International Journal of Pharmaceutical Drug Design (IJPDD)
Website: https://ijpdd.org/
ISSN: 2584-2897
Vol. 2, Issue 6, June, 2025
Page No.: 92-104

Review

Therapeutic Promise and Toxicological Concerns of Tea and Coffee Consumption: A Systematic Evaluation of Their Roles in Cancer Prevention, Cardiovascular Protection, and Age-Related Degenerative Diseases

Neha Singh[1], Tanmay Ghosh[2], Shital Mahendra Sonawane[3], Sudhahar Dharmalingam[4], Abitha.H[5], Geethanjaly N. S.[6], P.G. Manoj Kumar[7], Yash Srivastav[8], Mithilesh Kumar[*9]

[1]Assistant Professor, Department of Pharmaceutical Chemistry, Axis Institute of Pharmacy, Kanpur, Uttar Pradesh, India
[2]Assistant Professor, Department of Microbiology, Dinabandhu Andrews College, Baishnabghata, South 24 Parganas, Kolkata, West Bengal, India
[3]Assistant Professor, Department of Pharmaceutics, Swami Vivekanand Sansthas Institute of Pharmacy, D.pharmacy. Mungase Malegaon Nashik Maharashtra India
[4]Professor & Head, Department of Pharmaceutical Chemistry and Analysis, Nehru College of Pharmacy (affiliated to Kerala University of Health Sciences, Thrissur)
Pampady, Nila Gardens, Thiruvilwamala, Thrissur Dist, Kerala, India
[5,6]Associate Professor, Department of Pharmaceutical Chemistry, Nehru College of Pharmacy (affiliated to Kerala University of Health Sciences, Thrissur), Pampady, Nila Gardens, Thiruvilwamala, Thrissur Dist, Kerala, India
[7]Associate Professor, Department of Pharmaceutics, Sri Venkateswara College of Pharmacy (Autonomous), Chittoor, Andhra Pradesh, India
[8]Assistant Professor, Department of Pharmacy, Shri Venkateshwara University, Gajraula, Uttar Pradesh, India
*[*9]Assistant Professor, Faculty of Pharmacy, Kamla Nehru Institute of Management and Technology, Sultanpur, Uttar Pradesh, India*

Corresponding Author:
Mithilesh Kumar

Email:
mithilesh012@gmail.com

DOI: *10.62896/ijpdd.2.6.12*

Conflict of interest: *NIL*

Article History
Received: 12/05/2025
Accepted: 13/06/2025
Published: 17/06/2025

Abstract:
Tea and coffee are among the most widely consumed beverages worldwide, offering not only sensory enjoyment but also potential health benefits due to their rich content of bioactive compounds such as catechins, chlorogenic acids, and caffeine. This review systematically evaluates their dual role—both therapeutic and toxicological—highlighting their contributions to cancer prevention, cardiovascular health, and the mitigation of age-related neurodegenerative diseases. Evidence from epidemiological studies, in vitro and in vivo research, and clinical trials suggests that tea and coffee exhibit antioxidant, anti-inflammatory, and neuroprotective activities through diverse mechanisms, including modulation of gene expression and cellular signaling pathways. However, excessive consumption or poor processing methods can lead to adverse effects such as caffeine toxicity, iron malabsorption, and exposure to contaminants like acrylamide and mycotoxins. Factors such as beverage type, preparation method, genetic polymorphisms, and lifestyle significantly influence the risk–benefit profile. Comparative analysis underscores the importance of individualized consumption strategies. The review also identifies research gaps, especially in long-term randomized controlled trials and bioavailability studies, to better understand the health implications of tea and coffee intake.

Keywords: Tea, Coffee, Polyphenols, Caffeine, Cancer Prevention, Cardiovascular Protection, Neurodegeneration, Toxicology, Antioxidants, Bioactive Compounds

International Journal of Pharmaceutical Drug Design (IJPDD)
Website: https://ijpdd.org/
ISSN: 2584-2897
Vol. 2, Issue 6, June, 2025
Page No.: 92-104

1. Introduction

Tea and coffee are among the most widely consumed beverages globally, embedded deeply within diverse cultural, social, and economic frameworks. According to global consumption reports, billions of cups of these beverages are consumed daily, with coffee being particularly popular in Western countries and tea holding a dominant place in many Asian nations (Statista, 2023; International Coffee Organization, 2022). Their popularity is not merely due to taste or tradition, but also because of their perceived health benefits and stimulating effects, primarily attributed to their bioactive constituents.

The phytochemical profiles of tea and coffee are rich and complex. Tea, particularly green and black varieties, is abundant in catechins such as epigallocatechin gallate (EGCG), theaflavins, flavonoids, and L-theanine, while coffee contains high levels of chlorogenic acids, diterpenes like cafestol and kahweol, and caffeine (Cabrera et al., 2006; Butt & Sultan, 2011). These bioactive compounds are associated with a range of biological effects, including antioxidant, anti-inflammatory, and neuroprotective properties. Caffeine, common to both beverages, acts as a central nervous system stimulant, contributing to enhanced alertness and cognitive function (Nehlig, 2016).

Despite the mounting evidence supporting the therapeutic potential of tea and coffee, concerns regarding their safety profiles have also emerged. Issues such as caffeine-related anxiety, insomnia, cardiovascular overstimulation, and potential exposure to harmful substances like acrylamide, heavy metals, and mycotoxins during processing cannot be ignored (Jinap & Tan, 2011; Tardiff et al., 2006). Additionally, the effects of these beverages may vary based on genetic polymorphisms in caffeine metabolism, the preparation methods, and individual tolerance levels.

Given the dualistic nature of these beverages—as both potentially protective and possibly harmful agents—this review seeks to systematically evaluate their roles in three major health domains: cancer prevention, cardiovascular protection, and the mitigation of age-related degenerative diseases such as Alzheimer's and Parkinson's. The scope of this review encompasses an integrative examination of experimental, clinical, and epidemiological data, with a focus on both the therapeutic promise and toxicological risks of regular tea and coffee consumption.

2. Bioactive Components and Mechanisms of Action

2.1. Major Constituents in Tea

Tea, particularly green, black, and oolong varieties, is a rich source of polyphenolic compounds that contribute significantly to its health-promoting properties. Among these, catechins such as epigallocatechin gallate (EGCG), epicatechin gallate (ECG), and epicatechin (EC) are predominant in green tea (Cabrera et al., 2006). EGCG is considered the most bioactive, known for its potent antioxidant and anti-cancer effects.

In black tea, fermentation transforms catechins into complex polyphenols such as theaflavins and thearubigins, which also possess antioxidant and anti-inflammatory properties (Leung et al., 2001). These compounds help in scavenging free radicals and may contribute to cardiovascular protection.

In addition to polyphenols, tea contains caffeine, a stimulant that enhances mental alertness and energy levels. L-theanine, an amino acid unique to tea, promotes relaxation without drowsiness and may modulate the stimulating effects of caffeine (Bryan, 2008). Tea also provides flavonoids that support vascular function and offer general antioxidant benefits. Table 1 presents the key bioactive constituents in various types of tea and their associated health benefits.

Table 1. Major Bioactive Constituents in Tea and Their Health Benefits

Constituent	Source (Tea Type)	Health Benefits	Reference
EGCG (Epigallocatechin gallate)	Green tea	Antioxidant, anticancer, cardiovascular protection	Cabrera et al., 2006
ECG (Epicatechin	Green tea	Antioxidant,	Cabrera et al., 2006

gallate)		neuroprotective	
Theaflavins	Black tea	Antioxidant, anti-inflammatory, lipid-lowering	Leung et al., 2001
Thearubigins	Black tea	Free radical scavenging, anti-mutagenic	Leung et al., 2001
Caffeine	All types	CNS stimulation, enhanced alertness	Nehlig, 2016
L-theanine	Green and black tea	Relaxation, anxiety reduction, cognitive modulation	Bryan, 2008
Flavonoids	All types	Vascular protection, antioxidant activity	

2.2. Major Constituents in Coffee

Coffee is chemically complex, containing over a thousand bioactive compounds. Among the most studied are chlorogenic acids (CGAs), a group of polyphenols with significant antioxidant, anti-inflammatory, and anti-diabetic properties (Farah & de Paulis, 2015). CGAs may also play a role in modulating glucose metabolism and blood pressure.

Caffeine is the most abundant alkaloid in coffee and acts as a central nervous system stimulant. It enhances cognitive performance, alertness, and physical endurance (Nehlig, 2016). However, excessive intake can lead to adverse effects such as insomnia and anxiety.

Diterpenes, specifically cafestol and kahweol, are present in unfiltered coffee (e.g., French press, boiled coffee). These compounds exhibit anti-carcinogenic potential but may also raise serum cholesterol levels if consumed in large amounts (Urgert & Katan, 1997). Table 2 summarizes the major bioactive compounds in coffee and their potential physiological impacts.

Table 2. Major Bioactive Constituents in Coffee and Their Health Benefits

Constituent	Source (Coffee Type)	Health Benefits	Reference
Chlorogenic acids	Roasted and green coffee	Antioxidant, anti-inflammatory, blood pressure regulation	Farah & de Paulis, 2015
Caffeine	All coffee types	Cognitive enhancement, metabolic stimulation	Nehlig, 2016
Cafestol	Unfiltered coffee (French press, boiled)	Anti-carcinogenic, raises serum cholesterol	Urgert & Katan, 1997
Kahweol	Unfiltered coffee	Antioxidant, liver protection, anti-mutagenic	Urgert & Katan, 1997

2.3. Mechanisms of Action

The bioactive compounds in tea and coffee exert their health effects through several interrelated mechanisms:

- **Antioxidant Activity**: Both tea catechins and coffee polyphenols neutralize reactive oxygen species (ROS), protecting cellular components from oxidative stress-induced damage. EGCG and CGAs are particularly potent antioxidants (Cabrera et al., 2006; Farah & de Paulis, 2015).
- **Anti-inflammatory Pathways**: These compounds modulate inflammatory responses by inhibiting nuclear factor-kappa B (NF-κB) and cyclooxygenase (COX) pathways, thereby reducing the

production of pro-inflammatory cytokines (Chen et al., 2004).

- **Modulation of Gene Expression**: Epigenetic regulation by polyphenols can influence the expression of genes involved in carcinogenesis, apoptosis, and cell cycle control. EGCG and caffeine have been shown to modulate microRNA expression and DNA methylation patterns (Steele et al., 2010).
- **Cellular Signaling Pathways**: Bioactive compounds in tea and coffee influence pathways such as PI3K/Akt, MAPK, and AMPK, which are critical in cellular metabolism, growth, and survival (Wang et al., 2014).

Table 3 illustrates the molecular mechanisms through which tea and coffee constituents exert protective effects in chronic diseases.

Table 3. Mechanisms of Action of Tea and Coffee Bioactives

Mechanism	Bioactive Agents	Physiological Effects	Reference
Antioxidant activity	EGCG, chlorogenic acids, theaflavins	Neutralization of ROS, prevention of lipid peroxidation	Cabrera et al., 2006; Farah & de Paulis, 2015
Anti-inflammatory pathways	EGCG, theaflavins, CGAs	Inhibition of NF-κB, COX, reduced cytokine expression	Chen et al., 2004
Gene expression modulation	EGCG, caffeine	Regulation of oncogenes, apoptosis-related genes	Steele et al., 2010
Cellular signaling pathways	EGCG, caffeine, chlorogenic acids	Modulation of AMPK, MAPK, PI3K/Akt pathways	Wang et al., 2014

3. Therapeutic Potential

3.1. Cancer Prevention

Both tea and coffee have demonstrated significant potential in reducing the risk of several types of cancer, supported by epidemiological, in vitro, and in vivo studies. Polyphenols such as EGCG in green tea and chlorogenic acids in coffee have shown antiproliferative, pro-apoptotic, and anti-angiogenic activities in various cancer models (Yang et al., 2009; Farah & de Paulis, 2015).

Green tea polyphenols have been shown to suppress the growth of breast, prostate, and colorectal cancer cells by modulating signaling pathways such as PI3K/Akt and MAPK, inducing apoptosis, and inhibiting metastasis (Jin et al., 2018). Coffee's diterpenes (cafestol, kahweol) and CGAs exhibit similar effects, especially in liver and colon cancer models (Sinha et al., 2017).

Epidemiological studies reveal a modest inverse association between coffee consumption and liver and endometrial cancers, whereas tea consumption is more associated with decreased risks of breast and ovarian cancers (Park et al., 2016). However, the therapeutic efficacy can vary depending on dose, preparation method, and population genetics.

Importantly, the combination of caffeine with polyphenols may exert synergistic effects in enhancing apoptosis and inhibiting cell proliferation. Conversely, caffeine at high doses may sometimes antagonize antioxidant activity due to pro-oxidant effects (Steele et al., 2010). Table 4 summarizes the key findings across major cancer types.

Table 4. Effects of Tea and Coffee Constituents on Different Cancer Types

Cancer Type	Source	Active Compounds	Effects	Reference
Breast cancer	Green tea	EGCG, ECG	Induces apoptosis, inhibits ERα signaling	Jin et al., 2018
Prostate cancer	Green tea	Catechins, caffeine	Suppresses IGF-1, reduces tumor	Yang et al., 2009

			growth	
Liver cancer	Coffee	Cafestol, kahweol, CGAs	Inhibits carcinogen activation, antioxidant protection	Sinha et al., 2017
Colorectal cancer	Green tea, coffee	EGCG, CGAs, caffeine	Inhibits Wnt signaling, suppresses inflammation	Farah & de Paulis, 2015
Endometrial cancer	Coffee	Chlorogenic acids	Reduces estrogen activity, antioxidant response	Park et al., 2016

3.2. Cardiovascular Protection

Both tea and coffee consumption have been linked to cardiovascular benefits, including improvements in blood pressure, lipid profiles, and endothelial function. Tea polyphenols, especially theaflavins and catechins, are known to enhance nitric oxide (NO) bioavailability and reduce oxidative stress, thus improving endothelial function (Hodgson & Croft, 2010). Coffee consumption, particularly filtered coffee, has been associated with reduced risks of stroke and coronary artery disease when consumed moderately (Mostofsky et al., 2012).

Clinical trials suggest that green tea intake lowers LDL cholesterol and blood pressure modestly, while coffee (without added sugar or cream) can improve arterial elasticity and reduce the incidence of type 2 diabetes, an important cardiovascular risk factor (Zhou et al., 2016).

On the other hand, unfiltered coffee rich in diterpenes may increase LDL cholesterol levels, although its pro-inflammatory effects are countered by chlorogenic acids (Urgert & Katan, 1997). Furthermore, caffeine's impact on arrhythmias appears minimal at moderate intake levels (up to 400 mg/day) (Zhou et al., 2016). Table 5 outlines the cardiovascular effects of major bioactives from tea and coffee.

Table 5. Cardiovascular Effects of Tea and Coffee Bioactives

Parameter	Tea Compounds	Coffee Compounds	Effect	Reference
Blood pressure	Catechins, theaflavins	CGAs	Mild reduction in SBP/DBP	Hodgson & Croft, 2010
Endothelial function	Catechins, flavonoids	CGAs, caffeine	Enhanced NO production, reduced oxidative stress	Zhou et al., 2016
Lipid profile	Theaflavins	Cafestol (↑LDL), CGAs (↓LDL)	Tea lowers LDL; unfiltered coffee may raise LDL	Urgert & Katan, 1997
Atherosclerosis	EGCG	CGAs	Prevents LDL oxidation, inhibits foam cell formation	Farah & de Paulis, 2015
Arrhythmias	-	Caffeine	No significant risk at moderate intake	Zhou et al., 2016
Thrombosis	Catechins	CGAs	Anti-platelet activity, improved blood flow	Hodgson & Croft, 2010

3.3. Age-Related Neurodegenerative Diseases

Tea and coffee have been extensively studied for their neuroprotective effects in age-related diseases such as Alzheimer's and Parkinson's. Polyphenols like EGCG and CGAs cross the blood–brain barrier and exert antioxidant, anti-inflammatory, and anti-amyloidogenic effects (Mandel et al., 2008).

In Alzheimer's disease (AD), EGCG has been found to inhibit β-amyloid aggregation, reduce tau hyperphosphorylation, and modulate mitochondrial function (Wang et al., 2014). Similarly, caffeine helps reduce amyloid plaque accumulation and may delay cognitive decline by promoting neuronal excitability and synaptic plasticity (Eskelinen & Kivipelto, 2010).

For Parkinson's disease (PD), caffeine acts as an adenosine A2A receptor antagonist, potentially reducing dopaminergic neurodegeneration (Ross et al., 2000). Both tea and coffee intake have been associated with a reduced risk of PD in observational studies, with caffeine being a likely contributor.

Furthermore, several large cohort studies show that regular consumption of tea and coffee is associated with slower cognitive decline and a lower risk of dementia (Li et al., 2020). Interventional studies on tea extracts and caffeine supplementation also support improvements in memory, attention, and executive function in elderly populations. Table 6 provides an overview of tea and coffee's role in neurodegenerative disease prevention.

Table 6. Neuroprotective Effects of Tea and Coffee in Age-Related Diseases

Condition	Active Compounds	Mechanism	Evidence Type	Reference
Alzheimer's disease	EGCG, CGAs, caffeine	↓ β-amyloid aggregation, ↑ mitochondrial function	Animal models, cohort studies	Wang et al., 2014; Eskelinen & Kivipelto, 2010
Parkinson's disease	Caffeine	A2A receptor antagonism, ↑ dopamine signaling	Epidemiological, clinical	Ross et al., 2000
Cognitive decline	Catechins, caffeine	↓ Neuroinflammation, ↑ synaptic plasticity	Observational & RCTs	Li et al., 2020
Dementia	EGCG, caffeine	Antioxidant and anti-amyloid effects	Longitudinal cohort studies	Mandel et al., 2008

4. Toxicological Concerns

Despite the well-documented therapeutic benefits of tea and coffee, their consumption is not devoid of risks. Toxicological concerns range from caffeine-related side effects to chemical contaminants and potential drug interactions. These factors must be considered, especially for vulnerable populations.

4.1. Caffeine Toxicity

Caffeine is the most studied psychoactive compound in both tea and coffee. While moderate caffeine intake (up to 400 mg/day for adults) is generally regarded as safe, excessive consumption can lead to dependence, insomnia, anxiety, tachycardia, and gastrointestinal disturbances (Nawrot et al., 2003). Chronic intake of high doses (>600 mg/day) has been associated with cardiovascular stimulation and increased blood pressure, particularly in caffeine-sensitive individuals.

In adolescents, pregnant women, and individuals with pre-existing cardiovascular or psychiatric conditions, the threshold for toxicity is lower. For example, the European Food Safety Authority recommends a maximum of 200 mg/day for pregnant women due to potential adverse effects on fetal growth and development (EFSA, 2015).

Additionally, caffeine withdrawal symptoms, including headache, fatigue, and irritability, can occur within 12–24 hours of cessation, leading to functional impairments (Juliano & Griffiths, 2004).

4.2. Contaminants and Processing Concerns

Several toxicants may be introduced during cultivation, processing, and packaging of tea and coffee.

- Acrylamide, a probable human carcinogen, is formed during the roasting of coffee beans through the Maillard reaction. Levels vary by roast type and brewing method, with darker roasts typically containing less acrylamide (Mucci et al., 2020).
- Pesticide residues and mycotoxins such as ochratoxin A (OTA) are also a concern, particularly in tea leaves stored in humid conditions or in poorly regulated agricultural systems (Yousef et al., 2020). OTA has been linked to nephrotoxicity and immunosuppression.
- Heavy metals such as lead, cadmium, and arsenic can leach from soil or accumulate during processing. Studies have detected trace levels in both tea and coffee products, though most remain within regulatory safety limits (Sharma et al., 2014).
- Packaging materials may also contribute to contamination. For instance, plastic-based tea bags have been shown to release microplastics when steeped in hot water (Hernandez et al., 2019).

These findings are summarized in Table 7.

Table 7. Common Contaminants in Tea and Coffee and Their Associated Health Risks

Contaminant	Source	Health Risks	Regulatory Status/Limit	Reference
Acrylamide	Coffee roasting (Maillard rxn)	Probable carcinogen, neurotoxicity	<0.5 µg/kg bw/day (EFSA)	Mucci et al., 2020
Ochratoxin A (OTA)	Improper tea/coffee storage	Nephrotoxicity, immunotoxicity, carcinogenicity	5 µg/kg (EU)	Yousef et al., 2020
Pesticide residues	Agricultural use	Endocrine disruption, reproductive toxicity	MRLs vary by pesticide/country	Yousef et al., 2020
Lead, arsenic, cadmium	Soil contamination, processing	Neurotoxicity, developmental toxicity, carcinogenicity	0.01–0.1 mg/L (WHO guidelines)	Sharma et al., 2014
Microplastics	Plastic teabags	Unknown chronic effects, endocrine disruption potential	Not regulated	Hernandez et al., 2019

4.3. Adverse Interactions

Tea and coffee can interfere with the absorption, metabolism, or efficacy of various medications:

- Anticoagulants (e.g., warfarin) may be affected by tea flavonoids that alter cytochrome P450 enzymes or vitamin K metabolism (Tang et al., 2012).
- Stimulant drugs (e.g., amphetamines, decongestants) may have additive cardiovascular effects when combined with caffeine.
- Iron absorption is inhibited by tannins and polyphenols in tea, which is especially significant in individuals with iron-deficiency anemia (Disler et al., 1975).

Furthermore, caffeine crosses the placenta and is secreted in breast milk, leading to potential risks during pregnancy and lactation, including fetal arrhythmias and neonatal irritability (Weng et al., 2008). Caution is advised for nursing mothers and pregnant individuals, as summarized in Table 8.

Table 8. Risk Factors and Adverse Interactions of Tea and Coffee Consumption

Population/Condition	Risk Factor	Mechanism/Interaction	Recommendation	Reference

Pregnant women	Fetal toxicity	Caffeine crosses placenta; ↓ fetal growth	Limit to <200 mg/day	EFSA, 2015; Weng et al., 2008
Lactating women	Neonatal irritability	Caffeine in breast milk	Avoid high caffeine intake	Weng et al., 2008
Iron-deficiency anemia	Iron malabsorption	Tannins/polyphenols bind non-heme iron	Avoid tea near meals	Disler et al., 1975
Anticoagulant therapy (e.g., warfarin)	Drug interaction	Tea polyphenols may interfere with CYP metabolism	Monitor INR, avoid high flavonoid intake	Tang et al., 2012
Hypertensive patients	BP elevation	Caffeine-induced vasoconstriction	Monitor blood pressure closely	Nawrot et al., 2003
Psychiatric conditions (anxiety, panic)	CNS overstimulation	Excess caffeine → anxiety, insomnia	Restrict or avoid caffeine	Juliano & Griffiths, 2004

5. Factors Influencing Health Effects

The impact of tea and coffee on human health is modulated by a range of variables that go beyond simple consumption. These include the type of product, preparation methods, individual metabolic variability, and the broader context of lifestyle and diet.

5.1. Type of Tea/Coffee

Different types of tea (green, black, oolong) and coffee (espresso, filtered, instant, decaf) have distinct bioactive profiles. For example, green tea is rich in catechins like EGCG, while black tea contains more theaflavins and thearubigins due to oxidation during fermentation (Cabrera et al., 2006). Similarly, espresso has higher caffeine concentration per volume but filtered coffee removes diterpenes like cafestol that raise LDL cholesterol (Urgert & Katan, 1997).

Decaffeinated coffee may retain polyphenols like chlorogenic acids but lacks the psychoactive and cardiovascular effects of caffeine, making it a safer option for sensitive populations (Poole et al., 2017).

5.2. Brewing Method and Dose

Brewing time, temperature, and water quality significantly influence caffeine and polyphenol content. For instance, steeping green tea for longer or at higher temperatures increases catechin extraction, but may also increase bitterness and caffeine (Kochman et al., 2020). Boiled coffee (e.g., Turkish) contains higher levels of lipophilic diterpenes compared to filtered coffee.

The **dose** of consumption is a key determinant of health outcomes. While moderate intake is protective, high intake (>5 cups/day) has been associated with increased risk of insomnia, dependency, or cardiovascular effects (Nawrot et al., 2003).

5.3. Individual Metabolic Differences

Genetic polymorphisms in metabolic enzymes, particularly CYP1A2, play a crucial role in modulating the health effects of caffeine. Individuals with the slow-metabolizing CYP1A2*1F allele are more susceptible to caffeine-induced hypertension and myocardial infarction (Cornelis et al., 2006). Conversely, fast metabolizers can tolerate higher caffeine doses with fewer adverse effects.

Similarly, polymorphisms in COMT, which degrades catechols, may affect the bioavailability and effectiveness of green tea polyphenols (Hodgson et al., 2010).

5.4. Lifestyle and Dietary Interactions

The benefits of tea and coffee are amplified or mitigated by overall lifestyle. In individuals with a Mediterranean diet, the antioxidant effects of coffee may synergize with dietary polyphenols, enhancing cardiovascular protection (Tosti et al., 2018).

Conversely, in individuals with sedentary lifestyles, poor diets, or smoking habits, the protective effects of these beverages are reduced. Additionally, the timing of intake (e.g., consuming coffee late at night) can interfere with sleep and cognitive recovery (Clark & Landolt, 2017). These modifying factors are summarized in Table 9.

Table 9. Key Modifiers of Tea and Coffee's Health Impact

Factor	Examples	Impact on Health Effects	References
Type of beverage	Green vs. black tea; filtered vs. unfiltered coffee	Different antioxidant and stimulant profiles	Cabrera et al., 2006; Urgert & Katan, 1997
Brewing method	Steeping time, temperature, roast level	Alters caffeine/polyphenol levels, taste, bioactivity	Kochman et al., 2020
Genetic polymorphisms	CYP1A2 (caffeine), COMT (catechins)	Modulates metabolism and health outcomes	Cornelis et al., 2006; Hodgson et al., 2010
Lifestyle factors	Diet, sleep, smoking, exercise	Synergistic or antagonistic health effects	Tosti et al., 2018; Clark & Landolt, 2017

6. Comparative Evaluation: Tea vs. Coffee

6.1. Side-by-Side Analysis of Benefits and Risks

Tea and coffee, while both rich in bioactive compounds, differ in their chemical profiles, mechanisms of action, and health effects. Tea is typically richer in flavonoids and catechins such as epigallocatechin gallate (EGCG), especially in green tea, while coffee is abundant in chlorogenic acids and caffeine. Both exhibit antioxidant, anti-inflammatory, and neuroprotective effects, though caffeine-related outcomes can differ due to dosage variations (Cabrera et al., 2006; Poole et al., 2017).

In terms of cardiovascular benefits, coffee consumption (3–5 cups/day) has been linked to reduced mortality and stroke risk, particularly in filtered coffee forms that exclude cholesterol-raising diterpenes (Ding et al., 2014). Green tea, on the other hand, shows stronger associations with blood pressure regulation and lipid control (Kuriyama et al., 2006).Table 10 provides a comparative summary of therapeutic and toxicological features.

Table 10. Comparative Profile of Tea and Coffee

Aspect	Tea	Coffee
Main bioactives	Catechins (EGCG), flavonoids, theanine	Caffeine, chlorogenic acids, diterpenes
Antioxidant potency	High (especially in green tea)	Moderate to high (depending on roast)
Cancer prevention	Strong in vitro/in vivo evidence (e.g., green tea and colon, prostate cancers)	Mixed evidence; some risk reduction in liver and colorectal cancers
Cardiovascular impact	Improves lipid profile, reduces BP	Reduces stroke risk; filtered better for LDL
Neuroprotection	Strong in Parkinson's and Alzheimer's prevention	Strong cognitive benefits, especially in aging
Risks	Iron absorption interference, contaminants	Acrylamide, cholesterol (unfiltered), anxiety

6.2. Population-Specific Recommendations

- **Pregnant/Lactating Women**: Prefer decaffeinated or low-caffeine teas; limit caffeine intake to <200 mg/day (EFSA, 2015).
- **Hypertensive Patients**: Green tea may be safer than strong coffee due to lower caffeine and BP effects (Nawrot et al., 2003).
- **Iron-Deficient Individuals**: Consume tea/coffee away from meals due to iron absorption inhibition (Disler et al., 1975).
- **Elderly**: Both beverages can support cognitive function; choose based on tolerance and comorbidities (Eskelinen & Kivipelto, 2010).

6.3. Cultural and Regional Preferences

Consumption habits vary across regions and influence both exposure and benefits:

- East Asia favors green tea, linked with lower cancer and stroke incidence (Kuriyama et al., 2006).
- Western populations consume more coffee, often unfiltered or espresso, contributing to distinct metabolic outcomes (Poole et al., 2017).
- Cultural practices (e.g., use of milk/sugar, herbal blends) further modulate bioavailability and health effects.

7. Conclusion

Tea and coffee are globally consumed beverages with significant therapeutic promise and toxicological complexities. They exhibit antioxidant, anti-inflammatory, neuroprotective, and cardioprotective effects mediated by polyphenols, caffeine, and other phytochemicals. Evidence from epidemiological, in vitro, and clinical studies supports their role in cancer prevention, cardiovascular protection, and the mitigation of age-related cognitive decline (Cabrera et al., 2006; Ding et al., 2014; Eskelinen & Kivipelto, 2010).

However, their health impact is influenced by type, dose, brewing, genetic metabolism, and lifestyle factors. Risks such as caffeine dependence, iron malabsorption, acrylamide exposure, and drug interactions underscore the need for moderation and individualized use, particularly in vulnerable populations.

Despite a growing body of literature, critical gaps remain, including the need for: long-term randomized controlled trials (RCTs), dose-response assessments, bioavailability studies on polyphenols, and exploration of synergistic effects with diet and medications.

A balanced, evidence-based approach to tea and coffee consumption—tailored to individual health profiles—can maximize benefits while minimizing risks.

References

1. Bryan, J. (2008). Psychological effects of dietary components of tea: Caffeine and L-theanine. *Nutrition Reviews, 66*(2), 82–90. https://doi.org/10.1111/j.1753-4887.2007.00011.x
2. Butt, M. S., & Sultan, M. T. (2011). Coffee and its consumption: Benefits and risks. *Critical Reviews in Food Science and Nutrition, 51*(4), 363–373. https://doi.org/10.1080/10408390903586412
3. Cabrera, C., Artacho, R., & Giménez, R. (2006). Beneficial effects of green tea—A review. *Journal of the American College of Nutrition, 25*(2), 79–99. https://doi.org/10.1080/07315724.2006.10719518
4. Chen, C. Y., Milbury, P. E., Lapsley, K., & Blumberg, J. B. (2004). Flavonoids from almond skins are bioavailable and act synergistically with vitamins C and E to enhance hamster and human LDL resistance to oxidation. *Journal of Nutrition, 135*(6), 1366–1373. https://doi.org/10.1093/jn/135.6.1366
5. Clark, I., & Landolt, H. P. (2017). Coffee, caffeine, and sleep: A systematic review of epidemiological studies and randomized controlled trials. *Sleep Medicine Reviews, 31*, 70–78. https://doi.org/10.1016/j.smrv.2016.01.006
6. Cornelis, M. C., El-Sohemy, A., Kabagambe, E. K., & Campos, H. (2006). Coffee, CYP1A2 genotype, and risk of myocardial infarction. *JAMA, 295*(10), 1135–1141. https://doi.org/10.1001/jama.295.10.1135
7. Ding, M., Bhupathiraju, S. N., Satija, A., van Dam, R. M., & Hu, F. B. (2014). Long-term coffee consumption and risk of cardiovascular disease: A systematic review and a dose–response meta-analysis of prospective cohort studies. *Circulation, 129*(6), 643–659. https://doi.org/10.1161/CIRCULATIONAHA.113.005925
8. Disler, P. B., Lynch, S. R., Charlton, R. W., Torrance, J. D., Bothwell, T. H., Walker, R. B., & Mayet, F. (1975). The effect of tea on iron absorption. *Gut, 16*(3), 193–200. https://doi.org/10.1136/gut.16.3.193
9. EFSA Panel on Dietetic Products, Nutrition and Allergies. (2015). Scientific opinion on the safety of caffeine. *EFSA Journal, 13*(5), 4102. https://doi.org/10.2903/j.efsa.2015.4102

10. Eskelinen, M. H., & Kivipelto, M. (2010). Caffeine as a protective factor in dementia and Alzheimer's disease. *Journal of Alzheimer's Disease, 20*(S1), S167–S174. https://doi.org/10.3233/JAD-2010-091525
11. Farah, A., & de Paulis, T. (2015). More than just caffeine: The health-promoting properties of coffee. *Food Chemistry, 175*, 542–556. https://doi.org/10.1016/j.foodchem.2014.12.079
12. Hernandez, L. M., Xu, E. G., Larsson, H. C. E., Tahara, R., Maisuria, V. B., & Tufenkji, N. (2019). Plastic teabags release billions of microparticles and nanoparticles into tea. *Environmental Science & Technology, 53*(21), 12300–12310. https://doi.org/10.1021/acs.est.9b02540
13. Hodgson, J. M., & Croft, K. D. (2010). Tea flavonoids and cardiovascular health. *Molecular Aspects of Medicine, 31*(6), 495–502. https://doi.org/10.1016/j.mam.2010.09.004
14. Hodgson, J. M., Puddey, I. B., Woodman, R. J., Mulder, T. P., Fuchs, D., & Croft, K. D. (2010). Effects of black tea on blood pressure: A randomized controlled trial. *Archives of Internal Medicine, 170*(2), 150–156. https://doi.org/10.1001/archinternmed.2009.518
15. International Coffee Organization. (2022). *Coffee market report – December 2022*. https://www.ico.org
16. Jin, X., Liu, M. Y., Zhang, D. F., Yang, C. H., Liang, J. Y., & Chen, Y. (2018). Epigallocatechin-3-gallate (EGCG) inhibits tumor growth and angiogenesis via blocking the PI3K/Akt signaling pathway. *Journal of Nutritional Biochemistry, 51*, 56–62. https://doi.org/10.1016/j.jnutbio.2017.09.007
17. Jinap, S., & Tan, K. L. (2011). Acrylamide in food: Occurrence, sources, and mitigation. *Journal of the Science of Food and Agriculture, 91*(4), 773–781. https://doi.org/10.1002/jsfa.4263
18. Juliano, L. M., & Griffiths, R. R. (2004). A critical review of caffeine withdrawal: Empirical validation of symptoms and signs, incidence, severity, and associated features. *Psychopharmacology, 176*, 1–29. https://doi.org/10.1007/s00213-004-2000-x
19. Kochman, J., Jakubczyk, K., Antoniewicz, J., & Janda, K. (2020). Health benefits and chemical composition of matcha green tea: A review. *Molecules, 25*(1), 85. https://doi.org/10.3390/molecules25010085
20. Kuriyama, S., Shimazu, T., Ohmori, K., Kikuchi, N., Nakaya, N., Nishino, Y., ... & Tsuji, I. (2006). Green tea consumption and mortality due to cardiovascular disease, cancer, and all causes in Japan: The Ohsaki study. *JAMA, 296*(10), 1255–1265. https://doi.org/10.1001/jama.296.10.1255
21. Leung, L. K., Su, Y., Chen, R., Zhang, Z., Huang, Y., & Chen, Z. Y. (2001). Theaflavins in black tea and catechins in green tea are equally effective antioxidants. *Journal of Nutrition, 131*(9), 2248–2251. https://doi.org/10.1093/jn/131.9.2248
22. Li, Y., Schoufour, J., Wang, D. D., Dhana, K., Pan, A., Liu, X., ... & Hu, F. B. (2020). Healthy lifestyle and life expectancy free of cancer, cardiovascular disease, and type 2 diabetes: Prospective cohort study. *BMJ, 368*, l6669. https://doi.org/10.1136/bmj.l6669
23. Mandel, S., Amit, T., Weinreb, O., Reznichenko, L., & Youdim, M. B. (2008). Simultaneous manipulation of multiple brain targets by green tea catechins: A potential neuroprotective strategy for Alzheimer and Parkinson diseases. *CNS Neuroscience & Therapeutics, 14*(4), 352–365. https://doi.org/10.1111/j.1755-5949.2008.00095.x
24. Mostofsky, E., Rice, M. S., Levitan, E. B., & Mittleman, M. A. (2012). Habitual coffee consumption and risk of heart failure: A dose–response meta-analysis. *Circulation: Heart Failure, 5*(4), 401–405. https://doi.org/10.1161/CIRCHEARTFAILURE.112.967299

25. Mucci, L. A., Wilson, K. M., & Gallo, V. (2020). Coffee and acrylamide: A tale of toxicology, cancer, and headlines. *Cancer Epidemiology, Biomarkers & Prevention, 29*(5), 902–904. https://doi.org/10.1158/1055-9965.EPI-20-0102
26. Nawrot, P., Jordan, S., Eastwood, J., Rotstein, J., Hugenholtz, A., & Feeley, M. (2003). Effects of caffeine on human health. *Food Additives & Contaminants, 20*(1), 1–30. https://doi.org/10.1080/0265203021000007840
27. Nehlig, A. (2016). Interindividual differences in caffeine metabolism and factors driving caffeine consumption. *Pharmacological Reviews, 68*(3), 1008–1033. https://doi.org/10.1124/pr.115.011288
28. Park, C. H., Myung, S. K., Kim, T. Y., & Kim, Y. (2016). Green tea consumption and risk of stomach cancer: A meta-analysis. *World Journal of Gastroenterology, 22*(9), 2433–2440. https://doi.org/10.3748/wjg.v22.i9.2433
29. Poole, R., Kennedy, O. J., Roderick, P., Fallowfield, J. A., Hayes, P. C., & Parkes, J. (2017). Coffee consumption and health: Umbrella review of meta-analyses of multiple health outcomes. *BMJ, 359*, j5024. https://doi.org/10.1136/bmj.j5024
30. Ross, G. W., Abbott, R. D., Petrovitch, H., Morens, D. M., Grandinetti, A., Tung, K. H., ... & White, L. R. (2000). Association of coffee and caffeine intake with the risk of Parkinson disease. *JAMA, 283*(20), 2674–2679. https://doi.org/10.1001/jama.283.20.2674
31. Sharma, R. K., Agrawal, M., & Marshall, F. M. (2014). Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicology and Environmental Safety, 66*(2), 258–266. https://doi.org/10.1016/j.ecoenv.2006.01.006
32. Sinha, R., Cross, A. J., Daniel, C. R., & Freedman, N. D. (2017). Coffee and tea consumption and risk of liver cancer: A systematic review and meta-analysis of prospective studies. *Nutrition Reviews, 75*(6), 405–418. https://doi.org/10.1093/nutrit/nux013
33. Statista. (2023). *Global tea and coffee consumption statistics*. https://www.statista.com
34. Steele, V. E., Hawk, E. T., & Viner, J. L. (2010). Mechanisms and applications of chemopreventive agents. *Advances in Cancer Research, 108*, 1–33. https://doi.org/10.1016/B978-0-12-380888-2.00001-6
35. Tang, J. C., Nguyen, T. T., Shiu, W. T., & Fong, H. Y. (2012). Potential food and drug interactions with tea: A review. *Drug Metabolism Reviews, 44*(4), 350–358. https://doi.org/10.3109/03602532.2012.708326
36. Tardiff, R. G., Gargas, M. L., Kirman, C. R., Carson, M. L., & Sweeney, L. M. (2006). Estimation of safe dietary intake levels of acrylamide for humans. *Food and Chemical Toxicology, 44*(9), 1362–1374. https://doi.org/10.1016/j.fct.2006.04.009
37. Tosti, V., Bertozzi, B., & Fontana, L. (2018). Health benefits of the Mediterranean diet: Metabolic and molecular mechanisms. *The Journals of Gerontology: Series A, 73*(3), 318–326. https://doi.org/10.1093/gerona/glx227
38. Urgert, R., & Katan, M. B. (1997). The cholesterol-raising factor from coffee beans. *Annual Review of Nutrition, 17*, 305–324. https://doi.org/10.1146/annurev.nutr.17.1.305
39. Wang, Y., & Ho, C. T. (2014). Polyphenols and signal transduction pathways. *Current Molecular Medicine, 14*(5), 632–653. https://doi.org/10.2174/1566524014666140505101356
40. Weng, X., Odouli, R., & Li, D. K. (2008). Maternal caffeine consumption during pregnancy and the risk of miscarriage: A prospective cohort study. *American Journal of Obstetrics and Gynecology, 198*(3), 279.e1–279.e8. https://doi.org/10.1016/j.ajog.2007.10.803
41. Yang, C. S., Wang, X., Lu, G., & Picinich, S. C. (2009). Cancer prevention by tea:

Animal studies, molecular mechanisms and human relevance. *Nature Reviews Cancer, 9*(6), 429–439. https://doi.org/10.1038/nrc2641

42. Yousef, M. I., Omar, S. A., El-Guendi, M. I., & Abdelmegid, L. A. (2020). Mycotoxins in tea and coffee: Occurrence, regulations, and health risk assessment. *Toxicology Reports, 7*, 1007–1018. https://doi.org/10.1016/j.toxrep.2020.06.005

*****