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Review Article

Therapeutic Properties of Green Tea: A Review

Sonia Ratnani and Sarika Malik*

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Abstract
The most consumed beverage in the world is tea after water. Till today the consumption of black tea is 70% while that of green tea is only 20%. One reason for this percentage is lack of awareness about green tea and invested research. Green tea along with caffeine which imparts characteristic taste, bitterness and stimulating effect, is also rich in a group of chemicals, called catechin polyphenols (commonly known as tannins, which contribute to bitter taste and astringency) and deliver antioxidant properties. Furthermore, green tea also comprises of amino acids such as theanine along with alkaloids such as adenine, dimethylxanthine, theobromine, theophylline and xanthine. Some vitamins, like vitamin A, vitamin B1, vitamin B2, vitamin B3, vitamin C, and vitamin E are also found in green tea. The present review gives the study of various constituents of green tea and their impact on human health. Studies provide strong evidence that owing to antioxidant properties daily intake of green tea may be used as a preventive measure for different types of cancer and other diseases. This review gives a detailed analysis of constituents of green tea and highlighting it's potential as a natural nutraceutical. However, although much of the documented literature mentions positive effect yet much had to be explored on correlation between concentration of green tea and toxicity.

Keywords: green tea, polyphenols, human health, antioxidant

1. INTRODUCTION

Our health is wrapped in our lifestyle and genes today, thus, no food can protect us from diseases except our care and attention. Nowadays tea is considered to be second most consumed beverage in the world [1]. During last few years green tea has gained lot of importance as a beverage owing to its health benefits. Recent studies have shown that green tea helps in improving blood vessels hence lower the cholesterol and reduce the risk of cardio vascular diseases [2]–[5]. MRI's reveal that drinking green tea have greater activity and can enhance our brain's cognitive functions, particularly the working memory [6]. Green tea helps in controlling the levels of blood sugar in people suffering from diabetes [7]. It blocks the formation of plaque related to Alzheimer diseases [8][9]. It is found as fat burning supplement as it increases fat burning and boost the metabolic rate in human controlled trial. Most important due to presence of antioxidants it helps in lowering the risks of various type of cancer. These benefits have resulted in discussion which focus on the dietary guidance and recommended drinking for green tea [10]. Through available research it is an attempt to depict the health benefits of green tea. The aim of this review is to provide information and evidence pertaining to health benefits obtained from consumption of green tea with special reference to cancer diseases.

2. GREEN TEA: HISTORICAL PERSPECTIVE

Green Tea is one of the healthiest beverages originated from China more than 4000 years ago and has been used in traditional Chinese medicine for a wide variety of health benefits [11]. It comes from the steamed and dried leaves of the *Camella sinesis* plant. The plant originates from China and also produces black tea, oolong tea and several other varieties of tea through different processing methods. Green tea is made by harvesting the plant leaves, withering them and then steaming them. Steaming halts, the process of enzymatic oxidation– which causes the darkening of the tea leaves – and allowed the leaves to remain closer to their natural "green" state. This indicates that it goes through minimal oxidation during processing which possess powerful oxidants. The real history of green tea dates back to the 8th century, when the method of steaming the leaves to inhibit their oxidation was discovered. In the 12th century a new frying method of "fixing" the leaves was introduced. Both

Figure 1. Green tea plant.

of these processes resulted in teas that have the characteristic un-oxidized taste and appearance to modern green teas, and both processes are still in use today. Since those early days, as the popularity and production of green tea increased the methods of producing green tea have continuously evolved and improved.

2.1 Plant Description

Green, black, and oolong tea are all derived from the leaves of the *C. sinensis* plant. Originally cultivated in East Asia, this plant grows as large as a shrub or tree (Figure 1) [12][13]. Today, *C. sinensis* grows throughout Asia and parts of the Middle East and Africa.

People in Asian countries more commonly consume green and oolong tea while black tea is the most popular drink in the United States. Green tea is prepared from unfermented leaves, the leaves of oolong tea are partially fermented, and black tea is fully fermented. The more the leaves are fermented, the lower the polyphenol content and the higher the caffeine content. Green tea has the highest polyphenol content and 2-3 times less caffeine content then black tea.

2.2 Doses

Pediatric, Green tea has not been studied in children, so it is not recommended for pediatric use. *Adult,* depending on the brand, 2 to 3 cups of green tea per day (for a total of 240 to 320 mg polyphenols) or 100 to 750 mg per day of standardized green tea extract is recommended.

3. CHEMICAL COMPOSITION

Green tea mainly consists of mainly polyphenols (~90%), amino acids (~7%), theanine, proanthocyanidins, and caffeine (~3%). Among the different polyphenols, catechins and flavonols (myricetin, caempherol, quercetin, chlorogenic acid, coumarylquinic acid, and theogallin) form the major constituents (Figure 2) [14].

3.1 Polyphenols (Catechins and Flavanols)

About 30% of the leaves by weight are flavanols which comprise mainly of catechins (derives its name from Indian plant *Acacia catechu* (a tree of Fabaceae family, Acaria genes) from which it is isolated). Green tea comprises of catechin (C), epicatechin (EC), gallocatechin (GC), epigallocatechin (EGC), epicatechin gallate (ECG), epigallocatechin gallate (EGCG), and gallocatechin gallate (GCG) as the major catechins [15][16]. Green tea hence is considered to be principal source of catechins among various dietary sources [17]. These are mainly responsible for the astringency component in green tea. Among all catechins the four primary catechins EC, EGCG, ECG, and EGC form 80% of the total catechins (Figure 3) [18]. All these catechins similar properties while EGCG appears to be most potent catechin and accounts for 50—80% of the total catechins followed by EGC (9 –12%), ECG (9–12%) and EC (5–7%) [19].

Chemically catechins are polyphenolic compounds with diphenyl propane skeleton. The chemical structure consists of a polyphenolic ring condensed with six-membered oxygen containing heterocyclic ring that carries another polyphenolic ring at the 2 position. Catechins are characterized by multiple of hydroxyl groups on the A and B rings. EC is an epimer containing two hydroxyl groups at 3′ and 4′ position of B ring and a hydroxyl group at 3 position of the C ring [20]. The only structural difference between EGC and EC is that EGC possesses an additional hydroxyl group at 5′ position of the B ring. ECG and EGCG are ester derivatives of EC and EGC, respectively, through esterification at 3 hydroxyl position of the C ring with a gallate moiety (Figure 3) [21][22].

According to the European Food Safety Authority (EFSA), 126 mg of catechins are present in per 100 mL of green tea. Meanwhile, according to the Food and Drug Administration (FDA), 71 mg of epigallocatechin gallate will be present in per 100 mL of green tea [23].

3.2 Alkaloids

Leaves of green tea primarily contain alkaloids including caffeine, theobromine, and theophylline. They provide green tea's stimulant effects. Amount of caffeine (2—5%) in tea leaves depends on the age of the leaf with younger leaves to have it in high concentration [24].

3.3 Amino Acids

15—20% of dry weight of tea comprises of proteins in enzymes that constitute an important fraction of amino acids (1—4% dry weight) such as theanine or 5-*N*- ethylglutamine, glutamic acid, tryptophan, glycine, serine, aspartic acid, tyrosine, valine, leucine, threonine, arginine, and lysine. L-theanine has been studied for its calming effects on the nervous system.

3.4 Carbohydrates

5-7% dry weight of green tea comprise of carbohydrates which include cellulose, pectins, glucose, fructose, and sucrose.

3.5 Vitamins and Minerals

Vitamin content of green tea is higher than other drinks which thus make it superior. It comprises of important vitamins such as vitamin B_2, vitamin C, vitamin E and folic acid. Minerals are important as they act as bodily regulators. The approximate composition of minerals in tea is 5—7% as elements such as potassium (K), calcium (Ca), phosphorus (P), and magnesium (Mg), as well as small quantities of manganese (Mn), zinc (Zn) and copper (Cu).

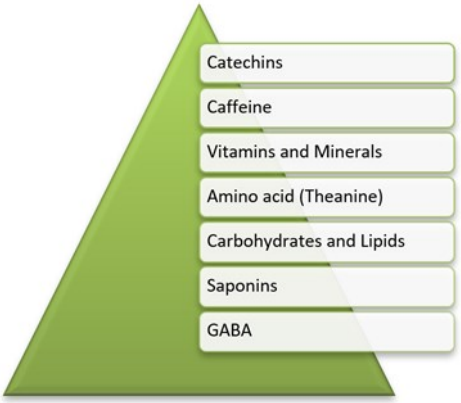


Figure 2. Chemical composition of green tea.

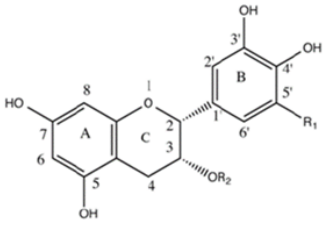
3.6 Lipids

Small amounts of lipids such as linoleic and α-linolenic acids also constitute green tea. The non-drying oil content of green tea leaves is 4% by weight with a solidifying temperature of around -5 to 15 °C [25].

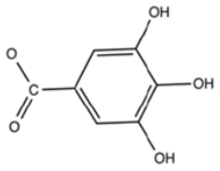
The composition of various constituents present in green tea varies with genetic strain, climatic conditions, soil properties, plucking season, position of leaf, processing and storage. Analysis and evaluation of components of green tea is needed to assess the potential benefits and risks associated with green tea. Researchers think the health properties of green tea are mostly due to polyphenols, chemicals with potent antioxidant potential. In fact, the antioxidant effects of polyphenols seem to be greater than vitamin C. The polyphenols in green tea also give it a somewhat bitter flavor.

4. HEALTH BENEFITS OF GREEN TEA

Tea catechins have been largely studied for their



Main catechin structure



Gallate group

	R1	R2
EC	H	H
EGC	OH	H
ECG	H	Gallate group
EGCG	OH	Gallate group

Figure 3. Different forms of Catechins.

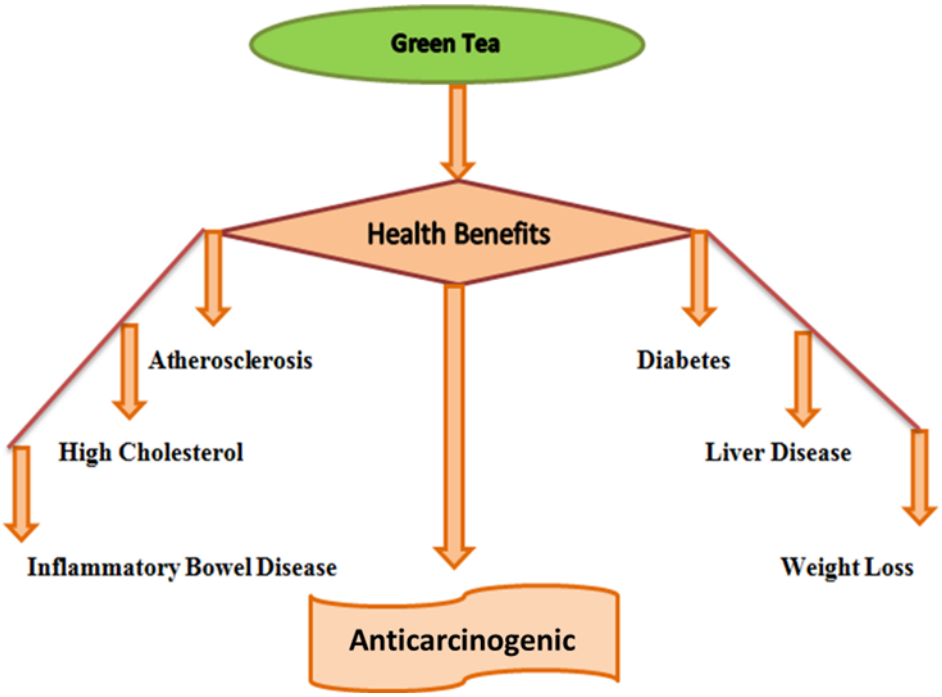


Figure 4. Health benefits of green tea.

antioxidant capacities and considered as important antioxidants. The antioxidant effects of catechins are presumed to play a major role in mediating the cardioprotective role of tea, although emerging evidence shows that catechins also have antioxidant -independent vascular effects, which will be discussed elsewhere in this review. Green tea catechins can exert both direct and indirect antioxidant effects on cardiovascular system. Catechins present antioxidant activity through scavenging reactive oxygen species (ROS), chelating redox active transition- metal ions, inhibiting redox sensitive transcription factors, inhibiting pro-oxidant enzymes and inducing antioxidant enzymes. Green tea intake lowers fasting serum total and LDL (low density lipid) cholesterol in adults: a meta-analysis of 14 randomized controlled trials.

In traditional Chinese and Indian medicine, practitioners used green tea as a stimulant, a diuretic (to get rid of the body of excess fluid), an astringent (to control bleeding and help heal wounds), and to improve heart health. Other traditional techniques use of green tea include treating gas, regulating body temperature and blood sugar, promoting digestion, and improving mental processes [26]–[29].

Green tea has been extensively studied in people, animals, and laboratory experiments. Results from these studies suggest that green tea may help treat the following health conditions (Figure 4).

4.1 Cancer

Several population-based studies suggest that both green and black teas help in protecting against some cancers hence it has potent anticarcinogenic behavior [30]–[37]. For example, the cancer rates tend to be low in countries such as Japan where people regularly consume green tea. However, it is not possible to be sure of these studies results whether green tea actually prevents cancer in people. Early clinical studies suggest that the polyphenols in tea, especially green tea, may play an important role in the prevention of cancer. Researchers also believe that polyphenols help killing the various cancerous cells in human being.

4.1.1 Bladder Cancer

Medical and healthcare system have defined complementary and alternative medicine (CAM) as an approach for patients suffering from bladder cancer. One of these strategies mentions intake of green tea and green tea polyphenols (GTP's) [38]. In one study that compared people with and without bladder cancer, researchers found that women who drank black tea and powdered green tea were less likely to develop bladder cancer. A follow-up clinical study by the same group of researchers revealed that people with bladder cancer,

particularly men, who drank green tea had a better 5 -year survival rate than those who did not drink green tea. People with cancer should consult with their doctor before adding tea to their daily diet.

4.1.2 Breast Cancer

It has been observed in laboratory test tube and animal studies that EGCG is responsible for inhibiting the growth of breast cancer cells. Numerous studies have investigated the therapeutic effects of green tea on breast cancer using different rodent models with a range of green tea products including green tea mixtures as well [29]. In a study of 472 women with various stages of breast cancer, researchers found that women who drank more green tea had the least cancer spread. It was especially true in premenopausal women in the early stages of breast cancer. They also found that women with early stages of the disease who drank at least 5 cups of tea daily before being diagnosed with cancer were less likely to experience a recurrence after they finished treatment. However, women with late stages of breast cancer had little or no improvement from drinking green tea.

There is no clear evidence about green tea and breast cancer prevention. In one very large study, researchers found that drinking tea, green or any other type, was not associated with a reduced risk of breast cancer. However, when the researchers broke down the sample by age, they found that women under the age of 50 who consumed 3 or more cups of tea per day were 37% less likely to develop breast cancer compared to women who did not drink tea. For more evidence additional studies are required to elucidate the potential risk and associated mechanisms of action.

4.1.3 Ovarian Cancer

In a study done with ovarian cancer patients in China, researchers found that women who drank at least one cup of green tea per day lived longer with the disease than those who did not drink green tea. In fact, those who drank the most tea, lived the longest. However, other studies found no beneficial effects [39].

4.1.4 Colorectal Cancer

There are conflicting results on the effect of green tea on colorectal cancer. Some studies indicate decreased risk on consumption of tea, while others show increased risk. In one of the study, women who consumed more than five cups of green tea per day faced a lower risk of compared to non-green tea drinkers. However, studies in women show that regular consumption may reduce the risk of colorectal cancer [40].

4.1.5 Esophageal Cancer

Studies in laboratory animals have found that green tea polyphenols inhibit the growth of esophageal cancer cells. However, studies in people have produced conflicting findings. For example, one large-scale population-based study found that green tea offered protection against the development of esophageal cancer, particularly among women. Another population-based study found just the opposite; green tea consumption was associated with an increased risk of esophageal cancer. In fact, the stronger and hotter the tea, the greater the risk. A number of epidemiologic studies have investigated the influence of consumption of green tea on the risk of esophageal cancer [41]. Given these conflicting results, more research is needed before scientists can recommend green tea for the prevention of esophageal cancer.

4.1.6 Lung Cancer

While green tea polyphenols have been shown to

Table 1. Possible mechanisms for the anti-carcinogenic activity of green tea.

No	Green Tea Component		Possible Mechanism for Anti-carcinogenic Activity
1	Catechins	EC	Anti-inflammatory Attenuation of oxidative stress Induction of apoptosis Inhibition of RTK's activation Inhibition of angiogenesis Anti-metabolic syndrome
2		EGC	
3		ECG	
4		EGCG	

Table 2. Effect of the treatment with green tea for 30 days on the lipid profile of hypercholesterolemic patients.

No	Days	Cholesterol (mg/dL)	LDL (mg/dL)
1	0	270 ± 21.8	184 ± 17.1
2	15	196 ± 30.0	110 ± 21.9
3	30	247 ± 20.8	167 ± 16.3
4	60	278 ± 19.1	166 ± 20

inhibit the growth of human lung cancer cells in test tubes, few clinical studies have looked at the link between drinking green tea and lung cancer in people, and the studies that have been done show conflicting results. One population-based study found that Okinawan tea, similar to green tea but partially fermented, was associated with lower lung cancer risk, particularly among women. But a second study found that green tea and black tea increased the risk of lung cancer. More studies are needed before researchers can draw any conclusions about green tea and lung cancer. Green tea should not be used by patients on bortezomib therapy [42].

4.1.7 Pancreatic Cancer

In one large-scale clinical study researchers compared green tea drinkers with nondrinkers and found that those who drank more tea was less likely to develop pancreatic cancer. This was particularly true for women, those who drank more green tea were half as likely to develop pancreatic cancer as those who drank less tea. Men who drank more tea were 37% less likely to develop pancreatic cancer. However, it is not clear from this population-based study whether green tea is solely responsible for lowering pancreatic cancer risk [43]. More studies are needed before researchers can recommend green tea for the prevention of pancreatic cancer.

4.1.8 Prostate Cancer

Laboratory studies have found that green tea extracts prevent the growth of prostate cancer cells in test tubes. A large clinical study in Southeast China found that the risk of prostate cancer went down with increasing frequency, duration, and quantity of green tea consumption. However, both green and black tea extracts also stimulated genes that cause cells to be less sensitive to chemotherapy drugs. People who are undergoing chemotherapy should ask their doctors before drinking green or black tea or taking tea supplements [44].

4.1.9 Skin Cancer

The main polyphenol in green tea is EGCG. Scientific studies suggest that EGCG and green tea polyphenols have anti-inflammatory and anticancer properties that may help prevent the development and growth of skin tumors. Hence it is work as anti-carcinogenic agent [45]–[47]. Its anti-carcinogenic activity due to some mechanistic effect is summarized in Table 1 [35].

4.2 Atherosclerosis

Population-based studies indicate that the antioxidant properties of green tea may help prevent atherosclerosis, particularly coronary artery disease [48]. Population-based studies are studied large groups of people over time and compared their living in different cultures and diets. Researchers believe green tea reduces the risk of heart disease by lowering cholesterol and triglyceride levels. Studies show that black tea has similar effects. In fact, researchers estimate that the rate of heart attack decreases by 11% with consumption of 3 cups of tea per day.

4.3 High Cholesterol

Research shows that green tea lowers total cholesterol and raises HDL cholesterol in both animals and people. One population-based study found that those who drink green tea are more likely to have lower total cholesterol than those who do not drink green tea. Results from one animal study suggest that polyphenols in green tea may block cholesterol from being absorbed in the intestine and also help the body get rid of cholesterol. In another small study of male smokers, researchers found that green tea significantly

reduced blood levels of harmful LDL cholesterol shown in Table 2 [21][49].

4.4 Diabetes

Green tea has been used traditionally to control blood sugar levels. Animal studies suggest that green tea may help to prevent the development of diabetes (type-1) and slow the progression once it has developed. In people with diabetes (type-1), their bodies make little or no insulin, which helps convert glucose or sugar into energy. Green tea may help regulate glucose in the body. Research also suggests that regular consumption of green tea may help manage diabetes (type-2) [50].

4.5 Liver Disease

Population-based studies have shown that those who drink more than 10 cups of green tea per day are less likely to develop liver problems. Green tea also seems to protect the liver from the damaging effects of toxic substances such as alcohol. Animal studies have shown that green tea helps protect against liver tumors in mice. It is important to note that 10 cups of green tea a day could cause problems due to high levels of caffeine [51].

Results from several animal and human studies suggest that catechins, may help treat viral hepatitis, an inflammation of the liver. In these studies, catechin was used by itself in very high amounts.

4.6 Weight Loss

Clinical studies suggest that green tea extract may boost metabolism and help burn fat. One study found that the combination of green tea and caffeine improved weight loss and maintenance in people who were overweight and moderately obese [52]. Studies shows consumption of green tea lowers LDL but not HDL cholesterol and leads to weight loss.

4.7 Other Uses

Preliminary studies suggest that drinking green tea can help prevent various diseases and improves health of living creatures [17][53]–[65]. It may also be useful in inflammatory diseases, such as arthritis. Research suggests that green tea may help arthritis by reducing inflammation and slowing the breakdown of cartilage. Chemicals in green tea may help treat genital warts, treat dermatologic conditions, and prevent symptoms of colds and flu. Green tea may play a role in preventing Parkinson disease, cognitive decline, and osteoporosis. It also works on various microorganisms and prevents various antimicrobial disease [15]. Studies also show that drinking green tea influences psychopathological function, cognition and brain function of human being [66].

Its activity for antiphotoaging, stress resisting,

Table 3. Possible interaction of medication with consumed green tea.

No	Medication	Purpose of Medication	Possible Effect(s) with Consumed Green Tea
1	Adenosine	For irregular unstable heart-beat	Inhibit the action of adenosine
2	Beta-Lactum	Antibiotic	Makes bacteria less resistant
3	Benzodiazepines	Anxiety	May reduce the sedative effect
4	Chemotherapy	Cancer	Less sensitive to drugs
5	Monoamine Oxidase Inhibitors	Depression	Increase in blood pressure
6	Quinolone Antibiotics	Antibiotic	Increase the risk of side effects

neuroprotection and autophagy is also very well studied [14]. The composition of green tea preparations that most closely reflects that of a traditional infusion is safe. Preparations based on concentrated extracts or containing high levels of individual constituents, EGCG, may require health-based guidance values to assure their safe use [10].

5. SAFETY AND TOXICITY

The use of herbs is a time-honored approach to strengthening the body and treating disease. However, herbs contain active substances that can trigger side effects and interact with other herbs, supplements, or medications. For these reasons, people should take herbs with care, under the supervision of a practitioner knowledgeable in the field of botanical medicine [67].

People with heart problems or high blood pressure, kidney problems, liver problems, stomach ulcers, and psychological disorders, particularly anxiety, should not take green tea. Pregnant and breastfeeding women should also avoid green tea [68].

People with anemia, diabetes, glaucoma, or osteoporosis should ask their health care provider before drinking green tea or taking an extract. People who drink large amounts of caffeine, including caffeine from green tea, for long periods of time may experience irritability, insomnia, heart palpitations, and dizziness. Caffeine overdose can cause nausea, vomiting, diarrhea, headaches, and loss of appetite [69].

Medications for treatment such as adenosine, beta-lactum, benzodiazepines, beta-blockers, and proponal. can interfere and cause adverse effects. Following Table 3 gives the possible interaction of medication with consumed green tea [70].

As reported, ingestion of excess green or associated preparations can cause one of the most detrimental effects as hepatotoxicity [71][72]. As published an intake amount of EGCG from 140 mg to~ 1000 mg/day is associated with hepatotoxicity and substantial inter-individual variability in susceptibility due to genetic factors. These findings have resulted in a cautionary labelling requirement in Powdered Decaffeinated Green Tea Extract which mentions as “Do not take on an empty stomach. Take with food. Do not use if you have a liver problem and discontinue use and consult a healthcare practitioner if you develop symptoms of liver trouble, such as abdominal pain, dark urine, or jaundice (yellowing of the skin or eyes) [10][73].

6. CONCLUSIONS

The present review has discussed the positive and negative impact of green tea on human health. Though studies have provided enough evidence for favorable effects related to heart diseases, cholesterol, blood fats, endometrial cancer, ovarian cancer and high blood pressure. However, there is insufficient evidence for blood disorders, bladder, colon, breast and cervix cancer and other ailments. Studies which report conflicting results may be presumed due to perplexing factors such as countable consumption, temperature, race, sex, age, lifestyle and genetic history. More attempts for clarification are still required to establish the reported effects.

AUTHOR INFORMATION

Corresponding Author

Sarika Malik — Chemistry Department, Ramjas College, University of Delhi, Delhi-110007 (India);
Email: sarikamalik@ramjas.du.ac.in

Author

Sonia Ratnani — Chemistry Department, Ramjas College, University of Delhi, Delhi-110007 (India);

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