancer is one of the major cause of mortality throughout the world. According to recent data from WHO, 8.2 million deaths are estimated per year due to cancer. Mostly lung, stomach liver, colon and prostate cancers cause most deaths every year. Life style and diet are the main reasons for cause of these types of cancers. Many research studies have been taken to prove anti-carcinogenic property of green tea. EPCG is the main constituent which has been studied in cancer research (Fujuki et al., 2003). The studies suggested that EPCG inhibit the tumour growth by several pathways which are: DNA hypermethylation, by inhibiting tumor proliferation and its metastasis, by promoting cell apoptosis and suppression of mutagens (Shirakami et al., 2012).

In males, the major cause of mortality due to cancer is from prostate cancer. Besides genetics factors, the environmental factors are the main reasons of prostate cancer. Improper life style and dieting habit affects prostate gland growth. These environmental conditions enhances chronic proliferation of cells and causes oxidative stress. This leads to alteration in the DNA formation and starts tumour growth or prostate gland atrophy (Minelli et al., 2009).

Green tea catechins have antioxidant property which play important role to remove free radicals (scavenging), reduce oxidative stress and inflammation. EPCG modulates the growth of cancerous cells and also activates apoptotic pathways which cause cell death (Piepraola et al., 2012). Green tea also reduces the risk of breast cancer, stomach cancer and liver cancer among tea consumers (Yu et al., 1995).

Anti-obesity activity

Obesity is one of the major problems now-a-days and occurrence of obesity increased for many decades. Genetic factors as well as life style are the main two reasons of obesity. There are many diseases which arise due to obesity

like cardiovascular diseases, diabetes, cancer and fatty liver disease (Kopelman et al., 2000). Fat is stored in adipose tissues in the form of fatty acids. Increased lipolysis of fatty acids or alteration of lipolytic pathway leads to obesity and other secondary diseases (Bezaire et al., 2009).

Many animal and clinical studies have been carried out which showed significant effect of green tea extract for weight loss (Wang et al., 2010). Polyphenolic content of green tea have many beneficial effects and prevent many life style related diseases. There are mainly three factors which cause obesity: energy expenditure, genes responsible for anorectic function and appetite stimulant or orexigenics. After two month animal study by using green tea extract found that animals have low level of serum LDL and elevated level of HDL (Cunha et al., 2013).

Daily use of green tea helps to prevent obesity by maintaining plasma lipid level (Mastumoto et al., 1993). Green tea catechins have antioxidant property which increase fat oxidation, lowering lipid peroxidation and increases thermogensis (energy expenditure) (Boschmann et al., 2007; Basu et al., 2010). Besides these effects, green tea also suppresses appetite and less absorption of nutrients from diet by suppressing orexigenic genes activity. Some research studies suggest that green tea polyphenoles transfer the glucose to the muscles so that it can be used as energy source instead of stored in adipose tissues (Murase et al., 2006).

Cardio-protective activity

Another benefit of green tea is to protect from cardiovascular diseases. Cardiovascular disorders are the cause with number of several secondary disorders which are inflammation, aggregation of platelets, myocardial infarction, brain stroke and lipid metabolism. Cardiovascular diseases occur due to consumption of high fat diet mostly saturated fats and little or no exercise and smoking. These all factors are associated with cardiovascular diseases like coronary artery thrombosis and hypertension.

Green tea acts as cardio-protective. A study revealed that daily consumption of 3 cups of green tea can reduce the risk of CVD up to 28% (Nakachi et al., 2000). According to data available from U.K study, there is decrese in mortality rate of people who had MI 11% by drinking three or more cup of green tea routinely (Peters et al., 2001). Green tea prevents from atherosclerosis also. Green tea have antioxidant property which lowers serum LDL by lipid peroxidation (Gomikawa et al., 2008). Other cardiovascular disorders like stroke and hypertension also cured by green tea. Regular intake of two to three cups of green tea combat with heart stroke 2% (Arab et al., 2009). There are many factors which cause hypertension in which age and Angiotensin converting enzymes (ACE) are two main causes. Arteries loose elasticity due to age factor which is major cause of action. Green tea

extract helps to regain the elasticity of arteries and also acts like ACE inhibitor which significantly reduces hypertension (Balasuriya et al., 2011).

Antimicrobial activity

A number of researches have been done that revealed; green tea extract has antibacterial and antiviral properties. A research study found antibacterial action of water and ethanolic extract of green tea. In this study, two bacterial strains were used *Sterptococcus mutans* and *Lactobacillus acidophilus* isolated from dental caries and from yogurt. Green tea extracts shows antibacterial activity by inhibiting the growth of both strains. Green tea has effective inhibitory action against other bacteria like *Escherichia coli*, *Salmonella typhi*, *Staphylococcus aureus* and *Entrococcus facalis* (Arifa et al., 2011).

Green tea contains poly-phenols which inhibit the growth of bacteria by breaking the cell membrane of microbes and by inhibiting the synthesis of fatty acids of bacterial cell wall (Reygaert et al., 2014). Green tea treats as well have prophylactic effect against various Gram positive and Gram negative bacteria. Green tea helps to grow the lactic acid bacteria and other good bacteria in intestinal tract and thus deemed as Prebiotic (Yang et al., 2003).

Catechnins of green tea have antiviral potential. A study revealed that epigallocatechin gallate (EPCG) inhibit the infection of virus by hindering the attachment of viral particle with cells. Catechin possesses antioxidant property change the life cycle process of HIV and inhibits its growth and integration with host cellular content (Yamaguchi et al., 2002). EPCG itself attach with CD4 T cells and thus hinder the site of binding with virus (Williamson et al., 2006). Besides the anti-HIV action, green tea consumption reduces other viral infection like influenza viruses, adenoviruses and herpes simplex virus.

Dental health

When several studies have been done on antioxidant property, antimicrobial properties and other activity of green tea, researchers found that green tea have positive impact towards oral health. After that many studies had done on green tea to reveal its effect on dental health. Studies found that daily consumption of green tea combat with dental caries, tooth loss and periodontitis (Gupta et al., 2014; Gaur et al., 2014). Main cause of dental diseases is infectious response that depends on some factors like presence of any microbial infection, personal oral hygiene, nutrition and host related factors. *Streptococcus mutans* is the most common bacteria which is responsible for dental caries. Regular intake of green tea decreases the chance of dental caries by having anti-Streptococcus activity (Naderi

et al., 2011).

Drinking green tea regularly has beneficial effect on periodintitis. Bacteria bind with teeth with help of their fimbrae and attached with epithelial cells of teeth and gum then cause inflammation. EGCG has the potency to block the binding of bacteria with epithelial cells. EGCG also prevent the tissue damage by inhibiting the production of inflammatory mediators like interlukin-8 (IL-8) (Gaur et al., 2014). Besides from catechins, green tea also contain fluoride and acts as natural source of fluoride. Fluoride plays important role to maintain oral health by inhibiting various dental problem even oral cancer (Parley et al., 2012; Okamoto et al., 2004).

Miscellaneous

Skin care

Green tea plays important role to cure skin diseases. Green tea shows effective action on eczema and acne. Green tea extract is very beneficial effect against sun burning specially protects from ultraviolet B rays. Catechins in green tea, mainly ECGC are used to treat skin disorder by inhibiting oxidative stress. ECGC alters the many pathways of skin inflammation by changing the chemical mediator generation pathway which responsible for inflammation. It can also reduce the cell proliferation and skin damage. In a study of USA, found that green tea reduce inflammation and skin destruction of the patients who were exposed to radiation for radiotherapy of cancer (Pajonk et al., 2006). Green tea also increases the life span of skin cell by increasing its rejuvenating power due to high antioxidant property. Thus green tea also used as anti-ageing agent (Lee et al., 2007).

Improves hair loss

As green tea helps to rejuvenate skin cells and decrease apoptosis, it also enhances the hair growth by inhibiting cell death of follicular cells. Green tea extracts works as hair tonic. Extract increase hair growth by various mechanisms including protection of hair follicles from radiations, increase or stimulate hair cell proliferation and altering the apoptosis pathways of hair follicular cells which enhances life span of hair cells (Charles et al., 2008). Green tea extracts combats with baldness in men. Presence of high level of free testosterone (sex hormone) is one of the main causes of baldness in men. Free testosterone is converted into dihyrotestosterone (DHT) with the help of 5α-reductase enzyme. Dihydrotestosterone (DHT) further reduces the life cycle of hair follicles which leads to hair loss and baldness. Green tea has potential to inhibit 5α-reductase enzyme and also stimulates sex hormone-binding protein globulin (SBGH) which remains the testosterone in bound form so that it cannot change into dihydrotestosterone (DHT) (Patil et al., 2010).

Increases insulin sensitivity

Flavonoids present in green tea increases the insulin sensitivity by different mechanism so green also used as anti-diabetic. A study has been done on sterptozotocin (STZ) induced diabetes mellitus. STZ causes beta cells destruction which leads to hypo-insulinemia and hyperglycemia. Green tea extract improves the insulin sensitivity by mimicking like insulin and also enhances the phosphorylation of tyrosine enzyme which increase glucose uptake. EGCG also prevent the beta cell damage (Tsuneki et al., 2004; Wu et al., 2004). 12 weeks study of rats having green results into low glucose level in fasting state and show ant-diabetic effects (Fiorino et al., 2012).

Toxic effect/negative effect of green tea

Many papers have been documented related to negative effect of green tea. Consumption of large amount of green tea can cause many adverse effects. Chemical derivatives of green tea cause acute hepatotoxicity. Green tea contains caffeine which can cause insomnia, central nervous system stimulation like nausea and vomiting.

Hepatotoxicity

Concentrated extract of green tea is consumed as a nutritional beverage now days due to its high beneficial effects. Couple of researchers has found that concentrated products of green tea cause toxicity (McCormick et al., 1999). Antioxidant property of green tea helps to combat with liver diseases but concentrated extract of green can cause hepatotoxicity. A study has carried out in which animals are divided into two groups each group has six animals. One group is control group and second group is green tea extract group in which three concentrations (1%, 1.5%, and 3%) of extract was given to animals for 25 days instead of water with normal diet. After experiment periods, livers were extracted and studied. Study has revealed that high concentration of green tea cause damage to the liver cells (Amal et al., 2011). Hepatotoxicity depends on frequency and concentration of green tea consumption like 100 ml of green tea (one cup) contains 50-100 mg of polyphenolic content (Luo et al., 1997).

A case study has described that concentrated product of green tea causes acute hepatitis in a 63-year old lady. She consumed green tea capsules during the treatment of breast cancer daily along with other medications. After hospitalization, liver biopsy showed that she was suffering with acute hepatitis. All analytical evaluations revealed that green tea capsules caused acute hepatitis to 63-year old lady. Analytical studies also showed that one capsule of green tea possess 725mg of tea extract in which 98% were poly-phenols and 45% EGCG were present. Concentrated product of green tea contains high amount of chemical constituents which can cause hepatotoxicity (Pillukat et al., 2014).

Iron deficiency anemia

Iron deficiency is one of the serious problems in the world which is caused by low iron absorption from the supplement. There are many factors present in supplements which can affect the absorption of iron from the diet. Green tea also cause iron deficiency if taken in excess amount. Although tannins present in green tea like catechin and epicatechin have many beneficial effect but high amount consumption of green tea also causes many side effects (Nawab et al., 2015).

Dietary iron is of two types one is heme iron and second is non-heme iron. Heme iron is better absorbed than non-heme iron. Tannins present in green interact with non-heme iron in the body and affects the absorption of iron. Concentrated green tea products and more than five cups in a day can cause iron deficiency anaemia (Nawab et al., 2015). The galloyl group of poly-phenolic content of green tea bind with non-heme iron and form a complex which decrease absorption of iron which leads anemia (Brune et al., 1979).

Tooth staining

Tooth staining affects the elegant look of the teeth so it the main interest of most of the people to rectify this problem. Tooth staining is of two types: extrinsic and intrinsic. Extrinsic tooth staining occurs due the deposition of chromogenic substances and imparts yellow, brown or green coloration (Vogel et al., 1975). The main cause of tooth staining is deposition of that chromogenic substance from the food or beverages. Saliva forms a protective covering around the teeth which is called acquired pellicle. Acquired pellicle protect the teeth from bacterial attack and direct organic acids (Soniu et al., 1975).

Green tea can cause tooth staining. Tannins present in green tea affects the acquired pellicle of teeth (Hjeljord et al., 1973). Tannins cause denaturation of pellicle proteins and leads to damage of protective layer of teeth. Denaturation of protein exposes the teeth to the tea which cause tooth staining. Studies have evidence that in-vivo studies concluded the tooth staining of tannic acids (Nordbo et al., 1977). High consumption of green tea can cause tooth discoloration due to having tannin content and it can cause dark brown stains on teeth in the presence of magnesium which is called stain promoting agents.

Interaction with drugs

Green tea and their concentrated forms have high consumption because of their several positive effects to the body. Green tea has potential to combat with serious CVS disorders by having different mechanism of action (Chen et al., 2016; Spadiene et al., 2014). Besides the beneficial effects of green tea, various green tea constituents interact with cardiovascular drugs. Rosuvastatin, tacrolimus, nadolol and slidenafil are the drugs which were studied for drug interaction studies.

Hyperlipidemic drugs are used in most CV disorders and statins are the first line drug for hyperlipidemia (Catapano et al., 2016). Catechins have many beneficial effect but some people consume green tea in high amount which increase the risk of drug interactions. A Korean group had studied pharmacokinectics of statin drug in the presence of EGCG (Kim et al., 2017). Two groups of volunteers received rosuvastatin with capsules of EGCG and rosuvastatin alone. Studied showed that EGCG may interferes with the metabolism of drug. Drug was excreted from the body in unchanged form which reflects that EGCG affects the metabolizing enzymes thus decrease the bioavailability of rosuvastatin (Olsson et al., 2002).

Nadolol is a beta-blocker which is used for CV disorders like hypertension, cardiac arrhythmia and in the attack of angina pectoris. Green tea and its byproducts change the pharmacokinetic and pharmacodynamic property of nadolol and decrease its efficacy by affecting t-half (Misaka et al., 2013). Green tea also affects the bioavailability of drug named sildenafil which is used to cure pulmonary hypertension. When drug is given by orally, it is metabolized by CYP450 enzymes in the liver. Catechins present in the green tea suppress the liver metabolizing enzymes like CYP 450. Inhibitory action of green tea is to CYP 450 decrease the bioavailability of sildenafil (Misaka et al., 2013; Satoh et al., 2016). Green tea also disturbs pharmacological action and absorption pattern of various drugs like MAO inhibitors, lithium and adenosine. Green tea is also contraindicated with warfarin due to presence of vitamin K in green tea extract (Emily et al., 2013).

Other health effects

Every 6-8 oz. cup of green tea has 30-60 mg caffeine. When green is taken for the purpose of weight loss usually consumed in high extent. High intake of green tea increases the level of caffeine also. Increase level of caffeine can cause many CNS problems like headache, insomnia, nausea, vomiting and anxiety. Excess consumption of green tea also affects the appetite and may cause diarrhea (Sarma et al., 2009). Besides CNS stimulation, caffeine also cause disturbance in heart rate, increase urination and restlessness.

A case study reported that green may cause pigmented contact chelitis due to the presence of nickel. Green tea bags are made up of nickel and contain 0.03 mg Ni/kg in one bag (Veien et al., 1986). In case study, a 40 year lady complained with dark patches and inflammation on lower lip. She did not have any effects of any topical medications. History showed that lady drinks green tea since last 10 year using tea bags. Study revealed that consumption of tea cause skin disorders which made up of nickel bags. Discontinuation of green tea eradicates the inflammation and pigmentation on lower lip (Lee et al., 2010).

Conclusion

Currently, there is increased trend of consuming green tea as a dietary product. Now a day, people are more concerned about their health and life styles. Green tea is a potent antioxidant that's why it is used to cure many diseases. But major populations in developed countries have no idea about to appropriate uses of green tea. They don't know about the concentration and frequency to use the green tea extract. They use it inappropriate way and blindly. Green tea extract have many beneficial effects on body. But it can cause many serious health issues when used in improper way. Concentrated form and excess consumption of tea in a day can cause serious health problems otherwise green tea have positive effects on our body. In this review we concluded that green tea is a remarkable herbal which gives magnificent results if utilize in proper manner in different ways like proper dosage form, frequency and concentration.

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Conflicts of interest

There are no conflicts of interest.

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