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Green Tea - Its Chemical Constituents and Health Benefits

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***Abstract* - With the rapidly changing lifestyle of the people in the present scenario there is an increase in various metabolic disorders affecting vital organs of the body. The advancement in the food processing sector due to the continuous efforts of the scientists has led to the acceptance of functional foods among the consumer. These Nutraceuticals act both as a food and medicine in the body. Green tea is one such Nutraceuticals which has immense potential in the treatment of several diseases as has been reported by studies. The health benefit of green tea is due to catechin, particularly (-)-epigallocatechin-3-gallate which is reported to have positive impact on the individual. In particular it is a good source of antioxidants and prevents chain reactions which cause cellular damage in the body. In this review paper, there is an elaborate description of green tea, its chemical constituents and the effect of it on several metabolic diseases like obesity, cancer, arthritis and so on.**

1. INTRODUCTION

Green tea is produced without fermentation and undergoes minimal oxidation possible during processing. Traditionally, black tea has been consumed worldwide; but, green tea is attracting more due to its medicinal functions. The tea infusion taste is affected by caffeine, polyphenol, and theanine present in the tea leaves. Quality and type of tea is greatly affected by the degree to which fermentation takes place. Tea is classified into 3 categories: 1st is green tea (unfermented); 2nd is oo-long tea (semi fermented); 3rd is black tea (fully fermented).

Green tea can be the raw material for extracts which are used in different beverages, dietary supplements and also in cosmetic items. Different verities have different functional role due to their culture practises and processing parameters.

2. CHEMISTRY OF GREEN TEA

Green tea mainly constitutes polyphenols, caffeine, amino acids and other nitrogenous compounds, vitamins, inorganic elements, carbohydrate and lipids. The infusion mainly constitutes polyphenols, caffeine, theanine, vitamin etc. Carbohydrate is the major constituent of tea leaf that includes cellulosic fiber and the next is protein, but these components are not soluble.

Polyphenol: tea polyphenols are generally infused with sizzling water or can be extracted with ethyl acetate. The taste of green tea is bitter and astringent due to polyphenol content. The green tea mainly constitute 6 kinds of catechin: (-)-EGCG is found in larger amount and next to this are (-)-EGC,(-)-ECg, (-)-EC are found in decreasing order. Minor components are (+)-GC and (+)-C. Catechins (-)-ECG and (-)-EGCG are ester type and are stronger in bitterness and possess astringent effect more than (-)-EC and (-)-EGC (Graham et al. 1992). Catechin synthesis is done in tea leaves using malonic acid-and shikimic acid-metabolic pathways. During shikimic acid-metabolic pathway an intermediary product is formed and gallic acid is derived from that. A number of papers have been published on the antimutagenic activity, suppressive effect of chromosome aberration, antioxidant activity, depressor effect on renal hypertension, inhibitory effects on arteriosclerosis of green tea polyphenols.

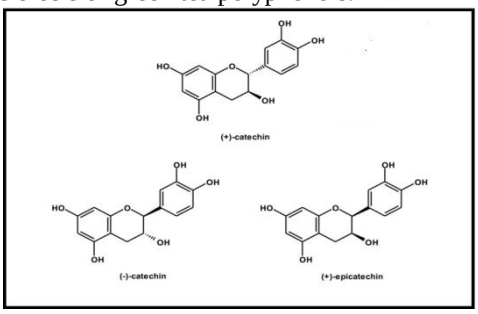

Figure 1 Structures of Different Catechins
(Source: journal.chemistry central.com)

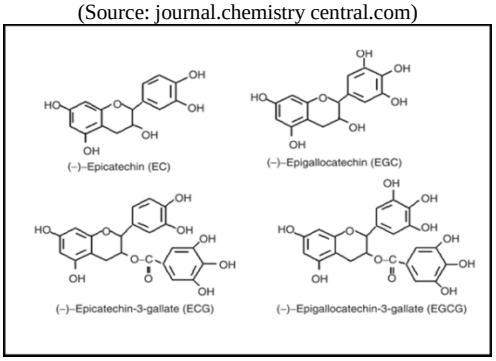

Figure 2 Structures of EC, EGC, ECG, EGCG
(Source: nature.com)

Caffeine: Caffeine is mainly a trimethyl derivative of purine 2, 6-diol and is produced from leaves of the tea plant from the ancient time. Coffee beans contain about 1.5 % caffeine, while caffeine content of green tea is up to 5%. It functions as a cardiac and also as a diuretic. It can also stimulate the cerebral cortex which results in central nervous system excitation. But, for certain people it is the cause for irritation in the gastrointestinal tract and sleeplessness (Np Seeram et al. 2006).

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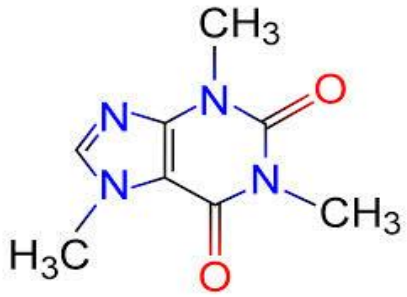

Figure 1 Structure of Caffeine
(Source: Commons.wikimedia.org)

Amino acids and other nitrogenous compounds:
Among total nitrogen found in the green tea infusion, one fifth of them originate from caffeine and related compounds. Other forms of nitrogenous compounds found in tea infusion are amino acids, amides, certain proteins, and nucleic acids. During tea manufacturing most of the proteins are bounded with tannins that make them insoluble. The total nitrogen content in the green tea extracts is 4.5 to 6.0 %, and free amino acids constitute half of it. Major amino acids found in the green tea infusion are Theanine and glutamic acid, and next to that aspartic acid and arginine are found. The amino acid content is found to be more in spring harvested tea leaves than harvested in other seasons (Takeo et al. 1979; Mizuno et al. 1965).

Vitamins: Commercially available green tea is rich in Vitamin C (VC, ascorbic acid) and contains near around 280 mg in 100 g dried leaves whereas oo-long tea and black tea contain less vitamin C because they undergo fermentation process (Chu et al. 1997).

Inorganic elements
In green tea leaves aluminium and fluorine content are found to be more as compared to other plants. It is shown that fluorine has preventive effect against dental caries and this exists as anion form in tea leaves. A number of fluorine compounds are produced by Fluoride anion, they prevent bacterial attack to teeth by covering the surface. Roasted tea at high temperature contains aluminium fluoride complex but not effective against dental caries (Chu and juneja etal. 1997).

Carbohydrates: Green tea contains near about 40% total carbohydrate and cellulosic fiber constitute one third of it. Green tea quality is affected by starch. Starch synthesis starts at dawn and finish with sunset. Therefore starch content in tea leaves significantly varies in a day. Tea harvested in afternoon content more starch as compared to harvested in morning but tea harvested in morning found to be better in terms of quality (Chu and juneja et al. 1997).

Lipid: Oil content of tea leaves is about 4 % by weight. The tea oil is non-drying, and its solidifying temperature is -5 to 15 ^{0}C (Takehiko et al. 1997).

3. HEALTH BENEFIT

Green tea has a numerous health benefit associated with it.

Weight loss: From recent study it has ben observed that catechin has major role in weight loss (Kao et al. 2000). An animal study on mice was performed by feeding different concentration of green tea (1-4 %) in their diet for 4 months. It has been observed that that the mice fed with green tea had a substantial suppression of food intake, gain in body and accumulation of fat tissue and lower level of triglycerides and cholesterol. It has been seen that serum leptin levels was decreased it indicates weight loss. Some of the study suggested that it increases thermogenesis i.e caloric expenditure is increased. This is due to an interaction occurring between catechin polyphenols with caffeine (Dulloo et al. 2000).

Cardiac Health:
Green and black teas are known to be sources of bioactive flavonoids which has high antioxidant activity (Leung et al. 2001). Experimentally it has been seen that some catechins have the property to inhibit a key enzyme (squalene epoxidase) in the pathway of biosynthesis of cholesterol. Theaflavin found two times effective in blocking the enzymatic activity. The green tea extract was rich in theaflavin which is an effective aide to a low-saturated-fat diet to reduce LDL in hypercholesterolemic grownups and was well accepted. Black tea flavonoids do not interfere with the synthesis of CoQ10. Consumption of tea seems to reduce cardiovascular risk. Theaflavin seems to have role in changing total cholesterol, LDLC, HDL and triglyceride (Maron et al. 2003). One Japanese study has been made on the effect of tea consumption on coronary heart diseases. The result shows that green tea was 58% effective against cardiac diseases whereas black tea has a capacity to reduce myocardial infarction by 68% (Imai et al. 1997). One Dutch study made over 15 years stated that risk of heart stroke was reduced by 31% than non-tea drunker (Geleijnse et al. 2002). According to a recent meta-analysis It has been observed that regular consumption of tea (3 or more cups daily) reduces the risk of heart attack (Peters et al. 2001).

Arthritis:
Green tea is rich in polyphenol which seems to have anti-inflammatory properties in animal testing lab (Haggi et al. 1999). One laboratory experiment suggested that it has positive effect on collagen-induced arthritis in mice. The arthritis risk seems to be 33% for the mice induced with polyphenol whereas the risk was 50% in case of mice not given with tea polyphenol. Cyclooxygenase 2, (TNF)-α (tumour necrosis factor), (IFN)-γ (interferon) are known as inflammatory mediators. It has been shown that there is remarkable reduction of the above mention inflammatory mediators in the arthritic joints of the mice which are fed with green tea polyphenols. Another extra benefit was that total IgG and type II collagen-specific IgG levels were found to be lower in the serum and arthritic joints of the mice treated with polyphenol (Haggi et al.1999).

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Bone density:
From one U.K study it has been seen that mean bone mineral density found to be significally greater in amount in case of tea drinkers (Hegarty et al. 2000). It has been concluded that drinking tea also protects from osteoporosis. From one animal study it has been observed that tea is rich in tannins which found to be the cause of decrease in absorption rate of calcium and iron. Both the tea found to be positive in case of manganese and copper absorption (Zeyuan et al. 1998).

Stress and theanine:
An amino acid is present in green tea known as L-theanine. It has tranquilizing effects on brain. Mainly due to the curative properties of green tea it has been used long before (Talbott et al. 2002, Huber et al. 2003). The theanine in later stage converted to catechins. Recent study suggested that L-theanine found to be associated with relaxation feeling. Again L-theanine disaffirms specific effects of catechin. It is associated with alpha wave generation which both relaxes and alerts mental state. One experimental study on women proved that L-theanine has most positive effect on generation of α-waves and categorised in the list of high anxiety subjects (Talbott et al. 2002). It lowers cortisol level so physical stress lowers down. One animal study suggested that theanine is an antihypertensive agent (Zhang et al. 2002). From one study it is found that theanine brings back higher blood pressure to normal level but do not show any effect on normal blood pressure (Yokogoshi et al. 1998; Yokogoshi et al. 1995). It acts as natural relaxant and removes worry, stress and anxiety and helps brain to focus (Huber et al. 2003).

Antiviral properties:
Tea catechins show a defending effect against human immunodeficiency virus (HIV) (Fassina et al. 2002; Yamaguchi et al. 2002).Kawai et al. studied the mechanism of the anti-HIV effect of green tea polyphenols and stated that EGCg (but not ECG) straight binds to the cell-surface CD4 molecules (Kawai et al.2003).

Aniti-carcinogenic Properties
Cancer is a major health problem worldwide. Present scenario reveals that high mortality occurs due to this disease. The main cause associated with cancer is its highly invasive behaviour which helps cancer cells to grow quickly and metastasisis. Green tea contributes to a number of health benefits. It is constitute of polyphenol compounds like (-) Epigallocatechin-3-gallate (EGCG), (−)--epigallocatechin (EGC), (−)-epicatechin-3-gallate and (−)-epicatechin (EC) (Khan et al. 2007). EGCG possess to have high anti-oxidant activity near around 25–100 times more active than vitamins C and E. It is the most potent among all the catechins (Cao et al. 2002). EGCG lowers down one expression of protein which is the causing agent for cancer cells (Khan et al. 2007).

Green tea and metastasis of skin cancer:
Increase in epidemic proportions leads to development of skin cancer. One prodrug known as 3-O-(3,4,5-trimethoxybenzoyl)-(−)-epicatechin (TMECG) is a trimethoxy derivative of ECG was tested against melanoma cells. It has been seen that cellular folate transport and expression of di-hydrofolate reductase was affected by TMECG. It has been observed from one animal experiment that tumor growth and metastasis has been inhibited and mean survival of treated individuals have been significantly increased (Sanchez et al. 2009). A group of mice was injected with human melanoma A2058 cells and treated with a diet constitute of lysine, proline, ascorbic acid, green tea extract and arginine. It has been noticed that the treatment repressed the tumour growth and inhibited MMP-9 and VEGF secretion (Roomi et al. 2006). Animal experiments are usually done on hairless mice (SKH-1) by feeding green tea polyphenol. It has been observed that ultraviolet B induced tumour incidence, tumour multiplicity and tumour growth was reduced. Green tea polyphenol reduced the expression of metalloproteinase (MMP)-2 and (MMP)-9 both of them influences tumor growth and metastasis. CD 31 and vascular endothelial growth factor expression reduced due to the action of green tea polyphenol. It enhanced the expression of proliferating cell nuclear antigen (PCNA), tissue inhibitor of MMP (TIMP) and cytotoxic CD 8(+) T cells. It was concluded that application of green tea polyphenol inhibited angiogenic factors and cytotoxic T cells in tumour environment (Mantena et al. 2005).

Green tea and metastasis of prostate Cancer:
Prostate cancer is one of the well-known non-cutaneous malignancy. Animal studies are done on PCa PC-3 cells with Traditional Botanical Supplement-101 (TBS-101). TBS-101 is a standardised botanical extract of panaxginseng, cranberry, green tea like similar botanical agents. Tumour growth was significantly inhibited in case of mice treated with TBS-101 than control group. High dose of TBS-101 showed no toxicity (Evans et al. 2009).

It has been seen that when EGCG and TRAIL combinable used there was reduction in the activities and expression of MMP-2,-3,-9 and TIMP1 up regulation takes place (Siddiqui et al. 2008). Again it has been proved that green tea polyphenol consumption leads to apoptosis of PCa cells therefore ultimately affects the dissemination of cancer cells. For this reason PCa development and progression inhibited and metastasis of PCa to distant organ sites is blocked (Gupta et al. 2001).

Green tea and metastasis of breast cancer:
Brest cancer is due to the invasive behaviour of breast cancer cells. Recently EGCG treatment was done in breast carcinoma cells. It has been observed that down regulation of epidermal growth factor receptor (EGFR), phosphorylation and m-RNA expression occurs due to treatment of EGCG. Reduction in ERK ½, in vitro cell growth, Phospho-ERK ½, MMP-2, MMP-9 and extra cellular MMP-inducer is noticed whereas TIMP-1 and TIMP-2 found to be increased (Farabegoli et al. 2010). Green tea consumption was treated against stage I, II, III breast cancer. Reduction in number of auxiliary lymph node metastases was found with stage I and II breast cancer premenopausal patients. Expression of estrogen and

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progesterone receptor found to be increased among post meno-pausal patients. From the above experiment it was observed that green tea consumption improves prognosis of stage I and II breast cancer (Nakachi et al. 1998).

Green tea and metastasis of lung cancer:
Lung cancer is one of the major public helath problem. One animal experiment was done on effect of green tea catechin against lung tumor metastasis on mice (SAMP) 10. Natural killer cell activity seems to be increased with increase in intake of green tea catechin. Mice were injected with K1735M2 lung metastatic melanoma cells and subsequent experimental lung metastasis was investigated after treatment with green tea catechin. It has been observed that there was significant reduction in the number of lung metastatic colonies in the catechin treated mice as compared to control group (Shimizu et al. 2010).

EGCG inhibited brochial tumour cells migration in 2D and 3D cell culture models. It also inhibited MMP-2, m RNA and intermediate filaments of vimentin found to be altered (Hazgui et al. 2008). Another animal experiment on Lewis mouse revealed that there is reduction in the number of lung colonies of lung carcinoma cells when treated with green tea catechin (Sazuka et al. 1995). Hence it is proved that green tea has inhibitory effect on lung cancer.

Green tea and metastasis of pancreatic cancer:
EGCG treatment inhibited viability, capillary tube formation and migration of human umbilical vein endothelial cells (HUVECs). One animal study revealed EGCG has inhibitory effect on pancreatic cancer growth, invasion, metastasis and angiogenesis (Shankar et al. 2008). From one experiment it is observed that tumour volume significantly reduced when treated with green tea extract. It proved that green tea had inhibitory effect on the pancreatic carcinogenic process and tumour promotion (Hiura et al. 1997).

Green tea and metastasis of liver cancer:
Liver cancer is known as hepatic cellular carcinoma. It has been observed that EGCG and CG depressed the invasion and migration of hepatocellular carcinoma cells which is otherwise known as SK-Hep-1 cells (Lee et al. 2007). One animal study revealed that liver weight increased 2 times than the normal level because of the injected hepatic metastasis cells in the control group whereas theanine inhibited hepatic metastasis and liver weight found to be near around constant when compared to normal level. Theanine found to be associated with increase in intracellular concentration of doxorubicin remain in ovarian sarcoma cells and theanine enhanced suppressive efficacy of doxorubicin on hepatic metastasis in vivo (Sugiyama et al. 1999).

Green tea and metastasis of colon cancer:
Colon cancer otherwise known as colorectal cancer is one of the most deadly cancer. Human colon cancer cell lines HCT 116 and HT29 were examined against relationship between Met activation, EGCG treatment and generation of H_2O_2. MET activaton was occurred by EGCG. It is concluded from the experiment that EGCG is a beneficial therapeutic agent in the colon, inhibits Met signalling, and acts against tumour spread and independent of H_2O_2 related mechanism (Larsen et al. 2009). It has been observed that EGCG-induced pro-MMP-7 production was byN-Acetyl -L-cyst eine, superoxide (O_2^-) dismutase and catalase, suggesting an involvement of oxidative stress in these events. EGCG treatment also induced pro-MMP-7 expression in human colorectal adenocarcinoma Caco-2 cell line (Kim et al. 2005).
Polyphenol compound found in green tea is a treasure with respect to medicinal aspects but they are prone to degradation under normal environmental conditions. So it is essential to encapsulate the compound and not to expose to ordinary environment. Liposome is an excellent way to encapsulate the green tea because it was stable and can be prepared easily.

4. CONCLUSION

The potential of green tea as a preventive measure in several metabolic diseases has led to its use as a Nutraceuticals. The presence of polyphenols in it is responsible for its medicinal effect. Various studies of green teas and trials on animal models have shown positive impact of it in the prevention of diseases like cancer, arthritis and several others. Instead there is a need of prolonged and long term research work and study on the impact of green tea in various metabolic diseases. Also work has to be done in order retain its functional component i.e. polyphenols as its original form since it starts degrading under normal environmental situations so the packaging of it has to be proper. Since black tea is very popular usually in Asian countries which is usually consumed by the people of all the sections of the society; henceforth proper research in the field of green tea also can lead to its wider acceptance in the society and thus can prevent these major diseases which is taking the lives of several people in the world. Finally the food processing sector must try to process green tea in a way that can enhance shelf life and also retain its natural aroma and flavour.

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